TEMPORARY STRUCTURES

Formwork for Concrete

Horizontal Formwork Design and Formwork Design Tables
Lesson 2: Concrete Formwork Design

Horizontal Formwork Design and Formwork Design Tables

Overview

The second lesson provides an overview on the basic structural wood design as it applies to concrete formwork. This lesson covers materials, methods and techniques associated with concrete formwork design and construction for slabs. This lesson intends to provide enough information to be able to design horizontal forms, which will be covered in step-by-step fashion in lesson 2. Also in this lesson, the use of design tables will be discusses. The design tables are used for preliminary design when rigorous structural analysis is required for formwork design.

Lesson Objectives

By the end of this lesson you will be able to:

- recognize horizontal formwork components, materials and accessories;
- explain design considerations for horizontal concrete formwork;
- design slab forms;
- design formwork using design tables.

Reading Assignment

M.K. Hurd, Chapter 5: 5.1 to 5.7, Chapter 6: 6-16 to 6-20, and Chapter 7.
Introduction

Horizontal concrete formwork, such as formwork for slabs, consist of sheathing, normally made of plywood, which rests on joists, and joists are supported by stringers, and stringers are supported on shores which carry the weight of the entire system. Figure 1 shows a typical slab form with its components.

![Figure 1 - Typical wall form with components identified. Plywood sheathing is more common than board sheathing material](image)

Slab from design

Design of slab forms can be summarized in the following design steps:

- **Step 1:** Estimate design loads
- **Step 2:** Determine sheathing thickness and and spacing of its supports (joist spacing)
- **Step 3:** Determine joist size and spacing of supports (stringer spacing)
- **Step 4:** Determine stringer size and span (shore spacing)
- **Step 5:** Perform shore design to support stringers
- **Step 6:** Check bearing stresses
- **Step 7:** Design lateral bracing

The following example illustrates a slab form design:

Vertical Loads

Vertical loads on formwork include:

- the weight of reinforced concrete;
- the weight of forms themselves (dead load); and
- the live loads imposed during the construction process (material storage, personnel and equipment).
For example, if the concrete weighs 150 lbs/ft³ (pcf), it will place a load on the forms of 12.5 lbs/ft² (psf) for each inch of slab thickness \[ \frac{150 \text{pcf}}{(12 \text{ in/ft})} = 12.5 \text{ psf/in} \], i.e., a 6-inch slab would produce a dead load of 12.5×6 = 75 psf (neglecting the weight of the form).

ACI Committee 347 recommends that both vertical supports and horizontal framing components of formwork should be designed for a minimum live load of 50 psf of horizontal projection to provide for weight of personnel, runways, screeds (equipment used for precise strike-off and consolidation of concrete surfaces) and other equipment. When motorized carts are used, the minimum should be 75 psf.

Regardless of slab thickness, the minimum design value for combined dead and live loads should be 100 psf, or 125 psf if motorized carts are used. Figure 2 shows a typical power buggy used for concrete placement.

![Figure 2 - Power buggy used for concrete placement](image)

Table 5-1 (page 5-2, text) shows vertical loads on forms for various types of slabs of varying thickness (using minimum live load of 50 psf, and neglecting weight of the form, which may be added by designer).

When slab form members are continuous over several supporting shores, dumping concrete on one span of the form member may cause uplift of the form in other spans. Forms must be designed to hold together under such conditions. If form members are not secured to resist this uplift, they should be built as a simple pan.

![Figure 3 - Dumping concrete on one span of the form can cause uplift of the form in other spans](image)

**SLAB FORM EXAMPLE:**

Design forms to support a flat slab floor 8 inches thick of high-strength concrete with a unit weight of 138 lb/ft³, using construction grade Douglas Fir-Larch forming
members and steel shoring. Ceiling height is 8 feet and bays are 15×15 feet. Assume forms will have continuing reuse.

