Structural Steel Design, Fabrication, and Construction

Jamie F. Farris, P.E.

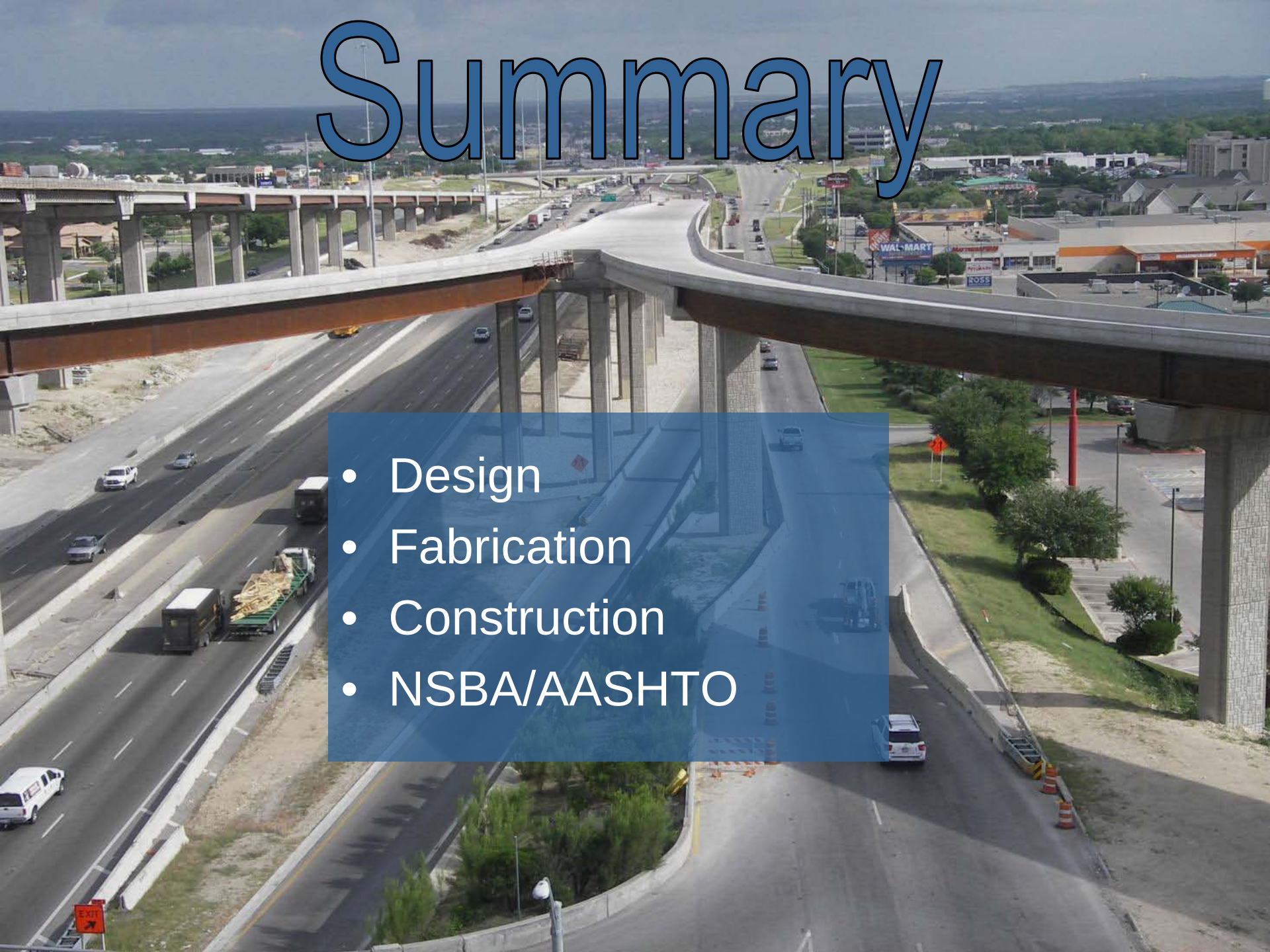
TxDOT Bridge Division

BRIDGE DIVISION

Texas Department of Transportation

October 11, 2011

Summary



- Design
- Fabrication
- Construction
- NSBA/AASHTO


6 Equal Spaces (Straight)
8.353' (Straight)
5 Equal Spaces (Curved)
9.172' (Curved)
9.000'
Drip Plate
℄ Girder No 1
S 47°06' 15.4" W
℄ Brg F7
57.750' *
55.750' *
Field Splice
5.000'
Drip Plate
Field Splice
Type XI End Cross Frames (Typ)
℄ Girder No 4
2 Eq Spa
2 Eq Spa
2 Eq Spa
Int Stiffner Spa
(Typ)
Steel Design
A
C
D
H
G
I
J
Bottom
Top
Bottom
6"
1'-5" Max
6"
1'-5" Max
6"
N
M
P
Q
PL 2
PL 1 1/4
PL 1 1/4
1'-0"
3"
typ
℄ Brg ES5
℄ Bent 12
℄ Brg E6
℄ Bent 13
Top of Slab
to Top of Web
12 1/2"
℄ Girde

