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Guide to Tilt-Up Concrete Construction

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Guide to Tilt-Up Concrete Construction

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Guide to Tilt-Up Concrete Construction

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Tilt-up concrete construction is commonly used in low- to mid-rise building construction. This guide reviews the many issues related to the planning and construction of tilt-up buildings to produce a quality tilt-up project. Major topics include preconstruction planning, foundations, special considerations for slab-on-ground construction, wall panel forming and casting, panel erection, connections and repairing, and painting. This guide also contains sections on sustainability and insulation systems, as well as references to the relevant codes and standards including updated Occupational Safety & Health Administration (OSHA) safety regulations.

Keywords: forming; finish; inserts; insulation; panel; precast; release agent; sandwich panel; site cast; sustainability; tilt-up.

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CHAPTER 1—INTRODUCTION AND SCOPE

1.1—Introduction

Tilt-up concrete construction is a unique form of site-cast precast construction where building elements commonly referred to as panels are constructed in job-site conditions and set in place within the building design. The conditions of casting location and positioning within the building design, therefore, necessitate tilt-up's own specialized set of design parameters and construction techniques. 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.

ACI defines tilt-up as “a construction technique for casting concrete elements in a horizontal position at the job site and then tilting them to their final position in a structure.” ACI 318 further states that tilt-up concrete construction is a form of precast concrete. Several features make the tilt-up construction method unique.

Tilt-up panels serve as many functions for building design as markets in which they are constructed. Panels, or perhaps better described as tilt-up elements are constructed with and without openings, sometimes consisting of only a grid of monolithic beams and columns. Wall panels are found flat, ribbed, curved (with broad to tight radii), and even biaxially curved. Elements have been constructed freestanding and cantilevered, simply supported, and connected in a variety of configurations. Elements have been taller than 96 ft (30 m) (Lucky Street Parking Garage, Hollywood, FL) and building façades have been stacked as high as 138 ft (42 m) (ASU Student Housing, Phoenix, AZ). Not all tilt-up elements are building panels, however. Although the majority produced annually are designed as either load- or nonload-bearing building envelope panels, tilt-up elements have also been featured as signs, monuments and art, walkways, stadium seat supports, spires, tanks, tunnels, and bridges.

1.2—Scope

This guide presents the basic concepts, techniques, and procedures used in tilt-up construction. The design of tilt-up wall panels, although not addressed in this guide, is addressed in the companion design guide ACI 551.2R, which is beneficial in content to both licensed design professionals and contractors. This guide includes a brief history of tilt-up concrete and a discussion of planning; foundation and floor slab construction; and wall panel forming, casting, and erection. It briefly describes typical connections used to attach the panels to the rest of the structure, and options for panel finishes are briefly described.

CHAPTER 2—DEFINITIONS

ACI provides a comprehensive list of definitions through an online resource, “ACI Concrete Terminology,” <http://www.concrete.org/Tools/ConcreteTerminology.aspx>. Definitions provided herein complement that resource.

bolster strip—continuous reinforcement support device for wire mesh or mat in a concrete slab or wythe element.

cribbing—wood blocking set under crane outriggers to spread the point load over a larger area to prevent damage to the supporting surface.

densifier—chemical applied to a concrete surface to fill pores, increasing surface density.

elastomeric paint—paint consisting of a polymer with elasticity, generally having low Young's Modulus and high yield strain compared with other materials that behave as a rubber-like membrane on the concrete surface to span cracks and decrease permeability.

hygrothermal analysis—analysis of the movement of heat and moisture through buildings, particularly a building envelope, component, or system.

membrane bond breaker—non-chemically active release

agent that prevents the bond of fresh concrete to the casting surface that dissipates with time.

penetrating bond breaker—chemically active release agent that prevents the bond of fresh concrete to the casting surface that requires cleaning methods to remove from substrate.

polyisocyanurate—thermoset plastic typically produced as foam and used as rigid thermal insulation.

polystyrene—rigid or foamed synthetic aromatic polymer made from the monomer styrene, a liquid petrochemical for use in extruded shapes or insulation boards.

polysulfides—sealants designed for joints that need to withstand prolonged immersion in liquids. Typical applications include swimming pools, fountains, cooling towers, fuel and chemical storage tanks, wastewater treatment, and petrochemical plants.

reentrant—inward corner of a concrete element that is typically recognized at windows and doors.

reveal—longitudinal recess in the surface of a concrete element.

spud vibrator—vibrator with a vibrating casing or a vibrating head used to consolidate freshly placed concrete by insertion into the mass. Also commonly referred to as a stinger.

thermal transmittance—measure of the rate of heat loss of a building component expressed as watts per square meter, per degree Kelvin, W/m^2K ; U-value is calculated from the reciprocal of the combined thermal resistances of the materials in the element, air spaces and surfaces, also taken into account is the effect of thermal bridges, air gaps, and fixings (commonly known as the U-value).

urethanes—thermosetting polymer formed by reacting an isocyanurate with a polyol, used in the manufacture of flexible, high-resilience foam seating, caulks, and rigid foam insulation panels.

wythe—each continuous vertical section of a concrete wall in monolithic thickness.

CHAPTER 3—HISTORY, TRENDS, AND SUSTAINABILITY

3.1—History of tilt-up construction

Although precasting building elements is sometimes considered an innovative concept in engineering, origins can be traced to as early as 4700 BC to a small village in Jarmo, Iraq, where the villagers made walls for their dwellings from tuff, a pressed mud. As cementitious materials became available, the quality and durability of these precast materials improved. The Romans produced pozzolan cement, which they used extensively in their building projects around 25 BC. It was not until the nineteenth century and the development of portland cement that concrete structures became integral to the construction process. By 1890, portland cement was widely accepted as the standard cementing material.

Early structures using portland-cement concrete were usually cast-in-place. By 1914, cast-in-place concrete rein-

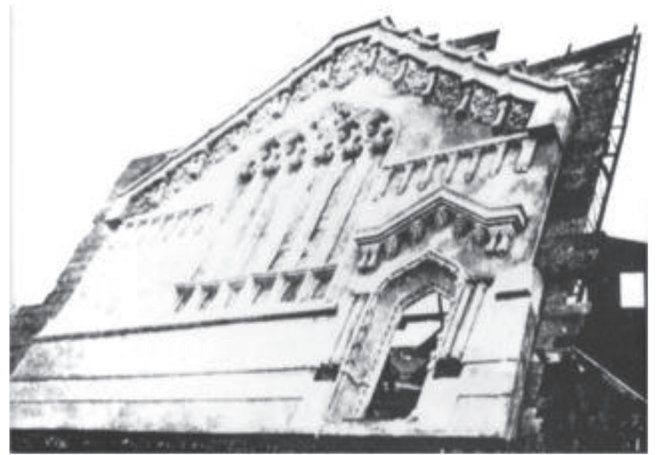


Fig. 3.1a—Front wall panel of Memorial United Methodist Church on tilt table.

forced with mild steel reinforcing bars was second only to structural steel as a building material.

