USING EXISTING AND NEW INNOVATIVE METHODS TO ACCELERATE REHABILITATION OF FOUR I-89 BRIDGES

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ABSTRACT

The Vermont Agency of Transportation (VTrans) used Accelerated Bridge Construction (ABC) with cross-overs and alternating traffic patterns on Interstate 89 (I-89) in Colchester, Vermont, to complete four deck replacement projects over six extended weekend closures. Several existing—but new to Vermont—practices as well as new innovative procedures and materials were used to successfully complete the deck replacements of all four bridges.

INTRODUCTION

For travelers to and from Burlington, Vermont—the state's most populous city and a major economic center—Interstate 89 provides a critical north-south link for commuters from Franklin, Grand Isle, and northern Chittenden Counties (See Figure 1). When the VTrans identified the need to rehabilitate Bridges 76 N&S and 77 N&S in nearby Colchester, it became a priority to minimize the inconvenience to the 2,500 vehicles that pass through this corridor each hour during the morning and evening commute. Traffic volumes drop through the project area overnight and during the weekends. To complete the bridge deck replacements and maintain two lanes of traffic along I-89 during the weekday peak traffic times, it was necessary to use Accelerated Bridge Construction (ABC) techniques.

Doing so required creativity, innovative techniques, and the use of existing practices that were new to the State of Vermont. VHB worked closely with Kubricky Construction Corporation (KCC), VTrans' contractor for this Construction Manager/General Contractor (CM/GC) project. VTrans, VHB, and KCC decided to use AccelBridge's proprietary prestressing methodology as the preferred method to achieve the deck replacements within the required 59-hour timeframe, between Friday at 7:00 PM, when the evening commute tapers off, and the start of the Monday morning commute at 6:00 AM. This project was the first in Vermont to use this methodology. In addition to AccelBridge's proprietary prestressing system, the project required the use of a flowable, non-shrink, quick-curing grout for the beam haunches and

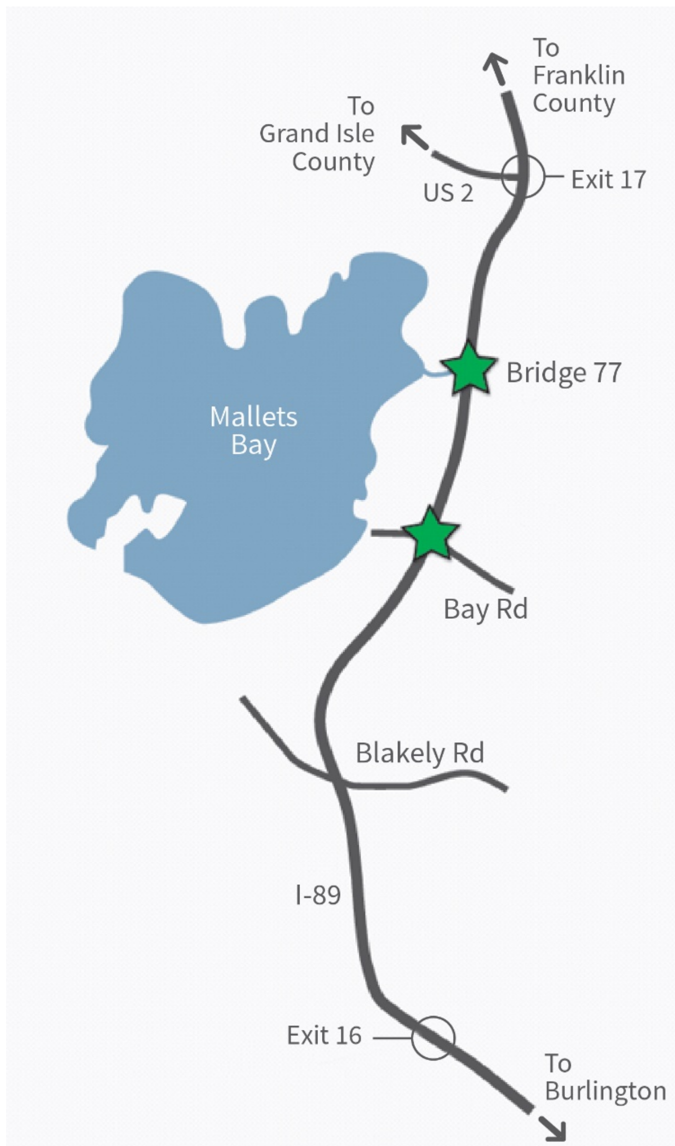

Figure 1 - Location of Bridges 76N&S and 77N&S

shear pockets of the precast concrete deck panels as well as a high-performance, rapid-setting concrete for the mid-span closure pour. Finally, a NYSDOT Class J Concrete, which is a stiffer concrete with a higher cementitious material, smaller aggregate and a higher volume of sand was used for the slip forming of the bridge rail—a process that had not previously been used in Vermont.

