Chapter 6
Engineered Trusses from Undervalued Hardwoods

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A significant volume of softwood lumber is used in engineered truss assemblies. Metal plate connected (MPC) trusses are commonly used in residential construction for both roof and floor applications. Currently, there are no truss manufacturers producing MPC trusses with hardwood lumber, primarily as a consequence of a lack of technical data on the performance of hardwood material in MPC trusses.

This chapter presents information that is critical to using hardwood lumber in MPC trusses. It summarizes results from several testing and demonstration studies and includes information on estimated design values for various metal plate connectors used with hardwood lumber, results of tests conducted

on full-size trusses manufactured from hardwood lumber, and demonstration of hardwood trusses in residential construction.

Laboratory Testing of Metal Plate Connectors and Full-Size Trusses

Knowledge of the metal plate connector to lumber joint strength is essential in the design of wood trusses. The property that controls the strength of this joint is the lateral withdrawal resistance of the metal plate connectors from the wood.

An extensive testing program was conducted to develop baseline information on the lateral withdrawal resistance of common types of metal plate connectors from hardwood lumber. Nineteen types of metal connector plates from eight manufacturers were included in the testing program. Nominal 2- by 4-inch lumber sections were prepared from sugar maple, red maple, and yellow birch cants. Each section was selected to be straight grained and free of knots. The specific gravity of each section was calculated based on weight and dimension measurements. Parallel and perpendicular to grain test specimens were then prepared using the lumber sections and various metal plate connectors. Specimen dimensions and testing protocols utilized are summarized in ANSI-TPI 1-1995. Data obtained from this test program is available from the USDA Forest Products Laboratory (Forsman and Erickson 2000).

Note that the goal of this program was not to develop a new or optimized plate design for hardwood lumber. The primary goal was to provide data on the performance of connector plates currently used with hardwood lumber and then use this information to derive design values that will allow truss designers to use hardwood lumber in their designs. A secondary goal was to compare derived design values with those used in the design of trusses whose lumber is from the southern pine and spruce-pine-fir lumber groupings.

In the demonstration study, fifty-four full-size trusses were manufactured and tested to failure to demonstrate the performance of red and sugar maple lumber as compared to similar trusses made from lumber from the southern pine and spruce-pine-fir (SPF) lumber groups. **Tables 6.1 and 6.2** summarize key elements of this study. **Figures 6.1 and 6.2** illustrate designs tested. The pitched chord trusses were manufactured from 2- by 4-inch lumber. They were designed to span 24 feet and had a 4:12 pitch. The parallel chord trusses were also constructed from nominal 2- by 4-inch lumber. For the pitched chord trusses a 1.8E-2100f_b machine stress rated (MSR) grade of lumber from the SPF lumber grouping was specified for chord members. A visual grade of No. 3

Table 6.1. – Description of pitched chord truss groups that were manufactured for testing.

		Chord lumber			Web lumber		
Group	No. of trusses	Species[a]	Grade	Moisture content	Species[a]	Grade	Moisture content
				(%)			(%)
1	6	SM	2,100f_b 1.8E	12 to 15	SM	No. 3 or Btr.	12 to 15
2	6	RM	2,100f_b 1.8E	12 to 15	RM	No. 3 or Btr.	12 to 15
3	6	DRM	2,100f_b 1.8E	12 to 15	DRM	No. 3 or Btr.	12 to 15
4	6	SYP	2,100f_b 1.8E	12 to 15	SYP	No. 3 or Btr.	12 to 15
5	6	SPF	2,100f_b 1.8E	12 to 15	SPF	No. 3 or Btr.	12 to 15
6	6	SPF	2,100f_b 1.8E	12 to 15	RM	No. 3 or Btr.	12 to 15
7	3	SPF	2,100f_b 1.8E	12 to 15	RM	No. 3 or Btr.	50 to 60

[a] SM is sugar maple; RM is red maple; DRM is Delaware red maple; SYP is southern yellow pine species classification; SPF is spruce-pine-fir species classification.

Table 6.2. – Description of parallel chord truss groups that were manufactured for testing.

