

**State-of-the-Practice for Full-Depth Precast Concrete Bridge Deck Design, Detailing and Utilization**

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**ABSTRACT**

*Various organizations such as AASHTO, FHWA, State DOT's and Industry are emphasizing bridge design and construction technologies that increase service life, lower life cycle costs and provide for rapid construction to minimize impact on traffic. Precast concrete bridge deck systems have been used for selected projects and have proven successful in meeting the national objectives. However, the use of precast concrete bridge decks has not become widely accepted and used for bridge construction. As a result, the full potential contribution to the national emphasis is not being achieved.*

*The objectives will be to present state-of-the-art information relative to design and details for full-depth precast concrete bridge decks. It is anticipated that the paper would provide an exchange of information and expand support and acceptance for the use of precast concrete bridge decks.*

**Keywords:** Precast, Concrete, Full-Depth, Bridge Decks

## **INTRODUCTION**

One of the identified needs (demands) in transportation today is accelerated construction of projects to minimize the time and safety impacts on the traveling public through work zones. The demand is equally applicable to new construction as well as rehabilitation and reconstruction. Several concepts have been identified that will contribute to reducing construction time including prefabrication of bridge components, off site assembly, etc. One component of prefabricated bridge components is full depth precast bridge decks.

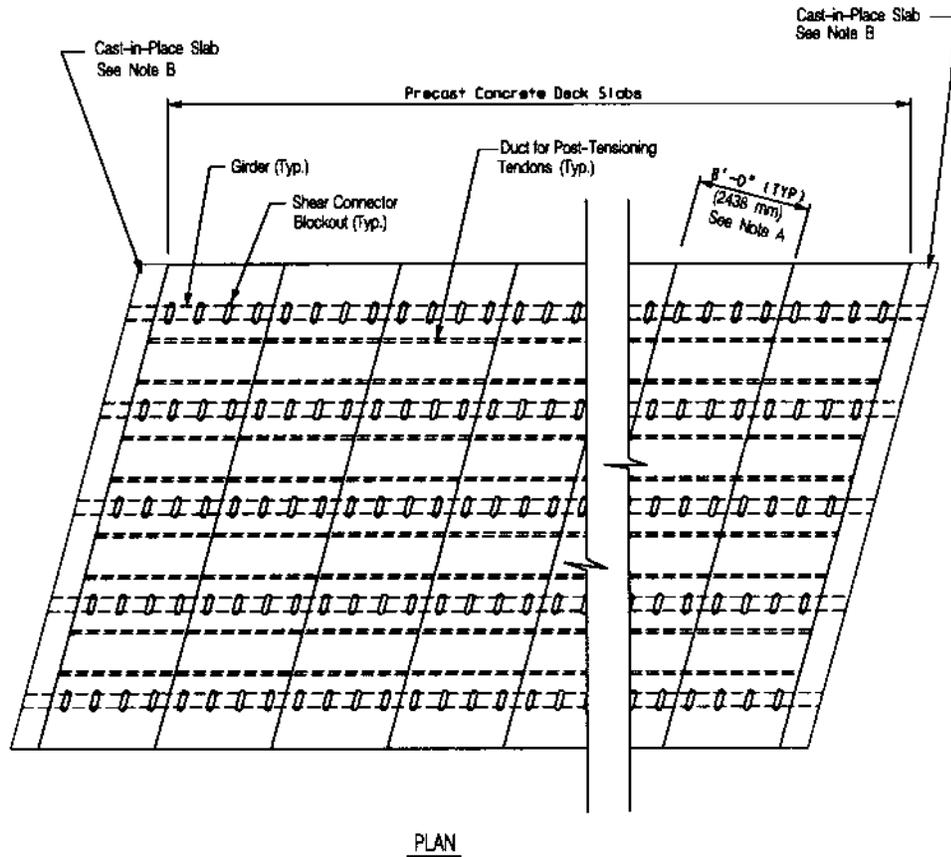
Several bridge deck replacement projects using full depth precast decks have demonstrated significant reductions in construction time and/or minimal impacts on traffic flow. The use of precast bridge decks dates back to the early 1970's and has been used successfully for many projects in several states<sup>1,2</sup>. However, currently the use of precast decks still remains a small percentage of decks constructed when compared to cast-in-place deck construction. Some reasons for the majority use of cast-in-place construction instead of precast construction are initial costs, concerns for long-term performance, no limit on construction time and the contractors are more familiar with CIP construction.

