# Tilt-Up Building Seismic Design

## Precast or Cast-in Place?

By Joe Steinbicker, P.E., S.E. and John Lawson, S.E.

Tilt-up buildings have been successfully designed and constructed throughout the United States for over fifty years. Today, the tilt-up method of construction is used extensively to build all types of buildings, currently at a rate of 300,000,000 square feet of tilt-up concrete panels constructed in the United States each year. Recently, with the adoption of the 2006 edition of the International Building Code (IBC) in conjunction with the ASCE 7-05 *Minimum Design Loads for Buildings and Other Structures*, there has developed some confusion over what building type should tilt-up construction be classified for the purposes of seismic design – monolithic cast-in-place or precast?

Courtesy of John Lawson

### Traditional Precast vs. Tilt-up

Traditionally, precast concrete buildings are considered as structures comprised of numerous small individual pieces of concrete cast at an off-site plant and trucked to the jobsite for assemblage and erection. These traditional precast elements are often in the form of beam elements, column elements, horizontal plank elements, and narrow vertical wall elements. Generally, seismic loads are resisted by coupling beams to columns for frame resistance, and coupling narrow wall elements together for composite shear wall resistance. In these situations, the individual element has little or no lateral resistance on its own, but relies upon the assemblage to achieve lateral resistance.

The American Concrete Institute (ACI) defines precast concrete in Section 2.2 of *Building Code Requirements for Structural Concrete* (ACI 318-05) and *Commentary* (ACI 318R-05) as a "Structural concrete element cast elsewhere than its final position in the structure." Under this broad definition, tilt-up concrete construction can be classified as site-cast precast. The ACI clarified this with ACI 318-95 when the following was added to Chapter 16, *Precast Concrete*, in the Commentary Section R16.1.1, "Tilt-up concrete construction is a form of precast concrete." As stated in Chapter 1 of the ACI *Tilt-Up Construction Guide* (ACI 551), several features make the tilt-up construction method a unique form of precast concrete, different from traditional methods:

*"Tilt-up panels are generally handled only once. They are lifted or tilted from the casting slab and erected in their final position in one, continuous operation. Tilt-up panels are generally of such large size and weight that they can only be constructed on site and in close proximity to their final location in the structure. Panel gravity loads are supported directly by the foundation instead of being supported by a structural frame. Typically, tilt-up panels are erected before the structural frame. Tilt-up panels are usually load-bearing for gravity loads and lateral loads. In fact, a whole industry developed around the tilt-up construction method. Tilt-up concrete construction is a unique form of site-cast precast construction and, as such, has its own specialized set of design parameters and construction techniques."*

By their nature, tilt-up panels are individually stable wall elements seldom requiring coupling devices for composite action. Penetrations within walls are surrounded by deep beams above which, in turn, are monolithically cast to wall pier elements at the sides. The only discontinuities are at the vertical panel joints, often twenty or thirty feet apart, and the panel-to-footing interface. The performance and ductility of this lateral force resisting system is closer to cast-in-place construction than traditional precast. Historically, the authors are unaware of any seismic performance problems at these interfaces.

### Structural Wall Classification

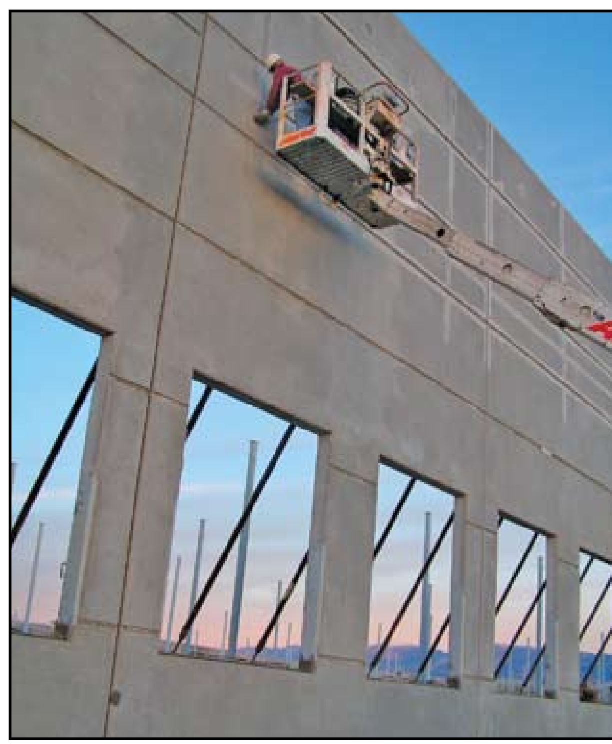
Current tilt-up engineering practices typically use the tilt-up concrete wall panels as Structural Walls, whether one story or multi-story. ASCE 7-05 defines a Structural Wall as, "Walls that meet the definition for bearing walls or shear walls." Furthermore, a Bearing Wall is defined as, "Any wall meeting either of the following classifications: 1) Any metal or wood stud wall that supports more than 100 lbs/linear ft (1,459 N/m) of vertical load in addition to its own weight, 2) Any concrete or masonry wall that supports more than 200 lbs/linear ft (2,919 N/m) of vertical load in addition to its own weight," and a Shear Wall (vertical diaphragm) as, "A wall, bearing or nonbearing, designed to resist lateral forces acting in the plane of the wall (sometimes referred to as a 'vertical diaphragm')." Walls that do not meet these criteria are instead classified as non-structural components. Clearly, tilt-up buildings are generally comprised of Structural Walls.

