Improved Tub Girder Details
TxDOT Research Project 0-6862

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Background

• Tub girders are primarily used for bridges with longer horizontally curved spans
• Large torsional stiffness for finished bridge.
• Open section that requires extensive bracing during construction
• Aesthetically appealing (smooth profile)
Motivation

- Many commonly used details are relatively inefficient (Geometrical configuration and bracing layout)
- Changes in these details can provide improved efficiency and economy

Tub Girder during Construction (Courtesy: Hirschfeld Industries)
Objectives – Proposed Improved Details

1. Web Slope

- a) Typical web slope (current)
- b) Lower web slope (proposed)

**Benefit:** Potentially reduce number of girder lines

2. Top Flange Offset

- a) Centered Top Flanges (current)
- b) Offset Flanges (proposed)

**Benefits:** Eliminate gusset plates and improve bracing efficiency
Objectives – Proposed Improved Details

3. Top Lateral Truss Layout
   a) Truss along the entire span (current practice layout)
   b) Truss diagonals only in regions of high shear deformations (proposed layout)

4. Internal Cross Frame Layout
   a) K-frames at every panel point (current practice layout)
   b) K-frames located efficiently (other distributions)

(Mainly for straight or mildly curved girders)

(Straight and horizontally curved girders)
Research Methods

- Experimental study:
  - Laboratory tests of 3 steel tub girders
  - Elastic-buckling tests (on-going)
  - Ultimate strength capacity of composite girders (expected to start Jan 2018)

- Analytical study:
  - Validation of Finite Element (FE) models (on-going)
  - Parametric FE Analyses (expected to start Jan 2018)
Experimental Study – Specimens

- **General features:**
  - Sized to remain elastic
  - 86 ft. long and 3 ft. tall (L/D=28)
  - Straight tub girders

- **Top lateral bracing:**
  - Single-diagonal type (SD-type)
  - Top diagonals directly connected to top flanges (no gusset plates)
Experimental Study – Specimens

1) Standard Section (Base Line)

2) Offset Flange Section
3) Lower Slope Section
Experimental Study – Specimens

1) Standard Section
2) Offset Flange Section
3) Lower Slope Section

86 ft. Girder lengths (84 ft. clear span)
Experimental Study – Loading Scenarios

Vertical loads:
• *Concentric* and *eccentric* vertical loads to simulate respective demands of only bending, and combined bending with torsion

Lateral loads:
• Lateral loads to simulate lateral bending combined with torsion
Experimental Study – Elastic Buckling Test Setup

3D View

Steel Tub Girder (L=86’)

South Support

2 Gravity Load Simulators

North Support
Experimental Study – Elastic Buckling Test Setup
Experimental Study – Elastic Buckling Tests

- Vertical loads applied with 2 Gravity Load Simulators (GLS):
  - *Concentric loads* to simulate *Bending (only)*
  - *Eccentric loads* to simulate *Bending + Torsion (horizontal curvature)*
    - $e = 8”$ (R $\approx 1200$ ft.)
    - $e = 16”$ (R $\approx 600$ ft.)
Experimental Study – Elastic Buckling Tests
Experimental Study – Elastic Buckling Tests

Eccentric Load Cases

\[ (1 - \alpha)P \]

\[ \text{Loading beam} \]

\[ \text{Actuator} \]

\[ \text{GLS} \]

\[ \text{Support} \]

Bending

\[ \frac{P}{2} \]

\[ \frac{P}{2} \]

Torsion

\[ \frac{Pe}{b} \]

\[ \frac{Pe}{b} \]
Experimental Study – Elastic Buckling Tests

GLS concentric
GLS eccentricity=8"
GLS eccentricity=16"
Experimental Study – Elastic Buckling Tests

Partial Top Lateral Bracing (TLB) (4 config.)

