

101<sup>st</sup> T.H.E. Conference  
February 24, 2015

Design & Construction of Skewed  
& Curved I-Girder Bridges  
How Do These Bridges FIT Together?



**Steel: The Bridge Material of Choice**  
**National Steel Bridge Alliance**

a division of the American Institute of Steel Construction  
[www.steelbridges.org](http://www.steelbridges.org)

# *What is FIT ?*



- The FIT of an I-girder bridge refers to the deflected girder geometry associated with a specific load condition to which the cross-frames or diaphragms are detailed to connect to the girders



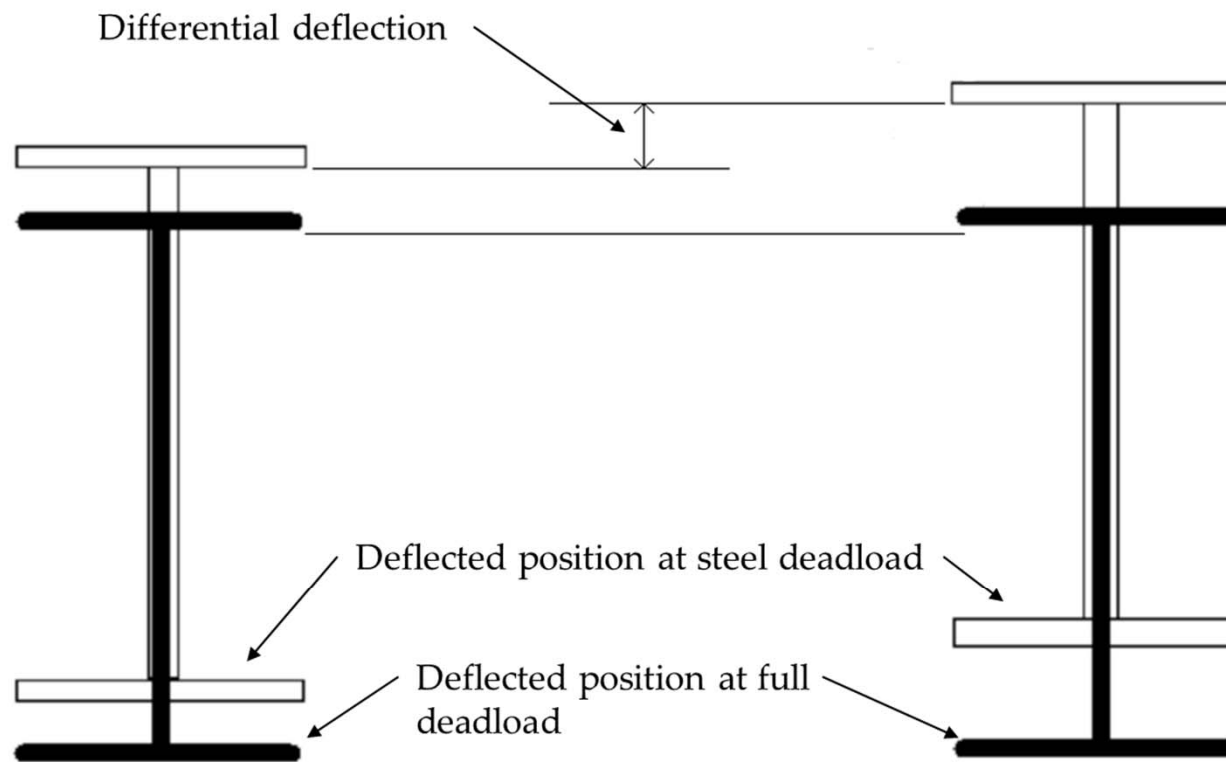
# What is FIT ?



