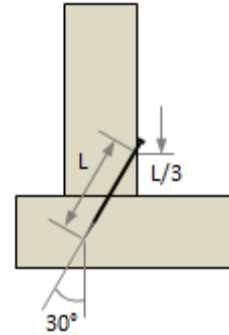# Toe-Nail Connection Design (NDS 2018)

This application determines the allowable lateral design load for a wooden toe-nail connection.

Wood properties are from NDS (2018).

Reference:
National Design Specification® (NDS) for Wood Construction, 2018 edition, American Wood Council

Parameters

Nail type
1 - Common wire
2 - Box
3 - Sinker

$nail\_type := 1$

Nail penny-weight

$nail\_weight := \text{"10d"}$

Lumber species
1 - Douglas Fir-Larch
2 - Douglas Fir-Larch(N)
3 - Hem-Fir(N)
4 - Hem-Fir
5 - Spruce-Pine-Fir

$lumber := 5$

Load duration factor
Table 2.3.2 NDS 2018 page 11

$C_D := 1.6$

Wet service factor
Section 10.3.3 NDS 2018 page 61

$C_M := 1.0$

Temperature factor
Table 2.3.3 NDS 2018 page 11

$C_t := 1.0$

$C_{tn} := 0.83$

Toe-nail factor for lateral design
Section 12.5.4.2 NDS 2018 page 91

Data from National Design Specification (NDS) for Wood Construction 2018

$\text{penny\_weight} := [\text{"6d"}, \text{"7d"}, \text{"8d"}, \text{"10d"}, \text{"12d"}, \text{"16d"}, \text{"20d"}, \text{"30d"}, \text{"40d"}, \text{"50d"}, \text{"60d"}]$

Standard nail dimensions for common, box and sinker steel wire nails
Table L4 NDS 2018 page 182

$$\text{len} := \begin{bmatrix} \text{"common"} & 2 & 2+\frac{1}{4} & 2+\frac{1}{2} & 3 & 3+\frac{1}{4} & 3+\frac{1}{2} & 4 & 4+\frac{1}{2} & 5 & 5+\frac{1}{2} & 6 \\ \text{"box"} & 2 & 2+\frac{1}{4} & 2+\frac{1}{2} & 3 & 3+\frac{1}{4} & 3+\frac{1}{2} & 4 & 4+\frac{1}{2} & 5 & \text{NULL} & \text{NULL} \\ \text{"sinker"} & \frac{17}{18} & 8+\frac{1}{8} & 2+\frac{3}{8} & 2+\frac{7}{8} & 3+\frac{1}{8} & 3+\frac{1}{4} & 3+\frac{3}{4} & 4+\frac{1}{4} & 4+\frac{2}{4} & \text{NULL} & 5+\frac{3}{5} \end{bmatrix}$$

$$\text{dia} := \begin{bmatrix} \text{"common"} & 0.113 & 0.113 & 0.131 & 0.148 & 0.148 & 0.162 & 0.192 & 0.207 & 0.225 & 0.244 & 0.263 \\ \text{"box"} & 0.099 & 0.099 & 0.113 & 0.128 & 0.128 & 0.135 & 0.148 & 0.148 & 0.162 & \text{NULL} & \text{NULL} \\ \text{"sinker"} & 0.092 & 0.099 & 0.113 & 0.120 & 0.135 & 0.148 & 0.177 & 0.192 & 0.207 & \text{NULL} & 0.244 \end{bmatrix}$$

$$\text{hea} := \begin{bmatrix} \text{"common"} & 0.266 & 0.266 & 0.281 & 0.312 & 0.3121 & 0.344 & 0.406 & 0.438 & 0.469 & 0.500 & 0.531 \\ \text{"box"} & 0.266 & 0.266 & 0.297 & 0.312 & 0.312 & 0.344 & 0.375 & 0.375 & 0.406 & \text{NULL} & \text{NULL} \\ \text{"sinker"} & 0.234 & 0.250 & 0.266 & 0.281 & 0.312 & 0.344 & 0.375 & 0.406 & 0.438 & \text{NULL} & 0.500 \end{bmatrix}$$

Reference lateral design values for single shear
Table 12B NDS 2018 page 111

$Z_{34} :=$

"d"	"G=0.5"	"G=0.49"	"G=0.46"	"G=0.43"	"G=0.42"
0.099	55	54	51	48	47
0.113	72	71	65	58	57
0.120	80	77	71	64	62
0.128	87	84	78	70	68
0.131	90	87	80	73	70
0.135	94	91	84	76	74
0.148	105	102	94	85	83
0.162	121	117	108	99	96
0.177	134	130	121	111	107
0.192	138	134	125	114	111
0.207	147	143	133	122	119
0.225	158	154	144	132	129
0.244	162	158	147	136	132

$Z_1 :=$

"d"	"G=0.5"	"G=0.49"	"G=0.46"	"G=0.43"	"G=0.42"
0.099	55	54	51	48	47
0.113	72	71	65	63	61
0.120	81	80	76	71	69
0.128	93	91	86	80	79
0.131	97	95	90	84	82
0.135	103	101	96	89	86
0.148	118	115	109	99	96
0.162	141	137	125	113	109
0.177	155	150	138	125	121
0.192	159	154	142	128	124
0.207	167	162	147	135	131
0.225	177	171	159	144	140
0.244	181	175	162	148	143