With continued national emphasis on the reduction of construction time and impact on the traveling public, it is anticipated that precast bridge decks will become more widely used and possibly become the normal construction method for bridge decks. To accomplish the predicted outcome, continued improvement and uniformity of details will be necessary. Current details have not changed significantly from those used in the earlier projects and some are not construction friendly and hinder achieving the full benefits from precast decks. Considerable effort is ongoing through various committee activities, research and day-to-day experience to improve the cost effectiveness, constructability, quality, durability and performance of precast concrete bridge decks.

## **CURRENT DETAILS**

Dr. Mohsen Issa<sup>1</sup> and the Precast/Prestressed Concrete Institute New England Region (PCINER)<sup>3</sup> have published guidelines and recommendations for the design, detailing and staging of precast concrete deck panels for new and replacement construction for both concrete and steel girders. Also, one state has developed similar details and allows a contractor to bid a precast deck as an alternative to a cast-in-place deck. In general the concepts developed are similar and generally represent state-of-the art details. All recommend and provide concepts for longitudinal post tensioning, blockouts for coupling the post-tensioning ducts, female to female transverse joints between panels, leveling devices for setting panels, pockets for shear connection for composite action and grout between the girder and panel. Both concepts provide for the panels to be designed as reinforced or prestressed in the transverse direction. Both reflect the possibility of minimum transverse prestressing to accommodate the handling stresses. Also, both include a separate concrete or asphalt overlay as the riding surface.

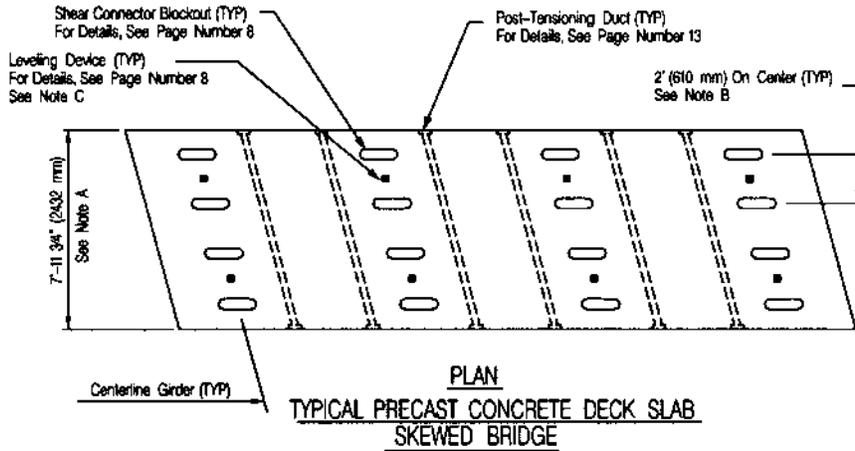
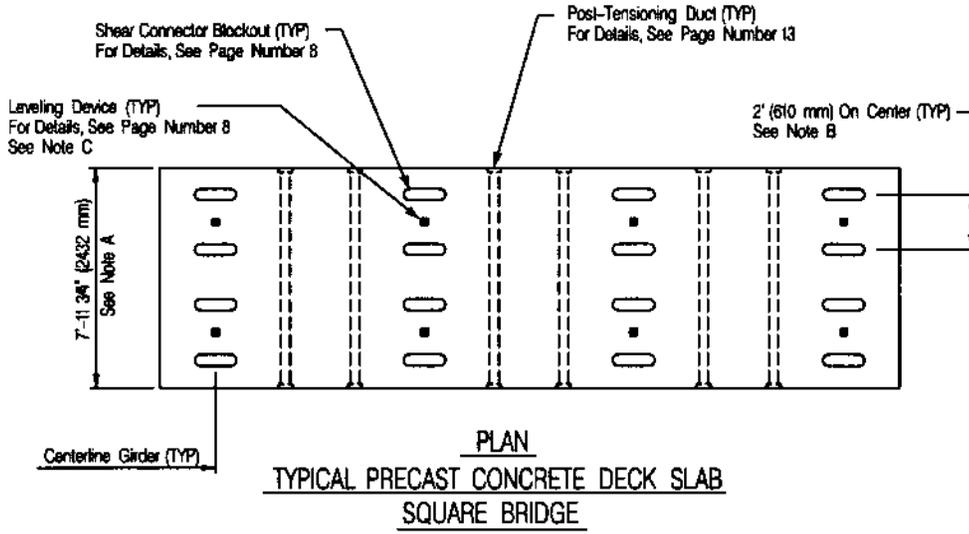
Typical details shown below taken from reference 3 are representative details commonly used:



