Composite Materials and Engineering Center
College of Engineering and Architecture

Report No. CMEC 13-008
Deck2Wall Spacer Testing to Determine Effects of Construction Details on Performance

Prepared

for

Decks Unlimited
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by

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Introduction

The ICC-IAS accredited Composite Materials and Engineering Center (CMEC), at Washington State University in Pullman, WA, performed a series of tests on deck ledger connections fabricated using Deck2wall spacers manufactured by Decks Unlimited. The connection testing was performed following the methods used by Carradine et. al. (2007)[1], which was the basis for the deck ledger connection provisions in R502.2.2.1 of the 2009 International Residential Code. Two spacers were evaluated (Figure 1). This report includes descriptions of specimens and testing performed, and tabulated results of test data.

Figure 1. Deck2wall Spacer products

[1] Carradine, D.M., D.A. Bender, F.E. Woeste and J.R. Loferski. 2007. Development of design capacities for residential deck ledger connections. Forest Products Journal 57(3):29-33.

Test Materials

The product was an injection molded, fiberglass reinforced polypropylene spacer received from and manufactured by Decks Unlimited. Supplied with the spacers were fasteners to attach the product to the ledger board. These fasteners were 1 5/8-inch Deck Mate all-purpose screw with a root diameter of 0.124-inches. The smaller of the two spacers was approximately 2 inches in diameter by 0.5 inches thick. The larger spacer was approximately 2 7/16 inches in diameter by 0.625 inches thick. All other materials used for testing were obtained locally by CMEC personnel.

Ledger testing was conducted on five configurations to determine the effects of different construction details on the ultimate strength of the connections. Table 1 describes each of the test configurations. Fifteen specimens were tested for each configuration. Each specimen consisted of the ledger to rim board portion described in Table 1, and also had a simulated deck portion that consisted of two joists that attached to the ledger and a backing member with joist hangers. Figure 2 shows a typical specimen ready to be tested. All configurations utilized nominal 2x8 preservative pressure-treated (PPT) Hem-Fir lumber for the ledgers and backing members. No. 2 Douglas-Fir 2x material was used for joist members. High-capacity Simpson Strongtie HUS28 hangers were used to attach the joist hangers to the ledger to ensure a failure would occur at the ledger to rim board connection. The joist hangers and backing member were reused multiple times during testing. The joists, siding, house rim board and ledger were new for each specimen.

Table 1. Descriptions of Ledger Test Specimen Configurations

Configuration[1]	Band Joist	T1-11 Siding Nominal Thickness (in)	Spacer Thickness (in)	Fastener		Replications
				Dia. (in)	Type	
HF-SPF-1	2x10 SPF	5/8	5/8	1/2	bolt	15
HF-SPF-2	2x10 SPF	5/8	5/8	1/2	Lag screw	15
HF-SPF-3	2x10 SPF	5/8	5/8	5/8	bolt	15
HF-SPF-4	2x10 SPF	5/8	5/8	5/8	Lag screw	15
HF-SPF-5	2x10 SPF	5/8	1/2	0.220	SST ledger screw[2]	15

[1]All ledger material was incised, PPT nominal 2x8 Hem-Fir lumber.
[2] SST Model # SDWS22500DB screw (0.220" diameter, 5" long)

Figure 2. Typical Ledger Testing Specimen with Incised Hem-Fir Ledger Attached Using a $\frac{1}{2}$ - Inch Diameter Lag Screw.

To conservatively simulate field conditions, materials used for the testing were conditioned prior to specimen fabrication and moisture content readings were obtained at the beginning of each test. All materials used for the ledgers, incised PPT Hem-Fir, were kept wet and were maintained at approximately fiber saturation during testing. Materials used for rim boards and siding were stored in a controlled environment where the temperature and relative humidity were maintained to achieve an average moisture content of approximately 12% (dry weight basis). Moisture content readings were obtained for all wood and wood-based materials prior to testing using a resistance-type moisture meter. The PPT Hem–Fir material used was incised and rated for ground contact.

