AN INVESTIGATION OF THE DETAILS AT THE SPLICE REGIONS OF SPLICED GIRDER BRIDGES

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ABSTRACT

Modern post-tensioned spliced girder bridges consist of precast, pretensioned girder segments joined at short cast-in-place closure pours, or splice regions, located within the bridge span(s). The specific details at the splice regions of existing bridges vary widely, and spliced girder detailing guidelines differ significantly among state Departments of Transportation (DOTs).

A survey was distributed to state DOTs throughout the country to investigate the various details that have been specified at the cast-in-place splice regions of existing bridges. The survey covered the use of specific splice region geometries, shear interface details (e.g., shear keys), post-tensioning duct materials, and details for the reinforcing bars extending from the precast segments. Constructability issues were included. An analysis of the survey results along with drawings of existing spliced girder bridges were used to identify splice region details that have been successfully implemented in the field.

A summary of the results of the investigation is presented. Use of specific details is also related to observations made during a recent experimental program focused on the shear behavior of spliced girders. The discussion provides valuable insights that can be applied during both the design and construction phases of post-tensioned spliced girder bridges.

Keywords: Post-Tensioning, Spliced Girder, Duct, Shear Key, Closure Pour

INTRODUCTION

Post-tensioned spliced girder bridges have been identified in many states across the country as a viable alternative to other bridge types (e.g., spliced steel plate girder, concrete segmental, etc.) in the moderate-span market. Implementation of spliced girder technology extends the capabilities of low-cost precast girder construction by providing the means to achieve span lengths in excess of 300 ft. Modern post-tensioned spliced girder bridges consist of precast, pretensioned girder segments joined at short cast-in-place (CIP) closure pours, or splice regions, located within the bridge span(s). Spliced girder technology is most commonly used to extend the span ranges of multi-span continuous bridges, as illustrated in Figure 1. The technology can also be applied to simple-span bridges when the span length would otherwise be limited by transportation restrictions.

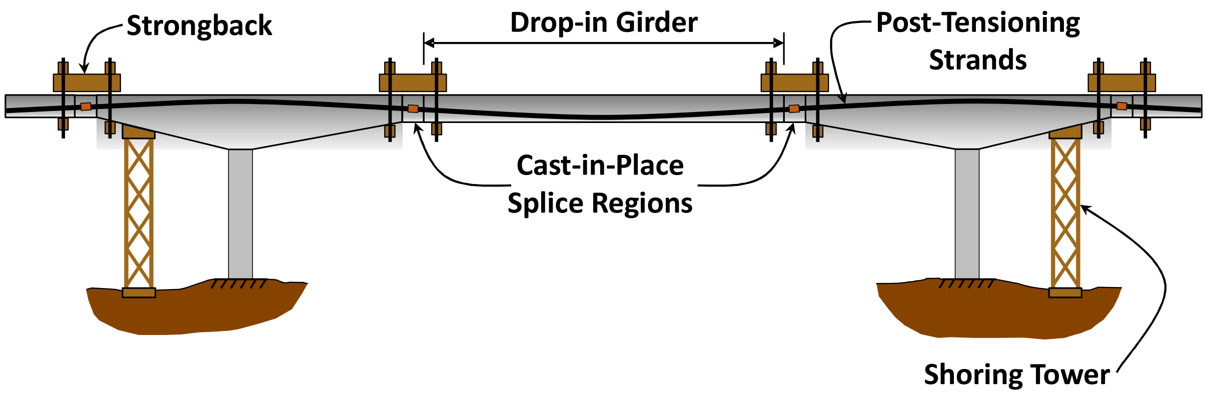


Fig. 1 Typical configuration of a multi-span continuous spliced girder bridge (with falsework in place)

As part of a research program focused on the performance of spliced I-girder bridges, an investigation was conducted to identify design and detailing practices for the cast-in-place splice regions located within the span lengths of spliced girders. At the location of a CIP splice region, the pretensioned strands of the precast segments are discontinuous, as illustrated in Figure 2. Continuity is provided primarily by the post-tensioned tendon. Although CIP splice regions introduce a potential weak point in a bridge span, relatively little guidance is provided in the *AASHTO LRFD Bridge Design Specifications* (2014)[1] in regard to special design and detailing measures to be taken for these locations. Furthermore, the *PCI Bridge Design Manual*[2] includes limited information concerning specific recommended detailing practices that ensure satisfactory strength and serviceability performance at splice regions of I-girder bridges. In connection with the lack of standardization, the splice region details of existing bridges vary widely, and spliced girder detailing guidelines differ significantly among state Departments of Transportation (DOTs).

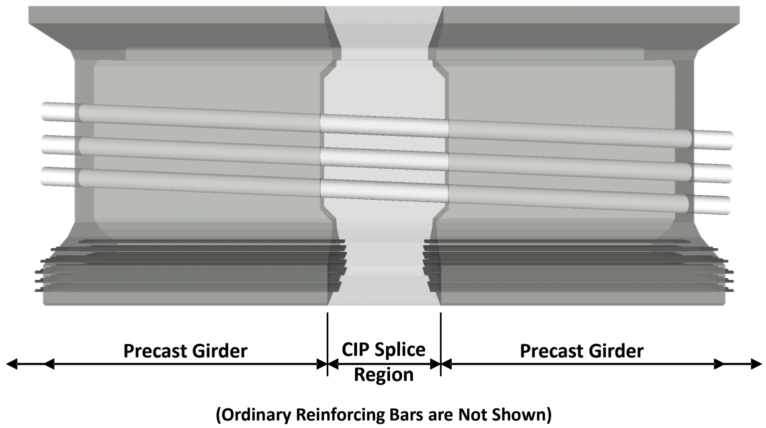


Fig. 2 Cast-in-place splice region

A survey was distributed to state DOTs throughout the country (outside of Texas) in the spring of 2013 to investigate the various details that have been specified at the CIP splice regions of existing bridges. Particular focus was placed on spliced I-girder bridges. Drawings of existing bridges and/or standard details provided by several of the participating DOTs were also reviewed to identify splice region details that have been successfully implemented in the field. The results of the investigation were coupled with observations gathered during a large-scale experimental program focused on the shear behavior of post-tensioned spliced girder specimens. The research included a comprehensive evaluation of design and detailing practices and the development of corresponding recommendations for CIP splice regions. Complete information of the study on the splice regions of spliced I-girder bridges is provided in Williams.[3]