**Step 1: ESTIMATE DESIGN LOADS:**

- Dead load, concrete and rebar, \( \frac{8 \text{ in.} \times 138 \text{ pcf}}{12 \text{ in.}} = 92 \text{ psf} \)
- Minimum construction live load on forms = 50 psf
- Weight of forms, estimated = 8 psf

Total form design load = 150 psf

**Step 2: SHEATHING DESIGN [Sheathing thickness and spacing of its supports (joist spacing)]:**

Let’s assume that a \( \frac{3}{4}'' \)-thick plywood sheathing will be used for this project. From Tables 4-2 and 4-3, for \( \frac{3}{4}'' \)-thick plywood:

TABLE 4-2: REPRESENTATIVE BASE DESIGN STRESSES, PSI, NORMAL LOAD DURATION, VISUALLY GRADED DIMENSION LUMBER AT 19 PERCENT MOISTURE, AND PLYWOOD USED WET

<table>
<thead>
<tr>
<th>SPECIES AND GRADE</th>
<th>Extreme fiber bending stress, ( F_b )</th>
<th>Compression ( \perp ) to grain, ( F_c )</th>
<th>Compression ( \parallel ) to grain, ( F_r )</th>
<th>Horizontal shear, ( F_s )</th>
<th>Bearing on face, ( F_b )</th>
<th>Modulus of elasticity, ( E )</th>
</tr>
</thead>
<tbody>
<tr>
<td>PLYWOOD SHEATHING USED WET: Plyform B/B, Class 1 (Grade stress level S0)</td>
<td>(1455)</td>
<td>( 57 )</td>
<td>(1,500,000)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

TABLE 4-3: EFFECTIVE SECTION PROPERTIES FOR PLYWOOD (12-IN. WIDTHS)*
FACE PLIES OF DIFFERENT SPECIES FROM INNER PLIES

| Sanded ply- | Minimum number of layers | Effective thickness for shear, all grades using exterior glue | 12-in. width, used with face grain parallel to span | 12-in. width, used with face grain perpendicular to span | Approximate weight, lb |
| wood, net | | | Area for tension and compression, in.² | Moment of inertia, in.⁴ | Effective section modulus, in.³ | Area for tension and compression, in.² | Moment of inertia, in.⁴ | Effective section modulus, in.³ | Rolling shear constant, lb/\( \text{in.}^2 \) | 4-ply sheet per sq ft |
| thickness, in. | | | | | | | | | | |
| \( \frac{3}{8}'' \) | 3 | 0.267 | 0.996 | 0.008 | 0.059 | 2.010 | 0.348 | 0.001 | 0.009 | 2.019 | 26 | 0.8 |
| \( \frac{1}{4}'' \) | 3 | 0.288 | 1.307 | 0.027 | 0.125 | 3.088 | 0.626 | 0.002 | 0.023 | 3.510 | 35 | 1.1 |
| \( \frac{1}{8}'' \) | 3 | 0.425 | 1.947 | 0.077 | 0.236 | 4.466 | 1.240 | 0.009 | 0.087 | 2.752 | 48 | 1.5 |
| \( \frac{3}{4}'' \) | 5 | 0.568 | 2.884 | 0.197 | 0.412 | 6.762 | 2.081 | 0.003 | 0.285 | 4.079 | 58 | 1.8 |
| \( \frac{1}{4}'' \) | 7 | 0.586 | 2.942 | 0.279 | 0.515 | 7.650 | 2.651 | 0.104 | 0.354 | 5.078 | 63 | 2.6 |
| \( \frac{1}{8}'' \) | 7 | 0.817 | 3.721 | 0.423 | 0.654 | 8.982 | 3.183 | 0.185 | 0.591 | 7.031 | 96 | 3.0 |
| \( \frac{1}{4}'' \) | 7 | 0.836 | 3.854 | 0.548 | 0.820 | 9.883 | 3.180 | 0.271 | 0.744 | 8.428 | 106 | 3.3 |

\[ F_b = 1545 \text{ psi} \]
\[ F_S = 57 \text{ psi} \]
\[ E = 1,500,000 \text{ psi} \]
\[ S = 0.412 \text{ in.}^3 \]
\[ I = 0.197 \text{ in.}^4 \]
\[ \text{lb/} \text{in.}^2 = 6.762 \text{ in.}^2 \]
Since forms will have continuing reuse, do not adjust base design values for short term load.

