AASHTO/NSBA Steel Bridge Collaboration
G13.1
Guidelines for Steel Girder Bridge Analysis

North Carolina Steel Bridge Workshop
Sponsored by the NCDOT and the NSBA
September 14, 2011
Raleigh, NC

Overall Presentation Outline

Introduction
Analysis Topics – Part 1
Break
Analysis Topics – Part 2
Overall Presentation Outline

**Introduction**

Analysis Topics – Part 1

Break

Analysis Topics – Part 2

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Introduction

Development of G13.1

G13.1 Topics

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AASHTO/NSBA Steel Bridge Collaboration - Task Group 13 - Analysis of Steel Bridges
Development of G13.1

G13.1 Topics

- Written by AASHTO/NSBA Task Group 13
  - A committee interested in steel bridge analysis issues
  - 69 members
  - A broad cross-section of the industry
Development of G13.1

- Mission Statement
  “Develop and maintain consensus recommendations on the applicability, advantages, and disadvantages of analysis techniques for various types of steel girder bridges”

Which means...
- Gather input from owners, designers, and industry
- Develop consensus recommendations / understanding of steel girder analysis issues
- Publish a guideline document on analysis of steel bridges
Development of G13.1

Timeline of TG13's efforts

<table>
<thead>
<tr>
<th>Activity</th>
<th>Date</th>
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<tbody>
<tr>
<td>Initial Meeting of TG 13</td>
<td>May 9, 2007</td>
</tr>
<tr>
<td>Survey of Current Practice</td>
<td>Summer 2007</td>
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<tr>
<td>Assigned Authors for G13.1</td>
<td>June 2008</td>
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<tr>
<td>Reviewed Draft of G13.1</td>
<td>November 2009</td>
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<tr>
<td>Collaboration Ballot of G13.1</td>
<td>April 2010</td>
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<tr>
<td>Initial AASHTO T-14 Review of G13.1</td>
<td>August 2010</td>
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<tr>
<td>AASHTO SCOBS Approval of G13.1</td>
<td>May 2011</td>
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<tr>
<td>Publication of G13.1</td>
<td>August 2011</td>
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From initial meeting to publication: > 4 years

Formal development of consensus

<table>
<thead>
<tr>
<th>Review</th>
<th>Comments Addressed</th>
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<tr>
<td>October 2009 Review by TG13</td>
<td>411</td>
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<td>March 2010 Review by TG13</td>
<td>193</td>
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<td>April 2010 Review by Industry</td>
<td>35</td>
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<td>February 2011 Review by T-14</td>
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<td>May 2011 Review by AASHTO Editor</td>
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<td><strong>Total Comments Addressed</strong></td>
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Development of G13.1

G13.1 Topics
G13.1 Topics

- Section 1: Modeling Descriptions
- Section 2: History of Steel Bridge Analysis

G13.1 Topics

- Section 3: Issues, Objectives, and Guidelines
  Common to All Steel Girder Bridge Analyses
  - Behavior Considerations
  - Section Property Modeling Considerations
  - Loads on the Permanent Structure
  - Strength Design
  - Inelastic Design
  - Fatigue Analysis and Evaluation
  - Wait, there's more...
G13.1 Topics

Section 3: Issues, Objectives, and Guidelines Common to All Steel Girder Bridge Analyses

- Superstructure Live Load Reactions for Substructure Design
- Constructability – Analysis Issues
- Prediction of Deflections
- Detailing of Cross Frames and Girders for the Intended Erected Position
- Wait, there’s still more…

- Cross Frame Modeling (2D vs. 3D)
- Deck Modeling
- Bearings, Substructures, and Boundary Conditions for Models
- Roadway/Structure Geometry Coordination
- Second-Order Effects
- Wait, there’s yet more…
G13.1 Topics

Section 3: Issues, Objectives, and Guidelines Common to All Steel Girder Bridge Analyses
- Phased Construction, Redecking, Widenings
- Temperature Effects
- Analyzing Older Bridges
- Discontinuities in Structures
- References to Benchmark Analysis Problems
- OK… that’s enough

Section 4: Analysis Guidelines for Specific Types of Steel Girder Bridges
- Plate Girders – General Issues
- Tangent Steel Plate Girders and Rolled Beams
- Curved Steel Plate Girders and Rolled Beams
- Tub Girders – General Issues
- Tangent Steel Tub Girders
- Curved Steel Tub Girders
- Bridges with Significantly Complex Framing
G13.1 Topics