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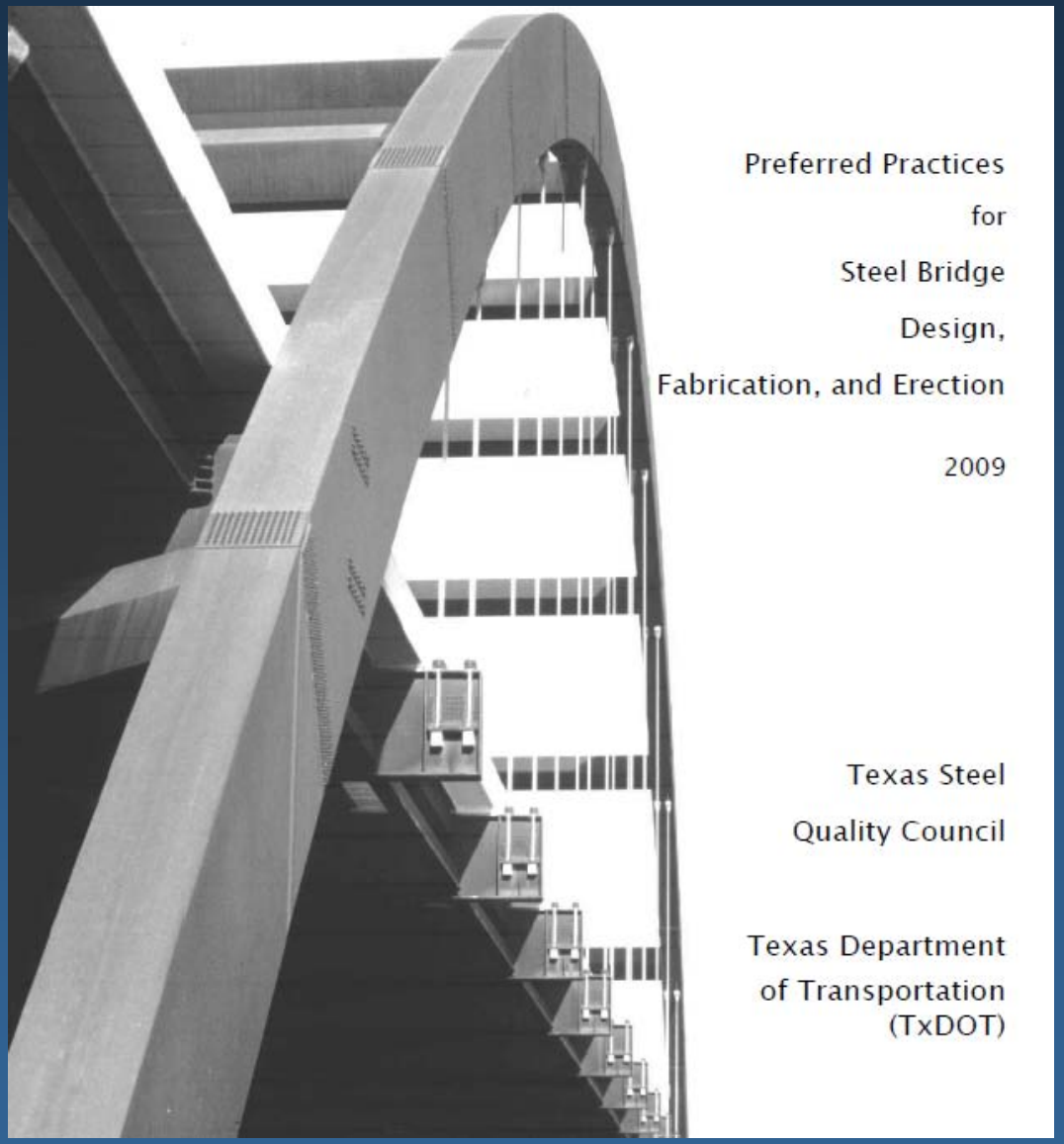
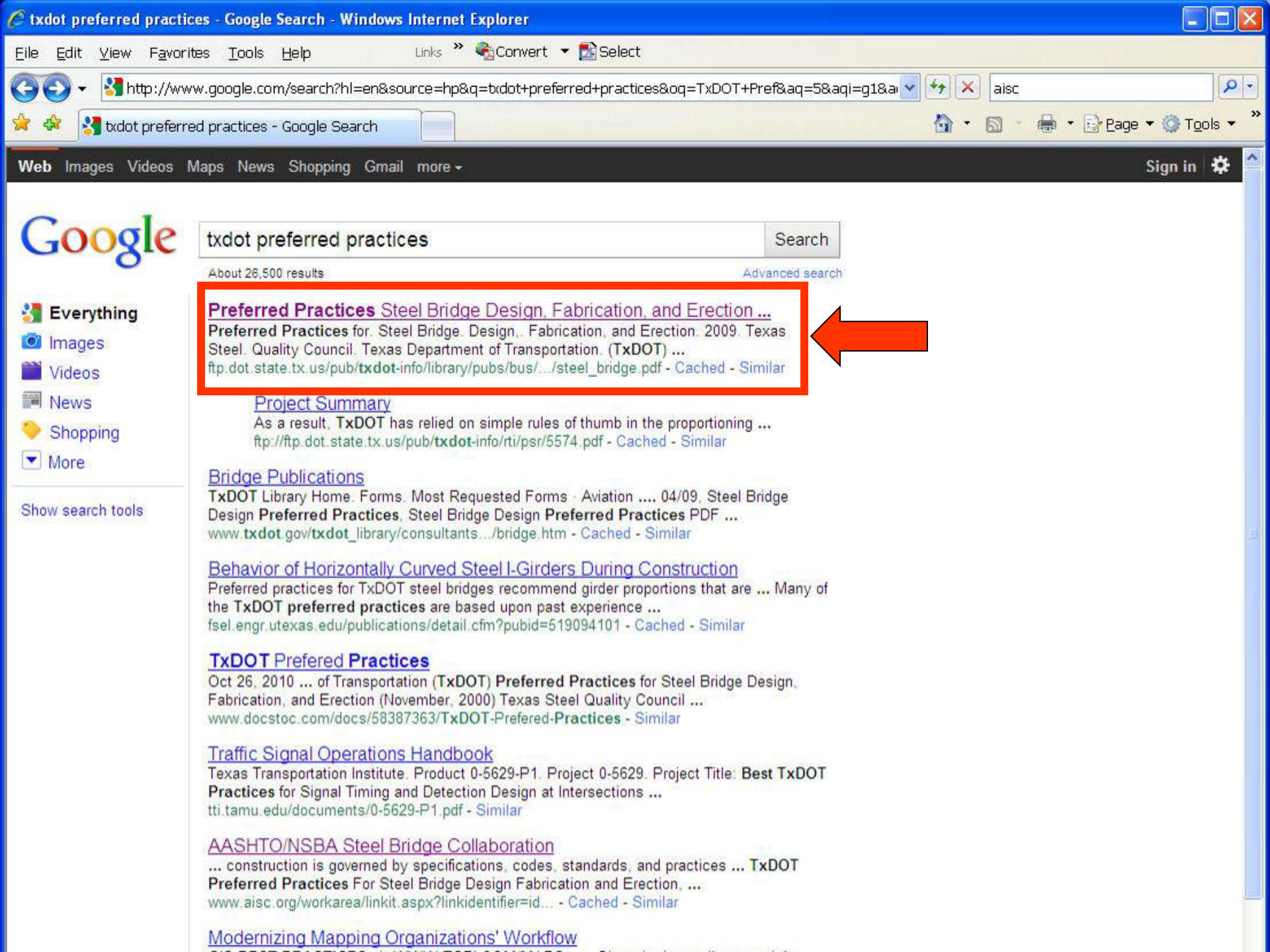
TxDOT Preferred Practices

