Tilt-up Concrete Construction For Agriculture

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Agricultural Engineers' Digest

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Agricultural Engineers' Digest

You can build concrete walls for farm buildings by casting them in sections on a horizontal surface and then tilting or lifting them into position. Use solid walls for machinery or grain storage buildings and for horizontal silos. Solid walls also make good partitions in livestock buildings. Use insulated tilt-up walls for farrowing, nursery, or other "warm" buildings. For insulated walls, cast insulation in the panels sandwiched between two concrete layers, which protect insulation from rodents, birds, livestock, fire, and physical damage. Custom-made pre-cast insulated panels can be purchased in some areas.

Planning

Site

Because the site influences the usefulness of a building throughout its life, select and prepare the location carefully. Pick a site with good drainage of surface and subsurface water away from the building. Plan for the future—leave space for access and for expansion, perhaps by removing and reusing the end walls. Locate livestock buildings downwind from a dwelling. Consider utilities and providing for waste disposal.

Clear the construction area of all vegetation, roots, large stones, and debris. Complete site grading before laying out the foundation. Place earth fill cut from high spots in 6" layers. Thoroughly consolidate each layer by tamping, rolling, and/or vibrating. Footings must rest on firm earth for adequate bearing.

For additional information, see "Farmstead Planning Handbook," MWPS-2.

Building Layout

A complete plan for your building helps speed construction and reduces the chance for errors.

Lay out the building lines and elevations with surveying instruments. An accurate layout prevents problems later when erecting panels.

Foundations

Establish the excavation lines and the foundation position by measuring from the building lines, Fig 1.

Some buildings are erected on pier foundations. Space the piers at the nominal panel length. Building loads are more concentrated than on a continuous foundation; make the piers large enough to prevent settling. Be sure the top surfaces of the piers are at the same level so that the panels can be easily set plumb and the tops of adjacent wall panels will be at the same elevation.

Put footings at least 3’ deep, and in cold climates, to below frost.

For more information on pier and continuous footings and foundations, see "Foundations for Farm Structures." Portland Cement Association.

Concrete quality

Quality concrete requires the correct amounts of Portland cement, fine and coarse aggregates, and water. Good concrete usually costs little more than poor concrete and is far more economical and far more durable under weathering, animal wear, and chemical attack.

Ready-mixed concrete has been carefully proportioned at the plant. Because added water reduces strength and durability, don't add water on the job. As long as the mix is workable, the less water the mix contains, the stronger and more durable the concrete will be.

Cement

Use not less than 6 bags of Portland cement per cubic yard of concrete with additives for 7% entrained air by volume. Air entrainment improves workability of fresh concrete and frost resistance of cured concrete.

This publication was developed by Jay Runestad and other engineers of the Portland Cement Association, Skokie, Ill. 60076; John Pedersen. MWPS; and E. A. Olson. University of Nebraska. Ret.
Water

Use water clean enough to drink. Use only as much water as the mix design calls for. Allow for the water in damp or wet aggregates.

Aggregates

Use well-graded, hard, dense, clean sand and coarse aggregate to make a medium or mushy mix; specify a 3" to 4" slump. If you have no vibrator, you may need to increase the slump, but don't exceed 6". Increase slump (workability) by reducing the amounts of sand and rock, or by adding cement and water, not just by adding water. Once the water-cement ratio has been selected for the strength of concrete you need, do not upset that balance.

A stiffer mix is more economical because it has more aggregate. It also can be finished sooner, which can save labor. For economy, use aggregates well graded to the largest size permitted:

- \( \frac{3}{4} \)" the thickness of an unreinforced slab on grade,
- \( \frac{3}{8} \)" the clear space between reinforcing bars and forms,
- or, \( \frac{5}{8} \)" the minimum dimension of nonreinforced members.

You can use 1\( \frac{1}{2} \)" aggregate in an unreinforced 4" slab, 3\( \frac{1}{4} \)" to 1" in solid wall panels, and 3\( \frac{1}{2} \)" in sandwich panels. If 3\( \frac{1}{4} \)" is unavailable, use the smallest size you can get. Crushed limestone is preferred because it is less apt to discolor.

Concrete Strength

Although durability is most important for most farm concrete, strength 3 to 7 days after casting is important for tilt-up wall panels. The strength needed to position the panels without cracking depends on the size of the panel and on the number and location of pick-up points. Select your panel size and concrete strength; then consult your concrete supplier for the mix design with the needed high early strength for lifting.

