Tilt-Up Engineering A-Z

By Laurence Smith, P.E.

Site cast Tilt-Up – a construction method in which concrete wall panels are cast on-site and tilted into place – has gained rapid acceptance in recent years due to its speed of construction, cost-efficiency and advanced architectural treatments. However, like all other aspects of the concrete industry, it is important for engineers to understand all aspects of the planning process in order to fully capitalize on the efficiencies of the Tilt-Up method. From beginning to end – or from A to Z – careful consideration of numerous details, figures, measurements and more will enable you to maximize the potential afforded with Tilt-Up.

Before beginning the design of any project, engineers should perform a careful evaluation of the project. Consider the usage of the building. Will it be for commercial, industrial or other use? How many stories will the building be? Know the square footages of the slab and walls. Does the floor-to-wall ratio exceed 80 percent? Bear in mind if weather will be a controlling factor and if the project location will have an impact on the ability to easily get workers or materials. Attending to these details helps ensure a solid foundation for project success.

Once the members of the design team evaluate project details, they can determine if the project is a good candidate for Tilt-Up. In fact, another product may provide a better option for the project. If Tilt-Up is the best candidate, the project must meet certain requirements. First, the site must have enough space for casting the panels and for a crane to work. If the wall area exceeds 80 percent of the available floor space, stacking or casting beds likely will be required. Further, sloped floors require alternate surfaces, while basements and pools bring their own challenges such as unique bracing plans. Carefully evaluate the cost associated with using the Tilt-Up method in order to determine if it is the most economical construction method available, but also be sure to consider other non-cost related factors such as speed of construction, energy-efficiency, durability and more.

200-ton truck mounted hydraulic boom crane lifting 43,000-pound panel.

Planning for Success

Success on the site begins with the designer and estimator. Many projects, especially smaller ones, require the designer and contractor to be ultra-efficient in order to provide value to the client. As a result, proper planning is essential. The planning process involves numerous steps, from choosing the wall assembly for the job to layout and erection sequencing.

Wall Assembly

Choosing the correct wall assembly involves considering three options: plain concrete panels, post-insulated panels or sandwich panels. Plain concrete panels are the least expensive, yet they offer the least energy efficiency. Post-insulated panels are mid-price options offering mid-range energy efficiency. Sandwich panels are the most expensive and highest in energy efficiency, as they provide the best use of thermal mass.

Panel Considerations

Next, panel height is determined. Factors to consider when planning panel height include the clear height to the structure's underside, the joist depth, the amount of roof slope and the roof parapet. The roof parapet may be of the plain-panel or sandwich-panel variety. While sandwich panels offer the ability to provide a complete thermal envelope, they may not be necessary, depending on the climate and building usage. Also, as the panel height is established, the depth of the panel below the finish floor needs to be considered. To determine the panel height, add measurements for the clear height, joist depth, amount of roof slope, roof parapet and depth of panel below finish floor.

In certain situations, a foundation wall is beneficial. A foundation wall eliminates a closure strip in the floor and a cold joint in the slab. With a foundation wall, more floor space is available as a casting surface, and less panel area is needed as a casting surface. In addition, panels weigh less and can therefore be wider, and lower lifting stresses are incurred. With a foundation wall, the floor offers easier erection for the crew and increases safety on erection day.

As panel height is determined, panel thickness also should be considered. Typically, panel thickness is between 5.5 and 10 inches. In extreme circumstances, such as very tall panels or those with large structural loadings, a panel thickness of 12 inches or more may be required. In these situations, remember that walls thicker than 10 inches require two layers of reinforcing. Note that the thickness cannot be less than the unsupported height divided by 50 (for single-layer reinforcing) or 65 (for double-layer reinforcing). These thicknesses are for the structural layer of concrete only. Any additional concrete, due to reveals or sandwich wythes, provides extra weight but not extra strength.

Cranes

Cranes come in numerous varieties and price ranges. Hydraulic cranes provide the least expensive option, conventional cranes are a mid-range option, and crawler cranes are the most expensive. Safety is of utmost importance when utilizing cranes on a site; therefore, special attention must be given to crane capacity. When considering crane capacity, first determine the weight of the heaviest panel. For a hydraulic crane, the capacity required is five times the weight of the heaviest panel. A conventional crane capacity required is four times the weight of the heaviest panel, and a crawler may require three and a half times the weight of the heaviest panel. Conversely, if there are few choices of machinery in the project area, it may be necessary to let the crane dictate the size of the panels. Because of their weight, sandwich panels often change the selection of the crane. In addition, don't forget the weight of the rigging.

