

RESEARCH RESULTS ON EXTENDING SPAN RANGES OF PRECAST PRESTRESSED CONCRETE GIRDERS

Reid W. Castrodale, PhD, PE, Ralph Whitehead Associates, Inc., Charlotte, NC
Christopher D. White, PE, Ralph Whitehead Associates, Inc., Tallahassee, FL

ABSTRACT

This paper presents an overview of the recently completed NCHRP Project 12-57 "Extending Span Ranges of Precast Prestressed Concrete Girders." This research is intended to promote the use of prestressed concrete girders for longer span bridges. Results of a comparative design study demonstrating the effect of design modifications on the maximum span length for a simple span bulb-tee girder bridge are also presented. The three design examples are highlighted, which include a long simple span bulb-tee girder bridge, a two-span continuous bridge using U-beams in a seismic region, and a high level three-span bridge with haunched bulb-tee girders. Proposed revisions to the AASHTO LRFD Specifications related to spliced girder design are summarized. Research conclusions and impediments to the use of spliced girders are also discussed.

Keywords: Bridges, Research, Long Span, Precast Concrete, Prestressed Concrete, Girders, Design (Examples), Design (Structural), Spliced Girders, Segments

INTRODUCTION

Since its first use for bridges in 1950 (1), precast, prestressed concrete has gained rapid acceptance as the preferred material for short to medium span bridges in the United States and around the world (2). Bridges built using prestressed concrete girders have proven to be economical, exhibit good structural performance, and require minimal maintenance. Improvements in materials, the introduction of new girder shapes, and advances in design methods have increased the span range of precast, prestressed concrete girders over the years. However, they are still used infrequently for spans in excess of 160 ft. This upper limit of practical application exists for a number of reasons, including material limitations, structural considerations, size and weight limitations on girder shipping and handling, and a general lack of information and design aids necessary to design longer spans using concrete girders.

There is a wide variety of approaches to address these limitations, including the use of high performance concrete, larger strand sizes, and modified girder shapes. However, the approach that provides the greatest increase in span capability for precast, prestressed concrete girders is the use of spliced girder technology. In this technique, girders are fabricated in several pieces that are later joined to make one single continuous girder. The segments are typically connected using internal post-tensioning tendons.

The ability to achieve greater spans with the use of spliced precast, prestressed concrete girders has introduced another material and structure type into the long-span bridge market. Where available, this added competition has improved the economy of long-span bridges. Use of spliced girder technology has also made a concrete alternate possible in situations where availability of fabricated steel girders has adversely affected project schedules.

NCHRP Project 12-57 (3) “Extending Span Ranges of Precast, Prestressed Concrete Girders” was initiated to address these issues by promoting the practical use of prestressed concrete girders for longer spans and by expanding their use to applications not normally associated with precast, prestressed concrete girder construction. The main objective in this research was to collect and present the necessary information to owners, designers, fabricators and contractors that will enable them to implement spliced girder technology to achieve longer spans. This transfer of information and experience was also intended to avoid the repetition of poor experiences or mistakes that have already been encountered in parts of the country where spliced girder construction is already being used.

This paper briefly outlines the research project and then summarizes a comparative design study and the three design examples developed as part of the research. An overview of proposed revisions to the *AASHTO LRFD Specifications* is also presented. Research conclusions and impediments to the use of spliced girders are also discussed.

RESEARCH PROJECT

As stated in the Research Project Statement:

The objective of this research is to develop recommended load and resistance factor design (LRFD) procedures, standard details, and design examples for achieving longer spans using precast, prestressed concrete bridge girders.

To accomplish this objective, NCHRP Project 12-57 included the following tasks:

- Review relevant foreign and domestic practice, performance data, research findings, design examples, design software, and other information related to long-span precast, prestressed girder bridges. Information on actual field experience was of particular interest.
- Identify and describe existing or new methods for extending the span length of precast, prestressed bridge girders. Develop a prioritized list of alternatives for extending the span length of concrete girders. These methods shall include, as a minimum, splicing, post tensioning, and enhanced concrete properties. List the advantages and limitations of each method and identify critical issues for design, fabrication, transportation, and construction.
- Determine if revisions to the *AASHTO LRFD Bridge Design Specifications* are needed in order to address the issues identified. Recommend a course of action to develop each specification change identified.
- Identify other actions needed in order to address the issues identified and make recommendations on implementation of these actions.
- Develop comprehensive design procedures for several design alternatives. Illustrate these procedures with design examples.
- Prepare recommended changes to the *AASHTO LRFD Bridge Design Specifications* to address the issues identified.

Upon completion of the research, a final report was submitted that documents the entire research effort and includes appendices containing a listing of spliced girder bridges, the design procedures, design examples and recommended specification changes.

INITIAL FINDINGS

One of the initial findings of the research was that most of the techniques and approaches for extending span ranges involve incremental changes in the conventional design methods and materials. These changes generally result in relatively small incremental increases in the span range for precast, prestressed concrete girders, as demonstrated in the comparative design study discussed later in this paper. Information is generally available in the literature or from commercial sources for implementing these techniques.

Therefore, while it is important to identify these issues to make more designers aware of their potential, a significant effort is not required in encouraging the use of these techniques.