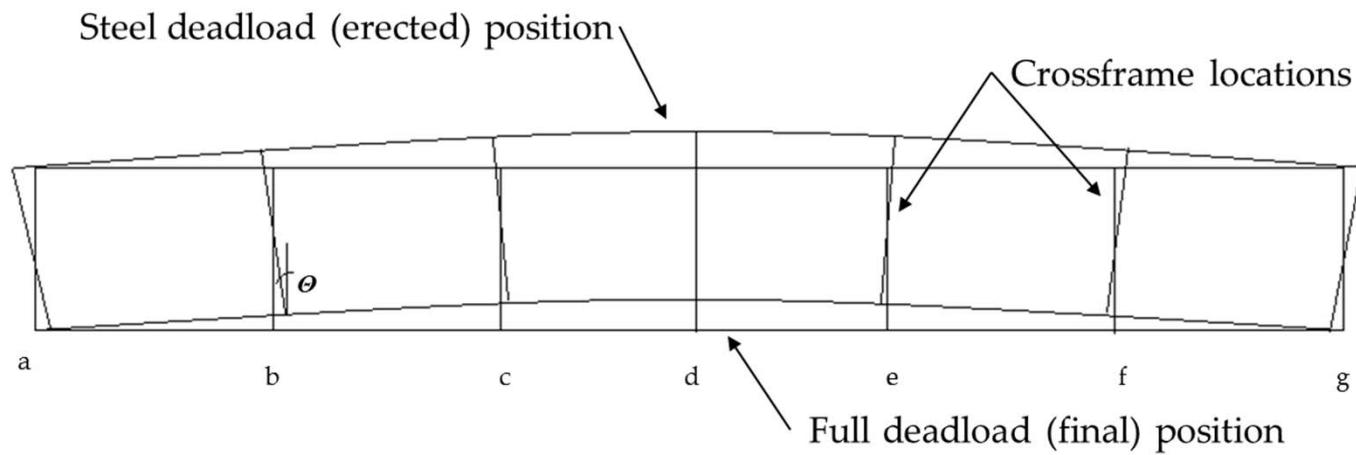
- Every bridge is FIT
  - A decision is always made about how to join the cross-frames to the girders on an I-girder bridge
  - The geometric relationship between the I-girders and the cross-frames changes as load is applied during construction
    - differential deflections and rotations
    - for curved girders, torsional displacements



# Differential Deflection



# Girder Rotation



# *What is FIT ?*



- The FIT decision must ...
  - allow cross frame installation during erection
  - limit the rotation demand at the bearings
  - facilitate deck joint alignment and barrier rail alignment at the bearing lines
  - in horizontally curved bridges, limit the magnitude of the locked-in dead load force effects