To rehabilitate the four I-89 bridges in the allotted time, the team used a new-to-Vermont existing traffic management technique. This allowed KCC access to one lane of the bridge one week before the weekend closure. By alternating the direction of travel on the left lane of the barrel where the bridges were not under construction, it was possible to have two lanes of traffic in each commuting direction in the morning and evening, allowing KCC to demo half the bridge deck the week before a weekend closure. This approach, used more often in larger cities, is unusual for Vermont. As a result, educating the public about what to expect was an important component of the traffic control plan's success. The team coordinated closely with state and local officials and developed an Incident Command System in the event the interstate should shut down or be reduced to one lane due to traffic accidents.

Using this combination of ABC techniques, unique materials, and traffic management, the four bridge decks were successfully replaced on an accelerated schedule with minimal impacts to the traveling public.

EXISITNG BRIDGE FEATURES AND SITE CONSTRAINTS

The four bridges are two pairs of I-89 bridges (76N&S and 77N&S) constructed in 1964 when the interstate was constructed. The bridges consist of a paved concrete deck supported on continuous steel beams spanning a local road, Bay Road, and Mallets Creek, which flows immediately into Lake Champlain. Each bridge carries two lanes of traffic and consists of two 12-foot-wide travel lanes with a 3-foot-wide shoulder and 2'-6" wide curbs with New England Traffic Consortium (NETC) 2-rail bridge rail. The overall width of the bridges is 35'-0" (See Figure 2).

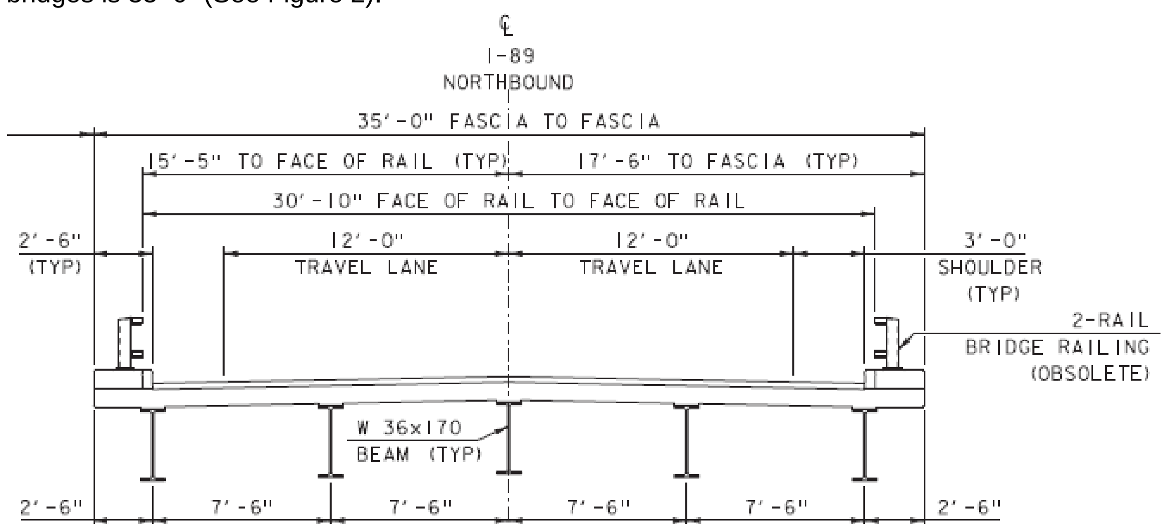

Figure 2 - Existing Bridges 76N&S and 77

Bridges 76N&S are 154 feet long with three spans, 43'-68'-43', and a 19-degree skew. Bridges 77N&S are 185 feet long with three spans, 50'-85'-50', and a zero-degree skew. All four bridges consisted of five steel beams spaced at 7'-6". Bridges 76N&S had residual camber placed into the beams. It was unclear if shear connectors were used on any of the four bridges, so deck coring was completed during design to verify they were not present. Each bridge had an expansion joint between the bridge deck, and a backwall that was supported on the abutment and independent of the bridge deck. The fixed end had a curtainwall connected to the existing concrete deck and the ends of the steel beams, making it independent of the abutment. All four concrete bridge decks were deteriorating, with Bridge 77S being structurally deficient with a Deck Condition Rating of 4.