- 3 diagonals @ each end
- 2 diagonals @ each end
- 1 diagonal @ each end
- No diagonals

Plan View
Experimental Study – Elastic Buckling Tests

Partial Top Lateral Bracing Layouts

No Top Lateral Bracing

Partial Top Lateral Bracing
Experimental Study – Elastic Buckling Tests

Internal K-frames Bracing Layout

- 3 different configurations:
  - Every 2 panel points
- Every 4 panel points
- Every 6 panel points
Experimental Study – Elastic Buckling Tests

Internal K-frames Bracing Layout

Every 2 panel points

Every 4 panel points

Every 6 panel points
Experimental Study – Elastic Buckling Tests

Test Program

- Test each tub girder with all configurations and eccentricities
- Total 36 elastic-buckling tests per tub girder

Elastic Buckling Test (LTB response)
Experimental Study – Lateral Bending Test Setup

Steel Tub Girder (L=86’)

North Support

South Support

Reaction Columns

3D View
Experimental Study – Lateral Bending Tests
Experimental Study – Lateral Bending Tests

Loading points at reaction column

Lateral load setup
Experimental Study – Lateral Bending Tests

Lateral Test (warping on top flange)
Experimental Study – Current Status

- Elastic buckling tests:
  - Tub girder #1 – COMPLETED
  - Tub girder #2 – COMPLETED
  - Tub girder #3 – ON-GOING

- Lateral bending tests:
  - Tub girder #1 – COMPLETED
  - Tub girder #2 – COMPLETED
  - Tub girder #3 – COMPLETED

- Ultimate Capacity Tests – To start on January 2018

Tub girder #1 = Standard
Tub girder #2 = Offset flange
Tub girder #3 = Lower slope
Experimental Study – Sample Results
Experimental Study – Lateral Bending Tests

- Standard tub girder with different top lateral bracing amount
- K-frames every 2 panels
- By adding diagonals at the end of the specimen the capacity to avoid LTB improves

Mid-span Twist Angle versus Total Load (Standard tub girder)
Experimental Study – Elastic Buckling Tests

- Standard tub girder with different top lateral bracing amount
- K-frames every 2 panels
- Eccentric case, e=16"

Mid-span Twist Angle versus Total Load *(Standard tub girder)*
Experimental Study – Elastic Buckling Tests

- Standard tub girder with different K-frame layout
- No top lateral bracing

Mid-span Twist Angle versus Total Load (Standard)
Experimental Study – Preliminary Results

- The specimens without top lateral bracing showed an elastic lateral torsional (LTB) buckling response.
- Amount of top lateral bracing had significant impact in the torsional stiffness of the specimens.
- Adding two top lateral diagonals at each end of the specimen produced most of the improvement in torsional stiffness.
- Partial top lateral bracing maybe a suitable alternative for straight and mildly horizontally curved bridges.
- K-frame bracing, and its configuration did not contribute to control LTB.
Analytical Study

- Validation of Finite Element models
  - FE models created in ABAQUS (FE software)
  - Validation of FE models with experimental results (on-going)

- Parametric study: (to start on January 2018)
  - Understand the impact of the proposed improved details on the fundamental behavior of steel tub girders
  - Parameters to consider (not limited to):
    - Girder proportions
    - Support and loading conditions
    - Bracing layout
Analytical Study – FE Models Validation (Example)

Validation of lateral displacements (*Standard tub girder*)
Analytical Study – FE Models Validation (Example)

Validation of bracing axial forces *(Standard tub girder)*
Analytical Study – Current Status

- Validation of FE models:
  - Tub girder #1 – COMPLETED
  - Tub girder #2 – COMPLETED
  - Tub girder #3 – ON-GOING

- Parametric study:
  - To start on January 2018
Upcoming Work & Final Product

- Conclude experimental work.
- Conclude validation of FE models.
- Perform extensive parametric study with the validated FE models.
- Analyze the potential application of the proposed details and their limitations
- Develop design methodology for proposed details:
  - Based on experimental tests and parametric study
  - Develop design examples for application of proposed details
Acknowledgement

- Texas Department of Transportation
- Hirschfeld Industries
UT Bridge V2.2

Plate girders

Tub girders
Erection sequence:
Deck placement sequence:
THANK YOU