Tilt-Up Planning

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Analysis

6.1. *Tilt-Up Construction Overview*

The following section has been developed for FedEx Ground and other owners in order to provide a basic overview of the feasibility, pre-planning and constructability of a tilt-up project. Providing the owner with sufficient knowledge about tilt-up construction will allow them to make a sound decision when choosing or comparing structural systems.

TILT-UP BACKGROUND INFORMATION

Tilt-up received its name from the method of constructing the vertical surfaces. Initially, concrete panels are formed horizontally and set (tilt-up) into their final position. The major cost savings comes from using concrete slabs as casting surfaces, reducing the need for extensive formwork. This method of construction has been utilized for over 50 years in the United States and is commonly found throughout the world. Tilt-up construction is primarily used in low rise structures but is not limited to only single story buildings. Buildings range in size from 5,000 s.f. homes to over 1,600,000 s.f. warehouses and distribution facilities. Tilt-up construction is limited only by the equipment placing the panels. Figure 7, illustrates examples of the most extreme uses of tilt-up construction.

Description	Building	Attribute
Largest Building (Footprint)	IKEA Distribution Center	1,704,748 sq ft
Largest Building (total floor area)	Eddie Bauer Distribution	1,750,000 sq ft
Largest Wall Area (including windows)	Old Navy Distribution Center	1,400,000 sq ft
Most Panels (single building)	El Paso County Detention Facility	1,310 panels
Most Panels (entire project)	El Paso County Detention Facility	1,300 panels
Largest Panel	Carson-Tahoe Replacement Hospital	2,742 sq ft
Tallest Panel	Seven Rivers Presbyterian Church	92' - 10 3/4"
Heaviest Panel	Distribution Center (Ontario, Ca)	310,000 lbs
Widest Panel	City Kia	69' - 3 1/4"
Tallest Cantilever Wall	Pearson Education / Rockefeller Group	52' - 4"
Largest Spandrel Panel	Public Safety Building (Orlando, Fl)	74' - 0"

Figure 7: Top 10 Tilt-Up Examples

TYPES OF TILT-UP PANELS

Non-insulated

Non-insulated panels are standard reinforced concrete panels. These panels are efficient and can be used under various loading conditions. Typically, non-insulated panels are used as retaining walls, barriers, and general enclosures that would hide items such as dumpsters and generators. These panels vary in size from 4" upwards of 10" depending on their intended use.

Insulated

Insulated panels are primarily used in colder climates or in cold storage facilities where heating or cooling costs are substantial. There are several ways of achieving an insulated tilt-up panel. One of the easiest ways to insulate the panels is to apply a rigid insulation or to install a furring system with batt insulation. Another method of creating insulated panels is to embed the insulation within the panel. "Sandwich" panels consist of two layers of concrete separated by a typical 2" layer of rigid insulation. These "sandwich" panels take advantage of the insulation while providing the durability of a standard tilt-up panel. As a load bearing panel the typical panel is comprised of an exterior wythe of concrete approximately 1 ½" to 2". The interior wythe of concrete varies from 4" up to 12" depending on the load requirements and is tied to the exterior wythe of concrete.

6.2. *Feasibility Review*

Determining the feasibility is the first step in planning a tilt-up building. Ideally, the perfect tilt-up building would be a large warehouse with basic highly repeatable walls where there would be ample room to form and cast the panels. Additionally, there should be enough room for the delivery, movement, and storage of materials. Figure 9 below illustrates some of the key questions that need to be analyzed prior to choosing tilt-up construction.

	Yes	No
Are the exterior surfaces essentially flat ?	☒	☐
Do they make up at least 50% of the total wall surface ?	☒	☐
Will most of the wall panels rest on the foundation as opposed to elevated lintel panels ?	☒	☐
Will most of the wall panels overall height be less than 30 feet ?	☐	☒
Can there be highly repeatable panels, in order to improve the efficiency of panel erection ?	☒	☐
Is there enough floor area available to provide a casting surface for the panels ?	☒	☐
Can the walls be divided into panels whose weight does not exceed the crane capacity ?	☒	☐

Figure 8: Tilt-Up Feasibility Questionnaire for the FedEx Ground Distribution facility

The above questions are designed to help identify if tilt-up is the right type of construction for the building. The feasibility questionnaire was filled out for the FedEx Ground Distribution Facility and the results determine that the building is capable of utilizing the benefits of tilt-up construction even though the typical height of the wall panels will be over 30 feet.

