DESIGN CONSIDERATIONS OF FULL-DEPTH PRECAST/PRESTRESSED CONCRETE BRIDGE DECK PANELS

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ABSTRACT

Development of a full-depth precast bridge deck construction system provides a very effective and economic design concept, and can be implemented for the rehabilitation of existing highway bridges as well as new bridge construction in order to shorten the time of reconstruction and bridge closures, and to minimize interference with traffic flow.

Most bridge decks are constructed using either cast-in-place concrete or precast structural concrete stay-in-place form panels with a cast-in-place deck. The use of these conventional deck construction techniques with associated curing requirements can easily take many months in comparison to the full depth bridge deck system that can be erected over a period of several days, or a few weeks.

Based on the findings from previous and current research and past practice on the full depth precast panel system, a very effective and economic design concepts and specification were developed for design, fabrication, and construction of post-tensioned full depth, full width, precast-concrete bridge deck systems. This paper presents the design consideration of a full depth panel that includes casting and placement tolerances, shear pocket dimensions and shear connections, transverse joint and the type of materials within the joint, vertical alignment, final grade adjustment, post-tensioning force, type of overlay materials, and parapet connections.

Keywords: Full-depth, Precast panel, Post-tensioning, Leveling bolt, Polymer Concrete, non-Shrink Grout, Shear Studs, Haunches, Transverse Joint, and Overlay.

INTRODUCTION

The scope of this paper is to develop the design considerations of full-depth precast prestressed concrete bridge deck panels under static loading. The investigation entails a detailed evaluation of system components, particularly the joints between adjacent precast panels as well as the connection between the slab and its supporting system, and adequacy of prestressing force provided to secure the tightness of the transverse joints. The proposed system provides a very effective and economic design concept, and can be implemented for the rehabilitation of existing highway bridges as well as new bridge construction in order to shorten the time of reconstruction and bridge closures, and to minimize interference with traffic flow.

This system combines high strength tendons and high performance concrete to produce durable deck panels that are effective in aggressive environments. The panels are connected to the steel stringers or prestress beams through shear pockets to provide composite action. The deck panels can either be precast or precast prestressed. In this type of construction, the entire bridge deck is of precast concrete to enable the rapid replacement of deteriorated decks, and render the rehabilitation process extremely cost effective. There is no additional field cast-in-place concrete acting structurally, except that used in the connections and slab closures.

In the past, structural beams needed enough contact area to provide the necessary friction between the steel and concrete slab for complete interaction. With the advent of shear connectors, the area that is necessary to transmit the shear loads to both materials was reduced, making composite design economically attractive. Composite systems permit savings of steel up to 20%. Shear connectors are important since they provide connections and points of interaction between the steel beams and the concrete slab. The goal is to have the neutral axes for both materials coincident so that the combination of the concrete slab with the steel beam acts as a single composite material.

The keyway joint is the structural element of a bridge that connects the ends of precast concrete units. The joint is subjected to several types of loads during bridge life such as flexure, tension and shear. The results of these events generate cracks that allow infiltration of water that is an important factor in steel corrosion. Some of the materials that can be used to fill the joints are set grout (non-shrink grout) and polymer concrete.

As revealed from the previous study (Issa et al. 1995) the structural performance of the most critical components of full depth precast concrete bridge deck systems under static loading that includes the transverse joints between adjacent precast panels, type of materials in the joint, the connection between the slab and its supporting system, and the amount of prestress force that is needed to secure the tightness of the transverse joints have been investigated.

LITERATURE REVIEW

Previous literature indicated that many states have experimented with precast concrete slabs for deck replacements offering a wide variety of design and construction methods. The first trials were started in the early 70's in New York, Alabama, and Indiana. The spans did not have any skew or superelevation. More projects involved new construction rather than rehabilitation, so that, fewer geometric fit up problems were experienced rather than with deck replacement. The deck-stringer system was primarily noncomposite, although some composite action was noticed.

Significant advances have been made since the mid-70's through the beginning of 80's. Many of the spans were composite and some involved complex geometries. Major structures were constructed nationwide by New York State Thruway Authority (NYSTA), Pennsylvania Turnpike Commission, Massachusetts Turnpike Authority, New York State DOT (NYSDOT), California DOT, Maryland State Highway Administration, Federal Highway Administration, Delaware River Joint Toll Bridge Commission, Pennsylvania DOT, Connecticut DOT, Virginia DOT, Iowa DOT, Alaska DOT and Public Facilities, Ohio DOT, and ILDOT.

A comprehensive study was conducted by the University of Nebraska (1997), jointly with HDR Engineering Inc. and Kiewit Construction Company to evaluate existing rapid bridge deck replacement methods and develop better procedures and new superstructure designs for future rapid deck replacement. Three main areas were investigated where modifications could be made to make deck systems more suitable for rapid replacement. These three areas correspond to the demolition process and equipment, the bridge deck system itself, and the bridge girder-to-deck connection.

A two-year research project entitled "Structural Behavior of Full Depth Precast/Precast Prestressed Concrete Bridge Deck Replacement" was completed (Issa et al. 1995, 1998). This project was funded by the Illinois Department of Transportation. The aim of this study was to evaluate the durability, performance, and cost effectiveness of full depth precast concrete bridge decks that can be installed on steel stringers, in order to formulate an optimum bridge deck system. This optimum design can help in further establishing the effectiveness of precast and prestressed concrete components in the design and construction of the bridges and highway systems across the country. The proposed bridge deck systems will introduce improved features to the construction and rehabilitation procedures employed by the transportation industry. The findings indicate that the potential to adopt the proposed design system is very promising, and could be of great interest throughout the nation. A major advantage in using the precast system is the minimum interference with traffic resulting from a reduction in construction time. In most cases, traffic is maintained in both directions during the rehabilitation process by either employing a two-phase construction plan or weekend and/or night closures of the bridge under construction. The advantages of such systems have also been reported by others (e.g., Knudsen 1980, Slavis 1983, Berger 1983).