Note A: Slabs shall be placed to the nominal spacing shown. Actual width of slabs shall be 7'-11 3/4" (2432 mm) wide.

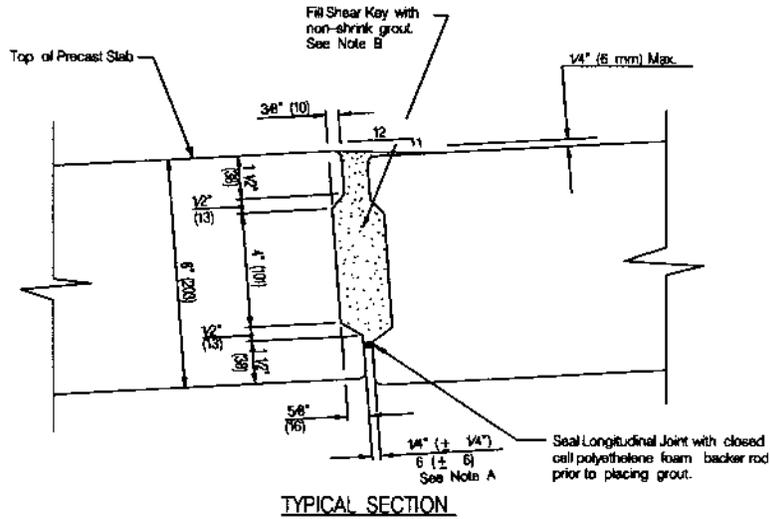
Note B: Cast-in-place closure pours shall be used to provide attachment to end bearing diaphragms. See Page Number 14.

Figure 1. Typical Deck Plan



- Note A: Deck slabs shall be placed to a nominal spacing of 8' (2438 mm) on center. The reduced width of slab is to accommodate a 10 mm wide (nominal) joint. For details of transverse joints, see Page Number 7.
- Note B: Blockouts for shear connectors shall generally be spaced at 2' (610 mm) on center. For special designs, this dimension may be changed.
- Note C: At least two leveling devices shall be used at each girder in order to achieve proper dead load distribution. For details, see Page Number 8.

Figure 2. Typical Square and Skewed Panels



NOTE A: The variation indicated is due to fabrication tolerances for sweep and camber of the slabs. The designer shall add the following note to the plans:  
 "The slab shall be placed at the nominal spacing shown on the plans with a 1/4" (6 mm) wide gap between the slabs. The width of this gap can vary due to tolerances of the slabs."

NOTE B: The designer shall add the following note to the plan:  
 "Grout for shear keys shall be rodded or vibrated to ensure that all voids in the shear keys are filled."