Test Methods and Results

Ledger assembly tests were conducted as described below to determine the effects on ultimate connection capacity of various construction details. All load, moisture content, and displacement measurements were obtained using instrumentation that was calibrated as part of the International Accreditation Service (IAS) accreditation maintained by the CMEC.

Ledger testing was conducted utilizing methods previously used for similar testing at Washington State University (Carradine et al. 2007). While there is an alternate method for testing rim boards, specifically APA Standard PRR–401 *Performance Standard for APA EWS Rim Boards* (APA, 2002), the methods prescribed by Carradine et al. (2007) were judged to provide more conservative results. PRR–401 recommends that the siding (OSB) and the rim board bear directly on the reaction support and that SPF be used for the ledger (with no requirement for MC control). Based on the methods utilized by Carradine et al. (2007), testing was conducted such that the rim board was the only portion of the ledger assembly that had bearing on the reaction support. Because decks are typically exposed to weather, ledger material was incised, PPT lumber and was tested in the wet condition, at or above the fiber saturation point. Wood is weakest at moisture contents at and above the fiber saturation point; therefore this was considered the most conservative condition under which to test the ledgers.

Tests were performed by applying a load at the center of both joist members using displacement control at a constant rate of 0.5 inches per minute until ultimate load was achieved. Loads were applied with a fixture attached to a hydraulic actuator that was servo-controlled using an MTS 407 controller as shown in Figure 2. The ledgers, rim boards, T1-11 siding, fasteners, the joists, and spacers were replaced for each test specimen; whereas, joist hangers and backing members were reused if no damage was observed.

During all testing, applied load, movement of the hydraulic actuator, and displacement of the ledger with respect to the rim board were sampled at 2 Hz and were acquired using *LabVIEW* version 7.1 software. A load cell having a capacity of 25,000 lbs was utilized to obtain load measurements and a string potentiometer mounted to the rim board and the ledger monitored the displacement of the ledger with respect to the rim board. These load and deflection measurements were used for generating load-displacement plots and for subsequent calculations. A string potentiometer mounted to the hydraulic actuator was used as feedback for controlling the movement of the actuator.

Results

Load and displacement data were acquired and allowed for the determination of the maximum load applied to each specimen. Tables 2 through 7 present the data for each test and averages for maximum load applied to the fastener and the deflection of the 5 configurations tested.

Each maximum load was adjusted for safety and load duration to derive adjusted connection loads, similar to those presented by Carradine et. al. (2007). The maximum load applied to the specimen was first divided by 2 because half of the load was carried by the ledger connection and half by the backing member at the opposite end of the joists. The load calculated after dividing by 2 was the maximum load applied to the fastener, as provided in Tables 2 through 6. This load was then divided by a safety factor of 3, providing a larger safety margin than that required by the International Building Code (ICC, 2009), which recommends a safety factor of 2.5. Additionally, the load was divided by a load duration factor of 1.6 to convert from a short-term load to a normal-duration load as per tabulated values in the ANSI/AWC NDS-2012 (*National Design Specification for Wood Construction*). Table 7 provides a summary of the adjusted connection data for the various configurations, as well as average deflections at ultimate load and at the adjusted connection load level. The comparable results from Carradine et al. are presented in Appendix A.

The ultimate loads for the 5/8-inch and 1/2-inch diameter bolts were similar, since ledger splitting typically controlled the connection capacities. Displacements of the ledgers relative to the band joists varied considerably due to slack in the system caused by the 1/16-inch oversized holes (as per NDS) for the through bolt specimens. The 1/2-inch diameter bolt connection tested herein was approximately 15 percent greater than the same size bolt (with no spacer) and 52% greater than the same size bolt with 1/2-inch stacked washers from the Carradine et al. study. Similarly, the ultimate load for the 1/2-inch lag screw connection tested herein was 77 percent greater than the same size lag screw (with no spacer) from the Carradine et al. study. One likely reason is that the polymer spacers are attached to the ledgers with three screws each, which had the effect of increasing the side member thicknesses and the dowel bearing strengths of the side members. Another contributing factor is that washers were used in the lag screw tests herein, but not in the Carradine et al. study. Most of the connections tested had some degree of localized crushing and splitting of the ledger, and the presence of a washer improved performance by increasing the bearing stress area at the bolt head. In addition, sampling variability of the materials tested could have contributed to some of the differences between tests.

