Load/deflection parameters for metal-plate connectors in yellow-poplar and sweetgum structural lumber

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Abstract

CSA-S347 truss plate tests were performed on three industry standard metal-plate connectors (MPCS) installed in yellow-poplar and sweetgum 2 by 4's. MPCs performed well in both hardwood species. The results of this study were compared to previous results with one of the MPCs in both southern pine laminated veneer lumber and southern pine No. 1 KD 2 by 4's. The wood-plate joints in sweetgum and yellow-poplar were equivalent to those in the southern pine.

The development of nontraditional uses for hardwoods, especially such soft hardwood species as yellow-poplar, sweetgum, and red maple, could be of great economic importance to both landowners and the lumber industry throughout the South. Most soft hardwoods are currently underutilized (8). Increased use of hardwoods in construction could provide markets for mature trees, reduce the pressure on the softwood resource, and provide an option for increased silvicultural diversity.

Wood trusses provide a major market, (2 billion board feet per year) for dimension lumber (3). Nearly all wood trusses in the United States are fabricated with metal-plate connectors (MPCs). Input for the standard computer modeling of wood/plate joints in truss design programs is lacking for hardwoods. The Structural Analysis of Trusses, a computerized wood/plate analysis program developed by Foschi (2), requires three load/deflection parameters for each load-to-plate axis and load-to-wood grain axis to fully model the joint deformation characteristics of the loaded truss. These parameters, as shown in Figure 1, are:

k : initial slope of the load/deflection curve

m 1: the slope of the load/deflection curve prior to failure

m 0: the y-intercept of m 1

These parameters are obtained by following the test procedures outlined in Canadian Standard CSA-S347 (1). They are useful because the load/deflection curve for any lumber/plate combination can be accurately described by the formula (6):

$$F = (m0 + m1 \times D) \times (1 - e^{(-k \times D/m0)})$$

where:

F = force per tooth

D = relative displacement between tooth and wood

Objectives

The objectives of our study were to obtain the joint-deflection parameters, maximum load per tooth, and load per tooth at critical slip for three industry standard MPCs installed in yellow-poplar and sweetgum dimension lumber. The species x plate interactions were also of interest.

Procedures

The study was designed as a randomized block 2 by 3 by 4 full factorial with 10 observations per cell. The factors were:

Lumber: Yellow-poplar and sweetgum
MPCs: Alpine MH, Mitek GNQ, and Mitek GNA- 16
TEST: AA, EA, AE, EE (Fig. 2)

The fabrication and testing recommendations of CSA-S347 were followed throughout the study using a BLH-120 universal test machine. Loads and deflections were measured with calibrated linear potentio-

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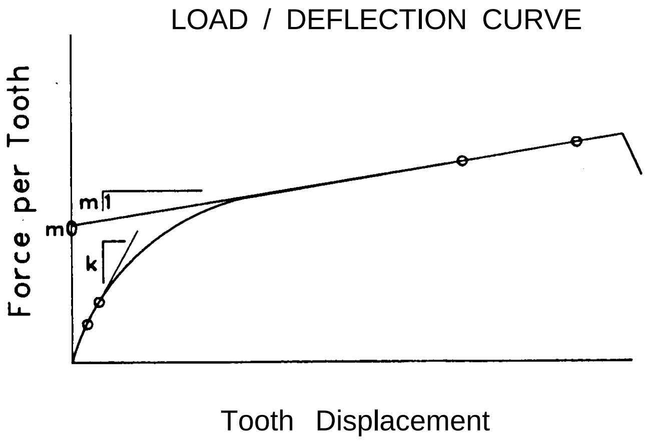

Figure 1. — Load/deflection curve.

