

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

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ABSTRACT

The New Hampshire Department of Transportation (NHDOT) has utilized precast concrete deck panels since the early 1990s to accelerate construction and to increase safety for workers and the public. Having confirmed the efficiencies of partial-depth deck panels, NHDOT has furthered its involvement with precast panels by using a full-depth precast concrete deck system for a phased bridge deck replacement. This article describes the challenges in designing and constructing this project. Specifically, the details of achieving longitudinal continuity between the panels through the use of post-tensioning are discussed. Also the details of achieving transverse continuity and providing negative moment capacity at the joint between the phases, located over an interior girder, are discussed. Specifics regarding the timeline for construction, including the use of an incentive/disincentive clause, are also presented. NHDOT is building on the success of this project as it plans for future projects to continue the use and development of this system.

Keywords:

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

INTRODUCTION

The public's demand for minimizing construction conflicts and delays is directly proportional to the volume of traffic. This demand is exponentially proportional when the volume of traffic is experienced in a vacation region.

The Mosquito Bridge, so named because of the unique shape of the original structure that carried US Route 3 over Winnisquam Lake, from 1850-1916 (see Fig. 1), carries 20,000 vehicles per day at the peak of summer vacation season. The deck of this 4 span bridge was in need of replacement, and New Hampshire Department Of Transportation (NHDOT), desiring to minimize traffic disruption, decided to use this site to examine the benefits and test the efficiency of full depth precast prestressed concrete deck panels.

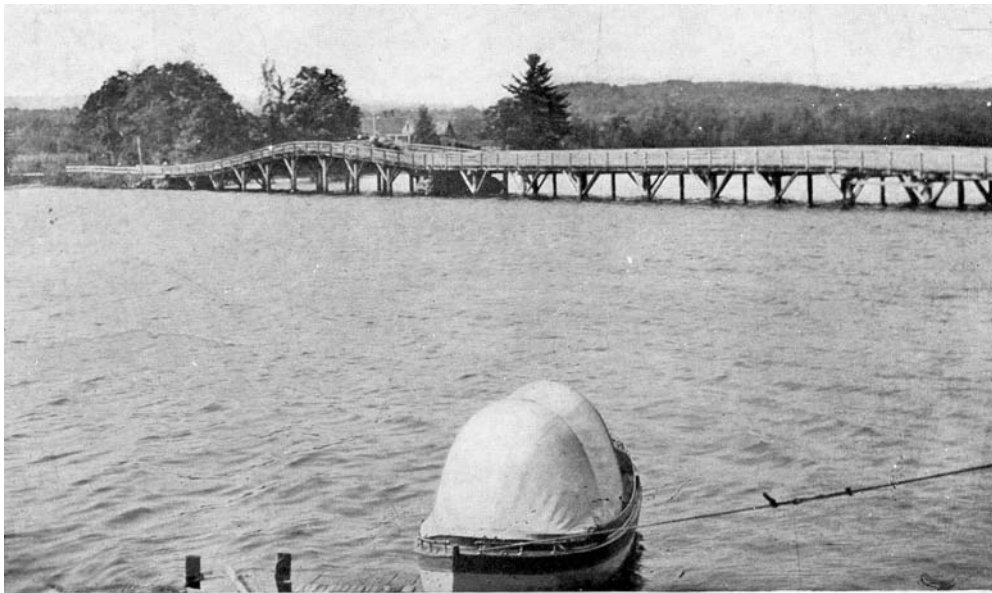


Fig. 1 Original Mosquito Bridge

BACKGROUND

NHDOT has been using partial depth deck panels since 1991, when they were used to redeck an interstate overpass. In 2001, the design of partial depth deck panels was standardized to allow their use on bridges that met the following criteria:

- Deck supported by straight girders
- Deck cross slope less than 4%
- Maximum Girder Spacing
 - Steel = 10'-0" (3.05 m)
 - Concrete = 12'-0" (3.66 m)
- Minimum Girder Flange Width
 - Steel = 12" (300 mm)
 - Concrete = 12" (300 mm)

- Bridge Length
 - Single Span = 150' (45.7 m) Maximum
 - Multi-Span = 175' (53.3 m) Maximum for any span
- Truck traffic less than 400 trucks per day

Since 2001, NHDOT's confidence level has increased to the extent that partial depth deck panels have been allowed on an interstate redecking project for a multi-span bridge with a maximum individual span of 200 ft (61.0 m) and with truck traffic of 2,300 trucks per day. This installation continues to perform very well. Partial depth deck panels have also been constructed with deck cross slopes greater than 5%. For some contracts, bidders are given the option whether to use partial depth panels or cast-in-place concrete.

