Evaluation of Fastener Head Pull-Through Strength of Wood

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With increased use of deformed-shank fasteners with increased withdrawal resistance, fastener head and washer pull-through has garnered increased attention and a need for inclusion in design. Fastener head and washer pull-through test data from studies of various fastener types and head or washer dimensions were analyzed to develop a best-fit model to predict fastener head pull-through capacity of wood. For the remainder of this report, fastener head and washer pull-through are referred to as "pull-through".

Fastener Head Pull-Through Test Data Sources

Pull-through test results were taken from several sources.

- Chow et al. [2] tested 6d common nails in one thickness of plywood and two thicknesses of OSB (n=50 per configuration; 5 configurations). Panels were conditioned at 20 °C and 65% relative humidity (RH). The reported nail head diameter, D_h, of 0.250 inches is used in this study.
- Chui & Craft [3] tested different sizes and types of fasteners including 6d and 10d common nails, power-driven nails with full and clipped (D-shaped) heads, and #8 and #14 wood screws in one thickness of plywood and OSB (n=30 per configuration; 16 configurations). The reported panel thickness of 0.437 inches in reference [1] is used in this study. Panels were conditioned at 20 °C and 80 % RH. Fastener head diameters were reported for each fastener type. Power-driven nails had heads that were oval shape and eccentrically-placed relative to the nail shank. For these power-driven nails, the value of D_h used in this study was taken as the average of the maximum and minimum diameters reported for each power-driven nail type.
- Herzog & Yeh [4] tested 8d box nails in plywood and OSB of different thickness (n=40 per configuration; 5 configurations). Panels were conditioned at 20 °C and 65 % RH. The reported D_h of 0.297 inches for the tested nails in reference [1] is used in this study.
- Munch-Andersen & Sørensen [1] summarized head pull-through test results for #10 wood screws in plywood and OSB of different thicknesses that were tested. A nominal head diameter, D_h = 0.366 inches, was used in this study for the #10 wood screws assumed to be based on ANSI/ASME B18.6.1 [8].
- Pirvu [5] reported on nail head pull-through testing in thick plywood and OSB panels (n=5 per configuration; 12 configurations). The tests were conducted on two nail head sizes, D_h=0.276 inches and D_h=0.272 inches, and five wood structural panel thicknesses. The specific gravity of the wood structural panels was not provided. A specific gravity of 0.5 was assumed in this study.

- Scholten [6] reported on pull-through testing on three sizes of flathead wood screws, and two sizes of bolts, with and without washers in wood and plywood (n=15 per configuration; 7 configurations). The wood side members consisted of two thicknesses of solid wood, 1-1/2 inches, and 2-1/2 inches thick, and a single thickness of plywood of 1-1/2 inches thick fabricated by face-gluing ¾-inch plywood pieces together. Wood screw holes were pre-drilled and countersunk so that the screw head was flush with the surface of the wood. Bolts holes were counterbored with a Forstner bit to ensure that the bolt head was 1/8-inch below the top surface of the wood specimen.

- Wilkinson [7] reported on pull-through testing conducted on 3/8-inch and 1/2-inch square-headed bolts, with and without washers, and 10d common nails, with and without washers in solid wood side members that were 1-1/2 inches thick (the number of specimens for each of the 7 configurations varied for a total of 200 tests). Nails were driven into pre-bored holes that were 90 percent of the nail diameter. The bottom of all fastener heads or washers were flush with the wide face of the wood side member.

Pull-Through Model Development

Pull-through data were fit to power models as shown in Table 1. Multivariable log-transform regressions were fit to peak pull-through test capacities, P_{test}, and independent variables to determine trends in the power model and to evaluate modeled estimates of the pull-through capacities, P_w, for a range of power factors (e.g. α, γ, and δ) for wood side member thickness, t, wood specific gravity, G, and either fastener head or washer area, A_h, net fastener head or washer area, A_{net}, or fastener head or washer perimeter, P_h. The net thickness of the wood side member was used for countersunk wood screws and counterbored holes. For countersunk wood screws, one-third of the head depth was subtracted from the thickness of the wood side member. For counter-bored holes for bolts and washers, the full depth of the counter-bored hole was subtracted from the thickness of the wood side member. Test reports were not always clear as to whether installation included the use of clearance holes, pilot holes, or no holes, especially for installation of smaller driven fasteners, so no attempt was made to account for the added contribution of shank friction, if present.

