Engineering for Stability in the Construction of Bridge Superstructures

AASHTO Subcommittee on Bridges and Structures Committee T-5 Loads

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Problem

- It is unacceptable for bridges to collapse at any time
- Such events (and near misses) are too common during erection and/or demolition
- The majority of engineering effort in projects is being placed in design rather than construction
- There is a general lack of criteria and guidance
- Global stability is a complicated issue
Solution

- FHWA has initiated effort to develop comprehensive manual and training course
- Product will attempt to provide
  - Summary of lessons learned
  - Understanding and analysis of global stability
  - Design criteria for erection
  - Guidance and best practices
  - Design examples
Related References and Activities

- AASHTO Guide Specs for Temp Works
- NCHRP 20-07 Task 245 “Update on Design and Construction Standards for Temp Works Used in Bridge Construction”
- NCHRP 725 “Guidelines for Analysis Methods and Construction Engineering of Curved and Skewed Steel Girder Bridges”
- TRB, ACI, ASCE, NSBA, PCI Committees
Challenges

- Filling gaps in AASHTO LRFD BDS
  - Girders with large lateral bending
- Criteria: loads, load factors, and combinations
  - Wind loads during construction
  - $\phi, \gamma$ for stability verification
  - Deflection control?
- ASD vs. LRFD conflicts
Proposed Manual Contents

- Introduction
- Failure Case Studies
- Typical Bridge Construction Practices
- Stability Fundamentals
- Global/System Stability
- Analysis for Stability
- Design Criteria
- Erection Plans
- Complex Bridge Construction
- Examples
Wind Loads

- AASHTO
  - 300 PLF

- ASCE 7-10
  - $F = 0.00256 \cdot k_z \cdot k_{zt} \cdot k_d \cdot G \cdot C_f \cdot A \cdot V^2$
  - Load factor in velocity

- ASCE 37 Reduction Factors
Wind

- One day, design velocity = 20 mph
- Velocity modification factors (Vmod=FV)

<table>
<thead>
<tr>
<th>Duration</th>
<th>Factor</th>
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</thead>
<tbody>
<tr>
<td>0 – 6 weeks</td>
<td>0.65</td>
</tr>
<tr>
<td>6 weeks – 1 year</td>
<td>0.75</td>
</tr>
<tr>
<td>1 year – 2 years</td>
<td>0.8</td>
</tr>
<tr>
<td>2 years – 5 years</td>
<td>0.85</td>
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</tbody>
</table>
ASCE 7-10

Chapter 29—Wind Loads on Other Structures and Building Appurtenances

Risk Category II

115 mph typical except coastal
Wind Distribution—Open Structure

- "Wind Effects on Structures" (3rd edition); Simiu and Scanlan
- British Standard 5400 (Loads); Vol. 1, Sec. 3, Part 14
- FDOT Standards
Wind Distribution—Open Structure

- $C_f = 2.2$ (min)
- $C_f = 2(1 + 0.05 \frac{s}{d}) \leq 4.0$
Construction Considerations—Wind

- ASCE 3-second gust
  - Fastest-mile/1-minute average x 1.25
  - Mean-hourly x 1.55
- Design limits on erection drawings
- Contingency measures provided
## Live Loads

- Workers and light tools: 20 psf
- Overhang: 75 plf
- Add if motorized buggies: 25 psf
- Screed: Manufacturer
- Other: Manufacturer
- Materials: Actual wt.
## Load Factors

<table>
<thead>
<tr>
<th>Load Combinations and Load Factors</th>
<th>DC</th>
<th>$C_{DL}$</th>
<th>$C_{LL}$</th>
<th>$C_{W}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strength I</td>
<td>1.25</td>
<td>1.25</td>
<td>1.5</td>
<td>—</td>
</tr>
<tr>
<td>Strength III</td>
<td>1.25</td>
<td>1.25</td>
<td>—</td>
<td>1.0</td>
</tr>
<tr>
<td>Strength VI</td>
<td>1.40</td>
<td>1.40</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Service</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>0.7</td>
</tr>
<tr>
<td>Uplift</td>
<td>0.90/1.35</td>
<td>0.90/1.35</td>
<td>—</td>
<td>1.0</td>
</tr>
</tbody>
</table>

$C_{W}$: for appropriate duration  
$C_{LL}$: include dynamic effects
Seismic—Owner Requirements
Dynamic Load Allowance

- 1.1 (min) on equipment on structure
- Crane loads
  - 1.0 lifting
  - 1.2 lifting (demolition)
- Incidental load
- Accidental release
Erection Stages to Check

- Girder lifting
- Single girder erected
- “Paired” girders erected
- Deck placement (if altered from contract plans)
  - Overhang
General Plan and Elevation
Framing Plan
Wind Load:

Use Figure 26.5-1A in ASCE 7-10 to determine basic wind speed for Risk Category II.

\[ V := 115 \text{ miles per hour} \]

Use ASCE 37-02 Section 6.2.1 to determine design wind speed reduction based on construction duration.

