



WIRE REINFORCEMENT INSTITUTE®

TECH FACTS Excellence Set in Concrete®

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Welded Wire Reinforced Tilt-up Panels

The popularity of site cast precast wall panels better known as tilt-up panels, like that of almost all other forms of precast concrete, has increased greatly in recent years. They are not only durable and economical but offer almost endless possibilities for interesting and attractive appearances. These can be obtained by using various combinations of exposed aggregate, concrete produced from different cements or with admixed colors, surface treatment, patterned forms, raised or depressed moldings, and they may be insulated—referred to as sandwich panels. Panels may be used structurally as well as architecturally in load-bearing and non-load-bearing (or curtain) walls, both exterior (where they are exposed to wind pressure) and interior (static and suction pressure). They may also have to be designed to resist earthquake and other natural forces.

The panels may be pierced by window, door, utility, or ornamental openings, or they may have solid surfaces. They are generally very wide although they may be relatively narrow members which serve as mullions or form ribs in decorative arrangements. The cross-section is usually solid, although it may be cored to reduce weight or formed in sandwich fashion around insulation.

Tilt-up wall panels are distinguished from other forms of precast units since they are cast at the job site rather than cast at a precast concrete manufacturing plant. The basic procedure involves casting the members on a horizontal surface, usually a floor slab, and lifting them into a vertical position to form the building wall.

While once considered a rather new construction system and generally thought of only in connection with one-story buildings, it is actually several decades old and has been used in many multi-story structures. The name tilt-up is derived from methods employed in earlier examples. The panels were cast on finished floor slabs with their lower ends lying along the edge of the building. They were then lifted by the upper end and revolved about the lower end into a vertical plane; they were thus tilted up directly into final position. However, as panel sizes were increased it became desirable to do the lifting at points other than the upper portion. Today, most tilt-up panels are cast face down (exterior side down). The panel inserts are designed by insert

manufacturers and are cast in the face up (interior side). Braces are attached after curing and the panel is rotated into position. Tilt-up construction has come a long way technologically from where it began many years ago. It can be used for anything from a one-story building up to a four or five story building. There are certain advantages that make the tilt-up procedure economical in a variety of circumstances.



Flat and curved tilt-up wall panels make up the facade of this Ohio project

One of these may be the very absence of the large plant; it is frequently claimed that the lack of a sizeable investment in fixed facilities is one of the things that make tilt-up work feasible. Shipping costs are almost always lower, as it is cheaper to move raw materials rather than finished products. The panels require less handling and there is less danger of damage. Ordinarily tilt-up panels are cast as required and therefore no storage problems arise. The expense of bottom forms is eliminated since the wall units are cast on a floor slab. It may be necessary to require more careful finishing of slabs than normal to achieve desired wall finishes.

Perhaps the most important feature is reduction or elimination of size restrictions. Since most plant-cast members must be moved by truck, their width is generally limited to about 8'0", although sometimes wider shipments can be arranged. Maximum weights and lengths are also regulated by law, and extremely long and heavy pieces, unless prestressed, may require elaborate and expensive precautions to avoid breakage in transit. Permissible size and weight may also be governed by handling equipment in the plant or at the site.

However, for the panel cast at the site these are minor problems. Width and length can be of any convenient dimension up to the maximum weight that can be raised with lifting equipment. Greater thicknesses and weights may be required and this, too, is of less concern with site casting.

Flat wall panels, cast on the floor slab, had been tilted into position before work began on the curved panels.



While some tilt-up panels have been prestressed, by far the greater portion of them have been of mild reinforced design. The reinforcement will perform several important functions:

1. To prevent damage due to lifting and handling stresses.
2. To increase the resistance of the surface to cracking because of shrinkage and temperature changes.
3. To assist in carrying the vertical loads as bearing walls.
4. To resist wind, earthquake, and other lateral forces. Welded wire reinforcement (WWR), with high strength wires accurately spaced, is well suited for all of these uses.

The action of precast panels is similar to that of other reinforced concrete members, and their design is very much like that of cast-in-place walls. Three kinds of forces must be considered; horizontal or wind and seismic forces, the weight of the member, and the forces received from the roof load in a load bearing situation. Stresses induced when lifting the panel are resisted by the panel inserts, usually no additional reinforcement is necessary for those stresses.

A complete discussion of the design of tilt-up panels is beyond the scope of this brochure. High strength welded wire reinforcement with yield strength, f_y up to 80,000 psi is a viable and cost-effective reinforcement material. Spacings of 3" to 16" can be provided with wire sizes up to D20 ($1\frac{1}{2}$ " diameter). More readily available WWR can be specified when spacings are 4" or 6" and wire sizes are less than D12 ($\frac{3}{8}$ "). It is recommended to refer to ACI 551R on Tilt-Up Concrete Structures for a more complete review of methods and procedures. It may be of interest to use the following checklist (Ref. ACI 551R) when preparing design documents.

Checklist when preparing architectural/engineering project drawings:

Elevations – Exterior architectural elevations showing panel dimensions, jointing, openings, areas of special

treatment such as facing aggregates, reveals, form liners, and scuffers.