Use concrete mix with a water-cement ratio of 0.40 lb water per lb cement for adequate strength. The trial mixes in Table 1 should produce adequate strength in 3 days cured at 70°F, 5 days at 60°F, or 7 days at 50°F.

If the panels can be cured for a week or more at or above 70°F, a water-cement ratio of 0.53 should be adequate. Avoid a ratio greater than 0.53 lb water/lb cement.

Table 1. Trial concrete mixes for tilt-up panels. Water-cement ratio = 0.40.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>size</td>
<td>%</td>
<td>lb</td>
<td>gal</td>
<td>lb</td>
<td>lb</td>
</tr>
<tr>
<td>in.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3( \frac{1}{2} )&quot;</td>
<td>7.5</td>
<td>340</td>
<td>40.9</td>
<td>850</td>
<td>1360</td>
</tr>
<tr>
<td>3( \frac{3}{4} )&quot;</td>
<td>6.0</td>
<td>263</td>
<td>31.7</td>
<td>658</td>
<td>2100</td>
</tr>
</tbody>
</table>

To adjust for the water in the sand, weigh and dry a sand sample. Dry the sample until no surface water is present and then weigh the dried sample again. Then:

\[
\% \text{ moisture} = 100 \times \frac{\text{loss of wt/wet wt}}{\text{lb water in sand}} = \frac{\text{wt of sand} \times \% \text{ moisture}}{\text{lb water in sand}}
\]

Subtract "lb water in sand" from the water required in the table; increase the amount of sand required by the same amount.

Example: Suppose a sample of sand weighed 1.0 lb when wet and 0.9 lb when dry. Loss of wt is 0.1 lb:

\[
\% \text{ moisture} = 100 \times 0.1/1.0 = 10%.
\]

For 3\( \frac{1}{2} \)" trial mix:

- lb water in sand = 10\% x 1360 = 136 lb.
- Subtract from water: 340 - 136 = 204 lb water in trial mix.
- Add to sand: 1360 + 136 = 1496 lb sand in trial mix.

Test cylinders taken of freshly mixed concrete can be properly cured and tested in a laboratory to assure adequate concrete strength.

Use a mixer large enough to make concrete for at least one panel per batch. Cast at least one whole panel at a time for uniform concrete in each panel and to avoid cold joints in the panels.

Begin curing immediately after the panels are cast and finished: provide a suitable covering, such as a spray or curing membrane or a covering of clear polyethylene film so that the fresh concrete cannot dry out for 3 to 7 days. Concrete develops strength by the chemical reaction between the cement and water. Curing time depends on the temperature of the concrete. There is little strength gain below 50°F; don't let fresh concrete freeze. In cold weather, you may need supplemental heat.

Insulation

The insulation value of sandwich wall panels depends on the thickness and type of insulation used.

Typical Panels

Examples of several applications for concrete wall panels are shown in Fig 2. Design and construction details are on the pages that follow.

Partition walls (non-load bearing)

Solid pen partitions are a simple application of tilt-up construction. Cast panels about 4' x 8' with right angle corners to rest on piers or leveling blocks. Then cast the sloped concrete floor against the panels, Fig 3a. Cast inserts in the panels for bolting them to wall panels or other partitions. Reinforcing is shown in Table 3.

Pen partitions can also rest on sloped floors. Form the ends so they are vertical when erected, Fig 3b. Bolt the panels to wall panels or other pen partitions. See Table 3 for reinforcing.

Insulated Half-Walls

Insulated concrete sandwich panels, about 4' high and 8' long, can be the rugged yet insulated lower portion of exterior walls of livestock buildings. The upper
walls and roof are conventional construction, Fig 4. See Table 4 and Fig 5 for reinforcing.

**Wall Reinforcement**

Masonry wall joint reinforcement, Fig 5, ties the wythes together, and its truss-like structure provides the required resistance to prevent one wythe from slipping past the other. That is, the joint reinforcement makes a sandwich panel resist bending somewhat like a solid panel.

Place the joint reinforcement between the strips of insulation to rest on the reinforcing steel. Then the upper wythe reinforcement can rest on the upper member of the joint reinforcement that protrudes up between the insulation. Position the joint reinforcement as shown in Fig 5, 2" to 3" from each edge and then 2 ft. o.c. Use 2½" wide joint reinforcement for 5½" thick panels and 4" joint reinforcement for 7½" thick panels.

