

# The WWR Option for Tilt-Up Panels

The tilt-up technique combines the advantages of a precast wall with the benefits of site casting, where size and thickness concerns become less of an issue

---

BY JEFF GRIFFIN

In recent years, tilt-up construction has grown rapidly (as much as 111% in the past 5 years) in response to increasing demands for durable and economical structures. As the industry grows, design professionals and contractors must investigate areas of innovation to continue the level of speed, versatility, and quality owners have come to expect from tilt-up construction. One such innovation is the use of welded-wire reinforcement (WWR) in tilt-up panels.

Although an accepted technique in many conventionally cast concrete structures, WWR in tilt-up panels is still relatively new. At the root of this technique is the use of welded-wire fabric (WWF)—a term which is now being phased out in favor of an industry-wide WWR specification. Many of the benefits of WWR (varying bar spaces, deformed bars, and the like) have been unexplored by those in the tilt-up industry.

In order for engineers and contractors to ascertain the value of an alternative reinforcing method for tilt-up panel construction, it is important that they recognize the different options available for incorporating WWR in tilt-up panels

and the advantages and disadvantages of WWR itself. A review of some of the design considerations involved in using WWR bar mats to reinforce tilt-up panels is an integral part of this assessment. The information provided in the following sections is based upon the experience of LJB Inc. (Dayton, Ohio) and CON/STEEL. CON/STEEL's 30-year history of design-build experience includes over 700 projects totaling more than 50 million ft<sup>2</sup> (5 million m<sup>2</sup>).

## WWR bar mat options

WWR bar mats, as shown in Fig. 1, offer engineers and contractors several opportunities for economical designs and efficient tilt-up panel construction. How the WWR technology will be implemented on a particular project should be evaluated on a case-by-case basis. Two approaches exist for the broad design of bar mats: base mats and specialty mats.

The base mat approach utilizes the WWR bar mat to satisfy the code-prescribed minimum reinforcing steel requirements, whether they be for

temperature and shrinkage, shearwall criteria, or otherwise. The most rudimentary form of a base mat is WWF, in which 4- or 6-in. (100 or 150 mm) bar spacing is common. Sheets of WWF are placed in the tilt-up panel and trimmed to accommodate its length, width, and any openings. An alternative is to design a mat specifically for the particular panel application, taking into account any openings and the overall panel dimensions. With both methods, the panel is augmented with loose, mild reinforcing steel bars (for example, ASTM A615, Grade 60) to satisfy the strength and/or deflection criteria. Figure 2 illustrates a tilt-up panel with a dock door designed by the base mat approach. Each panel leg has six No. 6 bars in each of two layers with three No. 4 bars above the opening for header reinforcement. The base mat consists of D20 bars at 8 in. (200 mm) on center vertically, and D20 bars at 16 in. (400 mm) on center horizontally. In this case, the base mat satisfied the design requirements for an adjacent solid panel, thus the close spacing of the vertical bars.

The second approach, the specialty mat, attempts to address all of the reinforcing steel requirements—code minimums, strength design, and deflection considerations—in a single bar mat. The mat is specifically detailed to match the overall panel dimensions and



Fig. 1: Welded-wire reinforcement (WWR) bar mats (Photo courtesy of CON/STEEL Tilt-Up Systems, Dayton, Ohio)



Fig. 2: Tilt-up panel with WWR augmented by conventional loose bars (Photo courtesy of CON/STEEL Tilt-Up Systems, Dayton, Ohio)

openings without the need for additional loose reinforcing steel bars or extensive field cutting. The solid (no openings) panel depicted in Fig. 3 is reinforced with a single WWR bar mat. The mat consists of D19 bars at 6 in. (150 mm) on center vertically, and D20 bars at 18 in. (450 mm) on center horizontally. Chord bars are incorporated into the mat, and it is detailed symmetrically from top to bottom so that it can be used in both the left and right sides of the panel. For tilt-up panels with openings, a series of specially designed bar mats can be used. Three mats could have been employed to reinforce the panel in Fig. 2, each with their own bar size and spacing: one for the field above the opening, one for the four layers of steel in the panel legs, and one for the field below the opening. Even header reinforcement can be incorporated into the appropriate bar mat.