- References
- Glossary
- Survey of Current Practice

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**“Lively Discussion Items”**

- "Recommendations" vs. "Understanding"
- Level of analysis (line girder / 2D, grid / 3D)
- Effects of deck placement sequence
- Phased construction analysis
- Substructures (integral, straddle bents, etc.)
- Detailing of cross frames and girders for intended erected position
Development of G13.1

G13.1 Topics

Overall Presentation Outline

Introduction

Analysis Topics – Part 1

Break

Analysis Topics – Part 2
Overall Presentation Outline

Introduction
Analysis Topics – Part 1
Break
Analysis Topics – Part 2

AASHTO/NSBA Steel Bridge Collaboration - Task Group 13 - Analysis of Steel Bridges

Analysis Topics – Part 1

Behavior Considerations
Constructability-Analysis Issues
Detailing for Intended Erected Position
Cross Frame Modeling
Deck Modeling

AASHTO/NSBA Steel Bridge Collaboration - Task Group 13 - Analysis of Steel Bridges
Behavior Considerations

Overview

- The Basics
- Effects of Curvature
  - Torsion – Stresses
  - Torsion – Rotations
  - Load Shifting
- Effects of Skew
Behavior Considerations

The Basics

- Shear
- Moment
- Primary Bending
  - Deflection
- Primary Bending
  - Rotation

Effects of Curvature

- Torsion – Stresses
- Torsion – Rotations
- Load Shifting
- Discussed in the context of "effects of curvature," but skewed bridges experience much of the same behavior
Behavior Considerations

- Torsion – Stresses, I-Girders
  - St. Venant Torsion
  - Warping Torsion

- Torsion – Stresses, Tub Girders
  - St. Venant Torsion
  - Warping Torsion
  - Shear Flow increases web and flange shear
  - “Pseudo Boxes”
Behavior Considerations

- **Torsion – Deformations**
  - Twisting
  - Warping
  - These deformations can potentially affect fit-up during construction

- **Load Shifting**
  - Center of Gravity is offset from line between supports
  - Girders on outside of curve carry more load
  - Load is transferred through diaphragms
Behavior Considerations

- **Effects of Skew**
  - Depend on the severity of skew and type of framing

- **Non-skewed diaphragms**
  - Diaphragm loads
  - Flange lateral bending
Behavior Considerations

- Skewed diaphragms
  - Diaphragm loads
  - Flange lateral bending

- “Nuisance stiffness” effects
  - Development of transverse load paths
Behavior Considerations

- “Nuisance stiffness” effects

Analysis Topics – Part 1

Behavior Considerations

Constructability-Analysis Issues
Detailing for Intended Erected Position
Cross Frame Modeling
Deck Modeling
Analysis Topics – Part 1

Behavior Considerations

Constructability-Analysis Issues

Detailing for Intended Erected Position

Cross Frame Modeling

Deck Modeling

Erection of Steel Framing

- General Guidance
  - NCDOT “Constructability Guidelines for Steel Plate Girder Bridges”
  - NCDOT Working Drawing Review (WDR) guidelines
  - AASHTO/NSBA S10.1 Steel Bridge Erection Guide Specifications
  - NCHRP 12-79 Task 9 Report
- Minimum items to consider in erection submittals
- Use of appropriate analysis methods
Constructability-Analysis Issues

- Investigation of Steel Erection Sequence
  - Stability throughout the erection sequence
  - Constructed geometry throughout erection sequence

- Critical Scenarios
  - Stability of girders during lifting
  - Single girder with minimal bracing
  - Minimal bracing in stages with few girders
  - Significant cantilever lengths
  - Significant curvature and/or skew – fit-up issues
  - Instability of incomplete framing under wind load
Constructability-Analysis Issues

- Why it is important to consider stability throughout the erection sequence...