Crane location is another important consideration in the planning process. Will the crane be positioned on or off the slab? If a crane is placed on the slab, remember that the crane's weight may damage the slab. A crane on the slab also may hinder space planning and slab usage. On the positive side, a crane resting on a slab has a smooth work surface, provides the operator and crew with better visibility, and usually moves quicker.

Choosing the Casting Surface

There are typically three casting surfaces from which to choose: slab, other panels (stack casting) or temporary casting beds.

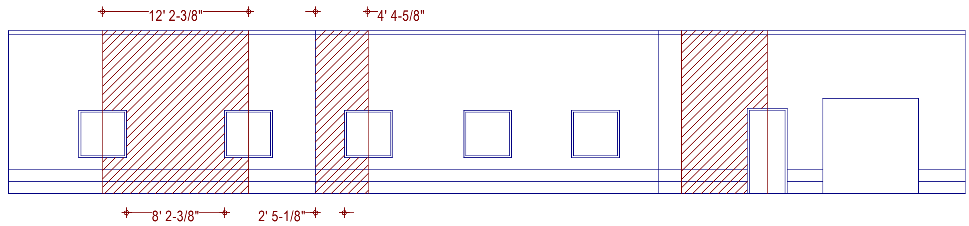

Figure 1.

Panelization of the Walls

When figuring the panelization of the walls, several items should be considered. First, take account of the floor plan and draw elevations. Establish gridlines, and then consider the openings and panelization. When considering openings and panelization, it is often helpful to locate openings over other openings. You will need to maintain an adequate "leg" on the other side of the opening. The larger the opening, the larger the "leg." This leg is required to support half of the tributary load from the (*Figure 1*) opening. The maximum width of the supporting leg is limited to 12 times the panel structural thickness. Finally, determine the panel joints and number the panels.

Panel Dimensions and Weights

A primary concern for project success is weight. If a panel is too heavy to lift, a Tilt-Up contractor/designer is faced with many problems. It is essential to know the dimension and weight of each panel.

Layout and Erection Sequencing

Whether a layout is complex or typical, different layouts require different erection sequencings. One of the most important steps for the Tilt-Up contractor is studying panel layout on the site, for casting and erection sequence, long before beginning work on site. Lift day is not the time to discover that panels cannot be set in place because other slabs are on the slab, obstructing the temporary braces. Therefore, the contractor should be very familiar with panel layout before erection day.

Finalizing the Design

With the planning complete, it's time to review final design details. Elements that require attention at this stage include the panel detailing, structural connections, structural design of the panels, lifting, bracing and erection.

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Conventional 200-ton truck mounted lattice boom crane lifting 52,000-pound panel.

Panel Detailing

Corner details for solid panels include simple butt joints, smooth-edge miters, sharp-edge miters and modified butt joints. It's important to remember to plan inside the corners for erecting sequence. Corner details for sandwich panels include simple butt joints, miter joints and modified joints. The key to success requires balancing beauty, function and cost.

Structural Connections

Structural connections include beam joist, deck, interior wall and foundation connections. The beam joist connection can either be a pocket or embedded plate. While pockets are faster for erection, they provide less eccentricity. Pocket placement is less forgiving, but if done right, they are less costly.

Many contractors use foam blocks to form pockets for structural connections. However, others recognize the ease of nailing something to a plywood box as compared to foam. In fact, some superintendents even fill the boxes with foam so they don't fill with spilled concrete. This makes removal even easier.

Other connections include the deck, interior wall and foundation connections. For the deck connection, fasten the angle to the panel before the panel is erected. Make sure to put a mark on the drill bit or use a short bit, as it is disappointing to lift a panel and find holes in the face resulting from a worker drilling all the way through the panel while attaching a piece of steel angle. Check the length of the anchors. For interior wall connections, use embedded plates in the top of the panel. If the wall supports joists, use open-top pockets. If fire rating is required, then usually only one mat of rebar is needed. Seismic design may result in more stringent requirements.

Structural Design of the Panels

Erected panels have to resist loads from many forces. Live loads come from wind, snow and rain. Seismic loads present additional force. The structure itself has dead loads, and the panels have their own self-weight. If applicable, panels must resist live loads from floors. Plus, the additional weight of the architectural layer of concrete in a sandwich panel can be a factor in taller panels.