Recognizing the potential time savings, acceptability of performance, and overall benefits of partial depth deck panels, NHDOT decided to expand on these advantages by using full depth deck panels. This would eliminate the need to construct a top mat of reinforcing steel as well as the time consuming concrete overpour required by partial depth deck panels to complete the bridge deck.

THE PROJECT

The present Mosquito Bridge was constructed in 1973 and experiences traffic volumes of 20,000 vehicles a day during the summer months. The four-span bridge has a total length of 468 ft (142.6 m) with end spans of 104 ft (31.7 m) and interior spans of 130 ft (39.6 m). The longitudinal elements are seven steel girders spaced at 7'-11" (2.41 m) with a top flange width of 1'-2" (0.36 m). The deck width, prior to the deck replacement, was 52'-5" (16.0 m) with a 5'-0" (1.52 m) wide sidewalk on the south side of the bridge. The bridge is built on a tangent horizontal alignment and on a crest vertical curve, which places the middle of the bridge approximately 3 ft (0.9 m) higher than the ends. The bridge has no skew.

Due to the generous width of the bridge, the deck replacement project was built in phases. Alternating two-way traffic was placed on two 11 ft (3.4 m) lanes during each phase of construction. The construction joint between phases was placed directly over the middle girder (see Fig. 2). The curbs were cast-in-place, to provide a continuous seal over the ends of the panels. A closure pour was required at each end, to encase the ends of the panels. The completed bridge was topped with a torch applied waterproofing membrane, and a bituminous wearing surface.

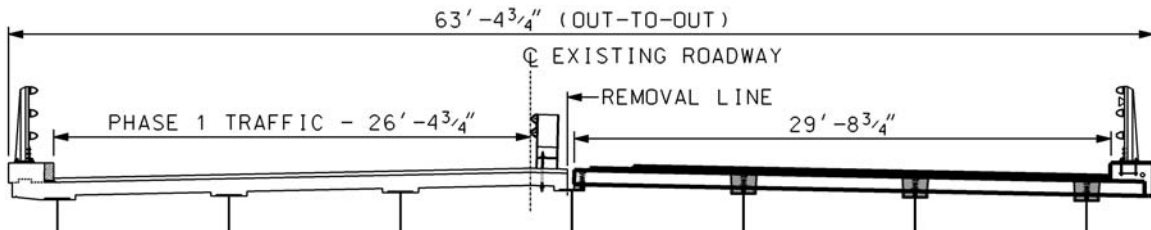


Fig. 2 Cross-Section During Phase 1

DESIGN

The designers looked to the PCI Bridge Design Manual¹ for guidance in the design of deck panels. Although the Manual only provides a limited discussion about the advantages of full-depth deck panels, it discusses the design of partial depth deck panels in detail. This was helpful in that the design issues faced by partial-depth deck panels are relevant for full-depth deck panels, as well. Regarding the sequencing of construction activities, the designers used the notes provided in Full Depth Precast Concrete Deck Slabs² as a starting point.

DETAILS

There were 3 different types of precast deck panels required for this project. Phase 1 required two types, which were nearly identical except for width extensions that were added to 3 panels to accommodate light fixtures. Phase 2 panels were all identical. A total of 116 panels were used. All panels are 8 in. (400 mm) thick and 8'-0" (2.4 m) in length. Phase 1 panels are 26'-4" (8.0 m) wide, except those that accommodate light fixtures, and Phase 2 panels are 25'-11" (7.9 m) wide.

The following details were used on this project:

Grouted shear keys – The fabricator was given a choice as to the shape of the shear keys (see Fig. 3). The actual constructed shear key is shown in Figure 4. There is a foam backer rod placed in the ¼ in. (6 mm) gap between the bottom panel edges to prevent leakage of the grout. All transverse joints between panels are filled with a high strength non-shrink grout. The sequence of construction requires this grout to achieve a strength of at least 1,500 psi (10 MPa) prior to post-tensioning of the longitudinal strand. Specifications require a strength of 6,000 psi (40 MPa) at 7 days.

