Chapter 7
I-Joists and Headers

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Prefabricated wood I-joists and headers are widely used in wood construction throughout the world. They are used in roof and floor systems in both residential and commercial applications. These structural members consist of flanges, which are made from either solid-sawn or laminated veneer lumber, that are adhesively bonded to a web that is made of plywood or oriented strandboard (OSB). Approximately 1 billion linear feet of wood I-joists and headers are manufactured annually. Currently, softwood species are predominately used for flanges. The work presented in this chapter was conducted to demonstrate the use of undervalued hardwood lumber for flanges in structural I-joists and headers.

Manufacture and Grading of Lumber for Flanges

A hardwood lumber manufacturer in northern Michigan provided approximately 100 nominal 2- by 6-inch hardwood lumber specimens for this demonstration study. The lumber was sawn from center cants and kiln-dried to a target moisture content (MC) of 15 percent. It was then planed and edged to a final thickness of 1.5 inches and width of 5.5 inches.

The modulus of elasticity (MOE) of each lumber specimen was determined using transverse vibration nondestructive testing methods. Each specimen was then visually graded by a certified grader from the Southern Pine Inspection Bureau. Note that the visual override criteria for machine stress rated (MSR) lumber requires that all lumber meet No. 2 or Better visual grade rules.

Based on current I-joist manufacturing standards, the following MSR grade categories were utilized:

- 2.0E Sugar maple, yellow birch
- 1.8E Sugar maple, yellow birch, soft maple, aspen

The MSR grade category used to manufacture headers was:

- 1.5E Red maple, aspen

Prior to manufacturing I-joists and headers, the lumber was defected according to additional requirements provided by the I-joist manufacturer. Knot size was limited to a maximum diameter of 1.0 inch, split depth was limited to 1/4 inch, and wane to 3/8 inch. Lumber defects were then removed. Sixteen-foot lengths of defect-free material were then manufactured by finger-jointing shorter lengths together with a phenol-resorcinal adhesive.

Lumber Yield

Table 7.1 shows the yield loss for each evaluated species of hardwood lumber.

There were substantial levels of deep drying splits in the sugar maple groups. This precluded their use for manufacturing I-joists and headers. Several other pieces of sugar maple lumber were excluded because of warp and other dimensional problems. The lumber used for I-joists and headers had

Table 7.1. — Yield loss of hardwood lumber used for manufacturing I-joists and headers.

		Loss by defect type (%)				
Species	MSR grade	Knots	Splits	Bark inclusion	Misc.	Total
Sugar maple	1.8E	6.1	10.5	1.5	20.7	38.8
	2.0E	5.4	38.4	3.0	--	46.8
Yellow birch	1.8E	7.6	3.9	1.7	2.7	15.9
	2.0E	2.9	--	--	--	2.9
Red maple	1.5E	3.0	12.2	3.5	--	18.7
	1.8E	5.7	10.0	1.8	0.4	18.0
Aspen	1.5E	8.5	13.6	--	1.9	23.9
	1.8E	4.1	5.5	--	--	9.6

been stored for almost 18 months. It is suspected that some of these splits and dimensional problems occurred during the storage period.

Manufacture and Performance of Demonstration I-Joists and Headers

Flange stock was manufactured from the 2- by 6-inch lumber by ripping the lumber into two sections and milling a rout into each section. The flange stock was then used to manufacture I-joists and headers. A phenol-formaldehyde adhesive was placed into the rout and OSB web material inserted. The assembled members were then pressed together in a continuous press. The finished members (I-joists and headers) were then placed into storage for 10 days prior to mechanical testing.

Shear Resistance

Testing was completed according to ASTM D5055-99, Standard Specification for Establishing and Monitoring Structural Capacities of Prefabricated Wood I-Joists (ASTM 1999). Seven-foot shear test specimens were cut with an OSB web joint located 12 to 18 inches from both ends of the joist. Each specimen was tested to failure. Maximum load was recorded and failure type and location determined.