**CHECK BENDING**

Since the sheathing thickness is selected, determine its maximum allowable span, which is the maximum spacing of joists. For design purposes, consider a 1-foot-wide strip of plywood. Then:

\[ w = \text{design load of 150 psf } \times 1 \text{ ft.} = 150 \text{ lb/lf} \]

\[ l = 10.95 \sqrt[4]{\frac{F_b S}{w}} = \sqrt[4]{\frac{1545 \times 0.412}{150}} = 22.6 \text{ in.} \]

**CHECK DEFLECTION**

Knowing the sheathing thickness, calculate the maximum allowable span which satisfies deflection requirements. Since no deflection requirement is specified, assume \( l/360 \) of the span. For \( \Delta = l/360 \):

\[ l = 1.69\sqrt[3]{\frac{EI}{w}} = 1.69\sqrt[3]{\frac{1500000 \times 0.197}{150}} = 1.69\sqrt[3]{19700} = 21.2 \text{ in.} \]

For \( \Delta = 1/16 \) in.:

\[ l = 3.23\sqrt[3]{\frac{EI}{w}} = 3.23\sqrt[3]{\frac{1500000 \times 0.197}{150}} = 3.23\sqrt[3]{19700} = 21.5 \text{ in.} \]

**CHECK ROLLING SHEAR**

Plywood sheathing should be checked for rolling shear (just as it is in vertical form design). For design purposes, consider a 1-foot-wide strip of plywood. Then:

\[ F_s = \frac{VQ}{Lb} = 0.6wL \times \frac{Q}{Lb} \quad \text{since } V = 0.6wL \]

So:

\[ L = \frac{F_s \times Lb}{0.6wQ} = \frac{57}{0.6 \times 150} \times 6.762 = 4.28 \text{ ft. or 51.4 inches} \]

\[ \Rightarrow l = 21.2 \text{ in. governs. Use 5 equal spaces of 19.2 inches on an 8-ft. wide plywood sheet.} \]

**Step 3: Joist Size and Spacing of Stringers to Support the Joists:**

Select a joist size and material to be used, then the spacing can be determined based on the size and material selected for the joist. Assume 2×4 construction grade Douglas-Fir-Larch to be used for joists (forms are used repeatedly, so there is no short-term load adjustment). Joists are generally assumed continuous over three or more spans. From Table 4-2: \( F_b = 1000 \text{ psi} \) and \( F_V = 95 \text{ psi} \) and should be adjusted for horizontal shear by a factor of 2 (refer to Table 6-3, page 6-9). \( E = 1,500,000 \text{ psi} \).

\[ F'_V = 2.0 \times 95 = 190 \text{ psi} \]
The uniformly distributed load on the joist is:

\[ w = \frac{\text{Joist spacing, in.}}{12 \text{ in./ft.}} \times \text{design load, psf} = \frac{19.2 \text{ in.}}{12 \text{ in./ft.}} \times 150 \text{ psf} = 240 \text{ lb/ft} \]

From Table 4-1B, for S4S 2×4s: \( bd = 5.25 \text{ in.}^2 \), \( I = 5.36 \text{ in.}^4 \), and \( S = 3.06 \text{ in.}^3 \)

**TABLE 4-2:** REPRESENTATIVE BASE DESIGN STRESSES, PSI, NORMAL LOAD DURATION, VISUALLY GRADED DIMENSION LUMBER AT 19 PERCENT MOISTURE, AND PLYWOOD USED WET

<table>
<thead>
<tr>
<th>SPECIES AND GRADE</th>
<th>Extents fiber bending stress, ( F_s )</th>
<th>Compression ( \perp ) to grain, ( F_{cs} )</th>
<th>Compression ( \parallel ) to grain, ( F_{c\parallel} )</th>
<th>Horizontal shear, ( F_s )</th>
<th>Modulus of elasticity, ( E )</th>
</tr>
</thead>
<tbody>
<tr>
<td>DOUGLAS FIR-LARCH</td>
<td>625</td>
<td>625</td>
<td>1300</td>
<td>95</td>
<td>1,000,000</td>
</tr>
</tbody>
</table>

**TABLE 4-1B:** PROPERTIES OF AMERICAN STANDARD BOARD, PLANK, DIMENSION, AND TIMBER SIZES COMMONLY USED FOR FORM CONSTRUCTION