Typical failure for this testing when using a through bolt connection was generally splitting of the ledger material along the connector location. When a lag screw was used as the ledger to house connector the typical failure was a withdrawal of the connector from the house band joist, along with partial splitting of the ledger. Photographs of typical failures are shown in Appendix B. The average moisture content and specific gravity of the test specimens is presented in Appendix C.

Table 2. Results from Ledger Testing on Configuration 1 Specimens - PPT Hem-Fir Ledger Attached to SPF Rim Board Through 19/32" T1-11 Using a 1/2 x 5" Bolt, and Between the Ledger and Siding was a 5/8" Deck2wall Spacer

Specimen	Max. Load (lbs)	Deflection at Max. Load (in.)	Adjusted Load (lbs)	Deflection at Adjusted Load (in.)
1-1	4,853	3.29	1,011	0.22
1-2	4,685	2.93	976	0.06
1-3	4,350	2.02	906	0.02
1-4	3,415	2.70	711	0.09
1-5	3,845	2.37	801	0.06
1-6	4,788	3.09	998	0.22
1-7	4,956	3.66	1,032	0.14
1-8	5,491	2.72	1,144	0.14
1-9	5,050	2.75	1,052	0.12
1-10	5,353	2.92	1,115	0.14
1-11	3,973	1.78	828	0.14
1-12	5,389	2.46	1,123	0.11
1-13	5,132	2.09	1,069	0.10
1-14	6,098	2.41	1,270	0.10
1-15	6,247	2.57	1,301	0.17
Average	**4,908**	**2.65**	**1,023**	**0.12**
COV	**16.0%**	**18.7%**	**16.0%**	**45.5%**

Table 3. Results from Ledger Testing on Configuration 2 Specimens - PPT Hem-Fir Ledger Attached to SPF Rim Board Through 19/32″ T1-11 Using a 1/2 x 5″ Lag Screw, and Between the Ledger and Siding was a 5/8″ Deck2wall Spacer

Specimen	Max. Load (lbs)	Deflection at Max. Load (in.)	Adjusted Load (lbs)	Deflection at Adjusted Load (in.)
2-1	3,462	1.58	721	0.20
2-2	3,509	1.31	731	0.14
2-3	4,077	1.35	849	0.17
2-4	3,202	1.15	667	0.12
2-5	3,303	1.09	688	0.16
2-6	4,863	1.55	1,013	0.30
2-7	3,487	1.28	727	0.16
2-8	3,893	1.51	811	0.18
2-9	4,054	1.47	845	0.19
2-10	3,647	1.46	760	0.16
2-11	4,229	1.36	881	0.17
2-12	3,730	1.40	777	0.11
2-13	4,362	1.49	909	0.26
2-14	3,856	1.45	803	0.19
2-15	4,010	1.25	835	0.22
Average	**3,846**	**1.38**	**801**	**0.18**
COV	**11.5%**	**10.4%**	**11.5%**	**27.3%**

Table 4. Results from Ledger Testing on Configuration 3 Specimens - PPT Hem-Fir Ledger Attached to SPF Rim Board Through 19/32" T1-11 Using a 5/8 x 5" Bolt, and Between the Ledger and Siding was a 5/8" Deck2wall Spacer

Specimen	Max. Load (lbs)	Deflection at Max. Load (in.)	Adjusted Load (lbs)	Deflection at Adjusted Load (in.)
3-1	5,536	2.24	1,153	0.22
3-2	4,985	1.64	1,038	0.18
3-3	5,106	2.57	1,064	0.25
3-4	4,333	1.90	903	0.23
3-5	4,037	1.30	841	0.25
3-6	4,800	2.38	1,000	0.41
3-7	4,543	1.75	946	0.13
3-8	5,011	1.42	1,044	0.20
3-9	5,039	2.17	1,050	0.23
3-10	5,016	1.88	1,045	0.21
3-11	6,847	2.41	1,427	0.30
3-12	5,243	2.54	1,092	0.22
3-13	5,073	3.11	1,057	0.23
3-14	6,084	1.72	1,267	0.22
3-15	6,035	3.65	1,257	0.27
Average	**5,179**	**2.18**	**1,079**	**0.24**
COV	**13.8%**	**29.1%**	**13.8%**	**25.6%**

