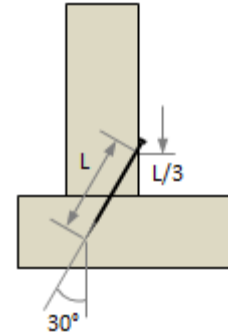


# Toe-Nail Connection Design (NDS 2018)

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 := "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

$C_t := 1.0$

### Toe-nail factor for lateral design

Section 12.5.4.2 NDS 2018 page 91

$C_{tn} := 0.83$

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

---

penny\_weight := ["6d", "7d", "8d", "10d", "12d", "16d", "20d", "30d", "40d", "50d", "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

$$Z_{34} := \begin{bmatrix} \text{"d"} & \text{"G=0.5"} & \text{"G=0.49"} & \text{"G=0.46"} & \text{"G=0.43"} & \text{"G=0.42"} \\ 0.099 & 55 & 54 & 51 & 48 & 47 \\ 0.113 & 72 & 71 & 65 & 58 & 57 \\ 0.120 & 80 & 77 & 71 & 64 & 62 \\ 0.128 & 87 & 84 & 78 & 70 & 68 \\ 0.131 & 90 & 87 & 80 & 73 & 70 \\ 0.135 & 94 & 91 & 84 & 76 & 74 \\ 0.148 & 105 & 102 & 94 & 85 & 83 \\ 0.162 & 121 & 117 & 108 & 99 & 96 \\ 0.177 & 134 & 130 & 121 & 111 & 107 \\ 0.192 & 138 & 134 & 125 & 114 & 111 \\ 0.207 & 147 & 143 & 133 & 122 & 119 \\ 0.225 & 158 & 154 & 144 & 132 & 129 \\ 0.244 & 162 & 158 & 147 & 136 & 132 \end{bmatrix}$$

$$Z_1 := \begin{bmatrix} \text{"d"} & \text{"G=0.5"} & \text{"G=0.49"} & \text{"G=0.46"} & \text{"G=0.43"} & \text{"G=0.42"} \\ 0.099 & 55 & 54 & 51 & 48 & 47 \\ 0.113 & 72 & 71 & 65 & 63 & 61 \\ 0.120 & 81 & 80 & 76 & 71 & 69 \\ 0.128 & 93 & 91 & 86 & 80 & 79 \\ 0.131 & 97 & 95 & 90 & 84 & 82 \\ 0.135 & 103 & 101 & 96 & 89 & 86 \\ 0.148 & 118 & 115 & 109 & 99 & 96 \\ 0.162 & 141 & 137 & 125 & 113 & 109 \\ 0.177 & 155 & 150 & 138 & 125 & 121 \\ 0.192 & 159 & 154 & 142 & 128 & 124 \\ 0.207 & 167 & 162 & 147 & 135 & 131 \\ 0.225 & 177 & 171 & 159 & 144 & 140 \\ 0.244 & 181 & 175 & 162 & 148 & 143 \end{bmatrix}$$

$$Z_{114} := \begin{bmatrix} \text{"d"} & \text{"G=0.5"} & \text{"G=0.49"} & \text{"G=0.46"} & \text{"G=0.43"} & \text{"G=0.42"} \\ 0.099 & 55 & 54 & 51 & 48 & 47 \\ 0.113 & 72 & 71 & 67 & 63 & 61 \\ 0.120 & 81 & 80 & 76 & 71 & 69 \\ 0.128 & 93 & 91 & 86 & 80 & 79 \\ 0.131 & 97 & 95 & 90 & 84 & 82 \\ 0.135 & 103 & 101 & 96 & 89 & 88 \\ 0.148 & 118 & 115 & 109 & 102 & 100 \\ 0.162 & 141 & 138 & 131 & 122 & 120 \\ 0.177 & 163 & 159 & 151 & 141 & 136 \\ 0.192 & 170 & 166 & 157 & 145 & 140 \\ 0.207 & 186 & 182 & 169 & 152 & 147 \\ 0.225 & 200 & 193 & 177 & 160 & 155 \\ 0.244 & 204 & 197 & 181 & 163 & 158 \end{bmatrix}$$

$$Z_{112} := \begin{bmatrix} \text{"d"} & \text{"G=0.5"} & \text{"G=0.49"} & \text{"G=0.46"} & \text{"G=0.43"} & \text{"G=0.42"} \\ 0.099 & 55 & 54 & 51 & 48 & 47 \\ 0.113 & 72 & 71 & 67 & 63 & 61 \\ 0.120 & 81 & 80 & 76 & 71 & 69 \\ 0.128 & 93 & 91 & 86 & 80 & 79 \\ 0.131 & 97 & 95 & 90 & 84 & 82 \\ 0.135 & 103 & 101 & 96 & 89 & 88 \\ 0.148 & 118 & 115 & 109 & 102 & 100 \\ 0.162 & 141 & 138 & 131 & 122 & 120 \\ 0.177 & 163 & 159 & 151 & 141 & 138 \\ 0.192 & 170 & 166 & 157 & 147 & 144 \\ 0.207 & 186 & 182 & 172 & 161 & 158 \\ 0.225 & 205 & 201 & 190 & 178 & 172 \\ 0.244 & 211 & 206 & 196 & 181 & 175 \end{bmatrix}$$

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

## Calculations

---

Length and diameter of nail

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

Length in inches

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

Diameter in inches

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

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

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

$$\text{shear\_design} := \begin{bmatrix} \text{"Thk"} & \text{"Z"} \\ \frac{3}{4} & Z_{34}[\text{ListTools}:-\text{Search}(d, Z_{34})[1], \text{lumber} + 1] \\ 1 & Z_1[\text{ListTools}:-\text{Search}(d, Z_1)[1], \text{lumber} + 1] \\ 1 + \frac{1}{4} & Z_{114}[\text{ListTools}:-\text{Search}(d, Z_{114})[1], \text{lumber} + 1] \\ 1 + \frac{1}{2} & Z_{112}[\text{ListTools}:-\text{Search}(d, Z_{112})[1], \text{lumber} + 1] \\ 1 + \frac{3}{4} & Z_{134}[\text{ListTools}:-\text{Search}(d, Z_{134})[1], \text{lumber} + 1] \end{bmatrix}$$

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

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

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

$$Z = 96$$

Allowable lateral design value  
for the toe nail (lbs)

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