		Chord lumber			Web lumber		
Group	No. of trusses	Species[a]	Grade	Moisture content	Species[a]	Grade	Moisture content
				(%)			(%)
8	6	SM	1,650f_b 1.4E	12 to 15	SM	No. 3 or Btr.	12 to 15
9	6	DRM	1,650fb 1.4E	12 to 15	DRM	No. 3 or Btr.	12 to 15
10	6	SPF	1,650f_b 1.4E	12 to 15	SPF	No. 3 or Btr.	12 to 15
11	6	SPF	1,650f_b 1.4E	12 to 15	RM	No. 3 or Btr.	12 to 15
12	3	SPF	1,650f_b 1.4E	12 to 15	RM	No. 3 or Btr.	50 to 60

[a] SM is sugar maple; RM is red maple; DRM is Delaware red maple; SYP is southern yellow pine species classification; SPF is spruce-pine-fir species classification.

SPF was specified for the web members. The lumber specified for the parallel chord trusses was 1.4E-1650f_b MSR SPF for the chords and visual grade No. 3 SPF for the webs.

Figures 6.3 and 6.4 show pitched and parallel chord trusses under test. **Tables 6.3 and 6.4** summarize test results obtained for pitched and parallel chord truss tests, respectively. Two important points were observed:

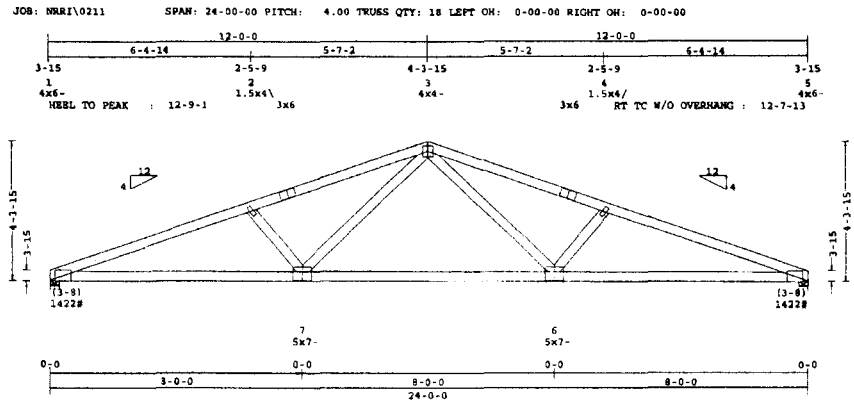

Figure 6.1. – Pitched chord truss design.

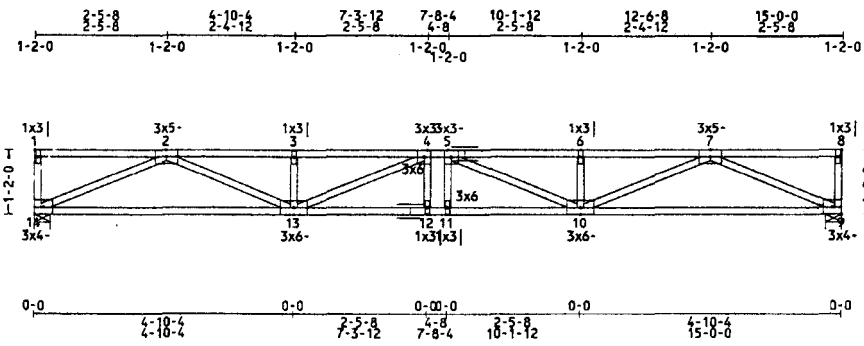

Figure 6.2. – Parallel chord truss design.

1. A typical failure mode for trusses manufactured from hardwood lumber was a tearing or failure of the metal plate connector. Typical failure modes for trusses manufactured from softwood lumber was withdrawal of the metal plate connector from the lumber.
2. Trusses manufactured from hardwood lumber performed at levels equivalent to or better than comparable softwood trusses.

Testing was conducted according to ANSI/TPI2- 1995 guidelines.

Figure 6.3 – Hardwood pithced chord truss during full-scale testing.

