Bridge Stability – An Overview of Critical Items and Checks

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Overview of Critical Stability Items

• Beams being fabricated and transported
• Beams being lifted
• Stability of partial in-place systems
• Other load effects
  • Overhang bracket concerns
  • Deck casting
• Specification requirements
  • Concrete bridges
  • Steel bridges
  • New(ish) developments in stability
Function of Bracing During Erection

- Provide stability
  - Strength ... more on this later
  - Stiffness ... more on this later
- Control geometry
- Primary load element for curved and skewed bridges
Girder Bracing During Installation

- Commonly only several lines of bracing are placed during erection.
- This photo shows most if not all bracing finally installed.
Bracing at Girder Support

- External stability of a system is essential
- Beams not only need to be connected to themselves but to the “outside world”
Bracing at Girder Support
Steel Girder Stability During Erection Stages

- Lifting
- Initial girder set
- First girder pair placed
- Subsequent girders placed
- Full girder and bracing installed
Setting Girder with Bracing Attached
Single Girder Pick and Set

- Stability of systems evolves through the life of the construction process

- What’s most critical?
  - 1<2<3<4 seems obvious
  - What about 1 vs 5?
  - Need to check a few possible controlling cases
Optimal Lifting Arrangement

• Girders are most stable with overhangs of between 20–30% of the total lifted length

• You can't use traditional LTB equations for this system. It is totally unbraced

• Nothing in AISC / AASHTO will help you out of this jamb
Setting Girder Pairs

- Setting in pairs
  - Stability is enhanced 😊
  - Weight is doubled 😞
Concrete Girder Stability During Erection Stages
Concrete Girder Stability During Erection Stages

Perspective of a beam free to roll and deflect laterally.

Center of gravity of the curved beam arc lies directly beneath the roll axis.
Roll Stability of Concrete Girders

- Initial lateral eccentricity, $e_i$, should include at minimum:
  - 1” accidental bearing misalignment
  - PCI sweep tolerance of 1/8” per 10’ of girder length
  - Offset factor on sweep = $(\ell_1/\ell)^2 - 1/3$
    - See figure — also used for center of mass of cambered girder

OFFSET OF CENTROID OF A PARABOLIC ARC

PARABOLIC ARC

OFFSET AXIS

Offset factor simplifies to $2/3$ for girders without overhangs
Temporary Bracing Measures Employed During Bridge Erection
Tension Constraint Temporary Bracing

- Secure against movement/slip as erection progresses and monitor daily.
- Hook, softener, load binder (6,000# working load min.), 1/2" plate fastened to brg. anchor bolts.
- 3" Ø steel pipe.
- Secure against movement/slip as erection progresses and monitor daily.
- Pier cap or abutment.
Girder Temporary Cable Bracing
Concrete Girder Temporary Bracing

BRACE MEMBER (TYP.)

T

T

FACE OF PIER OR ABUTMENT (TYP.)

BRACE MEMBER (TYP.)

T&C

T&C

BRACE MEMBER

T : TENSION BRACE
C : COMPRESSION BRACE
Concrete Girder Rod Bracing to Pier
Concrete Girder Tensioning
Compression Brace

*Note: Secure against movement/slip as erection progresses and monitor daily.
Temporary Brace at Exterior Girders
Concrete Girders X-Bracing
Multi-Rotational Bearing
Guided Bearing Restraint
Phased Construction Lateral Brace

1/2" EXTENSION PLATE WELDED TO L6 x 6

L6 x 6x 1/2 x 24"

2 - 7/8" DIA. HS BOLTS

8"

6"

L5 x 5 x 1/2"

FILL PLATE

L6 x 6x 1/2 x 12"

6 x 6 x 1/2" CLAMP P w/ 3/4" DIA. HS BOLT

2 - 3/4" DIA. A36 THREADED ROD THRU BOLT, NUTS & WASHERS T & B

GIRDER BEING ERECTED

EXIST. DECK

EXIST. GIRDER
Temporary Lean-on Brace
Lean-on Bracing ... Sidebar

• Hot off the presses from NSBA
• Design guide for use of lean on bracing in permanent structures
• Provides significant economy in completed bridges
Hold-down Using a Member Supported on Bottom Flanges
Deck Concrete Placement
Overhang Brackets on Box Girder
Typical Bracket for Steel Girder

