BUILDING A PRECAST BRIDGE IN 19 DAYS

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ABSTRACT

The Ohio Department of Transportation (ODOT) created Strategic Initiative #9 to "Build Bridges Smarter, Faster and Cheaper". One project undertaken by ODOT was to use a precast, post-tensioned slab bridge in place of a cast-in-place slab bridge. The bridge was longitudinally post-tensioned for continuity and also laterally post-tensioned. To accommodate school schedules and a festival, the bridge was to be completed in 16 days. The bridge was actually completed in 19 days. Delays were due to weather, equipment problems and confusion over plans/specifications. This project was generally considered a success and this paper highlights issues which lead to success. Among these were a successful partnering between ODOT and the contractor, a high level of up-front planning, using precast members so that the deck could be fabricated without closing the bridge and moving tasks within the schedule so that they could be completed before the bridge was closed or after the new structure was opened. The paper also details the problems and suggests remedies. One problem was that the contractor overlooked special provisions in the specifications. It is suggested that such provision be more clearly flagged. There was a lack of contingency plans for equipment failures. Some unexpected issues were overlooked in the planning phase. It was also noted that problems, which are normally not critical (such as delivering the slab units in the wrong order), become critical in an accelerated project.

Keywords: accelerated construction, bridge, concrete, post-tensioned, precast, slabs

INTRODUCTION

Ohio has one of the largest highway systems in the United States. It also has the 10th largest highway network, the fifth highest volume of traffic, the fourth largest interstate network, the fourth largest amount of freight shipments and the second largest inventory of bridges. Since the mid-1990's, the Ohio Department of Transportation has made maintenance of traffic in all bridge projects as delays from construction have far reaching economic impact. To this end, ODOT instituted Strategic Initiative #9 (SI-9) "Build Bridges Faster, Smarter, Better" in an effort to speed the construction of bridges and reduce delays. This paper discusses one of the SI-9 projects.

DESCRIPTION OF THE PROJECT

The first bridge chosen for the SI-9 program was GUE-513-1.80 located in the town of Quaker City, Ohio (approximately 50 miles east of Columbus). The existing bridge was a 2 span, concrete slab bridge, with each span being approximately 30 foot long. The superstructure was to be replaced, but the existing pier and abutments were to be re-used after repair. Another slab bridge was the logical replacement structure.

This bridge was chosen for rapid replacement. Because the site is in a rural area, the detour was approximately 25 miles for cars and 40 miles for trucks and large busses. Local officials were concerned about detouring school busses over this long distance and wanted the bridge built after the school year ended and with as little interference with the summer school term as possible. Another major factor in the decision to accelerate the construction was a festival held in Quaker City each summer. The festival is a major revenue source for the local community and it was desirable to have the bridge completed before the festival.

The engineer decided to use a post-tensioned, adjacent concrete slab unit for the superstructure. The rail would be precast concrete as well. Figures 1 – 6 show the details of the bridge structure.

It was recognized that accelerating construction was not simply a matter of using precast elements which could be assembled quickly. Careful planning and changes in "normal procedures" were also needed.

PRECONSTRUCTION MEETINGS

ODOT normally holds preconstruction meetings on all projects. For this project, ODOT and the contractor used the meeting to discuss potential problems before construction started. To assure there was enough time to resolve any potential problems, the meeting was held 6 months before construction was to begin.