Texas Steel Quality Council

- TxDOT
- FHWA
- Consultants
- Academics
- Fabricators
- Detailers
- Steel Mill reps

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Modernizing Mapping Organizations' Workflow


Material Selection

Unpainted Weathering Steel

- Preferred
- A 709 Grades 50W and HPS 70W
- More economical
- Consider location conditions before choosing
- Use details to prevent concrete staining

Prevent Concrete Staining

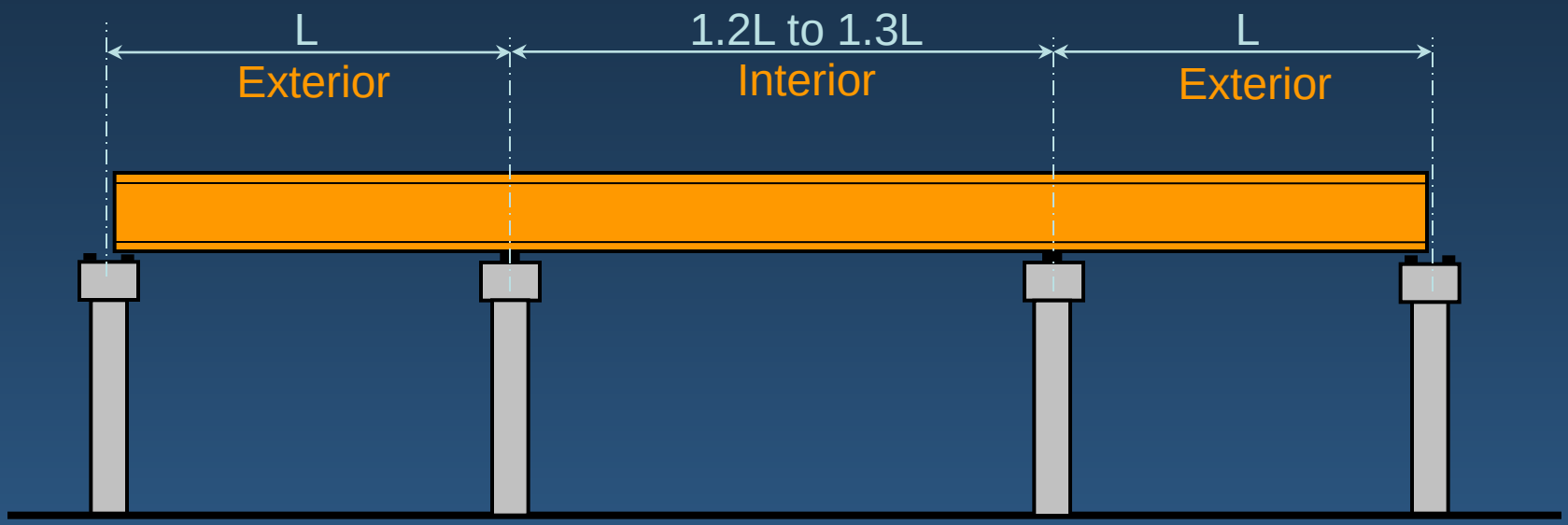
Weathering Steel

- Include drip tabs on all girders
- Additional options
  - Stainless steel trays
  - Paint area over Bent

Painted Steel

- System IV – non coastal new construction
- System III – coastal new construction
- More info - See Item 446 of TxDOT Spec Book