**Building Walls**

Insulated panels have two rather thin layers of concrete (wythes) relative to their height. The wythes are connected so they act together to resist bending while being lifted to an upright position. Fig 5.

**Table 2. R values for insulated concrete sandwich panels.**

<table>
<thead>
<tr>
<th>Panel composition, in.</th>
<th>Form lumber</th>
<th>Type of insulation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Expanded polystyrene</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Molded (R = 3.57/in.)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(R = 6.25/in.)</td>
</tr>
<tr>
<td>5½&quot;</td>
<td>1 3/4&quot; 2&quot; 1 3/4&quot;</td>
<td>2 x 6</td>
</tr>
<tr>
<td>6&quot;</td>
<td>2&quot; 2&quot; 2&quot;</td>
<td>2 x 6</td>
</tr>
<tr>
<td>7&quot;</td>
<td>2&quot; 2&quot; 2&quot;</td>
<td>2 x 6</td>
</tr>
<tr>
<td>7½&quot;</td>
<td>2&quot; 3&quot; 2½&quot;</td>
<td>2 x 8</td>
</tr>
<tr>
<td>7½&quot;</td>
<td>2&quot; 2&quot; 3½&quot;</td>
<td>2 x 8</td>
</tr>
<tr>
<td>8&quot;</td>
<td>2&quot; 3&quot; 3&quot;</td>
<td>2 x 8</td>
</tr>
<tr>
<td>9½&quot;</td>
<td>3&quot; 3&quot; 3½&quot;</td>
<td>2 x 10</td>
</tr>
</tbody>
</table>

**Fig 2. Typical panels.**

All of the panel types can be built with or without insulation.
Table 3. Solid concrete pen partitions.
Concrete compressive strength is 2000 psi at time of lifting.

<table>
<thead>
<tr>
<th>Solid panel thickness, in.</th>
<th>Reinforcing steel</th>
<th>Maximum panel height, ft.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bar size</td>
<td>Horiz. &amp; vert. spacing, in.</td>
</tr>
<tr>
<td>2½&quot;</td>
<td>#3</td>
<td>24&quot;</td>
</tr>
<tr>
<td>3½&quot;</td>
<td>#3</td>
<td>24&quot;</td>
</tr>
</tbody>
</table>

Fig 3a. Pen partitions—sloped floor between level panels.
Fig 4. Half-wall construction with sandwich panels.

Fig 3b. Pen partitions—panels set on sloped floor.
Form panel ends so they are vertical when the partitions are in place.

Fig 3. Pen partitions or non-load bearing walls.
Table 4. Reinforcing for building wall panels.
Concrete compressive strength at time of lifting is 2000 psi.

<table>
<thead>
<tr>
<th>Thickness (in.)</th>
<th>Reinforcing steel in each wythe a.</th>
<th>Maximum panel height, ft.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bar size</td>
<td>Horiz. &amp; vert. spacing</td>
</tr>
<tr>
<td>t</td>
<td>t_1</td>
<td>t_2</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Insulated walls</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 1/4&quot;</td>
<td>1 3/4&quot;</td>
<td>2&quot;</td>
</tr>
<tr>
<td>6</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>7</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>7 1/4&quot;</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>7 1/4&quot;</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>8</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>9 1/4&quot;</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Uninsulated solid panels</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 1/2&quot;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 1/4&quot;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7 1/4&quot;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

a. "Wythe" is the name for each of the two layers of concrete that enclose the insulation. Either wythe may be the face (outdoor) or back (indoor) layer.
b. Notes
  - Maximum panel width is 12'
  - Openings for fans, windows, or doors up to 1/3 of the panel width can be cast into these panels.

---

Fig 5. Wall reinforcing.
Vertical bars are close to panel faces. Insulation is 6" away from top and bottom of panel, but extends to sides of panel.
Combination building and manure pit walls.

These building wall and foundation panels can be modified to serve as the building wall and manure pit wall. Extend the insulation to 2' below grade as in the wall-foundation panels, with the rest of the manure pit wall solid.

The only changes needed are in the size and spacing of the reinforcing steel. Increase the amount of steel near the inside surface of the manure pit portion of the panels. See Table 5.

Adjust the vertical steel spacing in the upper portion of the panels (#3 @ up to 24") so the bars lap every 2nd or 3rd bar in the manure pit portion.

Example 1. 6' deep pit with 7" wall, Table 5 calls for 3 rears at 10.5"; therefore, place the vertical bars in the inside wythe 21" apart so they lap alternate bars in the lower portion of the panel.