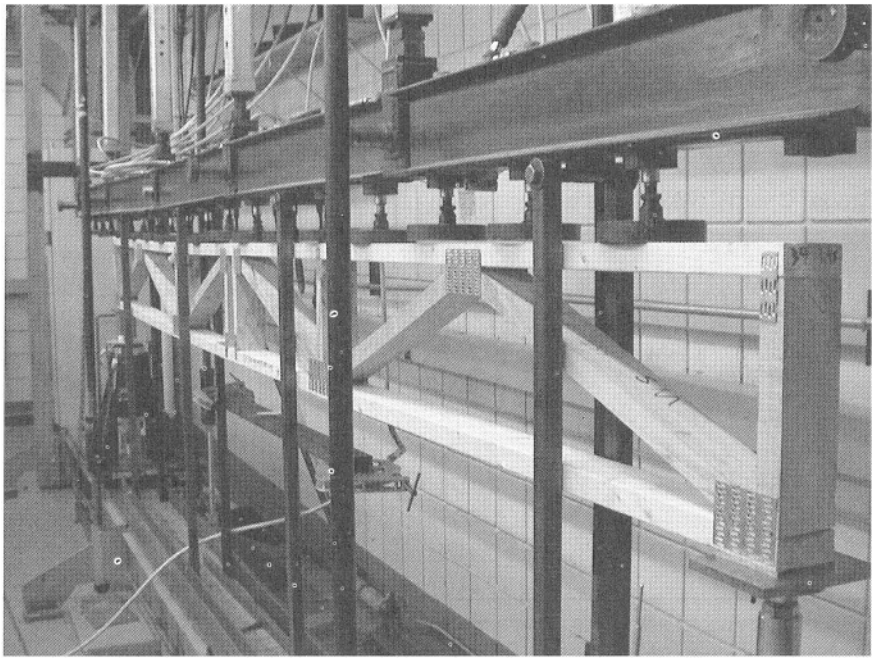

Figure 6.4 – Parallel chord tuss testing setup.

Table 6.3. – Summary of pitched chord truss testing results.[a]

Group	Species[b]		No. of trusses tested	Mean deflection and strength results			
	Chord	Web		Deflection at dead load	Deflection at design load	Total ultimate load	Failure load/design load
				- - - - - - (in.) - - - - - -		(lb)	
1	SM	SM	5	0.117	0.319	6,739	2.37
				(0.009)	(0.015)	(202)	(0.07)
2	RM	RM	5	0.119	0.349	7,063	2.48
				(0.016)	(0.032)	(1,148)	(0.40)
3	DRM	DRM	5	0.123	0.363	6,805	2.39
				(0.015)	(0.065)	(1,023)	(0.36)
4	SYP	SYP	5	0.118	0.345	5,360	1.88
				(0.014)	(0.025)	(470)	(0.17)
5	SPF	SPF	5	0.129	0.350	5,545	1.95
				(0.010)	(0.017)	(806)	(0.28)
6	SPF	RM	5	0.115	0.342	6,050	2.13
				(0.015)	(0.023)	(413)	(0.15)
7	SPF	GRM	2	0.139	0.380	5,190	1.82
				(0.013)	(0.001)	(127)	(0.04)

[a] Standard deviations are shown in parentheses.

[b] SM is sugar maple; RM is red maple; DRM is Delaware red maple; SYP is southern yellow pine species classification; SPF is spruce-pine-fir species classification; GRM is green red maple.

Table 6.4. – Summary of parallel chord truss testing results.[a]

Group	Species[b]		No. of trusses tested	Mean deflection and strength results			
	Chord	Web		Deflection at dead load	Deflection at design load	Total ultimate load	Failure load/design load
				- - - - - - (in.) - - - - - -		(lb)	
8	SM	SM	4	0.091	0.305	3,775	2.2
				(0.010)	(0.016)	(752)	(0.4)
9	DRM	DRM	5	0.107	0.384	2,988	1.7
				(0.006)	(0.010)	(312)	(0.2)
10	SPF	SPF	5	0.118	0.427	2,694	1.6
				(0.007)	(0.027)	(182)	(0.1)
11	SPF	RM	5	0.106	0.388	2,755	1.6
				(0.005)	(0.023)	(146)	(0.1)
12	SPF	GRM	3	0.100	0.390	2,834	1.6
				(0.007)	(0.034)	(326)	(0.2)

[a] Standard deviations are shown in parentheses.

[b] SM is sugar maple; RM is red maple; DRM is Delaware red maple; SYP is southern yellow pine species classification; SPF is spruce-pine-fir species classification; GRM is green red maple.

Estimated Design Values

Estimated design values derived from this testing program are summarized in **Table 6.5.** Note that these values were derived for a species grouping of sugar maple, red maple, and yellow birch. It was assumed that, in practice, no separation of species would occur. Before using these values, it is imperative to examine the technical information available from specific plate manufacturers. Of significant importance is a comparison of these values with those used in the design of trusses where the lumber is from the southern pine or SPF lumber groupings. **Table 6.6** illustrates such a comparison for one type of connector plate. Note that the design values derived for use with the sugar maple-red

Table 6.5. – Estimated design values for metal connector plates from eight manufacturers for wood from the sugar maple-red maple-yellow birch lumber grouping.