<table>
<thead>
<tr>
<th>Nominal size, inches, bsd</th>
<th>American Standard size, inches, bsd</th>
<th>Area of section, ( A = bd )</th>
<th>Moment of inertia, ( I = bd^3/12 )</th>
<th>Section modulus, ( S = bd^2/8 )</th>
<th>Board feet per linear foot of pieces</th>
<th>Approximate weight, lb per linear ft, for use in form design**</th>
</tr>
</thead>
<tbody>
<tr>
<td>2x4</td>
<td>1 1/4x3/4”</td>
<td>5.89</td>
<td>6.45</td>
<td>3.56</td>
<td>0.67</td>
<td>1.3</td>
</tr>
<tr>
<td>2x6</td>
<td>1 1/8x5/8”</td>
<td>9.14</td>
<td>24.10</td>
<td>8.57</td>
<td>1.00</td>
<td>2.0</td>
</tr>
<tr>
<td>2x8</td>
<td>1 1/8x5/4”</td>
<td>11.98</td>
<td>64.32</td>
<td>14.73</td>
<td>1.33</td>
<td>2.6</td>
</tr>
</tbody>
</table>

**CHECK BENDING**

Since the joist size is known, calculate its maximum allowable span, which is the maximum allowable spacing of the stringers.

\[ l = 10.95 \sqrt{\frac{F_s^2 S}{w}} = 10.95 \sqrt{\frac{1000 \times 3.06}{240}} = 39.1 \text{ in.} \]

**CHECK DEFLECTION**

Calculate the maximum allowable span that satisfies the deflection requirements, in this case \( l/360 \) of the span. For \( A = l/360 \)

\[ l = 1.691 \sqrt{\frac{EI}{w}} = 1.691 \sqrt{\frac{1500000 \times 5.36}{240}} = 1.691 \sqrt{33500} = 1.691 \times 56.79 = 95.2 \text{ in.} \]

**CHECK SHEAR**

Using Equation 6-12 (page 6-8, text), and solving for \( L \):
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**Lesson 2: Concrete Formwork Design (Horizontal)**

\[ f_v' = \frac{0.9w}{bd} \left( L - \frac{2d}{12} \right) \Rightarrow 190 = \frac{0.9 \times 240}{5.25} \times \left( L - \frac{2 \times 3.5}{12} \right) \Rightarrow 190 = 41.14L - 24 \Rightarrow L = 5.20 \text{ ft.} \]

or \( L = 59.5 \text{ in.} \)

Comparing the three spans calculated above, \( l = 39.1 \text{ in.} \) governs. Considering 15\times15 \text{ ft.} bays and desire for uniform spacing, 36 inch spacing is a reasonable number. This means that the spacing of stringers will be at 5 equal spaces per bay \((5 \times 36" = 180 \text{ inches} = 15 \text{ feet})\)

**Step 4: Stringer Size and Span (Shore Spacing):**

Determine the equivalent uniform loading on the stringer, \( w \).

\[
w = \frac{\text{Stinger spacing, in.}}{12 \text{ in./ft.}} \times \text{load on form, psf} = \frac{36 \text{ in.}}{12 \text{ in./ft.}} \times 150 \text{ psf} = 450 \text{ lb/lf}
\]

Assume that 4\times4 Construction grade Douglas-Fir-Larch stringers are to be used in this project. Knowing the size of the stringer, design for stringer span (which establishes a maximum spacing of the shores), using bending, deflection and shear criteria. From Table 4-1B for S4S 4\times4s:

\[ bd = 12.25 \text{ in.}^2, l = 12.50 \text{ in.}^4, \text{ and } S = 7.15 \text{ in.}^3; \text{ and } d = 3.5 \text{ in.} \]

**CHECK BENDING**

Stringer size is known, then calculate the maximum allowable stringer span (shore spacing).

\[
l = 10.95 \sqrt{\frac{F_v'S}{w}} = 10.95 \sqrt{\frac{1000 \times 7.15}{450}} = 43.6 \text{ in.}
\]

**CHECK DEFLECTION**

For the stringer size specified, calculate the maximum allowable span which meets the \( l/360 \) of the span deflection requirement. For \( \Delta = l/360 \)

\[
l = 1.69 \sqrt{\frac{EI}{w}} = 1.69 \sqrt{\frac{1500000 \times 12.50}{450}} = 1.69 \times 41666.7 = 1.69 \times 34.67 = 58.6 \text{ in.}
\]

**CHECK SHEAR**

Using Equation 6-12, for continuous beam:

\[
L = \frac{F_v'bd}{0.9w} + \frac{2d}{12} \Rightarrow L = \frac{190 \times 12.25}{0.9 \times 450} + \frac{2 \times 3.5}{12} = 5.75 + 0.58 = 6.33 \text{ ft} = 75.9 \text{ in.}
\]