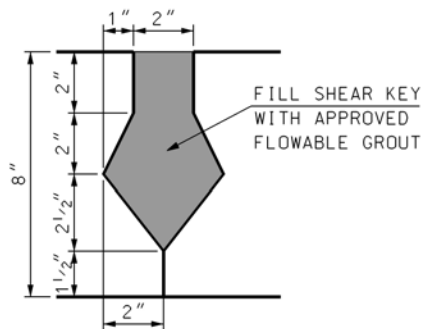


Fig. 3 Shear Key Alternative

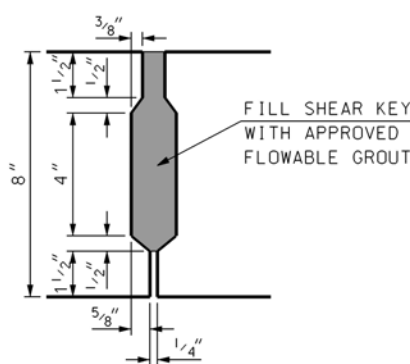


Fig. 4 Shear Key

Shear connectors – Blockouts for shear connectors are placed at 2'-0" (600 mm) on center to meet the requirements of AASHTO Standard Specifications for Highway Bridges³. The blockouts are oval in shape, rather than rectangular, in order to avoid stress cracks at the corner of the blockouts. The blockouts are also wide enough to allow

the placement of four shear connectors per blockout. Blockouts taper ½ in. (12 mm) down the 8 in. (400 mm) thickness of the panel, so as to provide the best possible interaction between the headed shear stud and the final grouted and post-tensioned deck panel. Blockouts over the middle girder are half ovals.

Longitudinal post-tensioning ducts – Although the project was designed using AASHTO’s Standard Specifications, these specifications do not prescribe a post-tensioning stress between the transverse joints. The AASHTO LRFD Bridge Design Specifications⁴ do require a post-tensioning stress of 250 psi (1.72 MPa) in areas of positive bending between each panel in order to maintain the integrity of the transverse joints. Neither code addresses the stress required in areas of negative bending. Considering 250 psi (1.72 MPa) as a minimum stress, the designer required an additional 150 psi (1.03 MPa), for a total stress of 400 psi (2.75 MPa), in order to account for the negative moment over the piers.

The plans depicted one possible duct layout that would accommodate this level of post-tensioning. The note pointing to the duct states, “POST TENSIONING DUCT (TYP) PER MANUFACTURER”.

Special Provisions required that “anchorage devices shall meet the requirements of Section 10.8.3 of AASHTO Specifications for Highway Bridges, Division II, 2002, and latest interims,” in order to adequately distribute the post-tensioning force.

Longitudinal panel closure pour – Phases 1 and 2 meet directly over the middle girder, which has a 1’-2” (0.36 m) wide top flange. To create negative moment capacity in this region, mechanical connectors were included in the Phase 1 panels, and a notch with embedded shop-bent reinforcing steel was provided in the Phase 2 panels (see Fig. 5). The mechanical connector and embedded bar allowed the bars from the two panels to each have adequate development length. These bars carry their load in a manner similar to any cast-in-place deck and were spaced according to NHDOT standards for CIP decks.

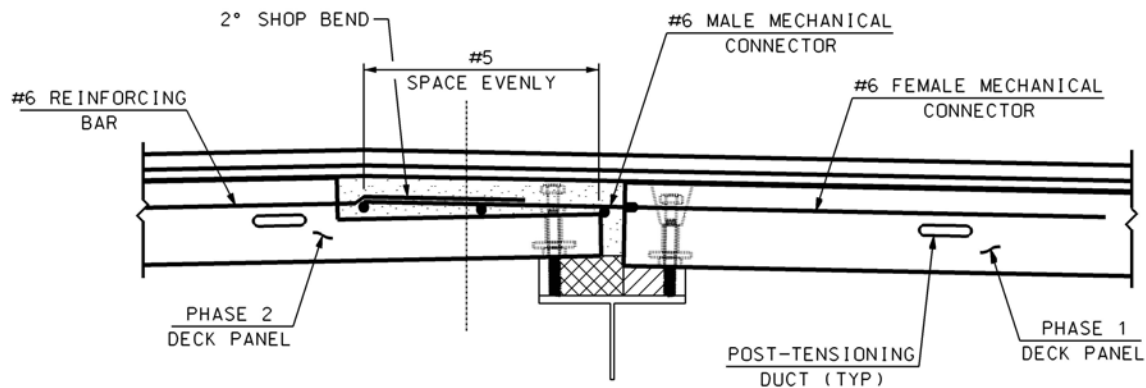


Fig. 5 Closure Pour Detail

CONSTRUCTION

One of the stated goals of this project was to construct the deck in as short a time as possible, and to have the bridge completely open for traffic during the summer months.