In the following sections, the results from the survey are summarized. Relevant observations from the spliced girder experimental program related to the fabrication of CIP splice regions are then presented.

SURVEY RESULTS: EXPERIENCE WITH SPLICED GIRDER DESIGN/CONSTRUCTION

A total of 25 state DOTs responded to the survey. The results indicated that 10 of the 25 DOTs were familiar with the design and/or construction of spliced I-girder bridges (Arizona, California, Florida, Georgia, Hawaii, Massachusetts, New York, North Carolina, Virginia, and Washington). Most of these state DOTs had experience with the construction of five or fewer spliced I-girder bridges, but three had experience with the construction of more than 20 bridges. A few DOTs noted that spliced girder bridges had been constructed in their states in the past but did not provide responses to the survey questions regarding CIP splice regions due to present unfamiliarity with the technology. The following sections focus on the experience of the 10 state DOTs that indicated current familiarity with the design and detailing of spliced I-girder bridges.

SURVEY RESULTS: POST-TENSIONING DUCT MATERIAL

Internal post-tensioned tendons are housed in ducts constructed of either galvanized steel or plastic (i.e., high-density polyethylene or high-density polypropylene). The survey participants were asked to indicate the percentage of spliced I-girder bridge projects in their state/district for which each duct material had been specified. They were then given the opportunity to provide an explanation of why one material may be preferred relative to the other. Based on the written explanations and frequency with which the duct materials had been specified, the survey responses imply that seven state DOTs prefer the use of steel ducts while only three DOTs prefer plastic ducts. The advantages of using each type of duct material according to the survey participants are presented in Table 1. It is important to note that the 10 state DOTs familiar with spliced I-girder bridge design/construction have used grouted ducts for all of their spliced I-girder projects. This trend may change in the near future with the use of wax as a filler material for internal post-tensioned tendons.[4]

Table 1 Advantages of duct materials (from Williams et al.[5])

Plastic Ducts	Steel Ducts
• Provide better durability • Less prone to corrosion • Have a smaller chance of being damaged during construction • Can be sealed better	• Require less support to prevent misalignment and displacement during casting (reference was made to Castrodale and White[6]) • Fit better within the web width because of ducts' exterior dimensions • Offer ease of placement

SURVEY RESULTS: DUCT DIAMETER TO WEB WIDTH RATIO

The diameter of the duct relative to the web width is a critical detail in the design of post-tensioned thin-webbed girders. The duct diameter to web width ratio can potentially impact both constructability and durability due to its direct relationship with the concrete side cover between the duct and the surface of the web. The ability of the concrete to easily flow within this limited space must be considered to prevent consolidation issues, especially at splice regions that are cast in the field rather than under controlled plant conditions.

The duct diameter to web width ratio also affects the shear capacity of the girder. Current AASHTO LRFD 2014 provisions consider a reduced, or effective, web width, illustrated in Figure 3, to account for the impact of a post-tensioning duct located within a girder web. The effective web width, b_v, is calculated using the following expression:

(1)

where b_w is the gross web width, k is a reduction factor, and $Ø_{duct}$ is the diameter of the duct. Article 5.8.2.9 of AASHTO LRFD 2014 defines the value of k as ¼ for grouted ducts and ½ for ungrouted ducts. It should be noted that the k-factor for ungrouted ducts is appropriate for ducts injected with a flexible filler such as wax.

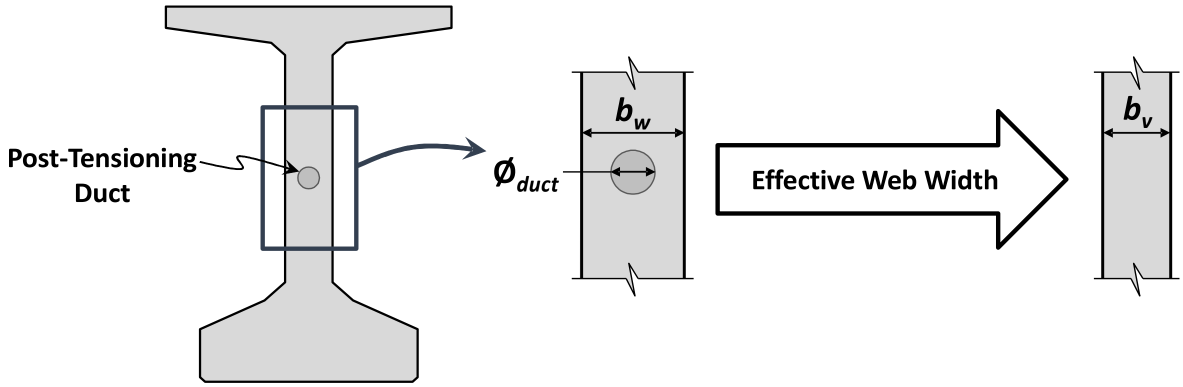


Fig. 3 Effective web width used by AASHTO LRFD 2014 to account for reduction in shear strength

The survey participants were asked to provide the combinations of girder web width and nominal duct diameter that have been used for spliced I-girder construction in their respective states/districts. They were also requested to estimate the percent of projects for which each combination had been specified. The duct diameter to web width ratios corresponding to the survey responses are presented in Table 2 with the state DOTs denoted by letters A through J.