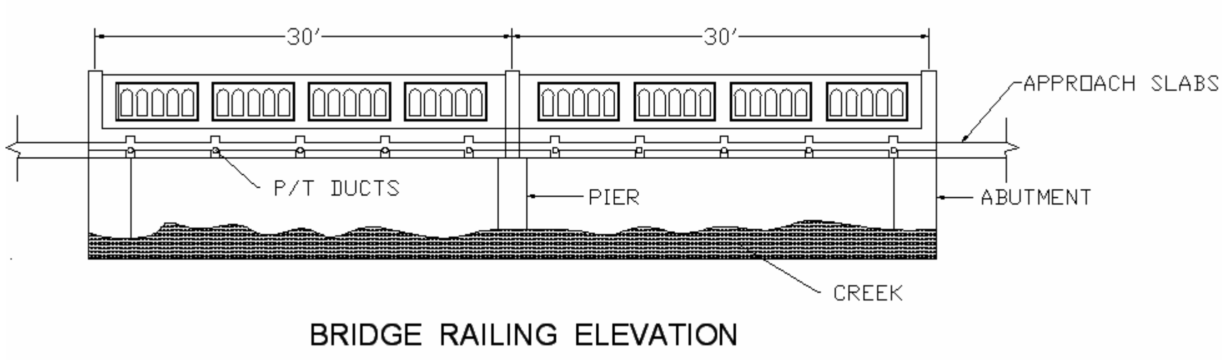
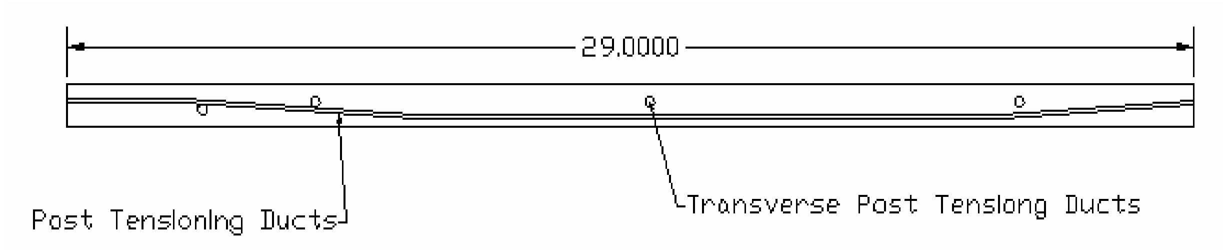


Figure 1 - Elevation of the Replacement Structure



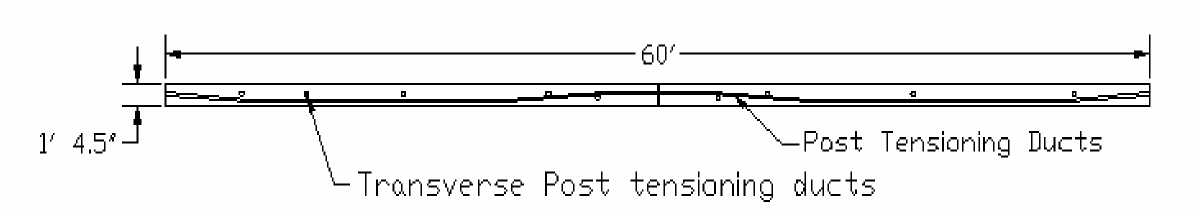


Figure 3 - Longitudinal Sections of the Deck. Single Panel (above) and Entire Length (below)