Details – Architectural details showing bevels, miters, chamfers, tapered recesses, door and window conditions, roofing, and flashing connections.

Panel elevation – Panel elevations drawn from the viewpoint of the fabricator (will panel be cast face up or face down) showing typical reinforcement and special reinforcement at major and minor openings. Recommended scale $\frac{1}{8}$ in. = 1 ft. and with each panel uniquely numbered.

Key plan – Key plan to indicate location of panels and panel designation.

Structural details – Structural details showing typical thickness (is facing aggregate and grout or architectural relief included in the structural thickness) and special thicknesses and widths of pilasters.

Reinforcement – Reinforcement details showing typical placement and clear cover requirements, pilaster reinforcement and tie configurations and welded wire reinforcement or rebar dowels for slab connection.

Connection details – Connection details showing anchor devices, embedded structural steel, base grouting, and connecting materials.

Miscellaneous details – Other items include necessity for mechanical and electrical coordination of openings, sleeves, conduits, and junction boxes.

Specifications – Specifications should include the specified compressive strength of concrete at 28 days, design yield strength of reinforcement, minimum strength, and density of concrete at time of lift, and allowable lift stresses. Requirements, if considered necessary, of a sample panel to include finishes, miters, corners, and other details.

Shop drawings – The contractor should be required to submit shop drawings which depict each panel.

An engineering feature to consider is the usual practice of making some allowance for impact. This can be reduced by careful handling, preventing bond by using a bond breaker or breaking by horizontal movement.

A more significant consideration is tensile stress on the outer face of the concrete. As in any reinforced concrete member, cracks develop when the applied forces increase to a point where the ultimate tensile strength of the concrete is exceeded. Additional load increase may widen the cracks. This effect must not be allowed

to cause permanent damage to the member. It is extremely difficult to compute with any certainty the width of cracks that will form or to know what size can be tolerated. Any restriction in this respect must usually be based on judgement and experience; however, the short time during which maximum stresses will occur indicates that there is less likelihood of trouble due to crack damage. Because the bending moment drop off as the panel is tilted, stresses will decrease and cracks will close. Note: reinforced concrete is elastic over a considerable range. For wall reinforcement welded wire reinforcement provides a superior type of reinforcement; it is not only effective in carrying tensile stresses but it will also minimize shrinkage cracks and control crack widths.

An additional provision found in most building codes is one governing the minimum amount of steel required in walls. The American Concrete Institute's "Building Code Requirements for Reinforced Concrete" (ACI 318) requires in Sections 14.3 and 21.5.2 that:

"Minimum ratio of vertical reinforcement area to gross concrete area shall be no less than 0.0012 for welded wire reinforcement (plain or deformed). Minimum ratio of horizontal reinforcement area to gross concrete area shall be 0.0020 for welded wire fabric (plain or deformed). For seismic, the minimum ratios (p_v) for shear walls is 0.0025 for both longitudinal and transverse reinforcement."

The larger figure for horizontal steel is justified because the length of a wall between points of support or control joints is generally more than its height and there is a greater possibility of cracking in that direction because of shrinkage and temperature change.

Table 1 gives minimum vertical and horizontal steel areas required by the ACI Building Code for walls from 4" to 8" in thickness, using welded wire reinforcement.

After a design analysis has been made, it is necessary to select sheets of welded wire reinforcement to furnish the required steel areas. There are several conditions that may occur. If a uniform distribution of forces has been assumed a style of reinforcement with constant size and spacing of wires will be suitable. If the maximum computed steel area is less than the minimum required by code, the latter would be employed.

Sheet size is another matter that must be given attention. Although widths up to 13'0" can be manufactured, they usually cannot be transported without special permits. For truck shipments, 8'6" is the limit. As far as length is concerned, sheets up to 30' or 40' can be obtained.

In splicing WWR, a splice of $1.51d$ (or min. of 2") measured on the wires parallel to the splice is sufficient, when:

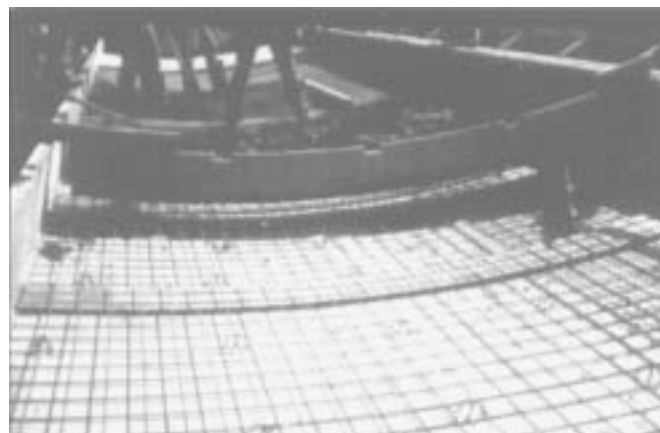
$$\frac{A_s \text{ provided}}{A_s \text{ required}} \geq 2 \text{ (Section 12.19.2)}$$