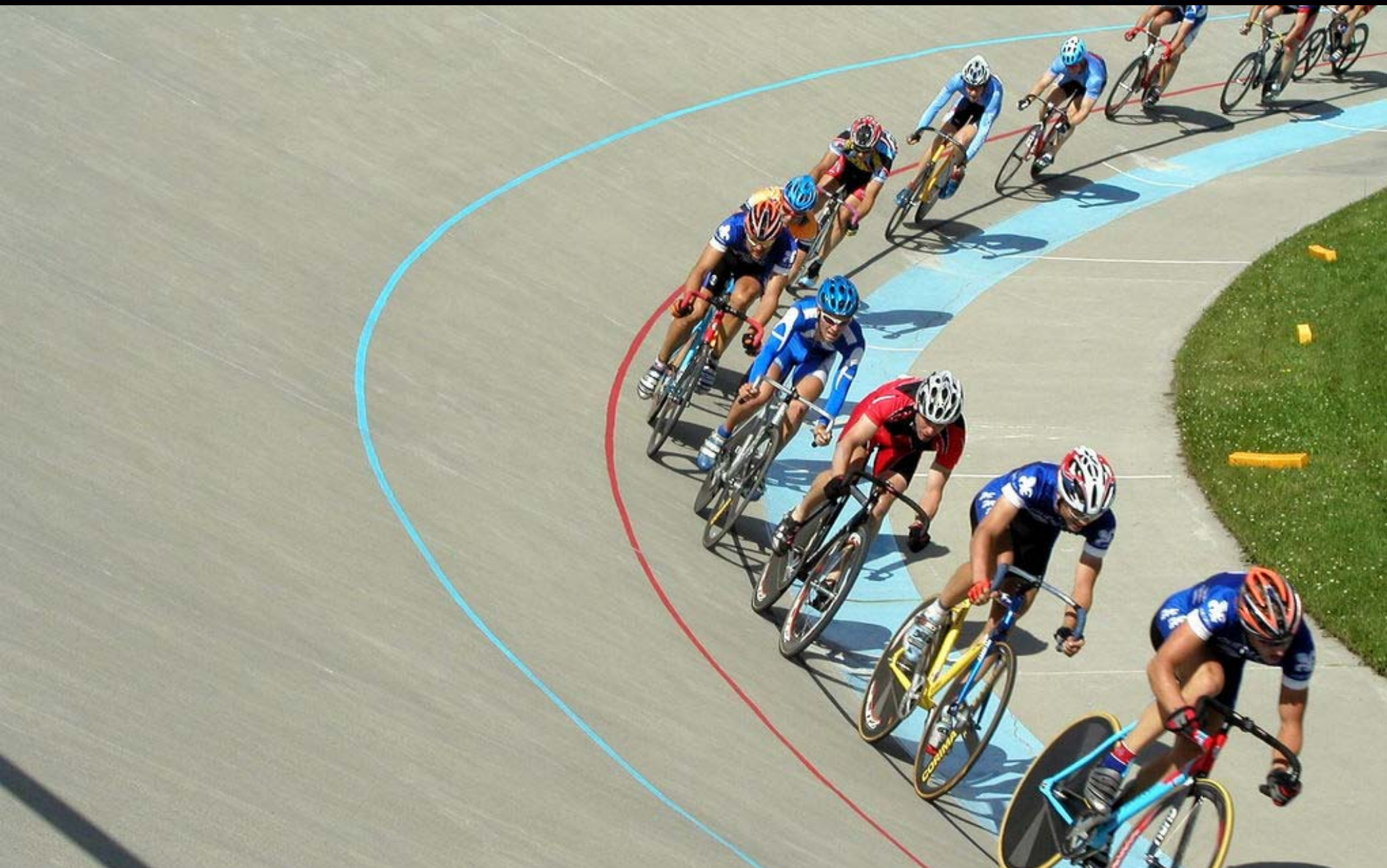
# *FIT Choice*



- The FIT choice is reflected in the drops on the fabricator's shop drawings (for I-girders)
  - drops – the difference in elevation between the top of webs for adjacent girders
    - differential deflection
    - roadway profile
    - cross slope



# *Superelevation*





# 3 FIT Choices



**TABLE 1 - COMMON FIT CONDITIONS**

<b>Loading Condition Fit</b>	<b>Construction Stage Fit</b>	<b>Description</b>	<b>Practice</b>
No-Load Fit (NLF)	Fully-Cambered Fit	The cross-frames are detailed to fit to the girders in their fabricated, plumb, fully-cambered position under zero load.	The fabricator (detailer) sets the drops using the no-load elevations of the girders (i.e., the fully cambered girder profiles).
Steel Dead Load Fit (SDLF)	Erected Fit	The cross-frames are detailed to fit to the girders in their ideally plumb as-deflected positions under the self-weight of the steel at the completion of the erection.	The fabricator (detailer) sets the drops using the steel dead load elevations, calculated as the fully cambered girder profiles minus the steel dead load deflections.
Total Dead Load Fit (TDLF)	Final Fit	The cross-frames are detailed to fit to the girders in their ideally plumb as-deflected positions under the total dead load.	The fabricator (detailer) sets the drops using the total dead load girder profiles, which are equal to the fully cambered girder profiles minus the total dead load deflections.

# *Customary Practice*



- Fabricators follow the direction that is in the plans (if there)
- AASHTO LRFD 6.7.2 – “For straight skewed and horizontally curved I-girder bridges with or without skewed supports, the contract documents should clearly state an intended **erected position** of the girders and the **condition** under which that position is to be theoretically achieved”