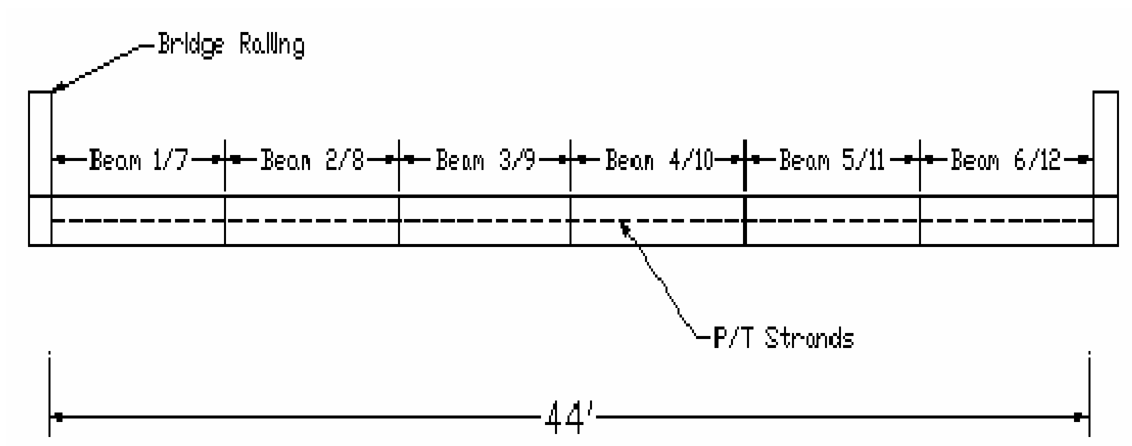


Figure 3 - Cross Section of the Deck

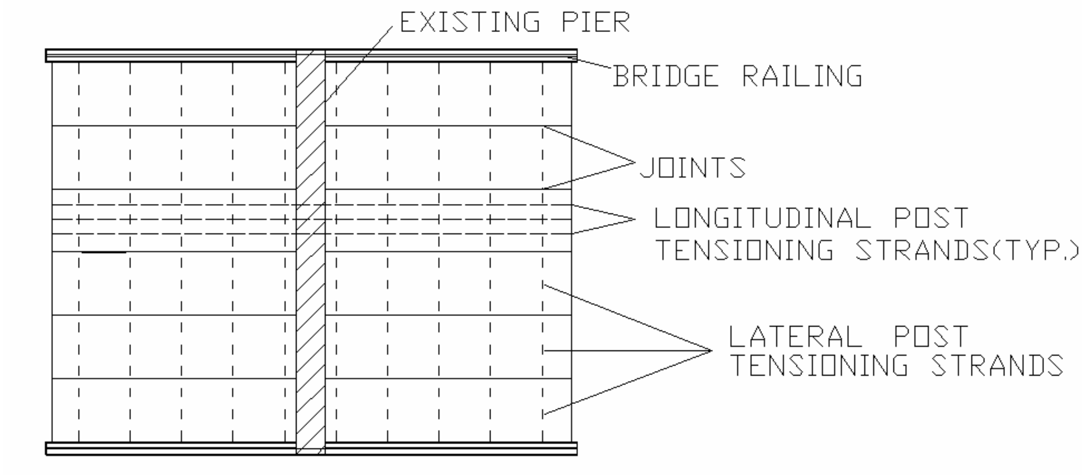


Figure 4 – Plan View

Figure 5 - Typical Panel

Figure 6 - Panels in the Yard – Mock-up Test

Bridge construction was a fast tracked process to be completed in 16 days with work being scheduled between June 16th and June 30th, 2003. The proposed work included the following:

1. removal of portions of existing concrete deck, sidewalk, railing and substructure units
2. construction of new portions of a cast-in-place abutment and wingwall;
3. setting of the precast bridge units, precast approach slab and precast railing;
4. grouting of the beam seat areas and the areas below the approach seats;
5. grouting the shear keys;
6. lateral and longitudinal post-tensioning;
7. grouting post-tensioning tendon ducts;
8. grinding and grooving the final riding surface;
9. placement of the sidewalk concrete
10. epoxy coating the sides of the fascia girders and general clean-up.

The meeting was attended by representatives from ODOT, the general contractor, the post tensioning subcontractor, the precast fabricator and the design engineering firm. Among the issues discussed were:

1. The contractor intended to employ two work shifts of eight hours each and work 7 days each week. Quaker City has a noise ordinance which would preclude

this. Since this was to be a short duration project, ODOT indicated that it would approach local officials and neighbors affected by the noise and secure permission to work the needed hours. One unusual condition was noted. There was a funeral home next to the bridge and it would be necessary to curtail noise if there was a funeral being conducted. Since this was an unlikely event (given the size of the town) and since it was also unpredictable, the decision was made to use the proposed schedule and adjust it as needed.

2. The limitation on the contractor was how long he could close the bridge. He asked to be able to saw cut existing slab from the abutments before actually closing the bridge. ODOT allowed this after the contractor had an engineer investigate the issues related to structural stability and safety.
3. The plans required the contractor to conduct a mock up test fit on the modular slab units in the precasting yard (Figure 6). This was to assure the correct alignment of the ducts for the post-tensioning strands. The mock up test would also help in checking the basic fit of the beams as any problems which occurred once the installation began at the site would be difficult to resolve within restricted time frame.
4. It was decided that weather days would be allowed as the contractor cannot control the weather. ODOT rules permit that a weather day is allowed only if less than two hours of work is performed on that day and this turned out to be a critical issue.
5. During both the pre-construction meeting and the mock up assembly, the precaster expressed a concern about the post-tensioning. The normal procedure is to post-tension one or two strands, measuring force and elongation. This data is then sent to the ODOT engineers for verification and approval, which often takes a few days. Such a delay would be unacceptable in an accelerated project. ODOT agreed to have engineers on site to verify the post-tensioning.

MOCK-UP TESTS

Special provisions in the contract provided for a full mock up test for the bridge assembly in the yard before the final assembly on the site (Figure 6). This requirement was included to check for proper fit-up and alignment, and to verify that every beam unit was constructed in compliance with all plan requirements. The contractor was to use blocking to stimulate the beam seats elevations at the abutments and pier. Unfortunately, no one remembered that the bridge had a slope and the blocking was not sloped. This became an important issue during construction. Post-tensioning cables were installed in all the decks (but not tensioned) to verify duct alignment.