Table 2 Duct diameter to web width ratios of existing spliced I-girder bridges

State DOT	Duct Diameter b_w	Percent of Projects	Note
A	0.43	100	---
B	0.5 (+/-)	Not Provided	Steel Ducts
	0.47		Polypropylene Ducts
	0.44		Polypropylene Ducts
	0.34		Polyethylene Oval Ducts
C	0.43	33	---
	0.42	67	---
D	0.42	50	---
	N/A – Ducts in pairs (side-by-side)	50	---
E	0.5	100	---
F	0.41	100	---
G	0.5	50	---
	0.43	50	---
H	0.53	100	---
I	0.5	30	---
	0.44	50	---
	0.38	20	---
J	0.56	33	---
	0.54	33	---
	0.31	33	---

The permitted duct diameter to web width ratio is limited to a value of 0.4 or less by Article 5.4.6.2 of AASHTO LRFD 2014. However, a majority of the spliced I-girder bridges represented in Table 2 have ducts with diameters that exceed the code limit, as indicated by the highlighted cells. In fact, all 10 DOTs reported that a significant portion, if not all, of the spliced I-girder bridges in their respective states had exceeded the limit. A similar observation for existing spliced I-girder bridges is also noted in the *PCI Bridge Design Manual*.[2] It is important to understand that the duct diameter to web width ratio may be even more critical at the location of duct couplers with diameters larger than the duct itself, as shown for a plastic duct in Figure 4.

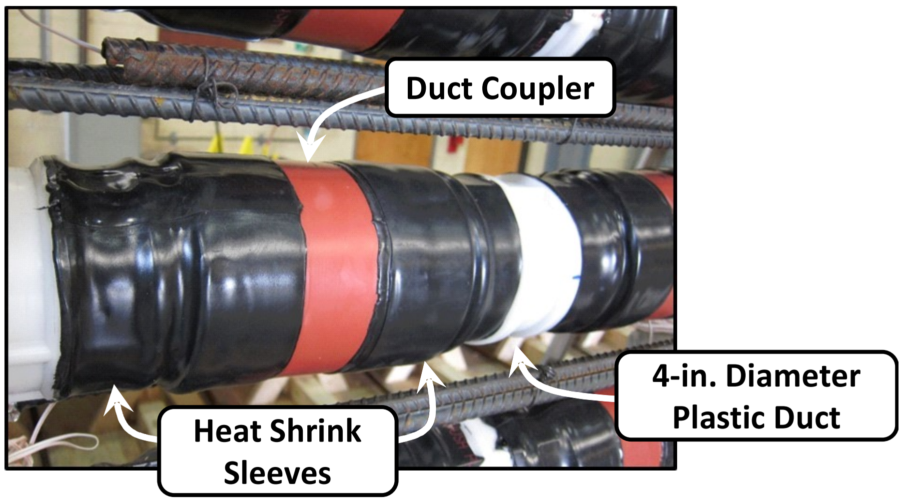


Fig. 4 Plastic duct coupler connection

Despite the relatively large values for the duct diameter to web width ratios of existing bridges, only four out of the 10 DOTs indicated that a reduction in shear strength due to the presence of post-tensioning ducts in the girder webs was considered for the design of spliced I-girders.

SURVEY RESULTS: CAST-IN-PLACE SPLICE REGION DETAILS

The survey results corresponding to specific details of the CIP splice regions of spliced I-girder bridges are addressed in the following sections.

LOCATION OF TRANSVERSE DIAPHRAGMS RELATIVE TO SPLICE REGIONS

A review of the drawings of existing spliced girder bridges reveals that transverse diaphragms are often, but not always, placed to correspond with the location of the CIP splice regions. If a bridge is detailed in this manner, more space is available to place the splice region concrete and potential congestion can be reduced. The transverse diaphragm may also enhance concrete confinement at the splice region.[6]

The survey participants were asked to indicate the preferred location of transverse diaphragms relative to splice regions in their state/district. According to the responses, a total of seven state DOTs prefer to place transverse diaphragms at the CIP splice regions. Three DOTs, however, indicated a preference for locating transverse diaphragms away from the splice regions.

SPLICE REGION GEOMETRY

The geometries of CIP splice regions vary widely among existing spliced I-girder bridges. In general, the geometry of a splice region can be defined by its length measured along the longitudinal axis of the girder, as shown in the elevation view in Figure 5, and the width of the web at the splice region, represented by b_{splice} at Section B-B in Figure 5.

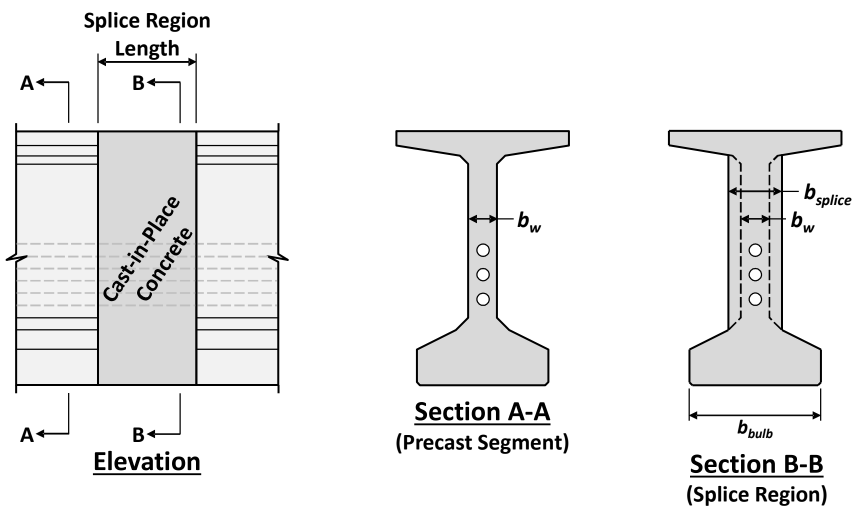


Fig. 5 Geometry of CIP splice regions of spliced I-girder bridges (adapted from Williams[3])