Figure 3. Transverse Joint

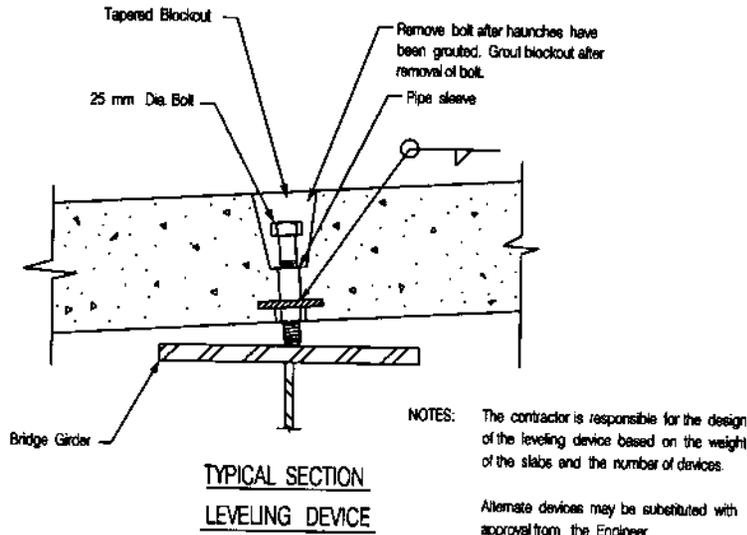


Figure 4. Leveling Bolt

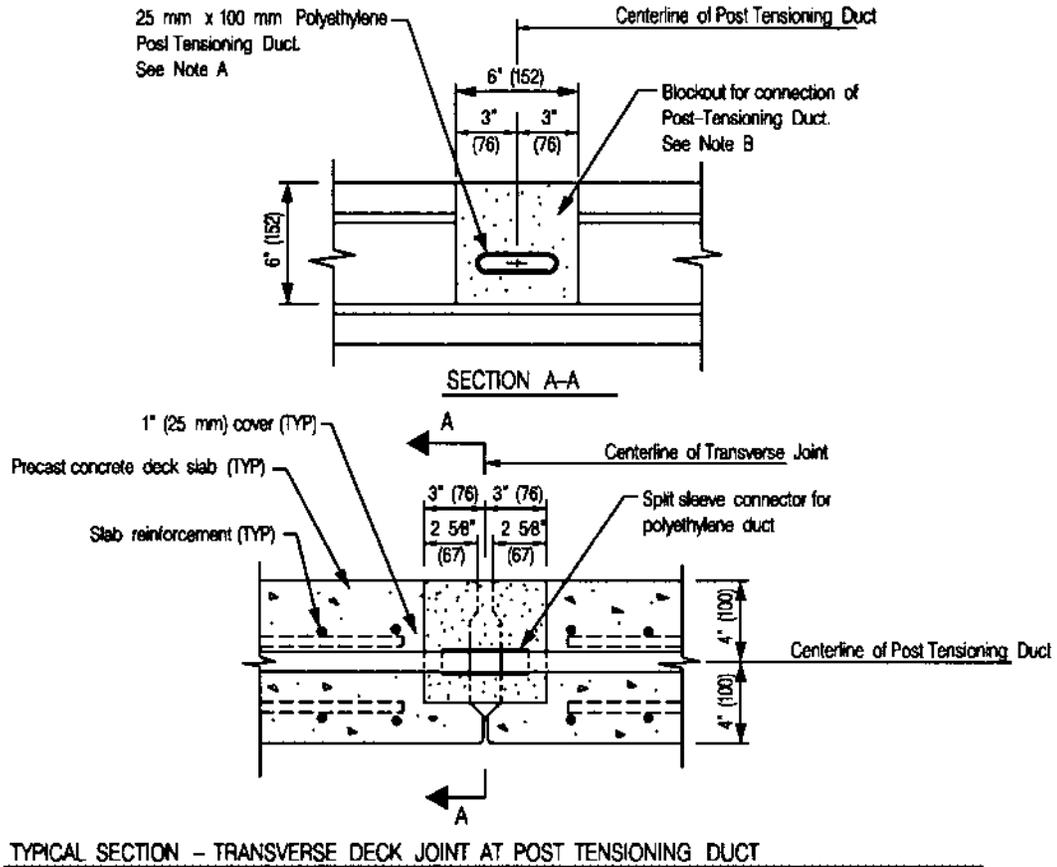