A second early finding of the research was that one technique, spliced girders, was found to provide significantly increased span ranges for precast prestressed concrete girders. This technique involves the fabrication of the girders in segments that are assembled into the final structure. While many spliced girder bridges have been constructed, the use of this technique is not widespread. Use of this technology also requires consideration of a number of issues with which the designer of conventional precast, prestressed concrete girders is typically not familiar. Furthermore, the information available in the literature regarding the implementation of spliced girder construction is limited. Therefore, it was determined that the main focus of the study would be on spliced girder construction.

It should be noted that splicing girders is simply an approach to make possible the use of longer or heavier girders than can otherwise be used. Therefore, the technique is often used in conjunction with other approaches for extending span ranges to achieve the maximum benefit.

LISTING OF SPLICED GIRDER BRIDGES

A significant activity of the research project was to collect information on spliced girder bridges that have been designed and built. This information was helpful in identifying construction techniques and details, but was also very helpful by demonstrating the variety of applications and conditions for which spliced girder construction had been used. A summary of the information on spliced girder bridges appears in a separate paper by the same authors also presented at this Symposium.

COMPARATIVE DESIGN STUDY

A comparative design study was prepared to demonstrate the effectiveness of a number of the highest ranked methods that were identified for extending span ranges of precast prestressed concrete girders.

A single span, simply supported bridge was selected as the subject of the comparative design study. The typical cross section was comprised of precast prestressed concrete girders at a fixed spacing as shown in Figure 1. Maximum spans were then computed for the bridge using the selected methods for increasing span lengths. Some design methods were also compared using different girder types. In general, design methods were considered individually, although the effect of combining methods was considered in a few cases. Calculations were performed using a commercially available software package.

The results were compiled and compared to give an indication of the effectiveness of each design variation for increasing the maximum span. Results from this study should be considered as giving an indication of trends. For other situations where girder

spacing, section type and other conditions are changed, the relative effect of different methods may vary from what is reported here. Combinations of different design cases are expected to provide additional benefit, although the effect may vary.

The study was conducted in two parts. The first considered a PCI BT-72 girder design with fourteen design variations. The second compared four design cases from the PCI BT-72 girder design with results using two other girder cross-sections of similar depth, an NEBT 1800 girder, and an AASHTO Type VI girder.

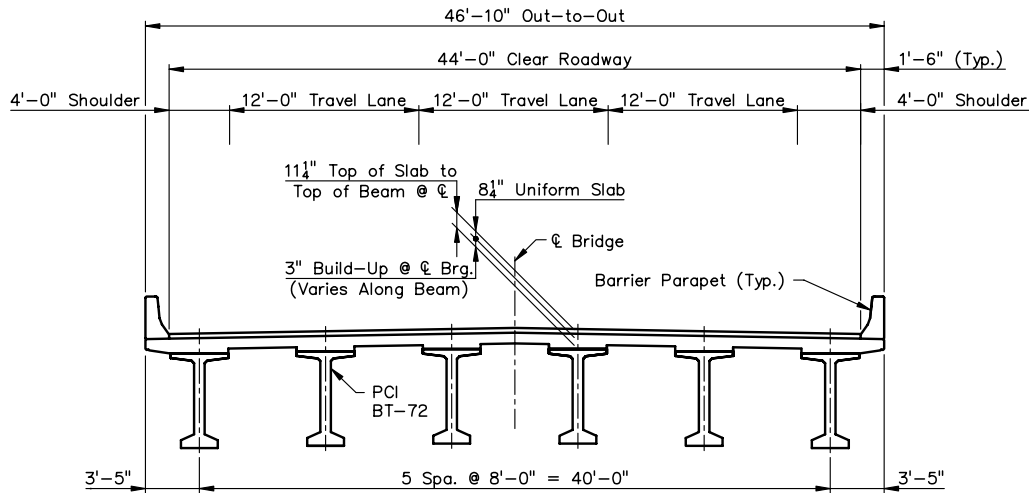


Figure 1: Typical Section of Bridge

DESIGN VARIATIONS

The first set of designs uses the PCI BT-72 girder. Table 1 summarizes basic design information for the base design and the fourteen design variations considered.

The second set of designs compares designs using the PCI BT-72 girder to designs using the NEBT 1800 and AASHTO Type VI girders, as shown in Figure 2. These girders are of equal or nearly equal height, but they differ in other dimensions. The four design cases considered for each cross-section type are shown in Table 1 by the underlined cases.