NHDOT included an incentive/disincentive clause in the project that would award the contractor \$5,000 per day for each calendar day where Phase 1 and Phase 2 deck replacement work was complete and pedestrian access was restored prior to June 30, 2006. Conversely, a \$5,000 per day disincentive would be assessed for each calendar day where Phase 1 and Phase 2 deck replacement work was not complete and pedestrian access was not restored prior to June 30, 2006. A \$25,000 incentive was also available to the contractor if all bridge work, including a sidewalk to be built in phase 3, was completed by June 30, 2006. An additional \$25,000 incentive was also available to the contractor if all work on the project was complete by October 6, 2006. The potential incentive was capped at \$100,000. The disincentive was not capped.

The contract bids were opened October 27, 2005 and the contract was awarded on December 7, 2005. The full depth deck panel shop plans were reviewed and approved during the early months of 2006.

As deck panels were being fabricated, hairline cracks were noticed at the corners of shear connector blockouts at the splice over the middle girder. (See Fig. 6 for the half oval blockout at the splice, although hairline cracks are not visible in the photo.) Discussions with the fabricator led to several different reinforcing details to attempt to minimize this cracking. No detail thoroughly eliminated it, but the longitudinal post-tensioning, applied at the end of each phase, closed the cracks and made them essentially unnoticeable.



Fig. 6 Blockout along Middle Girder

The contractor placed the temporary rail on March 21, 2006, which allowed him access to the roadway in order to begin saw cutting for the Phase 1 portion of the deck work. Next, steel K-frames were disconnected from the middle girder, and the deck removal began. This was complete on April 14, 2006, and deck panel installation then commenced. The first eleven panels were placed by crane from the end of the bridge, and all remaining deck panels were placed using a barge-mounted crane. The Phase 1 panels were completely set on April 21, 2006 (see Fig. 7). At this point the deck panels had not been adjusted, grouted, or post-tensioned.



Fig. 7 Panel Erection From Barge

There are 8 leveling screws per panel so that each panel is supported on two screws at each girder. The contractor used these bolts to achieve finished grade elevations provided on the plans. The bolts were then all torqued to within 15% of each other, so as to assure even dead load distribution among all the bolts. Bolts at the joints between the construction phases required only half as much torque as the others. Adjusting the panels via the bolts was a simple procedure for the contractor.

The next step in the project was to install the longitudinal post-tensioning strand. This was done by drawing strand from a coil (see Fig. 8) into a hydraulic feeder (see Fig. 9) that pushed the strand into the duct at a high rate of speed. The shop drawings had detailed the post-tensioning duct in a manner identical to the NHDOT plan details. This consisted of two oval ducts between each pair of girders that would each hold four 0.6 in. (15.2 mm) diameter post tensioning strands. This detail proved difficult to construct since it did not allow much additional annular space for installing the strand (see Fig. 10). Duct misalignment from precast panel to precast panel added to the difficulty, which may have been exaggerated by the presence of the vertical curve of the roadway profile. In order for the contractor to install the strand, he needed to install 0.5 in. (12.7 mm) diameter strand with the feeder for half the length of the bridge. He then installed 3/8 in. (9.5 mm) strand from the opposite end of the bridge. Next, he welded the two strands at the center of the bridge and pulled the smaller strand with a front-end loader in order to get the larger strand into the duct for the entire length of the bridge. Then he welded the 0.6 in. (15.2 mm) strand to the 0.5 in. (12.7 mm) strand and pulled the 0.5 in. (12.7 mm) strand in order to get the larger strand into the duct. The task of installing the strand in the ducts was expected to take one day per phase, however, due to the difficulty in inserting the strand through all deck panels over the full length of the bridge, the task took a total of eight working days for Phase 1.



Fig. 8 Coil of Strand



Fig. 9 Hydraulic Strand Feeder



Fig. 10 Longitudinal Post-Tensioning Strand

Based on discussions after the project was completed, it is believed that the contractor specified such tight duct spacings on the shop drawings because he thought the dimensions that detailed the post tensioning ducts were prescriptive rather than conceptual. Additional annular space and better duct alignment would have allowed this process to proceed more smoothly and in a more timely manner.

After all strands were inserted in a duct, it was sealed between each panel to prohibit the transverse joint grout from filling the duct, which would prevent effective grouting of the post-tensioning strands. The contractor used heat activated shrink wrap tape to seal these joints (see Fig. 11 for tape pulled back from joint at a duct with a grout injection port) and then grouted the transverse joints with Sure-Grip High Performance Grout by Dayton Superior. By May 5, 2006, the transverse joints had all been grouted for Phase 1.



