Design of Nailed Connections

• General
  • NDS provisions apply to
    • common wire nails and spikes
    • box nails
    • threaded, hardened-steel nails and spikes
  • Specifications should include minimum lengths (pennyweight) and diameters of nails or spikes
  • Nails and spikes conform to ASTM F1667

Design of Nailed Connections

• General
  • Nominal design values apply with or without pre-bored holes
  • Preboring helps prevent splitting
    • for $G > 0.6$, hole diameter $< 90\%D$
    • for $G \leq 0.6$, hole diameter $< 75\%D$
  • Toe-nails should be driven at 30 degree angle, distance of $L/3$ from member end
Design of Nailed Connections

• Design Values
  • Withdrawal, W:
    • from side grain
    • NOT from end grain
  • Lateral, Z
    • Single Shear Connections
      • wood-to-wood
      • wood-to-metal
    • Double Shear Wood-to-Wood
    • Combined Lateral and Withdrawal

Nail Withdrawal Design Values

• Withdrawal design values, W, (lb/in. of penetration) found by:

\[ W = 1380 \frac{G^2}{D} \]

\[ W' = W C_D C_M C_I C_{tn} \]

• Withdrawal load capacity of single nail found by multiplying \( W' \) by penetration depth

\[ \text{No. Nails} = \frac{\text{Actual Withdrawal Force}}{W' \Delta} \]
Nominal Design Values, Z, for Single Shear Nailed Connections

- Based on minimum Z from 4 different yield mode equations

\[ Z = \frac{D_t s F_{es}}{4K_\theta} \quad \text{(MODE I_s)} \]

\[ Z = \frac{D^2}{3K_\theta} \sqrt{\frac{1.75F_{em} F_{yb}}{3(1+R_e)}} \quad \text{(MODE IV)} \]

Nominal Design Values, Z, for Single Shear Nailed Connections

- Based on minimum Z from 4 different yield mode equations

\[ Z = \frac{k_1 D p F_{em}}{K_D (1 + 2R_e)} \quad \text{(MODE III_m)} \]

\[ Z = \frac{k_2 D t s F_{em}}{K_D (2 + R_e)} \quad \text{(MODE III_s)} \]
Nominal Design Values, $Z$, for Single Shear Nailed Connections

- Nominal values of $Z$ can be found in Tables 12.3A through 12.3H for common situations.
- Allowable values of $Z'$ found by:
  
  \[ Z' = Z C_D C_M C_t C_d C_{eg} C_{dl} C_{tn} \]

- For penetration depths between 6D and 12D:
  
  \[ C_d = \frac{P}{12D} \leq 1.0 \]

- Determine number of nails needed by dividing actual load by allowable lateral design value, $Z'$.

  \[ \text{Number of nails needed} = \frac{P}{Z'} \]
• NDS does not provide specific nail spacing guidelines

• Hoyle and Woeste recommended the following minimum nail spacings:

<table>
<thead>
<tr>
<th></th>
<th>Without Pre-bored Holes</th>
<th>With Pre-bored Holes</th>
</tr>
</thead>
<tbody>
<tr>
<td>End Distance</td>
<td>20</td>
<td>10</td>
</tr>
<tr>
<td>Edge Distance</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Spacing Perpendicular-to-Grain</td>
<td>10</td>
<td>3</td>
</tr>
<tr>
<td>Spacing Parallel-to-Grain</td>
<td>20</td>
<td>10</td>
</tr>
</tbody>
</table>

Nail Design Example

• Given:
  • 2x4 southern pine girt is nailed to southern pine 8x8 post
  • metal cladding is attached to girt
  • wind suction pressure = 25 psf
  • girts spaced 48 in. OC
  • posts spaced 96 in. OC
• **Find:**
  - How many 16d common wire nails are required to attach the girt to the post?

• **Assume:**
  - Dry fabrication and use conditions
  - Normal temperature conditions
  - No toe-nailing

• **Design Values:**
  - 16d common wire nail \(D = 0.162\) in.
  - length of nail = 3.5 in.
  - southern pine \(G = 0.55\)
  - Tabulated withdrawal design value:

\[
W = 1380 \frac{G^2}{D^5} = 1380 \frac{(0.55)^2}{(0.162)^5} = 50 \frac{lb}{in.}
\]
Adjustment Factors and final $W'$:

- $C_D = 1.6$ for wind load
- $C_M = 1.0$ dry fabrication / service
- $C_t = 1.0$ normal temperatures
- $C_{tn} = 1.0$ no toe-nailing

$$W' = W C_D = \left(50 \frac{\text{lb}}{\text{in. nail}}\right)(1.6) = 80 \frac{\text{lb}}{\text{in. nail}}$$

Withdrawal capacity of each nail:

- Penetration depth, $p$: $p = 3.5 \text{ in.} - 1.5 \text{ in.} = 2.0 \text{ in.}$

- Withdrawal capacity of one nail:

  $$\text{Capacity} = \left(80 \frac{\text{lb}}{\text{in. nail}}\right)(2.0 \text{ in.}) = 160 \frac{\text{lb}}{\text{nail}}$$
• **Withdrawal force at each girt-to-post connection:**

\[ P = \left( \frac{25 \text{ lb}}{\text{ft}^2} \right) (4 \text{ ft})(8 \text{ ft}) = 800 \text{ lb} \]

• **Number of nails required at connection:**

\[ \text{No. Nails} = \frac{800 \text{ lb}}{160 \text{ lb/nail}} = 5 \text{ nails} \]