To determine the CIP splice region lengths of existing bridges, the survey participants were asked to provide the minimum and maximum lengths that had been specified for splice regions in their state as well as the typical length. The survey responses are summarized in Table 3. Each of the DOTs also described the primary factors that impacted the chosen lengths of the splice regions. Excerpts from the comments provided by the survey participants are included in Table 3. In general, the splice region length was selected based on constructability considerations (e.g., concrete placement, splicing post-tensioning ducts, etc.) and/or the space required to splice/develop reinforcement.

Table 3 Specified splice region lengths

State DOT	Length (in.)			Comments
	Min.	Max.	Typical	
A	12	14	12	"PCI guidelines on spliced girders…"
B	18 (+/-)	20 (+/-)	N/A	"Length to make duct connections; reinforcing details"
C	24	Dependent Upon Skew	24	"The length should provide an adequate opening for proper placement of cast-in-place concrete"
D	4	30	N/A	"The shape of the splice…"
E	---	---	24	"The need to lap reinforcement"
F	---	---	12	"Want to minimize the length of the splice region to ease forming and casting but make it long enough to allow ducts to be spliced…proper consolidation and vibration of concrete and lapping/splicing of reinforcement"
G	---	---	10	"Need enough room for the concrete to flow around the ducts"
H	24	Special Cases	24	"Suitability for duct splicing, bar splicing and casting concrete"
I	24	48	24	"PT duct splice length; development length of the extended strands and rebars; space for shear reinforcement; room for working space"
J	24	36	24	"Constructability"

The survey responses also included typical values specified for the width of the web at the splice regions, b_{splice}. As previously noted, a transverse diaphragm located at a splice region generally improves constructability.[6] The responses from the three state DOTs that prefer splice regions to be located away from diaphragms were therefore of primary interest due to the construction challenges that can result. The survey responses indicated that for some spliced I-girder bridges in these states, a constant web width was maintained through the splice region (i.e., $b_{splice} = b_w$; refer to Figure 5). In other cases, the girder web at splice regions was widened to match the width of the bottom flange (i.e., $b_{splice} = b_{bulb}$).

SURFACE DETAIL AT SHEAR INTERFACE

The ends of the girder segments to be joined at splice regions are typically detailed to improve shear transfer between the precast and cast-in-place concrete. Surface details that have been specified at splice region interfaces are illustrated in Figure 6. Although not prevalent, some existing spliced I-girder bridges were not given a special detail or roughened at the ends of the precast segments. This case is represented by the "plain" interface in Figure 6.

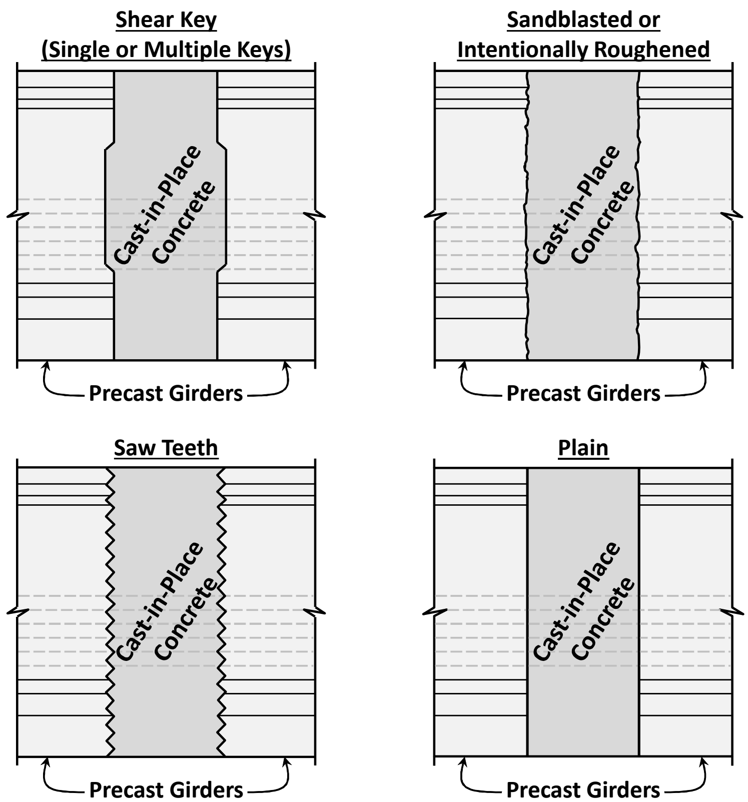


Fig. 6 Surface details specified at CIP splice regions (adapted from Williams[3])

As part of the spliced girder research, an interface shear transfer experimental program, reported in Williams,[3] was conducted to accompany the large-scale girder tests. No other testing program has focused specifically on the interface shear transfer mechanism at splice regions resulting from the various surface details that have been commonly specified at these locations. Little guidance has therefore been available to designers concerning the relative strengths and behaviors corresponding to these details.

