Effects of Installation Method on Nail Withdrawal Capacities

Ashlie Kerr[1] *Shelly Dean*[2] *David O. Prevatt*[3]

[1]*Graduate Student, Engineering School of Sustainable Infrastructure and Environment, University of Florida, Gainesville, FL 32611*

[2]*Undergraduate Student, Humboldt State University, Arcata CA 95521*

[3]*Assistant Professor, Engineering School of Sustainable Infrastructure and Environment, University of Florida, Gainesville, FL 32611*

ABSTRACT

Nail withdrawal capacities are tested in accordance with ASTM D1761 and are typically estimated using the empirical equation $W=6900G^{2.5}D$ given in the National Design Standard for Wood Construction. A previous study by Shreyans et al found that in-situ nail withdrawal capacities were over-estimated by the NDS equation and suggested that loss of capacity may be due to the installation of the nail through the sheathing, which is not done in ASTM D1761. This paper presents an experimental study that explores the effects of installation method on the nail withdrawal capacity by testing nails installed through both Oriented Strand Board (OSB) and Plywood. Type of nail used for testing was 6d common nails with diameter of 2.87 mm (0.113 in) and length of 50.8 mm (2 in).

The effect of installation method on nail withdrawal capacity was evaluated by comparing capacities using ASTM D1761 Standard Test Methods for Mechanical Fasteners in Wood to those obtained with the nail installed through the sheathing. The effect of the nail withdrawal method was also quantified for three methods: 1) Withdrawal with the sheathing left in place, 2) Withdrawal by means of a steel plate notched to fit around the installed nail, 3) Withdrawal by direct pull using a steel jaw.

Results demonstrated that installation through the sheathing consistently reduced the withdrawal capacity; however the test setup and withdrawal methods also significantly affected the withdrawal capacities. The National Design Standard empirical formula may be non-conservative in representing the withdrawal capacities of nails in a roof setting.

INTRODUCTION

Sheathing attachment is extremely important in residential structures. The roof is usually the first thing to fail in a windstorm and once this happens the remaining structure is more unstable. Wood residential buildings account for 60% of all damages in wind storms (Sparks, 1991) and 95% of residential economic losses are from failures associated with the roof (Baskaran, 1997). These failures are due in part to inadequate strength in fasteners (primarily nails) attaching wood sheathing to the wood rafter (Shreyans, 2012).

Nail withdrawal capacities are tested in accordance with ASTM D1761. This requires that the fastener to be withdrawn from the wood with a testing machine capable of keeping a constant withdrawal rate of 2.54 mm/min (0.1 in/min) with a gripping device that fits the base of the fastener head. In this study the Direct Pull Method described below would be the equivalent of the ASTM D1761 Test Protocol and thus all other test results will be compared to this.

Shreyans et al. performed in-situ tests on 1,458 nails from 17 Florida homes using a modified Portable Nail Extractor (m-PNE), which required the removal of the sheathing around the nail in order to test the withdrawal capacity. Results of the study demonstrated that not only was the withdrawal capacity affected by the method of sheathing removal, but also that mean in-situ nail withdrawal capacities were lower than nail withdrawal capacities implied using the NDS empirical equation. It was concluded that installation through sheathing may have been responsible for the loss in strength. The objective of this current study is to evaluate the effect of the nail installation method on the nail withdrawal capacity.

TEST METHODS

Materials

Nails were chosen to match those observed in the in-situ tests, and consisted of galvanized common nails with dimensions of 2.87 mm x 50.8 mm (0.113 in x 2 in). Sheathing consisted of 11.11 mm (7/16 in) oriented strand board (OSB) and 11.91 mm (15/32 in) 4-ply plywood. Framing members used were No. 2 Southern Yellow Pine 38 mm x 89 mm x 244 mm (nominal 2 in x 4 in, 8 ft long). Moisture contents and specific gravities were determined at five locations in each framing member in accordance with ASTM D2395 “Test Methods for Specific Gravity of Wood and Wood-Based Materials” and ASTM D4442 “Test Methods for Direct Moisture Content Measurement of Wood and Wood Based Materials.” The average values for each framing member are shown in Table 1.