Source of flange lateral bending moments
Overhang Bracket on Concrete Girder
Overhang Bracket Bracing Examples

OVERHANG BRACING - CONCRETE

OVERHANG BRACING - STEEL
System / Global Buckling Effects

Guidance for Designers
Global Buckling Capacity in Steel Girder Systems
System (Global) Buckling Mode

• What is the system buckling mode and how does this mode differ from conventional LTB?
Global Buckling of Narrow Steel Units

• Designer uses unbraced length $L_b$ for girder buckling
  • $L_b =$ distance between cross-frames
  • Cross-frame locations are brace points (more on this later)

• Girder systems with large length-to-width ratio
  • Susceptible to system mode of buckling
  • Spacing of cross-frames does not impact behavior significantly in system mode
History of Global (System) Buckling

- Girder had closely spaced internal K-frames (behaved very similar to a twin I-girder system)

Girder failed due to buckling
History of Global (System) Buckling

Contractor concerns about excessive lateral flexibility

3 Span Continuous Girders (135.5’-184.7’-203.9’)

3 Span Continuous Girders (135.5’-184.7’-203.9’)

Contractor concerns about excessive lateral flexibility
Global Buckling of Narrow Steel Units

- For a twin-girder system: $L_b$ vs. $L_g$
  - Bracing spacing controls individual girder lateral-torsional buckling
  - Bracing size and spacing doesn’t control system buckling
Global Buckling of Narrow Steel Units

Global Buckling
\( M_{cr} = 792 \text{ k-ft} \)

Buckling Between Cross-Frames
\( M_{cr} = 1384 \text{ k-ft} \)
System Buckling for 2 and 3 Girder Systems

AASHTO Eqn. 6.10.3.4.2-1:

\[ M_{gs} = C_{bs} \frac{\pi^2 w_g E}{L^2} \sqrt{I_{eff} I_x} \]

• Where:
  • \( M_{gs} \) = nominal buckling resistance of the girder system (k-in)
  • \( w_g \) = spacing of twin girders (in) or for 3 girder system use spacing between the two exterior girders
  • \( E \) = modulus of elasticity of steel girder (ksi)
  • \( L \) = length of span under consideration (in)
System Buckling for 2 and 3 Girder Systems

- Where:
  - $C_{bs}$ = system moment gradient modifier
    - $= 1.1$ for simply-supported units
    - $= 2.0$ for continuous-span units
  - $I_x$ = Non-composite single girder strong-axis moment of inertia
  - For non-prismatic girder properties — AASHTO recommends a length-weighted average for $I_x$, and $I_{eff}$. 
Effective Moment of Inertia

\[ I_{eff} = I_{yc} + (t/c)I_{yt} \]
Global Buckling of Narrow Steel Units

• Considering all of the girders across the width of the unit within the span, the sum of the largest total factored moments during deck placement should not exceed 70% of $M_{gs}$.

• Alternatives:
  • Add flange level lateral bracing
  • Revise the unit to increase system stiffness
  • Evaluate the amplified girder second-order displacements and verify they are within Owner-specified tolerances
  • Amplification can also occur under steel-only dead load as the buckling limit is approached
Roll Stability of Concrete Girders
Rollover Causes

• Initial girder rotation compounded by:
  • Lack of flatness of PPC bottom flange
  • Roll flexibility of bearings...
  • Leading to increased girder rotation

Note: Figure adapted from Mast (1993)
Red Mountain Freeway Bridge Collapse, 2007
Roll Stability of Concrete Girders

- Precast concrete girders during erection (after setting)
  - Simply supported condition (span = bearing-to-bearing)
  - Deck not poured yet (erection in progress)
  - No continuous lateral support from deck slab
  - Elastomeric bearings allow rotation about both axes
Roll Stability Influences

• Bearing slope and bearing type
• Bearing skew relative to girder centerline
• Girder imperfections
• Rollover controls stability, not lateral-torsional buckling
  • PPC girders do not crack under self-weight
  • Relatively large $I_y$ and $J$: no LTB
P-\(\Delta\) Effect

• Rotation (imperfection) causes:
  • Component of girder weight to be...
  • Applied about weak axis of girder, which...
  • Causes lateral deflection and...
  • Further shifts girder center-of-gravity, which...
  • Causes further lateral deflection
Simply-Supported Girder Rollover

