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Minimizing Risks When Lifting and Bracing

Today's Tilt-Up Structures

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By Joe Steinbicker

Every site-cast tilt-up concrete construction project requires hard work and planning before the building can be erected. Watching the enormous concrete panels being lifted and set into place is an awe-inspiring event that occurs only with careful planning, hours of training and experience, and a thorough knowledge of today's lifting and bracing equipment. By taking the time to properly prepare for lift day, you can minimize time wasted during the erection operation and ensure a smooth, safe process. Knowledge of today's equipment and its capabilities will allow you to maximize panel size and construction efficiency.

Selecting the rigging contractor and crane

Many people are needed for a successful panel lift. Experience and proven ability are the two most important criteria in a rigging contractor. The rigging subcontractor, general contractor, and concrete subcontractor review the casting layout of the panels. This ensures that the panels will be placed on the slab as close as possible to their final position to minimize crane time.

The most commonly used crane for lifting tilt-up panels is a truck crane with a lattice boom. The length of the boom is determined by the height of the panels, the height of the lifting beam and hardware, and the sling length required to lift the panels. This type of truck crane can legally travel on highways to a jobsite and be ready within hours once at the site. The use of crawler cranes is increasing and may be required in some cases. Crawler cranes have greater lifting capacity, which makes tilt-up projects with larger panels possible. Contractors are also performing more lifts from outside the building where crawler cranes have greater mobility and stability. They are, however, more difficult and costly to transport since they must be trucked in several sections and require additional assembly time.

Cranes are rated in tons of lifting capacity. Their capacity is the maximum load they can lift directly behind the bumper with the shortest boom. The crane capacity for a tilt-up project typically varies from 120 to 300 tons. The required lifting capacity is based on the weight of the heaviest panel to be lifted, the boom length needed, how far the boom must reach, and how many panels are to be lifted from each setup. Crane manufacturers provide a chart that a crane operator can reference. With this chart, the operator can determine how far the crane can reach with each of the panels being lifted.

Knowledge of today's equipment and its capabilities will allow you to maximize panel size and construction efficiency. By taking the time to properly prepare for lift day, you will minimize time

The lifting sequence

Before beginning the lift, the lifting crew should assemble to review the step-by-step details in a safety meeting. The lifting sequence should be precisely defined from beginning to end.

First, the crane operator lowers the lifting beam with the rigging attached, and the riggers connect the cables to the lifting inserts. The riggers straighten out any tangles in the cables, so that they do not kink or snag during lifting. Carpenters or laborers check that the braces will hang loose during the lift.

The foreman then gives the crane operator the signal to lift. When the cables are taut, the operator applies increasing tension to the panel through the rigging until the panel begins to slowly lift, pivoting about the bottom, which rests on the floor slab. Lifting continues until the panel is near vertical and off the floor. The panel is moved to its final location in the building and lowered into position. The bottom of each panel rests on two pre-leveled grout or plastic shim pads. The riggers use pry bars and wedges to move the panel until it comes to rest in the proper position on the control lines.

wasted during the erection operation and ensure a smooth, safe process.

With the panel securely resting on the pads, the braces are moved into position and attached to the floor slab with approved anchors.

After a panel has been set, but before the crane releases it, temporary erection braces must be installed to hold the panel plumb and in position, and provide resistance from wind. The minimum requirement is two braces per panel, but with the larger panels common today, additional bracing may be needed.

Bracing the panels

After a panel has been set, but before the crane releases it, temporary erection braces must be installed to hold the panel plumb and in position and to provide wind resistance. The minimum requirement is two braces per panel, but with the larger panels common today, three or four braces per panel may be needed to resist the construction period wind loads. Braces are usually made of steel pipe with about 18 inches of screw adjustment at the lower end. The upper end is bolted to an embedded wall brace insert, and the lower end attaches to the concrete slab, most often by a post-installed anchor bolt.

