NEW HAMPSHIRE'S SECOND USE OF FULL-DEPTH PRECAST CONCRETE DECK PANELS

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ABSTRACT

The New Hampshire Department of Transportation (NHDOT) first utilized full-depth precast concrete deck panels in 2006. With the success of NHDOT's first use of full-depth panels, the natural progression is to use and develop the system with a follow-up project. This article describes the differences between the first and second use of the system with regards to design and construction. Different details between the two projects are discussed as well as timelines for construction, including the use of an incentive/disincentive clause. With a second project completed, NHDOT gains the confidence and experience to continue to use full depth precast concrete deck panels on future projects.

Keywords:

Bridges, Full Depth Deck Panels, Highway, Longitudinal Post-Tensioning Ducts, Longitudinal Closure Pour, Precast Concrete, Prestressed Concrete, Shear Connectors, Grouted Shear Keys

INTRODUCTION

Construction conflicts and delays continue to be one of the most important issues to the motoring public. Technologies to minimize conflicts and shorten delays continue to be improved upon. Full depth deck panels are just one of the many technologies available to address this concern. With the NHDOT completing a second bridge rehabilitation project using full depth deck panels, this technology is being improved upon also.

Newbury Road over the Connecticut River connects NH Route 10 in Haverhill, New Hampshire, to US Route 5 in Newbury, Vermont (see Fig. 1). The deck of this 3-span bridge was more than 35 years old and in need of replacement. The bridge only carries 2,300 vehicles per day, but due to the distance to the nearest detour bridges (7.5 miles north to US Route 302 or 7.5 miles south to NH Route 25) closing the bridge was not a viable option to the people of Haverhill and Newbury. The Town of Haverhill also has a yearly fair nearby in late July and requested that the bridge deck be replaced as quickly as possible. For these reasons, one lane of alternating one-way traffic was to be maintained at all times. NHDOT's experience with full depth precast prestressed concrete deck panels on the Mosquito Bridge in Sanbornton, NH, provided valuable lessons, and it was decided to use and expand upon this method to replace the bridge deck on Newbury Road.

Fig. 1 Newbury Road Crossing Looking Towards Vermont

BACKGROUND

The NHDOT first used full depth deck panels in 2006 on the Mosquito Bridge in the Towns of Sanbornton and Belmont, NH. A paper was written about this project titled "New Hampshire's First Use of Full-Depth Precast Concrete Deck Panels" and was presented at the 2007 PCI National Bridge Conference in Phoenix, AZ, by David L. Scott, PE, and Jason A. Tremblay, PE. This paper is available through PCI as document NBC-07, The PCI National Bridge Conference Proceedings October 22-24 2007.

The Mosquito Bridge is a four-span continuous bridge with a total length of 468 feet. The two end spans measure 104 feet, and the two interior spans measure 130 feet. Seven steel girders, spaced at 7’-11”, support the new 8” thick deck panel that is pre-tensioned transversely and post-tensioned longitudinally, with an overall deck width of 53’-3”.

The constraints of the Haverhill – Newbury project lent itself well to utilizing full-depth panels again. Issues that arose from the Mosquito Bridge design and construction could be addressed while the Newbury Road crossing was being designed so these issues could be avoided. The Contractor for the Newbury Road crossing could also discuss construction issues with the Contractor of the Mosquito Bridge. Precasters and fabricators could do likewise.

THE PROJECT

The present Newbury Road crossing was constructed in 1970. The three span bridge has a total length of 486 feet with end spans of 146 feet and a middle span of 194 feet. There are four steel girders spaced at 9’-2” and the deck width is 31’-8”. Due to geometric constraints off the bridge, this width needed to be maintained for final conditions. The bridge is built on a tangent horizontal alignment and on a 4% vertical grade, with a 15-degree skew right ahead.

This deck replacement was completed in two phases and utilized precast full depth deck panels (without pre-tensioning) that were longitudinally post-tensioned after placement (see Fig. 2). Alternating one-way traffic was placed on an 11’-0” lane in both phase one and two. The construction joint between phases was located midway between the two interior girders. This construction joint had to be wide enough to accommodate the splice length of the deck reinforcing bars protruding from the panels to create a continuous region in the deck slab for positive moment due to applied loads. The curbs/copings were cast-in-place to provide a seal and uniform appearance over the ends of the panels. A closure pour was also required at each end of the bridge to account for any construction tolerances and to accommodate the skew. A machine heat-applied by torch waterproofing membrane was placed on the completed bridge deck, which was then paved over with a bituminous wearing surface.