TABLE 1
Minimum Areas of WWR Reinforcement in Accordance with the ACI Building Code

Wall Thickness (in.)	Steel Area (sq. in. per ft.)	
	Vertical A_{sv}	Horizontal A_{sh}
4	.058	.096
4 1/2	.065	.108
5	.072	.120
5 1/2	.079	.132
6	.086	.144
6 1/2	.094	.156
7	.101	.168
7 1/2	.108	.180
8	.115	.192

The ACI Building Code specifies one wire space plus 2" (two-wire splice) when the calculated stress exceeds one-half of the yield strength. In tilt-up panels, laps are generally vertical; that is the horizontal wires are spliced. When the panel width is small, or if there are several pick-up points across the panel, stresses in the transverse wires frequently will not be large and the 2" minimum splice discussed above is adequate. However, if very high stresses exist, then the two-wire overlap would be required.

For panels too wide for a single piece of welded wire reinforcement, the total width of WWR required is obtained by subtracting edge clearances from the panel dimension and adding the required splice, then dividing by 8' or 8'6" (max. shipping width allowed without permit), and the remaining width of sheets may be cut in the field from standard widths or made to order. Sheet length is simply the panel length less end clearances. It may be necessary to add or subtract to get a length which is an even multiple of the transverse-wire spacing.



With the welded wire reinforcement on chairs, the 3 inch exterior facing concrete was cast and struck off with a special template.

DESIGN DATA

- t = 9.25 IN
- f'c = 3.00 KSI
- fy = 60.00 KSI
- WT = 0.145 K/FT³
- Pdl = 0.18 KLF
- PII = 0.24 KLF
- e = 9.125 IN
- p = 0.0025
- d = 8.25 IN
- L = 40.00 FT

PROPERTIES

- Pwall = 2.24 K/FT
- Ec = 3155.92 KSI
- n = 9.19
- fr = 273.86 PSI
- Ig = 791.45 IN⁴
- Sg = 171.13 IN³
- Mcr = 46.86 IN-K

CALCULATION I CRACKED

- Pu = 2.84 KLF
- Ase = 0.32 IN²/FT
- a = 0.64 IN
- c = 0.75 IN
- Icr = 169.63 IN⁴ PER FEET

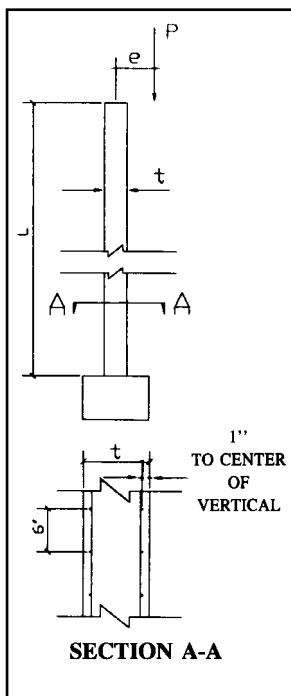
ALLOWABLE LOAD FOR DEFLECTION PER UBC 1991 EDITION (INCL. '92, '93 SUPPLEMENTS) IN PSF

- Mn = 154.60 IN-K/FT
- delta crack = 0.45 IN
- delta n = 6.93 IN
- delta service = 3.20 IN
- Ms = 92.58 IN-K
- Ws = 38.57 PLF
- ALLOW.
- LATERAL LOAD = 33.53 PSF

CHECK WALL STRENGTH FOR P-DELTA

- Wu = 46.94 PLF
- Mu = 124.94 IN-K
- PHI Mn = 139.14 IN-K

Use 9-1/4" x 40'-0"
 W// 6x6-W13.9 x W5.6
 60 KSI EACH FACE OR
 W/ 6x6-W11.1 x W4.5
 75 KSI EACH FACE



Consulting engineers should be contacted for specific tilt-up project designs. Most can provide manual analyses on a given wall project. Many can provide computer analyses similar to the one included in this Tech Fact report.

For guidance on panel inserts along with tilt-up panel safety contact the Tilt-Up Concrete Association, P.O. Box 204, Mt. Vernon, IA 52314 and the American Concrete Institute, 38800 Country Club Drive, Farmington Hills, MI 48331, (ask for Committee Report, ACI 551).

Example of the computer developed analysis was provided by Baumann Engineering, 567 San Nicholas Dr., Newport Beach, CA 92660.

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What an Engineer Says About WWR . . .

. . . in my opinion there is no better way to reinforce tilt-up walls than High Strength Welded Wire Reinforcement each face. Also, I feel that the step-through patterns and economy edge laps further increase the competitive advantage of High Strength Welded Wire Reinforcement.

Because of its inherent 2-way spanning capabilities, we see a superior performance during lifting as another distinct advantage.

Recently, more low-rise office buildings are designed with up to 5-story high concrete tilt-up walls at the exterior. The 2way action of the High Strength Welded Wire Reinforcement around the window openings is very valuable in carrying both gravity and wind forces . . .

—Hanns U. Baumann, S.E.
 Baumann Engineering



Large panel lift about to begin.