6.3. *Tilt-Up Construction Sequence*

The construction sequence for a tilt-up building is slightly different from the construction schedule of a metal wall system. One of the major differences is the sequence of activities for the erection of the roof and walls. The typical sequence of activities for constructing a tilt-up system is as follows:

1. Mass excavation and subgrade preparation
2. Form, Reinforce & Pour interior footings
3. Excavate and Place exterior foundations
4. Install all necessary underslab MEP conduits and equipment
5. Form, Reinforce, Pour & Cure floor slabs
6. Construct leveling pads on the perimeter footings
7. Set & Brace wall panels
8. Grout between footing and panel
9. Install roof
10. Remove wall bracing
11. Form & Pour closure strip

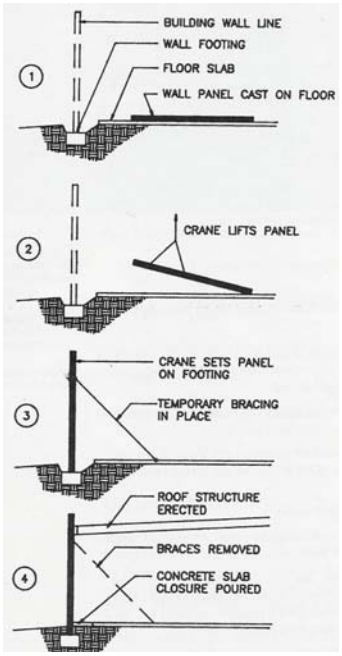

Figure 9: Tilt-Up Process

From the beginning of panel formation to the setting of the tilt-up panels, takes approximately 4-5 weeks. Enclosing the building as quick as possible allows other trades to gain access to the spaces in order to perform weather sensitive activities earlier. Ultimately, tilt-up structures maintain their appearance, structural integrity, and value.

The construction work flow for a tilt-up building is different than a typical steel structure. A typical steel erection sequence will start in one corner of a building or along a wall and work toward another specified location. Tilt-up workflows are based on the locations of the panels. The distribution facility is large enough to cast the panels on the exterior slabs and set them from inside the building. In order to accelerate the construction schedule the steel erector will have to start erection during the tilt-up process. The steel erector will begin erection near the center of the building

and work toward the exterior walls. Once the walls are set, the steel erector must go between the tilt-up panels and install the remaining structural members. The roof system will typically follow the steel erection sequence until the tilt-up panels are connected to the roof structure. See appendix D for examples of the original and modified steel erection sequences.

6.4. *Site Analysis*

Site analysis is a critical aspect of the tilt-up process. The Hagerstown site is over 100+ acres of land. So, there is ample room to utilize tilt-up construction. The property is undeveloped and there are no overhead utilities or obtrusions on the site prior to construction. During construction, 360° access to the building is a required by the local fire marshal. Therefore, access for delivery trucks, cranes and other equipment is acceptable.

6.5. *Foundation Analysis*

The foundation system for the distribution facility consists of spread footings, wall footings and piers. The current system is easily adapted to accept tilt-up panels. If the panels are non-load bearing the foundation walls and piers will be require modification to be able to accept the tilt-up panels. Prior to setting the panels, leveling pads will need to be installed at locations where the edges of the panel will be placed. After the panels are set and shimmed, non-shrink grout will be installed in order to provide a continuous bearing surface for the panels. Figure 10, illustrates the locations of the leveling pads and grout placement for both pad footings and continuous footings.

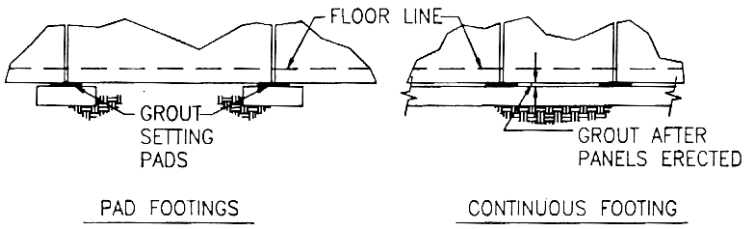

Figure 10: Panel Foundation Elevation

The foundation walls of the distribution facility are comprised of a 12" reinforced wall supported by a spread wall footing. The wall footings will require structural analysis to determine if the footings have sufficient load bearing capacity to withstand the additional weight of the tilt-up panels.