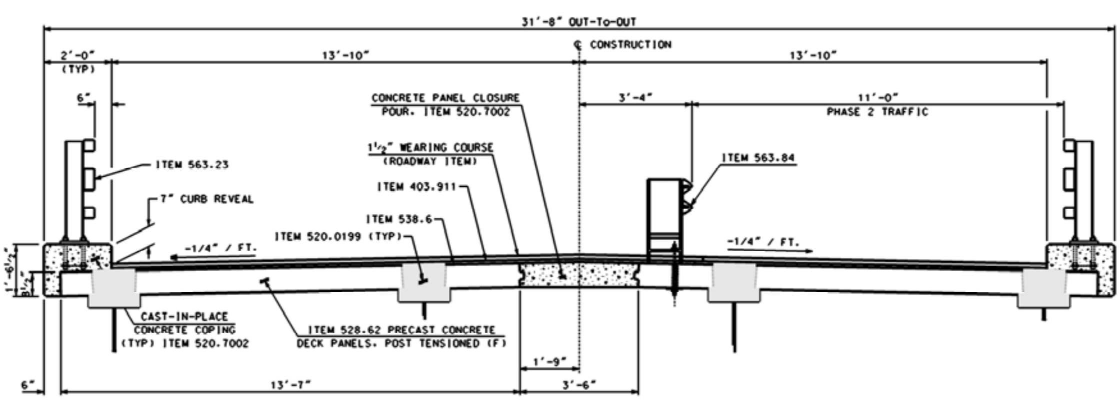

Fig. 2 Phase 2 Cross-Section

DESIGN

As with the Mosquito Bridge project, the PCI Bridge Design Manual[1] was utilized for guidance during the design of the full depth deck panels for the Newbury Road crossing. PCINE's Report titled "Full Depth Precast Concrete Deck Slabs[2]" was also used as a guide for deck panel details and construction sequencing notes. However, the Mosquito Bridge was designed using the AASHTO 17th Edition of the Standard Specifications for Highway Bridges[3]. Since then, the design code has been revised and the total loss of prestress is now calculated differently. The Standard Specifications calculated individual losses that included shrinkage, creep, and relaxation before and after transfer. The 3rd Edition of the AASHTO LRFD Bridge Design Specification[4] includes all of these losses under one variable to account for time-dependent losses or gains to reflect the results of new analytical investigations. As prestressing studies continue, it is possible that these equations will change again.

DETAILS

The standard full depth precast deck panel for this project was 8½" thick, 8'-0" in length, and 13'-7" in width. 59 panels were required in each phase for a total of 118 panels. Four panels in each phase had a scupper cast into them. The end panels had reinforcing projecting into the closure pour at the end of each abutment. Due to the geometry of the end panels, each one of these panels is different. So even though the panels are similar, six different panels were created for this project – 2 typical interior deck panels and 4 different end deck panels.

The following details were used on this project:
<u>Grouted transverse shear keys</u> – The fabricator was given a choice as to the shape of the shear key between adjacent full depth deck panels – a diamond shape and a more vertical irregular hexagon shape (see Fig. 3). The Contractor proposed to use the diamond shape shear key. On the Mosquito Bridge the Contractor used the thinner hexagonal shear key detail. Even though the panels butt together with the diamond shape shear key, a backer rod was placed in the bottom of the key to plug any voids so that the transverse shear key grout would remain in the key.

Before the longitudinal strand is post-tensioned, the shear key is filled with a high strength non-shrink grout. A minimum grout strength of 1,500 psi is required before any post-tensioning and a minimum strength of 600 psi is required by specification at 7 days. During phase 1 grouting operations, minimum strength was not reached at 7 days and was still slightly lower than the required 6,000 psi at 28 days. To truly correct the situation, it would have been necessary to remove and replace the grout from the keys that were already post-tensioned. Since the fix would cause more problems than leaving it alone, the grout in the keys was not replaced. The strength of this grout was determined to be of sufficient capacity to perform as designed, and thus was accepted.