# *Customary Practice*



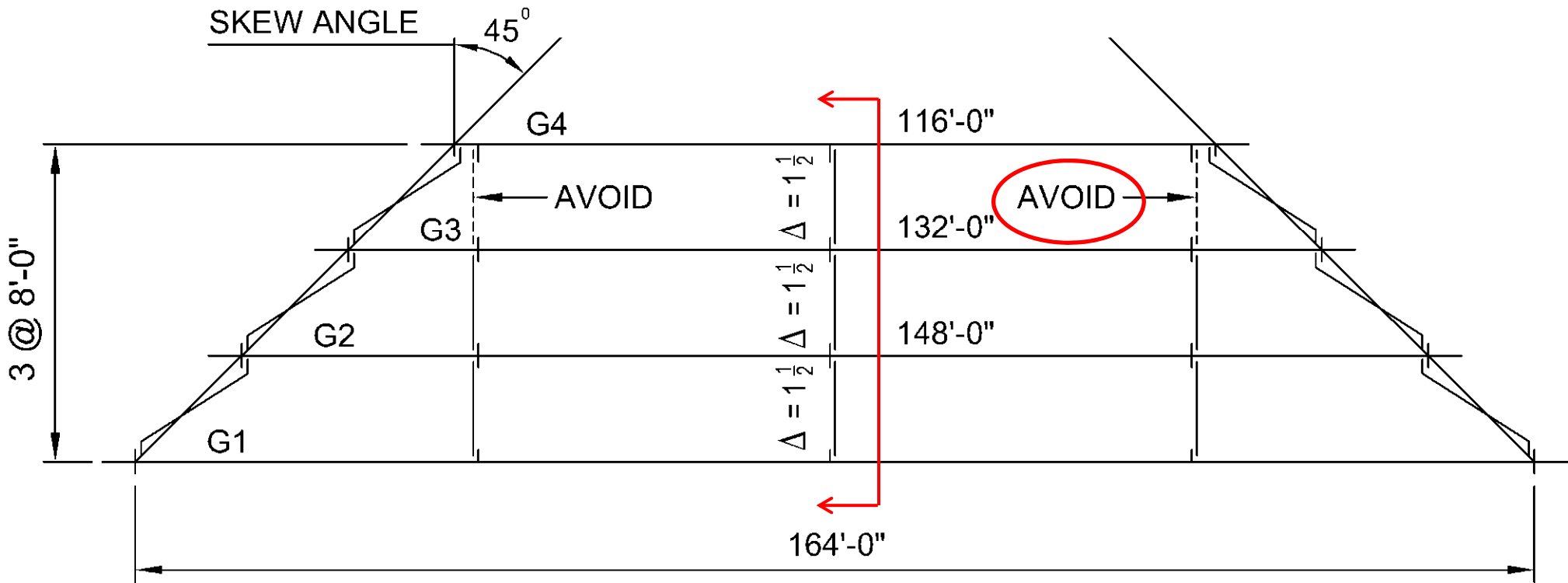
- Fabricators follow the direction that is in the plans (if there)
- Consider the drops – the difference in the elevations of the top of the webs for adjacent girders
- Rotations also affect fit (not just deflections)

# Customary Practice



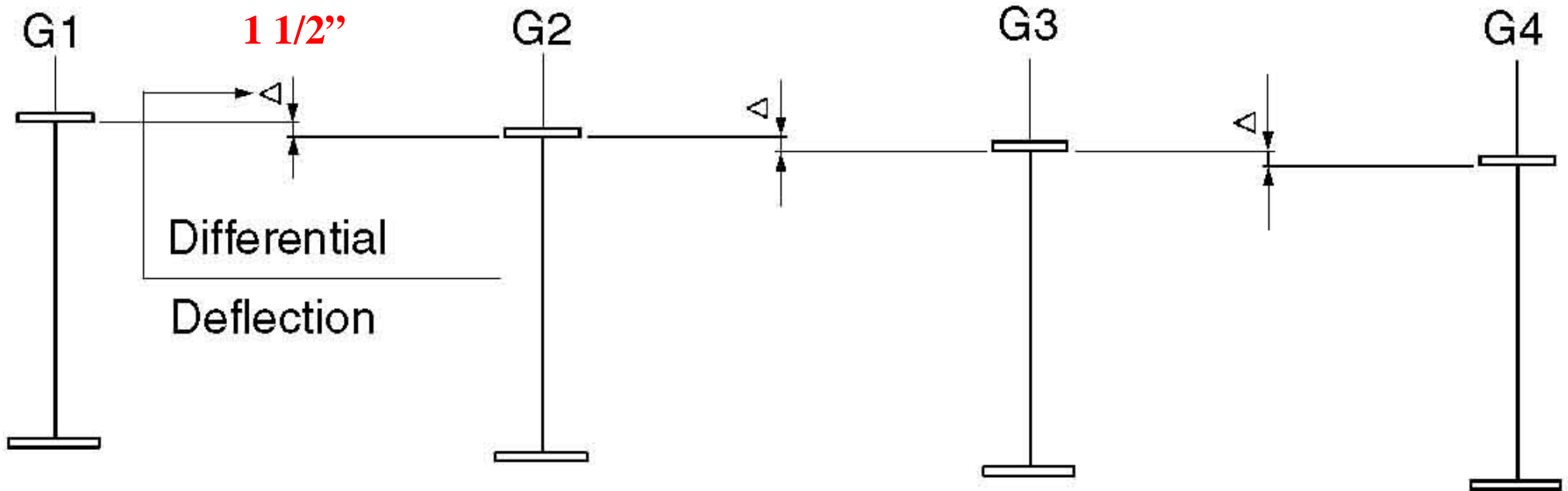
- Straight bridges, no skew
  - SDLF and TDLF are common
- Straight, skewed bridges
  - SDLF: easier fit in the field, “plumb” at erection
  - TDLF: some forcing, “plumb” at final
- Curved bridges
  - SDLF is common
  - ~~TDLF can be problematic~~