The survey provided the opportunity to determine the extent to which each of the interface surface details had been specified. The survey participants were asked to indicate the details that had been used in their state/district and to provide an estimate of the percentage of spliced I-girder projects for which each surface had been specified. The responses are summarized in Table 4. Comments from the participants that explain specific factors affecting the choice of the interface surface details are included. The results reveal that shear key details were the most popular among the 10 state DOTs familiar with spliced I-girder design/construction. Considering the estimated number of spliced I-girder bridges in each of the 10 states listed in Table 4, the total number of bridges detailed with shear keys in those states is over double the total number of bridges with saw teeth. Only one DOT indicated past use of intentionally roughened and plain interfaces but explained that plain interfaces are no longer being specified. It should be noted that the three states with the most experience with spliced I-girders differ in regard to preferred surface details.

Table 4 Surface details specified at shear interfaces

State DOT	Percentage of Projects				Comments
	Shear Key	Saw Teeth	Sandblasted or Int. Roughened	Plain	
A	100	0	0	0	---
B	100	0	0	0	---
C	100	0	0	0	"Simple detail that is easy to fabricate and control during fabrication"
D	100	0	0	0	"Shear keys are usually required in the design specs."
E	80	20	0	0	---
F	100	0	0	0	---
G	100	0	0	0	"We believe a shear key provides the best shear transfer mechanism"
H	0	100	0	0	---
I	30	0	20	50	---
J	0	100	0	0	"Complied with…Standard Details…"

INTERFACE REINFORCEMENT

Mild reinforcement (i.e., ordinary reinforcing bars) anchored in the precast segments is often detailed to extend into the CIP splice regions. The two primary purposes[6] for providing this interface reinforcement are (1) to satisfy interface shear (i.e., shear-friction) strength requirements and (2) to satisfy stress limits at the splice region (refer to Article 5.9.4 of AASHTO LRFD 2014). Potential details for interface reinforcing bars are shown in Figure 7. The survey participants were asked to indicate the reinforcing bar details that were typically specified at the splice region interfaces in their state/district. Considering that more than one bar detail is often used at a particular CIP splice region, the participants were not limited to the number of details that could be selected. The survey responses are summarized in Table 5.

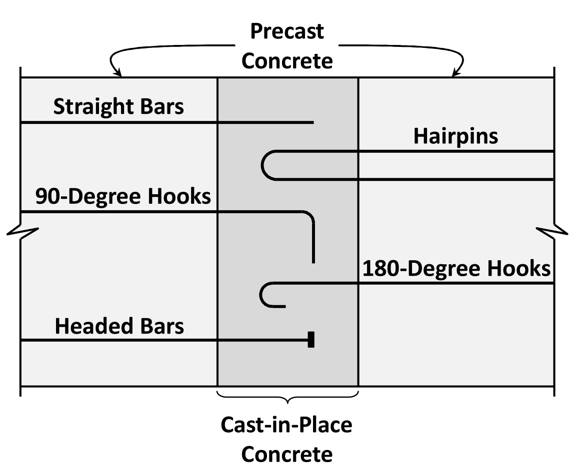


Fig. 7 Potential bar details for reinforcement crossing splice region interfaces (adapted from Williams[3])

Table 5 Bar details typically specified at splice region interfaces

State DOT	Typical Bar Details					
	Straight Bars	Hairpins	90-Degree Hooks	180-Degree Hooks	Headed Bars	Other
A		X				
B		X		X		
C		X	X	X		
D		X	X	X		No reinforcement (stepped joint)
E		X				
F	X	X				Lapped embedded plates
G		X	X			
H	X					
I			X			
J	X					

The survey results indicate that hairpin bars were the most common interface reinforcement detail. Hairpin bars have often been used in combination with other bar details, such as 90- or 180-degree hooks. According to the survey responses, headed bars are not a typical detail used for interface reinforcement. Once again, it should be noted that the details preferred by the three state DOTs with the most experience with spliced I-girders differ significantly from one another.

SURVEY RESULTS: CONSTRUCTABILITY AND OTHER ISSUES

The survey participants were given the opportunity to describe any constructability issues (e.g., problems with concrete consolidation, formwork, shoring, etc.) as well as any serviceability/aesthetic issues (e.g., cracking, discolored concrete, etc.) related to CIP splice regions. In regard to serviceability/aesthetic concerns, one state DOT noted that the color of the splice region concrete had typically not matched the color of the precast girder concrete. Moreover, another DOT reported that cracking at some splice regions had been observed due to shoring that allowed the pier segments to experience a slight rotation.

Several state DOTs described constructability issues that had been encountered in the field. Three DOTs noted difficulties with proper concrete placement. One DOT cited an instance in which the “[s]plices had to be removed and re-poured” due to poor concrete consolidation, and another DOT explained that the need to improve vibration methods became apparent when air pockets and voids were observed at splice regions. Problems with duct leakage were also experienced in two states. Leakage of steel ducts was reported for one project, and an instance was described in which grout crossed over from one plastic duct to an adjacent empty plastic duct. Furthermore, misalignment issues at the splice region were noted by two state DOTs. Problems related to falsework were also experienced in two other states, including the instance of a strongback failure during girder erection.

OBSERVATIONS DURING EXPERIMENTAL PROGRAM

After the survey was conducted, splice region details to be incorporated into two large-scale spliced girder test specimens were chosen based on the survey results. Drawings of existing spliced girder bridges and conversations with practicing engineers were also considered during the design of the splice regions. The primary focus of the experimental program was the shear performance of CIP splice regions with practical details. The flexural behavior of the girder specimens was also studied. The splice region details were therefore selected with the aim to achieve satisfactory strength and behavior while keeping constructability in mind. Further discussion regarding the chosen details is included in Williams.[3]

A splice region mock-up was constructed before fabricating the two large-scale spliced girder specimens to identify any potential concrete consolidation issues. The mock-up cast is described in the next section followed by a description of the splice regions of the large-scale specimens.