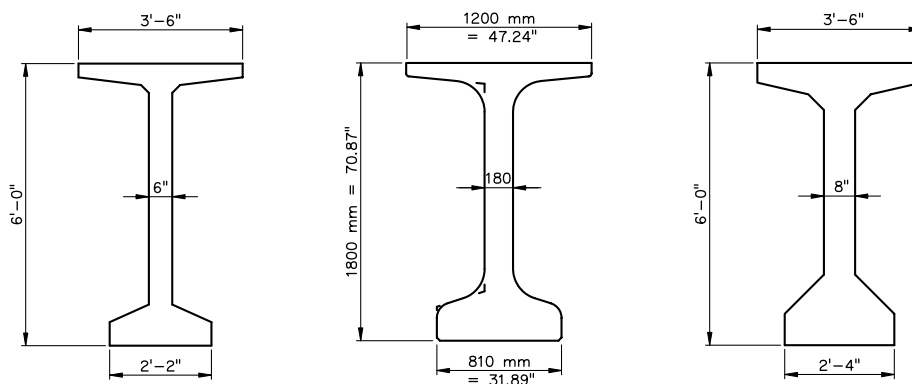


Figure 2: Basic Dimensions for Different Girder Types

Table 1: Basic Information for Design Variations

Design Case		f_{ci}	f_c	f_{cd}	w_c	w_{cd}	Web Width	Bottom Flange Depth	Strand ϕ
No.	Description	(ksi)	(ksi)	(ksi)	(kcf)	(kcf)	(in.)	(in.)	(in.)
<u>1</u>	<u>Base Design</u>	5.0	6.5	4.5	0.15	0.15	6.0	6.0	1/2
2	Increased f_{ci}	6.0	6.5	4.5	0.15	0.15	6.0	6.0	1/2
<u>3</u>	<u>High Strength Conc. (HSC)</u>	8.0	10.0	4.5	0.15	0.15	6.0	6.0	1/2
4	Lightweight Conc. Deck	5.0	6.5	4.5	0.15	0.12	6.0	6.0	1/2
5	Lightweight Conc. Beam	5.0	6.5	4.5	0.12	0.15	6.0	6.0	1/2
6	Lightweight Conc. Dk. & Bm.	5.0	6.5	4.5	0.12	0.12	6.0	6.0	1/2
7	Deeper Bottom Flange	5.0	6.5	4.5	0.15	0.15	6.0	8.0	1/2
8	Increased Beam Width	5.0	6.5	4.5	0.15	0.15	8.0	6.0	1/2
9	Bundled Strands	5.0	6.5	4.5	0.15	0.15	6.0	6.0	1/2
10	Top Strands Debonded	5.0	6.5	4.5	0.15	0.15	6.0	6.0	1/2
<u>11</u>	<u>0.6" ϕ Strands</u>	5.0	6.5	4.5	0.15	0.15	6.0	6.0	0.6
<u>12</u>	<u>0.6" ϕ Strands and HSC</u>	8.0	10.0	4.5	0.15	0.15	6.0	6.0	0.6
13	Decked Bulb Tee	5.0	6.5	6.5	0.15	0.15	6.0	6.0	1/2
14	Touch Shoring	5.0	6.5	4.5	0.15	0.15	6.0	6.0	1/2
15	Added Post-Tensioning	5.0	6.5	4.5	0.15	0.15	8.0	6.0	1/2

Underlined Design Cases are also used for the comparisons of different girder shapes.

RESULTS FOR PCI BT-72 VARIATIONS

The results of the fourteen variations on the base design using the PCI BT-72 are shown in Figure 3.

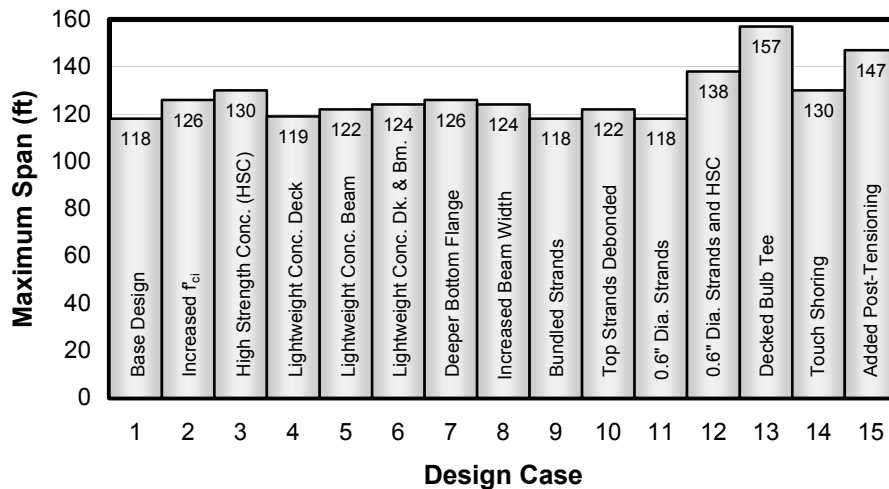


Figure 3: PCI BT-72 Variation Results

The greatest increase in maximum span length was obtained by casting the deck with the girder (decked bulb tee – Case 13) and by adding post-tensioning to a pretensioned girder (Case 15), with increases in maximum spans of 33.1 and 24.6 percent, respectively. These design variations are out of the ordinary and require significant additional effort in design and construction. However, they have been used successfully in some situations and regions.

The next most effective strategy for increasing the maximum span length was the combination of increased strand size with high strength concrete (Case 12), with an increase in the maximum span of 16.9 percent. The use of this strategy has become common and has served to significantly increase span ranges for precast concrete girders. Other design comparisons achieved increases in maximum spans from 0 to 10 percent.

A significant finding was the increase shown in Case 12, where two strategies were combined to produce a much higher increase in maximum span than either strategy alone. While other combinations of strategies were not investigated in this study, it appears likely that the combination of different strategies could provide impressive additional gains in maximum spans. Therefore, designers are encouraged to consider combinations of strategies.

RESULTS FOR DIFFERENT GIRDER TYPES

The results of the comparison between the PCI BT-72, NEBT 1800, and AASHTO Type VI girder designs for the four design cases are shown in Figure 4.