# • Skewed Girders



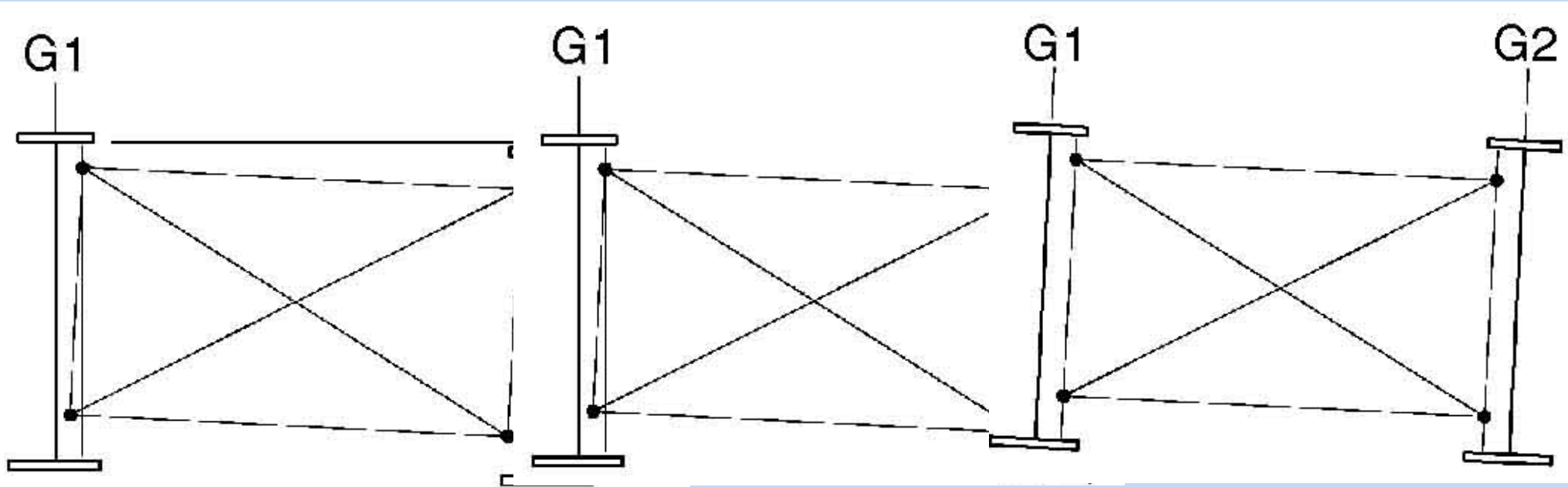
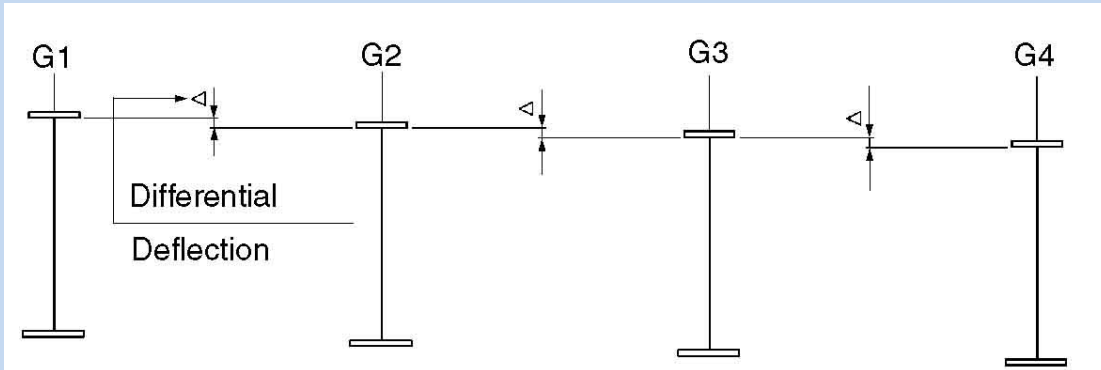
$\Delta$  = DIFFERENTIAL DEFLECTION