Bay Road is a local road that connects the Colchester Bay Area with US Route 2/7. There is a private campground immediately adjacent to I-89 on the northwest corner of Bridge 76S. In addition to vehicular traffic, Bay Road has a shared-use path on its south side that goes under the bridges (see Figure 3) and connects neighborhoods in the Colchester Bay area with those in Colchester Center. The shared-use path is also part of the Champlain Bike Way, which goes along state and local roads along Lake Champlain from southern Vermont to the Vermont/Canadian border. In addition to a local vehicular detour, a bike detour was required when Bay Road was closed for construction on Bridges 76N&S.

Figure 3 - Bridge 76S Looking East

Mallets Creek is an environmentally sensitive area with wetlands at the edges of the channel (see Figure 4) and a fish-breeding habitat. Due to its proximity to Lake Champlain, additional Vermont state permitting was required for the installation of a causeway to allow for the placement of cranes between and near the ends of the bridges during construction.

Figure 4 - Bridge 77N Looking North

In addition to the bridges' physical condition and site constraints, traffic volumes on the bridges varied from the morning commute, which had a large volume of traffic heading southbound, to the evening commute, which had a large volume of traffic heading northbound. This fluctuation required two lanes be available in the morning for southbound traffic and two lanes in the evening for northbound traffic. From past experience, VTrans had determined that the vehicles per hour (VPH) volume needed to be less than 1300 if the interstate was to be reduced to a single lane; otherwise there would be significant traffic delays. Based on the traffic volumes, the interstate could only be reduced to one lane in both the northbound and southbound direction from 9:00 AM to 2:00 PM and 7:00 PM to 6:00 AM the following day. It also meant the interstate could be reduced to a single lane in each direction from 7 PM on Friday to 6 AM on the following Monday.

PROJECT DEVELOPMENT

Due to the need to accelerate the removal and replacement of the existing concrete backwall, curtainwall, and concrete deck, precast concrete was the appropriate choice for all three bridge elements. The issue, however, was the time between the morning and evening peak traffic flows and the desire to not impact the interstate traffic during the Memorial and Labor Day weekends, the Fourth of July week, and the Columbus Day weekend, which is also Canadian Thanksgiving. These holidays increase interstate traffic volumes; therefore, the use of CM/GC was selected for the collaborative design environment in order to implement an efficient and cost-effective bridge deck replacement project.

Preliminary Design

As it takes two to three years to develop a project from preliminary design to Contract Plans, VTrans decided to start the CM/GC process near the completion of the Preliminary Plans just before the start of final design. This would not only reduce the timeframe from when the CM/GC started on the project to when the project was constructed, but it would also allow the CM/GC to participate in the preliminary plan quantity and cost reconciliations and during the final plan development when most of the bridge deck replacement design would occur. While VTrans wanted the CM/GC to have input into and agree with the Traffic Control Plans (TCP), the overall method of managing traffic during construction was vetted prior to bringing the CM/GC on board and then further refined with the CM/GC's input.

As precast concrete deck panels where the preferred option, the preliminary design focused on how those panels would be configured. VHB reviewed half-width and full-width deck panels. Another issue was whether the deck panels needed to be post-tensioned or whether they could be placed on the existing beams with the shear pockets grouted in place without post-tensioning. During preliminary design, VHB looked at how the deck panels would interact with the existing curtain and backwalls and how the expansion joint would be handled. The first thought was to extend the precast concrete deck over the curtain and backwalls. The skew of Bridges 76N&S was also reviewed, and the use of grade beams was evaluated to eliminate the skew in the precast concrete deck panels by having the panels extend past the begin/end of the bridge and be supported on the grade beams so the ends of the panels would have a zero-degree skew. The final preliminary design concluded that full-width precast concrete deck panels with the deck panels on Bridges 76N&S matching the skew of the bridges would be used, and they would either be post-tensioned, or the AccelBridge System would be used to put the deck panel joints into compression.

VHB and VTrans agreed that post tensioning was not the preferred method based on the time constraints but wanted to get further input from the CM/CG before making a final decision. The precast concrete deck panels would also end at the begin/end of the bridge, and approach slabs would be placed at each end of the bridge and positively connected to the deck panels. The existing back and curtain walls would be removed and replaced with precast concrete walls that the precast concrete deck panels would extend over. The precast concrete backwall was easy to design as it is a free-standing precast element that was attached to the existing abutment with dowels (see Figure 9). The precast concrete curtain wall required pockets at each of the beam locations so that steel reinforcing could be placed through the existing holes in the ends of the steel beams and the pocket filled with concrete to allow the precast concrete curtainwall to be positively attached to the ends of the beams just like the existing curtainwall (see Figure 5). The expansion joint would be moved off the bridge to the end of the approach slab, which would be supported by a sleeper slab on the expansion end.

