INSTANT BRIDGE – JUST ADD WATER

Nathaniel D. Benoit, PE, Maine Department of Transportation, Augusta, ME
Eric T. Calderwood, PE, Calderwood Engineering etc, Richmond, ME
Wayne L. Frankhauser, Jr., PE, Maine Department of Transportation, Augusta, ME
Dennis R. Hanson, EIT, Technical Construction Inc., Turner, ME
Kenneth R. Heil, PE, Figg Bridge Engineers Inc., Exton, PA
Jeffrey J. Tweedie, PE, Maine Department of Transportation, Augusta, ME

ABSTRACT

This report is a case study on a project under taken by the Maine Department of Transportation in 2004. In September of 2004 the Maine Department of Transportation completed construction of the Andover Dam Bridge in Upton, Maine. The design of the bridge consists of a 65-ft single span, precast, butted box beam superstructure, founded on pile-supported, integral abutments. The bridge is located on a local road in rural Maine, and the use of a long detour and rapid bridge construction techniques were determined more cost effective than the use of a temporary bridge. For this project the use of self consolidating concrete combined with a precast concrete substructure and superstructure enabled the bridge to be constructed while the road was closed for a total duration of 96 hours. This case study discusses the background information, specifics of the new construction, traffic considerations, construction sequence, precast components, and lessons learned by the Department during the construction of this project.

Keywords: Rapid Bridge, Precast Substructure, Integral Abutments, Self Consolidated Concrete

INTRODUCTION

In 2003 Maine Department of Transportation needed to replace an 18 ft wide posted bridge on the East B Hill Road in Upton, Maine. The existing bridge was a pony truss that had been strengthened with steel kickers from the abutments up to the first panel point, at a later date MaineDOT Bridge Maintenance had further stiffened the truss with the addition of two rolled beams at the roadway grade which were then connected to the truss floorbeams. A new, wider structure, capable of carrying all legal loads was needed. Due to the remote location, long detour, small traffic volume, and cost of a temporary bridge, the project was identified after preliminary design as a potential candidate for the implementation of rapid bridge technology. With the national move, and all the hype concerning rapid bridge construction, it became apparent to MaineDOT that it was only a matter of time before the driving forces of traffic concerns and environmental impacts would require the use of expedited construction techniques. MaineDOT was interested in using techniques that could be easily evaluated and duplicated or modified to suit other bridge construction projects. The effectiveness of the techniques would need to be evaluated both from the standpoint of cost savings, or lack thereof, and for its feasible use in other similar applications.

BACKGROUND

Maine was looking for a location to try a rapid bridge construction project, but one that MaineDOT could undertake on its own terms. Andover Dam Bridge in Upton, Maine crosses a pristine stream that is home to native brook trout. The site is relatively remote and shrouded in spruce trees. While there are only approximately 120 vehicles per day, a significant number of them are logging trucks. The destination of most vehicles is either the famous fly fishing on the Rapid River, as this is the easiest access point to the Pond in the River, or the Andover Wood Products Mill, one of the major employers in the Andover area. Any shut down of the East B Hill Road would result in a 55 mile detour (see figure 1), which would directly affect both delivery of logs to the mill, and travel time of workers at the mill who live on the other side of the bridge. Limiting the closure time to a matter of days would be a real benefit to the users of the East B Hill Road. Yet with only 120 vehicles per day if unforeseen consequences delayed the project there would not be a tremendous public outcry. The site was the perfect location to attempt rapid construction.

Contracting Techniques combined with precast concrete superstructure, substructure and approach slabs were seen as the keystones to decreased construction time. The elimination of a temporary bridge limited the right of way takings required, as well as the clearing for temporary approaches. It was estimated that a temporary bridge at this site would cost approximately $75,000 and the anticipated savings would be used to finance an incentive for early completion. Both the incentive and disincentive would need to be sizable to cover the contractor's additional cost to accelerate the work. Precast concrete superstructures have a long history of rapid fabrication and erection in the State of Maine and MaineDOT was very comfortable with their use on a span such as this one. Precast substructures were a new element to add to the equation, but without them it would have been impossible to reduce the road closure to much less than 40 days.