Figure 5. Post-tensioning Block-out and Coupler

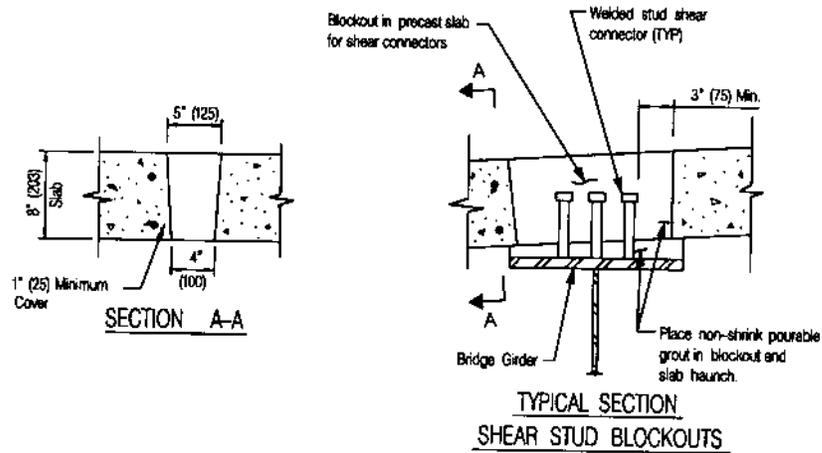
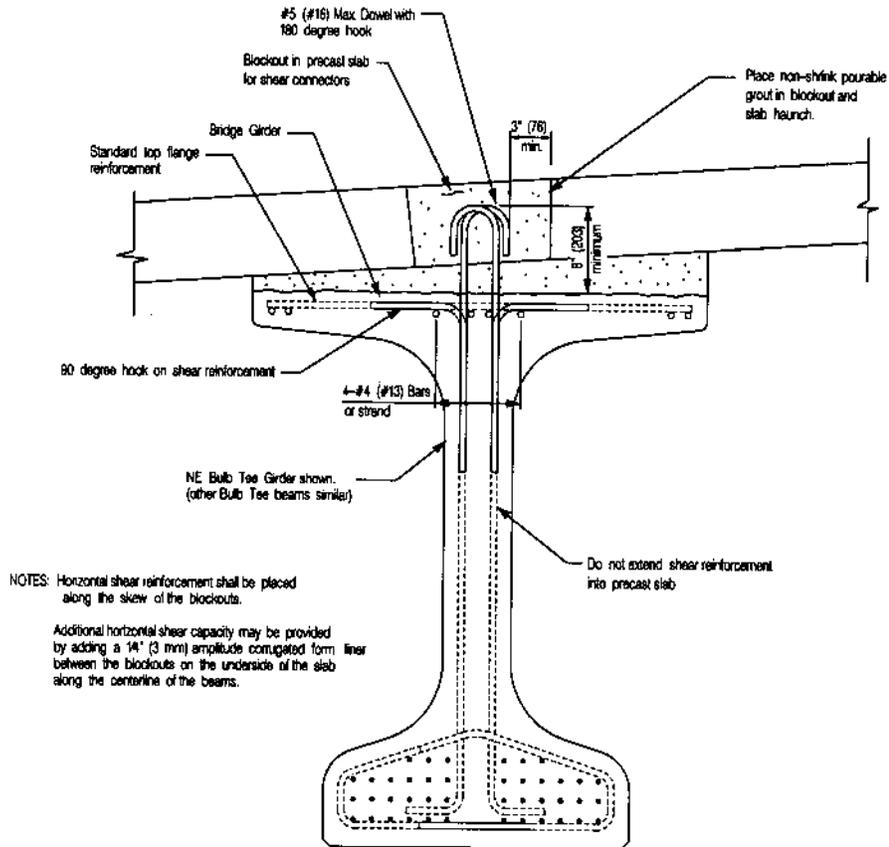
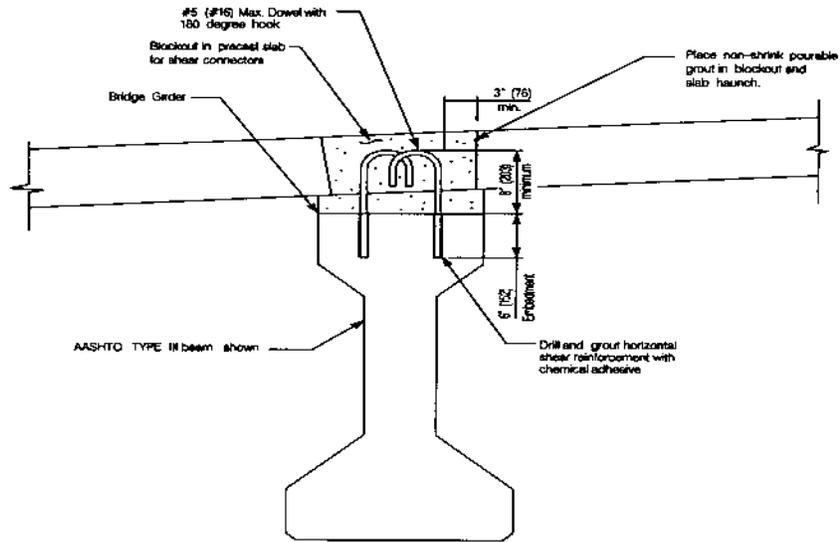