- Determined primarily by support properties
- Elastomeric bearing pads
  - Rotational stiffness constant $K\theta$ (from pad’s vertical stiffness)
  - Girder camber and roll effects create...
  - Uneven load distribution to bearing pad, which...
  - Reduces its stiffness (similar results from skew)
Support Properties

• For bearing pads set at skew to girder
  • Additional uneven load distribution in pad...
  • Further reduces its effective stiffness
  • Bearing stiffness modification factor accounts for skew (suggested values from FDOT):

<table>
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<th>Skew Angle (°)</th>
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<th>15</th>
<th>30</th>
<th>45</th>
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<tbody>
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<td>0.40</td>
<td>0.32</td>
<td>0.26</td>
<td>0.21</td>
</tr>
</tbody>
</table>

• Bearing pad stiffness not linear with load
  • Pad less stiff under girder self-weight than...
  • Normal service load combination (full dead + live)
Concrete Girder Stability During Erection Stages

- LRFD 5.5.4.3 “Buckling and stability of precast members during handling, transportation, and erection shall be investigated”
- C5.5.4.3 “This consideration does not make the designer responsible..., means and methods.” See PCI “Recommended Practice for Lateral Stability of Precast Prestressed Concrete Girders”
PCI Recommended Practices
Referenced by AASHTO as a guide for this issue
Girder Lifting
Roll Deformations

Perspective View of a Hanging Girder

Center of Mass of Deformed Girder Arc Lies Directly Beneath Roll Axis
Statics of Hanging Beams
Transportation Stability
Transportation Stability
Seated Girder Stability
Technical Basis for Bracing Requirements
Requirements for Bracing Systems

• Bracing plays a major role in the stability of the structural system.

• Effective bracing must satisfy both strength and stiffness to have a safe system.

• Provisions outlined in the following slides allow engineers to verify the adequacy of the bracing.
Simple Stability Bracing System

• Consider the following Simple System

\[ F = \beta \Delta \]

Summing moments about base

Equilibrium in displaced position:

\[ P\Delta - (\beta \Delta)L = 0 \]
\[ P\Delta = (\beta \Delta)L \]

\[ \beta \Delta L > P\Delta \quad \text{no sidesway} \]
\[ \beta \Delta L < P\Delta \quad \text{sidesway} \]
\[ \beta L = P_{cr} \]
Ideal Brace Stiffness

\[ \beta_i = \frac{P_E}{L} \]

\[ P_{cr} = PE = \frac{\pi^2 EI}{L^2} \]

\[ K > 1.0 \quad K = 1.0 \]
Real Columns — Brace Stiffness

Equilibrium:
\[ P\Delta_T = (\beta \Delta)L = \beta L(\Delta_T - \Delta_o) \]

\[ \Delta_T = \frac{\Delta_o}{1 - \frac{P}{\beta L}} \]

If \( \beta = \beta_i = PE/L \):

\[ \Delta_T = \frac{\Delta_o}{1 - \frac{P}{PE}} \]

If \( \beta = 2\beta_i = 2PE/L \):

\[ \Delta_T = \frac{\Delta_o}{1 - \frac{P}{2PE}} \]
Real Columns — Brace Stiffness

\[ \Delta = \Delta_0 \]

\[ \beta = \beta_i = \frac{P_E}{L} \]

\[ P_E = \frac{\pi^2 EI}{L^2} \]
Real Columns — Brace Strength

\[ F_{br} = \beta \left( \frac{\Delta_o}{P} - \Delta_o \right) = \beta \Delta_o \left( \frac{P}{\beta L} \right) \left( 1 - \frac{P}{\beta L} \right) \]

For \( \Delta_o = 0.002L \):

\[ \frac{F_{br}}{P} = \left( \frac{0.002}{1 - \frac{P}{\beta L}} \right) \]

If \( \beta = \beta_i = PE/L \):

\[ \frac{F_{br}}{P} = \left( \frac{0.002}{1 - \frac{P}{PE}} \right) \]

If \( \beta = 2\beta_i = 2PE/L \):

\[ \frac{F_{br}}{P} = \left( \frac{0.002}{1 - \frac{2P}{2PE}} \right) \]

\[ F_{br} = 0.004P \text{ at } P = PE \]
Torsional Bracing of Beams

The fundamental concept with torsional bracing is:

The beam or girder is fully braced at a location if twist is prevented.