6.6. *"Panelizing" the Building*

One of the most important steps in the design of a tilt-up building is determining the where the panels will be divided, the shape of the panels, and where the joints will occur. Several aspects of the panels would be taken into consideration when dividing, "panelizing", the panels such as:

- Where members frame into the panels
- Location of window and door openings
- Avoid lintels longer than 40 feet
- Approximate weight of the panel should not exceed 40 tons
- Leave at least 18" between panel openings
- The bottom of the panel should be at least 8" below the floor
- The types of corners (mitered or overlapped)

These are the most important considerations during the panelization of the structure. See Appendix E for panelized drawings of the distribution facility. Once the building's exterior façade has been panelized, a panel schedule is developed in order to facilitate future activities. See Appendix F for a panel schedule of the distribution facility divided by area and elevation.

6.7. *Analyzing the Casting/Lifting Surfaces*

Typically the floor slabs act as the casting surfaces for the tilt-up panels so additional analysis is required in order to check the structural integrity and design of the existing slabs. As a 'rule of thumb' the total surface area of the panels should not exceed 80% of the usable floor area. Usually the heaviest loads ever imposed on a slab are during the construction of the building. A 140 ton, eight wheeled truck mounted crane lifting a tilt-up panel can apply loads in excess of 200,000 lbs per tire on the floor slabs. Most industry designers/constructors recommend a 6" reinforced slab due to its increased

load carrying capacity. If a 4" or 5" slab is used, it is recommended that the slabs are thickened along the travel path of the crane and concrete trucks. Additionally, the subgrade plays a major role in the load bearing capacity of the slabs. The subgrade should be comprised of a granular, non-expansive soil compacted to at least 90%. Tilt-up contractors claim that the applied crane loads are able to be carried by a 6" reinforced slab with a properly designed and installed subgrade.

The subgrade and floor slabs of the distribution facility meet or exceed the industry recommendations. All of the interior slabs are 6" reinforced concrete with 6" of compacted aggregate subgrade and the exterior slabs are 8" reinforced concrete with 8" of compacted aggregate subgrade. Slab surface tolerances should be limited to F_F25/F_L30, which is the generally accepted standard. Currently the interior and exterior slabs do not comply with the general criteria due to the slab drainage design, but can be easily redesigned to meet the drainage requirements and slab surface tolerances. Figure 12 below is a section detail of the exterior concrete slabs.

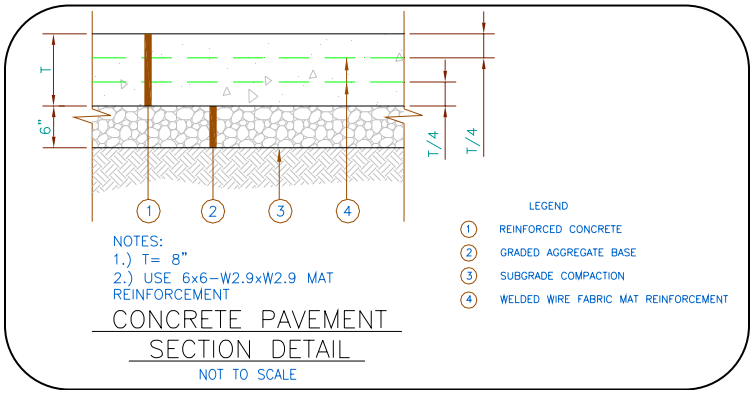

Figure 11: Exterior Concrete Section

6.8. *Panel Layout*

Planning the layout and forming sequences of the panels are fundamental components of the tilt-up construction process. Initially the tilt-up panels should not occupy more than 75%-80% of the total floor area. This allows for machinery, equipment and workers space to maneuver around the area. If tilt-up is to be used for a project where the panel area exceeds the floor area there are a couple of planning options that will allow for the use of tilt-up such as:

- Casting the panels outside the building on temporary casting slabs
- Stacking the panels (casting one panel on top of another)
- Perform multiple casts from the same casting area
- Cast panels on top of one another

Panels are typically cast exterior face down allowing architectural finishes to be applied to the panels easier. Casting panels from outside of the building takes more time because the panels would have to be rotated 180° in the air placing the rigging equipment out of view of the crane operator.

Determining where to cast the panels takes a great deal of planning and should include the general superintendent, the crane subcontractor, the tilt-up contractor and the crane operator. Together each team member will be able to help identify problem areas and develop an efficient solution. Developing an efficient layout will take several iterations but the benefits will be apparent when the casting and lifting process begins.