A comprehensive survey was conducted to identify bridge decks rehabilitated or built using full depth precast concrete decks for the rehabilitation of deteriorated bridges as well as new bridge construction (Issa et al. 1995c). Fifty-three questionnaires were sent to all departments of transportation in the United States as well as Ontario, Canada. The response was excellent as the collected data was analyzed. The results revealed that this concept has been used for two decades in a few parts of the United States and recently in Ontario, Canada. Results of the survey also indicated that several states had problems with some aspects of the system. These problems included improper design, inadequate configuration of the structural components of the system (i.e., joint between the panels and connection at shear pockets), poor construction procedures, unsatisfactory materials, and lack of post-tensioning in the longitudinal direction to secure the tightness of the transverse joint. As a result, this study determined the necessity for establishing code specifications for new bridge construction and rehabilitation using full depth precast and precast prestressed, concrete bridge deck panels.

A recent quarter-scale experimental program was conducted on three bridge models at the University of Illinois at Chicago. Three bridge models were fabricated and tested in accordance with the guidelines set forth in the earlier study. The first bridge model was a two-span continuous structure without post-tensioning. Furthermore, the second bridge was post-tensioned at a direct prestress level of 208 psi (1434 kPa) to determine the effect of post-tensioning on the behavior of the transverse joints between adjacent precast panels. The third bridge was identical to the second bridge, however, a larger prestressing force of 380 psi (2620 kPa) was provided to determine the effect of amount of post-tensioning.

The first cracking in the non-post-tensioned bridge model occurred in the transverse joints near the vicinity of the central support at 11 kips (49 kN), which ultimately lead to the failure of the bridge through complete splitting between the central panel and the joints. Cracking in the first bridge model only occurred in the two transverse joints at the central support. The second and third bridges experienced cracking at the central support at 35 and 40 kips (156 and 178 kN), respectively. However, more cracking developed away from that region within the central panel as the load was increased. The first cracking load was three times higher for the post-tensioned bridge models than the non-post-tensioned bridge.

Another three-year research project entitled "Experimental Evaluation of Full-Depth Precast/Prestressed Concrete Bridge Deck Panels" was completed (Issa 2002). This project was funded by the Illinois Department of Transportation. The objective of the project was to study the components of the system that are of concern are: connection between precast panels and supporting system, behavior of transverse joint between adjacent precast panels, materials in transverse joint, shear studs, leveling bolts, longitudinal post-tensioning, transverse prestressing for handling and erection, non-shrink grout, overlay, and construction sequence. The materials investigated within the joint were polymer concrete, non-shrink grout, and set-45. The transverse joints were subjected to direct shear tests, direct tension tests, and flexure tests. These tests exhibited the excellent behavior of the system in terms of strength and failure modes. Shear key tests were also concluded. These shear connection study focused at investigating the composite behavior of the system based on varying the number of shear studs within a respective pocket as well as varying the number of pockets within a respective panel. The results indicated that this shear connection is extremely efficient in tendering the system under full composite action.

Based on the results of the component study, a full-scale two-span bridge of 18 ft wide and 82 ft long was fabricated. The bridge deck panels were installed on steel girders and the bridge was post-tensioned using Dywidag bar and strands in the longitudinal direction.

The system proved its effectiveness in withstanding the applied loading that exceeded 8 times truck loading in addition to the maximum negative and positive moment application. Only hairline cracking was observed in the deck at the maximum loading applied. Of most significance, was the fact that full composite action was achieved between the precast panels and the steel supporting system, and the exceptional performance of the transverse joint between adjacent precast panels.

Research Significance

The paper presents a very effective and economic design for full depth precast panels that can be implemented for the rehabilitation of existing highway bridges as well as new bridge construction in order to shorten the time of reconstruction and bridge closures, and to minimize interference with traffic flow. This system combines high strength tendons and high performance concrete to produce durable deck panels that are effective in aggressive environments. The panels are connected to the steel stringers through shear pockets to provide composite action. The deck panels can either be precast or precast prestressed, and post-tensioned in the longitudinal direction to provide continuity and secure tightness in the joints between adjacent precast elements. In this type of construction, the entire bridge deck is of precast concrete to enable the rapid replacement of deteriorated decks, and render the rehabilitation process extremely cost effective. There is no additional field cast-in-place concrete acting structurally, except that used in the connections and slab closures.

Development of Design Detailed

The major parameters needed in designing the full depth bridge deck are:

- Precast panel dimensions and configuration.
- Size of mild reinforcement.
- Shear pocket dimensions and spacing, number and size of shear connectors that are required to achieve full composite action between the precast panels and the supporting system.
- Configuration of the joint between the adjacent precast panels (type and material).
- Post-tensioning force that is needed longitudinally (i.e., prestress level), to secure the tightness of the joints, and transversely, to account for handling and erection stresses.
- Crane size
- Type of overlay materials
- Parapets and parapet connections

Precast Panels

Precast concrete bridge deck panels can be used for replacement of existing deck slabs or for new construction. A typical precast panel that includes mild steel, shear connector, post-tensioning sheath ducts, location of leveling screws, and location of grouting ducts is shown in Figure 1. The supporting system may be precast prestressed concrete girders or AASHTO beams as shown in Figure 2.