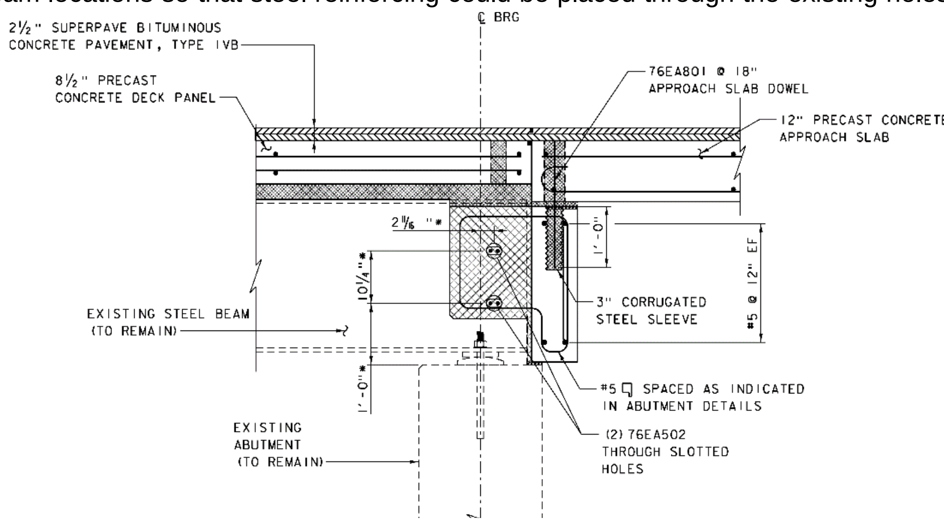

Figure 5 - Fixed End Precast Conc. Curtainwall & Approach Slab

In reviewing the traffic volumes, several concepts were developed, including removing a small portion of the existing deck and replacing it with a single precast concrete deck panel each night during low traffic volumes to closing the barrel over an extended weekend and removing and replacing the right half of the deck, then removing and replacing the left half the following weekend. All these concepts exposed weekday traffic to a joint between the existing and new bridge decks. The team had a window of 59 hours from 7:00 PM on Friday—when traffic volumes allowed for one lane in each direction—and 6:00 AM the following Monday when traffic volumes required two lanes southbound and one lane northbound. It was VTrans' and VHB's opinion that this timeframe did not allow enough time to demo the existing deck and replace it with precast concrete deck panels. Typically, when work is performed on an interstate bridge deck, traffic is either shifted over on the bridge to allow access to a portion of the bridge or sent to the left side of the opposing barrel using a cross-over to allow access to the entire bridge. This does not allow for two lanes in each direction during peak traffic volumes. In reviewing the traffic control options, it was decided that traffic would be managed using cross-overs, but the left lane of the opposing barrel would be multidirectional depending on the peak traffic demand. This allowed the contractor to have access to the left lane of the bridge while traffic was on the right lane of the bridge one week ahead of the weekend bridge closure. By allowing the contractor to demo half of the bridge deck a week ahead, the team agreed that the 59-hour period would be adequate for the removal of the remaining half of the bridge deck and the installation of the full-width deck panels over the entire length of the bridge.

Final Design and CM/GC

The first step in the final design process was to hire a CM/GC to assist with the design of the bridge deck replacement and further develop the traffic control plans. In addition to the CM/GC, an Independent Cost Estimator (ICE) was added to develop independent quantities and costs for each item at each plan submission milestone. The ICE acted as a check and balance to the CM's quantities and cost. VHB also developed quantities and costs for each of the plan milestones, including Final Plans, Pre-Contract Plans, and Contract Plans. The three quantity and cost estimates were reconciled at the end of each plan submission, and the Contract Plan reconciliation became KCC's bid. As the project was CM/GC, VTrans and KCC agreed on the project bid price based on input from the ICE.

For the precast concrete deck panel design and erection, the team felt that post tensioning was not the preferred method and opted for the AccelBridge System. The AccelBridge deck system had only been installed on three other projects in the world. It is simple for construction and can be put together rapidly with conventional materials, skills, and equipment.

There are two key components of the deck system: compressing the deck by jacking against the first precast concrete deck panel that is grouted and positively fastened to the steel beams and using epoxy in the match-cast joint instead of cast-in-place joints. This unique deck compression method is simple and economical. It saves material and labor associated with conventional post tensioning system yet retains the durability advantage of a compressed deck.