Constructability-Analysis Issues

- Deck Placement Sequence
  - Interim vs. final moment diagram
  - Partial early stiffness gain in deck
  - Deflections – composite vs. noncomposite
  - Deflections – potential for interim uplift conditions
  - Bearing rotations – interim vs. final conditions
  - Deck cracking – pour sequence, deck reinforcing
Constructability-Analysis Issues

- Overhang Analysis & Effect on Girders
  - Overhang width vs. girder spacing (1/4 to 1/3 S)
  - Traditional widths = typical overhang bracket systems
  - Effect of overhang loads on girders (addressed in AASHTO LRFD specs)

- Loads During Construction
  - Girder and deck dead load
  - Wind load on steel frame without deck
  - Live load – construction (workers, equipment, screed)
  - Live load – rehab or demolition (workers, equipment)
  - Miscellaneous loads (stockpiled materials)
Analysis Topics – Part 1

Behavior Considerations

Constructability-Analysis Issues

Detailing for Intended Erected Position

Cross Frame Modeling

Deck Modeling
Detailing for Intended Erected Position

- Two possible positions
  - Girder webs vertical (webs plumb)
  - Girder webs not vertical (out-of-plumb)

- Three stages of loading
  - No Load
  - Steel Dead Load
  - Total Dead Load
Detailing for Intended Erected Position

- Three common detailing methods
- No Load Fit (NLF)
  - Webs plumb under no load conditions
  - No force-fitting required
- Steel Dead Load Fit (SDLF)
- Total Dead Load Fit (TDLF)
  - Webs plumb under steel DL or total DL
  - Force-fit cross frames/girders under no load conditions
Detailing for Intended Erected Position

- Steel or Total Dead Load Fit (SDLF or TDLF)
  - Webs plumb under steel DL or total DL
  - Force-fit cross frames/girders under no load conditions

- Considerations
  - Detailing
    - Cross frame geometry is different for NLF vs. SDLF vs. TDLF
  - Fit-up
    - Plans must clearly specify detailing method or there may be fit-up issues during construction
  - Forces
    - NLF = Forces in final condition from traditional analysis
    - SDLF, TDLF = Technically a “lack of fit” analysis is required
    - See NCHRP 12-79 Task 8 Report for more guidance
**Detailing for Intended Erected Position**

### Example

- Girders straight, girder webs vertical
  - (final position, isometric view)

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**Detailing for Intended Erected Position**

### Example

- Diaphragm holes do not align with web stiffener holes when girders are cambered

- Cambered position
  - Back view showing girders rotated up from horizontal plane
  - Diaphragms not aligned (designed to fit in final position)
Detailing for Intended Erected Position

Example

Front diaphragm has been both tilted and rotated in order to match hole patterns with web stiffeners. Girders also rotated and tilted in this cambered state.

Girder web centerline tilted 1.2 deg from vertical.

Diaphragm fit to final shape (Total Dead Load Fit)

Diaphragm fit to cambered shape (No Load Fit)
Cross Frame Modeling

- **3D vs. 2D modeling**
- **Modeling cross frames in 3D analyses**
  - Refined analysis of stiffness and response
  - Direct analysis results for all members
- **Modeling cross frames in 2D analyses**
  - Approximations of stiffness and response
  - Must convert simplified results into member forces

Cross Frame Modeling

- **3D modeling**
  - Flanges: beam or plate elements
  - Webs: plate elements
  - Diaphragms, bracing: truss or plate elements
  - Deck: solid or plate elements
Cross Frame Modeling

- 2D ("Grid" or "Grillage") modeling
  - Girders modeled as line elements
  - Diaphragms modeled as line elements
  - Deck modeled in strips as line elements
  - Plate and eccentric beam models

Cross Frame Modeling

- 2D Modeling of Cross Frames
  - Flexural Stiffness Method
Cross Frame Modeling

- 2D Modeling of Cross Frames
  - Shear Stiffness Method

Analysis Topics – Part 1

- Behavior Considerations
- Constructability-Analysis Issues
- Detailing for Intended Erected Position
- Cross Frame Modeling
- Deck Modeling
Analysis Topics – Part 1

Behavior Considerations

Constructability - Analysis Issues

Detailing for Intended Erected Position

Cross Frame Modeling

Deck Modeling

Deck Modeling

- Composite vs. Noncomposite
  - If no shear connectors are provided...
    - Typically deck considered noncomposite for all loads
    - There may be some bond between deck and girder
    - When bond stress is exceeded, change to noncomposite behavior is sudden
Deck Modeling

- Composite vs. Noncomposite
- If shear connectors are provided...