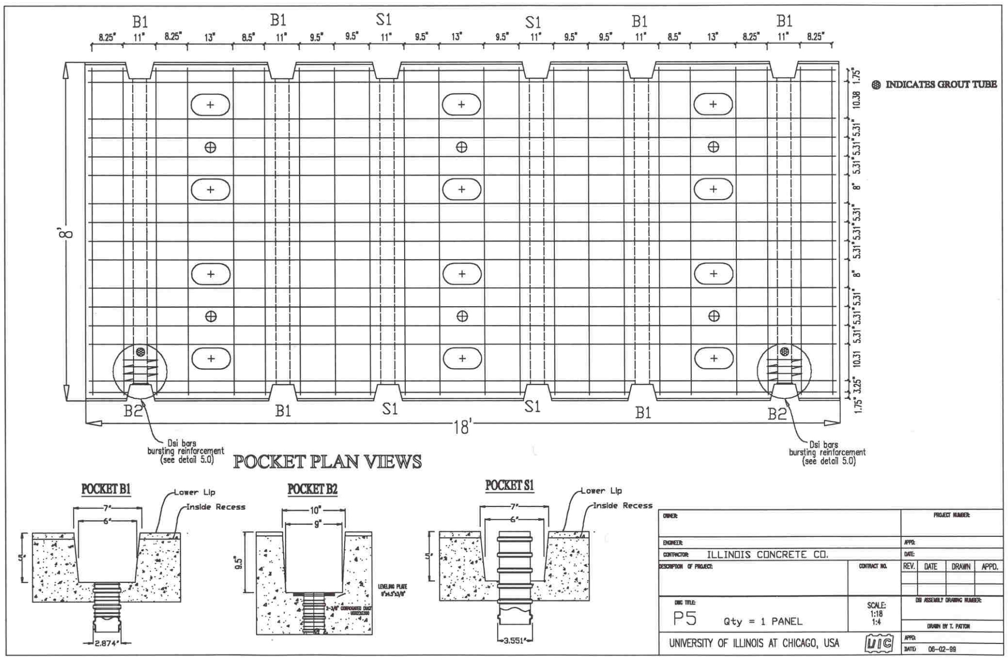

Fig. 1 Typical Precast Panels

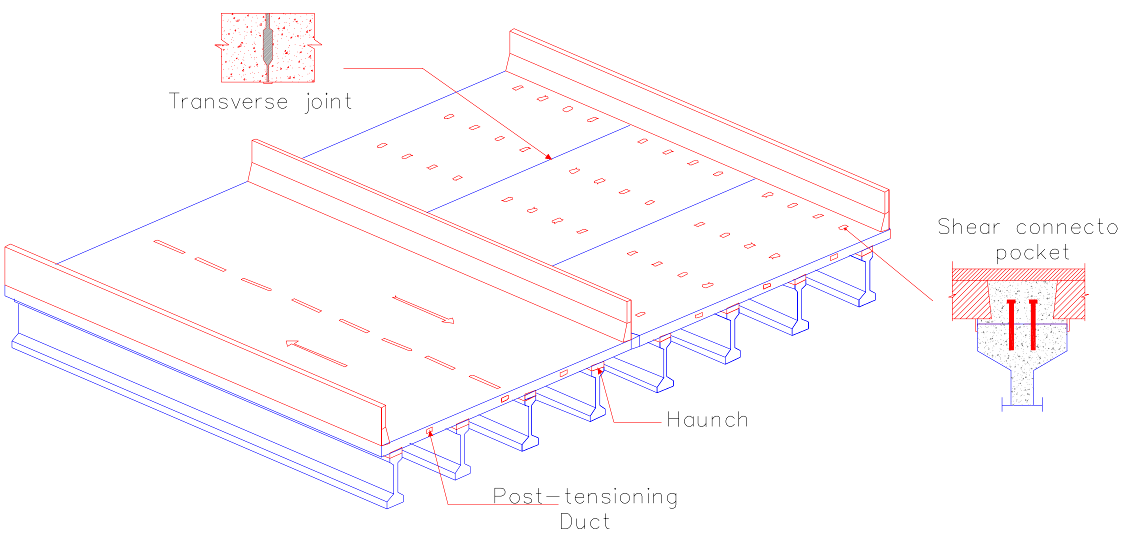

Fig. 2 Typical Layout of Precast Slab on AASHTO Beams

The panels may be designed for transverse flexure (main reinforcement perpendicular to traffic) with mild reinforcement, prestressing strands, bonded post-tensioning strands, or combination of each. Depending on the width of the precast panels, the panels must have a sufficient amount of transverse prestress to avoid cracking during handling and erection of the slab units.

High Performance Concrete Mix Design for Precast Panels

High Performance Concrete Materials is specified for the precast panels. The mix design for precast panels permits a wide latitude in the use of good quality of aggregate and cement. The suggested mix proportions of two mixes are shown in Table 1. The 28-day compressive strength of the concrete element must be 6,000 psi (34.5 MPa) minimum. The units can be shipped and used if their compressive strength has attained 4,500 psi (30 MPa) after 4 days. The maximum water-to-cement ratio is 0.38. The air content of the concrete mix must be within 5% to 8% total air. Table 2 shows the mixture proportions of a typical mix of the high performance concrete.

Table 1. Proposed HPC Mix Design for Mix 1 and Mix 2

Concrete Component	**MIX 1**	**MIX 2**
Portland cement **Type I**	525-575 lb/yd^3	575-620 lb/yd^3
Fly ash **Class C or F**	10% addition (by weight of cement)	20% addition (by weight of cement)
Silica fume	5% addition (by weight of cement)	5% addition (by weight of cement)
Ground granulated blast furnace slag (GGBFS)	15 % addition (by weight of cement)	-
Coarse aggregate	¾ in. Maximum size (No. 67/CA11) crushed stone	¾ in. Maximum size (No. 67/CA11) crushed stone
Fine aggregate	Natural siliceous sand	Natural siliceous sand
Water/cementitious material ratio	0.36-0.38 (including water from HRWR)	0.36-0.38 (including water from HRWR)
Air entraining agent	1-2 oz/100 lb. Portland cement	1-2 oz/100 lb. Portland cement
HRWR, AASHTO M194 Type F	Approx. 100-128 oz/yd^3	Approx. 100-128 oz/yd^3

Table 2 Recommended Mixture Proportions (lb/ yd^3) of HPC Mixes

Mix Proportion	Mix #1	Mix #2
Cement, Type I	578 (lbs.)	602 (lbs.)
Fly ash	58 (10%) (lbs.)	120 (20%) (lbs.)
Silica fume	29 (5%) (lbs.)	30 (5%) (lbs.)
GGBFS	87 (15%) (lbs.)	--
Fine aggregate	1088 (lbs.)	1088 (lbs.)
Coarse aggregate	1729 (lbs.)	1729 (lbs.)
Water	271 (lbs.)	271 (lbs.)
HRWR, Daracem-19, (ml)	2884	2884
MB-VR Standard Air- entraining admixture (ml)	444	444
Water/cementitious ratio	0.36	0.36

HPC Performance and Durability Criteria

The High Performance Concrete mix performance and durability criteria for the precast panels are shown in Tables 3 and 4.