From the above calculations, \( l = 43.6 \text{ in.} \) governs. Meaning that stringers CANNOT be more than 42.5 inches apart (span of singers). HOWEVER, in order
to select an appropriate span, we must consider the dimensions of the bay. The 15-ft. bay could be divided into 5 equal spaces of 36 inches [(180 in./5) = 36 in.] which is less than the maximum allowable span of 42.5 in. – Alternatively, we can check the possibility of using a deeper stinger, i.e. 3×6, in order to increase the shore spacing. Since bending is dominant here, we will check bending for a 3×6 member. For S4S 3×6s from Table 4-2: $F_b = 1000$ psf, and from Table 4-1B, $S = 12.60$ in.$^3$

$$l = 10.95 \sqrt{\frac{F_b S}{w}} = 10.95 \sqrt{\frac{1000 \times 12.60}{450}} = 10.95 \times 5.29 = 57.9 \text{ in.}$$

Now we can use 45-in. (3'-9'') support spacing for the 3×6 stringers, which will divide the bay into 5 equal spaces.

**Step 5: Shore Design to Support Stringers:**

Stringers are placed 36-inches apart, supported by shores spaced 45 inches apart. The area of support for each shore is:

$$\text{Area} = \left(\frac{36}{12}\right) \times \left(\frac{45}{12}\right) = 11.25 \text{ in.}^2$$

Then the total load per shore is:

$$11.25 \text{ ft.}^2 \times 150 \text{ psf} = 1688 \text{ lb.}$$

Figure below shows the formwork design and components graphically up to this point.

Adjustable patented steel shores which carry 3000 lb. safe working load are available and satisfactory for this job. Alternatively, if wood shoring is desirable, refer to Table 7-11 for wood shoring material. Both 3×4 and 4×4 are more than adequate to carry 1688 lbs for an effective length of 8 ft.
Step 6: Check Bearing Stresses:

Bearing should be checked where stringers bear on shores and where joists bear on stringers.

**Stringers bearing on shore:**

Assume the head piece of the adjustable steel shore is 11½×3 5/8". The 3×6 stringer is actually 2½ in. thick.

Figure below shows the stringer resting on the shore graphically.

If the headpiece is placed parallel to the stringer, bearing area is 2½×11½ or 28.75 in.². Bearing stress will be:

\[
\frac{\text{total shore load}}{\text{bearing area}} = \frac{1688}{28.75} \approx 59 \text{ psi}
\]

This is well below the base \( F_{c,\perp} \), which is obtained from Table 4-2 (the value of compression \( \perp \) to grain, \( F_{c,\perp} \), for No. 2 2×4 Douglas Fir-Larch is 625 psi).

**Joist bearing on Stringers:**

The two members are 1½ and 2½ in. wide.

Contact bearing area = 2½×1½ = 3.75 in.²

Average load transmitted by joist to stringer is:

Joist spacing × joist span × form load
\[
\frac{19.2}{12} \times \frac{36}{12} \times 150 = 720 \text{ lb.}
\]

\[
\frac{720 \text{ lb}}{3.75 \text{ in.}^2} = 192 \text{ psi}
\]

Bearing at this point is also low relative to the 625 psi base value for \( F_{cL} \).
FORMWORK DESIGN TABLES

Based on the principles outlined so far, safe spans for many timber and plywood formwork components have been calculated and arranged in tables for use by formwork designer. The tables cover single span beams, two-span beams, and beams continuous over three or more spans carrying a uniform distributed load. The tables can be used to develop a preliminary design for cases where rigorous structural analysis is required for formwork design.

Four sets of allowable (adjusted) stresses are included in the tables.

- Adjusted stresses for long term and short term loading stresses for formwork made of No. 2 grade Southern Pine and Douglas Fir-Larch.
- Adjusted stresses for both short term and long term loading of No. 2 Spruce-Pine-Fir and No. 2 Hem-Fir.

Table 7-1 shows the expressions which are used to calculate the safe support spacings (spans).

