Schedule Efficiency Associated With the Tilt-Up Construction Method: Case Study

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Tilt-up is an efficient method of construction means and methods that is best suited for large, flat projects such as commercial warehouses and distribution centers. The hypothesis is that this method of casting wall panels on site, and then tilting them upright, allows for certain unique activity sequences which could provide faster project completion. In order to prove this theory, analysis of two tilt-up projects completed within a mile of each other by the same contractor, and assessment of their schedules, will provide insight into the specific tasks that allow for better delivery speed. This methodology paired with interviews of team members, showed that successful scheduling began with procurement, and ensuring that the project team is adequately equipped to handle the scope. The results of the projects schedule comparison demonstrated an ability to form and cast wall panels prior to the walls footing being constructed. This allows for simultaneous completion of wall forming along with footing construction, which could not be achieved in other methods of construction. Following the tilt, roof structure is completed in sections allowing for structure, nailing and roofing to occur concurrently while fire sprinklers, electrical and concrete touch up work are finalized as well.

Key Words: Tilt-up, Schedule, Concurrency, Sequence, Panels

Introduction

With the growth of online shopping in recent years, and the need for distribution centers and storage facilities, the warehouse is something that many companies desire. Tilt-up construction lends itself nicely to large warehouses, storage facilities and distribution centers for companies like Amazon, FedEx, Target, Walmart and many more. Large, low-rise buildings with open floor space and the ability to incorporate numerous truck docking stations for import and export of product, is the ideal use for tilt-up construction. The process of casting wall panels on top of the building slab, not only saves time and money, but allows for a less complex construction method overall. Extensive formwork needed for vertically cast walls can be expensive and time consuming, so the ability to use minimal formwork for buildings substantial in size, is one of the reasons for these savings. If an owner wants a concrete building, tilt-up is a method that will provide many options in wall panel design that can be custom tailored on site to adjust for any architectural and structural need, including seismic.

The process of field cast tilt-up construction will typically involve the same or very similar technique across several projects. The first step involves forming and casting the buildings slab, then on top of the slab, the wall panels are horizontally formed and cast. This process involves a good deal of preconstruction work, in order make sure the panels will all fit on the slab, in a location that allows them to be easily set into position. The actual lifting of the wall panels will be done by the use of a crane in order to set the panels in place. Each panel will have steel embeds at its base which will line up with embeds in the footings, and be welded to improve the connective stability. Steel embeds are also incorporated at building corners along the vertical side of the panels, which are welded after erection. To keep the panels in the upright position until they are fully secured, diagonal steel braces are attached to the wall panels, and connected to the buildings slab to provide support while they are unstable. These braces can be extended or retracted prior to removal to ensure panels are plumb and aligned correctly. The connection points on the panels and slab will eventually be patched prior to project close-out. Once in place, the columns, girders and beams will be installed and finally the roofing.

This general order of activities is constant in almost every tilt up project, but in order to determine the most efficient schedule and project delivery, the sub-parts to the schedule need to be looked at, as well as factors such as procurement. Sequencing a schedule correctly is pertinent for successful construction, and with tilt-up operations, many activities can happen simultaneously with the ability to trade stack which refers to having different subcontractor trades carry out their work at the same time. The reason this is possible is mostly attributed to the size of the projects with tilt-ups often being more than 50,000 SF. This allows for activities to happen at different ends of the building prior to other activities finishing. Many tilt up buildings are not more than two stories with the most common being one story with possible mezzanines, so there are not schedule restrictions caused by lower levels not being ready for subsequent actives.

Scheduling is an incredibly variable aspect of construction, as there are many factors that can affect it. Putting more money and larger crews at any project will increase the speed, yet while owners care about fast projects, there is usually a threshold of what they will be willing to pay for quicker work. This brings in the idea of the golden triangle; time, quality and cost which is illustrated in figure 1. The schedule can be quick with cuts to quality and inflated cost, yet this is not often what is desired, yet instead a balance of speed along with quality and cost. Due to this clear linkage between more money and more speed, for the sake of this case study, the cost will not be addressed thoroughly. It would be an easy conclusion to say that putting more money towards scheduling will make it faster, so instead, the actual construction activities and sequencing of the schedules will be the larger focus.