Table 5. Results from Ledger Testing on Configuration 4 Specimens - PPT Hem-Fir Ledger Attached to SPF Rim Board Through 19/32" T1-11 Using a 5/8 x 5" Lag Screw, and Between the Ledger and Siding was a 5/8" Deck2wall Spacer

Specimen	Max. Load (lbs)	Deflection at Max. Load (in.)	Adjusted Load (lbs)	Deflection at Adjusted Load (in.)
4-1	4,205	1.54	876	0.17
4-2	4,503	2.19	938	0.25
4-3	4,845	1.50	1,009	0.23
4-4	4,575	1.53	953	0.30
4-5	4,689	1.82	977	0.19
4-6	4,009	1.23	835	0.15
4-7	4,427	1.99	922	0.19
4-8	4,804	1.83	1,001	0.28
4-9	4,532	2.44	944	0.19
4-10	3,394	1.36	707	0.17
4-11	3,642	1.39	759	0.16
4-12	3,422	1.31	713	0.13
4-13	4,564	1.21	951	0.19
4-14	4,476	1.30	933	0.18
4-15	4,414	1.72	920	0.19
Average	**4,300**	**1.62**	**896**	**0.20**
COV	**11.0%**	**22.6%**	**11.0%**	**24.1%**

Table 6. Results from Ledger Testing on Configuration 5 Specimens - PPT Hem-Fir Ledger Attached to SPF Rim Board Through 19/32" T1-11 Using a 0.220 SST Ledger Screw, and Between the Ledger and Siding was a 1/2" Deck2wall Spacer

Specimen	Max. Load (lbs)	Deflection at Max. Load (in.)	Adjusted Load (lbs)	Deflection at Adjusted Load (in.)
5-1	2,219	1.03	462	0.11
5-2	2,475	1.24	516	0.12
5-3	2,478	1.10	516	0.12
5-4	2,221	1.02	463	0.14
5-5	2,624	1.20	547	0.14
5-6	2,366	1.10	493	0.10
5-7	2,329	1.35	485	0.13
5-8	2,472	1.28	515	0.12
5-9	2,475	1.22	516	0.13
5-10	2,407	1.26	502	0.13
5-11	2,451	1.30	511	0.18
5-12	2,410	1.12	502	0.10
5-13	2,142	1.06	446	0.14
5-14	2,197	1.11	458	0.11
5-15	2,097	1.02	437	0.16
Average	**2,358**	**1.16**	**491**	**0.13**
COV	**6.4%**	**9.5%**	**6.4%**	**17.7%**

Table 7. Summary of Testing Results by Configuration

Configuration[1]	Band Joist	Spacer thickness (in)	Fastener	Ultimate Load		Design Load (lb)[3]	Average Displacement at Design Load (in)
				Average (lb)	Coefficient of Variation (%)		
HF-SPF-1	2x10 SPF	5/8	½-in bolt	4,908	16.0%	1,023	0.12
HF-SPF-2	2x10 SPF	5/8	½-in lag screw	3,846	11.5%	801	0.18
HF-SPF-3	2x10 SPF	5/8	5/8-in bolt	5,179	13.8%	1,079	0.24
HF-SPF-4	2x10 SPF	5/8	5/8-in lag screw	4,300	11.0%	896	0.20
HF-SPF-5	2x10 SPF	1/2	0.220-in SST screw[2]	2,358	6.4%	491	0.13

[1]All ledger material was incised, PPT 2x8 Hem-Fir lumber and all Configurations had 5/8-inch T1-11 siding between the band joist and ledger.

[2] SST Model # SDWS22500DB screw (0.220" diameter, 5" long)

[3] Design loads were calculated by dividing the average ultimate load by 3 (safety factor) and by 1.6 (duration of load factor).