- Skewed Girders



STAGE 1

# • Skewed Girders

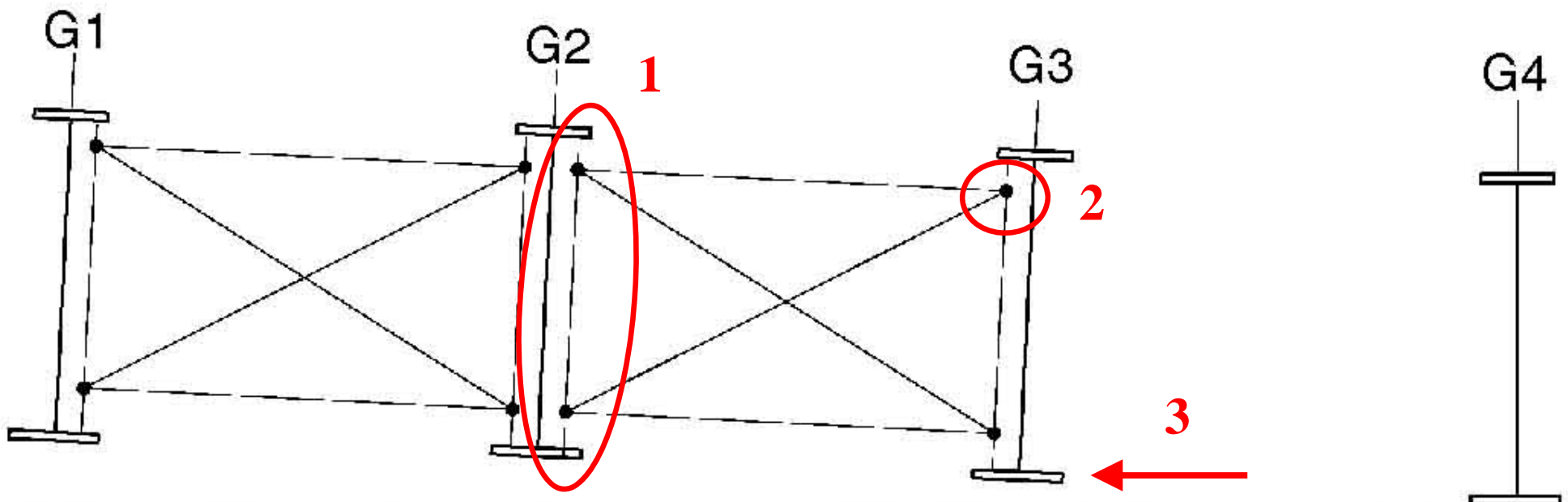


STAGE 2

STAGE 3

STAGE 4

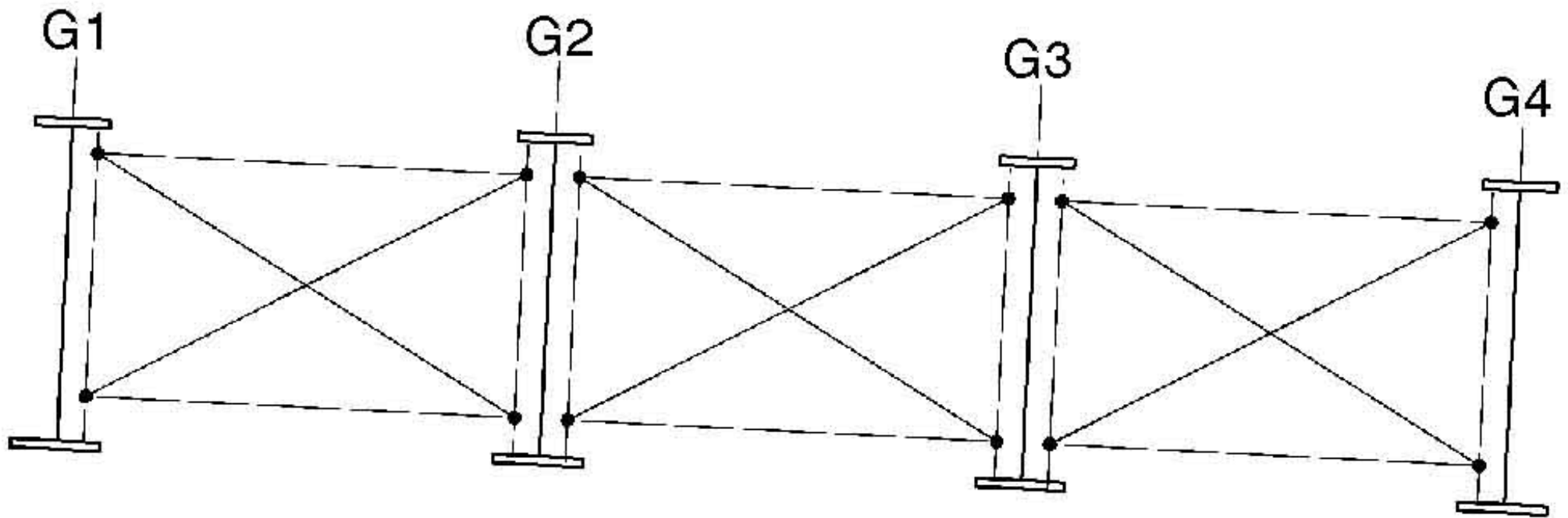
- Skewed Girders



STAGE 5

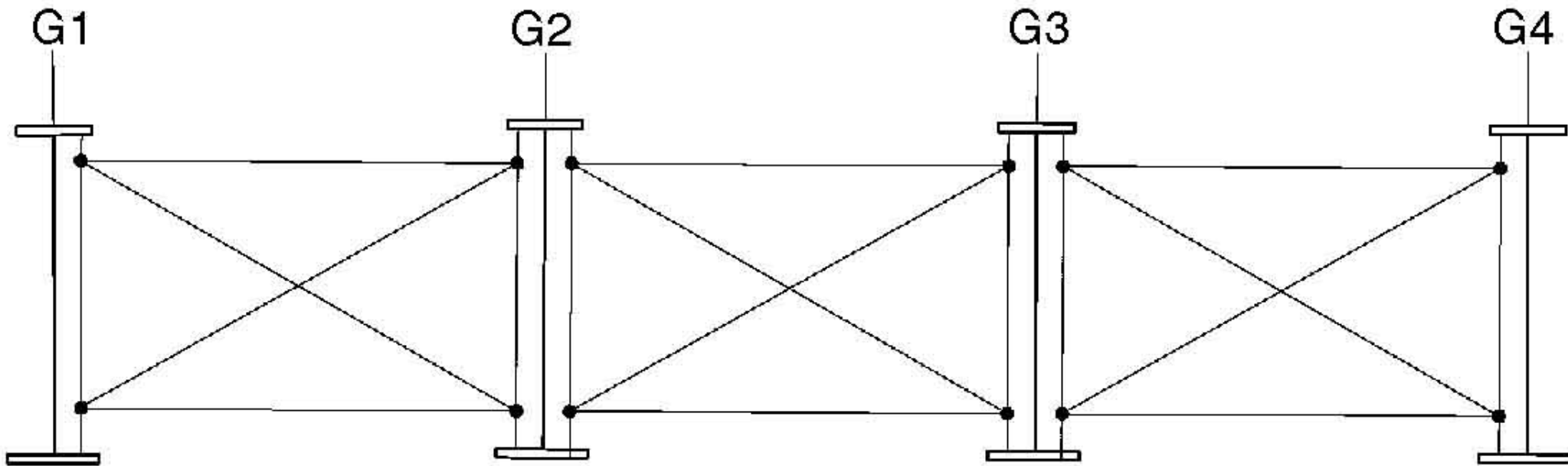


- Skewed Girders



STAGE 6

- Skewed Girders



STAGE 7

# Recommended FIT – straight, skewed



**TABLE 2 - RECOMMENDED FIT CONDITIONS FOR STRAIGHT I-GIRDER BRIDGES  
(INCLUDING CURVED I-GIRDER BRIDGES WITH  $L/R$  IN ALL SPANS  $\leq 0.03$  +/-)**

<b>Square Bridges and Skewed Bridges up to 20 deg +/- Skew</b>			
	<i>Recommended</i>	<i>Acceptable</i>	<i>Avoid</i>
Any span length	Any		None
<b>Skewed Bridges with skew &gt; 20 deg +/- and <math>I_s \leq 0.30</math> +/-</b>			
	<i>Recommended</i>	<i>Acceptable</i>	<i>Avoid</i>
Any span length	TDLF or SDLF		NLF
<b>Skewed Bridges with skew &gt; 20 deg +/- and <math>I_s &gt; 0.30</math> +/-</b>			
	<i>Recommended</i>	<i>Acceptable</i>	<i>Avoid</i>
Span lengths up to 200' +/-	SDLF	TDLF	NLF
Span lengths greater than 200' +/-	SDLF		TDLF & NLF

$$I_s = \frac{w_g \tan \theta}{L}$$

# Recommended FIT – curved



TABLE 3 - RECOMMENDED FIT CONDITIONS FOR HORIZONTALLY CURVED I-GIRDER BRIDGES

$$((L/R)_{MAX} > 0.03 +/-)$$

Radial or Skewed Supports			
	<i>Recommended</i>	<i>Acceptable</i>	<i>Avoid</i>
Span lengths greater than 250' +/- and $L/R > 0.1 +/-$	NLF	SDLF	TDLF
All other cases	SDLF	NLF	TDLF

“For the various recommended fit conditions presented in Tables 2 and 3, the span length, skew, and curvature limits should be considered approximate guidelines and should be evaluated in the full context of the geometric and structural complexity of the given bridge.”