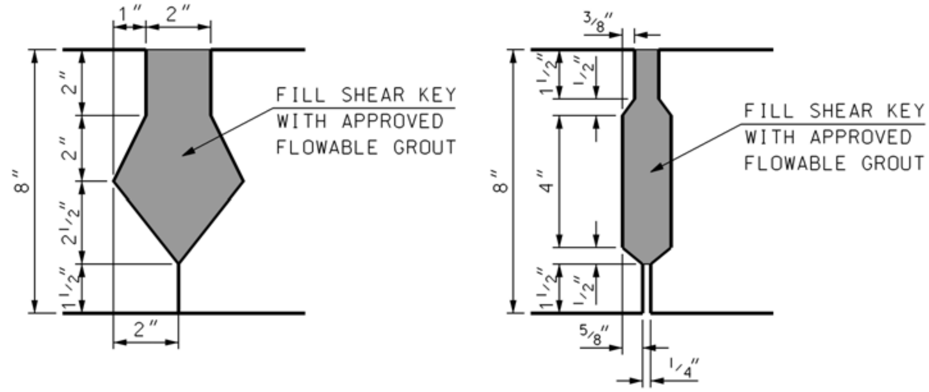

Fig. 3 Shear Key Alternatives

<u>Shear connectors</u> – Shear connector blockouts were placed at 2 feet on center to meet AASHTO requirements. Oval blockouts were used instead of rectangular ones to minimize stress cracks in the corners of the blockouts. The blockout was sized to place four shear connectors per blockout and also to allow room for the studs to be welded to the top flange of the girder. The blockouts tapered ½" from the top of the deck panel to the bottom (see Fig. 4). This allows for greater interaction between the shear studs and the full depth deck panel once this blockout is grouted and cured.

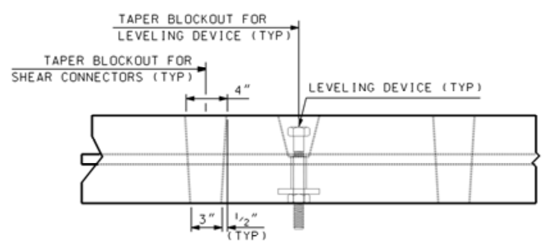

Fig. 4 Deck Panel Section (showing shear connector blockouts and leveling devices)

<u>Longitudinal post-tensioning ducts</u> – Section 9.7.5.3 of the 2007 AASHTO LRFD Bridge Design Specifications states, "precast components may be placed on beams and joined together by longitudinal post-tensioning. The minimum average effective prestress shall not be less than 0.25 ksi." PCINE Design Guidelines for Full Depth Precast Concrete Deck Slabs state, "for continuous spans, the Engineer must design for additional prestress to overcome the tensile stress due to negative composite dead load moments." An additional 0.15 ksi was required by design to account for the dead load negative moment.

Post-tensioning ducts were shown on the plans with a note that stated, "Fabricator shall determine exact location, size, and shape of post-tensioning ducts." Shop drawings gave exact locations of these ducts to facilitate ease of installation of the post-tensioning strand (see Fig. 5).

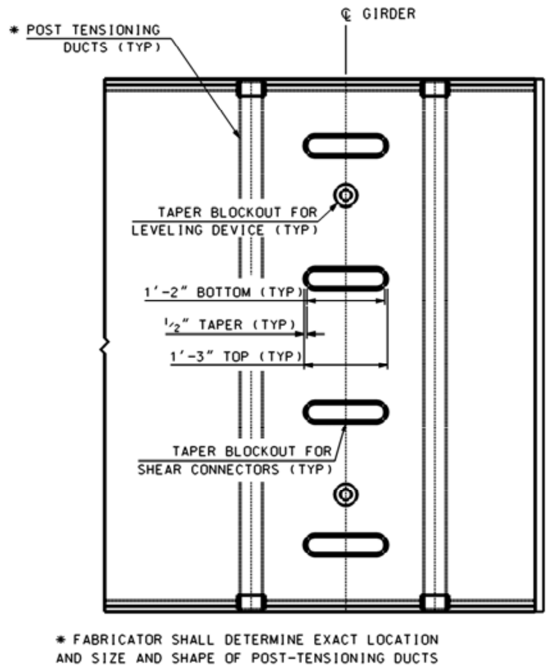

Fig. 5 Plan View of Deck Panel (showing post-tensioning ducts)