Braces are usually designed by the tilt-up hardware supplier who uses the brace capacities for the lengths and wind loadings required. A safety factor of 1.5 is typical. In some cases, long braces may need support in two directions to prevent them from buckling since a round pipe can buckle about any axis at mid-length. Larger capacity braces can be used if you want to avoid lateral bracing and knee bracing. An important reminder: Use hardware that matches the braces selected for the project. Improper matching can lead to fatigue or movement in the panels during this critical stage. The braces and associated hardware are typically rented.

During preparation for lifting, workers will connect the braces to the panel. This reduces lost time when the panel is raised because the brace hangs free and can be quickly fastened to the floor slab at its lower end once the panel is in position. While one crew member holds the brace in position, another drills a hole into the floor slab for the anchor bolt that will secure the brace. Alternatively, the brace can be connected to a cast-in-place floor brace insert, but these are rarely used. Occasionally, there may not be a floor slab in place during panel erection, in which case the brace is anchored to a “dead-man”—a block of concrete heavy enough to resist the applied brace loads.

The final operation is to release the crane and rigging hardware. While the crane is still holding the panel, the braces are adjusted until the panel is plumb. It is important to plumb the panel left to right (side-to-side) before plumbing it “in and out.” If the panel is plumbed “in and out” first, it can become jammed against the footing. Once the braces are secure and the panel is plumb, the crane slackens the cables, and the riggers disconnect the lifting hardware from the panels. The crane and crew then move to the next panel.

Going up causes bracing challenges

According to Ed Sauter, executive director of the Tilt-Up Concrete Association (TCA), a large majority of questions received by the Association center on proper specification of today's lifting hardware. “In the past, the usual limiting factor on panel size or height was the lifting capacity of the crane,” said Sauter. “Today, however, as newer and stronger cranes have come into use, the limiting factor on panel height is typically the bracing system used to temporarily brace tilt-up panels against wind loads during construction.”

To better understand these questions, it is important to review the evolution of tilt-up braces and inserts. Dave Kelly, chief of engineering for Meadow Burke, said the original commercially available braces in the 1950s were relatively light-duty and made of pipe with standard wall thickness that telescoped and were pinned with bolts at a particular length. The wall thickness of the pipe was necessary in order to resist the bearing loads from the bolts that allowed the telescopic feature. Roy Edgar, product specialist of Dayton Superior said that until the early 1980s, these telescope style braces were the only option. Depending on the type, they could be adjusted from 13 feet to 32 feet in length. The safe working load for these braces was about 6500 pounds at their minimum collapsed length. As these pipe braces were extended to their maximum length or used with a pipe extension, their safe working load was significantly reduced to about 3750 pounds. By adding a sub-support system of knee, lateral, and end bracing to stiffen the main pipe brace, said Edgar, the safe working load could be increased.

According to Kelly, in 1980, the first large-diameter, thin-wall, non-telescopic braces appeared. Because they did not telescope, they did not require thick-walled pipe to resist shear. It was possible to use larger diameter pipe with thin walls (0.12 inch), which kept the weight lower. Since these braces were larger in diameter than earlier brace models, they withstood more compression load but didn't weigh as much. Fixed in length, the braces were adjusted by changing the angle up and down the wall, and major length changes could be made by adding extensions. This type of brace remains the major component still used today. The longest large-diameter, thin-wall, fixed-length braces available today are about 62 feet long, which allows for the bracing of tilt-up panels up to about 75 feet high without fastening the bottoms of the panels to the foundation.

Braces are usually made of steel pipe with approximately 18 inches of screw adjustment at the lower end. The upper end is bolted to an embedded wall brace insert, and the lower end attaches to the concrete slab, most often by a post-installed bolt.

Today, the length and strength of temporary wind braces as well as their anchorages at each end limit the height of single tilt-up panels. Typically, the anchor in the wall panel is a four-legged coil insert with a mechanical capacity of 16,000 to 20,000 pounds. The pull-out force from the concrete varies with the thickness and strength of the concrete. A typical insert is rated at 9000 pounds of working strength which matches the maximum capacity of the wall braces available. Three types of floor anchors exist: cast-in-place coil, post-installed expansion bolts, and post-installed self-threading bolts. When properly installed, all can be satisfactory brace anchors. However, the concrete in which these anchors are installed—typically the floor—is sometimes inadequate because most anchors require a slab of 2500 psi concrete at least 5 inches thick. In order to resist the load, the anchor requires a minimum of 216 square feet of 5-inch-thick floor per anchor to develop the 9000-pound uplift load with a 1.5 safety factor.