CONSTRUCTION

The construction work began as scheduled on June 16th , 2003 and was completed on July 3rd. This was 3 days behind the original plan of completing work by June 30th. The significant delays were:

1. The contractor had intended to work two 8 hours shifts per day. The contractor actually worked a single shift each day which averaged about 12 hours day. This has the effect of losing 4 hours per day of work and increasing labor costs as the contractor must pay time and a half for the extra hours. The contractor cited two reasons for this. There was dead time in the day (e.g. waiting for grout to cure) and there wasn't justification for the additional shift. It was better to employ a single shift for however many hours were needed each day. The contractor also thought the overlap time between shifts would be too long. The supervisors would have to explain, in detail, every aspect of the work to the incoming supervisor. The incoming supervisor would then have to repeat the process with the workers. This is a time-consuming and tedious process. For each shift there is always some start-up and finish-up time (e.g. getting out or putting away personal tools). The contractor determined that a single shift would be most efficient.
2. Some of the delay was due to rain, which occurred on 3 different days. This pointed out a problem with the current ODOT rules. Current rules allow a weather day only if the contractor works less than 2 hours. This presents some incentive to the contractor not to work if he cannot work the entire day. Since the contractor was working extended shifts, the number of hours lost could be significant. In a fast track situation, it is to ODOT's advantage to have the contractor work as many days as possible, even if it is only partial days. Fortunately, ODOT used a partnering system. When a situation like this arose, the contractor and ODOT representatives met to find a mutually beneficial solution. As a result, ODOT granted some relief for weather even if the contractor worked more than 2 hours in a day.
3. Some of the delay was due to equipment problems. On the first two days the track hoe used to break up the old concrete broke down. On the 10th day, there were problems with a crane. These delays could have been avoided by reserve equipment available, but it is not clear if this would have been cost effective. An essential part of the fast track process is a cost-benefit analysis of the cost of reserve equipment and probability that reserve equipment will be needed.
4. The deck on the old structure was removed by using a rock drill, which was a time consuming process. It was suggested by the site supervisor that saw cutting the deck and then removing it with a crane might have saved time.
5. On day 5, the wrong deck units were brought to site. This caused a delay until the correct units were shipped. This would not have been much of a factor on a normal job, but it was important on an accelerated project. This shows the need to verify all shipments in these cases.
6. Field verification problems also caused delays. The plans of the bridge did not mention in detail the exact amount concrete which needed to be removed from the wing walls. The contractor also neglected to mark the centerline of the existing bridge before removal. This was a problem because the new deck was not centered on the re-used pier and there was some confusion about the placement of the new deck. A surveyor was brought to the site to determine the centerline, but

this caused a delay. It is always important to verify site conditions before construction, but for an accelerated job it is even more critical.

7. As noted in the section about the mock-up, a problem occurred during the placement of the beams. The mock up test was carried out on flat ground, but the abutments were sloped and this was not accounted for in the mock-up. Significant adjustments were needed for the correct alignment of the beams on site, requiring some “field engineering” of the shims. In the end, wood shims were used, which ODOT normally would not allow. This points outs a significant risk in accelerated construction. When problems occur, the owner must often choose between delays or less than optimal solutions to problems. The alignment problem also occurred with the PT ducts. The ducts were aligned perfectly during the mock up, but on site it took some effort and time to get them in line.
8. The grout was a problem. The type of grout needed for the shear keys (between the girders) was specified in the contract as a non-shrink grout with a minimum strength of 6000 psi prior to transverse post tensioning. Exposed concrete surfaces at blockouts and recesses had to be treated with a bonding agent prior to filling. However, it appears that parts of these provisions were overlooked by the contractor in the initial bid phase. The contractor then had to work quickly to find a suitable grout. The grout initially chosen by the contractor was not on ODOT’s list of accepted grouts and so it was rejected. A second grout was chosen from the approved list. The grout took almost twenty hours longer to set as compared to the one chosen by the contractor (this contributed to the contractor’s decision to use one shift). The grouting company was not familiar with the type of grout used and had difficulty working effectively with the grout. The grout did not come up to the required strength, although there were questions about whether the grout testing was done correctly. Normally, the grout between the beams is not an issue. The inspector verifies that the grout is mixed to the manufacturer’s specifications and the grout is then poured into the keyway. On a typical ODOT design, the grout is covered by waterproofing and asphalt or a cast-in-place composite deck. Since the grout is covered, no additional testing is done. For this bridge, the grout joints are exposed so a tighter quality control was needed. Testing procedures for the grout were available, but since the grout is usually not tested, no one thought to bring the testing equipment. Make-shift cylinders made of plastic pipe were used for specimens. In addition to the testing problems, the grout shrunk after curing and the cracks in the joints had to be sealed with high molecular weight Methacrylate (HMWM).
9. The bridge was designed to use the top surface of the beams as the final riding surface. After placement, post-tensioning and grouting, the tops of the beams would be ground to profile and grooved. However, the lifting lugs and post-tensioning grout tubes protruded from the top flanges of the beams. No one thought to leave dish-outs around these protruding elements so that the contractor could cut them back below the final riding surface. As a result, the contractor had to create these dish-out by jack-hammering them into the top flange. The protruding elements were cut back and the dish-out was covered with grout.