With this in mind, the tilt-up building structural system would be classified as a bearing wall system as defined by ASCE 7. In ASCE 7, Table 12.2-1, *Design Coefficients and Factors for Seismic Force-Resisting Systems*, there are now three categories under the heading for bearing wall systems that potentially apply to tilt-up buildings as a form of precast concrete construction. These are

Ordinary Precast Shear Walls, Intermediate Precast Shear Walls and Special Reinforced Concrete Shear Walls. The category of Intermediate Precast Shear Walls is new, and represents a transition in detailing and expected performance between ordinary and special systems. With the lack of the word "precast", the applicability of the Special Reinforced Concrete Shear Wall category to tilt-up may not be immediately obvious, but a quick reference to ACI 318-05 will clarify this application.

The intent of ACI 318-05 towards the proper classification of Structural Walls can be obtained by reviewing the provisions in conjunction with the commentary. Chapter 21 of ACI 318-05, *Special Provisions for Seismic Design*, Section 21.1 – Definitions, provides the following guidance. Structural Walls are defined as "Walls proportioned to resist combinations of shears, moments, and axial forces induced by earthquake motions. A shear wall is a structural wall. Structural walls shall be categorized as follows:" A Special Precast Structural Wall is defined as, "A precast wall complying with the requirements of 21.8. In addition, the requirements for ordinary reinforced concrete structural walls and the requirements of 21.2.2.3, 21.2.3 through 21.2.7, and 21.7 shall be satisfied." The commentary for this definition states, "The provisions of 21.8 are intended to result in a special precast structural wall having minimum strength and toughness equivalent to that for a special reinforced concrete structural wall of cast-in-place concrete." This establishes that a Special Precast Structural Wall is equivalent to a Special Reinforced Concrete Structural Wall.

Part of the initial confusion regarding the proper classification of tilt-up construction stems from the development of the precast concrete seismic design provisions. Much of the research work has been directed towards investigating the seismic performance of traditional precast concrete structures with improved connections. The landmark research associated with the PRESSS (Precast Seismic Structural Systems) Research Program has greatly influenced the specific ACI 318 seismic provisions for precast concrete systems. Inadvertently, these provisions are extending to site-cast tilt-up construction, because tilt-up falls under the broad umbrella of precast concrete. Although the precast concrete seismic provisions may



*Courtesy of John Lawson*

at first seem awkward to apply to tilt-up construction, a rational approach can be developed by understanding the intent of the provisions.

## Navigating the Code Provisions

Tilt-up walls in seismic regions must follow *Intermediate and Special Precast Structural Walls* provisions of 21.13.2 – "In connections between wall panels, or between wall panels and the foundation, yielding shall be restricted to steel elements or reinforcement." and 21.13.3 – "Elements of the connection that are not designed to yield shall develop at least $1.5S_y$." Some designers interpret this to mean that tilt-up panels used as Intermediate or Special Precast Structural Walls must be connected to the foundation. However, the Commentary for Section 21.13 – *Intermediate Precast Structural Walls* states in part, "Connections between precast wall panels or between wall panels and the foundation are required to resist forces induced by earthquake motions and to provide for yielding in the vicinity of connections." Many tilt-up panels, due to their large size and relatively low force levels, are stable as individual elements and do not require panel-to-panel connections or panel-to-footing connections to resist overturning (tension) forces due to earthquake forces. Thus, tie down connections to the footings are not required since no design tension force is calculated.

Chapter 16 of ACI 318-05, *Precast Concrete* Section 16.5.1.3 (c) states, "When design forces result in no tension at the base, the ties required by 16.5.1.3(b) shall be permitted to be anchored into an appropriately reinforced concrete floor slab on grade." The seismic shear forces can also be transferred between the tilt-up panels and the floor slab on grade, just as they are transmitted between a suspended structural concrete floor slab and a concrete structural wall. This is often analyzed with the shear friction principles of ACI 318 through the use of doweling reinforcement. Continuing the load path, the floor slab on grade must be designed to resist the forces being transferred as well.

## Conclusion

Tilt-up construction is a unique form of precast concrete sharing many similarities with monolithic cast-in-place concrete. As concrete code provisions have become more prescriptive and construction-type specific, confusion and unintended interpretations are always a risk. Fortunately, tilt-up construction has performed very well in terms of acting as a lateral force resisting system. Where it can be argued whether the precast seismic provisions were originally intended to apply to tilt-up, this article demonstrates that a tilt-up building can be navigated through these provisions successfully without compromising expected performance.▪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