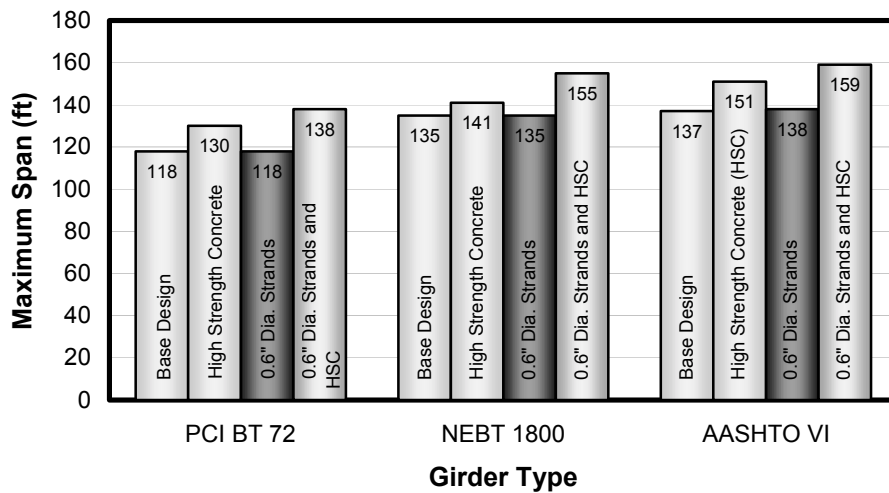


Figure 4: Maximum Spans for Different Girder Types

The increase in maximum span for the three design variations over the Base Design for each girder type indicates a similar relationship for the different girder types. The trends can be summarized as follows:

- High strength concrete increased the maximum span length. The span increase ranged from 4.4 percent to 10.2 percent with both the PCI BT-72 and AASHTO Type VI girders experiencing the same increase of 10.2 percent.
- The use of 0.6 in. diameter strands with normal strength concrete was not effective for increasing maximum span for these girders for the bridge cross-section considered.
- The combination of both high strength concrete and 0.6 in. diameter strands was most effective for increasing the maximum span for all girder types. The span increase ranged from 14.8 percent to 16.9 percent. The PCI BT-72 girder showed the greatest increase in spite of the fact that it has the smallest bottom flange, limiting the possible number of strand locations.
- The NEBT 1800 and AASHTO Type VI girders have a greater maximum span for all design cases investigated.
- The NEBT 1800 and AASHTO Type VI girders have maximum spans 17 ft and 19 ft larger, respectively, than the Base Design for the PCI BT-72 girder.
- The use of high strength concrete and 0.6 in. diameter strands increased the maximum spans of the NEBT 1800 and AASHTO Type VI girders by 20 and 22 ft, respectively, over the Base Design for the PCI BT-72 girder. This strategy for increasing span range is clearly most effective of those considered.

The comparison of designs for different girder types indicates that the AASHTO Type VI girder has the largest maximum span and the PCI BT-72 girder had the smallest maximum span for all design cases. The NEBT 1800 girder did not experience as great an increase in maximum spans for any of the design cases considered when compared to the other girders.

These conclusions tend to indicate that the AASHTO Type VI girder would provide the most efficient designs since it had the longest maximum spans. However, the Type VI girder is a much larger cross-section. Therefore, more information must be considered when comparing the performance of different girder sections to determine the most efficient and economical designs.

DESIGN EXAMPLES

Design examples are important resources that enable a designer to approach a new type of design with increased confidence because they clearly present all of the required issues and procedures necessary to complete the design. Since the design of spliced girder bridges is more complex than the design of conventional precast prestressed concrete girders, design examples were developed to facilitate the use of this type of construction.

Three design examples were developed representing several of the many different configurations for which spliced girder bridges can be used. A brief introduction to each design example is presented in this paper.

The examples are intended to be a reasonable solution for the site and conditions described. They may not be the absolute best solution for the bridge type presented. There are many aspects of each design that can be altered, such as the cross-section type, the sequence and method of construction and the sequence of post-tensioning.

The design examples were prepared using the *AASHTO LRFD Bridge Design Specifications* with Interims through 2003.

DESIGN EXAMPLE 1

The first design example is the simplest example, addressing a long simple span bridge. The elevation of the girder is shown in Figure 5 with the typical section shown in Figure 6. This could represent a long-span bridge over a stream crossing or over a wide “single point urban interchange” (SPUI). The specific application illustrated is a SPUI over an existing roadway where traffic must be maintained during construction. Details of the construction sequence are summarized in Table 2.