Testing conducted by Robert Duncan and Scott R. Lewis

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ACCREDITED

Appendix A

Table A1. Comparable ledger-to-house band joist connection test specimen average testing results from Carradine et.al. 2007.

Configuration*	Band Joist	Fastener	Ultimate Load (lb_f)		Design Load (lb_f)***	Average Displacement at Design Load (in.)
			Average	Coefficient of Variation (%)		
HF-1	2x10 SPF	½″ Lag Screw	2,170	17.4	451	0.19
HF-2	2x10 SPF	½″ Bolt	4,260	17.7	887	0.21
HF-3	2x10 SPF	½″ Bolt**	3,230	19.0	673	0.23

*All ledger material was incised, PPT nominal 2x8 lumber and all configurations had 15/32-inch OSB between the band joist and ledger.
**These configurations included a 1/2 inch stack of washers between the OSB sheathing and the deck ledger.
***Design loads were calculated by dividing the average ultimate load by 3 (safety factor) and by 1.6 (duration of load factor).

Appendix B

Figure B1. Typical Failure for Configuration 1, 1/2-inch Bolt.

Figure B2. Typical Failure for Configuration 1, 1/2-inch Bolt.

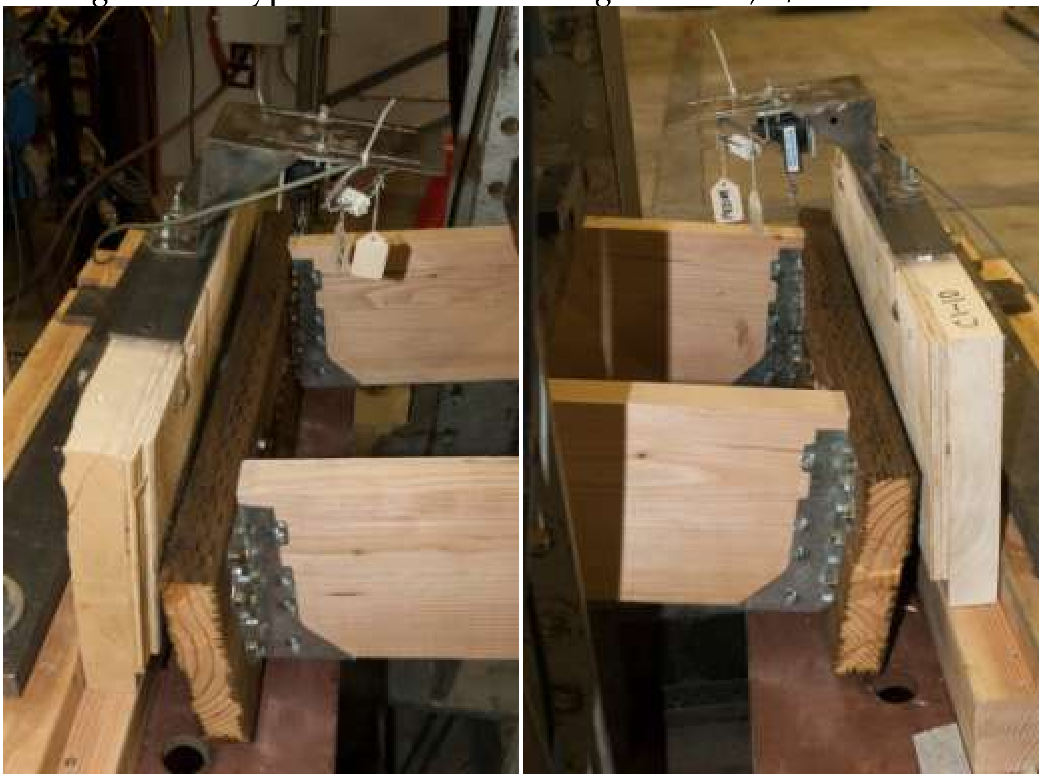

Figure B3. Typical Failure for Configuration 1, 1/2-inch Bolt.

Figure B4. Typical Failure for Configuration2, 1/2-inch Lag Screw.

