Evaluation of Common Design Policies for Precast, Prestressed Concrete I-Girder Bridges

More-stringent owner requirements affect span capability, girder spacing, prestressing requirements

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The *AASHTO LRFD Bridge Design Specifications* (AASHTO LRFD) provides bridge engineers with minimum design requirements for safe highway bridges. However, many bridge owners have adopted more stringent policies for the design of precast, prestressed concrete girder bridges. These policies specify design requirements for section properties, allowable tensile stress, and continuity.

Table 1–Effects of more stringent design policies on span capability, girder spacing, and required prestressing force

Conservative design policy	Reduction in span capability (%)		Reduction in girder spacing (%)		Increase in required prestressing force (%)	
	6 ft spacing	12 ft spacing	6 ft spacing	12 ft spacing	6 ft spacing	12 ft spacing
Gross section properties	1.8–3.0	1.9–3.0	9.7–12.6	6.5–8.7	5.7–8.0	5.7–8.0
Zero allowable tension	4.9–5.4	4.9–5.4	22.5–27.3	15.3–17.3	11.4–12.7	11.4–14.0
Simple span analysis	2.9–3.2	2.0–2.9	13.2–17.4	6.3–10.0	7.7–9.1	6.0–8.3

Table 2–Effects of combined stringent design policies on span capability, girder spacing, and required prestressing force

Reduction in span capability (%)		Reduction in girder spacing (%)		Increase in required prestressing force (%)	
6 ft spacing	12 ft spacing	6 ft spacing	12 ft spacing	6 ft spacing	12 ft spacing
10.2–11.1	10.0–10.6	46.2–52.2	29.6–33.6	28.6–34.0	28.6–30.9

Bridges designed using more stringent policies will be more robust and more costly when compared to bridges designed only to the minimum requirements. The most common differences include a reduction in span length, a reduction in girder spacing, or an increase in prestressing levels. This article attempts to quantify the sensitivity of common policies on the design of precast, prestressed concrete bridge girders. Span capability, girder spacing, and prestressing requirements are computed based on the minimum requirements set forth in the AASHTO LRFD. Each of the more stringent policies is then evaluated individually to understand its effect on the design. The combined effect of all the design policies is also investigated.

Survey of Design Policies

A survey of state departments of transportation (DOTs) was conducted to gauge the extent to which bridge owners deviate from the minimum requirements set forth in the AASHTO LRFD. Bridge owners were asked the following questions:

- What type of section properties policy does your state use for the design of precast, prestressed concrete girder bridges (gross, transformed)?
- What allowable tensile stress at service III policy does your state have for the design of precast, prestressed concrete girder bridges (AASHTO LRFD Table 5.9.4.2.2-1, zero tension at service limit state, other)?
- What continuity policy does your state have for the design of continuous precast, prestressed concrete girder bridges (AASHTO LRFD Section 5.14.1.4 "Bridges Composed of Simple Span Precast Girders Made Continuous," simple span moments for superimposed dead loads and live load, other)?

The responses of the 38 state DOTs that completed the survey are summarized in Figs. 1 through 3.

Sensitivity Study

The bridge sections used in this study are slab-on-girder systems composed of a cast-in-place concrete deck on precast concrete wide flange (WSDOT WF) I-girders. Interior girders are analyzed for various bridge configurations consisting of six WF girders. The bridge deck, with haunch build-up of 3 in., is assumed to be 7.5 and 9.5 in. thick for girder spacings of 6 and 12 ft, respectively.

The maximum strength of girder concrete is assumed to be 7 ksi at transfer of prestress and 9 ksi at service limit state. The 0.6-in.-diameter strands are jacked to 75% of the tensile strength.

The baseline designs use the most liberal provisions allowed by AASHTO LRFD; transformed section properties of strand and cast-in-place deck concrete, allowable tension in accordance with AASHTO LRFD Table 5.9.4.2.2-1, and full continuity for superimposed dead and live loads in accordance with AASHTO LRFD Section 5.14.1.4. Each of these policies is varied to investigate their sensitivity individually. The results are summarized in Table 1. The ranges indicated reflect girder depths from 36 to 100 in.

The results indicate that the design policy with the least impact on girder

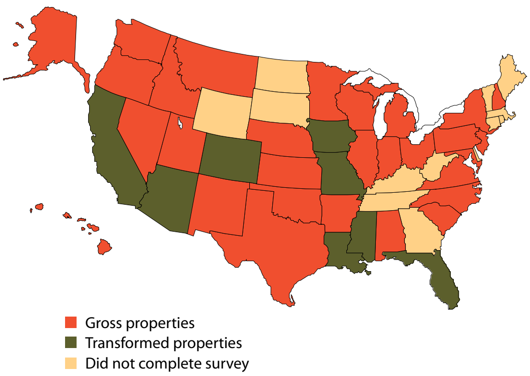

Figure 1. Survey results for section properties design policy. Drawing: PCI.

