Prestressed Concrete Bridge Design Seminar

Session 3 – April 27, 2021

Design 3: Lateral Stability

PCI Mid-Atlantic
A Chapter of the Precast/Prestressed Concrete Institute

PCI Northeast
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Girder Stability – Lifting & Transport

Stability can be an issue for long girders
- "Long" is relative to section type
- Really an issue of slenderness and lateral stiffness rather than length

Site access can also be a factor
- Spliced girder over Shelby Creek in KY
- Access route had up to 11% cross slopes
- Up to 14% grade into site
- Good discussion in Sept.-Oct. 1992 issue of *PCI Journal*, including stability considerations

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Girder Stability – Lifting & Transport

PCI *Recommended Practice for Lateral Stability* and spreadsheet have been developed to evaluate stability of girders
- Spreadsheet and instruction manual are now available
- An errata has been published for the Recommended Practice (RP)
- An update to the RP is underway – but will probably be 2022 or later before it is completed
- To get the details on how to evaluate lateral stability with these resources, take the four PCI eLearning courses in the T520 series

Several approaches can be used to improve girder stability during handling and erection

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Girder Stability – Lifting & Transport

Moving lifting loops & temporary supports in from ends helps improve stability

- **But stresses should be checked with altered support locations**

Some DOTs specify a maximum distance from end of girder to lifting loops or devices on standard beam sheets or in specifications

- **Lifting at about 1.5 x depth of girder is generally good**
- **Specifying use of a fixed distance from the end, such as 3 ft, can lead to problems**

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Girder Stability – Lifting & Transport

Increase overhang over supports to improve stability during hauling

- **Need to consider stresses, but will have full f'_c by time of shipping**

Girders must be securely attached to truck

- **Several types of details are used**
- **Rigid connections between the girder and truck are assumed**



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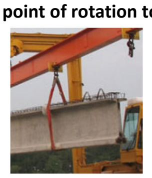
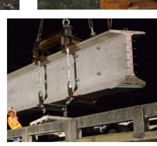
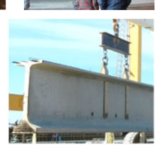
Girder Stability – Lifting & Transport

Rigid lifting devices raise the point of rotation to improve stability

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Girder Stability – Lifting & Transport

External stiffening frames have been used to improve stability

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Girder Stability – Lifting & Transport

Adding strands in the top flange have been used to improve stability

- **Top flange is less likely to crack, losing stiffness**
- **Improves stresses if lifting and support locations are moved from ends of girders**
- **Design using top strands and temporary top strands (debonded and detensioned) were discussed in an earlier presentation**

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Girder Stability – Lifting & Transport

In most states, designers are not assigned responsibility for considering lifting, handling, and transport

- **Girders are only designed to satisfy design requirements at transfer of prestress and in final conditions**

However, some girders, as designed and bid, cannot be safely handled and/or transported

- **Design must be modified to address high stresses or lateral stability**
- **For longer members, lifting loops are typically moved in from ends to address stability**
- **But then stress limits may be exceeded when lifting**
- **Design modifications after bid cause delays and increase costs**

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Girder Stability – Lifting & Transport

Recent revision to AASHTO LRFD Specifications addresses this issue

- **Adds mention of stability to Art. 5.5.4.3 and commentary**
- **Alerts designers to consider stability, but contractor still responsible**
- **Provides references for lateral stability analysis**

5.5.4.3—Stability

The structure as a whole and its components shall be designed to resist sliding, overturning, uplift, and buckling. Effects of eccentricity of loads shall be considered in the analysis and design.

Buckling and stability of precast members during handling, transportation, and erection shall be investigated.

C5.5.4.3

Stability during handling, transportation, and erection can govern the design of precast, prestressed girders. Precast members should be designed such that safe storage, handling, and erection can be accomplished by the contractor. This consideration does not make the designer responsible for the contractor's means and methods for construction, as discussed in Article 2.5.3.

Alert

Lateral bending stability analysis should be based on the "Recommended Practice for Lateral Stability of Precast, Prestressed Concrete Bridge Girders", Precast Concrete Institute, Publication CB-02-16-E. A detailed design example is presented in Seguirant, Brice, and Khaleghi (2009).