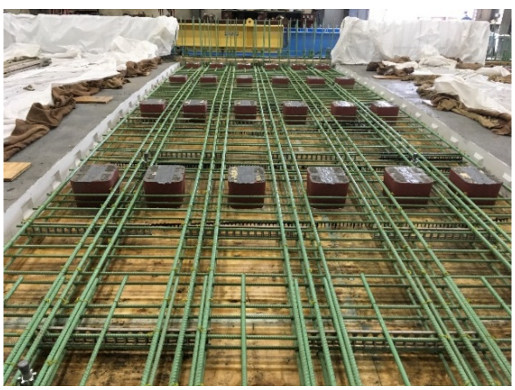

Figure 6 - Match Casting of Joints in Precast Concrete Deck Panel

The match cast joint is a proven construction detail in which the joint surface is clean and contains no rebar or post tensioning protrusions (see Figure 6). Such a simple detail not only reduces field labor time, but also enhances joint durability by eliminating the source of corrosion.

While the system lends itself to accelerated construction, to meet our 59-hour schedule, the grout still needed to achieve strength quickly. These materials were not readily available, and it was necessary for KCC to work with a local concrete producer to develop a rapid-set concrete mix design that would achieve the 2,500-psi required strength in six to eight hours. The development of this rapid-set, high-performance concrete became a critical path item as it would not be fully developed until the project was in the construction phase. VHB and KCC did extensive research to find a grout product that was flowable enough to grout the beam haunches and shear pockets of the precast concrete deck panels yet would achieve the required strength of 3000 psi in three hours versus traditional grouts that achieves this strength in 12 to 24 hours. Pro Spec Slab Dowel Grout, which is typically used for grouting slab dowels, was selected. Because it had not been used in this type of construction, KCC performed a mock-up of the steel beam with a precast deck panel to ensure the slab dowel grout performed as intended.

Additional precast elements that were reviewed and further modified during final design were the precast concrete backwalls, approach slabs, and sleeper slab. These elements were tailored to match KCC's means and methods. KCC also provided a constructability review of each design element, reducing the risk to VTrans and KCC during construction. The construction of the bridge rails was also vetted during final design; using slip forming to place the bridge rail is common in New York State, but not used in Vermont. VTrans agreed to the use of slip-forming, which required VHB to develop a special provision for this item, converting NYSDOT Type J mix into a concrete mix design more in line with VTrans' Construction Specifications.

In addition to providing insight into constructability, KCC reviewed and provided input into the TCPs. This task examined what could be done between peak traffic volumes and how to handle switching traffic patterns from peak to off-peak, then back to peak during the weekdays prior to the bridge closure. KCC also provided insight into temporary U-Turns and the area for equipment staging, which was ultimately placed in the median north of Bridge 76N&S and south of Bridge 77N&S. Because they would have instances where both bridges in either the northbound or southbound barrel would not be crossable, it was necessary to allow construction vehicles in the opposing barrel to cross from that barrel's left lane onto the median and back onto the barrel that was closed between the two bridges.

PUBLIC OUTREACH

As these four projects were on the interstate, public involvement during design was minimal, but with Bridge 76N&S over a local road and a private campground on the northwest corner of Bridge 76S, it was necessary to coordinate with the Town of Colchester and the campground. Multiple meetings were held with Town officials, including the Public Works Director and the Deputy Police Chief, to review the project and its impacts on Bay Road, which would be reduced to one lane and closed during the weekend bridge closures. This coordination allowed the road and shared bike path to remain open or only be reduced to a single lane with alternating one-way traffic during town events. Coordination with the campground allowed visitors, including fifth wheelers, to access the site easily

Prior to the completion of the design phase, a Public Outreach Coordinator (POC) was hired to assist VTrans during construction. The POC attended the last meetings with the town and the campground prior to the start of construction and served as a point of contact for both. The POC developed and managed the project website, communicated updates by email, and maintained a 24-hour telephone hotline, providing the public with information in different formats.

In addition to the POC, the team developed an Incident Command System in the event of an incident on the interstate that required emergency services and/or closed the interstate. The ICS group included VTrans Design, Construction, and Operations personnel; the POC; VHB; KCC; Vermont State Police; and the fire, ambulance, and police for the Town of Colchester. The ICS not only established a command structure in the event of an accident, but also allowed local authorities to provide input and fully understand traffic control when responding to an emergency. The ICS meetings led to the installation of additional signage, emergency detour packages, and an additional emergency U-turn that all proved to be useful during the construction process. It also allowed the local police to know where along US Route 2/7 they should be stationed to assist in the event of an interstate closure. Additionally, once the traffic control was in place, VTrans flew the site with a drone and provided the town emergency personnel with an ortho that showed the location of the cross-overs, temporary traffic barriers, and U-Turns so they were able to navigate the site more efficiently when responding to an issue during construction.

CONSTRUCTION

Extensive preparation was required prior to the installation of the precast concrete deck panels. This work also needed to be performed on an accelerated schedule as the first Bridge Closure Period (BCP) started on July 12 and the preparation work did not begin until early May. For example, the permit for the causeway work at Bridges 77N&S did not allow any in-channel work until July 1, leaving only 11 days for the causeway to be constructed.