# *Good Advice*



- First frame at  $1.5 \times$  web depth on skewed bridges
- Avoid oversize holes
- Tighten fasteners before pouring the deck
- When TDLF is used on skewed bridges, anticipate initial web layover required to 'force' fit cross-frames (and note it in the plans and shop drawings)
- Avoid TDLF on curved bridges. Given the stiffness and coupled vertical and torsional deflections of curved girders under load, there may be no practical way to assemble them since extra load would need to be applied to account for the 'missing' dead loads during erection

# *Design & Analysis*



- Forces associated with fit and associated construction
  - For SDLF/TDLF on a straight skewed bridge, the cross-frame internal forces due to the SDLF/TDLF detailing are approximately equal and opposite to the internal steel dead load/total dead load
  - SDLF and TDLF on curved bridges tends to increase internal cross-frame forces, since the cross-frames are used to twist the girders back in the direction opposite to the direction they naturally roll under the dead loads.
  - Curved bridges detailed to TDLF will not come back to plumb after deck pour

## Skewed and Curved Steel I-Girder Bridge Fit

Fit Task Force, NSBA Technical Subcommittee

Brandon Chavel, Domenic Coletti, Karl Frank, Mike Grubb, Bill McEleney, Ronnie Medlock, and Don White

*This is a stand-alone summary that is complimentary to a larger guide document on fit being published by the NSBA.*

### What is Fit?

The “fit” or “fit condition” of an I-girder bridge refers to the deflected girder geometry associated with a specific load condition in which the cross-frames or diaphragms are detailed to connect to the girders. Consideration of the fit condition is important since the geometrical relationship between the girders and cross-frames changes for different loading conditions.

In all bridge systems (trusses, arches, etc.), the steel components change shape between the fabricated condition, the erected condition, and the final condition. Therefore the associated relationship, or fitting, of the members also changes. When the changes are small, the fit choice can be inconsequential, but when the changes are large, the proper fit choice is essential for achieving a successful project.

The question, then, is in what condition should an I-girder bridge be detailed to fit? Certainly, the final condition is of great interest: to perform effectively in service, girders and cross-frames need to be in place

# Reference



- Executive Summary
  - Executive Summary of larger Fit Guide
  - available at [www.steelbridges.org](http://www.steelbridges.org)

The screenshot shows the NSBA website homepage. At the top left is the NSBA logo with the tagline "STEEL: THE BRIDGE MATERIAL OF CHOICE". To the right are links for "Join Now" and "User Login", and a search bar labeled "SEARCH AISC". Below this is a blue banner with the text "NATIONAL STEEL BRIDGE ALLIANCE" and "a division of American Institute of Steel Construction". Navigation links include "Go back to: Channels NSBA", "Printer Friendly Version", and "Send to a friend". A sidebar on the left lists: NSBA, NSBA LIBRARY, CALENDAR, NEWSROOM, PRIZE BRIDGE COMPETITION, WORLD STEEL BRIDGE SYMPOSIUM, and LEGISLATIVE UPDATE. The main content area features the NSBA logo, the text "NSBA's mission is to establish steel as the preferred material for bridges.", and a button for "NEWSLETTER". Below this is a section for "Modern STEEL CONSTRUCTION" with the text "visit the new website" and a link to "steelTOOLS.org". At the bottom right, there is a button for "PRESS".



# *More Information*



- Fit Guide – comprehensive
  - Large Task Group
  - Preparing for publication
- NCHRP Report 725  
Guidelines for Analysis Methods  
and Construction Engineering  
of Curved and Skewed  
Steel Girder Bridges
- AASHTO/NSBA S10.1 2014  
Steel Bridge Erection Guide



# *Thank you*



- Calvin R. Schrage
  - 402-440-3729
  - [schrage@steelbridges.org](mailto:schrage@steelbridges.org)
  
- National Steel Bridge Alliance
  - [www.steelbridges.org](http://www.steelbridges.org)