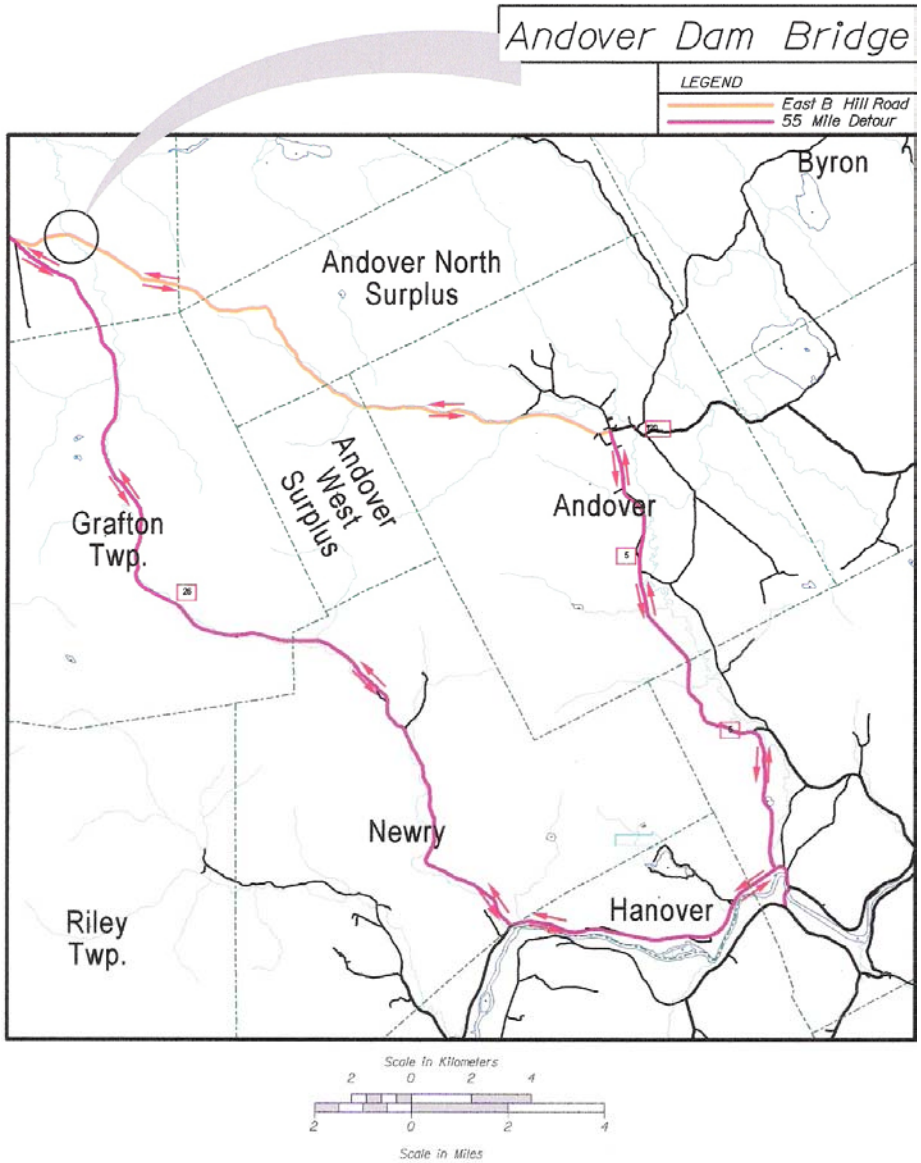

Figure 1

MaineDOT had experimented with a project similar to this the year before when they eliminated the temporary bridge and coupled that with a long detour. The biggest difference was that cast in place abutments were used, and the road was closed for approximately 45 days. This project had to take that next step, and reduce or eliminate any formwork, stripping and curing to be done in the field.