Table 7-1: Expressions Used in Calculating the Safe Support Spacings of Chapter 7 Design Tables

<table>
<thead>
<tr>
<th>CRITERION</th>
<th>SINGLE SPAN BEAM</th>
<th>TWO SPAN BEAM</th>
<th>THREE OR MORE SPANS</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\Delta_{\text{max}} = \frac{400}{d}$</td>
<td>$l = 1.32 \left( \frac{E'I'}{w} \right)$</td>
<td>$l = 1.77 \left( \frac{E'I'}{w} \right)$</td>
<td>$l = 1.63 \left( \frac{E'I'}{w} \right)$</td>
</tr>
<tr>
<td>$\Delta_{\text{max}} = \frac{160}{d}$</td>
<td>$l = 1.37 \left( \frac{E'I'}{w} \right)$</td>
<td>$l = 1.83 \left( \frac{E'I'}{w} \right)$</td>
<td>$l = 1.69 \left( \frac{E'I'}{w} \right)$</td>
</tr>
<tr>
<td>$\Delta_{\text{max}} = \frac{1}{16}$ in.</td>
<td>$l = 2.75 \left( \frac{E'I'}{w} \right)$</td>
<td>$l = 3.43 \left( \frac{E'I'}{w} \right)$</td>
<td>$l = 3.23 \left( \frac{E'I'}{w} \right)$</td>
</tr>
<tr>
<td>$\Delta_{\text{max}} = \frac{1}{8}$ in.</td>
<td>$l = 3.27 \left( \frac{E'I'}{w} \right)$</td>
<td>$l = 4.06 \left( \frac{E'I'}{w} \right)$</td>
<td>$l = 3.84 \left( \frac{E'I'}{w} \right)$</td>
</tr>
<tr>
<td>$\Delta_{\text{max}} = \frac{1}{4}$ in.</td>
<td>$l = 3.90 \left( \frac{E'I'}{w} \right)$</td>
<td>$l = 4.85 \left( \frac{E'I'}{w} \right)$</td>
<td>$l = 4.57 \left( \frac{E'I'}{w} \right)$</td>
</tr>
<tr>
<td><strong>BENDING</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$l = 9.60 \frac{F'<em>{b}s}{w} \frac{F'</em>{b}s}{w}$</td>
<td>$l = 9.80 \frac{F'_{b}s}{w}$</td>
<td>$l = 10.95 \frac{F'_{b}s}{w}$</td>
<td></td>
</tr>
<tr>
<td><strong>HORIZONTAL SHEAR</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$l = \frac{16F'_{b}bd}{15w} + 2d$</td>
<td>$l = \frac{19.2F'_{b}bd}{15w} + 2d$</td>
<td>$l = \frac{40F'_{b}bd}{3w} + 2d$</td>
<td></td>
</tr>
<tr>
<td><strong>ROLLING SHEAR, PLYWOOD</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$l = \frac{24F'_{s}}{w} \times \frac{1}{w} + 1.5$</td>
<td>$l = \frac{19.2F'_{s}}{w} \times \frac{1}{w} + 1.5$</td>
<td>$l = \frac{20F'_{s}}{w} \times \frac{1}{w} + 1.5$</td>
<td></td>
</tr>
</tbody>
</table>

$I = \text{spacing of supports, in.} \quad w = \text{load, lb per lineal ft} \quad S = \text{section modulus, in.}^3$

$d = \text{depth of section, in.} \quad E' = \text{modulus of elasticity, psi} \quad F'_{b} = \text{allowable bending stress, psi}$

$I = \text{moment of inertia, in.}^4 \quad b = \text{width of section, in.} \quad F'_{b} = \text{allowable horizontal shear, psi}$

$F'_{s} = \text{allowable rolling shear stress, psi} \quad \frac{Ib}{Q} = \text{rolling shear constant, in.}^5$

The tables are in four groups:

1. Table 7-2 through 7-4 for plywood sheathing
2. Tables 7-5 through 7-7 for joists, studs, stringers or any other beam components of the formwork where framing members are used singly
3. Tables 7-8 through 7-10 for wales or other formwork components where the members are used double
4. Table 7-11 and 7-12 for shore loading and bearing checks

Nominal lumber sizes are shown in the tables. All calculations are based on lumber finished on all four surfaces (S4S). Actual thicknesses are shown for plywood. In each table, it is shown whether the safe span is controlled by bending, deflection or shear.

**TABLE 7-5.2: SAFE SPACING, IN., OF SUPPORTS FOR JOISTS, STUDS, OR OTHER BEAM COMPONENTS OF FORMWORK, CONTINUOUS OVER THREE OR MORE SPANS**

Maximum deflection is in the span or in, whichever is smaller.