Example 2. 8' deep pit with 7" wall where machinery can drive close to the pit wall: vertical bars are #4 at 8.2". Only slight adjustment is needed in the upper steel to lap every 3rd bar in the lower steel. Lap rears 12".

Special panels can be cast for the building and manure pit walls. An opening in each panel for girdle support is shown in Fig 7. See Tables 4 & 5 for reinforcing details. A ledge on the panel supports slats. Fig 8.
Table 5. Reinforcing for manure pit walls.
Concrete compressive strength is at least 3500 psi before backfilling.

<table>
<thead>
<tr>
<th>Maximum manure pit depth</th>
<th>Wall thickness</th>
<th>Reinforcing steel</th>
<th>100 psf surcharge</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Horizontal Size</td>
<td>Vertical Size</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Spacing (in.)</td>
<td>Spacing (in.)</td>
</tr>
<tr>
<td>6'</td>
<td>6&quot;</td>
<td>#3 7.3&quot;</td>
<td>#3 12.2&quot;</td>
</tr>
<tr>
<td>7'</td>
<td>&quot;</td>
<td>&quot; &quot;</td>
<td>&quot; 7.8&quot;</td>
</tr>
<tr>
<td>8'</td>
<td>&quot;</td>
<td>&quot; &quot;</td>
<td>&quot; 9.4&quot;</td>
</tr>
<tr>
<td>6'</td>
<td>7&quot;</td>
<td>#4 11.4&quot;</td>
<td>#3 10.5&quot;</td>
</tr>
<tr>
<td>7'</td>
<td>&quot;</td>
<td>&quot; &quot;</td>
<td>&quot; 9.6&quot;</td>
</tr>
<tr>
<td>8'</td>
<td>&quot;</td>
<td>&quot; &quot;</td>
<td>&quot; 11.6&quot;</td>
</tr>
<tr>
<td>6'</td>
<td>8&quot;</td>
<td>#4 10.0&quot;</td>
<td>#3 9.2&quot;</td>
</tr>
<tr>
<td>7'</td>
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<td>&quot; &quot;</td>
<td>&quot; 9.2&quot;</td>
</tr>
<tr>
<td>8'</td>
<td>&quot;</td>
<td>&quot; &quot;</td>
<td>&quot; 7.6&quot;</td>
</tr>
<tr>
<td>6'</td>
<td>9&quot;</td>
<td>#4 8.9&quot;</td>
<td>#3 8.2&quot;</td>
</tr>
<tr>
<td>7'</td>
<td>&quot;</td>
<td>&quot; &quot;</td>
<td>&quot; 8.2&quot;</td>
</tr>
<tr>
<td>8'</td>
<td>&quot;</td>
<td>&quot; &quot;</td>
<td>&quot; 8.2&quot;</td>
</tr>
</tbody>
</table>

Casting Surface

Cast panels as near their final position as practical. A concrete floor is usually most convenient. The casting surface must be smooth and uniform. Provide a separate slab or sand bed outside the building. If casting space is limited, stackcast the panels. Each stack contains similar panels—e.g., panels with fan openings are cast on other panels with fan openings or on solid panels.

A sand bed covered with plastic is not recommended, because it is difficult to completely smooth the sand surface.

Place a bondbreaker over the floor before setting panel forms. 4-mil polyethylene is excellent and gives a dense, glasslike surface to one side of the tilt-up wall. Before placing the film, sprinkle the floor surface with water. Use a stiff broom to smooth the film; the water helps hold it down.

Many commercial bond-breaking liquids are efficient and low cost, and serve as both bond breaker and curing membrane. They are easily brushed or sprayed on the floor slab. If a good cover or bondbreaker is not applied, the panels may stick to the casting floor.

Consider a dimpled exterior surface, which uses the irregularities of a rock bed covered with 4-mil polyethylene. A uniform bed of 1" to 2" rock yields small dimples; 3" to 4" rock yields attractive large dimples.

To form a casting bed, level and smooth the earth. Set 2x4 forms as for a sidewalk (forms flat for 2" rock, on edge for 3" - 4" rock), Fig 9. Place the rock and cover with plastic, Fig 9a for a continuously dimpled surface. For a smooth edging around the dimpled panel, use 1x6's as shown in Fig 9b. Attach the plastic to the 1x6s as shown.

Edge Forms

Cast tilt-up panels in strong accurately constructed forms. Panels must be of the required height and width. Cast the panels ¼" to ½" less wide than nominal size to allow for caulking the joints.