**Stiffness requirement**

\[(\beta_T)_{act} \geq (\beta_T)_{req}\]
Torsional Stability Bracing Requirements

**Stiffness requirement**

\[(\beta_T)_{act} \geq (\beta_T)_{req}\]

- Actual (provided by the brace) > Required (to stabilize a beam to carry a certain moment, for a given span, and with certain section properties)
AISC Provisions — Required Stiffness

• AISC Bracing Provisions: Stiffness Requirements for Nodal Torsional Bracing — Equation A-6-11a:

\[ L = \text{Span of beam/girder} \]
\[ M_u = \text{Maximum factored moment w/in unbraced length } L_b \]
\[ \phi_{br} = \text{Bracing stiffness resistance factor} = 0.80 \]
\[ n = \text{Number of intermediate bracing lines} \]
\[ C_b = \text{Moment gradient factor} \]
\[ E = \text{Modulus of elasticity of beam} \]
\[ I_{ye} = \text{Effective moment of inertia (see next slide)} \]

\[ \beta_T = \frac{2.4LM_u^2}{\phi_{br}nC_b^2EI_{ye}^{eff}} \]
Stability bracing of beams is significantly impacted by the size of the compression flange. Since bridge girders often consist of singly-symmetric sections, $I_{yeff}$ accounts for the compression flange size versus the tension flange size:

$$I_{yeff} = I_{yc} + \frac{t}{c}I_{yt}$$

Note: $I_{yeff} = I_y$ for doubly symmetric shape
What About Provided Stiffness

• We have a springs-in-series problem
  • Crossframes have flexibility
  • They connect to connection plates which MAY have flexibility
  • They connect to girders which can deflect and rotate and thus have flexibility
Total Bracing Stiffness

- Actual torsional bracing stiffness of the entire system:

\[
(\beta_T)_{act} = \frac{1}{\left(\frac{1}{\beta_b} + \frac{1}{\beta_{sec}} + \frac{1}{\beta_g}\right)}
\]

\( (\beta_T)_{act} \) = Total system stiffness
\( \beta_b \) = Stiffness of cross-frame or diaphragm
\( \beta_{sec} \) = Cross-sectional stiffness (web and connection plate)
\( \beta_g \) = In-plane stiffness of the girder system

**Springs in series**

\[
\frac{1}{k_{total}} = \frac{1}{k_1 + \frac{1}{k_2 + \frac{1}{k_3}}}
\]
Cross-frame Types

- Tension-Only Diagonal System
- Compression Diagonal System
- K-Brace System
- Solid diaphragms
Component of Provided Stiffness — Bracing Stiffness, $\beta_b$
Tension-Only Diagonal System

**X-Frame: Tension-Only Diagonal System**

- $F_{br} = M_{br}/h_b$
- $M_{br}/2Fh_b/S$
- $2Fh_b/S$
- $L_d$
- $S$
- $h_b$
- $-F_{br}$
- $+2F_{br}L_d/S$
- $M_{br}$

*Image of a diagram showing forces and moments in a tension-only diagonal system.*
**Tension-Only Diagonal System**

\[
\beta_b = \frac{ES^2h_b^2}{2L_c^3} + \frac{S^3h_b}{A_c} + \frac{S^3}{A_h}
\]

- \( E \) = Modulus of elasticity (ksi)
- \( L_c \) = Length of diagonal (in)
- \( h_b \) = Height of brace system (in)
- \( A_c \) = Area of diagonal member(s) (in)
- \( A_h \) = Area of horizontal member(s) (in)
- \( S \) = Spacing of girders (in)
Compression Diagonal System

X-Frame: Compression Diagonal System

\[ F_{br} \]
\[ 2Fh_b/S \]
\[ -F_{br}L_d/S \]
\[ +F_{br}L_d/S \]
\[ L_d \]
\[ 0 \]
\[ 0 \]

\[ F_{br} \]
\[ F_{br} \]
\[ 2Fh_b/S \]
Compression Diagonal System

$$\beta_b = \frac{A_c E S^2 h_b^2}{L_c^3}$$

- $E$ = Modulus of elasticity (ksi)
- $L_c$ = Length of diagonal (in)
- $A_c$ = Area of diagonal member(s) (in)
- $h_b$ = Height of brace system (in)
- $S$ = Spacing of girders (in)
K-Brace System