Regardless of the design approach adopted, lap splicing of the WWR bar mats will be an issue. Three alternatives for lap splicing are available, and are illustrated in Fig. 4. The easiest, from a labor standpoint, is to detail the bar mats with long horizontal tails (Fig. 4(a)). Once these mats are positioned, vertical bars are tied to the overlapping horizontal bars of the adjacent mats, as depicted in Fig. 5. The second option (Fig. 4(b)) is to include the intersecting vertical bar(s) during fabrication and finger the horizontal tails underneath the adjacent bar mat (a procedure used in the panel of Fig. 3). Obviously, this requires more time and care in placement, but it eliminates the need for additional reinforcing operations once the bar mats are positioned. Both of these alternatives keep the same level for the horizontal reinforcing bar. If this is not a consideration for the designer, a third option is available where the adjacent mat is flipped over and simply lapped with the one already in position (Fig. 4(c)), eliminating some of the excess material required by the previous two procedures. This splice is not advisable if additional layers of vertical steel bars will be stacked on the mat, since the horizontal bars are on two different levels.

## Advantages and disadvantages

As with any procedure, there are inherent advantages and disadvantages to the use of WWR. The following sections identify examples an engineer or contractor may encounter when utilizing WWR mats in tilt-up panels. It is important to note that careful planning can maximize the benefit of the “advantages” offered or overcome the shortfalls outlined as “disadvantages.” Careful planning includes close communication with the bar mat supplier, whose assistance and collaboration can be invaluable in making the decision to use WWR bar mats an economical choice.

### Advantages

**Potential for quality control:** WWR bar mats are manufactured in a plant-controlled environment. As such, engineers and contractors can anticipate consistent and uniform spacing of the bars. With the addition of a

shop drawing-review stage, a system of checks and balances can be implemented whereby the correct number of bars are placed in the panel. In the field, prefabricated mats, by their nature, also offer some assurance that the bars do not bunch together or “float” within the plane of reinforcing. The contractor still faces the same challenges in maintaining quality control in placing the mats at the proper depth within the panel, but this is true for conventional loose-bar reinforcing methods as well.

**Maintaining “step-through” meshes:** Recent advances in manufacturing technology make larger mesh sizes possible, often at variable spacing. Larger deformed bars at a wider spacing can take the place of the 4- or 6-in. (100 or 150 mm) meshes common to WWR mats manufactured with light gage bars. The “step-through” meshes offer workers the ability to step between adjacent bars onto the casting slab.

**Labor reduction:** During the fabrication of WWR mats, the intersection of every horizontal and vertical bar is welded in the shop. This reduces the number of bars needing to be tied in the field. In fact, for panels where WWR is fully implemented, tying bars may be completely eliminated depending on the splice detail. The reinforcing can be placed in as little time as it takes to position the WWR mats. A secondary benefit is the diminishing or elimination of a number of the strenuous tasks demanded of the contractor’s employees by a conventional loose-bar reinforcing operation. Although hard to quantify, overall worker health and productivity can be improved when workers do not have to perform such tasks as bending over to hold bars not chaired in place or tying reinforcing bar intersections.

**Expedited panel construction:** Tilt-up panels can be reinforced in less time because of the labor reduction afforded by WWR bar mats. Preassembling the reinforcing decreases the amount of layout and coordination required. Because the construction time of the tilt-up panels is shortened, other items in the schedule benefit. Panels may be erected sooner, clearing the floor slab for other trades or permitting the erection of the perimeter steel to proceed earlier. However, the contractor must be aware of this advantage and anticipate the estimated time savings. Some of the impact of expedited panel construction can be lost if subsequent construction items are not available or future tasks do not conform to the shortened schedule.

**Higher-grade steel bars:** When higher-grade steel bars are used in fabricating WWR mats, there may be a reduction in the steel tonnage required to reinforce the tilt-up panels. Less weight can translate into other savings, such as reduced freight costs and fewer pieces to handle. Fewer bars in the matrix also make the placement of lift inserts and embedded items easier. Such advantages have some limitations, though, as discussed below.

### Disadvantages

**Higher material cost:** In general, higher-grade steel bars are more expensive than typical Grade 60 mild

reinforcement. As the cost of shop assembly is added on, WWR bar mats appear to be less economical from a first-cost standpoint. It is only when some of the advantages listed above are fully realized that the use of bar mats can become competitive. Project size and a great deal of repetition in the tilt-up panels can work to disguise the relatively high material costs of bar mats, as productivity



Fig. 3: Tilt-up panel reinforced with only WWR mats (Photo courtesy of CON/STEEL Tilt-Up Systems, Dayton, Ohio)