Joint sizes are critical in the application of sealants. For instance, avoid small butt joints (less than ¼") because they are hard to seal.

Also avoid joints greater than ¾" because they allow rodents to penetrate the joint and insulation.

Forms can be of metal, but edge forms are usually 2" lumber, Fig 10.

Bolt, nail, or weight down the forms to the casting surface to prevent movement. Check the forms for accurate dimensions.

Before placing the concrete and reinforcing steel, moisten wood forms so they do not absorb water from the fresh concrete and swell. Treat the forms with a bond breaker.

Leave the side form boards attached to braces and stiffener for reuse. The top form board can be attached to the panel as a plate. Square the forms and measure the diagonals. If the diagonals are equal, the panels have square corners.

Form window, door, and fan openings with pressure preservative-treated lumber. Bolts through the forms anchor them to the concrete so they are in place for securing windows, fans, or doors, Fig 11. Hold down forms for openings with weights.
Fig 6. Manure pit walls.

Fig 7. Panel to support girders under slats.

Fig 8. Panel with ledge for slats.
Lifting Inserts and Rigging Methods

Inserts permit attaching the lifting crane, partitions, braces, or other building parts. Lifting inserts positioned and attached to the upper form boards are shown in Fig 12.

Fig 12a shows a commercial insert. Attach lifting hardware, such as an angle iron, to the panel with the lifting insert bolt.

Fig 12b shows how to use standard bolts as lifting inserts. Attach the bolts to the reinforcing steel. When the panel is to be lifted, remove the nuts, and bolt a "T" iron to the top of the panel so that the top of the "T" is against the form board; lift the bottom web of the "T".

The lifting bolts can anchor the wall plate to the panels on top of the attached form boards.

For large panels, pick-up points are needed on the face of the panel. Interrupt the insulation around the pick-up points; provide at least a distance from the insert to the edge of the insulation equal to the thickness of one wythe. Fig 13.

Concrete accessories suppliers offer design information on size, type, and location of their lifting inserts for particular panels. The size and location of the lifting inserts depend on the weight, shape, and type of panel to be lifted, and on the strength of the concrete at the time of lifting. Follow a concrete accessories supplier's suggestions for the right combination of these variables.

Lift panels into position with a crane, A-frame, front-end loader, or truck-mounted lifting boom. Sample lifting insert locations and rigging are shown in Fig 14.

Panel weight divided by number of inserts must not exceed safe working load of the insert. The center line of the spreader bar and hook is over the center-of-gravity line of the panel.

Making the Panels

After the panel forms are positioned and squared and the bond breaker has been applied, place the first mat of reinforcing steel on chairs. The steel is a mat of rebars or wire mesh as specified. Extra reinforcing is needed around panel openings. If wire mesh is used, buy flat sheets rather than rolled mesh.

Place reinforcing in both wythes. To hold the two faces of the panel together and to transfer shear, place masonry joint reinforcement in the concrete, on the lower steel, and protruding up through the insulation. These ties also act as chairs for the second mat of rebars.

Next, place the first layer of concrete and screed it off to the desired thickness. The insulation, usually in 2' wide sheets, is then placed on the plastic concrete. After the top layer of concrete is placed, finish it to the desired texture.

Spray on curing membrane or spray-on bond breaker.

Securing Panels

One way to secure wall panels is shown in Fig 16. Leave the top form board or other similar board on
Fig 11. Forms for doors and windows.

the panel and bolted to it at the lifting inserts. Nail
and/or bolt on a wooden plate. This method is ade-
quate if the building is not subjected to large internal
pressures, such as in a grain storage structure.

Align the lower edge of the panels against the
dowels extending from the top of the footing, or in the
formed notch in the footing.

If the building length is no more than 4 times its
width and a rigid ceiling is installed, the panels can
be laterally supported by the roof. Where roofs are not
able to take lateral loads, use diagonal braces from
the trusses to bolts or inserts in the wall panels.
Where possible, bolt wall panels to concrete partitions
for lateral support.

The larger panels that extend from footing to
plate are supported by the floor. Cast steel inserts in-
to these larger panels so they can be welded together
for more strength. Fig 12.

Fasten corners by welding short angles to steel
plates anchored in the corner panels, or cast threaded
inserts at the corners so the angles can be bolted in
place. Fig 12.