$Z_{114} :=$

"d"	"G=0.5"	"G=0.49"	"G=0.46"	"G=0.43"	"G=0.42"
0.099	55	54	51	48	47
0.113	72	71	67	63	61
0.120	81	80	76	71	69
0.128	93	91	86	80	79
0.131	97	95	90	84	82
0.135	103	101	96	89	88
0.148	118	115	109	102	100
0.162	141	138	131	122	120
0.177	163	159	151	141	136
0.192	170	166	157	145	140
0.207	186	182	169	152	147
0.225	200	193	177	160	155
0.244	204	197	181	163	158

$Z_{112} :=$

"d"	"G=0.5"	"G=0.49"	"G=0.46"	"G=0.43"	"G=0.42"
0.099	55	54	51	48	47
0.113	72	71	67	63	61
0.120	81	80	76	71	69
0.128	93	91	86	80	79
0.131	97	95	90	84	82
0.135	103	101	96	89	88
0.148	118	115	109	102	100
0.162	141	138	131	122	120
0.177	163	159	151	141	138
0.192	170	166	157	147	144
0.207	186	182	172	161	158
0.225	205	201	190	178	172
0.244	211	206	196	181	175

$$Z_{134} := \begin{bmatrix} \text{"d"} & \text{"G=0.5"} & \text{"G=0.49"} & \text{"G=0.46"} & \text{"G=0.43"} & \text{"G=0.43"} \\ 0.113 & 72 & 71 & 67 & 63 & 61 \\ 0.120 & 81 & 80 & 76 & 71 & 69 \\ 0.128 & 93 & 91 & 86 & 80 & 79 \\ 0.135 & 103 & 101 & 96 & 89 & 88 \\ 0.148 & 118 & 115 & 109 & 102 & 100 \\ 0.162 & 141 & 138 & 131 & 122 & 120 \\ 0.177 & 163 & 159 & 151 & 141 & 138 \\ 0.192 & 170 & 166 & 157 & 147 & 144 \\ 0.207 & 186 & 182 & 172 & 161 & 158 \\ 0.225 & 205 & 201 & 190 & 178 & 174 \\ 0.244 & 211 & 206 & 196 & 183 & 179 \end{bmatrix}$$

Calculations

Length and diameter of nail

$\text{ind} := \text{ListTools:-Search}(\text{nail\_weight}, \text{penny\_weight}) = 4$

Length in inches

$$L := \begin{cases} \text{len}[1, \text{ind} + 1] & \text{nail\_type} = 1 \\ \text{len}[2, \text{ind} + 1] & \text{nail\_type} = 2 \\ \text{len}[3, \text{ind} + 1] & \text{nail\_type} = 3 \end{cases} \qquad L = 3$$

Diameter in inches

$$d := \begin{cases} \text{dia}[1, \text{ind} + 1] & \text{nail\_type} = 1 \\ \text{dia}[2, \text{ind} + 1] & \text{nail\_type} = 2 \\ \text{dia}[3, \text{ind} + 1] & \text{nail\_type} = 3 \end{cases} \qquad d = 0.148$$

Side member thickness

$t_s := L / 3 = 1$

Penetration of nail into the main member

$p := L \cdot \cos(30 \text{ deg}) - t_s = 1.598$

Penetration factor
Note 3, tab 11N, NDS 2018

$$C_d := \begin{cases} \dfrac{p}{10 \cdot d} & p < 10 \cdot d \text{ and } p \geq 6 \cdot d \\ 1 & \text{otherwise} \end{cases} \qquad C_d = 1$$

$$\text{shear\_design} := \begin{bmatrix} \text{"Thk"} & \text{"Z"} \\ \dfrac{3}{4} & Z_{34}\big[\text{ListTools:-Search}(d, Z_{34})[1], \text{lumber} + 1\big] \\ 1 & Z_{1}\big[\text{ListTools:-Search}(d, Z_{1})[1], \text{lumber} + 1\big] \\ 1 + \dfrac{1}{4} & Z_{114}\big[\text{ListTools:-Search}(d, Z_{114})[1], \text{lumber} + 1\big] \\ 1 + \dfrac{1}{2} & Z_{112}\big[\text{ListTools:-Search}(d, Z_{112})[1], \text{lumber} + 1\big] \\ 1 + \dfrac{3}{4} & Z_{134}\big[\text{ListTools:-Search}(d, Z_{134})[1], \text{lumber} + 1\big] \end{bmatrix}$$

$$shear\_design = \begin{bmatrix} \text{"Thk"} & \text{"Z"} \\ 0.750 & 83 \\ 1 & 96 \\ 1.250 & 100 \\ 1.500 & 100 \\ 1.750 & 100 \end{bmatrix}$$

Nominal design value for
single shear (lbs)
Table 12N NDS 2-18 page 111

$Z := shear\_design[\,ListTools:\text{-}Search(t_s, shear\_design)[\,1\,]\,][\,2\,]$

$Z = 96$

Allowable lateral design value
for the toe nail (lbs)

$Zd := Z \cdot C_D \cdot C_M \cdot C_t \cdot C_d \cdot C_{tn} = 127.488$