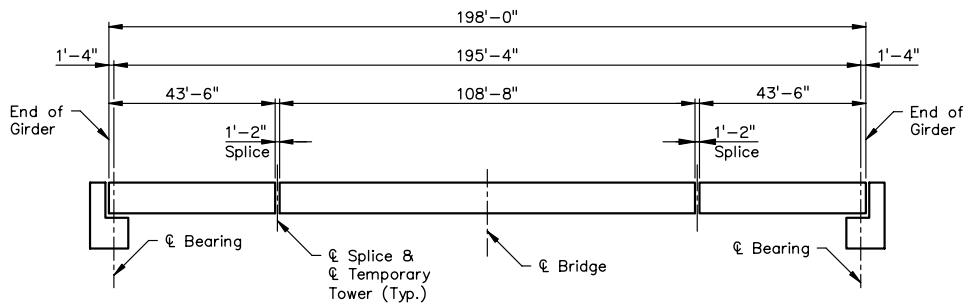


Figure 5: Design Example 1 – Girder Elevation

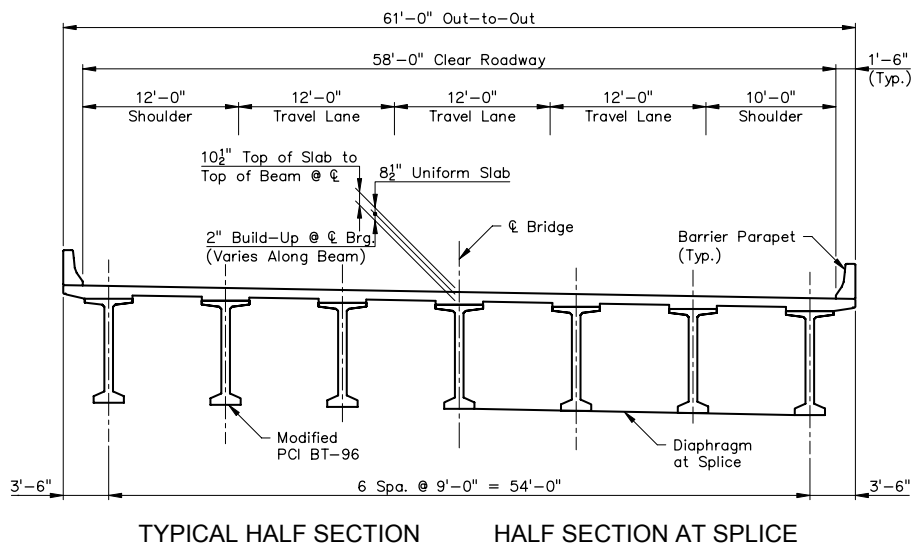


Figure 6: Design Example 1 – Typical Section

Details of this design example include:

- Simple span
- 96 in. deep modified PCI bulb-tees with an 8 in. web
- Three girder segments are used, with two lengths. All girder segments are pretensioned
- Girder segments are erected on permanent abutments and temporary towers
- Splices between girders are cast when the deck is cast on the girder segments
- All post-tensioning tendons are stressed after the deck and splice concrete are placed
- Post-tensioning tendon anchorages are located in end blocks at the end of each girder
- Conventional abutments and bearings are used

Table 2: Design Example 1 – Construction Stages

Stage	Description	Girder Age (days)
1	Stress pretensioning strands	-
2	Cast girder segments	0
3	Release Pretensioned strands	1
4	Erect girder segments	50
5	Placement of deck and splice concrete	60
6	Stress Post-tensioning tendons	75
7	Add parapets	100
8	Bridge open, add live load (HL-93) with dynamic allowance	140
9	Add future wearing surface	15,000
10	Final condition, after losses, with live load (HL-93)	27,500

DESIGN EXAMPLE 2

The second design example is more complex, representing a two-span bridge crossing an existing interstate, where maintenance of traffic issues are very important. The elevation of the girder is shown in Figure 7 with the typical section shown in Figure 8. This example also illustrates the application of spliced girder construction to sites where seismic design must be considered. Details of the construction sequence are summarized in Table 3.

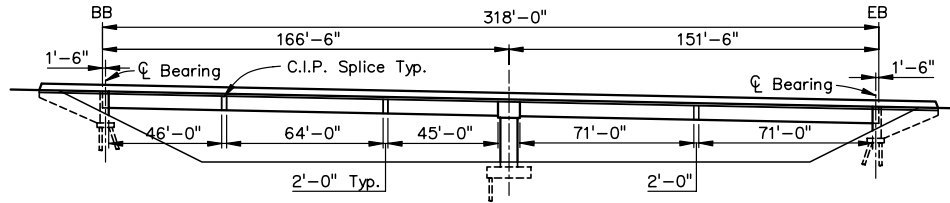


Figure 7: Design Example 2 – Girder Elevation

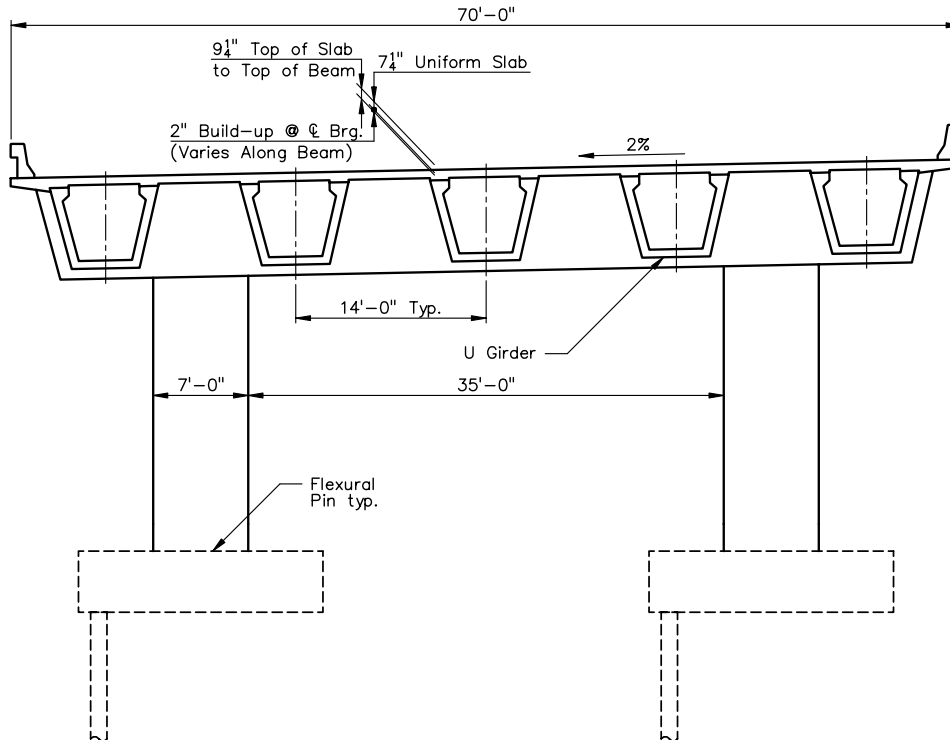


Figure 8: Design Example 2 – Typical Section, including Integral Pier Cap

Details of this design example include:

- Two unequal spans
- 6 ft deep U-beams
- Five girder segments are used, with several lengths. Three of the girder segments are pretensioned.
- Girder segments are erected on temporary towers and the interior pier.
- Splices between girders are cast after the girder segments are erected.
- After splicing, first stage post-tensioning tendons are stressed.
- The deck is cast on the continuous girders.
- Second stage post-tensioning tendons are stressed after the deck concrete is placed.

- Post-tensioning tendon anchorages are located in the cast-in-place end diaphragm, which rests on conventional bearings.
- The interior pier cap is integral, providing a fixed connection between the superstructure and substructure.

Table 3: Design Example 2 – Construction Stages

Stage	Girder Age (days)	Event	Loads
1	1	Transfer Pretension	Girder self weight
2	30	Set Girders on Falsework	Girder self weight
3	50	Pour splice, diaphragms	N/A
4	60	Stage 1 P/T	Falsework release forces
5	80	Pour CIP Deck	Fluid weight of deck
6	90	Stage 2 P/T	N/A
7	110	Place barriers	Traffic barriers
8	120	Open to full traffic	1.29 lanes of live load per girder
9	27,375	Service	Future wearing surface

DESIGN EXAMPLE 3

The third design example is the most complex of the three design examples. It addresses a three span bridge. A half-elevation of the bridge is shown in Figure 9 with typical sections shown in Figures 10 and 11. This type of structure has most often been used for crossings over navigable waterways, but can be used for any multi-span crossing where spans are greater than can be achieved using a constant depth cross-section. The concepts of the example can also be extended for use on bridges with more than three spans. Details of the construction sequence are summarized in Table 4.