Table 1: Specific Gravity and Moisture Content per Board

	Specific Gravity		Moisture Content	
Board	Mean	COV	Mean (%)	COV
A	0.47	4.8%	14.0	5.8%
B	0.48	1.9%	14.4	3.3%
C	0.44	8.0%	14.7	4.3%
D	0.57	6.1%	13.6	2.5%
E	0.43	2.0%	13.3	4.7%
F	0.50	7.3%	14.5	3.4%

Equipment

Nails were either installed through the sheathing or by means of a nail guide that ensured a nominally consistent embedment depth of 38.1 mm (1.5 in). Nails were installed using an air compression nail gun at an air pressure chosen to ensure the top of the nail head was not embedded beyond the specified lengths. Any nails that were embedded too far were not tested, and those that were not embedded far enough were corrected by using a hammer to impact the nails to the correct depth.

Withdrawal Methods
All withdrawal tests were performed using an Instron Universal Testing Machine (UTM) Model 3384 with 150 kN (33,721 lbf) capacity. The withdrawal rate for all tests was kept constant at 2.54 mm/min (0.1 in/min).

Test Matrix
Six different test methods were performed to quantify the effect of installation method on the nail withdrawal capacity. These six methods were chosen to best isolate the effects of the installation method and the withdrawal method. Two installation methods were considered, installation through sheathing and installation using the nail guide. Three withdrawal methods were considered which included direct pull using a steel jaw, indirect pull using a steel plate notched to fit around the nail shaft, and indirect pull using the sheathing itself. The test matrix is displayed in Table 2. Illustrations of the installation and withdrawal methods are shown in Figure 1.

Table 2: Test Matrix

Test ID	**Installation Method**	**Withdrawal Method**	**Number of Nails**
NGDP-S	Nail Guide	Direct Pull	134
NGSP-S	Nail Guide	Indirect – Steel Plate	59
OSB-S	OSB	Indirect – Sheathing	97
ODP-S	OSB	Direct Pull	60
PLY-S	Plywood	Indirect – Sheathing	76
PDP-S	Plywood	Direct Pull	40