SPECIFICS OF NEW CONSTRUCTION

The bridge in preliminary design was a very different structure than the one that was eventually to be constructed. Initially the proposed structure was a 65 foot prestressed precast butted box beam superstructure with a leveling slab, waterproofing membrane, and bituminous wearing course founded on spread footings on dense native soils. Although this was the optimum substructure unit given the site specific soil conditions, MaineDOT Bridge Maintenance prefers integral abutment type structures because they have no joints and therefore ease the maintenance of the structure. Because of this preference coupled with site specific scour concerns the decision was made to make the change to integral abutments founded on driven H-Pile. This opened the door to facilitate the implementation of rapid bridge technology. The leveling slab on the box beams was eliminated; the crown of the roadway was introduced in the abutments. The abutments and approach slabs would have to be precast in order to eliminate concrete curing times in the field. The abutments would be in segments to reduce their weight and bond outs would be provided to allow the driven H-Pile to penetrate into the abutment (see figure 2 for abutment configuration). Concrete could then be placed around the piling through fill sleeves to each bond out and the segments would then be post tensioned together. The new abutments were located sufficiently behind the existing abutments such that the piling could be driven behind the abutments, cut off below grade, and the existing abutments could then be backfilled again to carry traffic on the old bridge while new equipment was brought in to erect the superstructure and substructure units (see Figure 4 for construction sequence).