Figure 6. Composite Connection Detail for steel girder



TYPICAL SECTION - BULB TEE BEAMS  
NEW CONSTRUCTION

Figure 7. Composite Connection Detail for Concrete Girder



TYPICAL SECTION - AASHTO TYPE III AND LARGER BEAMS

DECK REPLACEMENT

Figure 8. Composite Connection for Deck Replacement

Details for the configuration of the female-to-female grouted key for the transverse joints from other sources seem to differ from the two guidelines. Geometry of the joint as recommended by others is reflected in Figure 9. The shape of the joint is generally consistent but the top opening width varies between details. Some show a width of 2 inches while others show a width of approximately 3.5 inches.

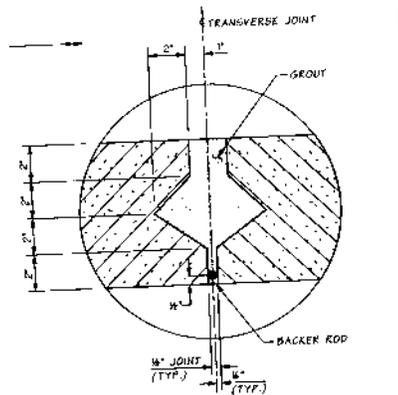


Figure 9. Additional Transverse Joint Geometry

## FUTURE ACTIONS

Although, the guide details have proven successful and are being used for projects, additional refinements are suggested to simplify the construction and details in order to further reduce the construction time, improve constructability, improve performance and gain support and acceptance from owners, producers and contractors for wider use.

Some efforts underway include NCHRP Project 12-65 “Full-Depth, Precast-Concrete Bridge Deck Panel Systems”. The primary focus of the NCHRP Project will be to investigate a full-depth, precast-concrete bridge deck that provides durability and ride quality without the use of post-tensioning and overlays. Another activity is a recently formed committee on full depth precast bridge decks, a subcommittee of the PCI Bridge Producers Committee. The objective of the PCI subcommittee is to identify and develop successful alternatives for a total precast deck. The PCI subcommittee membership consists of experienced individuals representing a wide array of the disciplines involved in the successful completion of a precast deck. The general objectives for both of these efforts is to improve the effectiveness, constructability and performance of precast decks while reducing the time required to construct, thereby gaining better acceptance and use of precast decks.