Table 3. HPC Mix Performance Criteria

Property	Required Values	Test Methods
Plastic Concrete Properties		
Total air content, plastic concrete	6½61½% (1)	AASHTO T152
Max. slump after High Range Water Reducer (HRWR) addition	7 in.	AASHTO T119
Slump, minimum after 45 minutes	4 in.	AASHTO T119
Initial set time, minimum	3 hours	AASHTO T197
Hardened Concrete Properties		
Post tensioning strength, minimum	4,500 psi	AASHTO T22
28-day compressive strength, minimum	6,000 psi	AASHTO T22
Total air content, hardened concrete	6½61½%	AASHTO C457
Max air void spacing factor	0.010 in	AASHTO C457
Min air void specific surface	500 in^2/in^3	AASHTO C457

(1) or as required to meet the total air content in the hardened concrete.

Table 4. Durability and Material Properties of HPC

Property	Required Value	Test Method
Freeze/thaw resistance	DF>90% at 300 cycles DF>85% at 500 cycles	AASHTO T161
Chloride permeability resistance	<2000 coulombs at 28 days	AASHTO T277
Chloride penetration resistance	½ - 1 in., <0.03% Cl^- by wt. of concrete at 90 days ½ - 1 in., <0.07% Cl^- by wt. of concrete at 6 months	Modified AASHTO T259/T260 (15% NaCl ponding solution)
Salt scaling resistance	Rating of 0-1 at 50 cycles	ASTM C672
Shrinkage	<600x10^{-6} in/in at 90 days	AASHTO T160

Crane Size

Construction using precast panels requires the availability of cranes in order to lift and place the panels on the deck grade. The cranes can be located on the bridge if the bridge strength and width can appropriately accommodate it. Cranes and other heavy equipment shall not be allowed on the bridge if it will impose structural inadequacies in the bridge. The boundary and constraint conditions could also significantly control the placement of the cranes or other related equipment such as tower lines, etc.

Leveling of Precast Panels

Leveling bolts should be used to adjust the grade of the precast slab units during placement. Each bolt should be torqued to insure that there is approximately equal bearing on each leveling bolt providing proper dead load distribution to each girder. There should be a minimum of two leveling bolts over each girder depending on the length of the precast panels. The leveling device is shown in Figure 3.

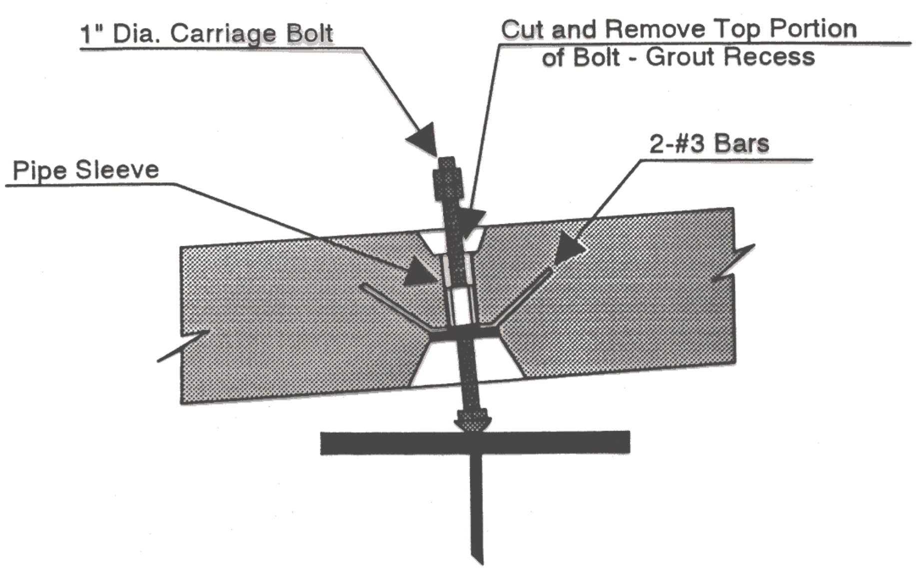

Fig. 3 Leveling Device

Haunches

A minimum of 1" haunch shall be provided between the precast panels and the beams to allow for any misalignment or irregularity. Forming for the haunch shall be made at the bottom of the panel so that grout can flow through the depth of the deck. Non-shrink grout for the girder haunches and shear connector blockouts shall have a one-hour compressive strength of 500 psi. Figure 4 shows a view of haunch before grouting. The thickness of haunch varies from 1" to 2" along the girder depending on its location. Haunches between the top of stringers and the bottom of deck panels shall be grouted through the grouting voids in sequence so that the grout shall be observed to be entering the grouting void and be at an elevation above the bottom of the next void prior to beginning grout application through the next void.

