

INNOVATIVE RESIDENTIAL FLOOR CONSTRUCTION: STRUCTURAL EVALUATION OF STEEL JOISTS WITH PRE-FORMED WEB OPENINGS

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by

NAHB Research Center, Inc.
400 Prince George's Boulevard
Upper Marlboro, MD 20774-8731

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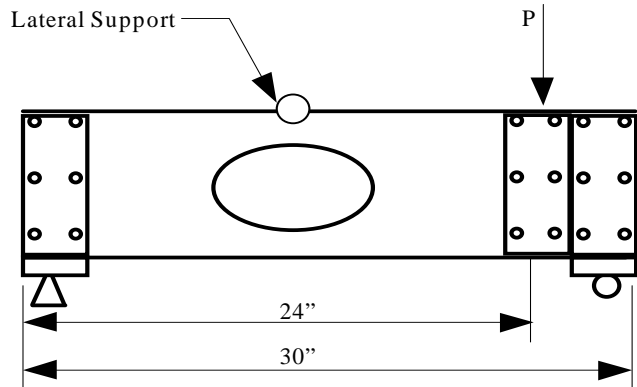


Figure 3 - Shear Test Setup

Bending Test

The purpose of this test was to investigate pure bending capacity of joists stabilized against lateral-torsional buckling. To stabilize the specimen against lateral-torsional buckling, each test specimen consisted of two C-shaped sections inter-connected by 23/32-inch (1.83 cm) thick oriented-strand-board (OSB) and 5/8-inch (1.6 cm) thick gypsum board strips. The 6-inch x 16-inch x 1/2-inch (15.2 cm x 40.6 cm x 1.3 cm) OSB strips were spaced at 24-inches (61 cm) on center and fastened to top flanges with #8 self-drilling, tapping screws (two screws per flange). The 5/8-inch (1.6 cm) gypsum board strips were also spaced at 24-inches (61 cm) on center and fastened to the bottom flanges with #6 self-drilling, tapping screws (two screws per flange). The test set up is shown in Figure 4. Vertical rollers were positioned at each end to prevent the joist from moving laterally and rotating. Rollers and bearing plates were used at each end of the assembly. Two concentrated loads were applied at third point locations of each specimen. This loading arrangement provided a pure moment region in the central portion of the beam while the two end sections experienced a linearly increasing bending moment with increasing distance from the ends. A deflection gage was placed under the assembly at mid-span to measure the vertical deflection of the test specimen.