6.9. *Panel Forming*

Planning the panel forming is the next step in the tilt-up construction process. The physical act of forming, reinforcing and pouring the panels should be performed by a reputable tilt-up contractor. Once the panels are poured, fixing careless errors will negatively affect the budget as well as the schedule. Developing and using forming and pre-pour checklist will ensure good quality control. Average contractors can form, reinforce and pour between 8 and 12 panels per 8 hour period.

6.10. Lifting, Setting & Bracing Panels

The day the life occurs is considered "the day of truth" because any errors in overall panel dimensions will become readily apparent. Dimensional errors at this stage of the process slow down or even stop erection and eventually increase costs due to the reduced productivity.

CRANE SELECTION

Selecting the right equipment for the job is an integral part of the construction process. The most common type of crane used for tilt-up erection is a 140 ton truck mounted crane. The lifting capacity of the crane should be rated for two times the weight of the heaviest panel. Using the panel schedule for the FedEx Ground facility, the heaviest panel is 40.1 tons and utilizing the factor of safety the minimum lifting capacity of the crane should be at minimum of 80.2 tons. A typical 100 ton crane is capable of lifting and setting all of the panels for the distribution facility, although a larger crane will allow for an extended working radius. Using a crane of this size will not overstress the 6" interior slabs or the 8" exterior slabs.

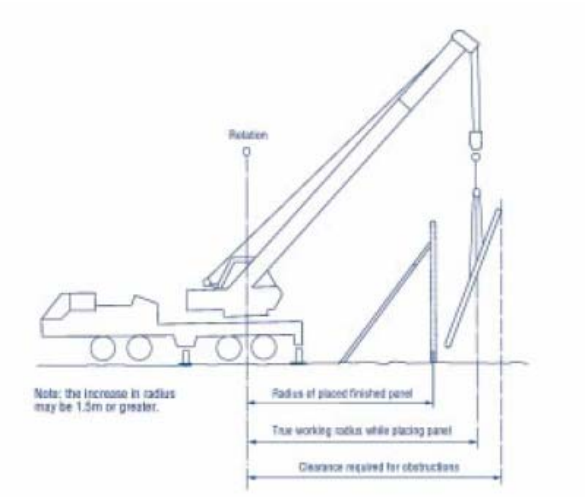

Figure 12: Crane Lifting Parameters

LIFTING, SETTING & BRACING

Lifting and setting the panels should be performed by an experiences rigging and setting crew. During the lifting process the crane operator will utilize a variety of lifts such as tandem picks, suitcase picks and a reverse picks that facilitate the lifting process. Each lift has its own specific use. The preferred typical lifting method will allow the up side of the panel to be in view of the crane operator at all times. The lifting schedule should

cater to this type of lift for quick and efficient erection. Once the panel is lifted, it needs to be set into its final position. Typically the panel will be placed without remobilizing the crane but sometimes it is necessary to "walk" the panel to its final destination. This process is time consuming and dangerous and should be avoided whenever possible. Before the crane releases the set panels, temporary braces must be installed in order to prevent the panels from blowing down during high winds and to hold the panels in position until the roof is installed.

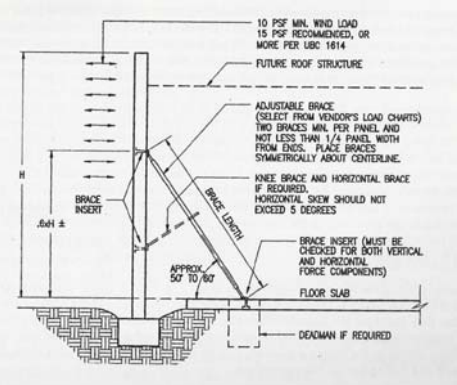

Figure 13: Panel Bracing Example

6.11. *Conclusion & Recommendation*

This analysis was a preliminary investigation into the use of tilt-up construction in lieu of a pre-engineered metal wall system. Initial research analyzed the following:

- Basic tilt-up system overview
- Feasibility Review
- Construction schedule overview
- Site analysis
- Foundation analysis
- Casting and lifting surface analysis
- Basic panel layout and forming

The current building and site parameters allow for easy adaptability of a tilt-up system. As a recommendation, tilt-up is a feasible alternative system and further analysis is required to determine the cost and schedule impacts of the proposed system.