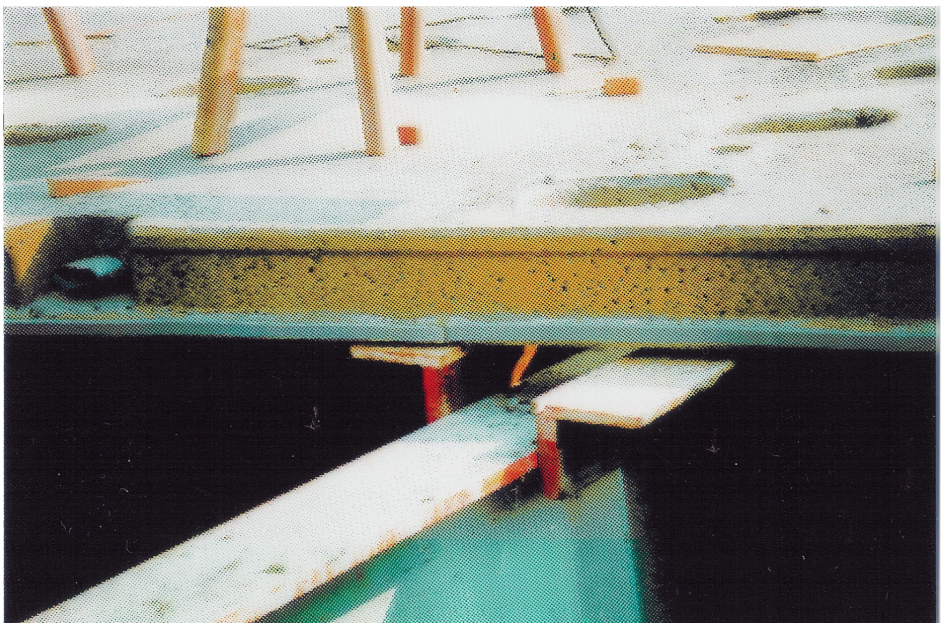

Fig. 4 Haunch before Grouting

Transverse Joints

The transverse joints between the precast panels should be of female to female type and have a nominal width of 1 inch at the top and ½ inch at the bottom as shown in Figures 5 and 6. The width of this joint may be adjusted in the field by ±¼ inch to account for casting tolerances. Any minor dimensional growth can be accounted for in the closure pours at the ends of the spans. The opening shall be enlarged through the entire depth of the panel to allow for securing the ducts once the strands are run through. The ducts shall be wrapped with duct tape to secure the duct. Figure 5 shows the forming of the transverse joint.

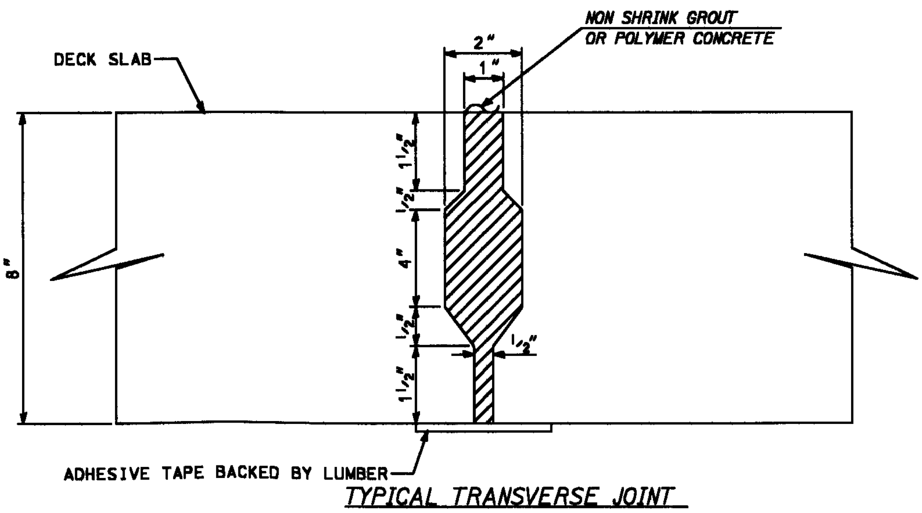

Fig. 5. Typical female to female type joint between precast panels

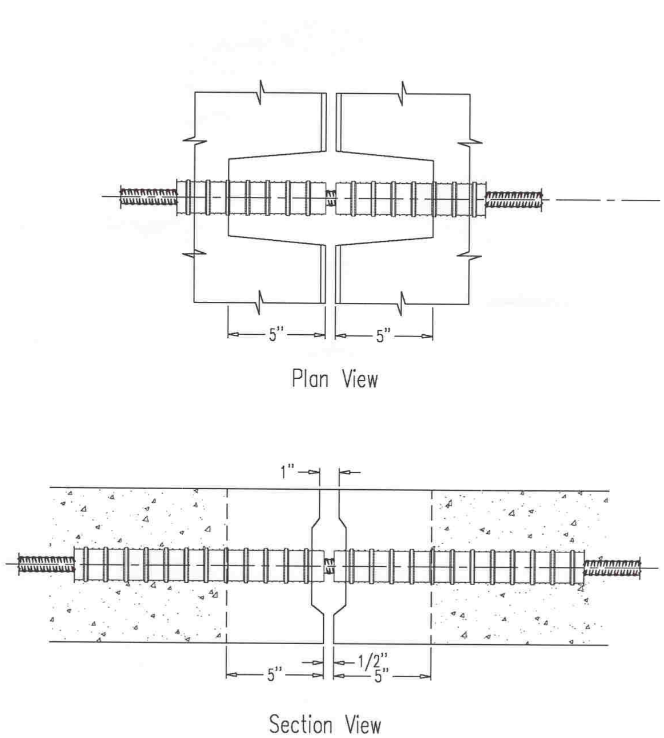

Fig. 6. Typical Transverse Joint

Materials in the Transverse Joint

The grout used within the transverse joints should be high early strength polymer grout to allow for post-tensioning of the precast slab units approximately one hour later. The process of applying the polymer concrete consists of priming concrete surfaces and furnishing, mixing, and placing polymer concrete for closure of transverse roadway joints between precast deck panels. Alternatively, set grout (non shrink grout) can be used within the transverse joints, if the post-tensioning is not required immediately after casting. Figures 7 and 8 show the mode of failure of different joint filling materials

Fig. 7 Failure mode in set grout flexural specimen

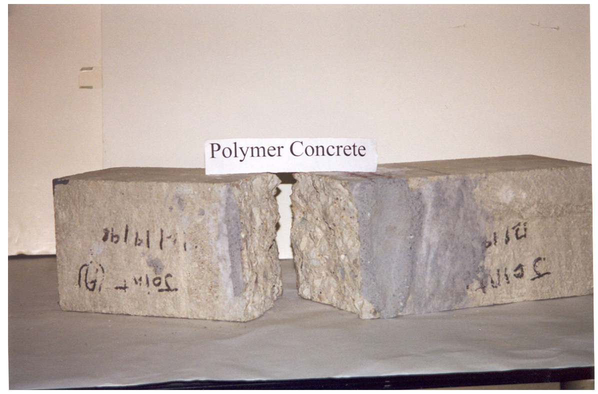

Fig. 8 Failure mode in polymer concrete flexural specimen

The sequence of construction for the precast concrete deck panels should be such that the longitudinal post-tensioning is accomplished after the transverse joints between precast panels have been grouted and before the slab is made fully composite with the girders in order to avoid inducing unusual stresses in the girders.