Some builders in the United States developed an early form of tilt-up construction in which a tilting platform was used. Aiken (1909) described the innovative method where walls for a building were constructed on a structural platform, then rotated or tilted upward by means of specially designed mechanical jacks, setting the panel in its final position. This tilt table method was used on the Jewett Lumber Company in Des Moines, IA, between 1906 and 1912, and on several Army facilities, factory buildings, and churches. The tilt table method was also used on the Memorial United Methodist Church in suburban Chicago. The church construction incorporated decorative precast elements that were embedded in the tilt-up panels (Fig. 3.1a and 3.1b).

Collins (1958) states that railroads during the period before World War I developed a technique for precasting large sections of bridges from reinforced concrete and setting them in place with their heavy cranes. The cranes, however, were mounted on railroad cars and required additional track to be laid to access the site.

The idea of precasting large structural units using reinforced concrete cast into molds or forms was hastened by World War I. The shortage of steel and labor caused by the war and the subsequent increase in building prices challenged engineers and contractors to develop new methods of building. Most improvements in precasting methods were developed in England and Western Europe. Precast elements, however, were small and easily handled without heavy equipment. In Russia, precast building elements developed using alternative casting methods due to more difficult conditions for fabrication and construction. There, larger sections were constructed using techniques similar to those now used in the United States. Erection was accomplished with stationary cranes.

In the United States, there was little advancement in the use of precast concrete elements until World War II. Three technological innovations, attributed to this era, made the erection and connection of site-cast elements more efficient. The first two of these developments were the heavy-duty



Fig. 3.1b—Memorial United Methodist Church, Zion City, IL, built circa 1906.

truck crane and electric-arc welding. The third development that made site casting of concrete elements a mature industry was transit- or ready-mixed concrete. The ready-mixed concrete concept made quality concrete available to anyone in any quantity on short notice.

As a result of these innovations, the number of buildings constructed with site-cast concrete elements increased significantly. There were construction projects incorporating new technologies and ideas in local areas of the Midwest, Texas, Pennsylvania, and the New England states. The most progress, however, was in southern California during 1945 and 1946. The dollar volume of work using this type of construction in southern California increased dramatically between 1946 and 1952. Other Sun Belt states soon followed.

Numerous surveys conducted by the **Tilt-Up Concrete Association (2013)** have found that tilt-up concrete is most prevalent in North America, with buildings constructed in every state in the United States, every province in Canada, and in many areas of Mexico. The strongest concentration of tilt-up activity occurs from British Columbia, south along the Pacific coast into Mexico, across the southern United States, and north along the Atlantic coast through Newfoundland. Pockets of strong activity can also be found throughout the Midwest, Plains, and Rocky Mountain states. Strong tilt-up industries have also developed in Australia, New Zealand, and several countries in Central and South America, while locations in Africa, Europe, the Caribbean, and southern Asia have recently been added to the regions where tilt-up is being used.

3.2—Trends

3.2.1 Building applications—Tilt-up construction was first used for large, plain, simple structures—most notably warehouses or distribution centers. This is still a common building type in tilt-up construction. Familiarity with tilt-up by licensed design professionals and the use of the broadening array of innovative finishes, discussed in later sections, have advanced tilt-up for use in many other types of buildings. These include correctional facilities, schools,

multi-story office buildings, retail structures, cold storage buildings, industrial and manufacturing projects, recreational facilities, churches, and multi-family housing. Most recently, applications for tilt-up construction have broadened to include smaller buildings and single-family residential structures.

3.2.2 Sandwich wall panels—Most model energy codes have minimum thermal performance requirements that can be met or exceeded using insulated sandwich wall panels. Tilt-up sandwich wall panels have been successful for more than half a century in controlling temperatures and increasing the thermal efficiency of tilt-up structures. Current increases in the minimum energy code requirements and the shift toward sustainable systems have helped sandwich walls grow in popularity and frequency of use. Whether it is schools, offices, correctional facilities, cold storage, or religious buildings, tilt-up sandwich panels can provide the durability, speed of construction, and design flexibility of tilt-up while providing significant R-value and moisture protection. In general, sandwich wall panels are comprised of two layers, or wythes, of concrete separated by a layer of rigid insulation, and are tied together with a series of connectors or fasteners. The performance of the tilt-up sandwich panel, both structurally and thermally, depends on the capacity of the connector and the detailing of the insulation layer, as discussed in **Chapter 11**.

3.2.3 Aesthetics—Economy provided in the tilt-up construction method has combined with the challenge of architectural variety and upscale aesthetics, using creative form and advanced finishes. Engineering creativity and craftsmanship of the construction professional together have delivered building form involving significant amounts of glazing with long spandrel concrete sections (Fig. 3.2.3a), deep recesses and graphics, extensive reveal patterns, complex geometric shapes, and angles and curves both out-of-plane and in-plane. The surface appearance and texture of tilt-up panels has also inspired more upscale architectural finishes. Exposed-aggregate finishes provide natural, durable concrete surfaces with low maintenance (Fig. 3.2.3b). Direct casting onto aggregate placed in a sand bed, sandblasting, power-washing techniques, and chemical retarders are some of the methods used to expose the aggregate in the panel surface to varying depths. These techniques are more dependable than in the past, producing more uniform aggregate exposure. Panel elevations fit into a broader variety of traditional community vernacular with thin brick, block, and stone finishes cast into the concrete (Fig. 3.2.3c).

3.3—Sustainability

Tilt-up construction offers several key characteristics to the goal for sustainable construction. By definition, the use of locally available materials to construct energy efficient building elements on-site embodies the essence of sustainability. Cement is the only component of a standard panel with high-embodied energy and CO₂ output; however, efficiencies in the production of cement coupled with the long, low maintenance life of the structure more than make up for this deficiency.