Figure 1. Time, quality and cost diagram

Literature Review

Generating a project schedule for a specific building can be approached from many different angles, as there are many factors to consider. Different building types and construction methods will require unique approaches based on material availability, labor, feasibility and sequencing. When constructing a tilt-up building, the flexibility of activity sequencing is critical to understand what tasks can be adjusted to save time. When attempting to achieve the best, and fastest schedule for the project, inflexible constraints are activities whose position in the schedule is not able to be manipulated, or repositioned to save time (Echeverry, 1991). For example in a tilt up project, an inflexible constraint would be the inability to begin hanging steel trusses until the wall panels have begun to be tilted. There is no possible way to begin installing the roof structure without the walls being upright, so stacking trades in this period of construction will not provide more speed. Echeverry's analysis of schedule components being manipulable, is consistent with the line of research of this paper in attempting to uncover what these activities are in a tilt-up project.

On any given tilt up project, various scheduling methods and theories could be implemented, or certain fast-paced sequences developed, yet without the proper management and oversight, the ideas on paper are simply ideas. With many large and fast projects, managements ability and involvement is a large determinant in whether or not the project can be delivered on time, or ahead of schedule (Kog et al, 1999). In fact it was determined from this research that the involvement of the PM, and frequency of meetings to address the schedule were the top two determinants in improving schedule efficiency. The project team will certainly make or break a projects schedule depending on their involvement, and ability to observe when time can be gained, or activities could be condensed.

Of course this factor is only somewhat controllable as every project will vary based on experience of the project team, and overall involvement with the project. While the tilt-up method of construction, from a wholistic view, is a somewhat simpler approach comparatively to other styles, a project manager and team experienced in the field will be able to deliver a faster project. Even with the best plan in place, and the perfect sequence of activities laid out, the team is what will be able to make the difference in speed.

That being said, the plan or method of scheduling should not be overlooked, and should be carefully crafted and maintained, in order to give the best chance to the project for being completed on schedule. Both projects looked at in this case study were delivered via the critical path method (CPM), which is commonly used in many construction projects. CPM scheduling involves first performing a forward pass with the schedule determining earliest each activity can start and finish, then looking from back to front to determine the latest each activity can start and finish. This uncovers activity float, which is quantified in number of days, and states the amount of time an activity can be delayed without affecting the overall finish date. The activities with no float are then determined to be critical path (Lu & Lam, 2008). These critical path activities would fall into the category of inflexible constraints.

In a survey of 65 of the top 400 contractors done by Dr. Patricia Galloway, it was uncovered how many contractors view this method and how they use it. From the survey it was found that over half of contracts typically require CPM scheduling, with almost 70% of contractors stating they prepare a CPM schedule even when it is not required. The main benefits seemed to be the ability to control work after the start of construction, develop look ahead schedules and coordinate subcontractors. CPM allows activities to be adjusted, or resources allocated accordingly depending on how they affect the critical path.

Looking more specifically at tilt-up projects, Silungwe & Luwaya put forth an article regarding the feasibility of tilt up construction for commercial projects, yet their data is somewhat surface level. They found through their research that, "Tilt-up construction was only beneficial in terms of time" and that tilt-up "can only be used when time is of much significance than cost" (Silungwe & Luwaya, 2020, p. 145). The main reason they presented for this perceived ability to be quicker than steel or precast buildings, had to do with the lack of vertical formwork that would make for a tough, and time consuming forming process. The paper also discusses the, "advantage of incorporating openings for doors, windows, service and generic openings alike before the panel can be lifted into place" (Silungwe & Luwaya, 2020, p. 142). Also mentioned in the article was a tilt-up project in Mansfield Texas that was able to be completed two weeks ahead of schedule due to the tilt-up process, as well as a statement from Jay-Ton Concrete in Tennessee regarding the timely completion of projects when using tilt-up. While Silungwe's & Luwaya's data and conclusions show a linkage between tilt-up and speed, the specific components of the schedule are not addressed thoroughly and should be looked into further.