Grout Materials for Posttensioning

The grout for the post-tensioning conduit shall consist of a mixture of Portland cement, water, and expansive admixture. The grout shall conform to the following requirements:

a. The grout mix shall have an unrestrained volumetric expansion of not less than 3 percent nor more than 8 percent.
b. The grout mix shall have a minimum 28day compressive strength of 4,500 psi, when tested by methods conforming to the requirements of ASTM C-109.
c. The water content of the grout shall be kept as low as possible for proper grouting. However, it shall not exceed 5 gallons per sack of cement.

Chlorides, fluorides, sulfates, and nitrates shall not be used. The water shall be potable. Portland cement for the grout shall be Type I or Type II cement.

The grout shall have an excellent durability record for similar installations in cold and dry climates. The grout shall be self leveling and easily pumpable. The contractor shall submit information relating to the acceptability of any grout or mortar to the engineer for review and approval at least 6 weeks prior to the start of grouting.

The grout shall be applied so that all voids to be filled are completely filled. The grout ingredients shall be added to the mixer in the following order: (1) water, (2) cement, and (3) admixture. The ingredients shall be mixed sufficiently to produce a uniform thoroughly blended grout with a minimum air entrapped. An excessive temperature rise due to extended mixing shall be avoided. No additional water shall be added to the grout after mixing.

The grouting shall not start before the post-tensioning operation is complete. The valves on all outlet tubes (drain, vent, and grout tubes) shall be closed except for the outlet tube closest to the grouting end of the conduit, which shall be open. The initial pump gage pressure shall be less than 40 psi, and shall gradually be increased until steady stream of grout, free of air and diluted grout, flows from the outlet tube. The outlet tube shall be closed, while simultaneously, the next outlet tube, in the direction of the flow of grout, shall be opened. At the completion of the grouting, all valves shall remain closed until the grout has cured, except the grout tubes at each end of the duct, which shall remain open during the curing of the grout.

The test performed on the grout shall take place as specified in the " Guide Specifications for Grouting of Post-Tensioned Structure,"1st Edition. An on-line device to limit the grout pumping gage pressure shall be set at a maximum of 150 psi. If the grout reaches the limiting pressure, the grouting operation shall be stopped and the grout flushed from the entire conduit.

Post-tensioning

Longitudinal post-tensioning should be provided for continuity between precast panels. The post-tensioning should be located at mid-depth in the slab units and shall run the entire length of the bridge or between closure pours. The post-tensioning shall transmit a prestress force of 150-200 psi minimum after all losses and after dead loads have been applied to the structure. The engineer must design for additional prestress to overcome the tensile stress due to negative composite dead load moments in continuous spans. A minimum prestress force of 300-400 psi may be used for the continuous spans. The post-tensioning details is shown in Figures 9 to 12.

The post-tensioning ducts shall be made continuous between precast slabs with watertight sleeves. After all slabs in a span or one post-tensioning segment of the span are set, the grade of the slabs shall be checked and adjusted to provide the required elevations. No construction equipment, or vehicles in excess of 5,000 pounds will be allowed on the precast deck slabs until the post-tensioning process is complete.

The use of precast concrete panels on curved structures is also acceptable. The slab units shall be cast in a trapezoidal shape with the longitudinal post-tensioning running along the curve. The design of the longitudinal post-tensioning should take into account the losses due to friction in the post-tensioning ducts.

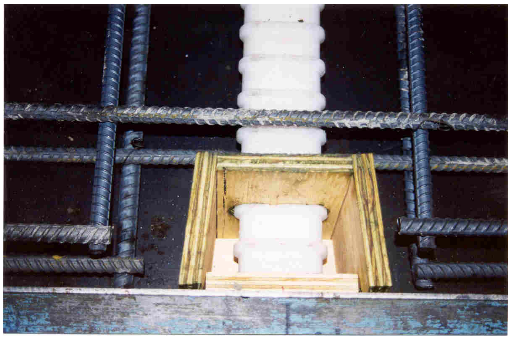

Fig. 9 Post-tensioning duct configuration

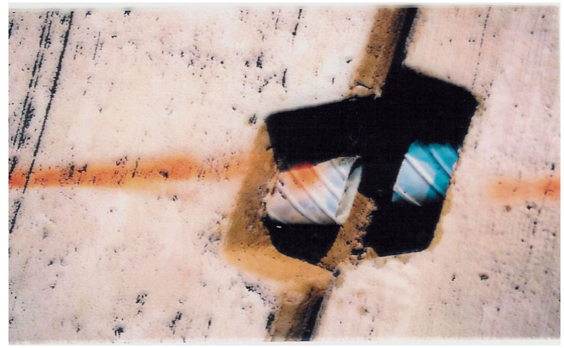

Fig. 10 Post-tensioning Full Depth Blockout at Transverse Joint

Fig. 11 Post-tensioning of 4(0.6 in.) strands

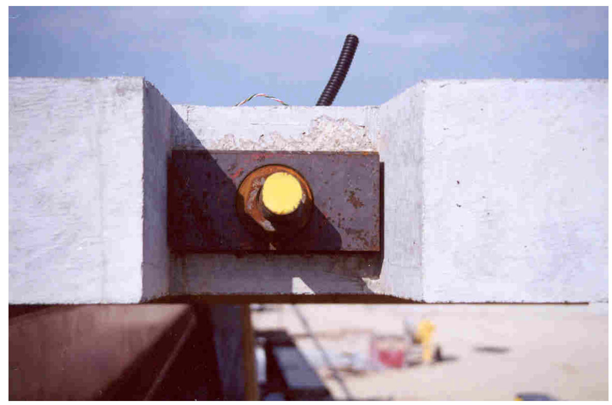

Fig. 12 Post-tensioning of Dywidag bar

Shear Pockets and connectors

After the post-tensioning is completed, the shear studs shall be installed and the haunches formed. The shear stud blockout and formed haunch shall be grouted using non-shrink grout. The shear stud blockout details are presented in Figure 13. The method for installation of the grout shall be such that no voids in the haunches and shear connector blockouts will occur. No superimposed dead loads or live loads shall be applied to the precast slabs until the non-shrink grout in the shear stud blockouts and the haunch has been in place for at least two hours.