During the last couple of years, most suppliers have developed longer and larger diameter pipe braces with a safe working load almost 50 percent stronger than earlier braces, which allows them to accommodate the taller panels. These newer braces have a fixed length with a safe working load of 9000 pounds at a length of 32 feet. One supplier offers a 40-foot-long 9000-pound safe working load brace. These longer and larger diameter pipe braces can also have extensions added to them, increasing their length to 52 feet, again with a reduction in the pipe brace's safe working load to around 3750 pounds. By adding a sub-support system of knee, lateral, and end bracing, a maximum safe working load of 9000 pounds is attainable for these longer braces.

Dispelling the myths

The replacement of telescoping with fixed length braces has reduced the use of knee, lateral, and end bracing to stiffen the main braces. But many tilt-up contractors, said Edgar, do not understand the relationship between the main brace and a sub-support system of knee, lateral, and end bracing used to stiffen a main pipe brace, and problems resulting from this confusion are frequent. Many times, a contractor will install knee braces only, leaving off both the lateral and end braces, he said. Or, he or she will install knee and lateral bracing, leaving off the end bracing. For example, when one style of telescoping brace has been extended to its maximum recommended length and used without properly installed knee, lateral, and end bracing, it is only one-fifth as strong as it would be with proper bracing. As such, it takes rive times the number of braces to be as safe.

Braces are usually designed by the tilt-up hardware suppliers using their brace capacities for the various lengths required and wind loadings. A safety factor of 1.5 is typical. Also, it is crucial to use hardware that matches the braces selected for the project.Improper matching may lead to fatigue or movement of the panels during this critical stage. The

“Using just one or two parts or improperly installing the sub-support system will not increase the value of the main bracing system, nor will it stiffen the main brace if all parts of the sub-support system are not rigidly connected so they will not move,” said Edgar.

To properly stiffen the main bracing system, the knee, lateral, and end braces should be properly attached to the main braces at or very near the main brace's mid-point. Knee bracing should be attached to the main brace, creating a 90-degree angle, plus or minus 15 degrees, with the main brace. Knee braces can be attached to the floor slab or to the panel as required to maintain the appropriate angle with the main brace, and end braces should be attached to the main brace at an angle of approximately 45 degrees with the floor slab.

braces and associated hardware are typically rented.

Kelly also cautions that many users do not understand that a round brace can deflect in any direction. Placing a prop under a sagging pipe brace does not eliminate the possibility of the brace deflecting sideways or even upwards as it must be prevented from movement in any direction in order to obtain the added strength from sub-bracing.

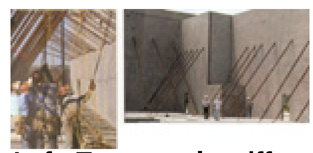
The proper hole diameter and depth is critical for installing floor brace anchors, as is the required torque to expand the anchor. To install anchors in the floor correctly, installers should be carefully schooled in the installation procedure for the particular anchor being used. This should include the hole diameter and depth necessary, the applied torque, and any spacers or special tools needed to ensure proper expansion of the holding device.

Testing ensures success

Most pipe brace anchors on the market today have been tested and their safe working load determined as a result of static tests, a means in which a single load—tension, compression, or an angle—is applied to the brace anchor. This testing method, however, results in a liberal value as some anchors, especially post-installed brace anchors, may yield a high static value but perform very poorly under cyclic loads (the load is reversed from tension to compression and back to tension again many times in succession). As such, cyclic testing is a better predictor of a brace anchor's capacity to brace a tilt-up panel against wind loads.

Wind loads are cyclic in nature; they gust and relax many times before the panels are structurally tied into a building. When this load is applied to an anchor it may affect the load capacity. The cyclic load may have the tendency to turn the bolt from the anchor or relax the expansive portion in the concrete that holds the anchor in place. One suggested practice to ensure a safe working load is to apply cyclic loads equal to the brace anchor's expected safe working load (tension and compression) at a test angle of 60 degrees (representing the typical angle used when bracing a tilt-up panel) for 100 cycles (200 total load applications), and then tension-test the brace anchor to failure.