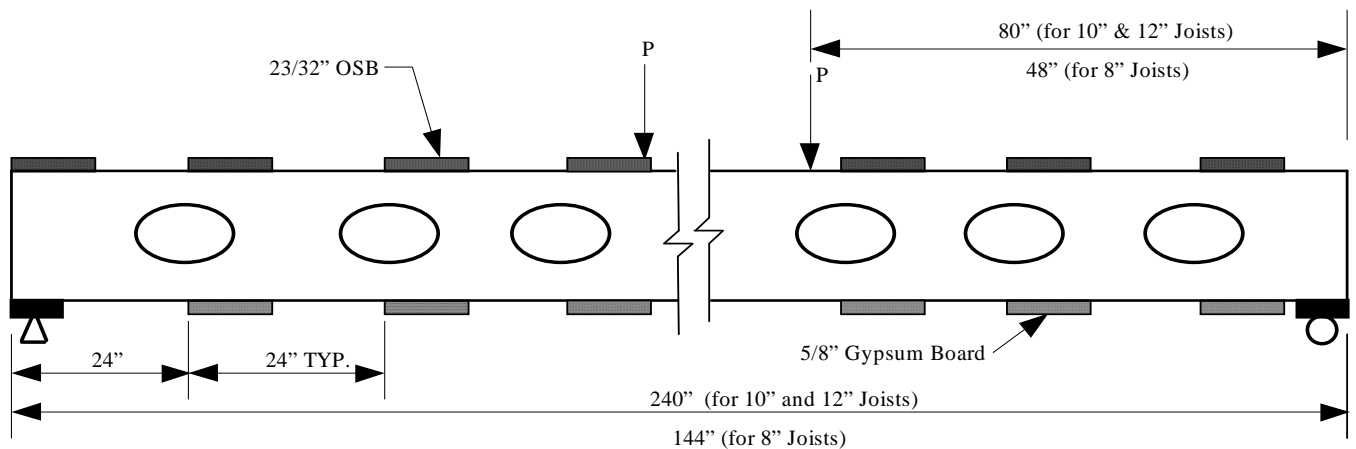


Figure 4 - Bending Tests Setup

Table 11
Comparison of Tested and Calculated Allowable Loads

Nominal Joist Size ¹	SSMA Designation	Failure Mode ²	Tested Ultimate Load ³ lb.	Allowable Tested Load ⁴ lb.	Allowable Load per AISI Design Specification ⁵ lb.	Allowable Load per AISI Design Guide Equations ^{6,7} lb.
2 x 8 x 43	800S162-43	S	5,285	2,643	967	701
2 x 8 x 43	800S162-43	ETF	543	272	268	241
2 x 8 x 43	800S162-43	ITF	1,543	771	497	455
2 x 8 x 43	800S162-43	STIFF	9,495	4,748	-	-
2 x 8 x 43	800S162-43	B	1,919	960	948	886
2 x 8 x 43	800S162-43	S & B	4,631	2,315	2,480	1,835
2 x 8 x 54	800S162-54	S	9,979	4,989	1,738	1,015
2 x 8 x 54	800S162-54	B	3,463	1,731	1,747	1,427
2 x 8 x 54	800S162-54	S & B	8,531	4,265	4,460	2,805
2 x 10 x 54	1000S162-54	S	3,094	1,547	1,530	862
2 x 10 x 54	1000S162-54	B	2,502	1,251	1,244	1,006
2 x 10 x 54	1000S162-54	S & B	7,487	3,743	3,900	2,422
2 x 12 x 54	1200S162-54	S	2,688	1,344	1,289	1,153
2 x 12 x 54	1200S162-54	ETF	879	439	347	305
2 x 12 x 54	1200S162-54	ITF	2,681	1,341	636	574
2 x 12 x 54	1200S162-54	STIFF	8,154	4,077	-	-
2 x 12 x 54	1200S162-54	B	2,496	1,248	1200	1,142
2 x 12 x 54	1200S162-54	S & B	6,419	3,210	3,480	3,174
2 x 12 x 68	1200S162-68	S	5,471	2,736	2,618	1,833
2 x 12 x 68	1200S162-68	ETF	1,502	751	718	631
2 x 12 x 68	1200S162-68	ITF	3,342	1,671	1,636	1,476
2 x 12 x 68	1200S162-68	STIFF	6,999	3,499	-	-
2 x 12 x 68	1200S162-68	B	4,766	2,383	2,404	2,073
2 x 12 x 68	1200S162-68	S & B	13,336	6,668	7,000	5,069

For SI: 1 inch = 2.54 cm, 1 lb. = 4.5 N.

¹Refer to Table 1 for actual joist dimensions.

²“S” indicates shear, “B” indicates bending, “S&B” indicates shear and bending, “ITF” indicates interior-two- flange loading, “ETF” indicates exterior-two-flange loading, and “STIFF” indicates stiffened ETF.

³Values are based on an average of three tests (minimum) per configuration for shear, bending and combined shear and bending, and an average of two tests for web crippling tests.

⁴The allowable tested load is calculated as the tested “ultimate” load divided by a factor of safety of 2.0 (refer to Appendix C).

⁵The calculations are based on actual yield stress and thickness (reported in Appendix A) in accordance with the AISI Design Specification [3] with unpunched webs.

⁶The calculations are based on actual yield stress and thickness (reported in Appendix A) in accordance with the AISI Design Guide [6]. Maximum hole size is 4.25-inches (10.8 cm) for 8-inch (20.3 cm) joists and 6.25-inches (15.9 cm) for 10- and 12-inch (25.4 and 30.5 cm) joists.

⁷The EOF and IOF reduction factors are used for the ETF and ITF loading conditions, respectively.

