TECHLINE

Forest Products Laboratory

Withdrawal Strength of Stainless Steel Nails

The withdrawal strength of a smooth nail driven into wood depends upon the fastener diameter, the depth of penetration of the fastener, and the wood specific gravity. Engineering design equations were developed from the empirical data relating these variables to withdrawal strength. Still, withdrawal also must depend upon the static coefficient of friction between the wood and the metal fastener. Different surface conditions that arise from cement or polymer coatings, or even differences in the metal surface topography, would be expected to change the coefficient of friction and therefore the withdrawal strength. When threaded nails are driven into wood, the wood cells separate and lodge between the thread crests. This lodged material must be broken before threaded nails are withdrawn from wood; therefore, frictional effects are expected to have reduced effect on withdrawal. Currently, the *Wood Handbook* (FPL 2010) indicates that the surface condition of smooth nails influences the initial withdrawal resistance, but the discussion of this effect is centered on surface coatings such as cement or polymers, not the metal type. Bonser and Scholten (1947) concluded the withdrawal resistance of aluminum nails was less than that of copper or steel wire nails, but the decrease in withdrawal capacity could be offset if the next larger diameter nail were used. The current version of the *National Design Specification for Wood Construction* (NDS) (AF&PA 2005) discusses only carbon steel nails and deformed shank nails. Nothing is stated about the withdrawal performance of stainless steel fasteners, although it is known that stainless steel bolts have a different coefficient of friction than carbon steel bolts (Charlton 2012). This factsheet summarizes recent testing on smooth and annularly threaded stainless steel nails at the Forest Products Laboratory (FPL).

Withdrawal tests conforming to ASTM D 1761 (ASTM 2005) specifications were conducted on three brands of stainless steel nails to determine if the base nail material affects withdrawal strength. These tests were conducted using 8d (3.33-mm-diameter) nails driven into Douglas-fir. An 8d threaded stainless steel nail was also tested. Additional withdrawal tests for two nail sizes, 6d (2.77 mm diameter) and 16d (4.24 mm diameter), from one manufacturer were conducted in three wood species. These tests were conducted to facilitate development of a design expression for various stainless steel nails over a range of specific gravities. To capture the NDS specific gravity bounds (0.31–0.76), three different wood species or species combinations were tested: basswood, Douglas Fir–Larch, and Southern Pine. All lumber was conditioned at 20 °C and 65% relative humidity to achieve an equilibrium moisture content of approximately 12% prior to withdrawal testing.

Current design values recently published in the NDS (AF&PA 2005) are based on research using bright, common, degreased, smooth shank nails. The original work mostly focused on 7d smooth shank nails, but additional sizes were included to investigate nail size effects (Gahagan and Scholten 1938). Based on this research, the FPL expression was developed to relate withdrawal strength, specific gravity, and nail diameter:

$$W = KG^{2.5}D \tag{1}$$

where W is allowable withdrawal design strength per unit length of nail penetration (N/mm); G, specific gravity of the member holding the nail point, based on ovendry weight and ovendry volume; D, shank diameter of nail (mm); and K, constant factor. When K is taken as 47.57 N/mm^2, Equation (1) represents the immediate withdrawal strength (FPL 2010). The NDS recently adopted a design expression for annularly threaded post-frame nails. This NDS expression is based on the following expression that predicts average experimental withdrawal strength:

$$W = 77.56G^2D \tag{2}$$

Average results for the withdrawal testing of stainless steel nails are listed in Table 1. The smooth-shank withdrawal data are shown for each nail diameter in Figures 1 to 3. The ratio of experimental withdrawal strength to FPL expression was calculated for each replicate, averaged, and listed in the table. Based on these

Table 1—Summarized results of withdrawal testing using stainless steel nails in three wood species

Nail type	Diameter (mm)	Wood species[a]	Nail penetration (mm)	Max load (N)	Measured withdrawal strength (N/mm)	Predicted strength[b] (N/mm)	Measured ÷ predicted
Smooth	2.77	BW	27.76	235	8.48	11.08	0.76
		DF	27.69	480	17.34	21.50	0.81
		SP	27.13	620	22.87	34.92	0.65
	3.38	BW	38.81	434	11.19	13.57	0.82
		DF[c]	37.69	815	21.70	30.38	0.71
		DF	49.17	980	19.91	27.95	0.71
		DF	25.91	575	22.19	26.88	0.83
		SP	38.86	931	23.96	43.55	0.55
	4.19	BW	58.47	721	12.35	16.85	0.73
		DF	59.21	1,293	21.78	37.69	0.58
		SP	58.62	1,421	24.25	53.83	0.45
Annular	3.38	DF	44.68	2,639	59.10	26.71	2.21

[a]BW, basswood; DF, Douglas Fir–Larch; SP, Southern Pine.
[b]Predicted values from the FPL equation (Eq. (1)).
[c]Repeated entries represent a different manufacturer.

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ratios, the average withdrawal strength value of smooth stainless steel nails is lower than the predicted withdrawal strength of smooth steel nails by at least 20% and as much as 50% in large-diameter nails in wood with high specific gravity. The manufacturer source of variation has little or no effect on smooth stainless steel nail withdrawal strength. At the same time, the annularly threaded stainless steel nails performed better than predicted by the NDS annularly threaded post-frame nail expression.