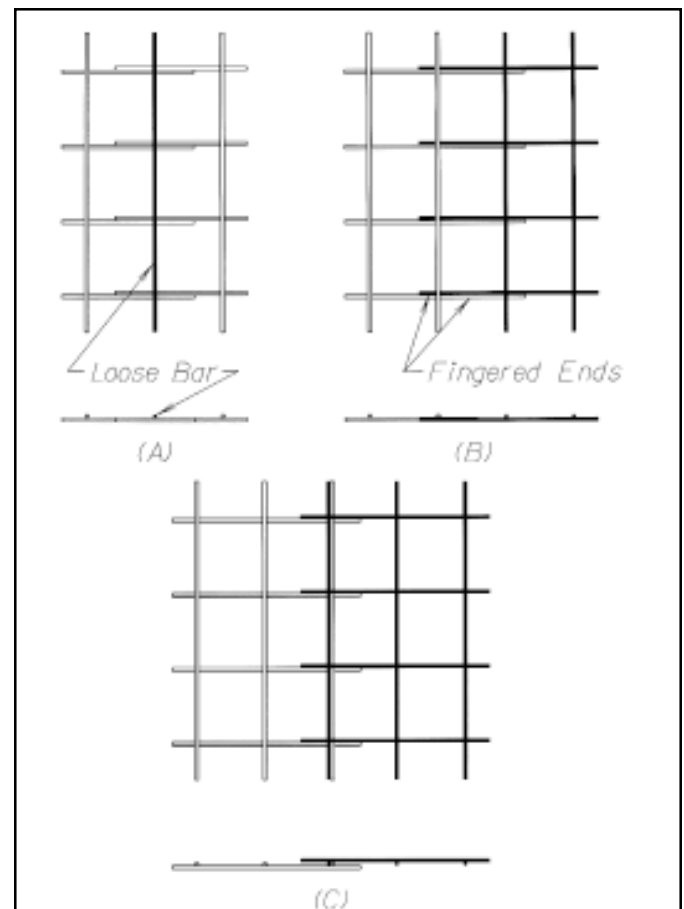


Fig. 4: WWR bar-mat splice options: (a) Loose vertical tie bar; (b) fingered horizontal tails; and (c) mat flipped over

becomes more of a governing factor. However, some contractors might argue that the other benefits afforded by the procedure makes any project a candidate for utilizing bar mats. This is especially true for those engineers or contractors using a base-mat approach where the main reinforcing is provided by loose bars.

**Weight of bar mats:** As tilt-up panels increase in size and bar mats grow in response, the weight of an individual mat becomes an important issue. It is common for large bar mats to require a piece of mechanical equipment for handling and placement in the tilt-up panel. This equipment may come at a premium, since it may be an additional item required for the project or an existing one that is pulled from a different task. If mats are placed in the tilt-up panel by hand, more workers may be required than would normally be scheduled in a conventional loose-bar reinforcing operation. This can either affect the scheduling of other tasks or increase the labor costs associated with panel construction.

**Higher-grade steel bars:** Although offering some benefits, the use of higher-grade bars does have limitations and can be a disadvantage to tilt-up panel design. With fewer reinforcing bars comes a potential for more cracking in the tilt-up panel, possibly beyond the level permitted by lifting analyses or governing codes. Employment of higher-grade steel bars can be affected by the availability from a particular manufacturer. For instance, if scheduling and manufacturing restraints require the use of a larger bar based on availability, the weight of the reinforcing steel within the tilt-up panels will increase.

**Limitations of manufacturing:** Even with the most current, advanced machines, there are limitations on the bar size and spacing that can be manufactured. As larger, mild reinforcing steel bars at fractional spacing are transformed into mats with smaller bars spaced at even 2-in. (50 mm) increments, excess reinforcing steel weight may be introduced and mesh spacing made tighter. Tall panels can also pose a problem if they exceed the length capabilities of some machines, thereby introducing vertical lap splices. As these examples demonstrate, the different manufacturing limitations make uniformity in



Fig. 5: Horizontal lap splice of WWR mats with loose vertical tie bar (Photo courtesy of CON/STEEL Tilt-Up Systems, Dayton, Ohio)

WWR bar-mat specification difficult. Engineers are then presented with a larger set of design considerations, and manufacturers must invest more time in interpreting the reinforcing steel requirements to meet their specific fabrication capabilities.

**Longer lead times:** Since the WWR bar mats involve a detailed manufacturing process, they take longer to fabricate than conventional loose reinforcing bars cut to length. Using bar mats in tilt-up panel construction can be more expensive if the schedule is delayed because the bar mats have not yet arrived. The longer lead times required when ordering bar mats also magnify the effect of errors, omissions, or damage to mats that must be replaced.