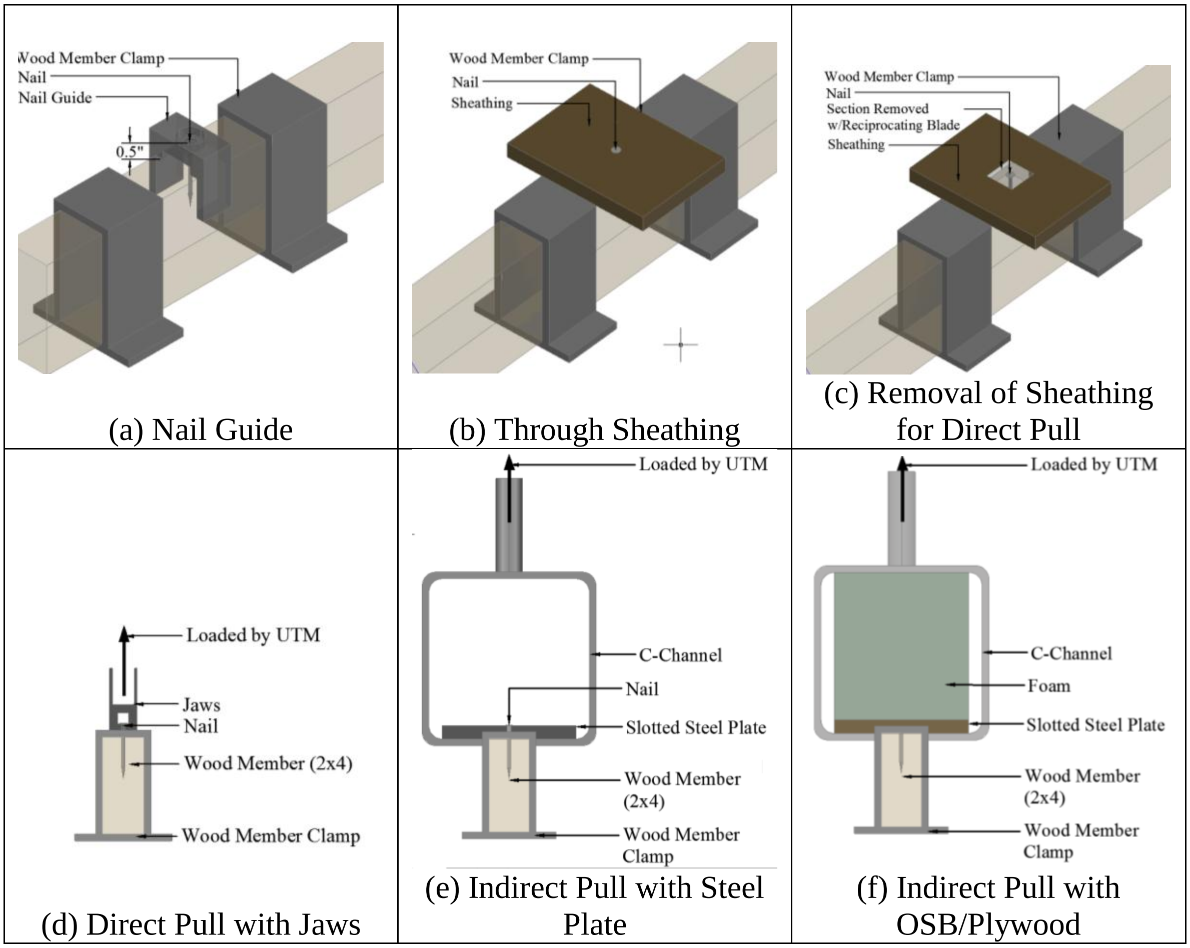

Figure 1: Nail Installation and Withdrawal Methods

When nails were installed through the sheathing but withdrawn using the direct pull method, it was necessary to cut away the sheathing from the nail. This was done using a Rockwell SoniCrafter Model RK5100K reciprocating saw, as Shreyans et al. demonstrated that this removal method had the least effect on the withdrawal capacity of the nails. When nails were withdrawn using the indirect method with sheathing, it was necessary to prevent the sheathing from failing prematurely during the test. This was accomplished by filling the C-channel shown in Figure 1f with dense closed-cell foam.

Nails were installed at the center of the narrow face of the SYP wood member 50.8 mm (2 in) on center with an initial offset of 101.6 mm (4 in) from the edge. Both sides of the wood member were used in these tests with no offset between the nails on opposite sides. Each specimen was labeled based on the board, the side, and the location. For example a nail tested on Board A, on side 2 and is the 16th nail tested on that board it would be given the name A2-16.

RESULTS

The maximum withdrawal load was recorded for each nail. The results were then reported in units of force per unit length which was calculated by dividing the recorded maximum load by the length of the nail embedded in the SYP wood member.

Table 3 reports the smooth shank nails average withdrawal and COV and Table 4 compares all the test methods to the Direct Nail Pull Method.

Table 3: Mean Withdrawal Capacity for Nails in kN/m* (COV %)

	Board	A		B		C		D		E		F	
	Specific Gravity	0.47		0.48		0.44		0.57		0.43		0.50	
	Side	1	2	1	2	1	2	1	2	1	2	1	2
Test Method	NGDP	27.7 (15)	23.7 (12)	24.5 (17)	28.3 (18)	25.1 (16)	23.6 (18)	19.0 (23)					
	NGSP	29.4 (13)		24.2 (23)				21.2 (23)					
	OSB		23.4 (17)			22.5 (9)			25.9 (10)	18.0 (13)			19.4 (19)
	ODP								22.0 (12)	13.4 (19)			13.7 (27)
	PLY				25.7 (11)		22.7 (11)				16.5 (18)	20.2 (20)	
	PDP										12.8 (19)	15.0 (27)	