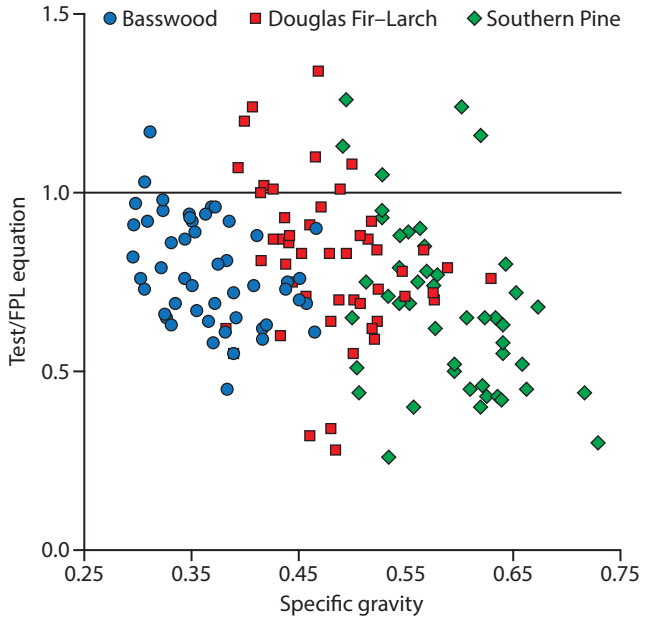

Figure 1. Measured withdrawal strength divided by that predicted by the FPL equation for 2.77-mm-diameter (4d) nails.

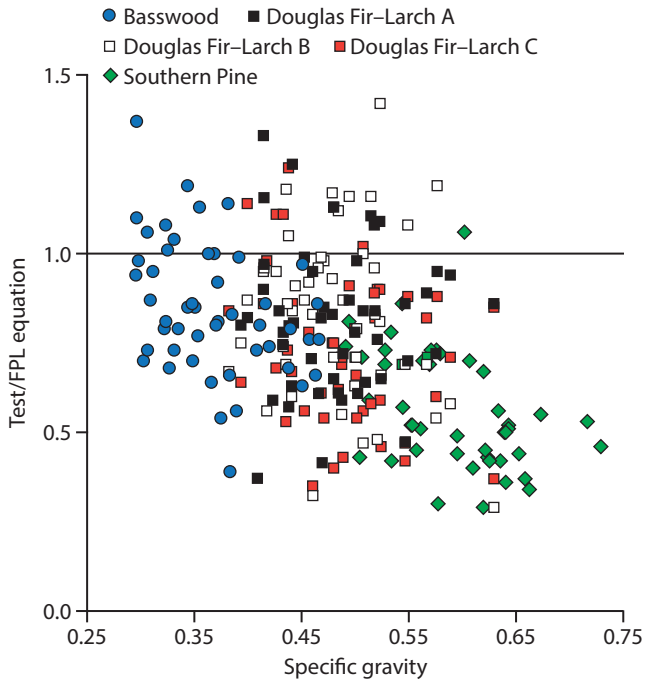

Figure 2. Measured withdrawal strength divided by that predicted by the FPL equation for 3.32-mm-diameter (8d) nails.

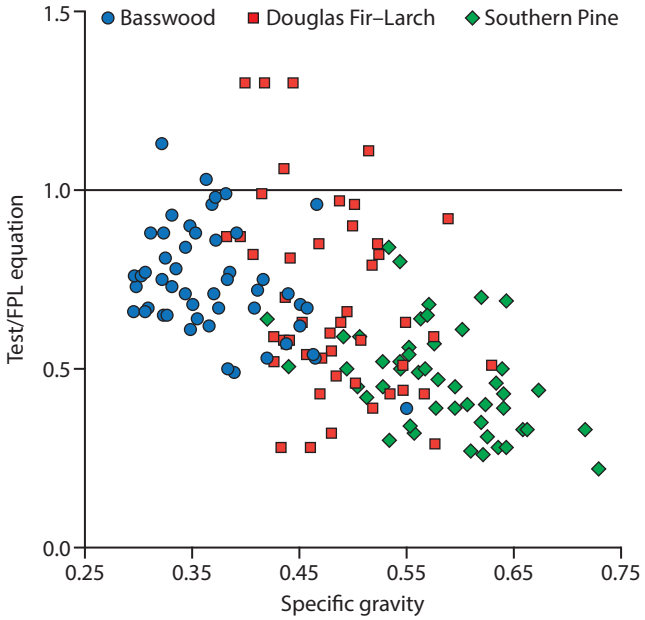

Figure 3. Measured withdrawal strength divided by that predicted by the FPL equation for 4.19-mm-diameter (16d) nails.

The results given here indicate that smooth-shank stainless steel nails may not have withdrawal resistance that complies with the NDS withdrawal function. Development of a withdrawal function or adjustment specific to smooth-shank stainless steel nails may be appropriate.

References

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