Initial investigation indicated a significant correlation of wood density with pull-through capacity; however, this correlation did not hold for wood structural panels. In order to address this issue in the modeling, all wood structural panels were assumed to have an "equivalent" specific gravity of G=0.5.

Some of the studies reported actual thicknesses of the wood side members, while other studies only reported the nominal thicknesses. Where provided, actual thicknesses were used, but if the actual thickness was not reported, the nominal thickness was used.

Table 1. Fastener Head Pull-Through Models

Model Description	Equation	m	α	γ	δ
Fastener Head Area	$P_{pred} = m\, t_{net}^{\alpha}\, G^{\gamma}\, A_h^{\delta}$	13070	0.61	2.00	0.64
Fastener Head Net Area	$P_{pred} = m\, t_{net}^{\alpha}\, G^{\gamma}\, A_{net}^{\delta}$	13318	0.69	2.02	0.57
Fastener Head Perimeter	$P_{pred} = m\, t_{net}^{\alpha}\, G^{\gamma}\, P_h^{\delta}$	2462	0.55	1.96	1.23

Values for A_h, and A_{net}, when raised to the associated δ factors in Table 1, are approximately proportional to the nominal fastener head or washer diameter, D_h for round-head fasteners. Since the fastener head or washer perimeter, P_h, is directly proportional to the fastener head or washer diameter for round-head fasteners, values for A_h and A_{net}, raised to the associated δ factor in Table 1 for those models, are also proportional to the fastener head or washer perimeter, P_h. All three models indicate that P_{test} values are approximately related to P_h values, linearly. As a result, the remaining model development in this report is focused on the Fastener Head Perimeter model.

From Table 1, it can be observed that the pull-through capacity increases with increased wood side member thickness for the thinner wood side members. However, as shown in Figure 1a, the increase is limited for thicker wood side members. Various limits based on the ratio of net thickness of the wood side member, t_{net}, to fastener head or washer perimeter, P_h, were evaluated and are shown in Table 2. The thickness limit was selected based on the ratio of the predicted pull-through capacity, P_{pred}, to the tested average pull-through capacity, P_{test}. Since the pull-through test results were reported as average capacities from various sources with different sample sizes, the quality of fit was weighted based on the sample size of the 70 reported averages. Factors of **γ** and **δ** for G and P_h, respectively, were relatively stable in most of the modeled range of t_{net}/P_h; however, the factor of α on t_{net} varied substantially, as shown in Table 2. To solve for a more stable value of α, the values of γ and δ were set to 2.0 and 1.0, respectively, and the analysis was repeated for α only. The final model values of α, γ and δ were set to 1.0, 2.0 and 1.0, respectively, and the net thickness for the Fastener Head Perimeter model was limited to $t_{net}/P_h \leq 0.8$ (see Table 2 and Figure 1b).

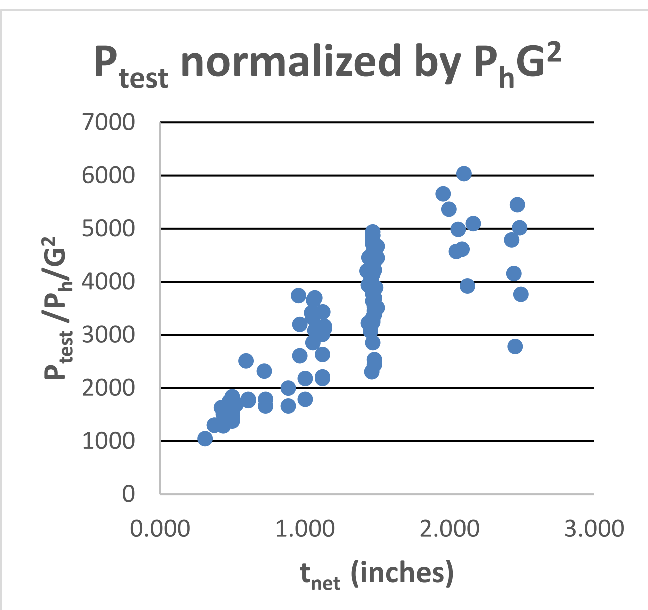

Figure 1a. Effects of Wood Side Member Thickness (no limit t_{net}/P_h)