K-Frame

\[ F_{br} \]

\[ 2Fh_b/S \]

\[ 2Fh_b/L_d/S \]

\[ +F_{br} \]

\[ -F_{br} \]

\[ 0 \]

\[ +2F_{br}L_d/S \]

\[ L_d \]

\[ 2Fh_b/L_d/S \]

\[ F_{br} \]

\[ F_{br} \]
Diaphragm/Deck or Through Girders
Component of Provided Stiffness – Cross-sectional Distortion, $\beta_{sec}$

- Cross-Sectional Distortion: depending on the region of the web outside of the depth of the brace, cross-sectional distortion can be significant.
Component of Provided Stiffness – In-plane Girder Stiffeners, $\beta_g$

\[
\frac{2M_{br}}{S} \quad S \quad \frac{2M_{br}}{S}
\]
In-plane girder stiffness, \((\beta_g)\)

\(\beta_g\) is a function of the stiffness of the individual girders as well as the number of girders across the width of the bridge:

\[
\beta_g = \frac{N_g S^2 EI_x}{L^3}
\]

\(N_g = \frac{24(n_g - 1)^2}{n_g}\)

\(I_x\) = in-plane moment of inertia of girders

\(n_g\) = number of girders across the width of the bridge that are interconnected by the braces.
REMINDER – Torsional Stability Bracing Requirements

Stiffness requirement

\[(\beta_T)_{act} \geq (\beta_T)_{req}\]

• As with column bracing, the ideal stiffness is not sufficient. A greater value, 2x the ideal stiffness, is the basis of the AISC design provisions.

\[(\beta_T)_{req} = \frac{2.4LM_u^2}{\phi_{br}nC_b^2EI_{yeff}}\]
AASHTO LRFD Upcoming 10th Edition
Bracing Design Provisions
AASHTO Provisions

• 6.7.4.2 Diaphragm/Cross-frames
  • Rolled beams - at least 0.5 x member depth
  • Plate girder – at least 0.75 x member depth
  • Curved bridge cross-frames - contain diagonals and top and bottom chords.

• AASHTO strength / stiffness bracing provisions
  • Except slenderness ratios...there are none!

**Until you came here today !!!**
Hot off the Presses !!!

- New requirements of AASHTO to be included in the 10th edition.
- Synopsis of those requirements is provided
6.7.4 Diaphragms and Cross Frames

• 6.7.4.2.1 ... Diaphragms or cross-frames for rolled-beam and plate-girder bridges shall satisfy the stability bracing stiffness and strength requirements specified in Article 6.7.4.2.2, as applicable.

• 6.7.4.2.2 Stability Bracing Requirements (new article)
6.7.4.2.2 Stability Bracing Requirements

**AASHTO Stiffness requirement**

\[(\beta_T)_{act} \geq \frac{2.4L}{\phi_{sb} nEI_{y eff}} \left(\frac{M_u}{C_b}\right)^2\]

• AISC requirement

\[\beta_T = \frac{1}{\phi_{br} nEI_{y eff}} \frac{2.4L}{\left(\frac{M_r^2}{C^2_b}\right)}\]

• In the AASHTO approach, if the bracing is not at least 0.8*member depth, the 2.4 becomes a 3.6
Cross-sectional Distortion ($\beta_{sec}$)

- New AASHTO 6.7.4.2.2
  - For diaphragms or cross-frames whose depth is at least 0.8 times the depth of the beam or girder, $\beta_{sec} = \infty$

![low distortion](image1)

![Significant distortion](image2)

- Otherwise AASHTO (and AISC) provide methods to account for web distortion associated with partial depth diaphragms / crossframes
AASHTO Diaphragm Strength Provisions

• AASHTO (6.7.4.2.2-14)

\[ M_{br} = \beta_T \theta_o = \left( \frac{2.4LM_r^2}{nEI_{yeff}C_b^2} \right) \left( \frac{L_{br}}{500h_o} \right) \]

• This is the same as AISC prior to 15\textsuperscript{th} edition. AISC now uses 2\% \( M_r \) as the required strength

• In the AASHTO equation, if the brace is not at least 80\% of beam height, 2.4 becomes 3.6
A Practical Example