Manufacturer and metal connector plate designation	Test configuration	Metal connector plate orientation	Design value
		(°)	(psi)
Alpine Engineered Products			
A 20	Parallel to grain	0	273
		90	149
	Perpendicular to grain	0	134
		90	165
A20H	Parallel to grain	0	222
		90	128
	Perpendicular to grain	0	126
		90	122
Cherokee Metal Products			
CA20	Parallel to grain	0	188
		90	145
	Perpendicular to grain	0	110
		90	141
CB20	Parallel to grain	0	214
		90	146
	Perpendicular to grain	0	125
		90	145
CC205	Parallel to grain	0	173
		90	158
	Perpendicular to grain	0	149
		90	141

Table continued on next page.

Table 6.5 *(continued).* — Estimated design values for metal connector plates from eight manufacturers for wood from the sugar maple-red maple-yellow birch lumber grouping.

Manufacturer and metal connector plate designation	Test configuration	Metal connector plate orientation	Design value
		(°)	(psi)
Computrus			
C20	Parallel to grain	0	198
		90	190
	Perpendicular to grain	0	148
		90	147
Eagle Metal Products			
E20	Parallel to grain	0	211
		90	194
	Perpendicular to grain	0	147
		90	152
MiTek Industries			
M20	Parallel to grain	0	210
		90	210
	Perpendicular to grain	0	142
		90	165
M20H	Parallel to grain	0	180
		90	160
	Perpendicular to grain	0	129
		90	140
M18	Parallel to grain	0	245
		90	251
	Perpendicular to grain	0	154
		90	160
M16	Parallel to grain	0	202
		90	144
	Perpendicular to grain	0	144
		90	163
Robbins Engineering			
RA20	Parallel to grain	0	244
		90	172
	Perpendicular to grain	0	129
		90	157
RB20H	Parallel to grain	0	221
		90	170
	Perpendicular to grain	0	139
		90	148

Table continued on next page.

Table 6.5 *(continued).* – Estimated design values for metal connector plates from eight manufacturers for wood from the sugar maple-red maple-yellow birch lumber grouping.

Manufacturer and metal connector plate designation	Test configuration	Metal connector plate orientation	Design value
		(°)	(psi)
Truswal			
TW20	Parallel to grain	0	197
		90	181
	Perpendicular to grain	0	129
		90	156
TW16	Parallel to grain	0	199
		90	163
	Perpendicular to grain	0	136
		90	148
TeeLok Corporation			
TL20	Parallel to grain	0	229
		90	204
	Perpendicular to grain	0	143
		90	163
TL20H	Parallel to grain	0	222
		90	175
	Perpendicular to grain	0	131
		90	165
TL18	Parallel to grain	0	256
		90	220
	Perpendicular to grain	0	148
		90	180
TL16	Parallel to grain	0	197
		90	153
	Perpendicular to grain	0	143
		90	141

maple-yellow birch lumber grouping were, in essence, significantly greater than values used for lumber from the SPF lumber grouping. It also important to note that the values for the sugar maple-red maple-yellow birch grouping are slightly lower than those currently used when designing trusses that use southern pine lumber.

Table 6.6. – A comparison of metal connector plate design values (estimated) for the sugar maple-red maple-yellow birch lumber grouping to design values for lumber from the southern pine ans spruce-pine-fir lumber groupings. Design values are for metal connector plates manufactured by MiTek Industries.

Plate design-ation	Test configuration	Metal connector plate orientation[a]	Design value (psi)		
			Sugar maple, red maple, yellow birch	Spruce, pine, fir	Southern pine
M20	Parallel to grain	0	210	197	249
		90	210	144	190
	Perpendicular to grain	0	142	144	184
		90	165	137	200
M20H	Parallel to grain	0	180	148	187
		90	160	108	143
	Perpendicular to grain	0	129	108	138
		90	140	103	150
M18	Parallel to grain	0	245	141	196
		90	251	138	188
	Perpendicular to grain	0	154	134	159
		90	160	109	152
M16	Parallel to grain	0	202	127	174
		90	144	82	126
	Perpendicular to grain	0	144	75	147
		90	163	107	122

[a] Relative to application of load.

Demonstration of Hardwood Trusses in Residential Construction

Several structures were constructed using trusses made from hardwood lumber. Two houses with attached garages were constructed in Duluth, Minnesota by the Duluth Chapter of Habitat for Humanity International. Red maple lumber was used as webs, and the trusses used in the garage were made entirely from red maple lumber. **Figures 6.5** is a photograph of one of the houses during construction, and **Figure 6.6** is a close-up of the red maple webs in the trusses.

