Temporary Structures

Wall Form Design - Part II

Wall Form Design Example (Continued)

- Design forms for 14 ft high wall to be concreted at the rate of 3 ft per hour, internally vibrated. Assume the mix is made with Type I cement, with no pozzolans or admixtures, and that the temperature of concrete at placing is 60°F. Slump is 4 in. The forms will be used only once, so short-term loading stresses will apply.
- Form grade plywood sheathing ¾ in. thick is available in 4 x 8-ft sheets, and 4500-lb coil ties are on hand. Framing lumber of No. 2 Douglas Fir-Larch is to be purchased as required.

Last session we did:

1) Determined the pressure on the form
2) Used 4 x 8 sheets of 3/4” thick plywood for sheathing in strong way.
3) designed for stud spacing of 1-ft O.C.
   3.1) Checked for Bending
   3.2) Checked for Deflection
   3.3) Checked for Rolling Shear
4) Stud spacing of 12-inch O.C. was verified.
Wall Form Design Example

**STEP 3:** STUD SIZE and SPACING OF WALES

(Wales support the studs)

Design for 2x4 S4S studs. Find the maximum span that can support a lateral pressure of 600 psf.

Equivalent uniform load, \( w \), is the max. lateral pressure times the stud spacing. Hence:

\[
 w = \text{max. lateral pressure times the stud spacing.} \\
\]

\[
 w(\text{stud}) = \frac{600 \text{ psi} \times 12 \text{ in.}}{12 \text{ in./ft.}} = 600 \text{ lb/lf ft} \\
\]

Studs can be considered as continuous beams subjected to uniform loading. Like the previous set of calculations, check for allowable span for bending, deflection, and shear.

**CHECK BENDING**

Assume using No. 2 Douglas Fir-Larch studs. From Table 4-2, the extreme fiber bending stress, \( F_{b} \), is 875 psi. However, this value should be adjusted.

<table>
<thead>
<tr>
<th>SPECIES AND GRADE</th>
<th>Design Bending Stresses, psi</th>
<th>Compression 1% grain</th>
<th>Compression 1% grain</th>
<th>Horizontal 1% grain</th>
<th>Modulus of elasticity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Douglas Fir-Larch</td>
<td>675</td>
<td>425</td>
<td>425</td>
<td>425</td>
<td>19,000</td>
</tr>
</tbody>
</table>

Table 4-2: Representative base design stresses, psi. Normal load duration, visually graded dimension lumber at 15 percent moisture, and plywood used wet.
Wall Form Design Example

- The first adjustment factor is the short-term loading factor of 1.25. The second adjustment factor is the size factor obtained from Table 4-2B, which is 1.5. Therefore:

\[ F'_b = 875 \text{ psi} \times 1.25 \times 1.5 = 1640 \text{ psi} \]

Wall Form Design Example

- The values of section modulus, \( S \), for 2x4 S4S No. 2 Douglas Fir-Larch can be obtained from Table 4-1B as 3.06 in.\(^3\).

Table 4-1B: Properties of American Standard Board, Plain, Dimension, and Timber Sizes Commonly Used for Form Construction

<p>| | | | | | | | | | | | | | | | |</p>
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</tr>
</tbody>
</table>

Wall Form Design Example

- The allowable stud span as a continuous beam is:

\[ l = 10.95 \sqrt{\frac{FS}{W}} \]

\[ l = 10.95 \sqrt{\frac{1640 \times 3.06}{600}} = 31.7 \text{ in.} \]
Wall Form Design Example

- **CHECK DEFLECTION**
  - The allowable deflection is less than \( l/360 \) of the span and 1/8 in., whichever is less.
  - Using Table 4-2, the values for modulus of elasticity for 2x4 \( S4S \) No. 2 Douglas Fir-Larch is \( E = 1,600,000 \) psi, and in Table 4-1B the value for the moment of inertia for is: \( I = 5.36 \) in.\(^4\)
  - For \( \Delta = l/360 \):
    \[
    \Delta = \frac{1.69 \times 5.36}{160000 \times 600} = 1.69 \times 24.3 = 41.0 \text{ in.}
    \]
  - For \( \Delta = 1/8 \):
    \[
    \Delta = \frac{3.84 \times 5.36}{160000 \times 600} = 3.84 \times 10.93 = 42.0 \text{ in.}
    \]

- **CHECK SHEAR**
  - From Table 4-2, allowable \( F_s \) (rolling shear stress) can be found to be \( F_s = 95 \) psi, which should be multiplied by 1.25 for short-term loading, as well as by a factor of 2.0 for horizontal shear adjustment. Therefore, the allowable shear stress is: \( F_s = 95 \times 1.25 \times 2 = 238 \) psi
  - A 2x4 \( S4S \) has an actual \( h = 1 \frac{1}{2} \) in. and \( d = 3 \frac{1}{2} \) in., which is obtained from Table 4-1B. Use the equation for maximum shear for a continuous beam and solve for \( I \):
    \[
    F_s = \frac{238 \times 1.5 \times 1}{600} = \frac{27.8 \times 7}{34.8 \text{ in.}}
    \]

**Horizontal Shear Adjustment**

- The shear stress factor can be applied to the base design value to increase the allowable horizontal shear stress when the length of splits or size of shakes and checks is known, as shown in Table 6-3. Designers may estimate an appropriate adjustment factor when they have general knowledge of the lumber quality available. Conservative practice would suggest use of the factor 1.00 whenever there is absolutely no information on splits, checks and shakes.