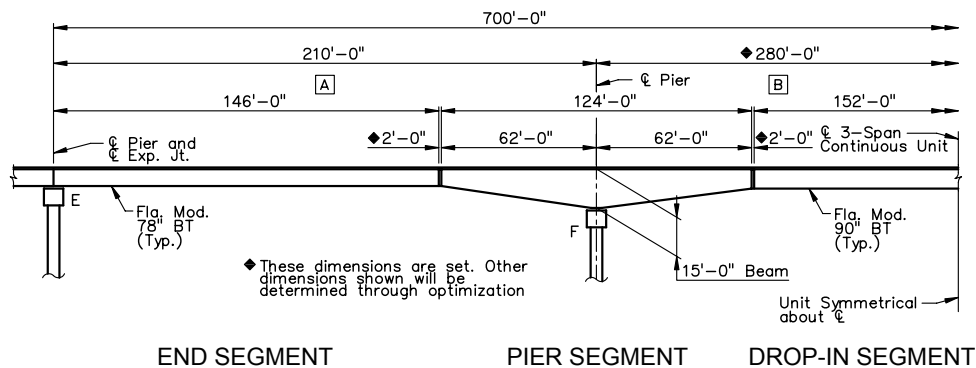


Figure 9: Design Example 3 – Girder Elevation

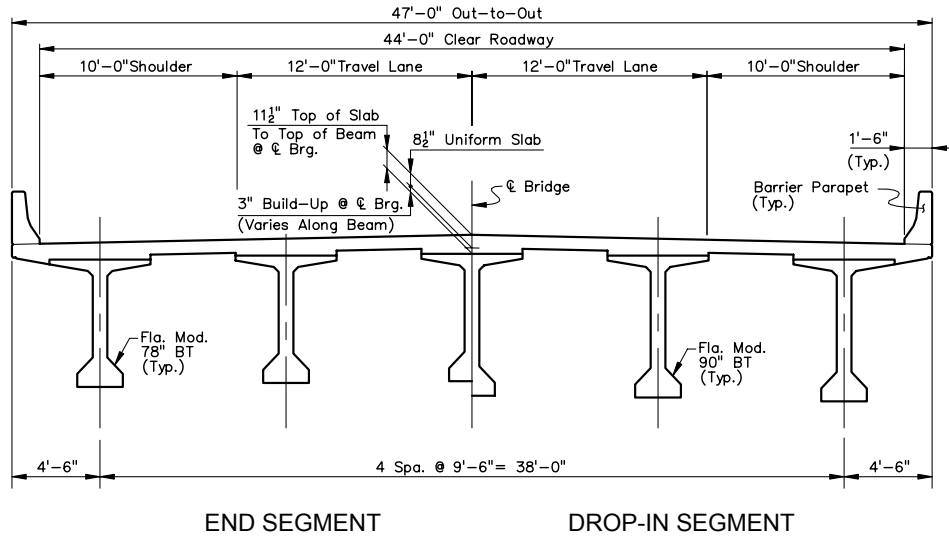


Figure 10: Design Example 3 – Typical Section for Constant Depth Girders

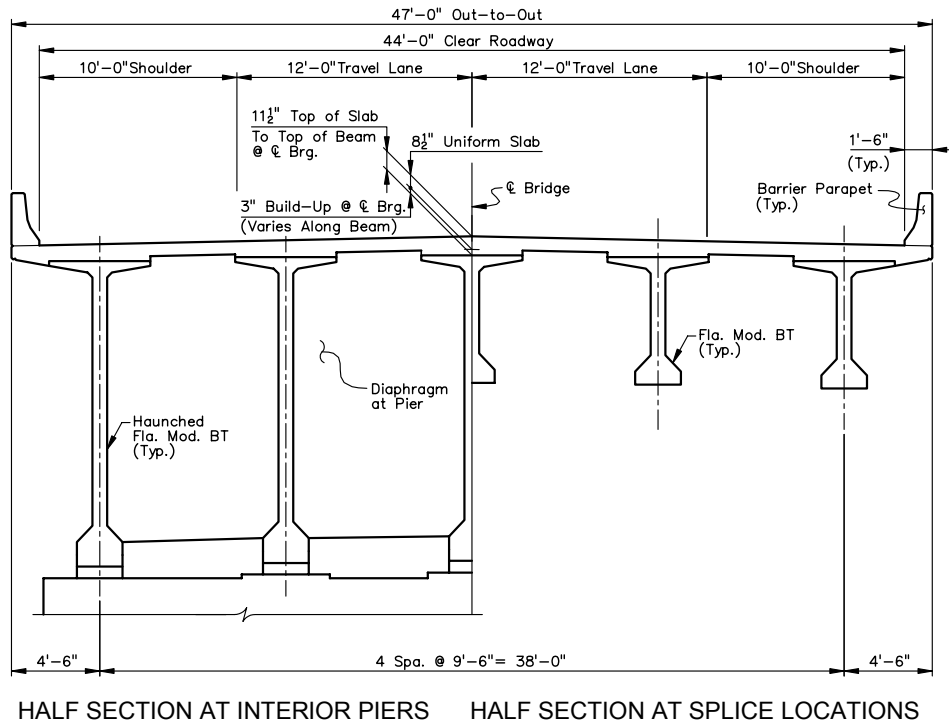


Figure 11: Design Example 3 – Sections at Critical Locations

Details of this design example include:

- Three spans, with equal end spans (symmetrical about center of bridge)
- End girder segments are 78 in. deep Florida modified bulb-tee girders; pier girder segments are haunched to 15'-0" deep at the interior piers, with a slightly varying bottom flange height; the drop-in girder segments are 90 in. deep Florida modified bulb-tee girders. All girder segments have a 9 in. web.

- Five girder segments are used, with three different lengths.
- The five girder segments are each pretensioned.
- The girder segments are erected on permanent piers, temporary towers and strongbacks.
- Splices between girders are cast after the girder segments are erected.
- After splicing, first stage post-tensioning tendons are stressed.
- The deck is cast on the continuous spliced girders.
- Second stage post-tensioning tendons are stressed after the deck concrete is placed.
- Post-tensioning tendon anchorages are located in end blocks at the end of each girder.
- The depth of the haunched girder segments at the interior pier and the depth of the drop-in girder segments in the center span were increased to satisfy live load deflection requirements. The pretensioning in the girder segments was also adjusted to improve the profile of the bridge under dead load conditions.

Table 4: Design Example 3 – Construction Stages

Stage	Description	Girder Age (Days)
0	Precast girders	1
1	Erect girders on piers, temporary falsework and strongbacks	60
2	Cast splices	70
3	Stress post-tensioning Tendons 1 and 2 (PT Stage 1)	84
4	Cast deck slab	98
5	Stress post-tensioning Tendons 3 and 4 (PT Stage 2)	119
6	Cast traffic barriers	133
7	Add live load (HL-93) with dynamic allowance	161
8	Add future wearing surface (FWS)	4,161
9	Service Life (i.e., "Final Conditions After All Losses")	27,500

PROPOSED REVISIONS TO THE *AASHTO LRFD SPECIFICATIONS*

A major goal for this research project was to develop proposed revisions to the *AASHTO LRFD Bridge Design Specifications (4)* where needed to allow, facilitate or clarify the use of extended spans for precast prestressed concrete bridge girders. To fulfill this project goal, the *Specifications* were reviewed to identify provisions that need revision. The review revealed that the most significant issues were related to the refinement of the *Specifications* for the design of spliced girders. Significant revisions do not appear necessary to implement strategies for extending span ranges other than the splicing of girders. Therefore, proposed revisions to the *Specifications* were developed to address issues related to spliced girder design.

BRIEF OVERVIEW OF REVISIONS

The most important issue identified to improve the *Specifications* for application to spliced girder design was to clarify the distinction between spliced girder and segmental construction. Revision of the *Specifications* in this area was essential so that designers may easily find and properly interpret the requirements that apply to spliced girder construction. The most reasonable approach to making the distinction was to treat spliced girder bridges as conventional prestressed concrete girder bridges with additional design requirements for the splice locations where some provisions related to segmental construction are applicable. This distinction prevents the unnecessary and inappropriate application of requirements for segmental construction, which appear to be intended for short-segment cast-in-place or match-cast box girder bridges, to spliced girder bridges. Revisions were worded to preserve as much flexibility in design options as possible to allow cases in which the boundaries between spliced girder and segmental construction, and other concepts, may be blurred.