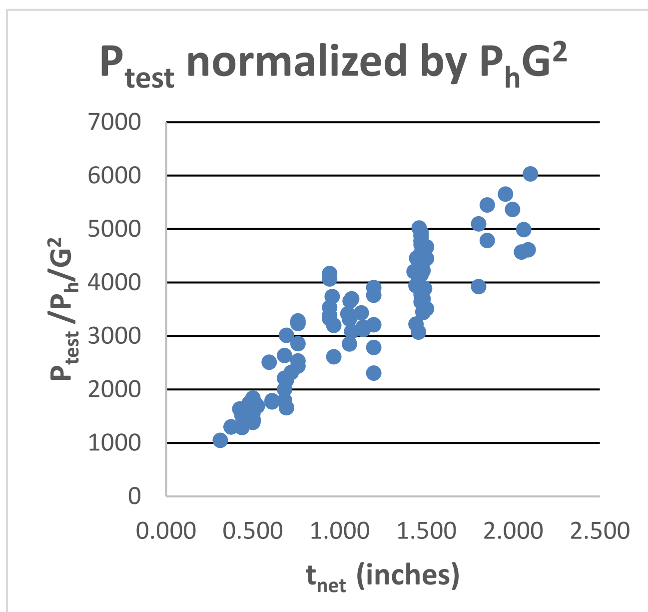

Figure 1b. Effects of Wood Side Member Thickness ($t_{net}/P_h \leq 0.8$)

Table 2. Evaluation of Model Factors and Net Thickness Limit

Wood Side Member Thickness Limit	**m**	**t_{net}^{α}**	**G^{γ}**	**P_h^{δ}**	**P_w / P_{test}**	
		α	**γ**	**δ**	**Avg**	**COV**
Multivariable log-transform regressions of t_{net}^{α}, G^{γ} and D_h^{δ}						
No limit on t_{net}/P_h	2462	0.55	1.96	1.23	1.04	0.15
$t_{net} / P_h \leq 1.0$	2697	0.68	1.96	1.12	1.03	0.15
$t_{net} / P_h \leq 0.9$	2819	0.73	1.97	1.07	1.03	0.15
$t_{net} / P_h \leq 0.8$	2986	0.81	1.97	1.01	1.02	0.15
$t_{net} / P_h \leq 0.7$	3192	0.89	1.97	0.93	1.00	0.15
$t_{net} / P_h \leq 0.6$	3508	0.98	1.96	0.82	0.97	0.16
$t_{net} / P_h \leq 0.5$	4398	1.15	1.95	0.63	0.96	0.18
Single variable log-transform regressions of t_{net}^{α} with γ = 2.0 and δ = 1.0						
No limit on t_{net}/P_h	2828	0.72	2.0	1.0	1.04	0.20
$t_{net} / P_h \leq 1.0$	2967	0.78			1.04	0.16
$t_{net} / P_h \leq 0.9$	3015	0.80			1.03	0.15
$t_{net} / P_h \leq 0.8$	3059	0.81			1.02	0.15
$t_{net} / P_h \leq 0.7$	3094	0.81			0.99	0.15
$t_{net} / P_h \leq 0.6$	3150	0.78			0.97	0.17
$t_{net} / P_h \leq 0.5$	3284	0.73			0.95	0.20
Final model results with α = 1.0, γ = 2.0 and δ = 1.0						
No limit on t_{net}/P_h	3271	1.0	2.0	1.0	1.23	0.28
$t_{net} / P_h \leq 1.0$	3327				1.16	0.20
$t_{net} / P_h \leq 0.9$	3354				1.14	0.19
$t_{net} / P_h \leq 0.8$	3391				1.11	0.18
$t_{net} / P_h \leq 0.7$	3441				1.08	0.19
$t_{net} / P_h \leq 0.6$	3575				1.06	0.20
$t_{net} / P_h \leq 0.5$	3942				1.07	0.24

The equation for head pull-through capacity was limited to a ratio of $t_{net}/P_h <= 0.8$ as shown in Equation 1a. For $t_{net}/P_h > 0.8$, t_{net} was limited to $0.8P_h$ as shown in Equation 1b.

$$P_{pred} = 3391 P_h G^2 t_{net} \quad \text{for } t_{net}/P_h \leq 0.8 \qquad \text{(Equation 1a)}$$

$$P_{pred} = 2713 P_h^2 G^2 \quad \text{for } t_{net}/P_h > 0.8 \qquad \text{(Equation 1b)}$$

Table 3 provides a comparison of the average pull-through test capacity, P_{test}, for each sample with the predicted pull-through capacity, P_{pred}, estimated from Equations 1a and 1b as applicable.