**Coversion 1kn/m = 5.7 lb/in*

Table 4: Comparison of Smooth Shank

Method	Mean Nail Capacity kN/m (lb/in)	Ratio to Direct Nail Pull
NGDP	24.6 (140.2)	-
NGSP	25.0 (142.9)	1.02
OSB	21.7 (123.8)	0.88
ODP	16.4 (93.6)	0.67
PLY	21.3 (121.5)	0.87
PDP	14.0 (79.7)	0.57

An observation from these tests was that the specific gravity seemed to have no discernible effect on the withdrawal rate as shown in Figure 2.

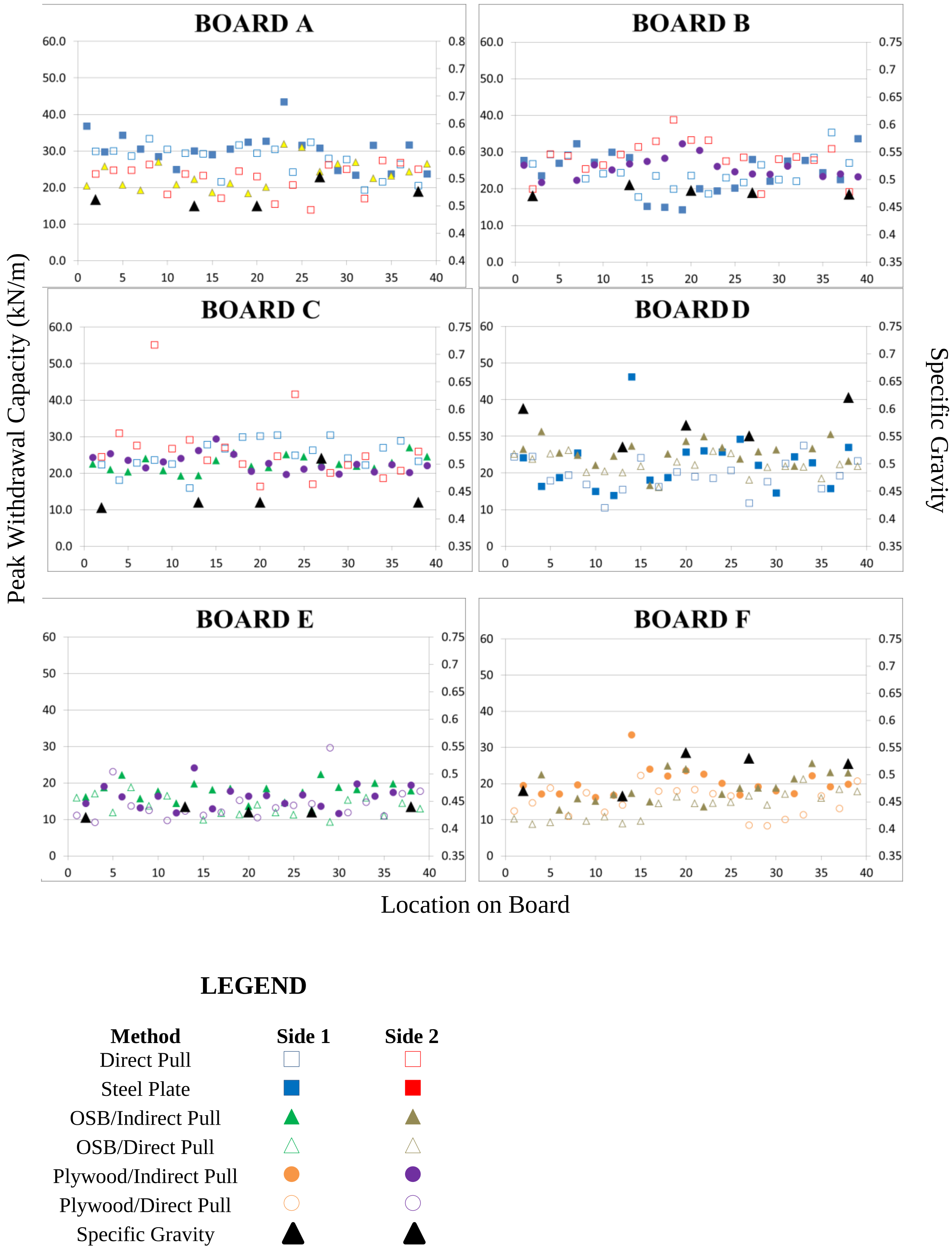

Figure 2: Withdrawal Capacity and Specific Gravity vs. Location on Board

Discussion

A Two Sample Student's *t*-test was performed using Matlab version R2009b in which the calculation were adjusted to assume unequal variance. The data was grouped together per method and tested to determine if there was a statistical similarity or difference between them. Table 5 shows a summary of the p values comparing each of the methods.

Table 5: T-test p-values comparing each test method

Test Method	NGDP	NGSP	OSB	ODP	PLY	PDP
NGDP	1	.3342	1.50E-5	3.57E-18	3.11E-6	1.95E-19
NGSP		1	1.27E-4	1.22E-13	2.79E-5	2.47E-16
OSB			1	3.12E-10	.3884	7.01E-13
ODP				1	7.91E-8	.0590
PLY					1	5.92E-11
PDP						1

A confidence level of 5% was used to determine that the sets of data were from the same sample. As indicated in Table 5, the Direct Nail Pull and Steel Plate Test can be treated as one sample population, the OSB and Plywood Indirect Pull as another sample population and the OSB and Plywood Direct Pull as a third. This demonstrates that the steel plate indirect pull method has no effect on the withdrawal rate in comparison to the ASTM D1761. An indirect pull with sheathing does affect the withdrawal capacity however the type of sheathing seems to have no effect. And finally, installation through sheathing, whether through plywood or OSB, also reduced the nail withdrawal capacities. Table 6 gives p values again from a Two Sample Student's t-test but now grouping the methods that the previous test determined to be from the same sample. Figure 3 gives the boxplots showing the median withdrawal for each test method group, with the box representing the 25^{th} to 75^{th} percentile.

Table 6: T-test pvalues comparing grouped test methods

Test Method Group	NGDP/NGSP	OSB/PLY	ODP/PDP
NGDP/NGSP	1	8.88E-10	6.39E-34
OSB/PLY		1	5.55E-19
ODP/PDP			1