Close the joint first by inserting a strip of insula-
tion cut to fit between the panels to reduce caulking
and to provide a better joint. Recess the insulation
about \( \frac{1}{2} \) in. Or, \( \frac{3}{8} \) to \( \frac{1}{2} \) rigid foam insulation can be
 glued to the edge of an erected panel before the next
panel is set. Also inset the insulation \( \frac{1}{2} \) in. Then close
the joint with caulk, Fig 12. Caulking materials such
as polysulfides, polyurethanes, and silicones are more
desirable than common oil-base caulking.
Fig 14. Sample lifting insert locations and rigging.

Fig 15. Wall panel alignment.

Fig 16. Welded corner.

Fig 17. Caulked joint.
APPENDIX A

<table>
<thead>
<tr>
<th>Thickness</th>
<th>Sect. mod.</th>
<th>Load</th>
<th>Thickness</th>
<th>Sect. mod.</th>
<th>Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>in.</td>
<td>in.</td>
<td>pounds</td>
<td>in.</td>
<td>in.</td>
<td>pounds</td>
</tr>
<tr>
<td>A</td>
<td>1-1/4&quot;</td>
<td>2-1/2&quot;</td>
<td>29</td>
<td>1/2&quot;</td>
<td>2-1/2&quot;</td>
</tr>
<tr>
<td></td>
<td>35</td>
<td>35</td>
<td>39</td>
<td>1/2</td>
<td>35</td>
</tr>
<tr>
<td>B</td>
<td>2-1/2&quot;</td>
<td>2-1/2&quot;</td>
<td>40</td>
<td>1/2</td>
<td>2-1/2&quot;</td>
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</tr>
<tr>
<td>C</td>
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Solid concrete panels

<table>
<thead>
<tr>
<th># Bar</th>
<th>Bar both ways</th>
<th>spacing, in.</th>
<th>@ ( f = 246 ) psi</th>
<th>@ ( f = 301 ) psi</th>
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<tr>
<td>H</td>
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<td>24&quot;</td>
<td>12</td>
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<tr>
<td>J</td>
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<td>24&quot;</td>
<td>12</td>
<td>9</td>
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<td>5-1/4&quot;</td>
<td>24&quot;</td>
<td>12</td>
<td>9</td>
</tr>
<tr>
<td>M</td>
<td>6-1/4&quot;</td>
<td>24&quot;</td>
<td>12</td>
<td>9</td>
</tr>
</tbody>
</table>

Loads

The greatest load expected on most tilt-up building walls is the panel weight during lifting. Two load cases are shown: Dead weight of the walls, which is adequate for most cases; dead weight + 50% which is adequate for many panels with windows and which provides for some rough handling.

Tied with masonry or rebar may be used on the panels if \( H/t = 25 \). If the load does not exceed 1000 lb, it is applied to the middle 1/3 of the panel thickness, \( H/t = 30 \).

Panel Width

Solid panels may be up to 16" wide. Sandwich may be up to 12" wide.

Special features for sandwich panels

The two concrete faces (wythes) are connected with reinforcing 24" oc and oriented vertically. Do not expose more than 10' of height to the outdoors, because of stresses induced by differential temperature expansion. The tops and bottoms must be solid; vertical edges need to be solid.

 spacings of @ \( f = 246 \) psi | Equivalents welded wire fabric |
| 24" | 6x6-W2.9xW2.9 | 20 | 6x6-W4xW4 | 16 | 4x4-W2.9xW2.9 |
| 12 | 4x4-W2.9xW2.9 |

Stresses

Tensile stresses during lifting are carried by the concrete (panels will crack before steel is significantly loaded). Strength at time of lifting is critical:

\[
\sigma = \begin{cases} \frac{500 \times (t_1 - t_2)^2}{12} \text{in}^4, & \text{for panels} \\ \frac{500 \times (t_1 - t_2)^2}{12} \text{in}^4, & \text{for sandwich panels} \end{cases}
\]

Panel strength

\[
\begin{aligned}
\sigma &= \frac{500 \times (t_1 - t_2)^2}{12} \text{in}^4 \\
S &= 2x1/12 \text{in}^2 \\
W_t &= (t_1 + t_2)bxh/144, \text{psf} \\
M &= f_t \times 5, \text{max, in-lb} \\
\end{aligned}
\]

Design limits are expressed as maximum panel height.

Top edge lift (\( M = W^2/8 \))

\[
H = \frac{(8xW/\sigma)^{1/2}}{C}
\]

Face lift (\( M = W^2/18 \))

\[
H = \frac{(18xW/\sigma)^{1/2}}{C}
\]