Refs

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Girder Stability – Lifting & Transport

AASHTO LRFD Art. C5.12.3.2 was also revised to address stability

- **Contractors are responsible for shipping and erection**
- **Text from Art. C5.5.4.3 is repeated stating that designers should consider preservice conditions as they may govern design**

5.12.3.2—Precast Beams

5.12.3.2.1—Preservice Conditions

The preservice conditions of prestressed girders for shipping and erection shall be the responsibility of the contractor.

C5.12.3.2.1

AASHTO LRFD Bridge Construction Specifications place the responsibility on the Contractor to provide adequate devices and methods for the safe storage, handling, erection, and temporary bracing of precast members. However, these preservice conditions may govern and should be considered in the design, as discussed in Article 2.5.3.

Added text

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Girder Stability – Lifting & Transport

AASHTO LRFD Art. 5.5.1.1 has been present in the LRFD since 1994

This article clearly indicates that designers are required to consider:

- **"stresses and deformations" for critical stages during "construction, stressing, handling, transportation, and erection"**

But how do designers know what to assume as they consider girder design at these stages, and lateral stability?

5.5—LIMIT STATES AND DESIGN METHODOLOGIES

5.5.1—General

5.5.1.1—Limit-State Applicability

Structural components shall be proportioned to satisfy the requirements at all appropriate service, fatigue, strength, and extreme event limit states at all stages during the life of the structure. Unless specified otherwise by the Owner, the load combinations and load factors specified in Section 3 and elsewhere in this section shall be used.

Prestressed concrete structural components shall be proportioned for stresses and deformations for each stage that may be critical during construction, stressing, handling, transportation, and erection as well as during the service life of the structure of which they are part.

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Girder Stability – Lifting & Transport

WSDOT has developed an excellent approach – a great example

- **WSDOT doesn't want fabricators to change a design to make it work**
- **So designers are required to consider handling and transportation**
  - **Designers check lifting and transportation using provided parameters**
  - **Design approach has become more complicated with new transport equipment**
- **References for WSDOT practice – *HIGHLY RECOMMENDED***
  - **Design example by Seguirant et al. in Fall 2009 issue of *PCI Journal (39 pp)***
  - **Owner's perspective by Brice in Winter 2018 issue of *ASPIRE***
  - **Procedures, assumptions, and responsibilities are clearly stated in WSDOT *Bridge Design Manual* Art. 5.6.3 & *Standard Specifications* Art. 6-02.3(25)LMN**
  - **Presentation by Brice for G/C PCI PCEF Meeting #25 on 8/13/20 – see PDF and supporting info at http://gcpci.org/index.cfm/technical/pcef**

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Girder Stability – Lifting & Transport

Another example is from SCDOT

- **SCDOT BDM Art. 5.5.2 Responsibilities**

15.5.2.1 Designer

The designer is responsible for choosing a cross section and providing a strand size and pattern to achieve the required allowable Service limit state stresses and factored flexural resistance. The designer is also responsible for a preliminary investigation of shipping and handling issues where larger or long beams are used or where unusual site access conditions are encountered.

15.5.2.2 Contractor

The Contractor is responsible for investigating stresses in the components during proposed handling, transportation, and erection.

- **As noted, contractor remains responsible for successful construction**
- **Preliminary evaluation is like an erection plan – a concept that will work**

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Girder Stability – Lifting & Transport

A final example is from GDOT B&SDM Art. 3.4.2.8

3.4.2.8 Beam Lengths

The maximum beam lengths for the PSC beams are:

- 50 feet for AASHTO Type I Mod. beams
- 65 feet for AASHTO Type II beams
- 85 feet for AASHTO Type III beams
- 125 feet for 54" Bulb Tee beams
- 135 feet for 63" Bulb Tee beams
- 150 feet for 72" and 74" Bulb Tee beams

AASHTO Type II beams are preferred for span lengths between 40 to 50 feet.

If the above maximum beam lengths are exceeded under an alternate bidding process, the engineer of record is responsible for performing a beam stability analysis.

Maximum beam lengths are based on stability considerations

- **Longer spans can be used for alt. bidding with analysis by EOR**

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Girder Stability – Summary

- Designers are using longer spans where lateral stability can be an issue
- Some designs may satisfy design requirements, but cannot be safely lifted or transported
  - Both stability limits and stresses may be exceeded
  - Design modifications are required
- Recent revisions to LRFD Specifications have clarified and expanded responsibilities of designers in these areas
- PCI and others have developed resources for performing analysis
- Owners should consider implementation of new requirements
  - Several examples were provided

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