Table 12
Ratio of Tested to Calculated Allowable Loads Due to Shear

Nominal Joist Size	SSMA Designation	Failure Mode	Allowable Tested Load/AISI Specification Allowable Load	Allowable Tested Load/AISI Design Guide Allowable Load
2 x 8 x 43	800S162-43	S	2.73	3.77
2 x 8 x 54	800S162-54	S	2.87	4.92
2 x 10 x 54	1000S162-54	S	1.01	1.78
2 x 12 x 54	1200S162-54	S	1.04	1.17
2 x 12 x 68	1200S162-68	S	1.05	1.49
Mean			1.74	2.63
Standard Deviation			0.867	1.463

Table 13
Ratio of Tested to Calculated Allowable Loads Due to Bending

Nominal Joist Size	SSMA Designation	Failure Mode	Allowable Tested Load/AISI Specification Allowable Load	Allowable Tested Load/AISI Design Guide Allowable Load
2 x 8 x 43	800S162-43	B	1.01	1.08
2 x 8 x 54	800S162-54	B	0.99	1.21
2 x 10 x 54	1000S162-54	B	1.01	1.24
2 x 12 x 54	1200S162-54	B	1.04	1.09
2 x 12 x 68	1200S162-68	B	0.99	1.15
Mean			1.01	1.15
Standard Deviation			0.018	0.063

Table 14
Ratio of Tested to Calculated Allowable Loads Due to Shear & Bending

Nominal Joist Size	SSMA Designation	Failure Mode	Allowable Tested Load/AISI Specification Allowable Load	Allowable Tested Load/AISI Design Guide Allowable Load
2 x 8 x 43	800S162-43	S & B	0.93	1.26
2 x 8 x 54	800S162-54	S & B	0.96	1.52
2 x 10 x 54	1000S162-54	S & B	0.96	1.55
2 x 12 x 54	1200S162-54	S & B	0.92	1.01
2 x 12 x 68	1200S162-68	S & B	0.95	1.32
Mean			0.94	1.32
Standard Deviation			0.016	0.20

APPENDIX A
TEST RESULTS

Table A1
Physical and Mechanical Properties of Test Specimens

Nominal Joist Size	SSMA Designation	Web Size (in.)	Flange Size (in.)	Lip Size (in.)	Yield Point ¹ (ksi)	Tensile Strength ¹ (ksi)	Uncoated Thickness ² (in.)	Elongation ³ (percent)	
								2" gauge	1/2" gauge
2 x 8 x 43	800S162-43	8	1.625	0.5	43.05	50.67	0.04460	25	38
2 x 8 x 43	800S162-43	8	1.625	0.5	45.12	49.66	0.04430	26	38
2 x 8 x 43	800S162-43	8	1.625	0.5	40.63	49.66	0.04430	24	38
2 x 8 x 54	800S162-54	8	1.625	0.5	57.41	66.67	0.05400	21	38
2 x 8 x 54	800S162-54	8	1.625	0.5	55.15	66.18	0.05440	20	34
2 x 8 x 54	800S162-54	8	1.625	0.5	56.78	66.67	0.05460	21	38
2 x 10 x 54	1000S162-54	10	1.625	0.5	50.36	64.75	0.05560	30	56
2 x 10 x 54	1000S162-54	10	1.625	0.5	50.36	64.29	0.05600	19	31
2 x 10 x 54	1000S162-54	10	1.625	0.5	48.53	64.69	0.05565	28	38
2 x 10 x 54 ⁴	1000S162-54	10	1.625	0.5	55.68	69.60	0.05460	18	28
2 x 10 x 54 ⁴	1000S162-54	10	1.625	0.5	56.51	69.72	0.05450	16	28
2 x 10 x 54 ⁴	1000S162-54	10	1.625	0.5	56.47	69.22	0.05490	19	28
2 x 12 x 54	1200S162-54	12	1.625	0.5	45.28	64.17	0.05610	30	50
2 x 12 x 54	1200S162-54	12	1.625	0.5	46.39	62.80	0.05605	22	50
2 x 12 x 54	1200S162-54	12	1.625	0.5	46.76	64.29	0.05600	28	47
2 x 12 x 54 ⁴	1200S162-54	12	1.625	0.5	52.00	70.57	0.05385	21	44
2 x 12 x 54 ⁴	1200S162-54	12	1.625	0.5	51.38	69.73	0.05450	21	44
2 x 12 x 54 ⁴	1200S162-54	12	1.625	0.5	57.20	70.11	0.05420	19	31
2 x 12 x 68	1200S162-68	12	1.625	0.5	62.24	70.45	0.07060	14	25
2 x 12 x 68	1200S162-68	12	1.625	0.5	59.49	67.99	0.07060	14	25
2 x 12 x 68	1200S162-68	12	1.625	0.5	58.82	67.23	0.07140	15	28