Tables 7.2 and 7.3 show the maximum load observed from the shear tests which were completed for the I-joist and header specimens, respectively. The results shown for the hardwood I-joists and headers were based on experimental testing. These results were compared against minimum acceptable quality control (QC) values that the industrial cooperator uses as part of their quality assurance program,

Table 7.2. – I-joist shear test results for hardwood and SPF lumber.

Species	MSR grade	No. of samples	Mean ultimate load	Pass QC requirements
			(lb)	
Sugar maple	1.8E	11	6,049	4 of 11
	2.0E	1	4,603	0 of 11
Yellow birch	1.8E	5	5,652	2 of 5
	2.0E	3	6,258	1 of 3
Red maple	1.8E	7	6,720	7 of 7
Aspen	1.8E	3	6,934	3 of 3
SPF	1.8E	QC	6,600 minimum	na

Table 7.3. – Header shear test results.

Species	MSR grade	No. of samples	Mean ultimate load	Pass QC requirements
			(lb)	
Red maple	1.5E	2	11,984	2 of 2
Aspen	1.8E	3	14,167	4 of 4
SPF	1.8E	QC	11,000 to 13,000 10,250 minimum	na

The sugar maple and yellow birch test specimens failed in horizontal shear between the lumber flange and the OSB. There appeared to be a lack of bonding in these joints. The amount of wood failure was extremely low. Examination of the failed specimens revealed that the sugar maple flange material appeared to be sufficiently wetted by the adhesive, yet a poor bond was evident. It is possible that the adhesive did not reach high enough temperatures during curing to obtain an optimum bond, or there was too large a gap between the lumber flange and the OSB. The lower density red maple and aspen showed excellent bonds between the lumber flange and the OSB.

Each of the alternate species evaluated for header stock showed that minimum acceptable performance was obtained for the limited sample set.

Moment Resistance

Moment testing was completed in accordance with ASTM D5055-98. Each sample was laterally supported to minimize off-axis buckling. Due to the short flange length, the span-to-depth ratio for these joists was 16:1, as compared to the recommended 17-21:l ratio. Moment capacity was determined for each specimen.

Results are shown in **Table 7.4.** The 16:1 span-to-depth ratio resulted in shear type failures as compared to typical bending moment failure types. This may have occurred since a poor bond existed between the sugar maple and the OSB and the yellow birch and the OSB.

The sugar maple (1.8E) I-joist moment capacity was equivalent to the spruce-pine-fir (SPF) lumber flanges even though relatively poor bonds existed between the sugar maple and the OSB. There were not enough other data points for the other species evaluated to draw any specific conclusions.

Table 7.4. – I-joist moment testing results.

Species	MSR grade	No. of samples	Maximum load	Moment capacity
			(lb)	(ft-lb)
Sugar maple	1.8E	5	4,651	12,403
	2.0E	1	5.010	13,360
Yellow birch	2.0E	1	4,372	11,659
Red maple	1.8E	1	4.117	10,979
Aspen	1.8E	1	4,455	11,880
SPF	1.8E	6	4,732	12,619

Nailing Performance

An important performance characteristic for pre-fabricated I-joists and headers is their response to nailing. Significant splitting of the flange in response to application of nails may result in unacceptable performance. To examine the performance of I-joists manufactured using hardwood flange stock, a study was designed and conducted to compare their performance relative to those made using SPF lumber as flange stock. A commercially available nail application system was used with 8d and 10d nails to simulate nailing patterns as specified in construction drawings provided by an industrial cooperator. Small joist sections were conditioned to two moisture conditions (5% to 6% and 12% to 13%). 8d nails were inserted 1.5 inches from the joist end, at mid-span of the joists, and through a rimjoist into a joist end. 10d nails were inserted through the top joist at the joist end and at mid-span. Each nailing location was evaluated for the number of joists that split.