Fig. 3.2.3a—Tilt-up spandrel panels.



Fig. 3.2.3b—Detailed exposed aggregate finish.



Fig. 3.2.3c—Thin brick tilt-up façade.

3.3.1 Carbon footprint reduction—On-site manufacturing, along with the use of locally available raw materials such as sand, gravel, and water, can significantly contribute to the sustainability of the structure by reducing fossil fuel consumption and emissions related to transporting the materials. On site, the size of tilt-up elements results in fewer lifts, fewer joints, and faster shell construction than many competing construction methods such as masonry, wood, steel, and cast-in-place, further reducing emissions and fuel consumption. Reduced waste of production materials and the ability to recondition unused or outdated buildings further adds to the sustainability of tilt-up by reducing the strain on landfills.

3.3.2 Energy efficiency—Tilt-up construction can be very energy efficient despite the low material R-value of concrete. Thermal mass, inherent in tilt-up and other concrete-based building systems, is largely responsible for structures that require less energy to heat and cool as well as providing greater degrees of comfort for occupants, even when insulation is not present. This is particularly true in temperate climates, and those with a dominant cooling load. Where insulation is required by code, or for a specific building program, the negligible concrete R-value of $0.08 \text{ ft}^2\text{-F-hr/BTU-in.} = 0.014 \text{ m}^2\text{-C/Watt-mm}$ is bolstered with many options for continuous insulation on the interior or exterior surface as well as in a configuration known as a sandwich wall construction. Tilt-up insulation systems effectively deliver a building envelope that meets minimum performance standards, significantly reducing thermal transfer and protecting the interior space conditioning needs. The degree of energy efficiency provided by these insulation system choices combined with the thermal mass can reduce the size of heating and cooling equipment required, further contributing to the sustainability of the system.

Another benefit to energy efficiency and a requirement found in the latest energy codes is a continuous air barrier. The low permeability of a solid concrete tilt-up panel decreases air and moisture infiltration into the structure—one of the major factors in equipment sizing and operation. The International Energy Conservation Code (**ICC 2012a**) defines such panels as a qualified air barrier envelope component. Additionally, the size of tilt-up panels results in fewer system joints that must be sealed to meet the continuous air barrier requirements. This results in building envelopes that are much higher in air tightness. The recent development of high emissivity wall coatings can further enhance the performance of tilt-up buildings in southern climates by reflecting more of the sun's energy, thus reducing cooling demand and costs.

3.3.3 Longevity—Concrete buildings have a distinct advantage in terms of building life because of the permanence and durability of concrete as a building material. Concrete structures have been continually in service since before 150 AD. Change of use is one of the most challenging aspects to the practicality of building life span. Tilt-up building structures, however, offer significant flexibility for modifications to embrace these changes and change of occupancy. Panels can be removed, reused, relocated, and

modified. Modifications can include both window and door openings. If demolition is required, the wall panels can be crushed, allowing the concrete and steel to be recycled.

3.3.4 Finishes—Tilt-up concrete structures can be painted, unfinished with exposed aggregate, have other materials embedded in the concrete, or left simply as unfinished concrete. Exposed aggregate panels, in particular when executed with retarders and unfinished concrete, provide a low-maintenance surface. The reduction in maintenance and elimination of coatings adds to the sustainable characteristics of the system. The use of form liners and the availability of thin brick embedded in the face of panels has further broadened the aesthetic variety for tilt-up, contributing to its use for virtually any building type.

3.3.6 Recycle/reuse/replace—Tilt-up construction employs recycling at several levels. Lumber, if used for side forms, is typically reused several times. When panels are replaced or destroyed, standard methods for recycling steel content as well as the concrete itself can be employed. Recycled concrete can be used as fill under slabs, sidewalks, road base, and as coarse aggregate in concrete mixtures. Careful consideration should be given to the types and source for recycled aggregate that may be used in panels. Cement content can be reduced by supplementary cementitious materials such as fly ash, slag cement, and silica fume. These products, formerly directed to landfills, can replace cement content. Recycling reduces direct and indirect costs, and lessens the production of CO₂.

3.3.7 Resilience—Tilt-up structures are not subject to attack by termites or other wood destroying organisms. Tilt-up structures have proven to be resilient for forces of nature including tornadoes and hurricanes and the wind born debris produced by these violent storms. As recent as May 2013, tilt-up buildings have withstood the intensity of EF-4 and 5 tornadoes as seen in Moore, OK. In fact, tilt-up is the building system of choice for many emergency shelters as well as emergency operation centers. Fire stations in Florida and Texas, for instance, are among the building types turning to tilt-up to withstand the intense forces of hurricanes, maintaining safety zones and functional services.

Fire resistance is an important characteristic of tilt-up building envelopes. Due to the height of so many of today's tilt-up buildings, an average panel thickness of 7 in. (178 mm) is common. Such panel thicknesses are rated at 4-hour fire resistance (**ICC 2012b**). This is important for separation within larger structures and for buildings, which require distance separations in urban settings. Tilt-up is also used for stair and elevator towers because of its strength and fire-resistive properties.

Resiliency is also expressed in the force-resistance from man-made threats, such as explosives and progressive collapse. Numerous tilt-up structures in Texas, California, District of Columbia, Florida, and Louisiana have been designed for progressive collapse using the structural efficiency and redundancy of tilt-up panels. Additionally, tilt-up panels have been studied by the Air Force Research Laboratory (**AFRL-RX-TY-TR-2008-4616**) and proven to perform

with substantial resistance to explosive charges without enhanced engineering.

CHAPTER 4—PRECONSTRUCTION PLANNING

4.1—Introduction

Preconstruction planning is essential for the smooth progression of events in the construction of a tilt-up building. Efficient on-site production operation is important to the economy of tilt-up construction. Successful production requires organization and planning.

Many projects are developed with a contractor as a member of the design team. This facilitates the coordination of the design with the construction process, thus enabling the coordination of construction logistics into the design process. A meeting between the licensed design professionals and contractor can address limitations and concerns such as slab thickness, panel size (height, weight, width, thickness, and configuration), temporary bracing requirements, finishes and reveals, use of new techniques, materials, erection, and crane access. This is of particular importance when team members are not familiar with tilt-up construction. The meeting should also address lead times and other logistical items that may impact the construction schedule.