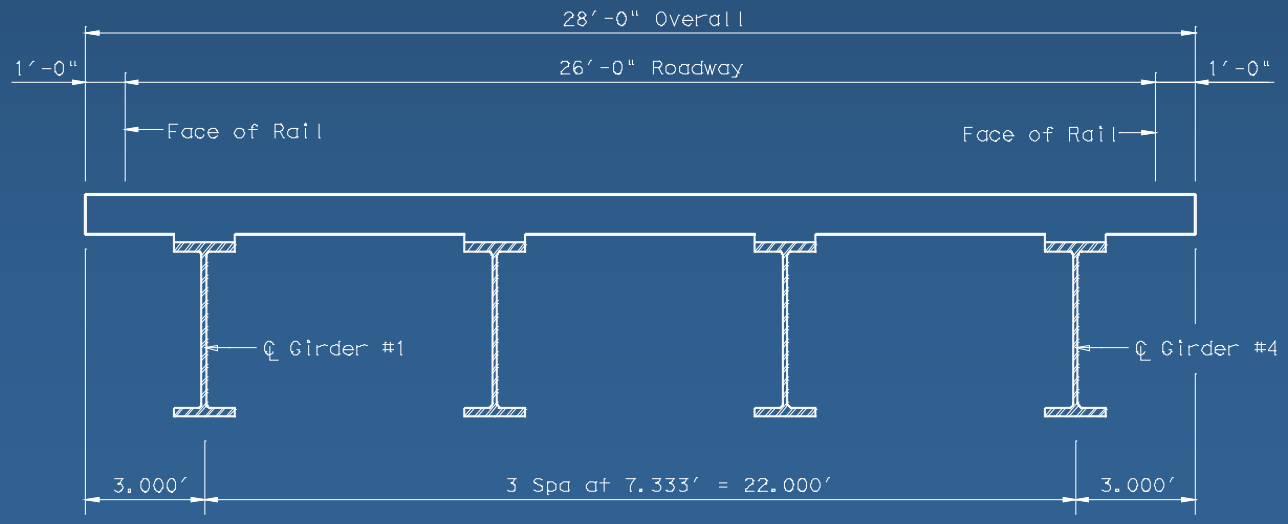
Span Configuration & Geometry



- 3 and 4 span continuous – Preferred
- Interior Spans 20-30% longer then End Spans
- Check uplift at the ends of continuous girders
- Avoid high skews or major differentials where possible

Girder Spacing

- I-girders
  - Limit CL-CL spa to 10 ft
  - Min of 4 girders for vehicular bridge span
- Tub girders
  - Limit web spacing to 10 ft
  - Min of 3 girders for vehicular bridge span
- Consider use of PCPs for straight girders



I-Shaped Plate Girders

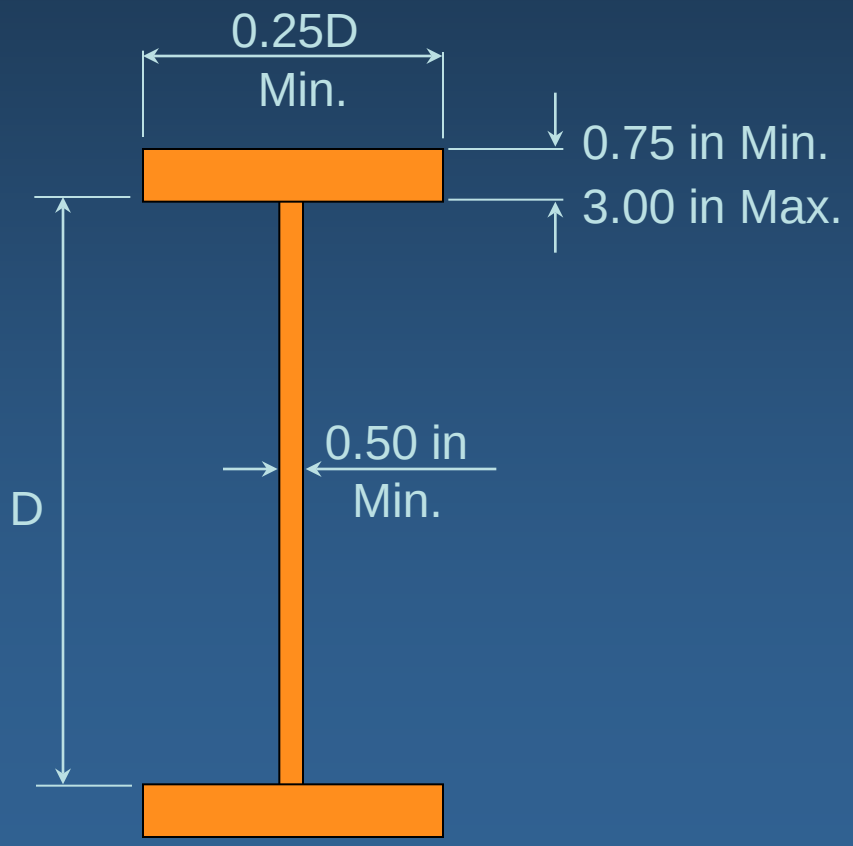
Geometric Constraints for Straight Girders