Some items that are suggested for evaluation and consideration are:

- Elimination of a separate overlay by use of an integral overlay
- Use match casting with epoxy for transverse joints between panels
- Better means of forming for grout beneath panels and temporary support.
- Elimination or reducing the Permanent Post-Tensioning.
- Use temporary Post-Tensioning for panel erection.

## OVERLAYS

The typical condition of a completed deck after all joints, block-outs and pockets have been filled and before the overlay is placed is shown in Figures 10 and 11.

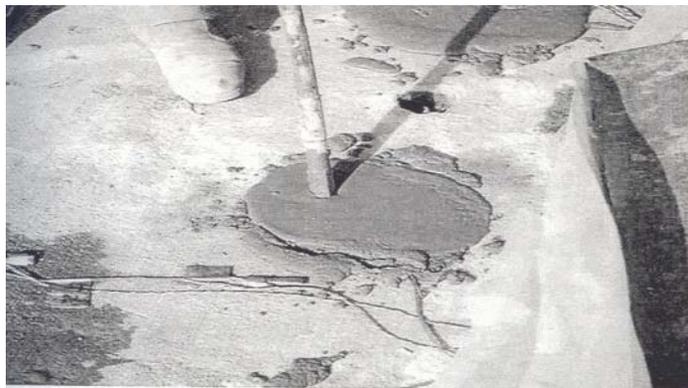


Figure 11. Filling a Shear Connector Block-out



Figure 10. Deck with all Joints and Pockets Filled

As the figures above reflect, it is difficult to fill the block-outs for shear reinforcement, post-tensioning, leveling screws and joints with non-shrink grout and get a smooth finish. Accordingly, with the proposed construction, an overlay is normally used to cover the block-outs and provide a smooth riding surface. The overlay would also, provide some protection from water and deicing salts penetrating around the block-outs if the fill grout shrinks away from the sides of the block-out or cracks. However, the overlay is an additional construction stage that takes time and adds to the total construction time. The increased construction time will vary from approximately three days for asphalt with a membrane to over 7 days for a concrete overlay. Also, an overlay will require some maintenance and probable replacement over time, especially when asphalt overlays with waterproof membranes are used. This will require disruption of traffic again in the future.

To minimize the additional construction stage and reduce the time, it is proposed that consideration of an integral concrete overlay be used. The block outs and joints can be filled or overfilled and the surface of the panels ground to profile leaving a smooth surface. The grinding would be an additional construction stage but generally take less time than placing an overlay. Also, future maintenance operations would be minimized and require major traffic impact only when the integral overlay needs to be removed due to chloride contamination.

## TRANSVERSE JOINTS

The success of the grouted transverse joint between panels depends highly on workmanship in mixing, placing and curing the grout. When quality construction has been achieved the joints have performed very well. However, the historical record of performance<sup>1, 2</sup> lists cracking and leakage of the joints as a major problem. To improve the probability of getting a good watertight joint, it is proposed that consideration be given to using a match cast joint with epoxy adhesive between panels. Some concepts of match cast joints have been tried in the past with mixed success. However, some projects are under construction that use match cast joints with epoxy adhesive. Reference 4 includes a technical opinion that the precast panel will deform elastically to accommodate the profile change within the typical length of two panels and permit the joint to be match cast. The application of epoxy 1/16 inch thick to both faces of the joint will accommodate the expected angle change between the panels for conditions created from typical vertical alignment used for most bridge profiles. This technology has been successfully used in segmental bridge construction for several years. It is believed that a reasonable alternative to a true match cast joint would be one constructed with a very stiff, supported and well aligned bulkhead or could be achieved by saw cutting the panel slabs cast continuous on a flat bed similar to the practice used by some producers for partial depth precast deck panels. Figure 12 reflects possible details for a match cast joint.