Research Methodology

Since schedules can be so volatile and variable based on situations that present themselves on jobsites during real projects, the best way to address tilt-up construction schedules is through case studies for completed projects. Choosing projects that were similar in scope, location and project team for this case study was a large factor in making them easy to compare. These projects also did not contain extravagant architectural features, or overly complex panel deigns that could possibly affect the schedule. The projects that will be expanded on are both standard tilt-up construction projects completed one year apart by the same general contractor, less than a mile apart.

The proximity of the projects is helpful to mitigate any delays based on site variability, and any differences from working in different jurisdictions or cities. One of the projects which will be formally known as Project One throughout the paper was completed in 2020 totaling 145,000 SF. Its counterpart which will be referred to as Project Two, was completed in 2019 totaling 89,000 SF. Both projects master baseline schedules were looked at and compared with respect to activity sequencing. In order to further expand on the projects and the tilt-up method, interviews were conducted with a few members of the project teams themselves. The project manager and senior superintendent were on both of the jobs, and in order to get varied point of view, the operations manager of the company who had formally been a project manager, was also included in the interview.

The main desire to conduct this research stems from the potential to save time, or possibly what areas of the schedule could be changed or altered to make them more efficient. This time saved will make owners and clients more satisfied as well as allow contractors more time to pursue other jobs. There are numerous different ways schedules can be altered, and of course safety is always of the utmost concern, and having many trades working in the same area could be a hazard. However if certain activities can be altered or certain aspects focused on, then time, and inevitably money will be saved.

Case Study

The reasoning behind looking into the sequencing and overall schedule delivery compared to other possible methods of construction, is mostly due to the size of the buildings paired with the unique wall casting method. With tilt-up construction being best suited for large one or two story buildings that have a fairly decent footprint, there are many areas in which work for many trades can concurrently occur. Using the schedules for projects one and two, these concurrencies can better be understood. The main focus is the schedule for Project One, and Project Two was used as a comparative measure to ensure there were not any major differences affecting the schedule. After comparing the two, the differences were minimal and therefore, using Project One's schedule backed up by Project Two's, will help discuss the schedule during the procurement phase, concrete structure phase, overhead roofing phase and finally best management practices (BMP) implementation.

Procurement

The main building that was focused on during the case study is the 145,000 SF distribution center which will be referred to as Project One. This distribution center was a fairly standard design and construction process compared to other tilt-up buildings, yet there were a few unique instances that affected the schedule. The first unique instance with this building had to do with the structural steel components with respect to two large moment frames. When it was uncovered that this project included two these steel frames, action had to be immediately taken in order to ensure the schedule was not affected. Now for a general project, steel is a long lead item and it needs to be ordered before any construction is underway, and this is typical for all projects. However with these moment frames being a little more unique than usual, both the superintendent and project manager on this project discussed in an interview, that they talked with the steel subcontractor prior to even having a contract with them. They both knew that this item if not addressed in the early phases of the project, it would constrain the schedule and affect the desired end date by the owner.

This ties back into the management of the project having a drastic effect on the schedule, as picking up on things like this could make or break the project duration. In each interview in which this project was discussed, long lead items were focussed on heavily. "Once the construction commences, it goes quick, typically only 6-8 weeks until the walls are tilted" (Dave Herson Senior Superintendent). The pre-planning for the projects is crucial as the construction operations move fast, and for the nature of the building itself. Many other methods of construction are this way too since it is impossible to complete work without the intended materials, yet there could be workarounds in other styles of buildings. It was an important item to note when interviewing both the project manager as well as the operations manager, that procurement needs to be built into the schedule. This is something that will affect the schedule greatly since material delivery is what the schedule relies on. Therefore, on every tilt up project every procurement activity, especially for long lead items, was a part of the master schedule.

Concrete Structure

When interviewing Isaac Dye, a project manager from the general contractor of the projects, who is now the current operations manager, they discussed many unique sequencing aspects of tilt-up construction that we can see applied to both project one and two. One of the main points of focus that Isaac brought up had to do with using the critical path method (CPM) to the advantage of the project. These buildings are reliant on the slab, as all of the building work occurs from that point on, so its critical that the slab is cast as soon as possible to then allow for walls to begin being formed, and eventually cast. This aspect of tilt-up allows the buildings footings to be a potentially time saving element.