Flange Width ≥ D/4

Flange Width ≥ 15 in

¾ in ≤ Flange Thick ≤ 3 in

Web Thick ≥ ½ in



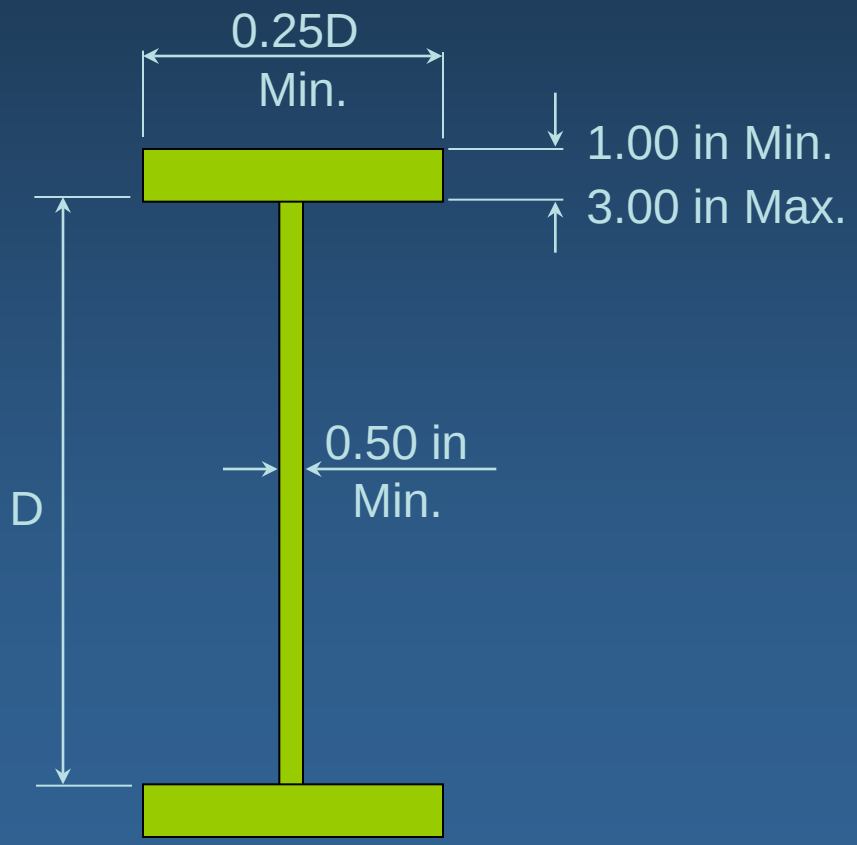
Geometric Constraints for Curved Girders

Flange Width ≥ D/4

Flange Width ≥ 15 in

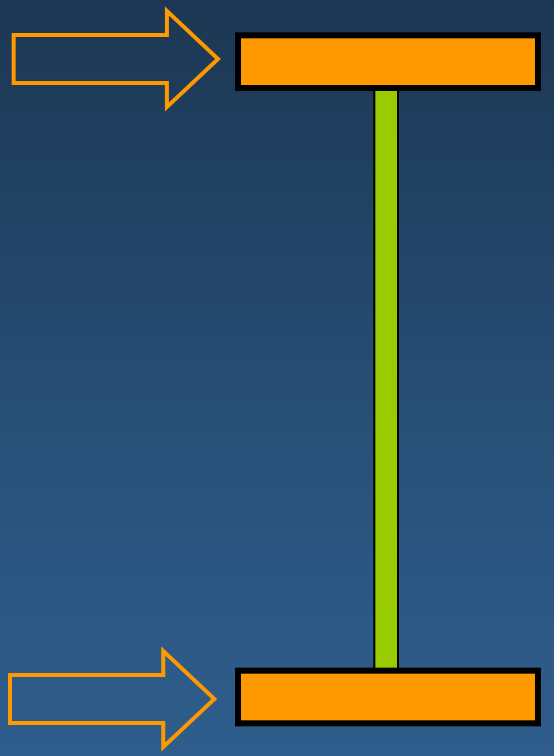
1 in ≤ Flange Thick ≤ 3 in

Web Thick ≥ ½ in



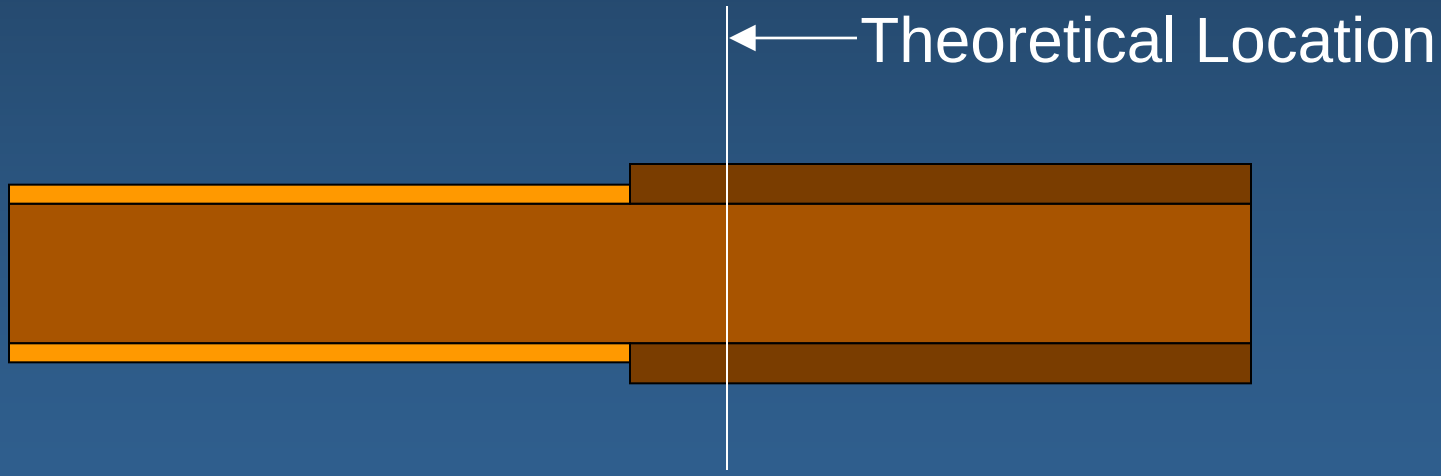
Flange Criteria

- Flange Width
  - Constant
  - Transitions at field splices
  - Top = Bottom
- Flange Thickness
  - Use 10 ft min length
  - Use only a few sizes
  - In lieu of lateral bracing – ↑ flange thickness
  - Use similar thicknesses across girders



Flange Criteria

- Flange splices – extend thicker flanges beyond theoretical flange splice location