Preparation

During the inspection process, the team identified repairs to be made to the existing substructure, including not only Class 1 (removal and repair of existing concrete to the first mat of existing reinforcing) and Class 2 (removal and repair of existing concrete 3/4 of an inch beyond the first mat of existing reinforcing to a maximum depth of six inches) surface repairs, but also Class 3 (removal and repair of existing concrete to a depth greater than six inches) repairs under one of the bearings on Bridge 76S. This required the installation of a web repair plate to strengthen the existing beam and a jacking system to take load off the bearing to make the necessary concrete substructure repairs.

A temporary crossover was installed at both the north and south sides of the contract limits to detour traffic to the opposite barrel, effectively closing one side during construction. Work included the protection/modification of median drainage, filling of the median to a level profile with the existing road, and paving/striping the travel lanes. This crossover was initially built to only accommodate the NB barrel due to the existing roadway profiles. After completion of the first three BCPs, parts of this crossover were removed and regraded to accommodate the opposite barrel for the final three BCPs. Other work included the installation of six emergency pull-off locations, the installation of a permanent U-turn on the south end of the project, a large detour and construction sign package, and the installation of a U-turn in the center of the job to be used for emergency services.

Since the time window available to perform this work was so short, a large amount of equipment, materials, and tools had to be brought in. Due to the limited access from one side to the other during construction, much of the equipment had to be doubled so that work could occur on each side of the bridges simultaneously. This required the installation of large staging areas on the north and south sides of the bridges at both locations. Due to the weight of the precast concrete deck panels, crane pads where installed using a large Geosynthetic Reinforced Soil System (GRSS) wall on the north side of the median between Bridges 76N&S as well as two causeways in the median on the south and north side of Bridges 77N&S. This allowed the use of smaller, wheeled cranes to erect the deck panels instead of larger crawler cranes. Finally, shielding was put in place on both NB bridges to protect the areas below against demo debris and slurry and act as an access platform to perform prep work to the beams and install the deck panels.

Deck Replacement

The bridge work was broken down into six BCPs, each made up of a 59-hour closure from 7:00 PM Friday through 6:00 AM Monday. All backwall work had to be performed before starting the deck replacements due to the short time period allowed during the closures. The first BCP included the excavation of the existing approaches down to the top of the existing abutment, removal of the existing backwalls/wingwalls, installation of precast backwall/wingwalls, backfilling, installation of new subbase, installation of precast sleeper slabs on the expansion end, and paving of the reconstructed areas at Bridge 77N.

During the week between the first and second BCP, temporary barrier was installed down the middle of the bridge deck and demolition was performed on half of bridge 77N. Saw cutters were used to cut the deck longitudinally down the middle, then transversely into equal sections so the existing deck pieces that were removed could be handled with the excavators. This saved time by reducing the amount of debris and labor required to break up the slabs using hydraulic hammers. After the removals, the beams were cleaned of debris, inspected for deterioration/potential repairs, and prepared for future welding of studs and haunch angles. BCP two consisted of the removal of the second half of Bridge 77N and the installation of the precast concrete deck panels, approach slabs, and preformed joint seal on the bridge. It also consisted of the same work performed in BCP one except it was completed on Bridge 76N.

Figure 7- Erecting Precast Concrete Deck Panels on Bridge 77S

After the existing deck was removed, the steel was surveyed to determine the necessary haunch elevations at each precast joint. Once these elevations were determined and the beams were cleaned, angles could then be welded to the top flange of the existing beams at the proper elevations. These angles were welded to the top flange similarly to that of a stay-in-place deck form, except steel straps where used in place of welding in the top flange tension zones. A piece of 1" foam would then be placed on the top of the outstanding horizontal leg of the angle to create a seal when the precast concrete deck panels were set in place. This would effectively create a formwork for the grout that was later poured to create the haunches.

After enough of the angles were welded in place, the first precast concrete deck panels were ready to be set (see Figure 7). This installation process worked from each end of the bridge; the first deck panel at each end became the anchor for the other deck panels when the precast concrete deck panels were jacked. Plastic shims were set in place on each beam at both joint locations to hold the deck panel at the correct elevation, which allowed the 1" foam to compress 1/4 of an inch to create the required seal for the haunches. Once they were set and determined to be in alignment, restraints were welded in place to hold the deck panels in alignment and hold them down when the deck panels were jacked. These restraints allow the deck panels to be jacked at a grout strength of 3500 psi, which was much less than the grout design strength of 5000 psi. Studs were then welded in the pockets and grout was poured in those same pockets to create the haunches and lock the first deck panel on each end of the bridge in place. Precast concrete deck panels were then set working towards the center of the bridge. Epoxy was applied to the deck panel face and come-alongs were used to pull the deck panels together at a specified tension using a load cell to monitor the forces. As the deck panels were set in place, shear studs were installed in each of the pockets of the precast concrete deck panels.