<u>Longitudinal panel closure pour</u> – Unlike the Mosquito Bridge, whose longitudinal joint was directly over the center of the center girder and required steel in the negative moment region, the longitudinal closure pour for the Haverhill-Newbury bridge was midway between the two interior girders. To form this joint, the panels placed in Phase 1 had female mechanical connectors cast into them and the panels in Phase 2 had reinforcing cast into them that extended into the closure pour area (see Fig. 6). Once panels in both phases were placed, male mechanical connectors were attached to the panels in Phase 1 and spliced to the steel in Phase 2 panels, creating a positive moment connection between the girders.

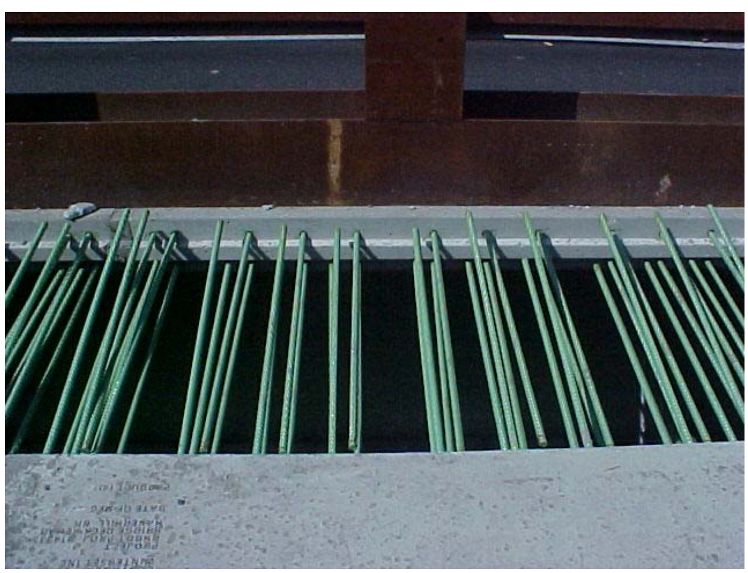

Fig. 6 Closure Pour Reinforcing (at mid-span of deck)

CONSTRUCTION

As previously stated, one lane of alternating one-way traffic was to be maintained at all times. Another stated goal of this project was to complete all the bridge work and have the bridge open to traffic before the Haverhill Fair on July 23rd, 2008. This was accomplished with an incentive/disincentive clause in the contract. If the Contractor completed the bridge work before the opening date of the Fair, they would receive a one-time incentive bonus of $25,000. The actual completion date to have all the bridge work done and the bridge open to traffic was August 8, 2008. If this date was met, the Contractor would also receive an incentive of $5,000 for each day that construction was completed before this date. For every day beyond this date the Contractor would be penalized with a disincentive of $5,000 per day. The maximum incentive was not to exceed $100,000. There was no upper limit to the dollar amount of the disincentive clause.

The contact bids were opened on October 10, 2007 and the contract was awarded on October 31, 2007. This schedule allowed the Fabricator to cast the panels during the late winter months when the Contractor was mobilizing and performing preliminary work at the bridge site. Full depth deck panel submissions were received and approved in February 2008.

The full depth panels for this project used mild reinforcing for the main steel and therefore did not require any pretensioning. Ducts were cast into the panels for longitudinal post-tensioning strands (see Fig. 7). The fabricator used two by fours placed inside the duct, which were ultimately removed, as well as a #5 reinforcing bar on top of the duct to hold the duct in place while casting the panels. Visual inspection from one side of the panel to the other showed that the ducts were straight and true.