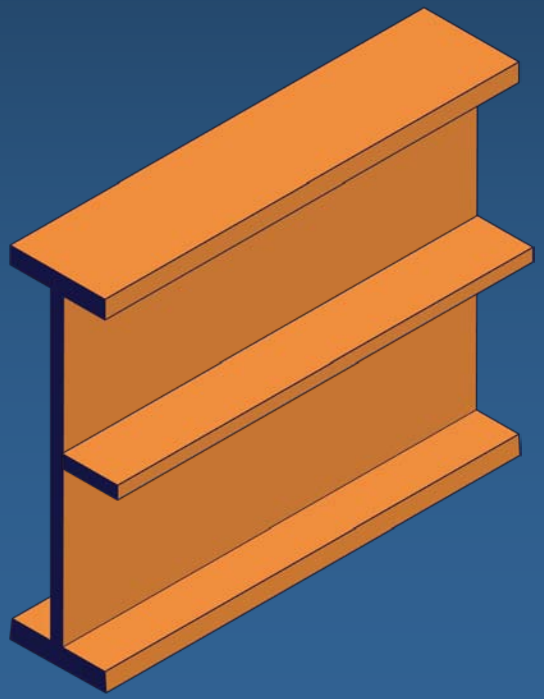
Web Criteria

- Web Depth
  - Whole inch increments
  - Dapped Ends: No more than 40% of web depth
  - Do not use haunched webs

- Web Thickness
  - Eliminate need for transverse stiffeners
  - Discourage use of fully stiffened web designs
  - Optimal designs have few sizes

Web Criteria

- Don’t use Longitudinal stiffeners unless web depth > 120 in



Present fabrication and fatigue problems

Field Splices

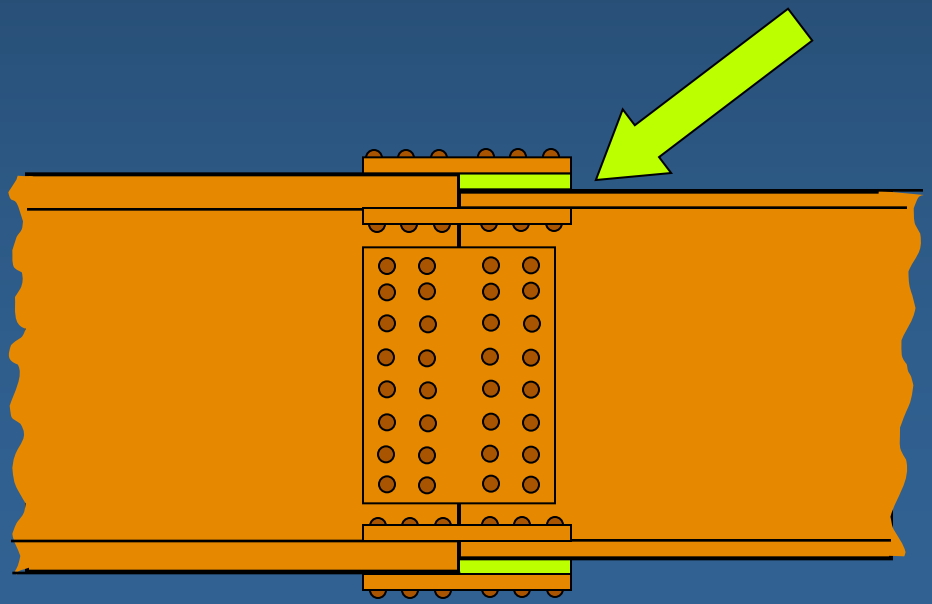
- Show in plans as welded
- Offer bolted splice option
- Locate at points of DL contraflexure
- Girder field length ~ 130 ft max
- Limit shipping width to 6 ft and height to 9 ft
- Web splice locations at least 10’ apart

Bolted Field Splices

- Galvanized bolts for painted steel
- 1”, 7/8”, ¾” Dia
- Class A surface conditions
- Splice PL thickness ≥ ½”
- Add 1/8” – ¼” to min edge distances in AASHTO LRFD

Splice Fill Plates

- Steel grade specified for girders – not available in thicknesses less than 3/8”
- Allow optional fill plate material (A 606, A 570, etc.)
- Spec Book 447.4.B



A325 vs. A490 Bolts

- Contractors prefer A325
- A325 bolts can be retightened
- A490 bolts are sensitive to tightening procedures
- A490 bolts require impact wrenches that might not be available

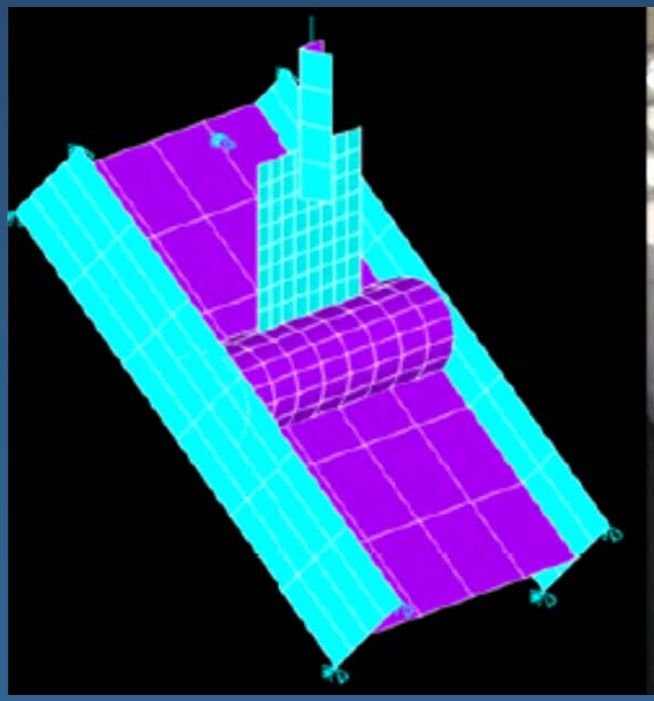
Diaphragms & X-Frames

- Max Spacing
  - Straight = 30 ft
  - Curved = 20 ft
- Provide at all end bearings
- Straight - Set parallel to skew up to 20^{o}. Set radial beyond 20^{o}
- Curved – set radial to girders