MOCK-UP CAST

A mock-up of a splice region (Figure 8) was constructed to incorporate the details to be used in the large-scale test girders. A splice region length of 24 in. was chosen, and the cross-section matched that of the precast segments that were spliced to create the test girders. The details of the mock-up are listed in Table 6. Several aspects (e.g., splice region length, interface surface detail, and hairpin detail of mild interface reinforcement) correspond to details that have been commonly specified according to the results of the survey. The bottom flange of the mock-up is shown in Figure 8. Along with the No. 6 hairpin bars, threaded rods extended 10 in. into the splice region to model pretensioned strands from the bottom flange of the precast segments. It should be noted that the formwork for the mock-up was fabricated using transparent plastic sheeting to allow the concrete to be observed during casting.

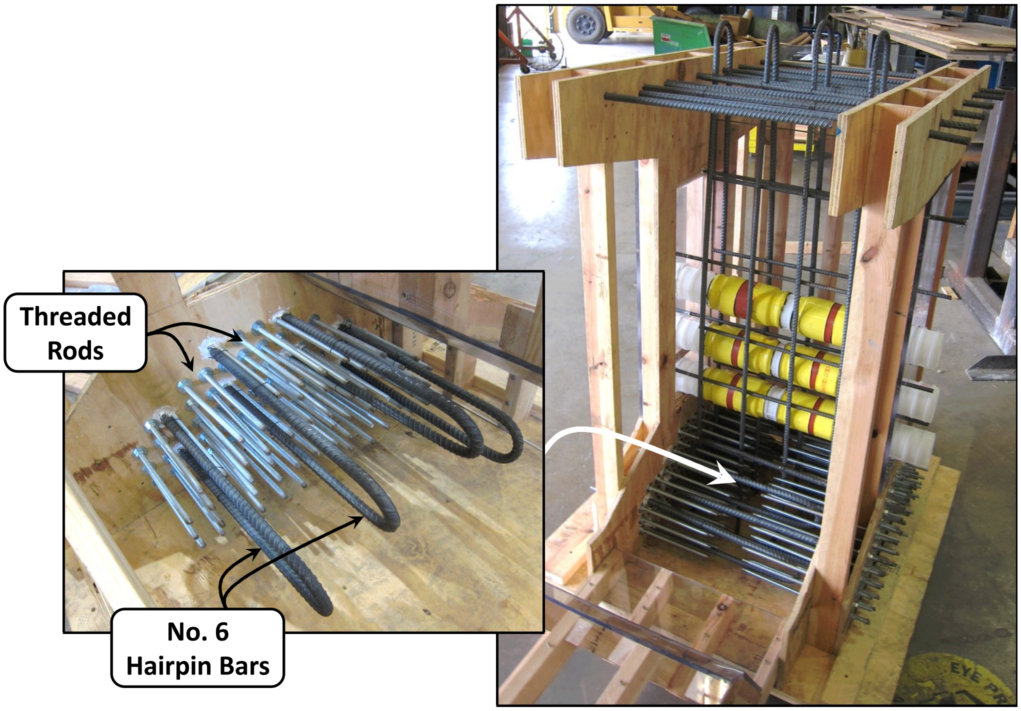


Fig. 8 Details of mock-up

Table 6 Summary of splice region details

Detail		Mock-Up	Test Girders
Splice Region Length		24 in.	
Web Width		9 in.[a]	
Post-Tensioning Ducts		3 Plastic Ducts with 4-in. Diameters	
Duct Diameter to Web Width Ratio		0.44	
Surface Detail at Interface		Shear Key with 1.5-in. Inset	Shear Key with 2-in. Inset
Interface Reinforcement (Extending from Each End)	**Bottom Flange**	4 - No. 6 Hairpins and Threaded Rods Representing Strand Extensions	Girder 1: 6 - No. 4 Straight Bars Girder 2: 8 - No. 6 Straight Bars
	Web	4 - No. 4 Straight Bars	8 - No. 4 Straight Bars
	Top Flange	6 (from One End) and 7 (from Other End) - No. 5 Straight Bars	Girder 1: 6 - No. 4 Straight Bars Girder 2: 6 - No. 5 Straight Bars
Vibration Method		Internal (Immersion) Vibrator Only	Internal Immersion and External Form Vibrators

[a]Web width at splice region matched web widths of adjacent precast segments of test girders

The concrete mixture design used for the mock-up and the splice regions of the two large-scale test girders (each cast at different times) is presented in Table 7. The mixture was designed to flow easily into the congested splice regions and to provide a high compressive strength. It was also necessary for the concrete to be readily available from a local ready-mix supplier. The target slump of the mixture was 8.0 in. The measured slump ranged from 7.5 in. (splice region cast for the first large-scale girder specimen) to approximately 9.25 in. (mock-up cast).

Table 7 Mixture design for mock-up and splice regions of test girders

Material	Details	Design Quantity	Units
Cementitious Material	Type I/II Cement	525	lb/yd^3 concrete
	Class F Fly Ash	175	
Fine Aggregate	Sand	1,190 to 1,221	
Coarse Aggregate	River Gravel (1” Nominal)	1,880	
Water	---	233	
Admixtures	High-Range Water Reducer	5.5	oz/cwt
	Water Reducer/Retarder	1.0 to 3.0	

During casting of the mock-up, an internal vibrator with a ¾-in. diameter head was used. Similar to actual field conditions, the person operating the vibrator was not able to see the concrete through the transparent formwork. Several days after the mock-up was cast, the formwork was removed. As shown in Figure 9, the concrete consolidated properly over the height of the specimen except within the bottom flange where honeycombing was observed. A similar issue in the field would likely require some repair of the splice region. As described in the following section, details of the reinforcement within the bottom flange were updated and additional measures were taken to prevent similar consolidation issues from occurring during fabrication of the test girders.

