Temporary Structures
Formwork Materials and Accessories

Lecture 2

Form Materials and Accessories

- Practically all formwork jobs require some lumber.
- Local supplier will advise what material and sizes are in stock or promptly obtainable, and the designer or builder can proceed accordingly.
- Southern yellow pine and Douglas fir, sometimes called Oregon pine are widely used in structural concrete form.
- They are easily worked and are the strongest in the softwood group. Both hold nails well and are durable.
- They are used in sheathing, studs, and wales.
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Form Materials and Accessories

Sheathing
Ties
Wales
Studs
Plate
Footing

Typical wall form with components identified. Plywood sheathing is more common than board sheathing material.

Parts of typical wall formwork
**Ties**

- A concrete form tie is a tensile unit adapted to holding concrete forms secure against the lateral pressure of unhardened concrete.
- A wide variety of ready-made ties with safe load ratings ranging from 1,000 lb to more than 50,000 lb are used today.
- They consist of internal tension unit and external holding device, and are manufactured in two basic types:
  - Continuous single member
  - Internal disconnecting type

Some commonly available single member ties.
Continuous Single Member Ties

- Continuous single member, in which the tensile unit is a single piece, and a special holding device is added for engaging the tensile unit against the exterior of the form.

- Some single member ties may be pulled as an entire unit from the concrete; others are broken back a predetermined distance, some are cut flush with the concrete surface.

Internal disconnecting Type Ties

- Internal disconnecting type, in which the tensile unit has an inner part with threaded connections to removable external members which make up the rest of the tensile unit. They generally remain in the concrete.
### Ties

- The two types of tying devices are identified commercially by various descriptive names, such as form clamps, coil ties, rod clamps, snap ties, etc.
- Except for taper ties, the continuous single member type is generally used for lighter loads, ranging up to about 5,000 lb safe load.
- The internal disconnecting type of tie is available for light or medium loads but finds its greatest application under heavier construction loads (up to about 70,000 lb).
Lumber Finish and Sizes

- Lumber which has been surfaced in a planning machine to attain smoothness of surface and uniformity of size is called “dressed” lumber.
- The surfacing may be on one side (S1S), one edge (S1E), two sides (S2S), two edges (S2E), or combination of sides and edges (S1S1E, S1S2E, S2S1E) or on all four sides (S4S).
- Dressed lumber is generally used for formwork, because it is easier to handle and work, but rough sawn boards and timbers may be used in bracing and shoring, or as a form surfacing material to secure a special texture effect in the finished concrete.

Lumber Finish and Sizes

- Minimum sizes of both rough and dressed lumber are specified by the American Softwood Lumber Standards, PS 20-70. It changes the dimensions to equate green and dry lumber.
- Lumber is commonly referred to by its nominal size.
- Minimum sizes for green lumber are selected so that as moisture is lost, it becomes the same size as dry lumber.

Specified actual size of a 2x4 for different moisture contents and finishes.
Table 4-1B shows actual dimensions and cross section properties of American Standard lumber at 19 percent moisture content.

- Actual, not nominal, sizes must always be used for design.

- Values of Table 4-1B can be safely used with either dry or green lumber.

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Table 4-2 shows base design values for several species of wood in common use for formwork.

- Design for formwork is based on the allowable or working stresses.
- Allowable stress depends on so many factors including the species of wood, grade, cross section, moisture content, and load duration.
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Adjustment for Load Duration

- For form work materials with limited reuse, ACI 347 permits design using allowable stresses for temporary structures or for temporary loads on permanent structures.
- In case of lumber, this is interpreted to mean the 25 percent working stress increase (adjustment factor of 1.25) shown in Table 4-2 for 7 days or less duration of load.

Adjustment factors for size and Flat Use

- **Size Factor.** Except for Southern Pine, the No. 1 and No. 2 lumber frequently used for formwork is subject to stress adjustment based on member size (use Table 4-2B).
- **Flat use factor.** When dimension lumber 2 to 4 in. thick is loaded on the wide face, the base value of bending stress can be multiplied by adjustment factors shown in Table 4-2B.

<table>
<thead>
<tr>
<th>WIDTH OF LUMBER</th>
<th>BENDING STRESS ADJUSTMENT MULTIPLIER</th>
<th>ADJUSTMENT FACTOR FOR COMPRESSION PARALLEL TO GRAIN</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Size Factor</td>
<td>Flat Use Factor</td>
</tr>
<tr>
<td>2 and 3 in.</td>
<td>1.5</td>
<td>1.5</td>
</tr>
<tr>
<td>4 in.</td>
<td>1.5</td>
<td>1.5</td>
</tr>
<tr>
<td>6 in.</td>
<td>1.4</td>
<td>1.4</td>
</tr>
<tr>
<td>8 in.</td>
<td>1.3</td>
<td>1.3</td>
</tr>
<tr>
<td>10 in.</td>
<td>1.2</td>
<td>1.2</td>
</tr>
<tr>
<td>12 in.</td>
<td>1.1</td>
<td>1.2</td>
</tr>
<tr>
<td>14 in and wider</td>
<td>0.9</td>
<td>1.0</td>
</tr>
</tbody>
</table>
Engineered Wood Products

- Plywood
  - Plywood is widely used for job built forms and prefabricated form panel systems.
  - Plywood is a flat panel made of a number of thin sheets of wood. A single sheet in the panel may be referred to as a ply, or layer.
  - A layer may consist of a single ply or it may be two or more plies laminated together with their grain direction parallel.