**Fewer suppliers:** Manufacturing WWR bar mats is not supported by every reinforcing bar supplier. Thus, the engineer or contractor evaluating the use of bar mats is limited to a smaller selection pool. Having fewer suppliers can also trigger a geographical impact on cost, since projects may incur a significant freight expense because of their distance for the source of supply. Loose reinforcing bars are much easier to obtain, even at short notice, due to the greater density of suppliers throughout any region.

**Additional site staging and storage requirements:** Particularly on projects with a significant number of WWR bar mats, site staging is critical. The bar mats must be sorted and stacked for easy installation. Their sheer size, though, often makes this task cumbersome. The mats can also require valuable storage space essential to other trades or tilt-up panel layout.

## Design considerations

Steel reinforcing bars serve several critical roles in the structural adequacy of a tilt-up panel, both during construction and after. Among these are assuring:

- Reduction of the cracking experienced in the concrete while panels are being lifted;
- Mitigation of the effects of temperature and shrinkage cracking throughout the life of the panel;
- Provision of load-carrying capacity for eccentrically applied axial loads in bearing-wall situations; and
- Resistance to the lateral pressures placed on a tilt-up panel by wind, seismic, soil, or hydrostatic loads.

With such importance placed on the reinforcing steel bars, it is essential that engineers, contractors, and suppliers understand the design aspects associated with converting conventional loose reinforcing bars to WWR bar mats.

As with all reinforced concrete members, the distance from the extreme compression fiber to the centroid of the tensile steel—referred to as the  $d$  distance—is a critical element in determining the ultimate strength capacity of a tilt-up panel. If larger, loose reinforcing bars are to be replaced with the smaller bars of a WWR mat in the field, a straight one-to-one substitution for steel area cannot be made. Some correction needs to be made to assure that the same moment capacity will result, whether by revising the bar chair height to provide the same  $d$  distance or

changing the amount of reinforcing to account for the smaller  $d$  distance. If the decision to use bar mats is made at an early stage, the engineer responsible for the tilt-up panel design can easily incorporate these considerations into the analysis. If the contractor elects to use bar mats at a later stage, he or she must be aware of the impact on the capacity of the panel and coordinate an acceptable solution between the engineer and supplier.

With the reduction in reinforcing steel through the use of high-strength steel deformed bars in the WWR mats, deflection issues can become more of a concern. The reader is cautioned to carefully review all governing codes for the minimum prescribed reinforcement independent of the steel yield strength. With potentially fewer bars in the tilt-up panel, the out-of-plane deflection at service and/or ultimate loading can increase beyond acceptable limits. An engineer must be aware of this consequence and correct the tilt-up panel design accordingly. Similarly, adequate reinforcing steel should be incorporated into the WWR bar mat to minimize the crack width in panels lifted as a cracked section. Both considerations may lead to reinforcing steel areas greater than required from the ultimate strength analysis. Alternatively, a double-layer system in thicker panels may be implemented with two separate chair heights, resulting in better strength, reduced out-of-plane deflection, and improved crack control when the bar mats are closer to the face.

### Summary

Finally, the WWR bar mat should be carefully designed to meet the contractor's needs for ease of placement and the supplier's requirements for ease of manufacturing. One example of this would be designing the bar mat to be symmetrical from top to bottom where it is critical to keep the horizontal bars in the same layer of reinforcing. One mat could then be used for both the left and right halves of a tilt-up panel simply by rotating the adjacent sheet 180 degrees. This cuts down on the setup and manufacturing costs for the supplier and reduces the site storage and coordination required by the contractor for a "left" and "right" mat. Taking advantage of shop drawings generated by the supplier can assist in the process. Even though the shop drawing-review phase will add a couple of days to the schedule, it will ensure that each project participant has an understanding of how the tilt-up panel must be constructed. It can also identify areas where more economy can be achieved by consolidating the number of bar mats

required for a project, or substituting available bar stock for the specified deformed bar.

WWR bar mats offer engineers and contractors a method of reinforcing tilt-up panels that is efficient and cost-effective. These benefits can only be achieved, though, by reviewing in advance the advantages and disadvantages of using WWR for a particular project, along with careful planning before construction begins. Design professionals, contractors, and suppliers should collaborate to ensure the best quality results from a tilt-up project that meets the design and performance requirements owners have come to expect.

Selected for reader interest by the editors.



ACI member Jeff Griffin, PE, PhD, is a structural engineer and client advocate with LJB Inc. of Dayton, Ohio. His primary responsibilities include the structural design of warehouse, industrial, and office facilities. He serves on ACI Committee 551, Tilt-Up Concrete Construction.

CIRCLE READER CARD # 12