4.2—Site layout and crane access

During preliminary construction planning of the project, it is important for the contractor to become familiar with the building site. Building location on the site can greatly affect many aspects of construction. Locating the building adjacent to a property line will affect foundation design and construction, panel layout and erection, and panel repairing and painting. A geotechnical engineer should determine the soil bearing capacity and advise of any soil removal or replacement requirements in addition to compaction requirements prior to the start of any construction activities.

Crane access in and around the site is critical to a smooth panel erection process. Many owners do not want the crane on the floor slab due to potential slab damage. As a result, many specifications restrict the crane to the building exterior or to an uncast strip of floor. If panel erection is to proceed from outside the building perimeter, the area should be graded smooth and compacted so no soft spots or ruts impede the crane's progress. Utility trenches into or around the building may restrict crane access. Lateral clearance around the building should also be sufficient to allow the crane to maneuver. This is especially critical in urban areas.

All overhead power lines within potential reach of cranes or other equipment should be carefully evaluated. The contractor should consult **OSHA 29 CFR 1926.1408** for required safe working distance based on the voltage, or deenergize and ground the overhead power lines within the operating reach of construction equipment. Proximity to airports can even require special permits for panel erection activities. Early planning for these situations is critical to be the least disruptive to surrounding property owners.

If crane access around the building is limited, some or all of the panels may have to be erected from within the

building perimeter. The panel erection crane is typically much heavier than a framing erection crane. Consequently, if the panel erection crane is required to drive on the slab, the slab edge may need to be thickened where the crane enters and exits the building. Slab recesses or other obstructions may also restrict crane access. Panel size, weight, and lift distance will dictate the required crane size. The crane's operation manual provides guidance on maximum reach. A general rule of thumb is that the crane's rated capacity should be three times the maximum panel weight.

The slab should be investigated wherever construction loads are to be placed, including loading applied from temporary wind bracing. If the crane is going to be placed on the slab during erection, the subgrade and the building slab must be able to withstand the loads applied during erection or slab damage will occur. The loads will vary depending on crane location and weight of the tilt-up panels. Also, placement of crane outriggers near slab corners, edges, and control and construction joints can contribute to floor damage. Timber cribbing should be placed under outriggers to distribute the load. For structural slabs, including those supported on deep foundations, the Engineer of Record should be made aware if the erection crane is going to be placed on these slabs. A licensed design professional should review this temporary construction loading condition.

For buildings with large plan areas, it may be beneficial to cast only the perimeter bay of the floor slab, which is enough to form and cast panels. This has the advantage of casting the majority of the slab after the panels and roof have been erected and casting in a relatively controlled environment. This staging can avoid placing large construction loads on the slab. Proper planning is required to designate traffic access in and out of the building and to areas of the slab that are to be cast.

Planning should consider which panels are to be used to allow the crane to exit the building. If the framing erection crane is scheduled to place the closure panel(s) into its final position, it should have the capacity to do so.

4.3—Review of drawings

Construction planning should involve a thorough review of the architectural and structural drawings. The contractor should ensure that the design intent is fully understood. Structural drawings should be compared with the architectural drawings to make sure reveals, chamfers, openings, and other items are not in conflict and can be constructed as intended without impeding on design concrete cover. Discrepancies, or areas in doubt, should immediately be brought to the attention of the licensed design professionals. If a more efficient design is visualized, it also should be brought to the attention of the licensed design professionals before commencement of construction.

When calculating the lifting stresses, the licensed design professional assumes an unreinforced panel and adds the needed steel to address the stresses. If the engineer of record has designed the same quantity and size of reinforcement in the same plane (location) the added reinforcement may not

be required but should be confirmed by the licensed design professional completing the lifting and bracing design.

All necessary information should be assembled for panel forming, casting, and erection. This information includes panel dimensions, opening dimensions, reinforcing, embedment plates, connections, architectural features, and similar items.

4.4—Production schedule

As with all construction projects, the contractor often uses a flow chart, Gantt chart (bar graph), or other visual form of planning depicting all stages and steps in the process, including the sequence in which they should proceed; the items that are dependent on other phases before they can proceed; lead time; the time period for completion; and the manpower, resources, and materials required for each task. The task of putting this schedule together can highlight problem or critical areas and provide a visual depiction of the entire process. The production schedule should be coordinated with overall building occupancy schedule.

Planning should also include scheduling of subcontractor start times and logistics for materials ordering. On large warehouse buildings, panel forming, casting, and erection may progress simultaneously with roof framing. Failure to account for these activities can produce inefficiency or even a safety hazard.

4.5—Submittals

Panel shop drawing submittals should include at least the following (Fig. 4.5):

- a) Openings and reveal locations
- b) Reinforcing steel, including concrete cover
- c) Lift and brace insert locations and product information
- d) Embedments
- e) Panel dimensions, including thickness
- f) Panel weight and concrete strength at time of lifting

It is also suggested that panel shop drawings include section cuts, the depth and shape of rustication, and the types and locations of panel finishes (including form liners and thin brick).

Material submittals should include at least the following:

- a) Concrete mixture proportion and substantiated 28-day compressive strength (prescriptive concrete requirements, if any; water-cementitious material ratio; air content and minimum lifting compressive or flexural strength)
- b) Bond breakers and curing compounds to check compatibility
- c) Form liners, reveal details
- d) Grouting and repairing materials
- e) Aggregate samples if exposed aggregate is used
- f) Any other materials integrated into the panel
- g) Reinforcing supports
- h) Finishes and coatings

Thorough construction planning also involves the concrete supplier, who should be aware of approved mixture proportions including flexural and compressive strengths, and quantities of concrete required for each slab and panel castings.

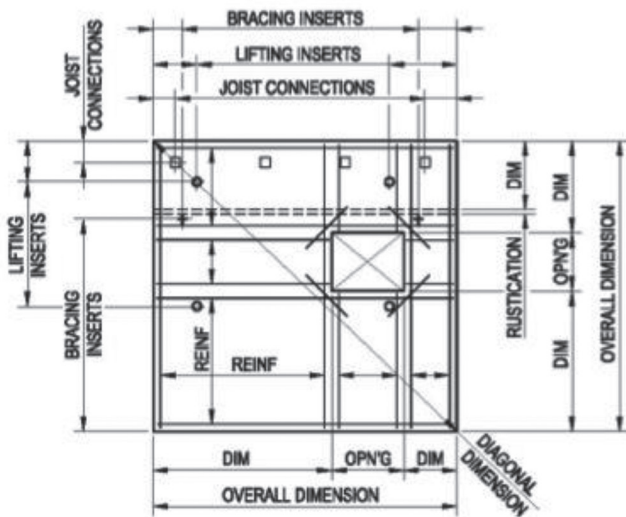


Fig. 4.5—Typical shop drawing excerpt.