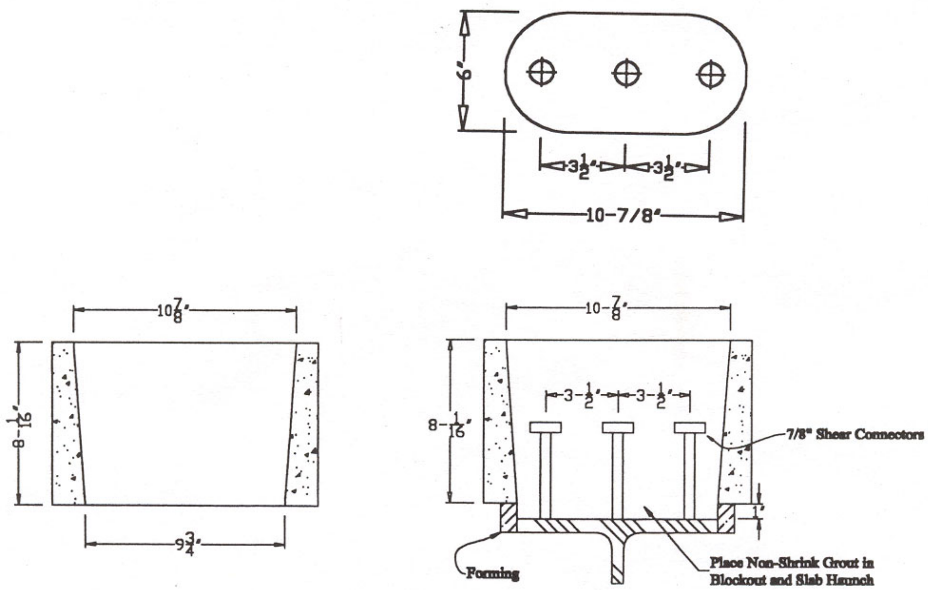

Fig. 13 Shear Stud Blockout Details

In making the slab units and the supporting system fully composite, the spacing of shear connector blockouts should be kept at two feet on center where possible. The design for variable horizontal shear can be accommodated by varying the number of shear connectors per blockout. The configuration of the shear connector blockouts should be of beveled shape to avoid any stress concentration at the corners. The shear connectors can be in the form of shear studs welded to the top flange of the steel girder as shown in Figure 13, or by grouting threaded bolts into the top flange of precast concrete girder as shown in Figure 14, or by using extended and bended bars as shown in Figure 15.

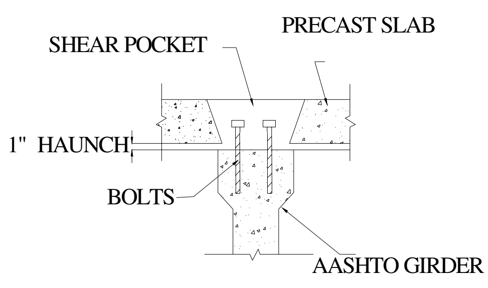

Fig. 14 Section View of two bolts shear connectors

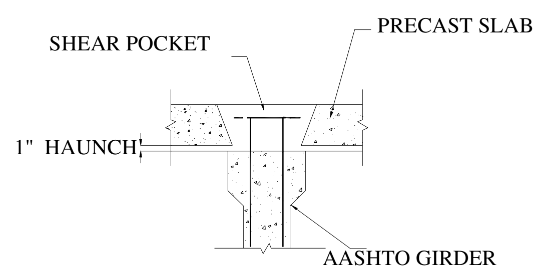

Fig. 15 Section View of embedment steel bars

Coupling of Dywidag Thread Bars

During the design process where continuity in the post-tensioning system is required, it is recommended to use Dywidag thread bars. Dywidag thread bars can be spliced easy by the use of couplers. Dywidag thread bars may be stressed to the allowable limits of the code. The maximum jacking stress may not exceed $0.80f_{pu}$, and the stress at transfer may not exceed $0.7f_{pu}$. The final effective prestress level depends on the specific application, installation procedure, stressing sequence and the rigidity of the structural system. In the absence of a detailed analysis of the structural system, the effective prestress level of $0.60f_{pu}$ can be used as an approximation.

As an illustrated example for using a Dywidag thread bar of 1¾ in. diameter, the anchor plate size should be 9.0x4.0x1¾ in., the nut extension is 2¾ in., the minimum bar protection is 4.0 in, the coupler length is 8.625 in., and the coupler diameter is 2.625 in. Figures 16 and 17 show the block-out and coupling of Dywidag Thread bars while Figures 18 shows the complete details of the coupling system.