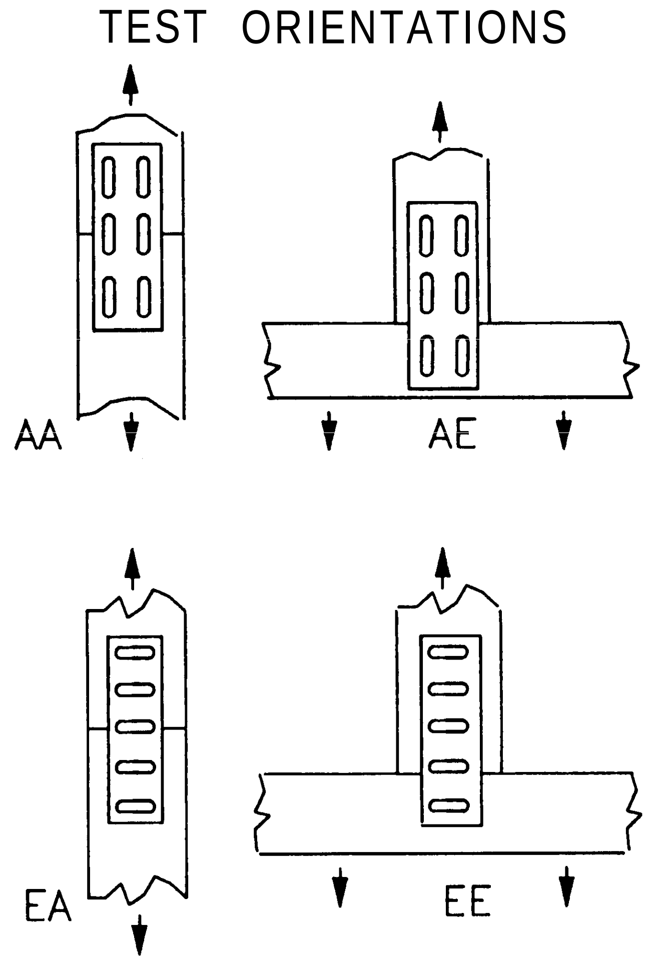

Figure 2. — Plate test orientations.

meters and recorded on a portable computer with an analog/digital board. Loads and deflections were scanned at 3-second intervals and recorded in a standard ASCII file.

The load/deflection data were imported into a spreadsheet program. Slopes for initial stages of loading *(k)* and for the period just prior to failure *(m* l) were calculated by regression. Generally, the minimum acceptable r^2 value for the regression used to calculate the slope was 0.90. Most r^2 values were greater than 0.95. The data for each test series were summarized in a separate spreadsheet. These summary data were exported to an ASCII file and analyzed using the PC-SAS statistical analysis package (5).

A small wafer (1.5 by 3.5 by 0.5 in. thick) was cut from the wood next to the MPC for each joint at the time of testing. This wafer was weighed and soaked in water for 48 hours. Its volume was then determined by its change in weight with immersion. The wafer then was ovendried and weighed again. Moisture content at the time of the test and specific gravity (SG) were added to the summary data. These values were included as continuous factor independent variables in the analysis.

Results and discussion

The average load/deflection parameters and SG data for the tests are shown in Table 1. Load/deflection parameters for sweetgum are consistently higher than those for yellow-poplar.

Since it was assumed that there would be major differences between the 4 different test orientations, a separate ANOVA was run for each test group of 60 specimens. The ANOVA form was:

Source of variation	Degrees of freedom
Lumber *(L)*	1
Plates *(P)*	2
L × P	2
Moisture content	1
Specific gravity	1
Error	52
Total	59

The values are statistically significant at the 0.05 level.

Test AA (plate parallel/wood grain parallel)

This is the standard lateral load plate test configuration specified in TPI-85 (7). Therefore, the results of this test are of primary interest to most researchers. The values for *k, m* l, and *m* 0 are detailed in Table 1 and shown graphically in Figure 3.

The initial slope, *k,* did not vary significantly with type of lumber, type of plate, or moisture content. SG did significantly affect *k*. This result is a bit surprising, because there is a major difference in the SGs of yellow-poplar and sweetgum. However, lumber type is a class variable and SG is a continuous variable or covariate.