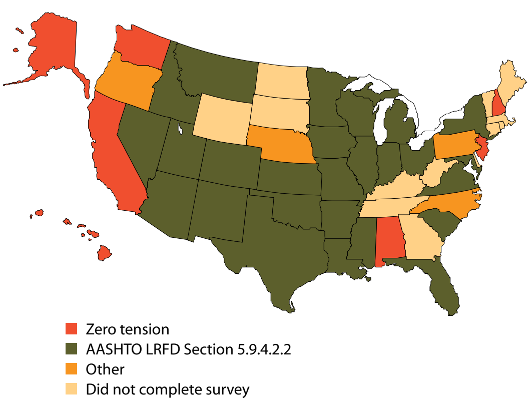

Figure 2. Survey results for allowable tensile stress design policy. Drawing: PCI.

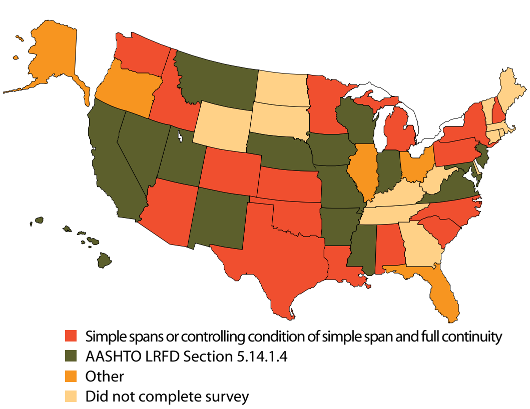

Figure 3. Survey results for continuity design policy. Drawing: PCI.

capability is the use of gross section properties. The allowable tension policy carries significantly more impact.

Combined Design Policies

Table 2 summarizes the results if all three conservative design policies are implemented relative to the baseline design. Again, the ranges indicated reflect girder depths of 36 to 100 in. In the case of the 6 ft spacing, the reduction in girder spacing becomes impractical as the spacing becomes narrower than the width of the girder top flange. In all cases, the increase in prestressing force requires concrete strengths at transfer in excess of 7 ksi.

Benefits of Conservative Design Policies

AASHTO LRFD recommends a minimum service life of 75 years for bridges. Conservative bridge design policies leave a margin of safety for unforeseen demands over the life of the structure. Supporting reasons for the conservative design policies include the following:

- **Historical increase in bridge live load:** AASHTO design live loads have been increasing over the past few decades from HS-15 to HS-20 to HS-25, and to HL-93 in 1994.
- **Increasing use of overload trucks:** Many permitted overload vehicles cross precast, prestressed concrete girder bridges, and often exceed the AASHTO LRFD-specified design live loads. The reserve capacity due to conservative design practices allows prestressed concrete girder bridges to withstand these vehicles. Commerce would be adversely affected if these overloads could not be safely and conveniently moved.
- **Increase in number of traveling lanes:** Lane widths on some routes have been reduced from 12 to 10 ft to accommodate more traffic lanes. Reserve capacity allows prestressed concrete girder bridges to accommodate increased traffic demand and conform to the minimum requirements specified by AASHTO LRFD without strengthening or other modifications.
- **Reserve capacity for girders damaged by over-height collisions:** Over-height load collisions with prestressed concrete girder bridges often result in broken strands. Prior to repairs, the reserve capacity of the undamaged girders helps to keep the bridge in service. Repairs by splicing and re-tensioning strands result in stress levels lower than the original design. Reserve capacity allows repaired prestressed concrete girders to satisfy minimum design requirements.
- **Uncracked concrete under service conditions:** The zero tension policy ensures that prestressed concrete girders remain uncracked for flexure under service load conditions, resulting in longer service life.
- **Reduced life-cycle cost:** The conservative design policies require more prestressing strands and possibly an additional line of girders, but result in longer service life and lower life-cycle cost.

Conclusion

This study shows the sensitivity of span capability, girder spacing, and prestressing requirements to three common owner adopted design policies. These policies are more stringent than the minimum requirements set forth in the AASHTO LRFD. As expected, the designs using the owner adopted policies result in a structure that is more robust than designs using the AASHTO minimum requirements.

Span capability is the least sensitive and girder spacing is the most sensitive to the design policies. Designing based on gross section properties in lieu of transformed section properties has the least overall influence. Reducing the allowable tension stress at the service III limit state has the greatest overall influence and has the greatest impact on girder spacing requirements.

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EDITOR'S NOTE

The full table of responses to the survey of design policies is available at www.aspirebridge.org. Click on Resources.