Table 7.5 shows the nailing test results for hardwood and SPF lumber at 5 to 6 percent MC, and **Table 7.6** shows the results at 12 to 13 percent MC. Each table shows the number of splits that occurred out of the total number of nails that were driven. The data shows that the majority of the splits occurred at the ends of the I-joists and when driven through the top of the joists into another joist. Very few splits occurred when the nails were located at midspan 18 inches away from a cut end. Slightly fewer nailing splits occurred at the higher MC level.

Conclusions

A significant volume of lumber tested met the criteria for several grades of MSR softwood lumber. This included MOE values and visual grading criteria. Additional defecting was completed prior to using the lumber for prefabri-

Table 7.5. – Nailing performance of hardwood I-joists at 5 to 6 percent moisture content using 8d and 10d nails.[a]

		Nailing location				
Species	MSR grade	Flange end (8d)	Flange midspan (8d)	Rimboard (8d)	Rimjoist top flange (10d)	Rimjoist bot-torn flange (10d)
Sugar maple	1.8E	4 of 12	3 of 6	0 of 6	2 of 3	2 of 3
Yellow birch	1.8E	1 of 12	0 of 6	0 of 6	2 of 3	2 of 3
	2.0E	3 of 12	0 of 6	0 of 6	3 of 3	2 of 3
Redmaple	1.8E	1 of 12	0 of 6	0 of 6	2 of 3	1 of 3
Aspen	1.8E	1 of 12	0 of 6	0 of 6	1 of 3	0 of 3
SPF	1.8E	1 of 12	0 of 6	0 of 6	2 of 3	2 of 3

[a] Values indicate the number of splits that occurred out of the total number of nails that were driven.

Table 7.6. – Nailing performance of hardwood I-joists at 12 to 13 percent moisture content using 8d and 10d nails.

		Nailing location				
Species	MSR grade	Flange end (8d)	Flange midspan (8d)	Rimboard (8d)	Rimjoist top flange (10d)	Rimjoist bot-tom flange (10d)
Sugar maple	1.8E	2 of 12	0 of 6	0 of 6	2 of 3	0 of 3
	2.0E	2 of 12	0 of 6	0 of 6	1 of 3	2 of 3
Yellow birch	1.8E	1 of 12	0 of 6	0 of 6	0 of 3	2 of 3
	2.0E	5 of 12	0 of 6	0 of 6	2 of 3	1 of 3
Redmaple	1.8E	1 of 12	0 of 6	0 of 6	2 of 3	1 of 3
Aspen	1.8E	1 of 12	0 of 6	0 of 6	1 of 3	0 of 3
SPF	1.8E	1 of 12	0 of 6	0 of 6	2 of 3	2 of 3

[a] Values indicate the number of splits that occured out of the total number of nails that were driven.

cated wood I-joists and headers. Deep checking in the sugar maple lumber caused the largest amount of downgrade.

I-joists and headers which were manufactured using red maple and aspen lumber for flange stock had shear strength values that were equivalent to or greater than values required for comparable I-joists manufactured using lumber from the SPF lumber grouping. I-joists manufactured using sugar maple and yellow birch lumber exhibited marginal bonding between the flanges and OSB webs. It was not clear whether the poor bonding was caused by lack of contact between the flanges and the webs, insufficient temperatures during curing of the adhesive, or some other factor.

During moment testing, a large number of the specimens failed in a shear mode rather than in bending mode. Two factors contributed to this phenomenon:

1. the span to depth ratio used was shorter than suggested, and
2. there was poor bonding between the hardwood lumber flanges and the OSB webs.

The nailing study showed that the dense sugar maple and yellow birch lumber resulted in slightly more splits when the nails were inserted 1.5 inches away from the joist end as compared to SPF. The other results were comparable between red maple, aspen, and SPF.

Literature Cited

American Society for Testing and Materials (ASTM). 1999. Standard specification for establishing and monitoring structural capacities of pre-fabricated wood I-joists. ASTM D 5055-99. ASTM, West Conshohocken, PA.

Undervalued Hardwoods
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