<table>
<thead>
<tr>
<th>Length of split or shakes</th>
<th>Adjustment Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>No splits</td>
<td>1.00</td>
</tr>
<tr>
<td>1/4 in. split</td>
<td>1.07</td>
</tr>
<tr>
<td>1/2 in. split</td>
<td>1.07</td>
</tr>
<tr>
<td>3/4 in. split</td>
<td>1.07</td>
</tr>
<tr>
<td>1 in. split</td>
<td>1.07</td>
</tr>
<tr>
<td>1 1/2 in. split</td>
<td>1.07</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Length of shakes or checks</th>
<th>Adjustment Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>No checks</td>
<td>1.00</td>
</tr>
<tr>
<td>1/4 in. checks</td>
<td>1.07</td>
</tr>
<tr>
<td>1/2 in. checks</td>
<td>1.07</td>
</tr>
<tr>
<td>3/4 in. checks</td>
<td>1.07</td>
</tr>
<tr>
<td>1 in. checks</td>
<td>1.07</td>
</tr>
</tbody>
</table>
Wall Form Design Example

- **SPACING OF THE WALES**
  - From the stud spans calculated above, the shortest span is based on bending which is 31.7 inches.
  - This means the wales, which are the stud supports CANNOT be spaced more than 31.7 inches apart (this span can be increased near the top, since in the top 4 ft., the pressure decreases linearly from 600 psf to 0).
  - The top and bottom wales are often set about 1 ft from top and bottom of wall forms.

Wall Form Design Example

- Place wales 12 inches from both top and bottom of the wall form.
- Then, 14' – 1' – 1' = 12 ft. or 144 inches remains for spacing the other wales, which can be no more than 31.7 inches apart.
- Set them at 30 in., except one span at 24 in. (smaller spans at the bottom).
- We place the smaller span near the bottom of the form where theoretically a higher pressure could occur.
Wall Form Design Example

STEPS 4 & 5: TIE DESIGN, WALE SIZE and TIE SPACING

- From the pressure diagram, the equivalent uniform load per lineal foot of wale is determined to be 1500 lb/lf.
- The problem statement indicates that 4500-lb coil ties are available and will be used.

(Cont'd)

- With the maximum load per lineal foot of wale being 1500 lbs, then the maximum tie spacing is:

\[
\text{Tie Spacing} = \frac{\text{Tie capacity}}{\text{Wale load}} = \frac{4500 \text{ lb}}{1500 \text{ lb/ft}} = 3 \text{ ft.}
\]
Wall Form Design Example

- **CHECK BENDING (Cont’d)**
  - Maximum bending moment for a uniformly loaded continuous beam (more than 3 supports) is:
    \[ M_{\text{max}} = \frac{wL^2}{120} \text{ in.}-\text{lb.} \]
  - The maximum moment of the member being designed is:
    \[ M_{\text{Max}} = F_b S \]
  - Therefore:
    \[ F_b S = \frac{wL^2}{120} \]
  - Or:
    \[ S = \frac{wL^2}{120F_b} \]

- **CHECK BENDING**
  - \( F_b \) is the allowable stress in the extreme fiber and was calculated to be 1640 psi (refer to top of page 16 of the handout). The span, \( L \), is 3 ft. or 36 inches, and \( w = 1500 \text{ lb/lf.} \)
  - Therefore the required section modulus, \( S \), can be calculated using the above equation:
    \[ S = \frac{wL^2}{120F_b} = \frac{1500 \times 36^2}{120 \times 1640} = 9.88 \text{ in.}^3 \]

- For order to avoid drilling of timbers, they commonly use double-member wale. So the required section modulus of 9.88 in.\(^3\) is for two members.
  - Referring to Table 4-1B, double 2x4s will yield a section modulus of 2x3.06 or 6.12 in.\(^3\), which is less than 9.88 in.\(^3\), and therefore not acceptable.
  - Checking the next larger size, 3x4, will result in:
    \[ S = 2x 5.10 = 10.20 \text{ in.}^3 > 9.88 \text{ in.}^3 \]
  - which satisfies the section modulus requirements. ⇒ Use double 3x4 wales.
Wall Form Design Example