Table 3. Data Summary and Comparison to Fastener Head Pull-Through Model Predictions

Fastener type	Study	n	Wood Type	t_{net} (in.)	G [1]	P_h (in.)	P_{test} (lbf)	P_{pred} (lbf)	P_{pred} / P_{test}
6d common nail	Chow	50	PLY	0.479	0.50	0.79	343	319	0.93
6d common nail	Chow	50	OSB	0.526	0.50	0.79	332	350	1.05
6d common nail	Chow	50	OSB	0.510	0.50	0.79	343	340	0.99
6d common nail	Chow	50	OSB	0.442	0.50	0.79	303	294	0.97
6d common nail	Chow	50	OSB	0.424	0.50	0.79	321	282	0.88
6d common nail	Chui & Craft	30	PLY	0.438	0.50	0.77	279	284	1.02
6d common nail	Chui & Craft	30	OSB	0.438	0.50	0.77	315	284	0.90
10d common nail	Chui & Craft	30	PLY	0.438	0.50	1.00	436	372	0.85
10d common nail	Chui & Craft	30	OSB	0.438	0.50	1.00	419	372	0.89
Clipped-head 2-3/8" power nail	Chui & Craft	30	PLY	0.438	0.50	0.70	246	260	1.06
Clipped-head 2-3/8" power nail	Chui & Craft	30	OSB	0.438	0.50	0.70	254	260	1.02
Clipped-head 3" power nail	Chui & Craft	30	PLY	0.438	0.50	0.64	252	236	0.94
Clipped-head 3" power nail	Chui & Craft	30	OSB	0.438	0.50	0.64	274	236	0.86
Full-head 2-3/8" power nail	Chui & Craft	30	PLY	0.438	0.50	0.88	338	325	0.96
Full-head 2-3/8" power nail	Chui & Craft	30	OSB	0.438	0.50	0.88	312	325	1.04
Full-head 3" power nail	Chui & Craft	30	PLY	0.438	0.50	0.75	303	279	0.92
Full-head 3" power nail	Chui & Craft	30	OSB	0.438	0.50	0.75	339	278	0.82
#8 Wood screw	Chui & Craft	30	PLY	0.438	0.50	0.89	316	329	1.04
#8 Wood screw	Chui & Craft	30	OSB	0.438	0.50	0.89	366	329	0.90
#14 Wood Screw	Chui & Craft	30	PLY	0.438	0.50	1.44	498	534	1.07
#14 Wood Screw	Chui & Craft	30	OSB	0.438	0.50	1.44	504	534	1.06
8d box nail	Herzog & Yeh	40	PLY	0.375	0.50	0.93	304	297	0.98
8d box nail	Herzog & Yeh	40	PLY	0.500	0.50	0.93	429	395	0.92
8d box nail	Herzog & Yeh	40	OSB	0.438	0.50	0.93	352	346	0.98
8d box nail	Herzog & Yeh	40	OSB	0.375	0.50	0.93	304	297	0.98
8d box nail	Herzog & Yeh	40	OSB	0.469	0.50	0.93	393	371	0.94
#10 Wood screw	Forintek	10	PLY	0.311	0.50	1.15	302	303	1.00
#10 Wood screw	Forintek	10	OSB	0.437	0.50	1.15	370	426	1.15
#10 Wood screw	Forintek	10	OSB	0.720	0.50	1.15	667	702	1.05
#10 Wood screw	Forintek	10	OSB	0.594	0.50	1.15	722	579	0.80
8d common nail	Pirvu	5	PLY	0.728	0.50	0.87	360	508	1.41
8d common nail	Pirvu	5	PLY	1.122	0.50	0.87	652	508	0.78
8d common nail	Pirvu	5	OSB	0.610	0.50	0.87	382	448	1.17
8d common nail	Pirvu	5	OSB	0.886	0.50	0.87	360	508	1.41
8d common nail	Pirvu	5	OSB	1.004	0.50	0.87	472	508	1.08
8d common nail	Pirvu	5	OSB	1.122	0.50	0.87	472	508	1.08
7d common nail	Pirvu	5	PLY	0.728	0.50	0.85	382	494	1.29
7d common nail	Pirvu	5	PLY	1.122	0.50	0.85	562	494	0.88
7d common nail	Pirvu	5	OSB	0.610	0.50	0.85	382	441	1.16
7d common nail	Pirvu	5	OSB	0.886	0.50	0.85	427	494	1.16
7d common nail	Pirvu	5	OSB	1.004	0.50	0.85	382	494	1.29
7d common nail	Pirvu	5	OSB	1.122	0.50	0.85	472	494	1.05
#14 Wood Screw	Scholten	3	DF	1.46	0.51	1.50	1250	1578	1.26