For slope prior to failure, *m* l, the main effects of lumber and type of plate and the lumber x plate interaction were statistically significant (Fig. 3B). Moisture content and SG did not significantly affect slope to failure.

The *y* - intercept of *m* 1, *m* 0, was significantly affected by differences due to plate type and the lumber x plate interaction (Fig. 3C). The effect of SG was also statistically significant.

Maximum load per tooth and load per tooth at critical slip (0.030-in. deflection for AA and EA orientations; 0.015-in. deflection for AE and EE orientations) varied significantly with the type of lumber, type of plate, and SG. The lumber x plate interaction was not significant. These values are not shown graphically.

Test AE (plate parallel/wood grain perpendicular)

This orientation approximates the web-to-bottom-chord metal-plate connection in a light-frame truss. The load/deflection parameters are presented in Table 1 and graphically in Figure 4.

The initial slope, *k*, was not significantly altered by any main effect or interaction. Figure 4A shows that the values of *k* are roughly double those of the AA orientation in Figure 3A.

The only statistically significant main effect on the final slope, ml, was by the type of plate. It is obvious from Figure 4B that the values for the GNQ plate are higher than for the other two plates. Also note from Figure 4B that, for the GNQ plate, sweetgum has a lower value for ml than yellow-poplar.

The parameter *m0* is shown in Figure 4C. The ANOVA showed a statistically significant difference due to the main effects of plate type and SG.

Test EA (plate perpendicular/wood grain parallel)

The parameters for this test are not shown graphically. The values for all the parameters are roughly comparable to those of Test AA (Table 1).

The ANOVA indicated that the *k* value was significantly affected only by the main effect of plate type. The ml value was affected by plate type and the lumber x plate interaction. Plate type and SG were significant main effects for *m* 0.

Test EE (plate perpendicular/wood grain perpendicular)

The *k* values for test EE are the highest of any of the tests (Table 1). They are 2.5 to 3 times greater than those of tests AA and EA.

None of the main effects or interactions significantly affected *k* or *m* 1. Plate type, the lumber x plate

Table 1. – *Average data for 10 MPCs by species.*

Test, species, and MPC	Teeth	*k*	*m* 1	*m* 0	Max.[a]	Crit.[b]	MC	SG
	(No.)				------(lb.)------		(%)	
AA								
Sweetgum								
GNQ	48	6,204	222	102	117	97	9.2	0.50
GNA-16	36	5,326	444	96	130	95	9.3	0.50
ALP MH	48	6,047	273	84	99	88	8.8	0.51
Yellow-poplar								
GNQ	48	4,766	142	79	92	68	9.3	0.40
GNA-16	36	4,633	129	94	108	70	8.5	0.40
ALP MH	48	5.100	119	70	75	63	8.5	0.41
AE								
Sweetgum								
GNQ	24	12,113	870	125	155	115	8.9	0.50
GNA-16	20	14,865	551	181	205	138	9.2	0.49
ALP MH	24	10,928	405	117	134	104	9.1	0.50
Yellow-poplar								
GNQ	24	11,708	1,130	61	86	74	8.4	0.40
GNA-16	20	10,579	335	123	145	86	7.9	0.40
ALP MH	24	10,010	253	80	93	67	8.5	0.40
EA								
Sweetgum								
GNQ	24	5,050	166	84	94	82	9.5	0.49
GNA-16	18	6,121	141	121	132	101	10.0	0.49
ALP MH	24	4,215	75	80	87	69	10.0	0.50
Yellow-poplar								
GNQ	24	4,346	96	67	74	60	9.5	0.40
GNA-16	18	5,765	53	93	101	63	8.9	0.38
ALP MH	24	3,225	67	52	63	46	9.3	0.38
EE								
Sweetgum								
GNQ	12	18,778	346	165	183	121	8.4	0.52
GNA-16	10	21,724	302	286	305	182	9.5	0.51
ALP MH	12	21,280	326	163	178	128	9.2	0.50
Yellow-poplar								
GNQ	12	17,762	231	124	136	94	9.7	0.41
GNA-16	10	14,424	363	176	199	115	9.2	0.39
ALP MH	12	12.663	347	117	134	93	8.0	0.39

[a]Maximum load per tooth.
[b]Load per tooth at critical slip.

interaction, and SG had statistically significant effects on the *m0* parameter.