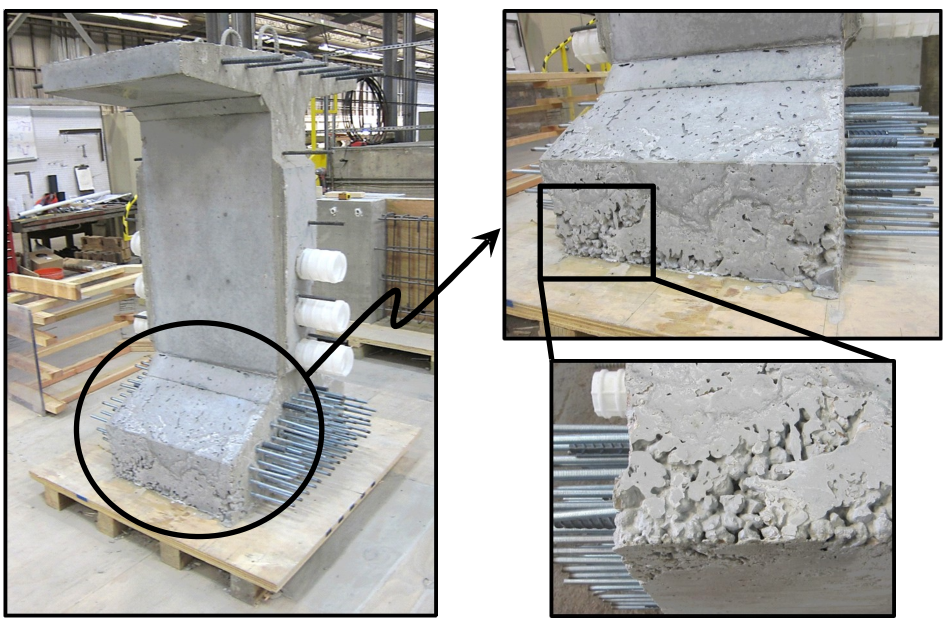
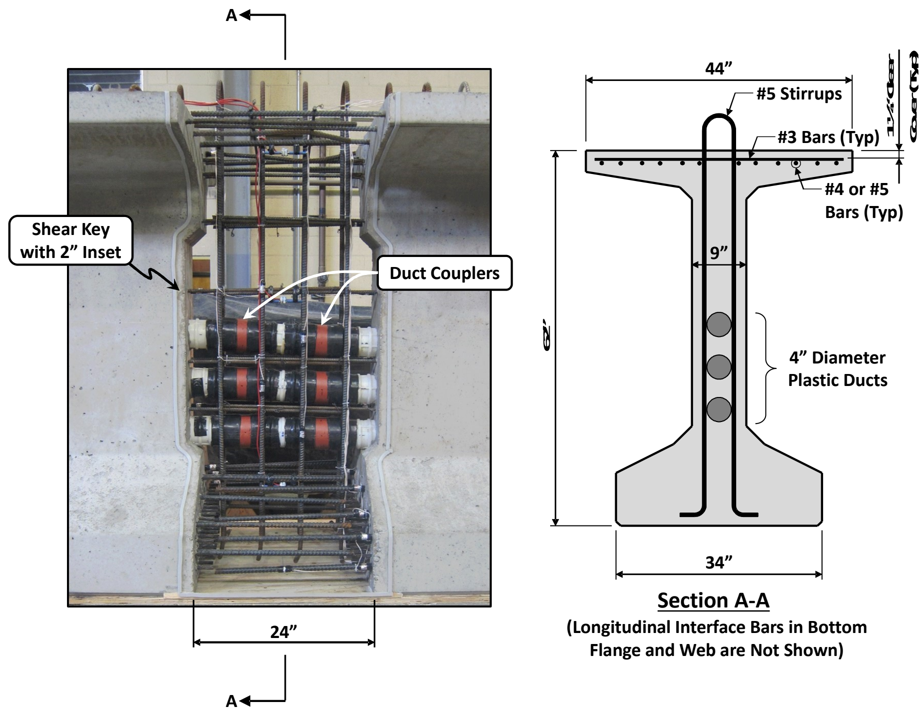
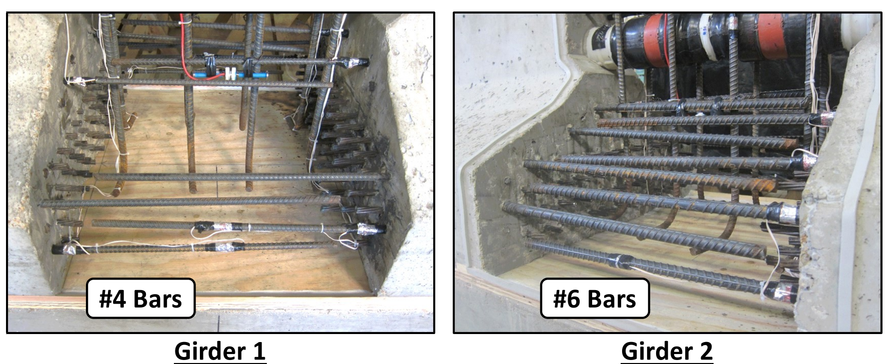


Fig. 9 Concrete consolidation issues of mock-up (adapted from Williams[3])