A large garage was constructed utilizing trusses manufactured from low-grade sugar maple lumber. The trusses were designed as modified storage trusses with a 26-foot span. The pitch was 6:12 with a foot overhang at the truss

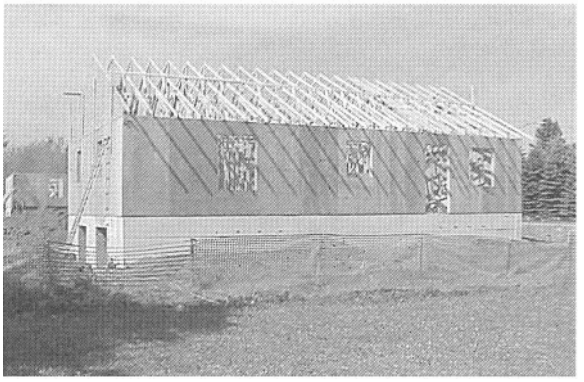

Figure 6.5 – Habitat for Humanity house.

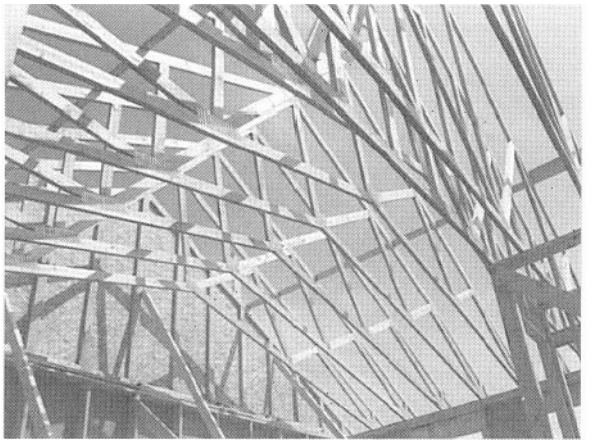

Figure 6.6. – Metal plate trusses containing red maple web lumber.

ends. The trusses were hand set 14 inches on center. **Figures 6.7 and 6.8** show photographs of the installed trusses.

Conclusions

Based on the demonstration studies summarized in this chapter, the following can be concluded:

1. Design values for various metal plate connectors used with a species grouping of sugar maple-red maple-yellow birch have been established. These values are greater than published values for lumber from the SPF lumber grouping. They are slightly lower than values for lumber from the southern pine lumber grouping.

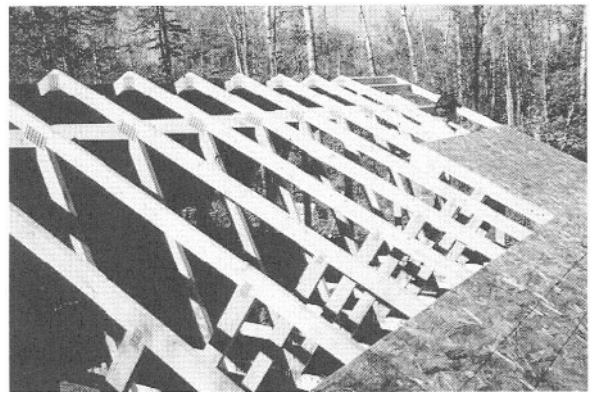

Figure 6.7. – OSB sheathing covering hard maple web demonstration trusses.

Figure 6.8. – Close-up of hard maple web, SPF bottom chord, and Douglas-fir top chord truss demonstration project.

2. Laboratory tests of full-size trusses manufactured using low-value hardwood lumber revealed performance comparable to or greater than equivalent softwood trusses.
3. Hardwood trusses were installed in three buildings. Monitoring revealed outstanding performance.

Literature Cited

Forsman, J. and J. Erickson. 2000. Final Report to USDA Forest Products Laboratory on the Lateral Strength of Metal Connector Plate Teeth Joining Sugar Maple, Red Maple, and Yellow Birch Species Grouping. USDA Forest Service, Forest Products Laboratory, Madison, WI.

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Financial support for the development of this publication was provided to Northern Initiatives through the USDA Forest Service Northeastern Area's Rural Development Through Forestry Program.

ISBN1-892529-32-7

Publication No. 7234

Printed in the United States of America.

0510500