CHECK SHEAR

To check the horizontal shear for the double 3x4 wales, use the horizontal shear stress formula for a uniformly loaded continuous beam.

\[
f_h = \frac{w}{L - 2d} \text{ or } f_h = \frac{0.9w}{2d}
\]

(They are the same formulas)

From Table 4-1B, the value of \( wb \) for a 3x4 member can be obtained as: 8.75 in.² (or simply: 2.5” x 3.5” = 8.75 in.²)

\[
f_h = \frac{0.9 \times 1500}{2 \times 8.75} \left( \frac{2 - 2 \times 3.5}{12} \right) = \frac{77.14 \times 2.42}{186} \approx \frac{238}{238} \text{ psi} \Rightarrow \text{O.K.}
\]

Therefore the stress in the double 3x4 members meets the requirements. (The value of the adjusted allowable shear stress of 238 psi was calculated before - refer to page 20 of the handout).

STEP 6: BEARING CHECK

Check:
1) bearing of the studs on wales and
2) bearing between the tie washer or tie holders and wales.

From Table 4-2, the value of compression Perpendicular to grain, \( F_{c_{\perp}} \), for No. 2 2x4 Douglas Fir-Larch is 625 psi.

<table>
<thead>
<tr>
<th>Length of bearing, in</th>
<th>1/2</th>
<th>1</th>
<th>1 1/2</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>6 0.5</th>
<th>more</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factor</td>
<td>1.79</td>
<td>1.37</td>
<td>1.25</td>
<td>1.19</td>
<td>1.13</td>
<td>1.09</td>
<td>1.00</td>
<td></td>
</tr>
</tbody>
</table>

\[
(1.13 + 1.09)/2 = 1.11
\]
Wall Form Design Example

- **TIES**: Assume a 3½ in.-square tie washer.
- Then the bearing area is:
  \[(3\frac{1}{2}\text{ in.})^2 - \frac{3}{4}\text{ in.} \times 3\frac{1}{2}\text{ in.} = 12.25 - 2.63 = 9.63 \text{ in.}^2\]
- Since this is a short bearing length, \(F_{cL}\) should be multiplied by a factor of 1.11 (refer to page 13 for 3½ in. bearing length):
  - Adjusted \(F_{cL} = 625 (1.11) = 694 \text{ psi}\)

**The actual bearing stress is then:**

\[
\frac{4500 \text{ lb}}{9.63 \text{ in.}^2} = 467 \text{ psi} < 694 \text{ psi} \Rightarrow \text{O.K.}
\]
Wall Form Design Example

Bracing for Lateral Loads

- Consider the necessary bracing for a wall form 14 ft. high, above grade, in an area where the local building code specifies a minimum 20 psf wind loading.

- Table 5-7 (page 6 of the handout) indicated that 140 lb per lineal foot should be used for design of bracing, since the wind force prescribed by local code gives a value larger than the 100 lb/ft minimum established by ACI Committee 347.
Wall Form Design Example
Bracing for Lateral Loads

- Strut Bracing
  - If wooden strut bracing is provided, strong enough to take either a tension or compression load, then single side bracing may be used.
  - Nailed connections at either end must be strong enough to transmit the tension load, and wales or other form members must be strong enough to transmit accumulated horizontal forces to the strut bracing.

Wall Form Design Example
Bracing for Lateral Loads

- Strut Bracing
  - If wooden bracing is attached 1 or 2 feet below the top of the wall, the bracing must carry more than the 140 lb per ft load applied at the top.

\[ H' \]
\[ 14' \]
\[ 12' \]

- \( H' \) the horizontal bracing force 2 feet from the top of the wall would have to be \((14/12')(140 \text{ lb/ft}) = 163 \text{ lb per ft}\) in order to balance the 140 lb/ft design load applied at the top of the wall.

- If end of the brace is put 8 feet from the wall, use the relationship between sides of the right triangle to find the length of brace and load it must carry.
Wall Form Design Example
Bracing for Lateral Loads

- **Strut Bracing**

  ![Diagram of strut bracing](image)

  \[ t = \sqrt{h^2 + x^2} \]

  \[ t = \sqrt{(12)^2 + (8)^2} = \sqrt{208} = 14.15 \text{ ft} \]

  \[ (\text{tension}) \text{ compression in strut} = H' \times \frac{14.15}{8} \]

  \[ (\text{tension}) \text{ compression in strut} = 163 \times \frac{14.15}{8} = 290 \text{ lb per ft of wall} \]

- If struts are spaced every 8 feet along the wall, then \( 8 \times 290 = 2320 \text{ lb} \) must be carried by each brace.

- Many wood members strong enough to carry this load in compression will also be adequate in tension. However, the strength of connections (nails, etc.) must be made adequate for the tension load.