LARGE-SCALE SPLICED GIRDER SPECIMENS

Details of the CIP splice regions of the large-scale spliced girder specimens are provided in Table 6 for easy comparison with the details of the mock-up. The splice regions are also shown in Figure 10. Three primary changes were implemented based on the results of the mock-up cast. First, to ease congestion in the bottom flange compared to the mock-up, the pretensioned strands from the precast segments that extended into the splice regions of the test girders were cut within approximately 3 in. from the face of the precast segments. While allowing the strands to extend farther into the splice region within the bottom flange may have had a beneficial effect on flexural cracking behavior, ensuring that concrete could consolidate properly took precedence.[3] The second change that was implemented for the splice regions of the test girders was improved vibration. In addition to the use of an internal vibrator, an external vibrator was attached to each side form of the splice region to enhance concrete consolidation. The third modification was the addition of a row of $\frac{5}{64}$-in. diameter holes that were drilled into the bottom of the side forms (at the bottom flange) to permit any trapped air to escape during casting. Other updates to the splice region details were also made after the mock-up cast was performed (refer to Table 6), but these changes were not due to consolidation concerns. For example, to simplify the reinforcement details, straight bars were used within the bottom flange at the splice regions of the test girders instead of hairpin bars. It should be noted that the mild interface reinforcement within the bottom flange differed between the two girder specimens, as shown in Figure 10(b) and noted in Table 6. This variation allowed the effect of the bars on the flexural behavior of the girders to be evaluated during the load tests.[3]





(b)

Fig. 10 Splice regions of large-scale girder specimens – (a) splice region details; (b) interface reinforcement in bottom flange

Within the splice regions of the test girders, each plastic duct was connected using two couplers, as indicated in Figure 10(a). Heat shrink sleeves were used to seal the ends of each coupler. No duct leakage was observed during the experimental program. To ensure that post-tensioning ducts can be properly coupled within the limited space of a splice region, the coupling detail should be considered during the design process. Special care must also be taken to protect the ducts extending from the ends of the precast segments from being damaged during transport. If appropriate measures are taken to seal the ducts, potential problems during the concrete cast and subsequent grouting operations can be avoided.

The completed splice regions of both test girders are presented in Figure 11. The changes implemented based on the mock-up cast resulted in improved concrete consolidation. Moreover, no adverse effects on concrete placement caused by the additional reinforcement in the bottom flange of Girder 2 were observed. As described in Williams,[3] the chosen splice region details also resulted in satisfactory strength and behavior of the spliced girder specimens. The general procedure in Article 5.8.3.4.2 of AASHTO LRFD 2014 with consideration of the effective web width, b_v, provides conservative shear strength estimates for the girders.[3]

(a) (b)

Fig. 11 Completed splice regions of large-scale girder specimens – (a) Girder 1; (b) Girder 2

SUMMARY AND CONCLUSIONS

Post-tensioned spliced girders are a cost-effective option for moderate-span bridges and are therefore becoming more common. Although the basic configurations of spliced girder bridge spans are often similar, details specified at the cast-in-place splice regions have varied significantly. A survey was conducted to investigate design and detailing practices for CIP splice regions of spliced I-girders. State DOTs that have had experience with spliced I-girder design/construction were given the opportunity to explain the reasoning behind selected splice region details and share specific issues encountered in the field. Despite the wide variety of details that have been used, important trends and popular details were identified. Furthermore, the experiences shared by the participants are valuable to state DOTs that are considering the implementation of spliced girder technology for the first time.

The results of the survey were used to develop splice region details to be tested in the laboratory. Prior to the fabrication of large-scale spliced girder test specimens, a mock-up cast was performed to determine if the selected details and casting techniques would result in satisfactory concrete consolidation over the height of the splice region. Despite careful design of the concrete mixture and high measured slump, improper concrete consolidation was observed within the bottom flange of the mock-up. The mock-up cast highlighted the importance of being mindful of congestion within the splice region. Updated details and other measures taken as a result of lessons learned from the mock-up cast prevented the consolidation issues of the mock-up from reoccurring in the large-scale test girders.

This study of splice region details along with the observed performance of the spliced girder specimens presented in Williams[3] emphasize that spliced I-girders provide an economical option for extending span ranges of precast concrete bridges. With the careful selection of splice region details and strict quality control measures for the closure pours, potential construction and aesthetic issues can be avoided.

REFERENCES

1. AASHTO LRFD, *Bridge Design Specifications*, 2014, Seventh Edition with 2016 Interim Revisions, American Association of State Highway and Transportation Officials, Washington, DC, 2014, 2150 pp.
2. *PCI Bridge Design Manual*, Third Edition, Second Release, Precast/Prestressed Concrete Institute, Chicago, IL, 2014, 1620 pp.
3. Williams, C. S., *Behavior of the Cast-in-Place Splice Regions of Spliced I-Girder Bridges*, Ph.D. dissertation, The University of Texas at Austin, Aug. 2015, 415 pp.
4. Abdullah, A. B. M., Rice, J. A., Brenkus, N. R., and Hamilton, H. R., "Full-Scale Experimental Investigation of Wire Breakage Detection in Deviated Multi-Strand Tendon Systems," *Journal of Civil Structural Health Monitoring*, V. 6, No. 2, Apr. 2016, pp. 217-235.
5. Williams, C. S., Moore, A. M., Al-Tarafany, D., Massey, J. B., Bayrak, O., Jirsa, J. O., and Ghannoum, W. M., *Behavior of the Splice Regions of Spliced I-Girder Bridges*, Rep. no. 0-6652-2, Center for Transportation Research, The University of Texas at Austin, 2015, 265 pp.
6. Castrodale, R. W., and White, C. D., *NCHRP Report 517: Extending Span Ranges of Precast Prestressed Concrete Girders*, Transportation Research Board, Washington, DC, 2004, 603 pp.