#14 Wood Screw	Scholten	3	SP	1.46	0.57	1.50	1120	1971	1.76
#14 Wood Screw	Scholten	3	PLY	1.45	0.50	1.50	1460	1516	1.04
#14 Wood Screw	Scholten	3	DF	2.49	0.44	1.50	1090	1174	1.08
#14 Wood Screw	Scholten	3	SP	2.45	0.55	1.50	1260	1835	1.46
#18 Wood Screw	Scholten	3	DF	1.45	0.51	1.82	1900	2336	1.23
#18 Wood Screw	Scholten	3	SP	1.45	0.57	1.82	1820	2919	1.60
#18 Wood Screw	Scholten	3	PLY	1.44	0.50	1.82	2030	2230	1.10
#18 Wood Screw	Scholten	3	DF	2.48	0.44	1.82	1770	1744	0.99
#18 Wood Screw	Scholten	3	SP	2.44	0.55	1.82	2290	2724	1.19
#24 Wood Screw	Scholten	3	DF	1.44	0.51	2.31	2370	2934	1.24
#24 Wood Screw	Scholten	3	SP	1.44	0.57	2.31	2420	3665	1.51
#24 Wood Screw	Scholten	3	PLY	1.43	0.50	2.31	2430	2801	1.15
#24 Wood Screw	Scholten	3	DF	2.47	0.44	2.31	2440	2808	1.15
#24 Wood Screw	Scholten	3	SP	2.43	0.55	2.31	3350	4387	1.31
3/8" Bolt w/o washer	Scholten	3	DF	1.14	0.51	2.25	1850	2252	1.22
3/8" Bolt w/o washer	Scholten	3	SP	1.14	0.57	2.25	2280	2813	1.23
3/8" Bolt w/o washer	Scholten	3	PLY	1.13	0.50	2.25	1930	2146	1.11
3/8" Bolt w/o washer	Scholten	3	DF	2.17	0.44	2.25	2220	2658	1.20
3/8" Bolt w/o washer	Scholten	3	SP	2.13	0.55	2.25	2670	4154	1.56
3/8" Bolt w/ 1" washer	Scholten	3	DF	1.07	0.51	3.14	3020	2964	0.98
3/8" Bolt w/ 1" washer	Scholten	3	SP	1.07	0.57	3.14	3150	3703	1.18
3/8" Bolt w/ 1" washer	Scholten	3	PLY	1.06	0.50	3.14	2870	2823	0.98
3/8" Bolt w/ 1" washer	Scholten	3	DF	2.10	0.44	3.14	3670	4331	1.18
3/8" Bolt w/ 1" washer	Scholten	3	SP	2.06	0.55	3.14	4740	6638	1.40
1/2" Bolt w/o washer	Scholten	3	DF	1.06	0.51	3.00	2590	2796	1.08
1/2" Bolt w/o washer	Scholten	3	SP	1.06	0.57	3.00	2780	3493	1.26
1/2" Bolt w/o washer	Scholten	3	PLY	1.05	0.50	3.00	2560	2662	1.04
1/2" Bolt w/o washer	Scholten	3	DF	2.09	0.44	3.00	2680	4110	1.53
1/2" Bolt w/o washer	Scholten	3	SP	2.05	0.55	3.00	4150	6298	1.52
1/2" Bolt w/ 1.25" washer	Scholten	3	DF	0.97	0.51	3.93	3270	3345	1.02
1/2" Bolt w/ 1.25" washer	Scholten	3	SP	0.97	0.57	3.93	3330	4179	1.25
1/2" Bolt w/ 1.25" washer	Scholten	3	PLY	0.96	0.50	3.93	3670	3182	0.87
1/2" Bolt w/ 1.25" washer	Scholten	3	DF	2.00	0.44	3.93	4080	5145	1.26
1/2" Bolt w/ 1.25" washer	Scholten	3	SP	1.96	0.55	3.93	6720	7878	1.17
10d Nail	Wilkinson	6	DF	1.47	0.50	0.95	768	610	0.79
10d Nail	Wilkinson	6	RO	1.47	0.67	0.95	1399	1096	0.78
10d Nail	Wilkinson	6	SP	1.48	0.55	0.95	728	739	1.01
10d Nail	Wilkinson	6	WH	1.47	0.47	0.95	599	539	0.90
10d Nail	Wilkinson	6	WF	1.48	0.42	0.95	408	431	1.06
10d Nail w/ 0.375" washer	Wilkinson	3	DF	1.47	0.50	1.18	1228	941	0.77
10d Nail w/ 0.375" washer	Wilkinson	6	RO	1.48	0.67	1.18	1790	1690	0.94
10d Nail w/ 0.375" washer	Wilkinson	6	SP	1.47	0.55	1.18	1184	1139	0.96
10d Nail w/ 0.375" washer	Wilkinson	6	WH	1.46	0.47	1.18	1058	832	0.79
10d Nail w/ 0.375" washer	Wilkinson	5	WF	1.48	0.42	1.18	734	664	0.90
3/8" Bolt w/o washer	Wilkinson	6	DF	1.48	0.50	2.40	2533	3011	1.19
3/8" Bolt w/o washer	Wilkinson	6	RO	1.47	0.67	2.40	5076	5370	1.06