X-frame Half Pipe Stiffeners

Skewed Bridges

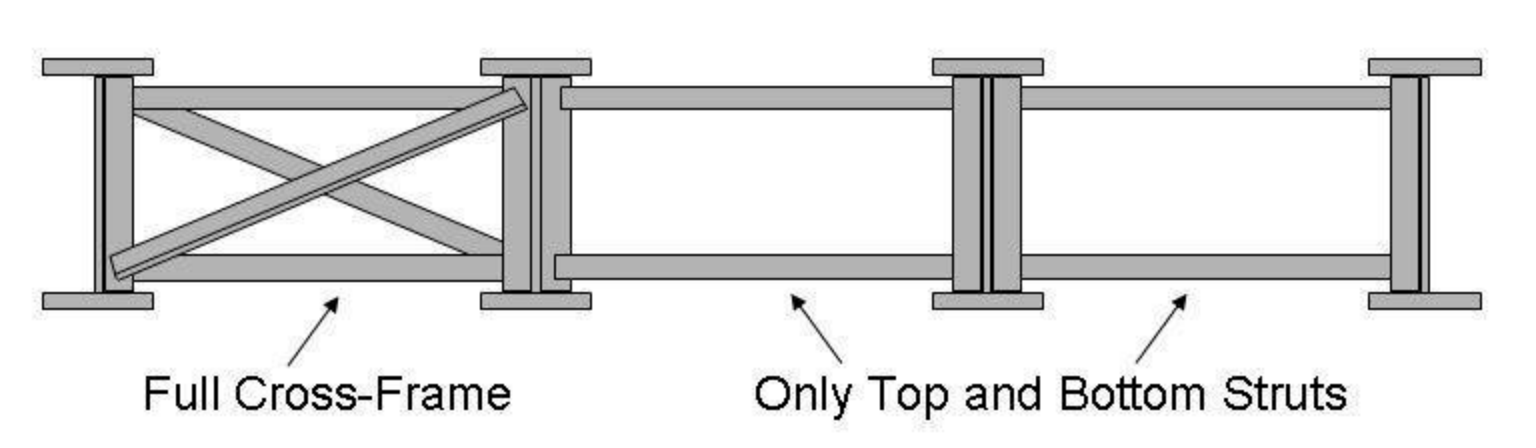
- Research Project 0-5701
- Gives girders higher buckling capacities
- Serves as a bearing stiffener
- Coming soon: Added to SGMD Standard



Lean On Bracing

Straight Bridges

- Research Project 0-1772
- Struts transfer forces to 1 or 2 X-frames
- Minimize LL induced brace forces
- Reducing number of braces



Stud Connectors

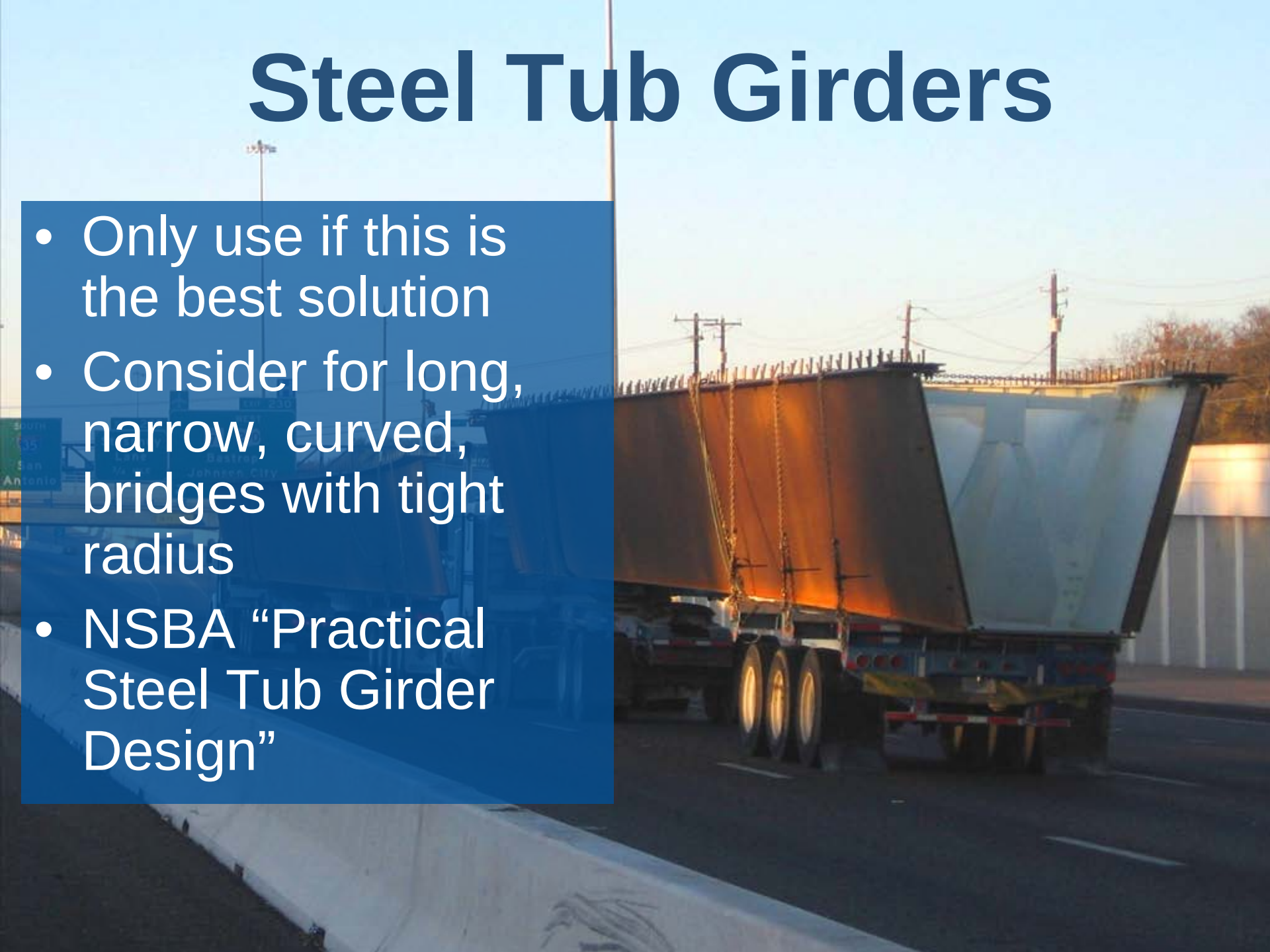
- Full length of girder
- Min longitudinal Spa ≤ 4d
- SGMD Standard
- Not required on top of flange splice plates