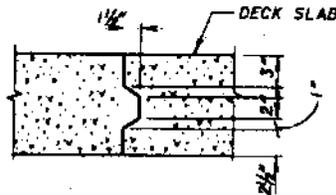


Figure 12. Typical Keyed Match Cast Joint

## DECK PANEL SUPPORT

Plans from a recent project<sup>5</sup> include the current technology for supporting metal stay-in-place (SIP) deck forms to temporarily support the precast deck panel without the need for leveling bolts. The concept includes using the support angle normally used for steel SIP forms along each edge of the flange and setting the panels on the support angle. Grading the support angle and panel would be achieved the same as grading the steel SIP form for cast-in-place (CIP) decks and result in a uniform bearing and flush match at the top of panels at joints which would minimize the amount of grinding necessary to get a smooth surface. The support angles also serve as the form to retain the grout between the panel and flange. The approach will eliminate the need for leveling bolts, filling the void left after removing the bolt and eliminate the need for some neoprene gasket or form along the flange to retain the grout between the panel and girder top flange. The concept is shown in Figure 15.

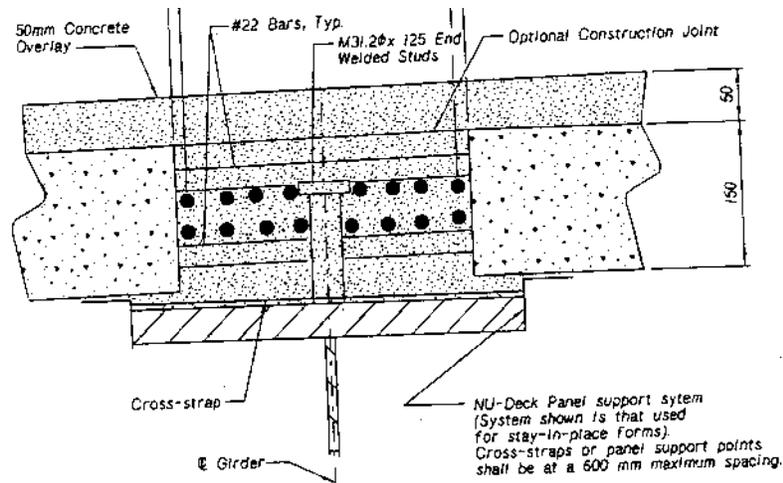


Figure 15. Panel Support by SIP Form Angles

## GEOMETRY CONTROL

To achieve the match cast joints and utilize the panel support and grading concepts delineated above, it will be necessary to explore better methods to accommodate varying transverse slopes in the top of the panels. It appears reasonable that the technology used for geometry control and casting segments for segmental construction could be used effectively for precast bridge deck panels. Projects with varying cross slopes, super-elevations and crown reversals, have been successfully accommodated in segmental construction.

## POST-TENSIONING

The amount of longitudinal post-tensioning impacts construction time because of the number and size of tendons that have to be installed, stressed and grouted. A summary of past projects and the design guides mentioned earlier reflect that a wide range of post-tensioning requirements has been specified for past projects. The two guidelines vary relative to the magnitude of recommended post-tensioning. One recommends 250 psi minimum compression and the other recommends 150 psi minimum compression. Neither the AASHTO Standard Specifications for Highway Bridges nor the AASHTO LRFD Bridge Design Specifications provide adequate guidance on this issue. Accordingly, further research and refinement of the longitudinal post tensioning requirements are needed for post-tensioned full depth bridge decks. Also, the permanent post-tensioning may be eliminated by use of temporary post-tensioning with match cast epoxied joints.

## CONCLUSIONS

Full-Depth Precast Bridge Decks have been successfully used for several projects and by several states. However, the concept is used for a relatively small percentage of new and replacement bridge decks. Research and committee activities are ongoing to identify barriers to expanded use and to improve and enhance details to improve serviceability, cost

effectiveness and construction speed. Recommendations included are provided for consideration by researchers, committees and others as applicable in further advancing the precast concrete bridge deck technology and use.

## REFERENCES

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5. Skyline Bridge, Project Number NH-6-7(114), Structure Number SL28B00216, State of Nebraska Department of Roads, Bridge Division.