3/8" Bolt w/o washer	Wilkinson	6	SP	1.48	0.55	2.40	2498	3643	1.46
3/8" Bolt w/o washer	Wilkinson	6	WH	1.47	0.47	2.40	2000	2642	1.32
3/8" Bolt w/o washer	Wilkinson	6	WF	1.47	0.42	2.40	1539	2110	1.37
3/8" Bolt w/ 0.785" washer	Wilkinson	6	DF	1.47	0.50	2.75	3394	3425	1.01
3/8" Bolt w/ 0.785" washer	Wilkinson	6	RO	1.47	0.67	2.75	6022	6150	1.02
3/8" Bolt w/ 0.785" washer	Wilkinson	6	SP	1.47	0.55	2.75	3524	4145	1.18
3/8" Bolt w/ 0.785" washer	Wilkinson	6	WH	1.48	0.47	2.75	2848	3047	1.07
3/8" Bolt w/ 0.785" washer	Wilkinson	6	WF	1.48	0.42	2.75	2176	2433	1.12
3/4" Bolt w/o washer	Wilkinson	18	DF	1.49	0.50	4.40	4280	5557	1.30
3/4" Bolt w/o washer	Wilkinson	6	RO	1.48	0.67	4.40	6836	9911	1.45
3/4" Bolt w/o washer	Wilkinson	6	SP	1.48	0.55	4.40	5829	6679	1.15
3/4" Bolt w/o washer	Wilkinson	12	BS	1.50	0.42	4.40	2727	3947	1.45
3/4" Bolt w/o washer	Wilkinson	6	WH	1.48	0.47	4.40	3593	4877	1.36
3/4" Bolt w/o washer	Wilkinson	5	WF	1.48	0.42	4.40	2865	3895	1.36
3/4" Bolt w/ 1.75" washer	Wilkinson	12	DF	1.50	0.50	5.50	6118	6990	1.14
3/4" Bolt w/ 1.75" washer	Wilkinson	12	BS	1.50	0.42	5.50	4527	4932	1.09
3/4" Bolt w/ 1.875" washer	Wilkinson	6	DF	1.47	0.50	5.89	7037	7340	1.04
3/4" Bolt w/ 1.875" washer	Wilkinson	6	RO	1.47	0.67	5.89	12870	13179	1.02
3/4" Bolt w/ 1.875" washer	Wilkinson	6	SP	1.47	0.55	5.89	8507	8881	1.04
3/4" Bolt w/ 1.875" washer	Wilkinson	6	WH	1.47	0.47	5.89	5915	6485	1.10
3/4" Bolt w/ 1.875" washer	Wilkinson	7	WF	1.47	0.42	5.89	4307	5179	1.20
Count	**n =**	**1359**		110	110	110	110	110	**110**
Average				1.184	0.509	2.096	2058	2392	**1.11**
COV				0.494	0.105	0.694	1.03	1.02	**0.18**
Min				0.311	0.420	0.637	246	236	**0.77**
Max				2.494	0.670	5.890	12870	13179	**1.76**

[1] For wood structural panels, the effective specific gravity was assumed to be G=0.50.