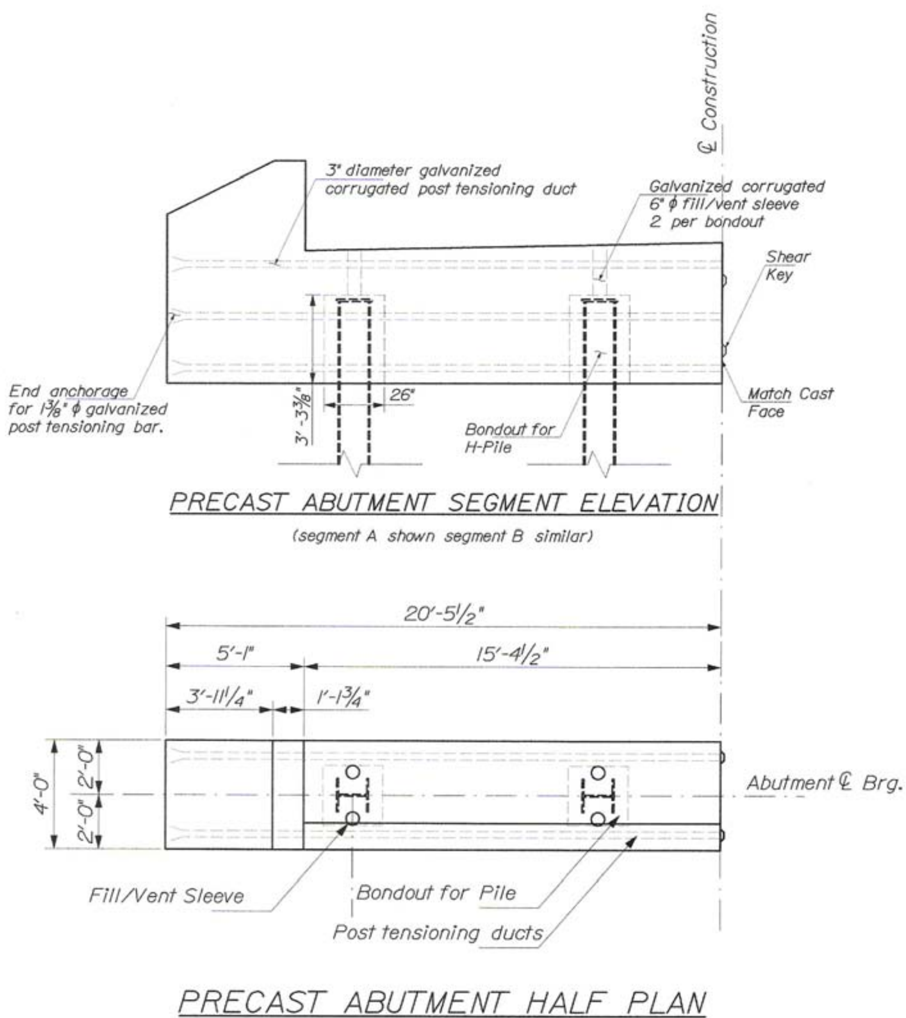

Figure 2

Several factors would determine the geometry of the precast abutment segments. Conceptually the units would be required to:

1. have sufficient post tensioning to carry the passive earth pressure required of integral type abutments
2. be light enough to ship and handle
3. have bond outs of sufficient size to allow for out of position piling, and the cumulative effects of several pile out of position
4. have joints that are impervious to water flow

Due to a layer of boulders and cobbles, pile driving required pre-excavation through the boulder and cobble layer. Given the consistency of the remaining material through which the pile would need to be driven, coupled with MaineDOT's construction experience, a practical out of position limit of 6" around each pile was used to develop the pile bond outs within the abutment sections. After cutoff, a 1" plate (see Figure 3) was welded to the top of each pile to facilitate bond with the concrete to be cast through the fill sleeves in the abutments. Conceptually it was anticipated during the design phase that the precast segments would bear directly on these bearing plates; however the contractor proposed supporting the bottom of the abutment with a steel frame welded to the piling. The bottom of the precast abutment segments would set the vertical control for the entire bridge. This had the advantage of allowing some additional vertical tolerance in the bond outs for the piling, as well as being easily adjustable in the field during the initial closure period. Using a 14 inch H-pile section with 6 inches of tolerance for out of position piling led to a bond out dimension of 26 inches square. Leaving 11 inches for the minimum wall thickness at the bond out sections yielded a total abutment width of 48 inches (see figure 2 for abutment geometry). To facilitate fabrication and shipping, each abutment was to be cast in two separate pieces, an A segment and a B segment. Each segment weighed approximately 33 Tons. Shear keys were constructed between the A & B segments, and the segments were match cast against the mating segment. A structural adhesive epoxy was applied to each joint prior to post tensioning the abutment segments together; this provided a waterproof bond at the match cast joint between the segments. Six 1-3/8" diameter galvanized post tensioning bars would become the main reinforcing steel within the abutment components and carry the full passive pressure of the backfill during thermal expansion cycles maintaining a minimum of 100 psi of compression at the joint. Self consolidating concrete, modified with a shrinkage compensating admixture, was placed through fill sleeves in the abutment. This assured adequate consolidation around piling sections and completed the connection of the abutment segments to the piling.