Table 4-3 shows the effective section properties for plywood.

<table>
<thead>
<tr>
<th>Sanded Plywood, Nominal Thickness, in.</th>
<th>Minimum number of layers</th>
<th>Effective thickness for shear, all plies using exterior glue, in.</th>
<th>Area for moment of inertia, ft²</th>
<th>Effective section modulus, KS in.⁴</th>
<th>Rolling shear constant, lb/ft²</th>
<th>Area for moment of inertia, ft²</th>
<th>Effective section modulus, KS in.⁴</th>
<th>Rolling shear constant, lb/ft²</th>
<th>Approximate weight, lb</th>
</tr>
</thead>
<tbody>
<tr>
<td>1⁄₄</td>
<td>3</td>
<td>0.267, 0.996, 0.008, 0.059, 2.010</td>
<td>0.048, 0.001, 0.009, 2.019</td>
<td>0.062, 0.002, 0.023, 3.510</td>
<td>0.056, 0.001, 0.009, 2.019</td>
<td>0.062, 0.002, 0.023, 3.510</td>
<td>0.056, 0.001, 0.009, 2.019</td>
<td>0.062, 0.002, 0.023, 3.510</td>
<td></td>
</tr>
<tr>
<td>3⁄₈</td>
<td>3</td>
<td>0.288, 1.307, 0.027, 0.125, 3.088</td>
<td>0.120, 0.009, 0.087, 2.752</td>
<td>0.164, 0.027, 0.194, 3.119</td>
<td>0.120, 0.009, 0.087, 2.752</td>
<td>0.164, 0.027, 0.194, 3.119</td>
<td>0.120, 0.009, 0.087, 2.752</td>
<td>0.164, 0.027, 0.194, 3.119</td>
<td></td>
</tr>
<tr>
<td>1⁄₂</td>
<td>3</td>
<td>0.425, 1.947, 0.077, 0.236, 4.466</td>
<td>0.240, 0.009, 0.087, 2.752</td>
<td>0.319, 0.027, 0.194, 3.119</td>
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<td>0.240, 0.009, 0.087, 2.752</td>
<td>0.319, 0.027, 0.194, 3.119</td>
<td></td>
</tr>
<tr>
<td>5⁄₈</td>
<td>5</td>
<td>0.550, 2.475, 0.129, 0.536, 5.924</td>
<td>0.328, 0.009, 0.087, 2.752</td>
<td>0.426, 0.027, 0.194, 3.119</td>
<td>0.328, 0.009, 0.087, 2.752</td>
<td>0.426, 0.027, 0.194, 3.119</td>
<td>0.328, 0.009, 0.087, 2.752</td>
<td>0.426, 0.027, 0.194, 3.119</td>
<td></td>
</tr>
<tr>
<td>3⁄₄</td>
<td>7</td>
<td>0.568, 2.884, 0.197, 0.412, 6.762</td>
<td>0.431, 0.009, 0.087, 2.752</td>
<td>0.510, 0.027, 0.194, 3.119</td>
<td>0.431, 0.009, 0.087, 2.752</td>
<td>0.510, 0.027, 0.194, 3.119</td>
<td>0.431, 0.009, 0.087, 2.752</td>
<td>0.510, 0.027, 0.194, 3.119</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>7</td>
<td>0.617, 3.721, 0.243, 0.654, 8.892</td>
<td>0.513, 0.009, 0.087, 2.752</td>
<td>0.596, 0.027, 0.194, 3.119</td>
<td>0.513, 0.009, 0.087, 2.752</td>
<td>0.596, 0.027, 0.194, 3.119</td>
<td>0.513, 0.009, 0.087, 2.752</td>
<td>0.596, 0.027, 0.194, 3.119</td>
<td></td>
</tr>
<tr>
<td>1¼</td>
<td>7</td>
<td>0.836, 3.854, 0.548, 0.820, 9.883</td>
<td>0.630, 0.009, 0.087, 2.752</td>
<td>0.731, 0.027, 0.194, 3.119</td>
<td>0.630, 0.009, 0.087, 2.752</td>
<td>0.731, 0.027, 0.194, 3.119</td>
<td>0.630, 0.009, 0.087, 2.752</td>
<td>0.731, 0.027, 0.194, 3.119</td>
<td></td>
</tr>
</tbody>
</table>

*Use listed KS value in bending calculations and use l only in deflection calculations. Properties taken from 1998 edition of Reference 4-8 for all product standard grades except Structural I and Marine. If B-B Plyform grade is used, values from Reference 4-9 (some slightly higher) can be used for design.
Plywood at the bottom – face grain parallel to span – is used the strong way. With face grain perpendicular to the span direction, the specimen at the top is used the weak way.

