Investigation on Cross-frame Behavior in Steel Girder Bridges

prepared by:

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Outline

• Motivation
  — Use of steel girder bridges in AL
• Background
  — Technical Challenges
  — Gaps between knowledge and practice
• Current Comprehensive Analysis for Steel Girder Bridges
  — NCHRP 12-79 Project (725 report)
• Research Goals & Program
• Next Steps

Motivation: Use in AL

Steel Girder Bridge is one of the most efficient, economical, and aesthetically pleasing design options for

— Long span
— Curved roadway
— Sharp Skew

Background: Challenges

• Curved geometry and skewed support cause
  — Differential deflection ($\delta_1 \neq \delta_2$)
  — Torsional rotation ($\theta \neq 0$)

• Difficult to predict the deflected geometry

Background: Recognized Concerns

• Lack of Proper Analysis Tools
  — 1980s~2006, the following tools have been developed based on multiple NCHRP projects
    • 1D Line Girder Analysis Method + V-Load Method
    • 2D Grid Analysis Method (DESCUS and MDX)
  — Results in more than 30% normalized error for skewed and curved steel girder bridges [NCHRP 12-79, 2012]
• Lack of Clear Guidance on Detailing
  — Multiple cross-frame fitting details are available
    • No load fit (NLF)
    • Steel dead load fit (SDLF)
    • Total dead load fit (TDLF)—ALDOT practice
  — But what are the potential impacts when using different detailing methods?
Gaps Between Knowledge and Practice

- Due to the lack of analysis tools, current structural analysis assumes:
  - Exactly plumb girders;
  - Zero flange lateral bending stresses;
  - Zero cross-frame locked-in stresses.
- But the potential concerns remain:
  - NLF detailing may produce undesired demand in bridge supports due to twist (i.e., layover) under dead loads, and leave a larger internal stress after the construction;
  - SDLF and TDLF detailing methods induces locked-in stress during erection due to the lack-of-fit between cross-frames and girders.

NCHRP 12-79 Project

- Report 725 published in 2012, based on the 3D FE analysis of a total of 58 I-girder bridges, it suggests to avoid TDLF with span length >200 ft and L/R >0.1.
- Report 725 contains the analysis of the following cases:
  - Out of the total 58 I-girder bridge cases, 16 are existing bridges that have been constructed (others are example bridges found in literature for parametric studies)
  - Out of the 16 existing bridges, 3 are continuous-span, curved I girder bridges with skewed supports (and L/R > 0.1)
    - 2 are detailed as NLF
    - 1 is detailed as TDLF—Alabama Galleria Bridge

Research Goals & Program

- Research Goals
  - Develop an accurate procedure to investigate the impact of cross-frame fit-up details on the behavior of the steel girder bridges.
  - Apply this procedure to characterize the behavior of existing ALDOT representative steel girder bridges.
- Research Program
  - Select representative ALDOT bridges
  - Conduct numerical analysis to investigate the impact of cross-frame fit-up details
  - Update the numerical analysis with experimentally validated cross-frame models
  - Reporting and conclusion

Research Tasks

- Task 1: Selection of Representative Bridges and Cross-frames
  - Factors: span length, deck width, curvature of the girder line, and skew of the supports;
  - Bridges with representative cross-frame designs (X- and K-frames).

- Task 2: Development of Analysis Procedure using 3D Finite Element Program
  - Model the cross-frames with the experimentally validated behavior;
  - Consider the following effects:
    - Geometric Nonlinearity
    - Residual Stress
    - Live and dead element (simulating possible loss of girder sections)

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Research Tasks

- Task 3: Experimental Study of Selected Cross-frames
  - NCHRP 12-79 applied truss element to model cross-frame members, which may have overestimated the cross frame stiffness [TxDOT, 2014]
  - Experimentally test the representative cross-frame designs to update the analysis in Task 2.

Research Tasks

- According to TxDOT research (@Utexas, 2014) on cross-frame, using truss element will overestimate the stiffness of cross-frame.

Research Tasks

- Truss Element Model

Research Tasks

- Shell Element Model
Research Tasks

- So far
  - Numerical tools have been developed
- What’s next
  - Complete the numerical analysis with representative bridges with NLF and TDLF;
  - Select critical cross-frames for experimental study;
  - Update the numerical analysis with experimentally validated cross-frame models.

Experimental Setup

Thank you!

If you have any inputs or comments, please send them to wsong@eng.ua.edu!

NCHRP 12-79 Project

- Based on the analysis of a total of 58 I-girder bridges, the NCHRP Project 12-79 has made the following recommendations:

  | Table 2 Recommend Fit Conditions for Straight I Girder Bridges (0.0 ≤ tan θ ≤ 0.05) |
  | --- | --- | --- |
  | Recommended | Acceptable | Avoid |
  | Any Span length | SDLF | TDLF | NLF |

  | Table 3 Recommend Fit Conditions for Curved I Girder Bridges (θ ≥ 0.03) |
  | --- | --- | --- |
  | Radial or Skewed Supports | Recommended | Acceptable | Avoid |
  | Span lengths ≥ 250 ft and 0 < θ ≤ 0.03 | NLF | SDLF | TDLF |
  | All other cases | SDLF | NLF | TDLF |

NCHRP 12-79 Project

- 2008-2012 by Dr. Donald W. White
- 3D FEA for 58 I-girder bridges + 18 tub-girder bridges
  - A (6% error) ~ F (30% error)
  - Errors are large for skewed and curved I-girder bridges