If specifications require it, or if the architect has special finishing requirements such as exposed aggregate, a sample panel should be made for approval. This mock-up panel should be a minimum of 32 ft² (3.0 m²), using the same materials and methods proposed for the finished building. This panel will serve as the basis for acceptance and help to establish the range of acceptable finishes on other panels.

Submittals should be approved before commencement of any aspect of the work that is influenced by the respective material or work item.

4.6—Staging

Job-site staging can begin when most of the submittals have been approved. Staging involves selection of locations for support structures and materials storage, fabrication areas, and paths for movement of materials and heavy equipment such as concrete trucks, cranes, and concrete conveyance equipment.

All planning should be done with safety as an underlying goal. Essential items should be placed in areas that will not be affected by rain or other adverse weather. In winter conditions, provisions for removal or depositing of snow may be advisable.

4.7—Crews

Crew size, productivity, and tasks should be carefully planned. Crew tasks should be sequenced to avoid over-running production of the preceding crew. Typical crews include floor preparation, panel layout, forming, reinforcement, inspection, concrete, preerection, erection layout, lift and brace preparation, erection, and grouting or repair. To reduce manpower, personnel from one crew can staff other crews. If several tilt-up operations occur simultaneously, additional personnel may be required.

4.8—Panel layout and erection

One of the more important items to discuss during preconstruction planning is the panel-casting and erection

sequence. Additionally, the contractor should determine if there is sufficient slab area to cast the panels and maneuver equipment during construction. A planning session to review these items should be held early in the planning phase and should include the superintendent, concrete subcontractor, panel crane operator, and framing erector if the closure panel will be set. A typical casting and erection sequence plan is shown in Fig. 4.8a. The plan shows where panels are to be formed and cast, as well as their final erected positions. Crane access through the building and the panel erection sequence are also shown. Crane size and access in and around the building, including whether or not the crane is permitted on the slab, and site layout greatly affect the panel casting layout.

Figure 4.8b shows variations in the forming locations for panels near a corner, based on decisions such as temporary casting slabs, stack casting and crane access, size, or reach capacity. A proper layout plan should provide enough space between the panel being erected and panels yet to be erected to attach temporary braces to the slab. Corners require added coordination due to the increased brace congestion compared with elsewhere in a building.

A licensed design professional should verify the capacity of the slab to support construction, casting, and bracing loads.

Typically, all panels are erected during one crane mobilization. Phasing of panel erection can cost more if there is a second crane mobilization fee. A second crane mobilization, however, could accelerate the schedule by allowing the first phase of panels to be erected before all panels are cast and cured.

To optimize the construction schedule, panels should be cast in nearly the same order as they are to be erected and as close as possible to their final position. Time could be lost if

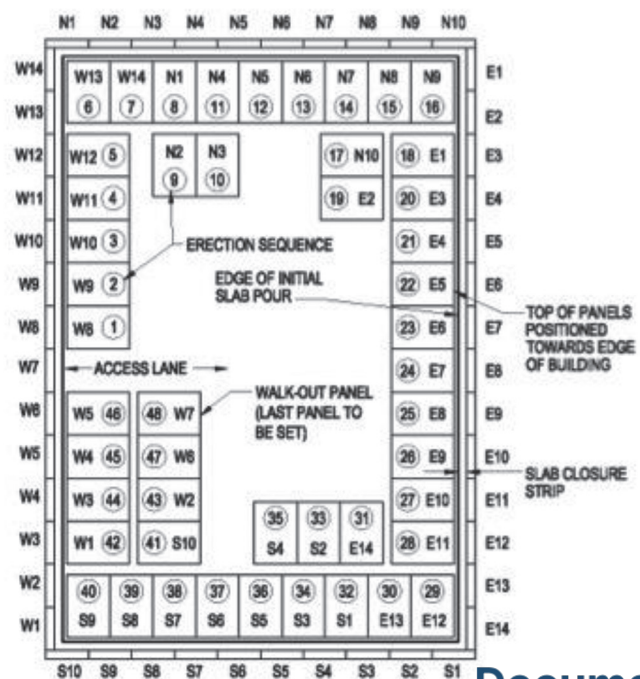


Fig. 4.8a—Casting and erection sequence plan.

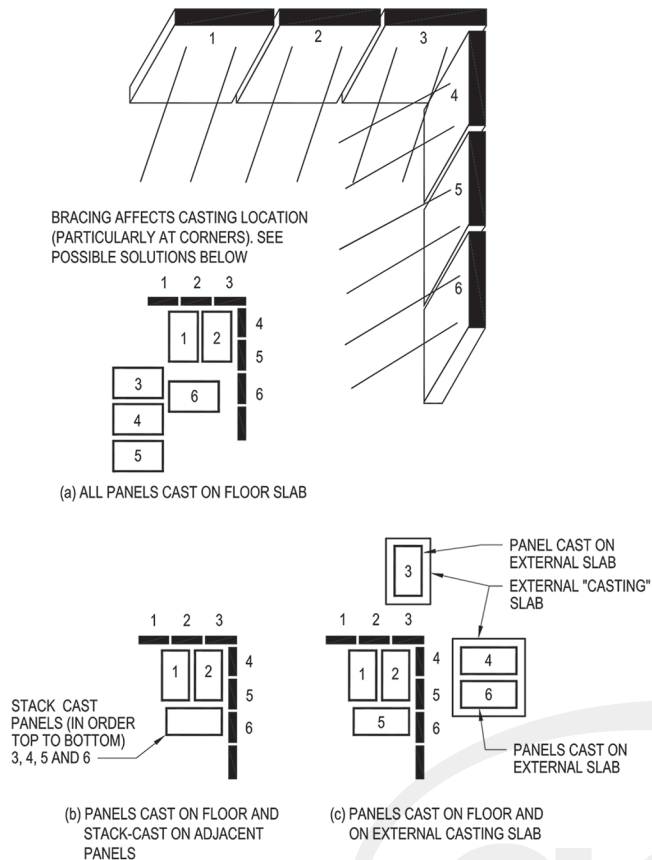


Fig. 4.8b—Alternative panel forming location.

the first panel to be erected is the last panel to be cast, or if the panel is cast too far from where it is to be erected. If panels are cast in the wrong location, they may have to be lifted and temporarily braced while other panels are moved out of the way or they may have to be walked to the correct location while attached to the crane. In addition to the increased cost and time involved, safety concerns increase each time panels are handled. Lifting insert manufacturers may require increased safety factors if panels are handled more than once. The applied bending stresses from additional handling can also add to durability and performance concerns, which derive from cracks occurring during erection and the possibility of damage to the panels. Panels should be arranged so they are erected consecutively. It is difficult to break a panel free when it is cast between two other panels. Lack of planning panel sizes and casting locations may require a larger crane than anticipated or scheduled.