Rebar placement is an important consideration in panel design. In a single-layer of rebar, the vertical bars are positioned in the middle of the structural thickness of the panel. Horizontal bars are usually on the outside of the verticals. In a double-layer of rebar, maintain cover for vertical bars. Pay attention to reveals and their depth. Horizontal bars are usually in between vertical bars. Although two layers of reinforcing may be considered by many as a lot of extra work, depending on the panel size and loading, it is often more cost-effective, resulting in a much stronger panel for a lower cost.

Further considerations ensure proper rebar placement. Indicate chair sizes on the panel drawings so the TCA Certified Supervisor can inspect prior to concrete placement. Make sure the superintendent checks the rebar placement prior to placing of the concrete. Indicate the number of vertical bars on the panel drawing, not the spacing. This makes it much easier for the foreman to double check. In addition, use plastic chairs specifically designed for Tilt-Up applications. Discuss chairs with the design engineer and rebar subcontractor. Make sure the site superintendent can adequately inspect chair placement.

Lifting

For successful lifting, be sure to discuss lifting hardware with the panel design engineer as all inserts are not created equal. Next, determine the configurations of the inserts. The configurations are based on panel weights and dimensions, and are affected by insert capacity and panel thickness. Finally, have a meeting with the crane supplier. At this meeting, discuss the crane capacity and type of crane that will be used, as well as the rigging capacity and the rigging configuration.

Lifting hardware also should be evaluated during this stage. Check the manufacturer's literature for the insert's safe working load. Note that the insert capacity changes with panel thickness. Panel weight will affect the number of lift inserts necessary. The insert orientation depends on panel width and height. In some situations, it is more efficient to use additional inserts due to the rigging setup.

Bracing

Once you know the brace length, it is easy to look up its safe working load in the manufacturer's literature. To determine bracing loads, first calculate the total panel horizontal load

230-ton track mounted lattice boom crane lifting 80,400-pound panels.

at the brace location. Then, convert this into a diagonal (axial) load in the brace. Finally, divide this load into the brace's safe working load to determine minimum number of panel braces. Remember, panels need a minimum of two braces for stability: brace geometry with knee bracing and knee braces fastened to main brace at midpoint. Knee braces are installed perpendicular to the main brace, while lateral bracing must be installed to be effective. To determine the floor slab thickness, refer to the estimated method from the TCA Bracing Guidelines.

Proper attention to the bracing plan layout will help minimize conflicts, such as two braces intended to occupy the same space. Although completely preventable, this is a common occurrence at building corners. Remember, lift day can cost as much as $15/minute, so alleviate conflicts before the crane arrives.

When setting floor inserts, a location drawing showing where to put them prior to placing the concrete slab should be prepared. This drawing should take no more than 10 to 15 minutes to produce, and will save time and money in the field. It also points out any potential conflicts at the corners prior to the slab being poured. If knee bracing is required, it usually will be installed faster since the braces will be better aligned.

Proper brace attachment also should be a priority and their total cost should be evaluated. For example, most Tilt-Up contractors use drilled-in expansion anchors for bracing, and the cost of a tang (coil or spring) is approximately $0.40 each. Further, the cost of a cast-in-place insert is $6 each. However, the cost of a 200-ton crane, eight-man lift crew and a supervisor is $15 per minute, so be sure to evaluate the cost incurred while the expansion anchors are being installed.

A few final items will ensure appropriate bracing is achieved. Never remove the braces without the design engineer's permission. If knee bracing is specified, lateral bracing must be installed. Finally, check bolts daily, and never use a bent or damaged brace.

Erection

For erection to go smoothly, the field will need several documents. These documents include: the panel layout diagram, the floor insert location drawing, a full set of panel drawings with detail sheet, the foundation plan, the structural steel drawings and building elevations. The site should have several copies of the panel layout drawing an insert placement drawing in 11- by 17-inch size, and at least one at ¼-inch scale.

Project Success

With a thorough understanding of the Tilt-Up process, engineers and contractors can ensure a smooth project. Key to success is an appreciation that many mistakes or even slow-downs in the field can be alleviated, which is crucial to minimizing the cost impact of the crane. Yet another key to success is communication. As all members of the team – from design to construction – commit to open lines of communication, a Tilt-Up project can be constructed smoothly, efficiently and with results that make certain the client is well-satisfied.▪

Laurence Smith, P.E. is a partner and director of the Dartmouth, Nova Scotia-based firm of J.W. Lindsay Enterprises. Smith currently maintains a license to practice engineering in four provinces of Canada and serves as the Past President of the board of directors for the Tilt-Up Concrete Association. He may be reached via email at ***ljsmith@jwlindsay.ca****.*

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