The major points of the proposed revisions may be summarized as:

- Article 5.14.1.3 Spliced Precast Girders has been added to specifically address the detailing and design of spliced girder bridges. This new article contains provisions from Article 5.14.1.2.6 Transverse Construction Joints and some appropriate provisions related to spliced girder construction from Article 5.14.2 Segmental Construction. Additional information from other articles in the *Specifications* and other sources has also been added.
- Article 5.14.2.4.7 Precast Segmental Beam Bridges has been deleted, with its contents distributed to the new Article 5.14.1.3 as appropriate.
- A definition of “Segmental Construction” is proposed to replace the definition of “Segmental Components” currently appearing in Article 5.2. A definition of “Spliced Precast Girders” is also proposed to emphasize the distinction between the two types of construction.
- The provisions of Article 5.14.1.2.7, which address precast girders made continuous, have been moved to a new Article 5.14.1.4 Simple Span Precast Girders Made Continuous. The introduction to the article has been revised to more clearly reflect the intent of this type of construction, limiting it to simple span construction with closure joints at interior piers, and to coordinate its requirements with the new section on spliced precast girders.
- Article 5.14.1.2.8 Longitudinal Construction Joints has been moved to Article 5.14.4.3.3d which is a subarticle related to precast slab bridges.
- With the addition of Articles 5.14.1.3 and 5.14.1.4, current Article 5.14.1.3 Cast-in-Place Girders and Box and T-Beams must be renumbered as Article 5.14.1.5.

- Several other articles have also been revised to address additional issues and concerns. Some others have been included for comment or to note ongoing revision activity by AASHTO Subcommittee on Bridges and Structures Technical Committee for Concrete Structures T-10.

CONCLUSIONS

The objective of this research project was to identify options and provide resources that would encourage the use of longer spans for precast, prestressed concrete girders. The research has focused on spliced girder technology because it has the greatest potential for increasing span ranges of precast prestressed concrete girders.

The following specific conclusions can be drawn from the research performed as part of NCHRP Project 12-57:

- Spliced girder bridges have a proven record of accomplishment, with over 250 spliced girder bridges having been constructed, some of which were constructed as early as 1952, shortly after the first prestressed concrete bridge in the US was built.
- A variety of options is available for increasing the spans of precast, prestressed concrete bridge girders. These options range from the enhancement of material and design parameters to the addition of post-tensioning and splicing of girders.
- For the specific conditions of the comparative design study, an increase in maximum span of up to 17% was achieved using a combination of enhanced material properties, and an increase of 33% was achieved using a decked bulb tee.
- Spliced girders can be successfully designed using the existing *AASHTO LRFD Specifications*.
- The *AASHTO LRFD Specifications* should be revised to clarify and improve their usefulness for spliced girder bridges. An improved specification will facilitate the application of the *LRFD Specifications* to the design of spliced girder bridges.
- Design resources are available for design of spliced girder bridges, including computer design programs.

It appears that there is little need for research specifically directed toward extending span ranges of precast, prestressed concrete bridge girders or spliced girders that would be required to remove obstacles for the increased use of these concepts. The only exception to this appears to be the decked bulb tees, where research is needed to develop and demonstrate a connection between units that will allow their use on primary roads. This research has been approved as NCHRP 12-69.

Research would be helpful in some areas to refine design procedures or results of design requirements, such as:

- Estimation of long-term deflections (currently multipliers are used)
- Verification of prestress losses
- Comparison of designs requiring full deck removal for replacement with designs requiring full deck removal with the deck stressed and with designs with the deck stressed and partial or no removal of the deck

The researchers identified a number of impediments to the implementation of spliced girder technology in areas where it is not currently used. These issues are not material or design related and would require cooperation from the parties involved in the design and construction of bridges to resolve. These issues include:

- Reluctance of owners to utilize technology with which they and their consultants, fabricators and contractors are unfamiliar
- Reluctance of designers, fabricators, contractors to utilize technology with which they are unfamiliar
- Reluctance of contractors to utilize technology that may add risk, additional subcontractors and other complicating factors to a project
- Limitations on transportation of girder segments, due to weight or length, in the jurisdiction of the project or in adjacent jurisdictions through which girder segments must be transported
- Reluctance of owners to utilize post-tensioned concrete structures because of concerns regarding inspection of ducts after grouting and for the life of the structure
- Lack of availability of design tools (software)
- Concern about performance of spliced girders in extreme events, such as earthquakes and vessel impact
- Concern about availability of erection equipment for large segments or utilization of temporary supports
- Lack of cost estimating data to allow appropriate comparisons of design alternates
- Lack of clarity or restrictive provisions in the *LRFD Specifications* addressing spliced girder technology

These concerns have been addressed by NCHRP 12-57. Therefore, an aggressive implementation and distribution strategy is recommended in order to fully realize the potential for the technologies discussed in this report.

REFERENCES

1. *Reflections on the Beginnings of Prestressed Concrete in America*, Precast/Prestressed Concrete Institute, Chicago, IL (1981) 368 pp.
2. Dunker, Kenneth F., and Rabbat, Basile G., "Performance of Prestressed Concrete Highway Bridges in the United States - The First 40 Years." *PCI Journal*, Vol. 37, No. 3. (May-June, 1992) pp. 48-64.
3. Castrodale, R.W., White, C.D., "Extending Span Ranges of Precast, Prestressed Concrete Girders," Project No. 12-57, National Cooperative Highway Research Program, NCHRP, National Research Council, Washington DC, submitted September 2003.
4. AASHTO LRFD Bridge Design Specifications, 2nd Edition with Interims, American Association of State Highway and Transportation Officials. Washington, DC. (1998-2003).