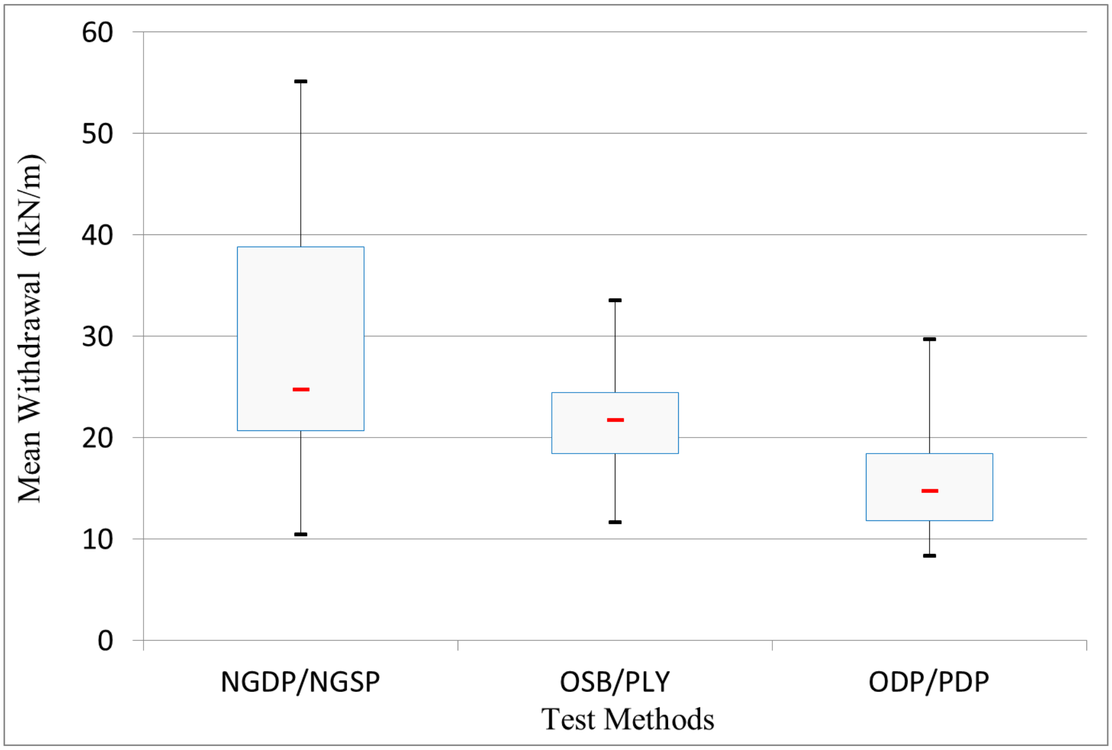

Figure 3: Withdrawal vs. Test Method Group

The statistics indicate that the three test samples are from different sample sets. This demonstrates that installing through sheathing does affects withdrawal capacity.

Conclusion

In the ASTM D1761 Standard Test Methods for Mechanical Fasteners in Wood the setup and method is similar to the Direct Pull method. The direct pull method does not give withdrawal strengths parallel to real world applications. In the National Design Standard, the empirical equation $W=6900G^{2.5}D$ does not take into account how the nail is installed. Though it is generally accepted that nail withdrawal values are dependent primarily on embedment length and specific gravity of the framing member, this study suggests that other factors, such as installation through sheathing, may also be of importance. Further testing will be performed to establish this trend with a larger dataset and further isolate the effect of installation through sheathing.

ACKNOWLEDGEMENT

The authors wish to acknowledge the financial support of the Florida Department of Emergency Management. Assistance was also given by National Science Foundation Summer Research Experience for Undergraduates (NSF-REU) In addition David Roueche and Jeandonna Doreste helped in the analysis of the data and lastly Sushmit Shreyans a former graduate student who contributed his knowledge when needed as the data was analyzed and the tests were being performed.

REFERENCES

AF&PA. *National Design Specification for Wood Construction (Nds)*. Washington, D.C.: American Forest and Paper Association, 2005a.

AF&PA. "National Design Specification for Wood Construction. In *Dowel-Type Fasteners*." Washington D.C., 2005b.

ASTM. "Test Methods for Mechanical Fasteners in Wood, D1761-06." West Conshohocken, PA: ASTM International, 2006a.

ASTM. "Test Methods for Direct Moisture Content Measurement of Wood and Wood-Base Materials, D4442-07." West Conshohocken, PA: ASTM International, 2006b.

ASTM. "Test Methods for Specific Gravity of Wood and Wood-Based Materials, D 2395 -02." West Conshohocken, PA: ASTM International, 2006c.

Baskaran, A., and O. Dutt. "Performance of Roof Fasteners under Simulated Loading Conditions." *Journal of Wind Engineering and Industrial Aerodynamics* 72, no. 1-3 (1997): 389-400.

Matlab, Version R2009b, Mathworks Inc.

Shreyans, Sushmit, Ashlie Kerr, D.O. Prevatt, and Kurtis R. Gurley. "In-Situ Nail Withdrawal Strengths in Wood Residential Roofs." In *ATC&SEI Advances in Hurricane Engineering*. Miami, FL, 2012.

Sutt, E., T. Reinhold, and D. Rosowsky. "The Effect of in-Situ Conditions on Nail Withdrawal Capacities." Paper presented at the World Conference of Timber Engineering, Whistler, BC, 2000.