The contractor completed work such as site clean-up, sealing the sides of the beams, etc., after the bridge was opened. This is an exception to the normal A+B contract and was made to allow the bridge to open. This exception was in the spirit of the accelerated construction philosophy. The key was to get the bridge open as soon as possible, even if the overall project time was not shorter. Figures 7-10 show bridge construction.

Figure 7 - Placing the Deck Slabs, Transverse PT Ducts are Visible

Figure 8 - Slab Placement - Longitudinal PT Ducts Are Visible

Figure 9 – PT Ducts

Figure 10 – PT Tendons

Figure 11 – Post-tensioning

Figure 12 – The Completed Bridge

POST CONSTRUCTION

The completed bridge is shown in Figure 12. An essential part of the SI-9 project was to hold a post-construction meeting to determine what worked and what needed to be improved. This meeting was attended by representatives of the ODOT, the prime contractor, various sub-contractors, the design engineer and the research agencies.

The first issue raised was the grout. The engineer specified a fast-set grout without determining specific products which could be used. He later stated that he assumed the contractor would do some research on the grouts available. Unfortunately, unusual grout specification was not clearly flagged in the contract documents and contractor missed it. This created a problem as the contractor did not account for the unusual grout in the bid and there were delays because the contractor did not have an acceptable grout when the project started.

The contractor wanted to use a quick setting grout which was not on ODOT's approved list. ODOT denied the contractor's request and asked the contractor to use a grout on the approved list. All of the approved grouts required at least 24 hours to set. As previously noted, waiting for the grout to set caused a delay. The Contractor suggested that ODOT should either add more materials to the approved list or completely do away with it; perhaps replacing it with a performance based specification. Giving the contractor greater flexibility may help in cutting down the construction time.

It was also noted at this meeting that a partnering relationship developed between the ODOT and the contractor. All parties noted that this was very helpful in getting work done quickly and amicably. The role of the project manager also came up. It was observed that it is usually difficult to contact or seek immediate advice/suggestions from the ODOT engineer or the design engineer. In this project, the manager assumed more of a proactive role and provided the necessary clarifications whenever they were sought. He was also given more authority to make decisions and this helped keep the project on track.

The contractor also mentioned that in a project of short duration like this one, motivating the entire team is a difficult. Tasks cannot be spaced out, but need to performed one after the other and there is no luxury of thinking about the problems. Problems adversely affect the morale of the team.

OBSERVATIONS BY THE RESEARCH TEAM

In the end, the Quaker City Bridge Project was a success. The bridge was completed in 19 days rather than 16 days, but it was still completed within a reasonable enough time that project's objective, having the bridge open for school bus and festival traffic, was accomplished. The research team made several observations:

1) The incentive on the project was $5,000/day, $25,000 maximum. The penalty was $5,000/day. State law limits these values. The research team noted that these are not large incentives or penalties. While these incentive/disincentives will work to speed up construction, they will do so only in a limited way as the dollar values are not that high. In another SI-9 project (PIC-22), the incentives and penalties were much higher and contractor responded by bringing in his best crews, bringing in extra crews, looking for innovative ways to speed up construction, etc.