<table>
<thead>
<tr>
<th>Uniform load, lb per lineal ft</th>
<th>P⅓ varies with member E' = 1,600,000 psi</th>
<th>Fv = 225 psi</th>
</tr>
</thead>
<tbody>
<tr>
<td>lbs</td>
<td>lbs</td>
<td>lbs</td>
</tr>
<tr>
<td>100</td>
<td>75</td>
<td>110</td>
</tr>
<tr>
<td>300</td>
<td>55</td>
<td>66</td>
</tr>
<tr>
<td>400</td>
<td>45</td>
<td>55</td>
</tr>
<tr>
<td>500</td>
<td>30</td>
<td>40</td>
</tr>
<tr>
<td>600</td>
<td>20</td>
<td>30</td>
</tr>
</tbody>
</table>

**NOTE:** Span values above solid line are controlled by deflection. Within the dashed box horizontal shear governs span. Elsewhere bending controls span.

**Sheathing Design: Tables 7-2 to 7-4**

Tables 7-2, 7-3, and 7-4 were calculated for both long term and short term loading using the information from Table 4-2, for face grain parallel and perpendicular to direction of the span. Tables 7-2 through 7-4 are applicable to plywood sheathing for columns, slabs, and walls. They cover plywood supports as a single span beam, two span beam, or a beam continuous over three or more spans. Theoretical deflection of spans in these tables do not exceed 1/16 in.

**Joists, Studs, Beams: Tables 7-5 to 7-7**

Tables 7-5, 7-6, and 7-7 are applicable to joists, studs, or any other form members loaded uniformly as a beam. Tables 7-5.1 through 7-5.4 are beams continuous over three or more spans with the following adjusted (allowable) stresses:
Joists, Studs, Beams: Tables 7-5 to 7-7

Tables 7-6 and 7-7 are like Table 7-5, except that span length are calculated for simply supported and two-span rather than continuous beams.

Note: Beam sizes are given in conventional fashion with b or the width of beam face to which load is applied given first and the second number indicating depth of beam or d.

2x4 (nominal size):

\[
\begin{align*}
  b &= 2 \\
  d &= 4 
\end{align*}
\]

4x2 (nominal):

\[
\begin{align*}
  b &= 4 \\
  d &= 2 
\end{align*}
\]

Double Members: Tables 7-8 to 7-10

Tables 7-8, 7-9 and 7-10 are similar to Tables 7-5, 7-6, and 7-7 in terms of allowable (adjusted) stresses and general layout, but they cover double members which are commonly used for wales and frequently for stringers. Spans are calculated on the basis of these members side by side with their longer dimension as the depth of the beam.

Wood Shores: Tables 7-11 and 7-12

Table 7-11 shows allowable loads on wood shores for some of the more commonly used timber sizes, with base value of compression parallel to the grain Fc ranging from 1100 to 1600 psi, with modulus of elasticity values from 1,200,000 psi to 1,600,000 psi. Table 7-11 shows no load when \( l/d \) exceeds the recommended limit of 50.

Flat Slab Example:

Use the design tables in Chapter 7 to make a preliminary selection of a stringer, joist, and sheathing combination suitable for forming a flat slab with dead plus live load of 200 psf supported on shores spaced 4 ft on centers in both directions. Assume that No. 2 Douglas-Fir-Larch is selected for multiple-use forms.

From Table 4-2, the base stress values are:
\[ F_b = 875 \text{ psi} \]
\[ F_v = 95 \text{ psi} \]
\[ E = 1,600,000 \text{ psi} \]

As explained above, Tables 7-5.1, 7-6.1, and 7-7.1 are developed with adjusted stresses that can be applied for No. 2 Douglas Fir-Larch or Southern Pine, under long term loads, with conditions as stated.

**STRINGERS**

With shores placed 4 ft on centers both ways, the stringers will be 4 ft apart and have a span of 4 ft between supports.

They will be designed as continuous beams with an equivalent uniform load equal to the distance between stringers times the uniform load on the formwork (psf):

\[ 4 \text{ ft} \times 200 \text{ psf} = 800 \text{ lb/lf} \]

Use Table 7-5.1, since the stringers will be continuous over three or more spans. Enter the table at the left on the 800 lb/lf load line.