Vertical loads on formwork include:

- the weight of reinforced concrete
- the weight of forms themselves (dead load)
- the live loads imposed during the construction process (material storage, personnel and equipment).

The concrete weighs 150 pcf, it will place a load on the forms of 12.5 psf for each inch of slab thickness. i.e., a 6-inch slab would produce a dead load of $12.5 \times 6 = 75$ psf (neglecting the weight of the form)
Vertical Loads

- 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 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.
Vertical Loads

- Table 5-1 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).

<table>
<thead>
<tr>
<th>Slab Thickness (in)</th>
<th>20 Lbs live load</th>
<th>40 Lbs live load</th>
<th>60 Lbs live load</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>50</td>
<td>80</td>
<td>110</td>
</tr>
<tr>
<td>4</td>
<td>65</td>
<td>100</td>
<td>135</td>
</tr>
<tr>
<td>5</td>
<td>80</td>
<td>120</td>
<td>160</td>
</tr>
<tr>
<td>6</td>
<td>95</td>
<td>140</td>
<td>190</td>
</tr>
</tbody>
</table>

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.

![Diagram showing upward movement when fresh concrete is placed](image-url)
Temporary Structures

**Formwork Materials and Accessories**

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**Lateral Pressure of Fresh Concrete**

- Loads imposed by fresh concrete against wall or column forms differ from the gravity load on a horizontal slab form.
- The freshly placed concrete behaves temporarily like a fluid, producing a hydrostatic pressure that acts laterally on the vertical forms.
- This lateral pressure is comparable to full liquid head when concrete is placed full height within the period required for its initial set.

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**Lateral Pressure of Fresh Concrete**

- With slower rate of placing, concrete at the bottom of the form begins to harden and lateral pressure is reduced to less than full fluid pressure by the time concreting is completed in the upper parts of the form.
- The effective lateral pressure—a modified hydrostatic pressure—has been found to be influenced by the weight, rate of placement, temperature of concrete mix, use of retardant admixtures, and vibration.
Factors Affecting Lateral Pressure on Forms

- Weight of concrete
- Rate of placing (the average rate of rise in the form)
- Vibration
- Temperature (affecting the set time)
- Other variables
  - Consistency of concrete
  - Ambient temperature
  - Amount and location of reinforcement
  - Maximum aggregate size (MSA)
  - Cement type, etc.

EQUATIONS USED IN CALCULATIONS OF THE SAFE SUPPORT SPACING IN FORMWORK DESIGN

<table>
<thead>
<tr>
<th>CRITERION</th>
<th>SINGLE SPAN BEAM</th>
<th>TWO SPAN BEAM</th>
<th>3 OR MORE SPANS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>BENDING</strong></td>
<td>$l = 9.80 \sqrt{\frac{f_s l}{w}}$</td>
<td>$l = 9.80 \sqrt{\frac{f_s l}{w}}$</td>
<td>$l = 10.95 \sqrt{\frac{f_s l}{w}}$</td>
</tr>
<tr>
<td><strong>DEFLECTION FOR</strong></td>
<td>$l = 1.37 \frac{E}{w}$</td>
<td>$l = 1.83 \frac{E}{w}$</td>
<td>$l = 1.69 \frac{E}{w}$</td>
</tr>
<tr>
<td>$\Delta = l/360$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>DEFLECTION FOR</strong></td>
<td>$l = 2.75 \frac{E}{w}$</td>
<td>$l = 3.43 \frac{E}{w}$</td>
<td>$l = 3.23 \frac{E}{w}$</td>
</tr>
<tr>
<td>$\Delta = 1/16$ in.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>DEFLECTION FOR</strong></td>
<td>$l = 3.27 \frac{E}{w}$</td>
<td>$l = 4.08 \frac{E}{w}$</td>
<td>$l = 3.84 \frac{E}{w}$</td>
</tr>
<tr>
<td>$\Delta = 1/8$ in.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>HORIZONTAL SHEAR</strong></td>
<td>$l = \frac{16F'_{bd}}{w} + 2d$</td>
<td>$l = \frac{19.2F'_{bd}}{15w} + 2d$</td>
<td>$l = 13.33 \frac{F'_{bd}}{w} + 2d$</td>
</tr>
<tr>
<td><strong>ROLLING SHEAR, PLYWOOD</strong></td>
<td>$l = \frac{24F'_{sd}}{w} \times \frac{lb}{Q} + 1.5$</td>
<td>$l = \frac{19.2F'_{sd}}{w} \times \frac{lb}{Q} + 1.5$</td>
<td>$L = \frac{F_s}{0.6w} \times \frac{lb}{Q}$</td>
</tr>
</tbody>
</table>
Form Design

- When the material for formwork have been chosen, and the anticipated loading estimated, a form should be designed strong enough to carry the anticipated loads safely, and stiff enough to hold its shape under full load.

- At the same time the builder or contractor wants to keep costs down by not overbuilding the form.

Form Design

- Refer to class handouts for wall and slab form design.
Questions?

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