Once all the precast concrete deck panels were set in place, an approximate 3'-6" closure pour was left remaining in the center of the bridge. Formwork was installed from under the deck panels using coil rod threaded into inserts that were cast into the precast concrete deck panels. This also created a location to set the hydraulic jacks in place to jack the deck panels and place them in compression. The deck panels were jacked once the specified grout strength (3500 psi) was reached in the end deck panel's shear pockets. Once the deck panels were jacked, reinforcing was installed in the closure pour between the jacks and Rapid Set High Performance Concrete (HPC) was placed between the jacks to keep the compression force locked into the deck panels (see Figure 8).

Figure 8 - Precast Conc. Deck Panels Closure Pour with Jacking and Reinforcing Installed (Bridges 77N&S)

After completion of the jacking and the placement of the first Rapid Set HPC pour, the haunches were grouted using the Slab Dowel Grout. The Slab Dowel Grout was mixed on-site from bags using large portable grout mixers and placed in the deck panel's shear connector pockets one beam at a time, working from the low point to the high point on each beam to assure that all voids were eliminated. After the Rapid Set HPC acquired a strength of 2500 psi, the tension was taken off the jacks and the jacks removed. Reinforcing and Rapid Set HPC concrete were then installed in the areas previously occupied by the jacks.

During installation of the deck panels, the temporary approaches installed in the previous weekend bridge closure were removed and the approach slabs were installed as four precast concrete panels with a 14" joint between each of the panels. Hoop bars extend from each of the panels into the joint and longitudinal reinforcing was placed in the hoop bars and Rapid Set HPC was placed in each of the closure pours between the panels positively connecting the panels together. The expansion end approach slab was positively connected to the precast concrete deck panel through a transverse closure pour. Longitudinal reinforcing extended from the approach slab panels and were spliced with headed dowels that were threaded into inserts at the ends of the deck panels (see Figure 9). The fixed approach slab was positively connected to the precast concrete backwall using vertical dowels (see Figure 5). The preformed joint was then installed between the approach slab and the sleeper slab on the expansion end.

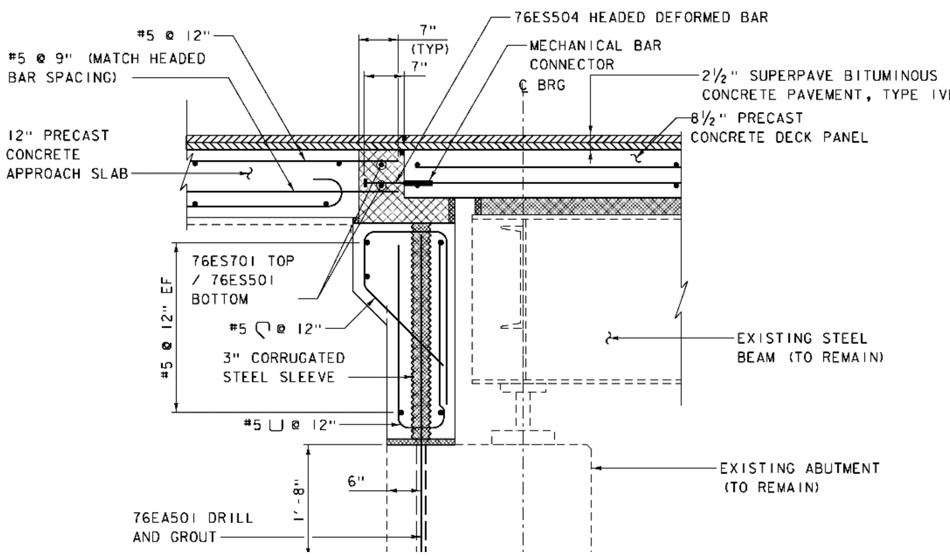

Figure 9 - Exp. End Precast Conc. Backwall & Approach Slab

Braced temporary barrier was set across the bridge deck on the east and west side of the deck to protect traffic until the bridge rail could be slip formed which occurred during BCP three for Bridge 77N and at an additional off-peak bridge closure for Bridge 76N. This same deck replacement process was then performed on Bridge 76N during the third BCP.

After completion of the NB barrel, including the slip formed bridge barrier, the crossovers were removed/readjusted to accommodate the SB barrel. During this process, the shielding was jumped from the NB bridges over to the SB bridges in preparation of demo, and equipment/tools were staged to accommodate construction on the south side of the interstate. The entire process was repeated, except Bridge 76S was closed first due to its proximity to the campground.