Note which members can be used for stringers having a 48-in. span. Among the smaller members that are suitable are:

\[ 2\times10 \Rightarrow \text{Allowable span 55”} \]
\[ 3\times8 \Rightarrow \text{Allowable span 59”} \]
\[ 4\times6 \Rightarrow \text{Allowable span 55”} \]

The 2×10 provides the necessary span with the least lumber (but check with local suppliers for availability).

Shore spacing places the stringers 4 ft apart, and this 4 ft then is the span of the joists. How joists are spaced depends on requirements of the sheathing. Assume 3/4-in. Plywood Class I or equal quality plywood is used with its face running in the direction of the span. Since sheathing is continuous over several spans, refer to Table 7-2. The right side of the table, with \( F’_v = 1545 \text{ psi} \), applies since this is a multiple-use form. From the column for 3/4-in. thickness with face grain parallel to the span, for load of 200 psf, read the allowable span of 19 in.
In order to use 4×8 sheets of plywood efficiently, a span of 96 ÷ 5 or 19.2 inches probably will be used, dividing each 8-ft. piece of plywood into five equal spans, while permitting edge support for the plywood panels.

**JOISTS**

This 19.2-inch becomes the required joist spacing, and joist span has already been fixed at 4-ft.

What is the required joist size?

Joist loading = Joist spacing (ft.) × Load on forms

\[
\frac{19.2}{12} \times 200 = 320 \text{ lb/lf}
\]

Again using Table 7-5.1 since joists are continuous over several spans, note that a 2×6 loaded at 300 lb/lf has an allowable span of 59 in. and at 400 lb/lf has an allowable span of 51 in.

By inspection, the 2×6 appears to be the lightest joist that would be satisfactory on a 48-in. span.

But also consider the 4×4 which has an allowable span of 53 in. at 400 lb/lf. The 4x4 is often selected for this type of form, because its shape provides inherent lateral stability.

**Bearing**

A check of bearing stresses where joists rest on stringers and where stringers rest on shores would be advisable.

Use the tables to determine spacing of wall form members, assuming continuous reuse of the forms and No. 2 grade Douglas Fir-Larch or equal lumber, with sheathing of plywood. Design a 10-ft high wall form for a maximum lateral pressure of 600 psf, assuming no reduction of pressure near the top of the form.

**SHEATHING**

Assuming that 1-in. plywood is used with face grain vertical, the grain will be perpendicular to the span between the studs, and plywood will be continuous across several spans.

The right side of Table 7-2 applies because the lower stress levels are recommended when forms are designed for continuing reuse, and the far right column applies because the face grain is perpendicular to the span.

Entering the table at 600 psf level, we find span of 13 in.

It is decided to set the studs 12 in. O.C. so that they can be uniformly spaced and also support plywood at the panel edges.

**STUDS**

With the studs 12 in. apart, the load per lineal ft is

\[
\frac{12}{12} \times (600) = 600 \text{ lb per ft.}
\]

Assuming that the studs are continuous over three or more spans, refer to Table 7-5.1 for choice of span and member. Entering table at left on the 600 lb/lf load line, the 3×4 stud has an allowable span of 37 in. Support for studs (wale or ties) would be
needed at about 3-ft intervals. Placing top and bottom wales 6 in. above bottom of form and 6 in. below top of form would permit use of four wales spaced 3 ft apart.

**WALES**

If double wales are spaced ft apart, the equivalent uniform load per lineal ft is

\[
\frac{36}{12} \times (600) = 1800 \text{ lb per ft.}
\]

Assuming continuity of wales, the left side of Table 7-8.1 would be used to determine spacing of wale supports. Entering the table from left on the 1800 lb/lf load line, a convenient span and double member combination may be chosen from the left side of the table where adjusted bending stresses are applicable for long term loading of Douglas fir-Larch of Southern Pine.

For example, if double 2×6 wales are used the spacing between ties that support the wales can be a maximum of 33 in.

A check of the load capacity of available ties might help in confirming the wale selection.

If the double 2×6 were used with supporting ties spaced at 33 in., the average tie load would be

\[
\frac{33}{12} \times \frac{36}{12} \times 600 = 4950 \text{ lb}
\]

A tie with a safe working load of 5000 lb should be selected. With a tie spacing of 24 in., the necessary tie capacity will be 3600 lb. \([24/12 \times 36/12 \times 600 = 3600 \text{ lb}]\)