Fig. 11 Shrink Wrap Tape At Duct Joint

The contractor post-tensioned the strand on May 10, 2006 (see Fig. 12). This decreased the overall length of the deck and, as mentioned earlier, caused all hairline cracks at the shear connector blockouts over the middle girder to disappear. Post tensioning did not induce any cracks into the panel ends nor did it cause any adverse differential movement between the panels and the girders.



Fig. 12 Jacking of Post Tensioning

Shear connectors were then installed on the girders, with four in each blockout (see Fig. 13). Inspection of the shear connectors could only be done by sounding the studs with a hammer. Replacing inadequately welded studs is problematic due to the difficulty in working within the confines of the blockout.



Fig. 13 Shear Connectors

Construction then slowed as the region received 5.5 in. (140 mm) of rain in 2 days and an additional 5 in. (127 mm) in the following week. It was not until June 14, 2006 that the contractor completed grouting the Phase 1 longitudinal ducts to protect the strand, and installing grout over all haunches and shear connector blockouts located over the tops of the girders. The contractor used SikaGrout®-300 PT to grout the longitudinal ducts, and used self-consolidating concrete as bedding for the full depth panels and to fill the shear connector pockets. Curb, bridge rail, barrier membrane, and asphalt pavement were then installed.

Phase 2 of the work progressed similarly to Phase 1, with the biggest delay being caused by difficulties with the installation of the longitudinal post tension strands. One unique feature of the Phase 2 work was the closure pour between the phases. The detail shown in Figure 5 worked well, except that some of the Phase 2 panels were too thick over the middle girder, so that the contractor had difficulty installing the threaded mechanical connector reinforcing into the Phase 1 panel. Also, the transverse #6 reinforcing bars that extended from the Phase 2 panel were not bent sufficiently at the fabrication shop; the contractor needed to bend each bar downward in order to adequately provide concrete clear cover. The insufficient bend was an issue because the closure pour is located along the bridge crown line and because the Phase 1 and Phase 2 panels are placed along opposing 2% slopes to create the roadway crown.

The Phase 2 work was completed on August 31, 2006 (see Fig. 14). Due to difficulties experienced by the contractor and the associated delay to the construction schedule, the Department and contractor are still discussing the amount of the disincentive to be assessed.



Fig. 14 Completed Bridge

LESSONS LEARNED

While rapid bridge construction is a viable approach to reducing the amount of time that traffic is inconvenienced, 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. For instance, schedules should allow time to mitigate issues that could arise in the fabrication and delivery of precast panels. If the schedule is so tight that any interruption in the contractor’s supply will guarantee that he is forced to pay a disincentive, then owners should expect the contractor’s bid price to reflect that risk.

The need for excellent quality control is clear, especially with regards to the location of post-tensioning ducts and overall panel dimensions. In the case of this project, the Phase 2 panel thickness over the middle girder also was important. In general, any detail that, if done incorrectly, will slow the contractor’s progress requires additional vigilance. This is

especially relevant during the time the contractor is performing work that is eligible for an incentive. Similarly, items that cannot be easily inspected once installed, such as post-tensioning grout, require extra attention at the time of installation.

Finally, designers need to create plans that are clear regarding what details the fabricator is responsible to address in the shop drawings. If dimensions on the plans are included to merely indicate one possible method of accomplishing the work, these dimensions should be noted as such.

The contractor also gained experience in this type of construction. Following the completion of this project, they constructed a bridge deck for a municipally owned bridge using very similar details to those used on the Mosquito Bridge. Tighter quality control helped the contractor avoid the conflicts that occurred in this project.

WHAT'S NEXT

The NHDOT considers this project a successful application of full-depth deck panels. It is estimated that if the deck had been cast-in-place, it would have required 34 working days per phase to construct. If delays, primarily due to strand installation, were avoided, this project is estimated to have required 11 working days per phase to construct. The increase in cost for deck items was approximately 45%, which is expected to diminish as contractors become more familiar with the installation of full depth panels.

Another project is planned for 2008 that will build on the lessons learned in this project. Layout of this future project will require either a complete bridge closure, thus making the incentive/disincentive more important to the public, or construction in phases with a rebar splice and deck closure pour in the positive bending region, between girders, rather than over the middle girder.

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CREDITS

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