LESSONS LEARNED

As with all projects, regardless of the amount of planning, coordination, and collaboration, there will always be takeaways and the Colchester I-89 Deck Replacement Project is no exception. These combined bridge deck replacements were the first in the State of Vermont to use the AccelBridge System, a rapid-set high performance concrete and grout that achieved the required strengths within 8 and 5 hours, respectively; the first to use the left lane of the opposing barrel of an interstate in one direction in the AM and another direction in the PM; and the first to develop an ICS plan for a construction project.

Design

By using the CM/GC process, the owner (VTrans), designer (VHB), and contractor (KCC) conducted biweekly or monthly coordination meetings depending on the need, focusing on construction and the use of materials. Notes from these meetings were taken, distributed, and agreed upon, however not all the information agreed upon during those meetings was incorporated into the Contract Plans. It is important that the items discussed and agreed upon at those meetings be included in the Contract Documents for consistency, and to prevent issues that were resolved during design from becoming issues again during construction. All these issues were resolved during construction; however, it would have been more efficient if the agreed-upon information were included in the Contract Documents.

Traditionally, VTrans' bridge closure periods require specific work to be completed. If that work is not completed, the contractor does not receive an incentive and it is charged a disincentive until the work is completed. For this project, we specified that in addition to the items required to open the bridge to traffic—the precast deck panels, approach pavement, temporary traffic barrier—that the modular expansion joint and the approach slabs be completed as well. When the bridge closure period was underway, it became clear that the modular expansion joint, which is weather dependent, and the approach slabs were not detrimental to public safety, and temporary measures could have been used to open the bridge to the traveling public without decreasing safety. The incentive could have been modified, if the approach slabs were not installed, or kept the same if the moisture content would not allow the installation of the modular expansion joint due to a rain event.

It is important to have the right people involved with the CM process, including not only the design staff, but also those who will have influence over the project during construction. While the CM/GC process was successful for this project, it would have been beneficial to have KCC's superintendents and VTrans construction staff present at most of the collaboration meetings. To accommodate those staff working remotely on other construction projects during the project design, video or conference calls could be used to allow their participation.

Construction

The innovative nature of the construction method and the Vermont location made it difficult to get the materials approved through the VTrans approval process. For example, Rapid Set HPC concrete (Figure 10) drove the critical path in multiple instances throughout the closures. The project required a mix design that would reach 85% of its capacity in six hours and provide enough working time to properly install the product on site. The product still needed to meet the 5000-psi strength requirement,

Figure 10 - Placement of Rapid Set HPC at Closure Pour after Removal of Jacks

which could not be confirmed until the breaks were performed 28 days later. Although the mix was created, it was difficult to get approval in accordance with the VTrans standard specification as many of the notices and necessary break data could not be acquired before construction. This risk could have been mitigated if the process had started earlier.

The proper sampling and curing of the grout/concrete drove the weekend closures. Although the ambient temperatures were not low on the first two bridges, the grout still took longer than expected to come to strength. After completing the first bridge, it was determined that samples needed to be placed at the pour locations as more heat was generated from the larger pours than was generated by the 2x2 cubes exposed to the elements. Blankets were also used to maintain some of that heat, allowing the strength gain to happen more rapidly. This allowed the materials to perform as expected and allowed KCC to stay on schedule.

Redundancy was key. KCC had to be prepared for the worst-case scenarios with the materials and means to fix potential issues. Location was a challenge: if something went wrong, how would it be fixed in the middle of the night on Sunday in northern Vermont? This was mitigated by having subcontractors and suppliers on-call for weekend shutdowns, ready to help perform an install or get material on site. Finally, the schedule was always changing, and subcontractors had to be managed to avoid delays. Additionally, subcontractors had to arrive early, so they were prepared to begin work immediately when needed. If the schedule was running behind due to weather or other issues, this created idle time for the subs and cost that was not originally identified during the estimating process.

CONCLUSIONS

All four bridge decks were successfully removed and replaced over six weekend closures. The successful completion of the four deck replacement projects, including the addition of approach slabs and the sleeper slab on the expansion end, confirms that ABC projects with short closure durations can be effectively developed and executed with proper planning, design, support, public outreach, and contractor coordination. Furthermore, successful ABC projects are a benefit to their communities, transportation agencies, and the public as they reduce impacts to natural and cultural resources, significantly decrease roadway closure duration, and provide safer bridges with longer service lives. To continue to attain these benefits through ABC, design and construction techniques should be updated continuously to reflect advances in technology and insight gained through constructing ABC projects.