Tilt up construction utilizes two types of footings for a given building; spread footings which are under the building slab and are used to support the interior columns, and a continuous perimeter footing. Both of these tasks are time consuming and take significant manpower as each will involve excavation, rebar installation and a concrete pour. However, the spread footings which rest underneath the buildings slab, are tied to the critical path of the project because of the slab being needed to cast and eventually tilt the wall panels. Organizing the schedule in a linear fashion by pouring the perimeter footing, then pouring the interior footings, and finally the slab, should be adjusted to instead sequence these events with overlap.

This new sequencing would prioritize the interior spread footings in order to complete these the quickest, and get the slab poured. Then the continuous footing could wait to be complete right up until the actual tilt date in the schedule. This means that the interior footings will be done allowing the slab to be poured and wall panels beginning to be formed and cast in order to achieve the desired tilt date. Then, simultaneously while the walls are being completed on the slab, the continuous building footing can begin to be worked on which can be seen below in Figure 2.

This is only possible through a tilt up construction method because usually the footings will have to come first no matter what, as the entire building will rest on top of it. However, in tilt-up construction, the footing which the walls will rest on, is not needed until the day of the tilt. Until then the walls are lying face down on the slab with the perimeter footing lying outside the building.

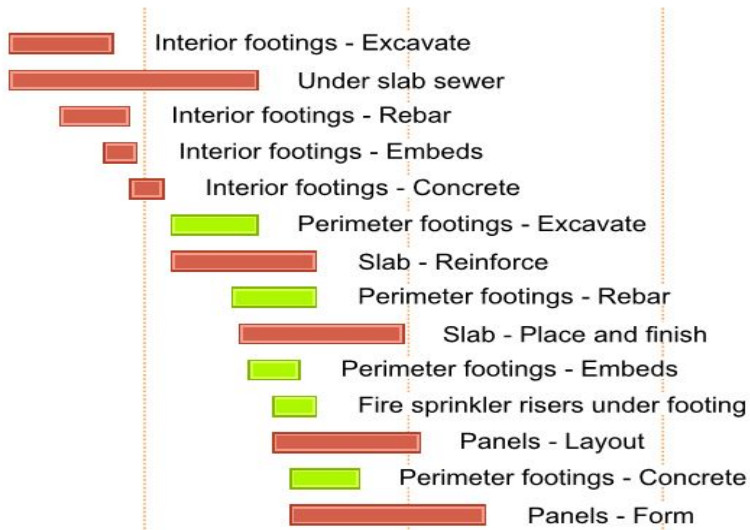

Figure 2. Project One slab, footings and panel construction

The perimeter footing lying underneath the walls can now be thought of as a flexible schedule constraint as it can be shifted to save time unlike many other construction methods where it is imperative that it comes first. Now in the interest of efficiency and time, it would not be common to delay the start of the perimeter footing until the last possible second, even if it could be done, but instead completing the interior footings then beginning on slab rebar and concrete while the perimeter footing is being excavated and tied with rebar. It can be seen in figure 2 with the interior footings complete, the perimeter footing was scheduled to begin while simultaneously having the building slab begin receiving rebar. It was not until the wall panels were midway through being formed on the completed slab that the perimeter footing received concrete. It can also be noticed that all of the tasks associated with the perimeter footings are in green indicating they are not critical path and could be delayed if necessary. This was the original contract schedule for Project One and looking deeper into the as built schedule of the project, there are some changes that can be addressed.

The as-built schedule, or the final schedule of what actually occurred for this project, has some differences as well. This is not out of the ordinary and in fact would be unusual if the baseline schedule that was the original path was held to without any change at all. Each job is unique and Isaac Dye stated that during a job, "you may see a faster way to do something" which with the critical path method, can be achieved. Overall however the sequencing followed the trajectory of the baseline contract schedule, and the main differences came from minor duration changes in single tasks based on labor variations as well as minor changes in dates due to weather, as well as owner changes. For this paper, the baseline schedule of the project is accurate and relevant to the topics addressed and will provide the necessary data moving forward.

Roof Structure

Once the walls have been erected and are in their final upright position, a number of concurrencies begin to present themselves in a heavy fashion. The tilt date on these projects was critical and had to be met without question due to the availability of the crane, and the critical path relying on it. This is also the case because of what follows the tilt date, and how quickly the project moves after the walls are up. Senior Superintendent Dave Herson discussed in an interview how they the tilt date from the contact schedule, then using the help of the CPM, will adjust the schedule on site if necessary in order to make the tilt-date with no exceptions.