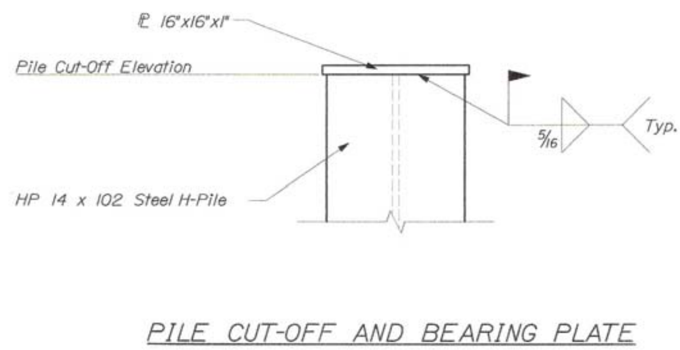

Figure 3

Facets of the superstructure were customized to allow rapid construction as well. Neither a structural slab nor a leveling slab were considered because setting up screed rails, casting, and curing them would unnecessarily slow down construction. The crown of the roadway then had to be introduced into the structure at the abutments. In order to achieve the proper roadway profile a shim course of pavement was placed between the base course and finish course. The additional dead load of the shim course was accounted for during the design of the superstructure. The initial plan called for the construction of permanent curb and railing during single lane closures during the day after the new bridge was opened to traffic, but the contractor opted to precast the curb sections on the beams. This saved time and cost and allowed the permanent railing to be installed without the need for temporary traffic barrier except at the ends of the structure. The shear keys between boxes were wider than MaineDOT's standard width, and were filled using a self consolidating concrete modified with the addition of a shrinkage compensating admixture. This allowed the shear keys to be grouted very rapidly. In order to facilitate a rapid closure the approach slabs could not be cast in place either, but were in fact precast in 4 sections and pitched to drain runoff away from the structure in both directions. (A below grade approach slab is the preferred method of constructing approach slabs in Maine.) Traffic was allowed directly on top of the precast units. Waterproofing membrane and bituminous pavement were applied during single lane closures after the structure was opened to traffic.

CONSTRUCTION SEQUENCE

The contractor was given 192 hours of total allowable closure time. The number of closures and duration of each were left to the contractor to decide. In order to ensure the closure was limited to the minimum time required an incentive of $200.00 per hour was offered if the closure took less than 192 hours. An additional incentive of $10,000 was provided for simply meeting the 192 hour deadline. The incentives were combined with a graduated disincentive beginning at $300.00 per hour and ending at $600.00 per hour for each hour the road was closed in excess of the allowable 192 hours. In order to be effective the incentive and disincentive had to be by the hour, if we had used a per day rate it would be easy to use the whole day once a part of it had been used, but using a per hour rate made it even more imperative to make the road opening requirements very clear to the contractor.

THREE INITIAL CLOSURE PERIODS

The first closure period was used to remove obstructions to pile driving and install the driven H-pile at abutment #1. The pre-excavation was required to be moderately deeper than shown on the plans, and although we came close to the water table, we were not required to drastically modify the construction procedure with the addition of a separate cofferdam, pumps and sedimentation basins. Once the pile driving was complete the driving frame was welded to the driven pile at exactly the proposed elevation of the bottom of the abutments. This would serve to support the abutment segments during the final closure. Careful measurements to each pile were taken from the centerline of construction. These would be used during fabrication of the abutments to verify the locations of the bond outs in the precast units. The elevation to remove the existing abutment to was carefully located on the abutment face. This would be used later to perforate the abutment facilitating easy removal during the final closure. The installation of piling went over without incident, and the native soils were placed back into the hole and compacted adequately to open the road to traffic. The total road closure period for the first closure period was 12 hours.