Design Equations for the *National Design Specification (NDS) for Wood Construction*

Since most fastener heads and standard washers in the NDS are round, Equations 1a and 1b are converted to use fastener head or washer diameters, D_h. Also, due to the limited sampling of the wider fastener head and washer diameters, it was deemed appropriate to limit use of Equations 1a and 1b in design applications to values of $D_h \leq 0.5$ inches. The estimates of pull-through capacities are divided by a factor of 5 to match similar adjustments for fastener withdrawal in the NDS. Pull-through design values, W_H, in accordance with Equations 2a and 2b are approximately 1/5 of ultimate load determined from pull-through tests:

$$W_H = 690\,\pi\,D_h\,G^2\,t_{net} \qquad \text{for } t_{net}/D_h \leq 2.5 \qquad \text{(Equation 2a)}$$

$$W_H = 1725\,\pi\,D_h^2\,G^2 \qquad \text{for } t_{net}/D_h > 2.5 \qquad \text{(Equation 2b)}$$

Table 4 provides a comparison of the average pull-through test capacity, P_{test}, for each sample with the pull-through design values, W_H, estimated from Equations 2a and 2b as applicable.

Table 4. Comparison of P_{test} to NDS pull-through design values, W_H

Fastener type	Study	n	Wood Type	t_{net} (in.)	G [1]	D_h (in.)	P_{test} (lbf)	W_H (lbf)	P_{test} / W_H
6d common nail	Chow	50	PLY	0.479	0.50	0.250	343	65	5.29
6d common nail	Chow	50	OSB	0.526	0.50	0.250	332	71	4.66
6d common nail	Chow	50	OSB	0.510	0.50	0.250	343	69	4.96
6d common nail	Chow	50	OSB	0.442	0.50	0.250	303	60	5.06
6d common nail	Chow	50	OSB	0.424	0.50	0.250	321	57	5.59
6d common nail	Chui & Craft	30	PLY	0.438	0.50	0.244	279	58	4.82
6d common nail	Chui & Craft	30	OSB	0.438	0.50	0.244	315	58	5.43
10d common nail	Chui & Craft	30	PLY	0.438	0.50	0.319	436	76	5.77
10d common nail	Chui & Craft	30	OSB	0.438	0.50	0.319	419	76	5.54
#8 Wood screw	Chui & Craft	30	PLY	0.438	0.50	0.283	316	67	4.72
#8 Wood screw	Chui & Craft	30	OSB	0.438	0.50	0.283	366	67	5.46
#14 Wood Screw	Chui & Craft	30	PLY	0.438	0.50	0.459	498	109	4.58
#14 Wood Screw	Chui & Craft	30	OSB	0.438	0.50	0.459	504	109	4.63
8d box nail	Herzog & Yeh	40	PLY	0.375	0.50	0.297	304	60	5.04
8d box nail	Herzog & Yeh	40	PLY	0.500	0.50	0.297	429	80	5.33
8d box nail	Herzog & Yeh	40	OSB	0.438	0.50	0.297	352	70	5.00
8d box nail	Herzog & Yeh	40	OSB	0.375	0.50	0.297	304	60	5.04
8d box nail	Herzog & Yeh	40	OSB	0.469	0.50	0.297	393	75	5.21
#10 Wood screw	Forintek	10	PLY	0.311	0.50	0.366	302	62	4.89
#10 Wood screw	Forintek	10	OSB	0.437	0.50	0.366	370	87	4.27
#10 Wood screw	Forintek	10	OSB	0.720	0.50	0.366	667	143	4.67
#10 Wood screw	Forintek	10	OSB	0.594	0.50	0.366	722	118	6.12
8d common nail	Pirvu	5	PLY	0.728	0.50	0.276	360	103	3.50
8d common nail	Pirvu	5	PLY	1.122	0.50	0.276	652	103	6.34
8d common nail	Pirvu	5	OSB	0.610	0.50	0.276	382	91	4.19
8d common nail	Pirvu	5	OSB	0.886	0.50	0.276	360	103	3.50
8d common nail	Pirvu	5	OSB	1.004	0.50	0.276	472	103	4.59
8d common nail	Pirvu	5	OSB	1.122	0.50	0.276	472	103	4.59
7d common nail	Pirvu	5	PLY	0.728	0.50	0.272	382	100	3.82
7d common nail	Pirvu	5	PLY	1.122	0.50	0.272	562	100	5.62
7d common nail	Pirvu	5	OSB	0.610	0.50	0.272	382	90	4.25
7d common nail	Pirvu	5	OSB	0.886	0.50	0.272	427	100	4.27
7d common nail	Pirvu	5	OSB	1.004	0.50	0.272	382	100	3.82
7d common nail	Pirvu	5	OSB	1.122	0.50	0.272	472	100	4.72
#14 Wood Screw	Scholten	3	DF	1.46	0.51	0.476	1250	319	3.91
#14 Wood Screw	Scholten	3	SP	1.46	0.57	0.476	1120	399	2.81
#14 Wood Screw	Scholten	3	PLY	1.45	0.50	0.476	1460	307	4.76
#14 Wood Screw	Scholten	3	DF	2.49	0.44	0.476	1090	238	4.59
#14 Wood Screw	Scholten	3	SP	2.45	0.55	0.476	1260	371	3.39
10d Nail	Wilkinson	6	DF	1.47	0.50	0.302	768	124	6.22
10d Nail	Wilkinson	6	RO	1.47	0.67	0.302	1399	222	6.31
10d Nail	Wilkinson	6	SP	1.48	0.55	0.302	728	150	4.87
10d Nail	Wilkinson	6	WH	1.47	0.47	0.302	599	109	5.49