Comparison with southern pine and laminated veneer lumber (LVL)

A potential manufacturer or user of yellow-poplar or sweetgum trusses will want to know how their performance might compare with that of trusses made with frequently used softwoods. In a previous study, the senior author estimated the load/deflection parameters for Alpine MH plates in conventional southern pine lumber and southern pine LVL (4). In those tests, data were collected manually and deflections were read from gauges at 100-pound load increments. Although the same BLH-120 testing machine was used in both studies, results may not be entirely comparable. Nevertheless, the results are interesting.

Table 2 shows the comparisons for Alpine MH plates in the four types of lumber. Some key comparisons are highlighted in Figure 5. Values for sweetgum

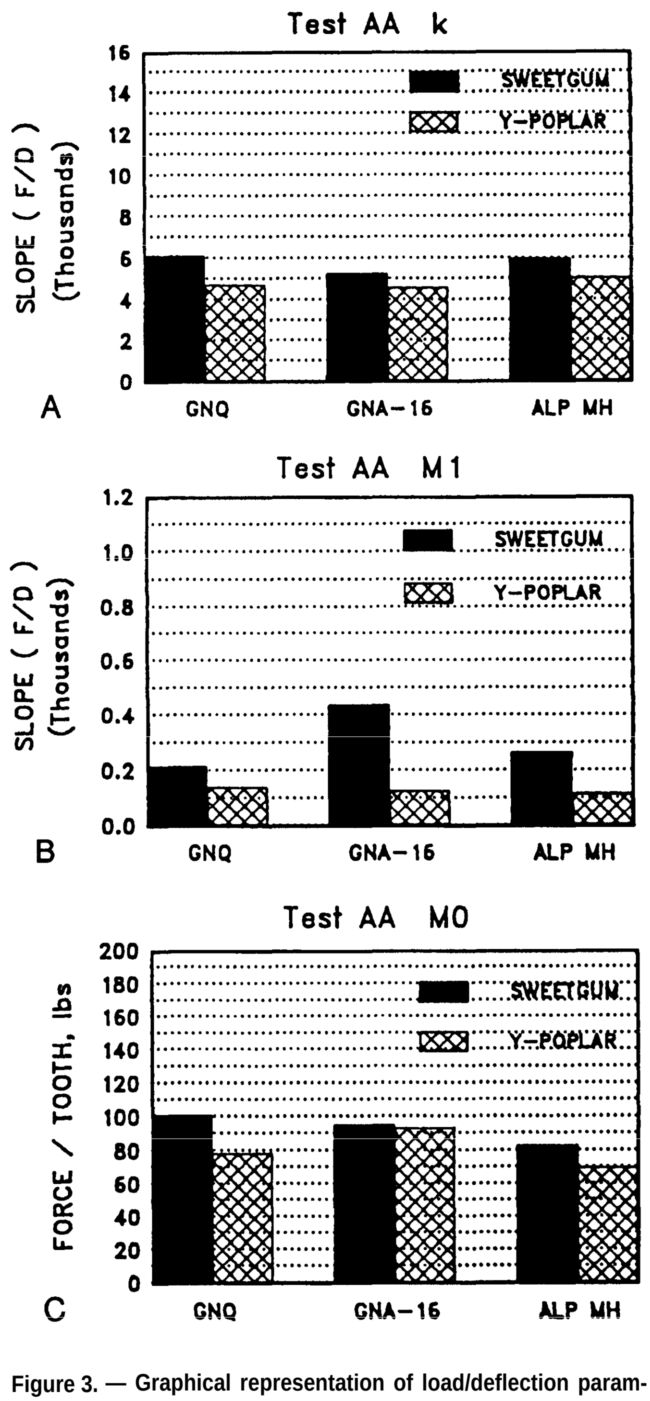

Figure 3. — Graphical representation of load/deflection parameters for test AA.