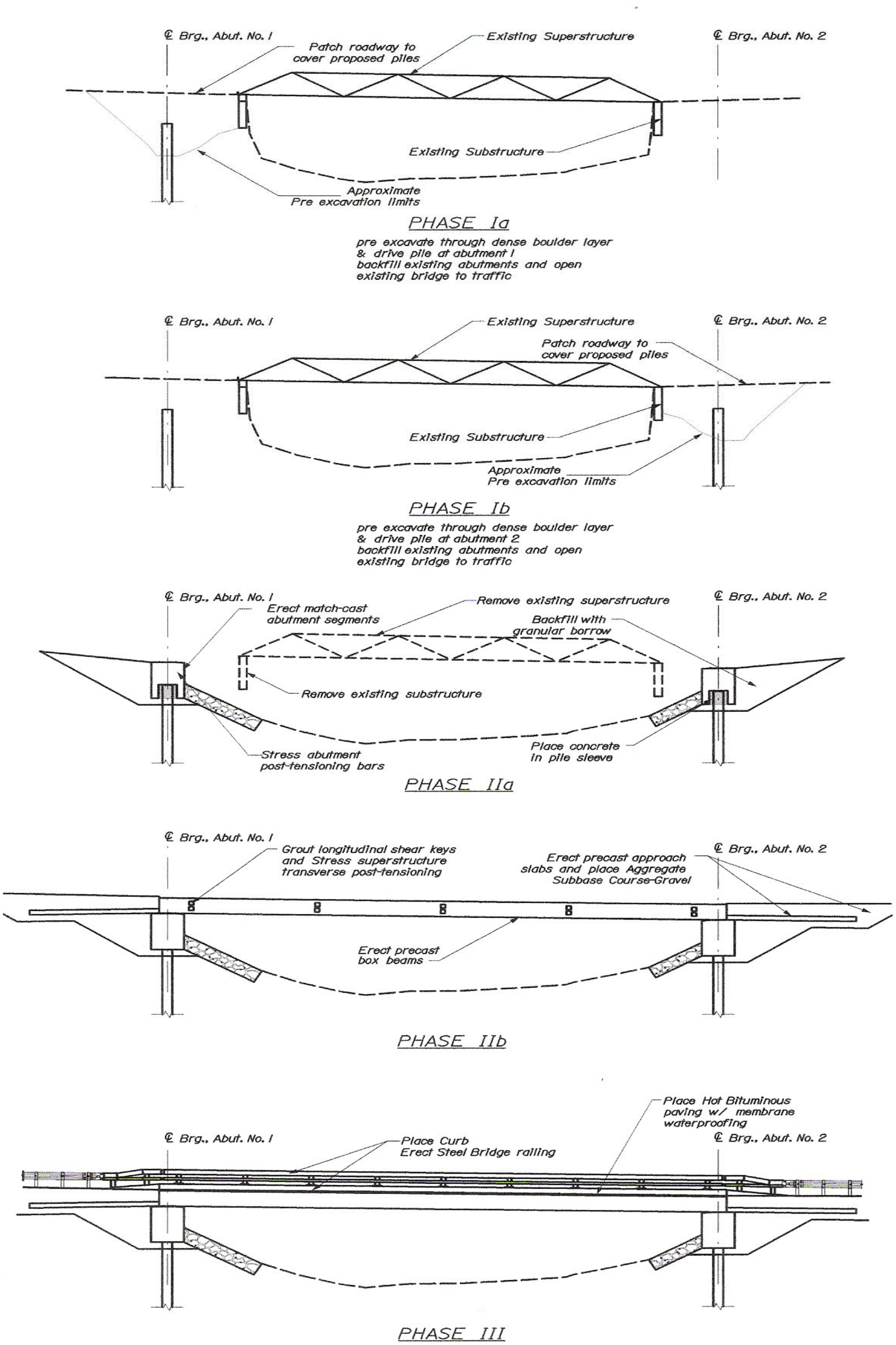
℄ Brg., Abut. No. 1
Patch roadway to cover proposed piles
Existing Superstructure
℄ Brg., Abut. No. 2
Existing Substructure
Approximate Pre excavation limits
PHASE Ia
pre excavate through dense boulder layer & drive pile at abutment 1 backfill existing abutments and open existing bridge to traffic
℄ Brg., Abut. No. 1
Existing Superstructure
℄ Brg., Abut. No. 2
Patch roadway to cover proposed piles
Existing Substructure
Approximate Pre excavation limits
PHASE Ib
pre excavate through dense boulder layer & drive pile at abutment 2 backfill existing abutments and open existing bridge to traffic
℄ Brg., Abut. No. 1
Erect match-cast abutment segments
Remove existing superstructure
℄ Brg., Abut. No. 2
Backfill with granular borrow
Remove existing substructure
Stress abutment post-tensioning bars
Place concrete in pile sleeve
PHASE IIa
℄ Brg., Abut. No. 1
Grout longitudinal shear keys and Stress superstructure transverse post-tensioning
Erect precast approach slabs and place Aggregate Subbase Course-Gravel
℄ Brg., Abut. No. 2
Erect precast box beams
PHASE IIb
Place Hot Bituminous paving w/ membrane waterproofing
℄ Brg., Abut. No. 1
Place Curb
Erect Steel Bridge railing
℄ Brg., Abut. No. 2
PHASE III