4.9—Casting beds and stack casting

If the required casting area exceeds that available, or if the floor slab cannot be used for casting, temporary casting slabs at the perimeter should be investigated. The proximity to the floor slab should be planned to minimize crane sets and movements while maintaining the safe maneuver of all panels to their designed location.

Stack casting of panels (Fig. 4.9) can occur on the floor slab (6.2) or on temporary casting slabs (6.2.5). It is recommended that contractors understand the impact of panel configuration



Fig. 4.9—Stack-cast panels.

on the stack casting operation. Casting smaller or equal size panels and openings that are easily aligned maximize the effectiveness and simplify the method. However, creativity and experience frequently allow contractors to broaden the application. Additionally, the height of the stack is important. Maximum height is dependent on many variables and is directly related to the thickness and type of panel (that is, solid or sandwich). The casting surface inside the panel face should be finished to the same quality as the primary casting surface. Formwork should be properly braced if stack casting is required.

4.10—Concrete placement and testing

Limited site access for concrete trucks may necessitate the use of a concrete pump for placement. Panels are often erected within 7 days of being cast. Specified flexural and compressive strength tests should be conducted by an accredited testing agency in accordance with **ASTM C78/C78M** and **C39/C39M** before erection to verify concrete strengths meet or exceed erection requirements. Tests should be conducted on beams and cylinders cast from the same concrete used in the panels and cured and stored on site in conditions similar to those experienced by the panels. For accurate slump tests, the concrete slump should always be taken at the point of placement (end of chute or hose), not at the hopper, if placement equipment is being used. The testing agency should be notified when panels are to be cast so they can fabricate test specimens and perform other on-site quality tests such as slump and air content of the fresh concrete.

4.11—Panel orientation and bracing

Another item to be addressed during preconstruction planning includes determining whether the panels should be cast inside face-up (more common) or outside face-up, or if they should be braced to the inside or outside of the building. When panels are braced outside of the building, it may be necessary to provide temporary helical ground anchors, or deadman blocks, outside the building to anchor the braces. Exterior bracing will not be possible if the building is located adjacent to a property line or other site constraints, such as the grade on or proximity to other buildings or

structures on the site, or the proximity of other construction activities. Alternatively, the panel can be lifted and braced in a temporary location with braces initially attached to the outside face of the panel. Additional braces should then be attached to inserts on the inside face. At this point, the panel can be moved to its final position and braced in the normal manner to the floor slab. This will double or triple the time required to erect the panels. Refer to **Chapter 8** for panel bracing.

4.12—Safety planning

While all construction projects require safety planning, tilt-up construction has specific safety issues that should be addressed. The planning process should include a meeting among the superintendent, crane operator, rigging foreman, and all other personnel involved in the erection process before panel erection begins. Crewmembers should be assigned specific tasks for handling braces and hardware attachment. Only individuals directly involved with the erection process should be near the panel being erected. No one should be permitted to walk under a panel while it is being tilted, on the blind side of the panel when the crane is traveling with it, or between the crane and the panel. The crew should remain alert and look out for the safety of fellow workers.

The rigging foreman, who the crane operator looks to for all signals, should be experienced in handling panels, have received formal training, and be completely familiar with the precise set of hand and arm signals used to communicate with the crane operator. The rigging foreman should be able to demonstrate proper use of all lifting hardware, bracing hardware, and any tools or equipment that may be necessary. Prior to arriving on site, the rigging foreman should review rigging requirements as designed by the licensed design professional responsible for the lifting and bracing design.

CHAPTER 5—FOUNDATIONS

5.1—Foundation systems

Foundations transfer loads from the structure to the soil or rock supporting the structure. In the case of tilt-up building envelopes, the foundations are loaded with 75 percent of the dead load when the panels are erected. Therefore, it is important to understand the relationship of foundation design to the construction process and the assumptions made in the design process that may or may not fully exist during that process. An understanding of the variations in foundation types and how they impact the construction process is equally as important to the tilt-up planning process.

Foundation systems can be categorized as shallow or deep. Shallow foundations bear on a soil layer at a reasonable depth below the surface. These include continuous footings, spread footings, combined footings, and mats. Deep foundations, such as piles and drilled piers, transmit loads by friction or bearing at some depth below the surface. The permissible soil-bearing capacity or pile-load capacity is typically specified in the geotechnical report prepared for the project. The geotechnical engineer is responsible for the selection and design of any foundation element.

Depending on site and building conditions, subgrade preparation may be necessary. This can include excavation and removal of poor soils, compaction of existing soils, or importing engineered fill. The prepared subgrade should be maintained throughout construction as it affects the designed integrity of the supporting slab condition for panel erection.

5.2—Continuous footings

Where soil conditions are adequate for the use of shallow foundations, continuous strip footings are typically used to provide support to interior and exterior tilt-up wall panels (Fig. 5.2a, b, and c). The engineer of record determines the continuous footing size and reinforcement. How the panel is set on the footing during erection should always be considered during footing design and construction. Typically, panels will be set on shim packs in two locations temporarily. This is a far greater load than the continuous footing and is designed to support and may subject the footing to cracking if the load is not distributed as promptly

NOTES:

1. CONNECTION OF PANEL TO SLAB OR FOUNDATION IS REQ'D BY CODE. SEE CHAPTER 8 FOR TYPICAL CONNECTIONS.
2. REINFORCING NOT SHOWN.
3. JOINT BETWEEN SLAB AND PANEL IS REQ'D WHEN SLAB POURSTRIP IS NOT UTILIZED.