10d Nail	Wilkinson	6	WF	1.48	0.42	0.302	408	87	4.68
10d Nail w/ 0.375" washer	Wilkinson	3	DF	1.47	0.50	0.375	1228	191	6.45
10d Nail w/ 0.375" washer	Wilkinson	6	RO	1.48	0.67	0.375	1790	342	5.23
10d Nail w/ 0.375" washer	Wilkinson	6	SP	1.47	0.55	0.375	1184	231	5.14
10d Nail w/ 0.375" washer	Wilkinson	6	WH	1.46	0.47	0.375	1058	168	6.28
10d Nail w/ 0.375" washer	Wilkinson	5	WF	1.48	0.42	0.375	734	134	5.46
Count	**n =**	**861**		49	49	49	49	49	**49**
Average				0.921	0.506	0.324	612	128	**4.92**
COV				0.587	0.084	0.224	0.62	0.68	**0.17**
Min				0.311	0.420	0.244	279	57	**2.81**
Max				2.494	0.670	0.476	1790	399	**6.45**

[1] For wood structural panels, the effective specific gravity was assumed to be G=0.50.

Perimeter Model for Non-Round Head Fasteners

The perimeter model was fit to limited types of non-round head fasteners and the results should not be extended to significantly different fastener head shapes, like those of T-head nails and staples. For head shape consistent with those addressed in Table 4 data, the fastener head diameter model in Equations 2a and 2b is converted to a fastener head perimeter model with Equations 3a and 3b as follows:

$$W_H = 690\ P_h\ G^2\ t_{net} \quad \text{for } t_{net}/P_h \leq 0.8 \qquad \text{(Equation 3a)}$$

$$W_H = 550\ P_h^2\ G^2 \quad \text{for } t_{net}/P_h > 0.8 \qquad \text{(Equation 3b)}$$

Conclusion

Head pull-through test results from 1359 individual tests of round head nails, clipped-head nails, wood screws, hexagonal and square-head bolts, and washers were analyzed. Test data were reported for fasteners pulled through dry sawn lumber, plywood or OSB. Nominal fastener head and washer diameters ranged from 0.239 to 1.875 inches and wood side member net thicknesses of 0.31 to 2.38 inches. Design equations for fastener head pull-though were developed as shown in Table 5. The design equations did not subtract any added contribution of shank friction that may be present in the pull-through capacity test result, so no further increase for shank friction should be taken in design.

Table 5. Summary of Fastener Head Pull-Through Model Equations

Fastener Head Type	**Equations for Calculating Pull-Through, W_H (lbf) [1]**	
	Wood Side Member Net Thickness Limit	**NDS Design**
Round-Head Fasteners and Round Washers	$t_{net}/D_h \leq 2.5$ $t_{net}/D_h > 2.5$	$W_H = 690\ \pi\ D_h\ G^2\ t_{net}$ $W_H = 1725\ \pi\ D_h^2\ G^2$
All Fasteners and Washers	$t_{net}/P_h \leq 0.8$ $t_{net}/P_h > 0.8$	$W_H = 690\ P_h\ G^2\ t_{net}$ $W_H = 550\ P_h^2\ G^2$

[1] Design equations are limited to $D_h \leq 0.5$ inches due to insufficient data for application to larger values of D_h.

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