Figure 4

The second closure period was used to remove obstructions to pile driving and install the driven H-pile at abutment number two. Although, after the initial closure's success, spirits were high it became apparent early on that we would not be quite so fortunate on the second day. Once the hole was opened up and we excavated below the existing road gravel, the excavator began to take out buckets full of nothing but rock, we had found the remains of the bridges namesake, the Andover Dam. Nonetheless we were fortunate not to find any log crib below the stone, or what our biggest fear was, below the existing abutment. Once we had excavated through the obstruction layer we found that the existing abutment had a heel that projected into and interfered with the pile driving locations. The contractor had to get a Hoe Ram on site. At this point it was clear that we would not be driving pile today. The pile driving subcontractor had serious, well founded, safety concerns regarding driving pile after dark, and we would therefore have to fill the excavation with material through which we could drive the pile up to the bottom of the new abutment location. The remainder of the hole was filled in with native soils and compacted sufficiently to open the road to traffic. The total road closure period for the second closure was 12 hours.

The third closure period was used to complete the preparatory work at abutment number two. The existing abutment had been marked during the previous closure to indicate when we could stop digging. The pile driving frame was installed and the piles were driven to the required resistance, although one of the pile encountered an obstruction causing it to deviate significantly from its theoretical position, it was pulled and restarted several times with the same results. Finally, although not exactly in the right position the last pile was driven. Careful measurements were taken to the actual piling locations. The frame was then erected and welded to the piling at the exact elevation required for the bottom of the abutments. Native materials were used to backfill the existing abutment and the road was opened to traffic. The total road closure period for the third closure was 12 hours.

SIX WEEKS OF PREPARATION

During the 6 weeks following these initial closure periods, preparations were being made to facilitate an expedited schedule during the last closure period. The existing abutments were perforated with two inch diameter holes at a two foot spacing located at the required cutoff elevation. While this did not impact the structural capacity of the existing bridge it facilitated easy removal during the fourth and final closure. Granular backfill and riprap were stockpiled just off site. Coordination between the contractor and his subs and suppliers was critical. Everything had to come together at the same time.

The Abutments were under fabrication. No modifications were required at the bond out locations for abutment #1; abutment #2 was moderately modified to better reflect the actual location of the driven H-pile. The pile that had encountered an obstruction that altered its final location was out of position by exactly the six inch tolerance that we had allowed for in the bond outs. While theoretically it would be possible to erect the segments if they were constructed as designed, we decided to shift the bond out for that piling sufficiently to allow the greatest flexibility in the field.

Once all the preparations were made, materials stockpiled, concrete trial batched, precast concrete boxes and abutments were all fabricated and were either delivered or on the road. The stage was set for the fourth and final closure.

THE FINAL CLOSURE PERIOD

The first day of the final closure period was full of activity. Work was taking place on both sides of the river simultaneously. One large excavator worked at removing the soil down to the driving frame, carefully uncovering it to reveal the support for the abutment segments at abutment #1. Simultaneously, a second excavator removed the grade beams and concrete deck from the truss. A hydraulic crane set up to place the abutment segments at abutment #1. At this point it was critical that the segments be erected at abutment #1 early in the day to allow the crane time to break down and travel all the way around the detour in order to be prepared to set the abutment segments at abutment #2. The abutment segments were erected very smoothly, and post tensioning began immediately. Once the post tensioning was complete, backfill was placed carefully on both sides of the abutment keeping the elevation approximately the same so as not to shift its alignment at all. The existing truss was removed and the old abutments were removed to their final elevations, 1 foot below the finished slope line. Riprap was placed in areas that would be located underneath the new superstructure. Self consolidating concrete was placed through the fill sleeves to permanently connect the abutment to its foundation piling. The first day was complete after about 14 hours of the final closure period.