2) Construction was slowed by equipment break-down. The research team wondered why spare equipment was not available. This requires a risk vs. reward analysis.
3) Grout selection and quality control of the grouting process are major issues. These same issues came up on several SI-9 projects. The issues regarding selection were discussed in the previous section. There is a need to have better QA/QC for the grouting process. Unlike in other ODOT projects where the grout work is usually covered with a layer of concrete or asphalt, the grout in this case remained exposed. It seemed that the need for better grout QA/QC was missed.
4) The fact that the bridge was prefabricated greatly contributed to the speed of construction and post-tensioning it made the design efficient. The post-tensioning was also an issue only because the number of contractors who do such work is limited as is the number of suppliers of post-tensioning materials. The precaster noted that he got no response from some post-tensioning material suppliers when he asked for bids. There is a concern that, in the future, the ability to construct post-tensioned bridges quickly may be limited by available contractors.
5) In a project of this nature the margin of error is very small. There are many ways in which the project could get off schedule. Faulty or broken equipment, inclement weather, shipping delays/problems and material/labor availability could all effect the schedule. The contracting agency could ask for a contingency plan from the contractor even before the project begins. This could offer a certain degree of assurance that even if the project is delayed for unavoidable reasons the contractor is capable of getting it back on schedule.

CONCLUSIONS

The Quaker City Bridge was the first of the series six bridges that will be built in Ohio using innovative techniques, methods and materials to reduce the time of construction. Fast tracking hadn't been used extensively in Ohio before so this was a first time effort for both the contractor and the contracting agency. The project was a success even though it was completed two days later than planned. In the end, ODOT agreed that some of the delays were beyond the contractors' control (such as rain) and the contractor received one day's incentive. Some conclusions drawn from this work were:

1. Partnering is essential. The contractor and contracting agency formed a cordial relationship of partnering. The atmosphere was thus conducive to quality performance. The contractor was motivated to do the job well and on time and the contracting agency was always ready to assist them on the task. The role assumed by the project manager in this project was a proactive one. There were times when the engineer could not immediately be reached. The manager had the authority to make some of the decisions which otherwise would have to wait for the engineer. This kept the work progressing and delays due to the inability to communicate with the engineer were avoided.

2. The design engineer must be aware of local contractor capabilities. The design used was also a first in the state of Ohio. Post tensioning has not been used extensively before and there are just two post tensioning companies in the state. Moreover, the two companies specialize in different materials for post tensioning like rods and strands. If a bridge is to be post tensioned using a particular material there is a complete dependence on one company. This over dependence may lead to complacency on the part of the supplier and any problem faced during post tensioning could adversely affect the schedule. And, strictly adhering to the schedule is of paramount importance in an accelerated project. Thus, when designing it might be helpful to keep in mind the skill of the contractors and the sub contractors and the availability of the materials needed for the construction.
3. Use of unusual specifications must be clearly flagged. There were significant issues with the selection of and the QC/QA for the shear key grout. Most of these issues revolved around the fact the performance of the keyway grout for this project had to be much better than that for a normal adjacent box beam bridge. When there are unusual material requirements, the design engineer needs to be sure that state agency and the contractor(s) are aware of these requirements. Simply adding language to the project specifications is insufficient as this may be missed. Some type of a letter specifically outlining these issues is needed.
4. Morale can be a problem. Since there are difficulties/problems being faced throughout the construction process the morale of the construction team may sag. It is necessary that an effective channel of communication and problem solving mechanism be in place so that so that morale of the construction team remains high.
5. Incentives may not always be sufficient. The contractor bid 14% below the state estimate at $379,000 to win the A+B contract for this construction. The incentive offered was $5,000 per day up to a maximum of $25,000. At the post construction meeting the contractor said that this was a sufficient incentive. However, there is a question as to how much a contractor would do to earn a $25,000 incentive. To earn any incentive, the contractor might have to employ an additional shift of workers, work with additional equipment or keep equipment on stand by so as to offset delays due to equipment malfunction. The incentives may not be large enough to make these options cost-effective.
6. Agency policies may have to be changed to facilitate fast track construction. For example, the ODOT rain delay policy may encourage a contractor not to work on a given day rather than work a partial day.
7. Contingency plans are needed. It would be useful for both the state agency and the contractor to explore "what if" scenarios, e.g. what if the crane breaks down? What if a certain material isn't available? etc. By anticipating problems, the job schedule can be maintained.
8. Use of accelerated construction is not without risks. There is often little time available to determine how to solve problems in the field. When problems occur, the owner must sometimes choose between accepting a delay to allow for careful analysis of the problem and accepting a quick solution which would not have been an acceptable solution in a normal situation.

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