Reuse recommendations



Left: To properly stiffen the main bracing system, knee bracing should be attached to the main brace, at or very near the main brace's mid-point, creating a 90-degree angle with the main brace. Above: At a corner, the bracing must be intertwined to maintain support for the panels.

In addition to proper testing, many in the industry advocate inspection of the reusable parts—lifting hardware and braces. Although cranes, lifting beams, spreader bars, and cables are periodically inspected, Federal OSHA regulations require a minimum safety factor of five for these devices; lifting device inspection has been left to the suppliers because of the liability and proprietary nature of the devices. When shipped from a supplier, reusable lifting hardware units must meet the OSHA required minimum safety factor of five to one, while pipe braces must meet the industry standard factor of safety of 1.5. The lifting contractor should have qualified personnel inspect all reusable hardware upon receipt for any signs of shipping damage, tampering, or intentional alteration. If any of these conditions, or other irregularities, are found, the supplier should be notified for replacement units.

The life span of lifting hardware is based on the amount of use, period of service, and operating environment. As such, proper care, use, and storage are essential for maximum service and safety. Lifting hardware is subjected to wear, overloading, corrosion, rusting, deformation, heat, bending, intentional alteration, and many other factors that may affect its safe working load. The user should visually inspect all braces before installing them, and daily while they are supporting panels. The determination of when to remove a unit from service is best decided by these daily inspections. Do not attempt to field straighten bent pipe braces or lifting hardware; rather, replace them with undamaged units. Field welding, field bending, or modifying any reusable hardware may reduce its load-carrying capacity and may be hazardous.

Alleviating human errors

Unfortunately, most problems occur from human error, not product failure. “During the course of more than 40 years of field incident investigation on tilt-up projects,” said Kelly, “I have found that almost all are human errors in the field.”

Common errors include using too small a crane, short or under-capacity lifting cables or spreader bars, misplaced lifting inserts, omitted or misplaced reinforcing units or strongbacks, incorrect dimensions on the panels, incorrect braces, misplaced braces, too few braces, incorrect knee and cross-bracing, incorrectly installed brace anchors, and concrete that is too weak. Usually one mistake alone does not cause the incident, said Kelly, but in combination, mistakes add up to problems. For example, lifting inserts slightly misplaced would not have broken the panel, but in combination with a short cable and weak concrete the panel broke.

Edgar said his investigations of accidents that occur during the tilt-up erection process or after the panels are braced and standing also typically results from human error and the combined effect of several mistakes. For instance, insert failure—when a lifting insert pulls out of the concrete—is usually caused by two or three of the following:

- The concrete is not up to the specified strength. Since the insert's capacity is directly related to the strength of the concrete, the insert capacity is reduced.
- The sling length is shorter than specified. Shorter cable lengths increase the load on the lifting insert.
- The panel is subjected to an impact load. The crane operator applies too much force to the panel, it “pops” up and then falls back down again, placing an additional load on the lifting insert.
- The use of vertical rigging is specified, but the panel is lifted using a V-type rigging. Depending on the angle, it will apply greater loads to the insert than anticipated. For instance, if you are using a V-type rigging so that a 90-degree cable angle is formed, it will apply 41 percent more load to the insert than anticipated. Maximum deviation, in the rigging, from true vertical should be plus or minus 5 degrees.

Other essential elements for success include:

- Ensure that lifting hardware is compatible with the lifting inserts and that both are supplied by the same manufacturer.
- Never exceed safe working loads.
- Make readily available the proper number of remote release lines for lifting hardware and other equipment necessary for installing the post-installed floor brace anchors.
- Be sure the crane and rigging are of the proper capacity.
- Finally, there is little argument that success clearly lies in hiring experienced professionals in every facet of the tilt-up project.

“Experienced designers, suppliers, contractors, and subcontractors have been through the process many times and probably, through previous errors, have learned valuable lessons that can save time and money,” said Kelly.