### Positive moment region
- Deck considered full composite once cured
- In special cases – may see partial early stiffness gain
- Transient loads act on short term composite section
  - Modular ratio = $n$
- Permanent loads act on long term composite section
  - Modular ratio = $3n$

### Negative moment region
- Without shear connectors in negative moment region
  - No composite action
  - Deck concrete and longitudinal reinforcing considered totally ineffective
- With shear connectors in negative moment region
  - Deck longitudinal reinforcing acts as part of composite section
Deck Modeling

- **Effective Width**

- **Simplified analyses (line girder, 2D Grid)**
  - Historically limited to 12 times deck thickness, ¼ of span length, or girder spacing
  - Currently full width considered fully effective
  - Longitudinal direction – deck modeled in strips
  - Transverse direction – deck neglected in line girder
  - Transverse direction – deck effectively modeled in strips, particularly at cross frame locations

Deck Modeling

- **Effective Width**

- **Refined analyses (2D P&EB, 3D)**
  - Deck is explicitly modeled in the analysis using plate, shell, or brick elements
  - Longitudinal and transverse effects captured directly
Analysis Topics – Part 1

Behavior Considerations
Constructability - Analysis Issues
Detailing for Intended Erected Position
Cross Frame Modeling
Deck Modeling

Overall Presentation Outline

Introduction
Analysis Topics – Part 1
Break
Analysis Topics – Part 2
Second-Order Effects

What is a “second-order” analysis?

- Any analysis which considers the deflected position of the structure in satisfying equilibrium
- AASHTO LRFD Section 4 also uses the terms “large deflection theory” and “stability analysis”
- AASHTO LRFD Sections 4 and 6 also use the term “geometric nonlinear analysis”

Generally two types of second-order analyses

- Buckling analysis
  - Eigenvalues (buckling load levels)
  - Eigenvectors (buckling modes)
  - “K-factors” are derived from eigenvalue buckling analyses
- P-delta analysis (P-Δ, P-δ)
  - Effects of load times relative displacement are considered incrementally via “iterative analysis”
Second-Order Effects

- Column and beam-column analysis

  ![Diagram of column and beam-column analysis]

  - Additional moment (couple) due to the axial force acting through the relative transverse displacement of member (or segment) ends
  - Additional moment due to the axial force acting through the transverse displacement relative to the member (or segment) chord

- What about steel girders?

- Many contributors to flange lateral bending
  - Curvature
  - Skew
  - Overhang brackets
  - Wind

- Approximate moment amplifier in AASHTO LRFD 6.10.1.6 is simple and conservative

- Construction cases typically most critical
Second-Order Effects

- Global stability of narrow steel girder systems
  - Two-girder bridge (pedestrian bridges, etc.)
  - Intermediate stages during construction, widening
  - Refined computer analysis, or Yura method

Analysis Topics – Part 2

Second-Order Effects

- Phased Construction, Redecking, and Widenings
- Analyzing Older Bridges
- Plate Girders – General Issues
- Tangent Steel Plate Girders
- Curved Steel Plate Girders
Analysis Topics – Part 2

Second-Order Effects

Phased Construction, Redecking, and Widenings

Analyzing Older Bridges

Plate Girders – General Issues

Tangent Steel Plate Girders

Curved Steel Plate Girders

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Phased Construction, Redecking, and Widenings

- There are no simple, hard and fast rules
  - Consider each case on its merits
  - For any given bridge, some considerations may be significant, some may be negligible
  - Consider the entire bridge, not just the portion being worked on
- Every bridge, every stage, is unique
Phased Construction, Redecking, and Widenings

- Dead load deflections

- Noncomposite vs. composite deflections
  - Think through each stage of construction

- Temporary vs. permanent conditions
  - Temporary overhangs
  - Temporary barriers

- Deck removal and partial deck removal
  - Rebound effects

Phased Construction, Redecking, and Widenings

- Live load deflections
  - May effect cross frame design and detailing
  - May effect quality of deck slab finish
  - May be shedding of some live load from the completed (composite) stage to the not yet completed (noncomposite) stage
Phased Construction, Redecking, and Widenings

- Stability of all stages during all steps in the construction sequence
  - Refer to previous discussion on second-order effects

Phased Construction, Redecking, and Widenings

- Cross frame design and detailing
- Fully connected approach
  - Tight holes, no closure pour
  - Cross frames installed before deck placement
  - Refined analysis (2D or 3D) required to quantify loads and deflections
  - May be more appropriate for curved or severely skewed bridges
Phased Construction, Redecking, and Widenings