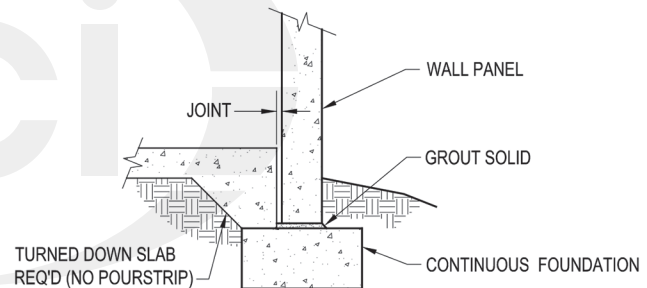


Fig. 5.2a—"At grade" continuous strip footing.

NOTES:

1. BRACE PANEL DURING BACKFILL UNTIL INFILL SLAB HAS REACHED NECESSARY STRENGTH.
2. SEE CHAPTER 8 FOR TYPICAL CONNECTIONS.

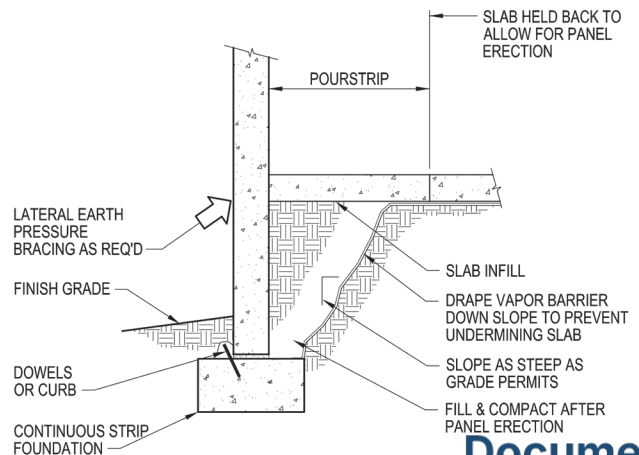


Fig. 5.2b—Dock continuous strip footing.

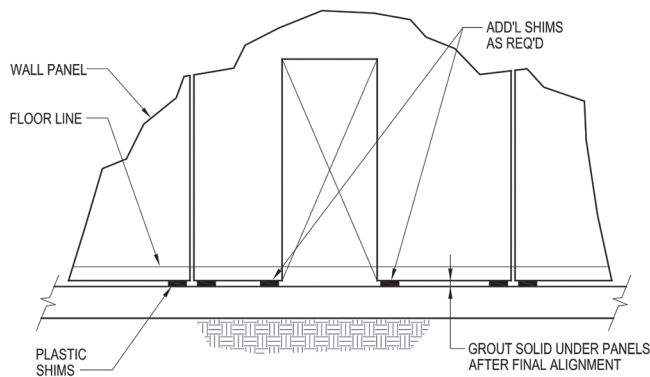


Fig. 5.2c—Continuous foundation elevation.

as possible with grout (5.6.1 and 5.6.2). Continuous reinforcement in footings helps to distribute panel loads over weak spots in the subgrade. Heavier reinforcement might be required if the footing should span trenches, drain lines, or other site features. Footing width is inversely proportional to soil capacity, so wider footings are necessary for softer soil conditions. Panels are usually centered on continuous footings unless property lines or other restrictions exist. At a minimum, the bottom of the footing should extend below frost depth in accordance with the geotechnical engineering report and local building codes.

Continuous footings can usually be installed before or after the slab when a portion of the perimeter slab is left out. When the slab has no closure strip, however, the continuous footing should be installed prior to the slab so that the slab can be turned down on top of the footing.

In some instances, the panels are placed directly on a thickened edge cast integral with the slab-on-ground. This is usually an integral beam to accommodate the additional loads created by the direct bearing of the panel. This type of direct bearing can cause cracks in the slab near the junction of the thickened slab edge and slab due to the rotation of the beam when the panel load is applied.

5.3—Spread footings

Where soil conditions permit, isolated spread footings at panel joints may be used to provide support for tilt-up wall

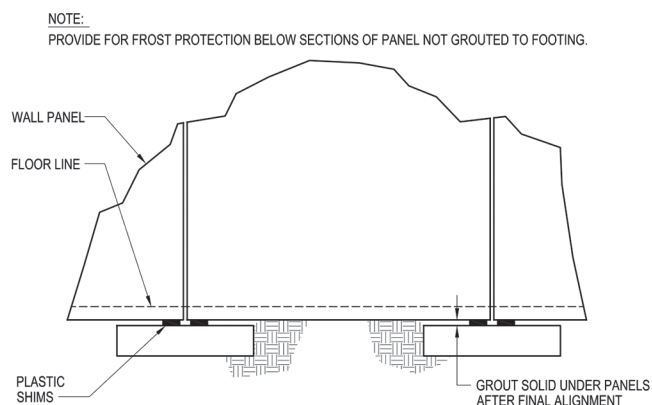


Fig. 5.3—Spread foundation elevation.

panels (Fig. 5.3). Panels are centered on the footing unless property lines or similar restrictions exist and have been accounted for in the design. At minimum, the bottom of the footing should be at or below the foundation embedment depth and also extend below frost depth as required by the geotechnical engineering report and local building codes. Provisions should be made to address frost heave under the unsupported panel edge if it does not extend below frost depth.

Spread footings are typically wider than continuous footings and therefore require placement before the slab, or a generous slab closure strip should be provided.

5.4—Foundation walls

Site conditions or design considerations may necessitate the use of foundation walls. Because these walls are formed as cast-in-place walls, the formed wall area will require more time, material, and labor than if the same wall area is an integral part of the tilt-up panel. They also reduce the weight from height and occasionally thickness reductions, thus impacting the crane size. The footing is constructed as a continuous element with reinforcement dowels projecting vertically. Typically, reinforcement is placed horizontally and vertically in the center of the foundation walls for at-grade conditions. Using a foundation wall where the exterior grade is well below finished floor elevation requires the wall to be designed as a cantilevered retaining wall resisting the backfill pressure and may require reinforcement on both faces or temporary construction bracing. Dowels projecting horizontally from the top of the foundation wall may be required for connection to the floor slab (Fig. 5.4). Panel connections to the slab or foundation walls more commonly found are described in 9.2.

Foundation walls generally favor the use of a perimeter slab closure strip so that the construction of the foundation walls can occur at approximately the same time as the construction of the tilt-up panels. Otherwise, the construction of the tilt-up panels should be delayed until the foundation walls and slab are complete.