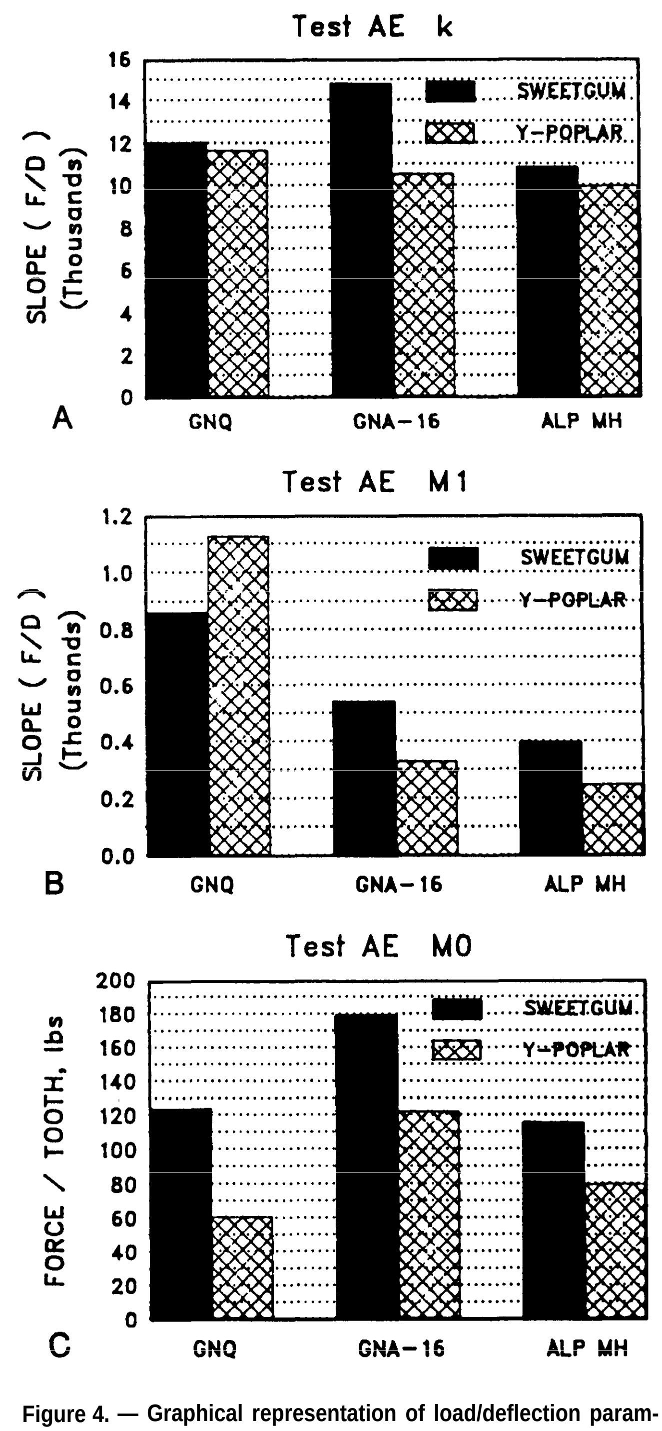

Figure 4. — Graphical representation of load/deflection parameters for test AE.