Assume 6 weeks to 1 year as duration for steel erection and deck pour.

\[ \text{Fact} := 0.75 \]

Design Wind Speed

\[ \text{DWS} := \text{Fact} \cdot V \]

\[ \text{DWS} = 86.2 \text{ mph} \]

Incorporate modified Design Wind Speed into ASCE 7-10 equations
Velocity Pressure Exposure Coefficient  

(ASCE 7-10, Sect 29.3.1)

Assume Surface Roughness C - Open terrain with scattered obstructions having heights generally less than 30 feet. Therefore, Exposure Category C

Table 29.3-1, for Height = 30 feet, \(K_z = 0.98\). Say \(K_z = 1.0\).

Take wind directionality factor as 0.85 and topographic factor as 1.0.

\[K_z := 1 \quad K_{zt} := 1 \quad K_d := 0.85\]

Velocity Pressure  

(ASCE 7-10, Eq. 29.3.1)

\[q_z := 0.00256 \cdot K_z \cdot K_{zt} \cdot K_d \cdot D W S^2\]

\[q_z = 16.2 \quad \text{psf}\]

Gust Effect Factor

\[G := 0.85\]

Net Force Coefficient

\[C_f := 2.2\]

since ratio of girder spacing to depth, \(S/d < 2\)
Net Pressure

\[ Q_z := G \cdot C_f \cdot q_z \quad Q_z = 30.3 \text{ psf} \]

One Day (Girder Setting) Design Wind Speed

\[ V := 20 \text{ mph} \]

Use 1.0 construction period Factor

\[ \text{Fact} := 1.0 \]

Design Wind Speed:

\[ DWS := \text{Fact} \cdot V \quad DWS = 20 \text{ mph} \]
One Day Girder Setting Velocity Pressure (ASCE 7-10, Eq. 29.3.1)

\[ q_{z_{set}} := 0.00256 \cdot K_z \cdot K_{zt} \cdot K_d \cdot DWS^2 \]

\[ q_{z_{set}} = 0.9 \text{ psf} \]

One Day Girder Setting Net Pressure

\[ Q_{z_{set}} := G \cdot C_f \cdot q_{z_{set}} \]

\[ Q_{z_{set}} = 1.6 \text{ psf} \]

1.6 psf is negligible and can be ignored for short-duration events like girder picks which would not be occurring unless the wind is minimal anyway. However, use 5 psf as a minimum pressure for stability checks for pieces that are already set to account for accidental loading, etc.

\[ Q_{z_{set}} := 5 \text{ psf} \]
Wind Forces on Girders:

Exposed height for girder group = 5.33 feet (worst-case) + 24'-7" bridge width * 5% cross-slope

\[ h := 5.33 + 24.58 \cdot 0.05 \quad \text{h} = 6.56 \]

Exposed height for single girder being set = 5.33 feet (worst case) \[ h_{set} := 5.33 \]

Force to first girder

\[ P_1 := Q_z \cdot h \quad P_1 = 198.5 \quad \text{lb/ft} \]

Force to 1 girder during setting (one day)

\[ P_{set} := Q_{z\text{set}} \cdot h_{set} \quad P_{set} = 26.6 \quad \text{lb/ft} \]
Wind Forces on Girders, continued:

198.5 lb/ft

Wind Load to Girders

26.6 lb/ft

Wind Load to 1st Girder During Setting (One Day)
For the purpose of this example, 4 erection stages will be analyzed for forces in the girders:

Case 1: One girder set, Span 1 segment and Pier segment with cantilever into Span 2 up to field splice.
Case 2: Two girder set, Span 1 segment and Pier segment with cantilever into Span 2 up to field splice.
Case 3: Six girder set, Span 1 segment and Pier segment with cantilever into Span 2 up to field splice.
Case 4: All Span 1, Span 2, and Pier segments set.
Case 2
Case 3
Case 4
## Erection Analysis Output Summary

<table>
<thead>
<tr>
<th>CASE</th>
<th>SEGMENT</th>
<th>$M_x$ (k*ft)</th>
<th>$M_y$ (k*ft)</th>
<th>P (k)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Span</td>
<td>772</td>
<td>76</td>
<td>0</td>
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<tr>
<td></td>
<td>Pier</td>
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<tr>
<td>2</td>
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<tr>
<td></td>
<td>Pier</td>
<td>-1430</td>
<td>114</td>
<td>11</td>
</tr>
</tbody>
</table>

Strength III: 1.25 DC + 1.0 CW
Questions