- Cross frame design and detailing
- “Disconnected” approach
  - Slotted holes or cross frames installed after deck placement
  - Closure pour
  - Simplified analyses may be sufficient
  - May be more appropriate for straight, non-skewed bridges

Analysis Topics – Part 2

Second-Order Effects

Phased Construction, Redecking, and Widenings

Analyzing Older Bridges

Plate Girders – General Issues

Tangent Steel Plate Girders

Curved Steel Plate Girders
Analysis Topics - Part 2

Second-Order Effects

Phased Construction, Redeking, and Widenings

Analyzing Older Bridges

Plate Girders - General Issues

Tangent Steel Plate Girders

Curved Steel Plate Girders

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Analyzing Older Bridges

- Routine bridge inspections
  - "Hands on," every two years
  - General documentation of condition and section loss
Analyzing Older Bridges

- **Special inspections**
  - Focus on specific details with a history of problems
  - May be more frequent

- **Damage inspections**
  - Case by case depending on what happened

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Analyzing Older Bridges

- **Overheight Vehicle Damage**
Analyzing Older Bridges

- Overheight Vehicle Damage

- Errant Vehicle Damage
Analyzing Older Bridges

- Errant Vehicle Damage
  - I-70 Bridge Strike, Hays, KS
Analyzing Older Bridges

- Errant Vehicle Damage
  - I-70 Bridge Strike, Hays, KS
Analyzing Older Bridges

- Fire Damage
  - I-880, San Francisco, CA
Analyzing Older Bridges

- Fire Damage
  - I-880, San Francisco, CA
Analyzing Older Bridges

- **Load rating**
  - Routine ratings – simpler analysis methods
  - Refined analysis when appropriate
  - Consider condition of bridge, degradation of materials, section loss
  - Consider composite behavior appropriately – are there shear connectors?

- **Fatigue evaluations**
  - Not typically part of routine evaluations, but may be appropriate in older steel bridges, especially if:
    - Details with a history of problems
    - Cracking has been observed
  - Load-induced fatigue
    - In-plane fatigue stresses due to repetitive loading
  - Distortion-induced fatigue
    - Out-of-plane stresses due to unrestrained connection details
Analyzing Older Bridges

- **Bridges with hinges**
  - Some details are fracture-critical
  - Consider appropriately in the analysis – does the hinge still function or is it seized/frozen?

- **Non-destructive load testing**
  - Very complex structures
  - Structures with a history of problems

- **Steps**
  1. Instrument bridge
  2. Apply a limited number of known loadings
  3. Calibrate analysis model to measured responses
  4. Then perform analysis of other load cases
Plate Girders – General Issues

- Cross frame modeling
- Lateral bracing
- Narrow systems – stability analysis
- Narrow systems – redundancy analysis
- Variable depth girders
- Width to span ratio
Plate Girders – General Issues

- Lateral bracing
  - Less common than in the past
  - May be appropriate for some curved bridges
  - May be appropriate for long spans for wind resistance

- Top flange lateral bracing
  - Affects noncomposite behavior only

- Bottom flange lateral bracing
  - Affects both noncomposite and composite behavior

- Straight, no skew, top flange bracing only
  - Simplified analysis may be sufficient

- More complicated, or w/bottom flange bracing
  - Refined analysis (3D) probably required
Plate Girders – General Issues

- Narrow systems – redundancy analysis
  - Two-girder (“twin-girder”) bridges = nonredundant
  - For I-girder bridges, sophisticated analysis may demonstrate redundancy, but reliable load paths are tricky to provide and analysis is very difficult
  - Tub girder bridges are a different story…

- Variable depth girders
- Analysis model
  - Stiffness must be modeled correctly or else moment, shear, and dead load deflection predictions will be erroneous
- Detailed stress analysis
  - Refined (3D) analysis
  - Hand analysis per AASHTO LRFD and Blodgett
Plate Girders – General Issues

- Width to span ratio
  - Influence on secondary effects

Analysis Topics – Part 2

- Second-Order Effects
- Phased Construction, Redecking, and Widenings
- Analyzing Older Bridges
- Plate Girders – General Issues
  - Tangent Steel Plate Girders
  - Curved Steel Plate Girders
Analysis Topics - Part 2

Second-Order Effects
Phased Construction, Redecking, and Widenings
Analyzing Older Bridges
Plate Girders - General Issues