Fig. 7 Precast Deck Panels (at fabricator's plant)

The Contractor did some preliminary site work before the bridge was restricted to one lane of alternating one-way traffic. This work started on December 7, 2007 and included installing the subdecking beneath both phases of traffic, loosening bolts from diaphragms in the center bay to allow movement of the girders when the deck was removed, and bolting temporary barrier to the existing deck for traffic control. Deck removal for Phase 1 began on February 18, 2008 and was completed on March 18, 2008. This included removal of the concrete deck as well as removal of shear studs and grinding the studs flush. With this half of the deck removed, the Contractor then removed and replaced the bearing assemblies by jacking the exposed steel girders.

On April 7, 2008 the Contractor placed the first 18 panels (see Fig. 8). 30 panels were placed the following day and the remaining 11 panels were placed on April 9, 2008. At this point the deck panels had not been adjusted for grade, grouted, or post-tensioned.


Fig. 8 Placement of Deck Panels

While waiting for the materials and equipment to install the longitudinal post-tensioning strand through the ducts, the Contractor grouted the shear keys between adjacent panels (see Fig. 9). Notes on the contract plans, as well as the sequence of work submitted by the Contractor, showed this work being done after the longitudinal strand was installed. The reasoning for this is that hand holes between panels where the ducts aligned could be accessed if necessary during the installation of strand. Since the Contractor had grouted the hand holes along with the rest of the shear key before any strand installation, he didn't allow himself any way to access the duct without removing grout already placed. This was obviously a risk for the Contractor.

For Phase 1 panels, this was not an issue. Installation of prestressing strand in Phase 1 post-tensioning ducts was started and completed on April 14th. This task went much smoother than the Mosquito bridge project due to better duct alignment and panel dimensional tolerances (see Fig. 10). Strands were pushed through the ducts. Per contract provisions, panels were not to be post-tensioned until they had aged a minimum of 45 days. This was to limit shrinkage once the panel is set and grouted into place.

Since panels were cast in February, this provision would require the Contractor to wait until early April to post-tension. The State and Contractor came to an agreement that would allow the Contractor to post-tension before the 45-day period, but the incentive/disincentive date would be adjusted to reflect the additional days the Contractor would gain by not waiting the 45 days. Post-tensioning was achieved with a monostrand jack, tensioning from one end.

Fig. 9 - Grouted Handhole Fig. 10 - Aligned Ducts in Handhole

Over the next month the following construction activities took place: Shear studs were welded to the top flange of the girder through the blockouts that were cast into the panels. These voids, as well as the girder haunch, were grouted using a self-consolidating concrete mix. The haunch was formed using two by fours placed along the edges of the top flange of the girder. Cast-in-place end closure pours for this phase were completed, along with the coping pour. Bridge rail was installed and the Phase 1 deck received torch-applied barrier membrane and hot bituminous pavement. On May 20, 2008, the Contractor switched traffic over to the completed deck and began the process all over again for Phase 2.

With less than two months to go before the Haverhill Fair incentive deadline on July 23rd, the Phase 2 deck removal was completed on May 31, 2008. All 59 panels were set on June 4, 2008 and leveled to grade on June 5th. The Contractor once again grouted the shear keys before placement of the post-tensioning strand. Strand placement commenced on June 10, 2008. The first several ducts went smoothly but in the third duct the strand could not be pushed the entire length of the duct. Since the hand holes were already grouted, the Contractor could not see what was blocking the strand. The Contractor measured the length of the strand that went into the duct and removed the grout from the hand hole at that length to identify the problem. Due to slight misalignment of the ducts the strand had broken through the splice at the hand hole and could not continue along the duct. The Contractor had to remove the grout from the affected hand holes, align the ducts so the strand could be installed smoothly and regrout the handhole (see Fig. 11 and Fig. 12). So instead of the strand installation taking one day to complete, as in Phase 1, it required 3 days.


Fig. 11 - Misaligned Ducts in Handhole


Fig. 12 – Regrouted Handhole

The Contractor performed the same tasks as in Phase 1 to complete this half of the bridge deck. The only additional work in Phase 2 was installing the center splice bars and forming the deck for the center cast-in-place closure pour. Final paving for Phase 2 was completed on July 8, 2008. Subdecking was removed over the next two weeks and the bridge was opened to traffic in time for the Haverhill Fair. The Contractor received the one-time incentive bonus of $25,000 for having the bridge open by July 23, 2008. Overall, the Contractor received $60,000 total incentives for the entire project.