For example, John R. Neyer, P.E., president of Neyer Construction, Inc. of Cincinnati, said that its policy always is to have a second person check the location to ensure that the inserts are not displaced or knocked over. Then, concrete cylinders are taken and tested before the panels are lifted. If the time between casting and erection is short, he said, workers increase the concrete strength. If the cylinder test strength is close to the required strength, Neyer Construction will perform field strength tests.

“When erecting the panels, we set a plan and communicate the plan to everyone on the project,” said Neyer. “By working with the same erection contractor, we have developed a team that can safely and efficiently erect the panels.”

<i>— Joe Steinbicker, P.E., S.E., is president of Steinbicker & Associates, Dayton, Ohio, which specializes in tilt-up design; Jim Baty, is technical director of the Tilt-Up Concrete Association. Information for this article was provided by Dayton Superior (www.daytonsuperior.com) and Meadow Burke (www.meadowburke.com)—both of whom serve the tilt-up industry's lifting and insert needs. TCA was founded in 1986 to improve the quality and acceptance of tilt-up construction. For more information about the TCA, visit www.tilt-up.org.</i>

Checklist for the rigging subcontractor

The rigging subcontractor should use this checklist to guide the jobsite walk-through, typically with the crane operator, several days prior to lifting. Check for the following:

- The crane must be able to access the site.
- For the crane to access the floor slab, there must be a properly constructed ramp so that the edge of the slab won't crack.
- The terrain over which the crane will travel must be level and the soil able to support the crane.
- OSHA requires 10-foot minimum horizontal separation between power lines and any part of the crane or rigging. Arrangements can be made with the electric company to shut off the power if necessary
- Look for underground hazards that could cause a problem, such as insufficiently compacted trenches or old sewer lines
- Discuss with the job superintendent and concrete subcontractor the lifting sequence and the path the crane will follow so nothing will be in the way. This discussion should also involve the crane operator
- Another item for early discussion with the job superintendent is thickening the floor slab at the points where the crane will enter and exit to minimize the possibility of cracking the slab.
- All forms will be stripped and debris removed.
- Lifting inserts and brace connection inserts will be accessible and in the right place, and braces will be in place on

the panels.

- Footings and grout pads will be ready.
- All tools will be ready (shovels, bars, shims, hammers, drills, wrenches, and so forth).
- Contractor's personnel will be available (carpenters and laborers).
- The schedule for crane move-on and start of lifting should be reviewed.
- The erection manual prepared by the hardware supplier shows each panel and locates pick-up points, brace connection points, cable lengths, and other information. It must be read and reviewed.
- A safety meeting must be held before you connect to the first panel. The TCA has pocket reference guides for this. Account for any language barriers. Many contractors offer the meeting in both Spanish and English. One contractor holds a safety meeting every day of lifting to ensure that the crew does not become complacent.
- Since there can be regional variations in responsibilities between the different disciplines, the tilt-up contractor should ensure that panel rigging and lift engineering, bracing design, and slab design are coordinated through one “engineer of record.”
- Lifting should proceed only after test cylinders and test beams verify that the concrete strength meets the specified design strength. But note that adverse weather can change the time that it takes for the concrete to reach the required strength. Consider using maturity methods to monitor actual concrete strength. Contact TCA for additional information.**Survey says bracing problems are common**

According to Edgar, one accessory supplier conducted a 10-year study of reported accidents representative of a variety of different product lines, not just tilt-up. Approximately 66 percent of all reported accidents were found to be related to tilt-up, mainly the result of bracing problems. In general, these problems were caused by one of the following errors:

- Knee, lateral, and end bracing not installed when specified.
- Knee, lateral, and end bracing not installed properly.
- Improper installation of floor anchors.
- Braces hit by fork trucks during installation of bar joists.
- Braces hit by a panel during positioning.
- Missing alignment pin for telescoping brace, reducing brace capacity to zero.
- Alignment pin not having a stop installed, allowing alignment pin to fall out, reducing brace capacity to zero.
- Failure to install main braces at 90 degrees, plus or minus 5 degrees, to the face of the panel.