One of the larger reasons for this ability to have concurrency of work relates back to the typical size of these buildings and the ability the have the required space for each trade to complete work simultaneously. Isaac Dye stated that the buildings are divided into sections at this point, and roof structure along with subsequent tasks can be completed in segments since the building is so large. For instance, as seen in figure 3 below, roof structure section 3, roof nailing section 2, and roofing section 1, all begin on the same day as each other. Meanwhile while the roof structure and its other components are being completed, underneath, other trades are completing their scopes of power and lighting.

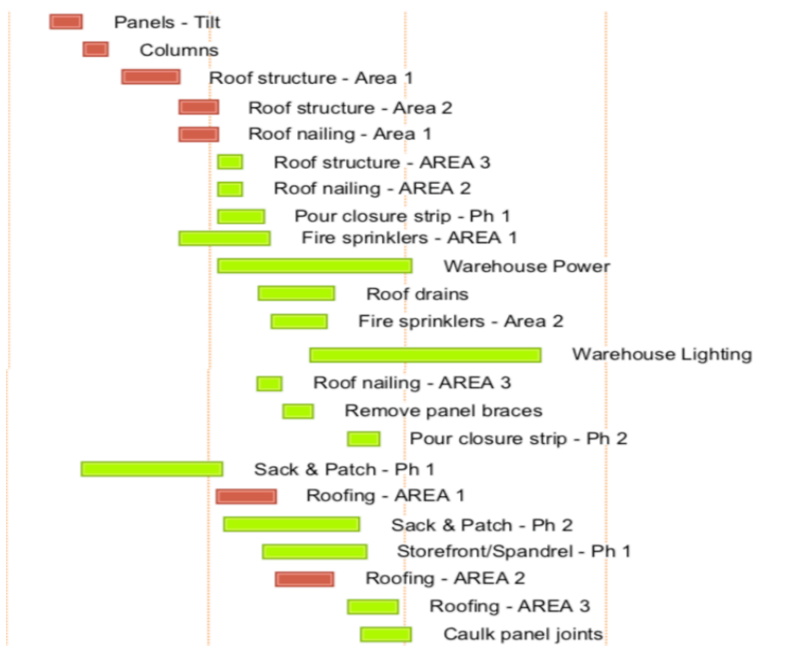

Figure 3. Project One overhead work and concrete touch up.

Other tasks are also happening concurrently with the roof structure such as the closure strip as well as the sack & patch. The closure strip is a concrete strip usually around 4 feet wide running the length of the building which locks the building slab and the wall panels together in place. Sack & Patch is the process of cleaning the panels and repairing any damage on the inside and outside such as holes from the braces and pick points. The vertical yellow lines in the figure below represent one month intervals, so it can be seen that after the wall panels are completely done being tilted, in a span of just over 10 weeks, the entire roof is closed off and the final tasks such as paint can commence. This sequence and concurrency of trades working on different sections of the buildings all at once can show just how important the tilt date is for a project of this caliber.

BMP Implementation

As Kog discusses, the top two key determinants for a successful scheduling of a construction project have to do with the involvement of the PM, and the frequency of meetings. This was also mentioned in one the interviews conducted with operations manager Isaac Dye as well as with project manager Nick Graham. The BMPs that they wanted to make sure were incorporated were to first, start with a realistic schedule. It does no good to a project to have such a fast schedule planned when the project team knows they can not carry it out. Starting with a feasible schedule will allow the team to more easily make up time if the opportunity becomes available, rather than if they are already up against the wall. More importantly it was stated that weekly project meetings and weekly master schedule updates are crucial.

Updating the master schedule weekly will show a realistic view of where the project is headed and if time needs to be gained. Senior Superintendent Dave Herson uses this master schedule to make his weekly three week look ahead schedules that will be distributed to all of the subcontractors and parties involved. The reason then that the weekly schedule update by the PM is important, is because that will affect these look ahead schedules if incorrect. If the look aheads are made using the baseline schedule, then activities could be off as they may be at different points. This is where the communication of field and office team member is crucial and the overall involvement of the team plays a large role in keeping the project on schedule and running smoothly.