NOTE:
CONNECTION OF PANEL TO SLAB OR FOUNDATION WALL IS
REQ'D BY CODE. SEE CHAPTER 8 FOR TYPICAL CONNECTIONS.

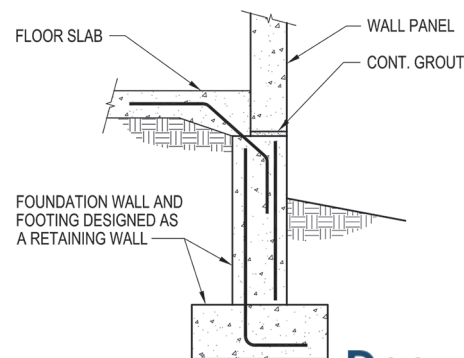


Fig. 5.4—Foundation wall system

5.5—Deep foundations (piles and drilled piers)

Where soil conditions dictate the use of deep foundations, continuous grade beams on piles or pile caps on groups of piles may be used to provide support to tilt-up wall panels. Grade beams or pile caps are constructed similar to continuous strip footings. Panel widths are centered on the continuous grade beam or pile cap unless property lines or similar restrictions exist. If piles are centered on the grade beam and not staggered, rotation of the grade beam due to accidental misalignment of the as-built components should be prevented by bracing the top of the grade beam to the slab, or by taking other appropriate measures. Floor slabs supported on piles may not be adequate to support construction loads from the panel erection crane. For this reason, panel erection for pile-supported buildings often takes place with the crane located outside the building perimeter.

Foundation systems for drilled piers are similar to those on piles when grade beams or caps are used. If the drilled pier is of sufficient diameter, however, panels may bear directly on the drilled pier without the need for a grade beam or cap.

Because deep foundations require more time to construct than conventional shallow foundations, the process of installing piles or drilled piers should begin well in advance of panel work. The decision to incorporate a slab closure strip is based on whether the slab is at-grade or dock-high and required timing of the slab placement. Dock-high conditions and early slab placement generally dictate the use of a slab closure strip while at-grade conditions and delayed slab placement can avoid a slab closure strip and realize the benefits of not having to fill and compact the closure strip as well as having to place and finish the closure strip slab.

5.5.1 Continuous grade beams—When panel widths can be established before foundation construction, the panels can be designed and constructed to span from pier to pier with the piers centered on the panel joints. The purpose of the grade beam then would be to prevent frost heave. The licensed design professional may specify the reinforcement of the grade beam. If panel widths cannot be established before foundation construction, or if drilled pier capacity or size does not permit placement only at panel joints, the grade beam should be designed and constructed to span from pile to pile and provide continuous support to the panels. Continuous horizontal reinforcement and reinforcement stirrups should be provided as specified to permit the grade beam to span from pile to pile. Grade beams should be sufficiently wide to allow for staggered or slightly mislocated piles. Pile embedment into the grade beam should be specified by the engineer of record (Fig. 5.5.1).

5.5.2 Individual pile caps—Individual pile caps used to support the panels are usually located under the joint of adjacent panels. Panel widths should be finalized before foundation construction. The pile cap size and reinforcement as well as pile embedment into the cap should be specified by the engineer of record (Fig. 5.5.2). Pile caps can usually accommodate small tolerances of less than 3 in. (75 mm) in pile location. As with individual spread footings, the bottom of the cap should extend below frost depth as required by local building codes. Provisions should also be made to

NOTES:

1. CONNECTION OF PANEL TO SLAB OR GRADE BEAM IS REQ'D BY CODE. SEE CHAPTER 8 FOR TYPICAL CONNECTIONS.
2. JOINT BETWEEN SLAB AND PANEL IS REQ'D WHEN SLAB POURSTRIP IS NOT UTILIZED.

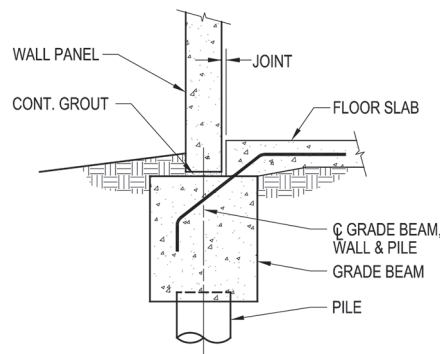


Fig. 5.5.1—Pile/grade beam foundation.

NOTES:

1. PROVIDE FOR FROST PROTECTION BELOW PANEL AND SLAB AS REQ'D
2. CONNECTION OF PANEL TO SLAB OR PILE CAP IS REQ'D BY CODE. SEE CHAPTER 8 FOR TYPICAL CONNECTIONS.
3. JOINT BETWEEN SLAB AND PANEL IS REQ'D WHEN SLAB POURSTRIP IS NOT UTILIZED.

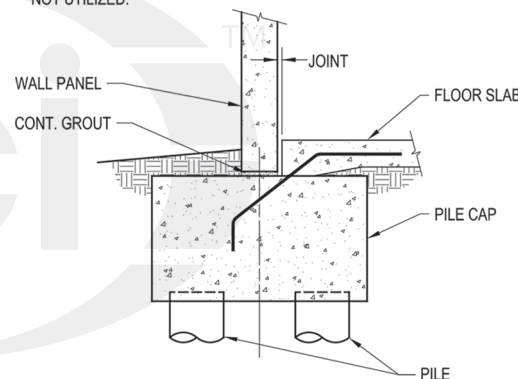


Fig. 5.5.2—Pile and pile cap foundation.

address frost heave under the unsupported edge of the panel if it does not extend below frost depth.

5.6—Foundation elevation versus bottom of panel elevation

It is common for the contractor and panel engineer to shorten the panel height to accommodate setting or bearing pads and provide for adjustment. This is accomplished by removing panel height from the base of the panel during the shop drawing phase. An adjustment of 1 to 2 in. (25 to 50 mm) is common for continuous footings, spread footings, and piles or piers with grade beams. An adjustment of 1 in. (25 mm) or less is common for foundation walls.

5.6.1 Setting (bearing) pads—Setting or bearing pads are positioned on top of the foundation system to temporarily support the wall panel during the erection and bracing process. Typically, two separate pads are placed 1 to 3 ft (0.3 to 0.9 m) in from each end of the panel to provide the most effective bearing. Although a single pad can be used under the joint of abutting panels, localized shear forces can be