LESSONS LEARNED

One issue identified from the Mosquito bridge project was the presence of hairline cracks at the corners of shear connector blockouts. This was noticed at the half blockouts for shear studs that were required over the center girder (see Fig. 13). This was most likely due to inadequate reinforcing around the blockout as well as the stress from the pretensioning strand.

The Haverhill-Newbury project did not have panels with pretensioning strand, which provided an opportunity to more fabricators to construct the panels. With pretensioning in the panels, NHDOT requires a PCI B2 plant certification, whereas without the pretensioning, NHDOT standard requirements for precast fabricators were all that was necessary. These requirements included proof from the contractor that the fabricator is capable of and has the organization and plant for performing the work in manufacturing the panels as well as casting a trial panel.

This project did not have half blockouts for shear studs since the closure pour was between girders as opposed to over the center girder (see Fig. 14). So while avoiding the problems of the closure pour being located over a girder, a new problem arose from the closure pour between girders.

In Phase 1, female mechanical splice bars were placed in the panels. Panels in Phase 2 had reinforcing extend from the panel. The intent was to place Phase 1 panels, then place Phase 2 panels, place male mechanical connectors into Phase 1 panels, and splice them to the reinforcing extending from Phase 2 panels. The Contractor felt that there wouldn't be enough room to screw the reinforcement into the mechanical connectors once the Phase 2 panels were set, so he installed the male mechanical connectors before placing Phase 2 panels. This made placing the panels in Phase 2 cumbersome since the reinforcing bars in the closure pour area from both panels interfered with each other. This required greater control while setting Phase 2 panels. Though the width of the opening for the closure pour must be at least equal to the splice length of the bar, providing additional width on future projects will give the Contractor more room to install any mechanical splice bars and to maneuver the panels into place.

Fig. 13 - Shear Connector Half Blockout (Mosquito Bridge)

Fig. 14 - Shear Connector Blockout (Haverhill-Newbury)

Since this technology is still relatively new to New Hampshire, it is necessary to make Contractors aware of differences between full depth deck panels, partial depth deck panels, and cast-in-place decks. Even though information is provided in the contract plan notes and special provisions within the contract proposal, past and potential problems should be communicated to the Contractor to ensure that they are aware of the construction difficulties and contract requirements.

One example that occurred on this project was grouting the shear keys before placing the post-tensioning strands. The Contractor thought that he was saving time by grouting these first. This approach would have allowed the post-tensioning Contractor to thread and tension the strand at the same time. However with the problem with installing the strand that arose in Phase 2, the post-tensioning Contractor was on the site two days longer than necessary, while waiting for the Contractor to correct the duct alignment problem.

Even though the special provision in the contract documents mentioned splicing the ducts together and that duct tape is not considered adequate for this connection, the Contractor did have some areas that were duct taped. This occurred where the strand penetrated the splice and got caught, causing delays with the post-tensioning strand placement.

The special provisions also mentioned that panels shall not be post-tensioned until they have attained a minimum 45-day cure to avoid shrinkage. The Contractor needs to be made aware of this curing time requirement so panels can be fabricated in a timely fashion to avoid delays.

Initially the Contractor thought he could build this project more quickly using conventional methods. After the project was completed he realized that the full depth panels would allow projects to be built faster but only if everything is in place and ready to go. Similar to the Mosquito Bridge project, designers must remember that additional time in the construction schedule may be needed by the Contractor to prepare for the "rapid" portion of the construction. The Contractor should be made aware of this so that scheduling of work and delivery of materials do not delay the project.

WHAT'S NEXT

The NHDOT learned from the previous Mosquito Bridge project and applied that knowledge to the Haverhill-Newbury project. Through these two projects, the NHDOT gained additional experience with rapid construction techniques for bridge deck replacement. Whenever appropriate, the Department will develop more deck replacement projects with full depth deck panels so that Contractors achieve a comfort level with this type of construction and reflect that experience in their bid prices for a more economical project.

ACKNOWLEDGMENTS

The Authors extend their appreciation to the Federal Highway Administration, which provided support and funding for this project through the Innovative Bridge Research and Deployment Program. In addition, the Authors acknowledge the valuable input provided by the University of New Hampshire and the Vermont Agency of Transportation.

CREDITS

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