Conclusion

Combined with the research of the schedules, along with the interviews conducted with industry professionals, the reasons for some of the unique efficiency aspects of the schedules were presented. Below in figure 4, a sample project schedule for a tilt-up building that has a 100,000 SF footprint can be seen. This shows a highly condensed project schedule illustrating the topics discussed in the paper, and showing the concurrences that are available with this construction method.

It was seen from the schedule figure 2, that the perimeter footings being able to be non-critical path, allowed for the unique ability to complete this task concurrently with slab and wall construction. If for some reason the project needed to pick gain time or was behind schedule, this is an activity with a large scope that could be manipulated within the schedule. Being able to alter the location of wall footings in the schedule is something that could not be done with many other methods of construction, as the footings usually need to come prior to the walls.

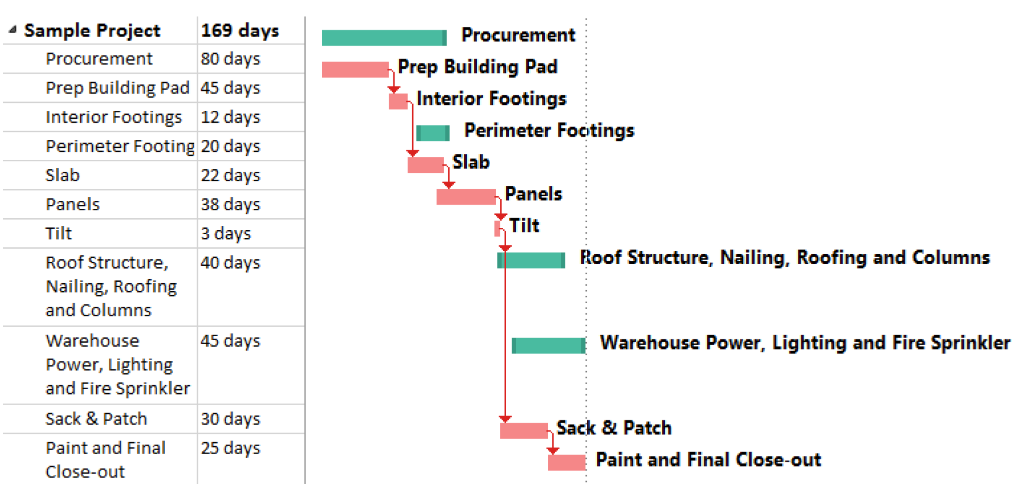

Figure 4. Sample Project Schedule

Another reason for a fast-paced construction schedule has to do with the amount of activities that occur following the tilt-up of the wall panels. With tilt-up construction projects having a large footprint, the overhead and roof activities can happen at the same time. The roof structure, roofing, and roof nailing, along with fire sprinklers and warehouse power are all happening on top of each other instead of having to work in a more traditional method from bottom to top, and finish with MEP work. Many of these tasks are not critical path either which opens up the opportunity to shift the tasks if needed. The most efficient tilt-up schedule for a project around 120,000 SF can be seen below based off the research that was conducted in this paper.

Future Research

With this avenue of research conducted, many factors that may affect the schedule of a tilt-up project were not addressed. The focus here was towards sequencing of activities, and trade concurrencies that will affect the schedule and which may differ from other methods. The site work was also disregarded for the purpose of this case study, mainly due to the differences in various sites, whereas the tilt-up building is fairly constant from project to project. With this being said, there are new avenues with which could be investigated deeper in having impact on the schedule.

To begin with, cost. Price is an incredibly important factor in affecting a project as a whole. A possible area of research could be the investigation of different cost allocating procedures, and whether or not funneling a higher percentage of money towards certain aspects of the project, while minimizing budgets for others will have a dramatic effect on the schedule. The concept of value engineering can be considered for this method of construction as well. Value engineering isn just simply a way to save money by cutting corners, but rather the opposite. This method will provide quality projects, while also saving the owner money, and possibly affecting the schedule. Furthermore, a comparison of a building similar in scope and size, yet varying in method of delivery such as a steel framed, or CMU building, could provide further insights on various schedule efficiency factors.

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