The second day of the final closure was similarly exciting. Abutment #2 segments were placed and post tensioned. Abutment #2 was backfilled, and self consolidating concrete filled the pile bond outs. Rip rap was placed in front of abutment #2. The precast box beams were erected, and the hydraulic crane was broken down and sent home. The second day of the final closure period was complete after about 38 hours of the final closure period.

The third and final day of the final closure cleaned up most of the details. The approach slabs were set at the appropriate grade, the precast box beam superstructure was anchored into the abutments, lateral post tensioning strands between box beams were installed, and the shear keys between the box beams were filled with self consolidating concrete. Bond outs in the curb were filled with the same concrete mix. Bridge rail was installed, gravel was placed and the approaches were graded, and the structure was opened to traffic. The final closure period lasted a total of 60 hours. The total elapsed road closure time for the bridge replacement was only 96 hours.

FINAL COMPLETION

Several elements were then completed under traffic with only single lane closures. This included grouting the post tensioning tendons within the abutments, installing waterproof membrane and bituminous pavement, grouting the post tensioning pockets. Completing the approach work also was done under traffic.

LESSONS LEARNED

MaineDOT learned several lessons during the construction of the Upton Andover Dam Bridge. Operations taking place simultaneously tend to be extremely equipment intensive, and there is a tremendous amount of real estate required for lay down areas, storage, and equipment in order to keep multiple operations going simultaneously. Plan on separate closures for pile driving and make sure there is plenty of room behind the existing abutments to avoid piling and the bottom of a battered mass concrete abutment sharing the same physical space. Take more borings than you think you need, because once the road is closed you are committed. Keep the details simple and clean, nothing fancy. Don’t pin the box beams to the abutments, pin the approach slabs instead. Don’t be tempted to reduce the incentive, or to cut the allowable closure time significantly, because it must be possible for the contractor to achieve a bonus significant enough to account for the additional expenses of accelerating the work.

CONCLUSIONS

The experimental rapid bridge in Upton, Maine was a very successful project and will lead to the use of similar techniques on other bridge replacement projects where a reduction in traffic disruption is beneficial. MaineDOT was initially concerned that even though we would be eliminating a temporary bridge with significant cost associated with it, the accelerated schedule, incentive, and precast substructure would drive the cost above that of a more conventionally constructed bridge. That concern proved to be unfounded, and although it is difficult to say for certain, it’s generally agreed within the Department that the project resulted in a cost savings. Part of the reason for this may lie in the equipment intensive operations which lend themselves well to rental equipment. Additionally, when the construction duration is limited, the contractor has less overhead cost associated with the project.

The environmental benefits seem to be very promising. The area which would have been cleared and used for temporary approaches to a temporary bridge could remain wooded. Areas that were destabilized by excavating for the new abutments were completely stabilized with the final rip rap placement the same day. The excavation only stayed open for a matter of hours.

While vehicular travel time was significantly impacted during the closure periods, people had sufficient advanced warning and could plan their schedules accordingly. They did not seem to mind the bridge closing for a few days.

MaineDOT has realized that rapid bridge construction can save the state money and limit inconvenience for the traveling public. In a state where much of the economy is dependent on tourism it is sometimes beneficial to shift the disruption caused by construction to a period more acceptable to the local business community. MaineDOT has already put these same techniques to work on two other projects which are under construction during the writing of this paper. Both of these projects have more significant traffic volumes and are in more prominent locations. Although this is not going to become the standard construction methodology in the state, it is going to be another tool that the bridge designer can have in his toolbox to be applied in the right circumstances to save money, traffic disruption, and environmental impacts.