For SI: 1 inch = 2.54 cm, 1 ksi = 6.9 MPa

¹Tested per ASTM A 370 [14].

²Tested per ASTM A 90 [15].

³Tested per ASTM A 370 [14] for a 2-inch (5.1 cm) and ½-inch (1.3 cm) gauge length.

⁴Joists used for bending and web crippling tests (where required).

Table A2
Mean Physical and Mechanical Properties of Test Specimens^{1,2}

Nominal Joist Size	SSMA Designation	Web Size (in.)	Flange Size (in.)	Lip Size (in.)	Yield Point (ksi)	Tensile Strength (ksi)	Uncoated Thickness (in.)	Elongation ⁴ (percent)
2 x 8 x 54	800S162-54	8	1.625	0.5	56.44	66.50	0.05433	21
2 x 10 x 54	1000S162-54	10	1.625	0.5	49.75	64.58	0.05575	26
2 x 10 x 54 ³	1000S162-54	10	1.625	0.5	56.22	69.51	0.05467	18
2 x 12 x 54	1200S162-54	12	1.625	0.5	46.15	63.75	0.05605	27
2 x 12 x 54 ³	1200S162-54	12	1.625	0.5	53.52	70.13	0.05418	20
2 x 12 x 68	1200S162-68	12	1.625	0.5	60.18	68.56	0.07087	14

For SI: 1 inch = 2.54 cm, 1 ksi = 6.9 MPa

¹Values shown represent the mean of three tests per specimen.

²Refer to Table A3 for standard deviation and coefficient of variation (COV).

³Joists were used for bending and web crippling tests.

⁴Average elongation in 2-inch (5.1 cm) gage length is shown.

Table A3
Standard Deviation and Coefficient of Variation of Physical and Mechanical Properties

Nominal Joist Size	SSMA Designation	Standard Deviation (σ)		
		Yield Strength (ksi)	Tensile Strength (ksi)	Uncoated Thickness (in.)
2 x 8 x 43	800S162-43	2.26	0.58	0.00017
2 x 8 x 54	800S162-54	1.17	0.28	0.00031
2 x 10 x 54	1000S162-54	1.06	0.25	0.00022
2 x 10 x 54 ²	1000S162-54	0.47	0.26	0.00021
2 x 12 x 54	1200S162-54	0.78	0.83	0.00005
2 x 12 x 54 ²	1200S162-54	3.20	0.42	0.00033
2 x 12 x 68	1200S162-68	1.81	1.69	0.00046
Nominal Joist Size	SSMA Designation	Coefficient Of Variation (COV) ¹		
		Yield Strength	Tensile Strength	Uncoated Thickness
2 x 8 x 43	800S162-43	0.0526	0.0117	0.0039
2 x 8 x 54	800S162-54	0.0207	0.0043	0.0056
2 x 10 x 54	1000S162-54	0.0213	0.0039	0.0039
2 x 10 x 54 ²	1000S162-54	0.0083	0.0038	0.0038
2 x 12 x 54	1200S162-54	0.0169	0.0130	0.0009
2 x 12 x 54 ²	1200S162-54	0.0597	0.0060	0.0060
2 x 12 x 68	1200S162-68	0.0300	0.0246	0.0065

For SI: 1 in. = 2.54 cm, 1 ksi = 6.9 MPa

¹COV equals the standard deviation divided by the mean.

²Joists were used for bending and web crippling tests.