Tangent Steel Plate Girders
Curved Steel Plate Girders

Tangent Steel Plate Girders

- No skew or limited skew
  - Simplified analysis (line girder)
  - NCDOT / NCSU factors for DL deflections
- Severe skew
  - Refer to previous discussions
  - Consider refined analysis
**Tangent Steel Plate Girders**

- **Multiple different skews**
  - Refined analysis may be appropriate
  - Consider girder twisting, cross frame forces
  - Watch out for uplift

- **Through-girder bridges**
  - Simplified analysis (1D or 2D) generally sufficient
  - Check top flange stability
  - Design floor beam – girder connection carefully
Analysis Topics – Part 2

Second-Order Effects
Phased Construction, Redecking, and Widenings
Analyzing Older Bridges
Plate Girders – General Issues
Tangent Steel Plate Girders
Curved Steel Plate Girders

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Curved Steel Plate Girders

- Three levels of analysis
  - 1D Approximate methods (Line Girder+factors, V-load)
  - 2D (“Grid” or “Grillage”) methods
  - 3D methods

Line Girder+Factors

- Any line girder analysis tool can be used
- Factors from FHWA “Curved Girder Workshop”
- Approximate! Good for prelim. design, sanity checking
Curved Steel Plate Girders

- **V-Load Method**
  - Hand method, statics-based
  - “V-Loads” are the shears in diaphragms
  - Good for preliminary design or sanity checking more complex analyses

- **2D “Grid” Analysis**
  - Girders modeled as line elements
  - Diaphragms modeled as line elements
  - Deck modeled in strips as line elements
  - Plate and eccentric beam models
Curved Steel Plate Girders

- Grid Analysis Computer Tools
  - MDX
  - DESCUS I & II
  - General FEM programs
  - Others

Advantages of Grid Analysis
- Simple modeling
- Efficient (level of modeling effort)
- Some find it easier to understand
- Computer tools readily available
Curved Steel Plate Girders

- Disadvantages of Grid Analysis
  - Diaphragm modeling
  - Deck modeling
  - Load Distribution
  - In sum: Is a grid analysis sufficient for your bridge?

Curved Steel Plate Girders

- 3D Analysis
  - Flanges: beam or plate elements
  - Webs: plate elements
  - Diaphragms, bracing: truss or plate elements
  - Deck: solid or plate elements
Curved Steel Plate Girders

- 3D Analysis Computer Tools
  - BSDI 3D System (limited LRFD capabilities)
  - General FEM programs
  - Others

Advantages of 3D Analysis
- All pieces and parts modeled - rigorous
- Direct analysis results for all pieces and parts
- Greater refinement
- Greater accuracy (?)
Curved Steel Plate Girders

- Disadvantages of 3D Analysis
  - Greater modeling effort
  - More complicated model
  - Results less “intuitive”
  - In sum: Is the refinement worth the effort?

Curved Steel Plate Girders

- Modeling considerations
  - Boundary conditions – modeling bearings
  - Modeling substructure stiffness
  - Modeling connectivity between deck and girders
  - Modeling offsets
    - Girders to deck
    - Cross frame members to flanges
  - Modeling live loads
Curved Steel Plate Girders

- Which is best? 1D? 2D? 3D?
  - “It depends”
  - Understand the behavior of your structure
  - Choose the right level of analysis

Analysis Topics – Part 2

- Second-Order Effects
- Phased Construction, Redecking, and Widenings
- Analyzing Older Bridges
- Plate Girders – General Issues
- Tangent Steel Plate Girders
- Curved Steel Plate Girders
Overall Presentation Outline

Introduction
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Analysis Topics -- Part 2

Wrap-up

- **Topics covered**
  - Behavior Considerations
  - Constructability-Analysis Issues
  - Detailing for Intended Erected Position
  - Cross Frame Modeling
  - Deck Modeling
  - Second-Order Effects
  - Phased Construction, Redecking, and Widenings
  - Analyzing Older Bridges
  - Plate Girders – General Issues
  - Tangent Steel Plate Girders
  - Curved Steel Plate Girders
Wrap-up

- Not satisfied? Want more?
  - Read G13.1

- Want even more?
  - Read the references mentioned in G13.1

- What else can you do?
  - Talk to senior engineers

Always remember...
- Each bridge is unique
- Think about the anticipated behavior of the structure
- Consider how the bridge will be constructed
- Choose an appropriate analysis method
Questions?