• Scenario
  • Simple span – 200 ft
  • 4 beams @ 12 ft on center
  • Web depth 86 inches (about L/28 for the web alone)
  • Factored construction moment at midspan = 14,000 FK
  • S/D = 144 / 86 = 1.67 > 1.5 a K-frame is recommended.
  • Minimum size angle to meet kl/r = 6x6x3/8 for the top chord. Try this for all members
  • Crossframes at 25 ft on center
  • Cb = 1 for simplicity
K-Brace System

\[ \beta_b = \frac{2ES^2h_b^2}{8L_c^3 \frac{S^3}{A_c}} + \frac{S^3}{A_h} \]

- \( E \) = Modulus of elasticity (ksi)
- \( L_c \) = Length of diagonal (in)
- \( A_c \) = Area of diagonal member(s) (in)
- \( A_h \) = Area of horizontal member(s) (in)
- \( h_b \) = Height of brace system (in)
- \( S \) = Spacing of girders (in)
K-Brace System

\[ \beta_b = \frac{2ES^2h_b^2}{8L_c^3/A_c} + \frac{S^3}{A_h} \]

\[ = \frac{2(29000)(144^2)(86^2)}{8(112^3)/4.38} + \frac{144^3}{4.38} = 2.74 \times 10^6 \]
In-plane girder stiffness \((\beta_g)\)

\(\beta_g\) is a function of the stiffness of the individual girders as well as the number of girders across the width of the bridge:

\[
\beta_g = \frac{N_g S^2 EI_x}{L^3}
\]

\[
N_g = \frac{24(n_g - 1)^2}{n_g}
\]

\(I_x =\) in-plane moment of inertia of girders

\(n_g =\) number of girders across the width of the bridge that are interconnected by the braces.
In-plane girder stiffness \( (\beta_g) \)

\[
N_g = \frac{24(n_g - 1)^2}{n_g} = \frac{24(4 - 1)^2}{4} = 54
\]

\[
\beta_g = \frac{N_gS^2EI_x}{L^3} = \frac{(54)(144^2)(29000)(211,532)}{(2400^3)} = 4.97 \times 10^5
\]
Total Bracing Stiffness

\[(\beta_T)_{act} = \frac{1}{\left( \frac{1}{\beta_b} + \frac{1}{\beta_{sec}} + \frac{1}{\beta_g} \right)}\]

\[(\beta_T)_{act} = \frac{1}{\left( \frac{1}{2.74 \times 10^6} + \frac{1}{\infty} + \frac{1}{4.97 \times 10^5} \right)} = 4.21 \times 10^5\]
6.7.4.2.2 Stability Bracing
Requirements

**Stiffness requirement**

\[
(\beta_T)_{act} \geq \frac{2.4L}{\phi_{sb} nEI_{yeff}} \left(\frac{M_u}{C_b}\right)^2
\]

\[
\beta_T = \frac{2.4(2400)(14,000*12)^2}{0.8(7)(1)(29000)(3449)} = 2.90 \times 10^5 \leq 4.21 \times 10^5
\]

Design is satisfactory even with minimum kl/r angles

If it didn’t work, solutions include:

- Increase the size of the angles
- Add a line of crossframes
- Switch to an X Frame
- Increase Ixx to increase the in-plane girder stiffness
\[ M_{br} = M_{br} = \beta_T \theta_o = \left( \frac{2.4LM^2}{nEI_{yeff}C^2_b} \right) \left( \frac{L_{br}}{500h_o} \right) = 135 \text{ ft} \cdot \text{kips} \]

\[ F_{br} = \frac{135 \text{ ft} \cdot \text{kips}}{86 \text{ in}} = 19 \text{ kips} \]
Summary — Good News

• AASHTO now has REQUIREMENTS (in the 10th edition) requiring that flexural members be braced with members of sufficient stiffness and strength.

• Stiffness is required to control distortion (twist) in girders.

• Restraint of twist requires a strength design check of the bracing system.

• Calculations on selected bridges show that typical crossframes, designed for kl/r requirements meet or come close to meeting the stiffness and strength requirements.
Summary - Warnings

• Where are these provisions likely to cause problems?
  • Long spans, narrow cross section
  • Example, 300 ft span, 34 ft roadway, 4 or 5 beam cross-section
  • Example calcs show these GIRDERs satisfy AASHTO
  • The in-plane stiffness component of these bridges may be too low for bracing by diaphragms alone to be sufficient
  • These bridges may need a partial length lateral bracing system
Questions or Comments