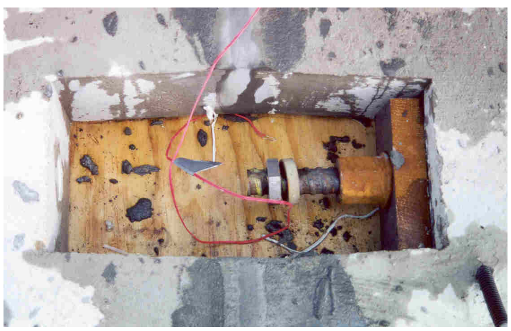

Fig. 16 Block-out for coupling of Dywidag Thread bars

Fig. 17 Coupling of Dywidag Thread bars

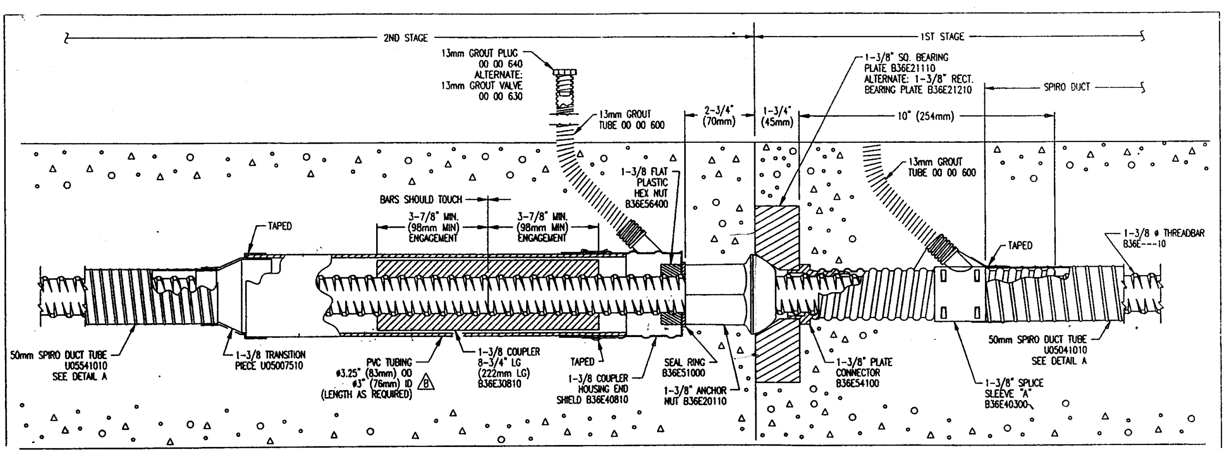

Fig. 18 Typical Coupling System

Fabrication and Placement of the Deck Panels

The fabrication and placement of the precast panels shall include the following:

a. Details shall outline the method of stressing sequence, jacking force, strain due to jacking and effective force for each tendon, and give complete specifications and details of the prestressing steel, coupling details if necessary, and anchorage devices and other data pertaining to the post-tensioning operation.
b. Complete details of the method, materials, and equipment used in the grouting operation, including the manner of mixing, the equipment to be used, step-by-step procedure to be followed and the sequence for grouting of the conduits.
c. The size of the anchorage assemblies and pockets shall be detailed.
d. The details for splicing the post-tensioning ducts at the transverse precast slab joints.
e. The manner of securing the conduit and other components into place.
f. Type and location of lifting inserts or devices.
g. Details of vertical adjusting hardware.

A corrosion inhibitor admixture may be incorporated into the concrete used to fabricate the precast panels, cast-in-place closure pours, concrete parapets, and the concrete used to fill the shear connector pockets in the precast slabs. The corrosion inhibitor shall be a solution of 29 to 32 percent by weight of calcium nitrite and water with a unit weight of at least 10½ pounds per gallon.

Parapets

Precast parapets can be used. Precast concrete parapets are the most conventional technique for construction, reducing construction time. Parapets can also be cast in place on the bridge panel through extended steel bars from the precast panels. The cast in place of the parapet can cover all the misalignments at the ends of the panels.

Overlays

Overlays are required to provide a smooth riding surface. Several types of overlays are being utilized by DOTs and State agencies. The most common types of overlays used are described below:

Latex-modified concrete

A typical latex-modified concrete mixture contains 658 pounds of cement per cubic yard, 15% latex solids by weight of cement, and has a water-cement ratio of 0.35. The latex modifies the pore structure of the concrete and reduces its permeability. The minimum thickness of the overlay shall be 2 ¼" in.

Silica fume concrete

Typical silica fume concrete mixtures contain 658 pounds of cement per cubic yard, 8% to 10% silica fume by weight of cement, a water-cement plus silica fume ratio less than 0.40, and enough HRWRA to provide a six to eight inch slump. One of the biggest advantages of micro silica concrete overlay is its reduced permeability to chloride penetration. The minimum thickness of the overlay is 2 ¼" in.

Polymer overlay

Polymer overlays are highly resistant to water, deicing chemicals, acids, petroleum products, and they have high skid resistance values. The short curing periods required for this type of overlays make it a good candidate for bridges where it is not practical to close lanes for a prolonged duration. Overlays are constructed with epoxy, unsaturated polyester styrene and methacrylate and graded aggregates. Multiple-layer epoxy and premixed polyester styrene overlays constructed with graded silica and basalt aggregate have been found to provide skid resistance and protection against chloride intrusion for 15 to 20 years particularly in Portland cement concrete decks with black reinforcing steel.

CONCLUSIONS

Full-depth precast prestressed concrete bridge deck is the most economic and effective system for replacement of existing bridge deck or for new construction. This system can eliminate traffic disruptions during bridge construction while maintaining or improving long-term performance. Sufficient amount of transverse prestress should be provided to avoid cracking during handling and erection of the slab unit. Leveling bolts should be used to adjust the grade of the precast slab units during placement. There should be a minimum of two leveling bolts over each girder depending on the length of the precast panels.

A minimum of 1inch haunch shall be provided between the precast panels and the beams to allow for any misalignment or irregularity. The transverse joints between the precast panels should be of female-to-female type and have a nominal width of 1 inch at the top and ½ inch at the bottom. The grout used within the transverse joints should be high early strength polymer grout to allow for post-tensioning of the precast slab units approximately one hour later.

Longitudinal post-tensioning should be provided for continuity between precast panels. The post-tensioning should be located at mid-depth in the slab units and shall run the entire length of the bridge or between closure pours. The shear connectors can be studs or headed and threaded bolts welded to the top flange of the steel girder grouted into the tops of girders or extended and bended bars.

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