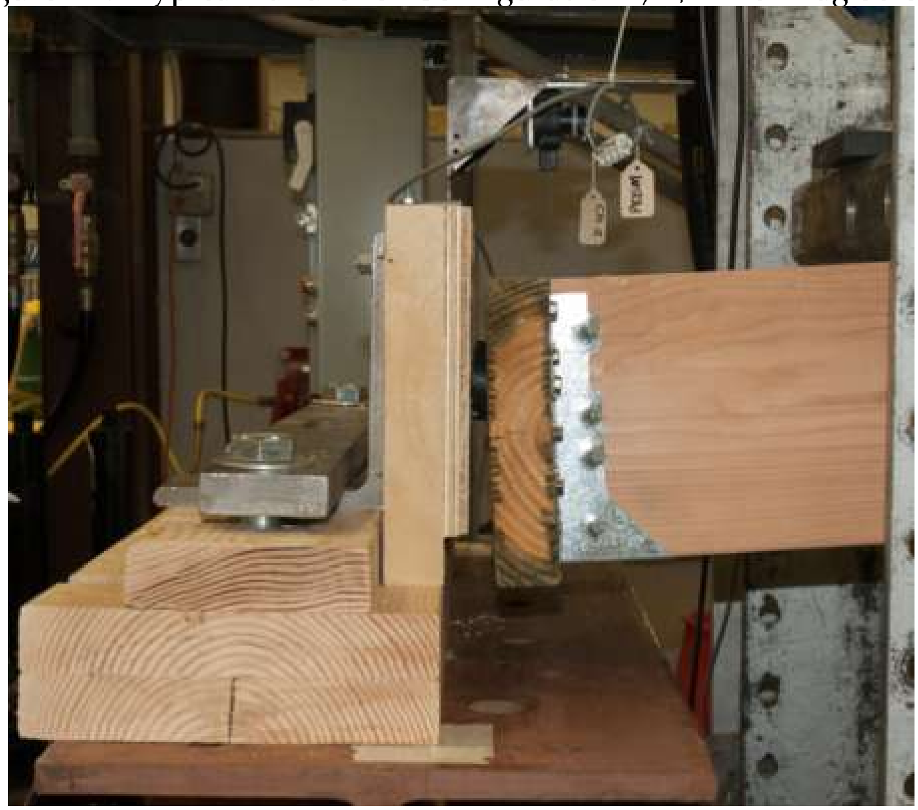

Figure B5. Typical Failure for Configuration2, 1/2-inch Lag Screw.

Figure B6. Typical Failure for Configuration2, 1/2-inch Lag Screw.

Figure B7. Typical Failure for Configuration3, 5/8-inch Bolt.

Figure B8. Typical Failure for Configuration3, 5/8-inch Bolt.

Figure B9. Typical Failure for Configuration3, 5/8-inch Bolt.

Figure B10. Typical Failure for Configuration3, 5/8-inch Bolt.

Figure B11. Typical Failure for Configuration3, 5/8-inch Bolt.

Figure B12. Typical Failure for Configuration 4, 5/8-inch Lag Screw

Figure B13. Typical Failure for Configuration 4, 5/8-inch Lag Screw

Figure B14. Typical Failure for Configuration 4, 5/8-inch Lag Screw

Figure B15. Typical Failure for Configuration 4, 5/8-inch Lag Screw

Figure B16. Typical Failure for Configuration 5, Simpson SST Ledger Screw

Figure B17. Typical Failure for Configuration 5, Simpson SST Ledger Screw

Figure B18. Typical Failure for Configuration 5, Simpson SST Ledger Screw

Appendix C

Table C1. Average Moisture Content and Specific Gravity of Ledger and Band Joist Material for Each Configuration

Configuration	HF Ledger Moisture Content (%)	HF Ledger Specific Gravity	SPF Band Joist Moisture Content (%)	SPF Band Joist Specific Gravity
HF-SPF-1	37.0%	0.41	12.6%	0.37
HF-SPF-2	35.5%	0.42	12.4%	0.37
HF-SPF-3	33.7%	0.44	13.0%	0.38
HF-SPF-4	25.5%	0.43	12.7%	0.35
HF-SPF-5	39.2%	0.42	12.4%	0.34