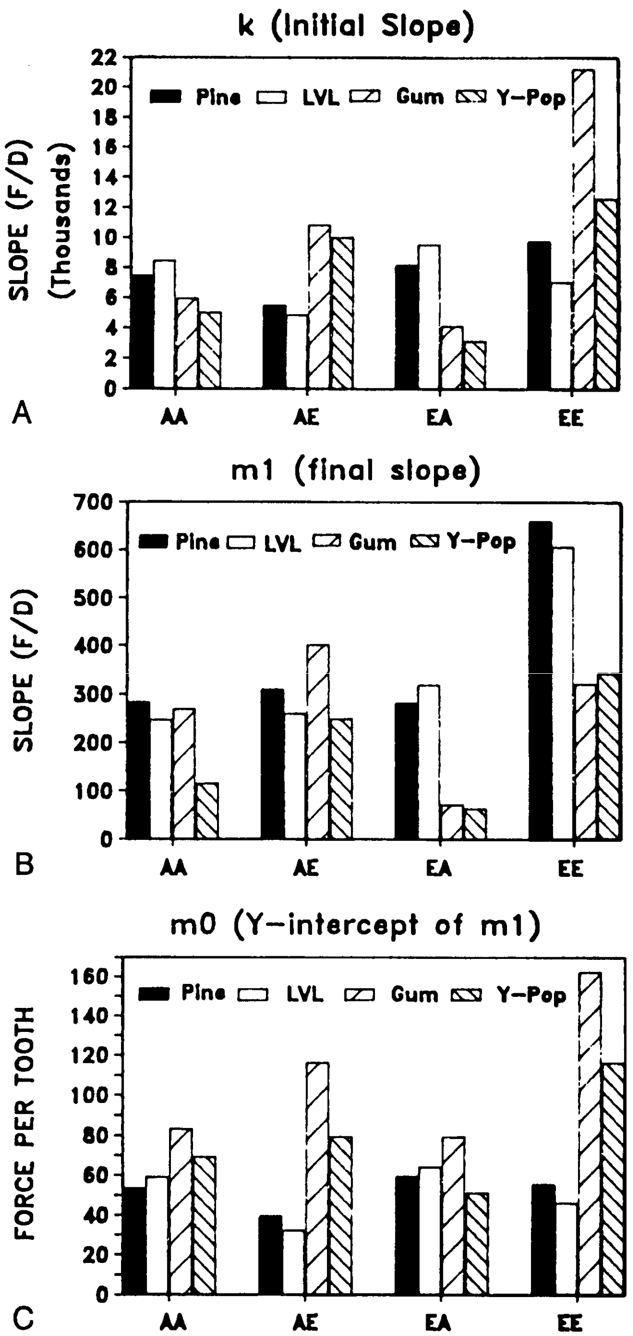

Figure 5. — Test parameters for Alpine MH plates in four types of truss lumber.

Table 2. – *Comparison of load/deflection parameters for Alpine MH plates in southern pine, laminated veneer lumber, yellow-poplar, and sweetgum*

Lumber	Test	*k*	*m* 1	*m0*	Max.[b]	Crit.[c]
					---(lb.)---	
	AA	7,500	285	54	65	62
Southern pine[a]	AE	5,533	312	40	50	40
	EA	8,209	284	60	77	66
	EE	9,794	661	56	76	63
	AA	8,541	251	60	72	67
LVL[a]	AE	4,947	264	33	44	34
	EA	9,625	323	65	83	73
	EE	7,160	610	47	65	53
	AA	6,047	273	84	99	88
Sweetgum	AE	10,928	405	117	134	104
	EA	4,215	75	80	87	69
	EE	21,280	326	163	178	128
	AA	5,100	119	70	75	63
Yellow-poplar	AE	10,010	253	80	93	67
	EA	3,225	67	52	63	46
	EE	12,663	347	117	134	93

[a] Data from McAlister (4).
[b] Maximum load per tooth.
[c] Load per tooth at critical slip.

and yellow-poplar measured in the present study were generally as high or higher than reported values for southern pine or LVL for the *m* 0 parameter. The slope to failure, *ml,* was generally much flatter for the hardwoods than the softwood materials. However, the values for maximum load per tooth and load per tooth at critical slip were essentially the same for southern pine, LVL, yellow-poplar, and sweetgum. These similarities indicate that, from the standpoint of fastener performance, yellow-poplar and sweetgum are suitable for use in trusses.

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