Bearings

- Select from TxDOT SGEB standard
- Triple check bearing seat elevations
- Avoid costly HLMR, disc, pot bearings
- Bent Cap geometry

Steel Tub Girders

- Only use if this is the best solution
- Consider for long, narrow, curved, bridges with tight radius
- NSBA “Practical Steel Tub Girder Design”

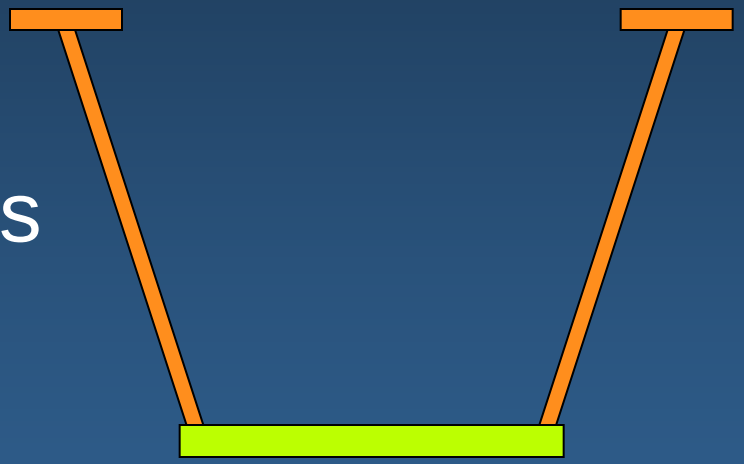


Tub Girders

- Constant shape
- Rotated with x-slope
- Top flange and Web – same requirements as I-girder
- Avoid details more critical than Cat. C

Bottom Tension Flange

- > ¾” thick
- w/t ≤ 80
- Classified as fracture-critical for 2-girder spans
- All bottom flange edges – extend 2 in + beyond web CL

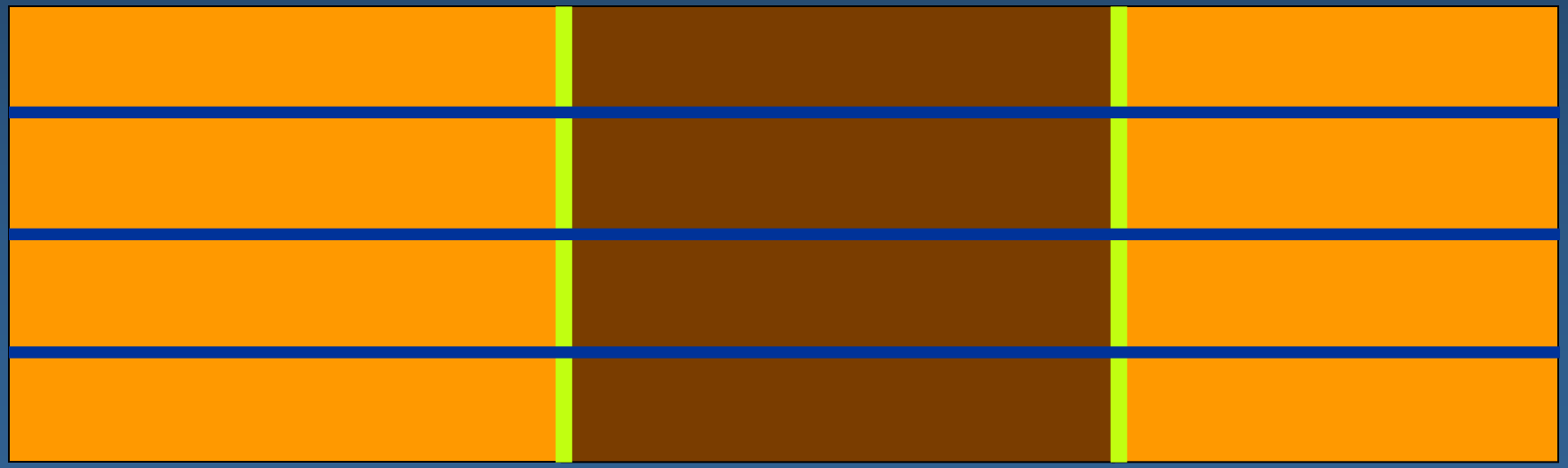


Inspection Access


Steel Fabrication

Slabbing and Stripping

Girder Elevation



Top View

Slabbing and Stripping

Multiple Head Cutting Bed - Strips Out Flanges From Wider Plates


QUICKMILL # 2

Narrow Gap Electroslag Welding

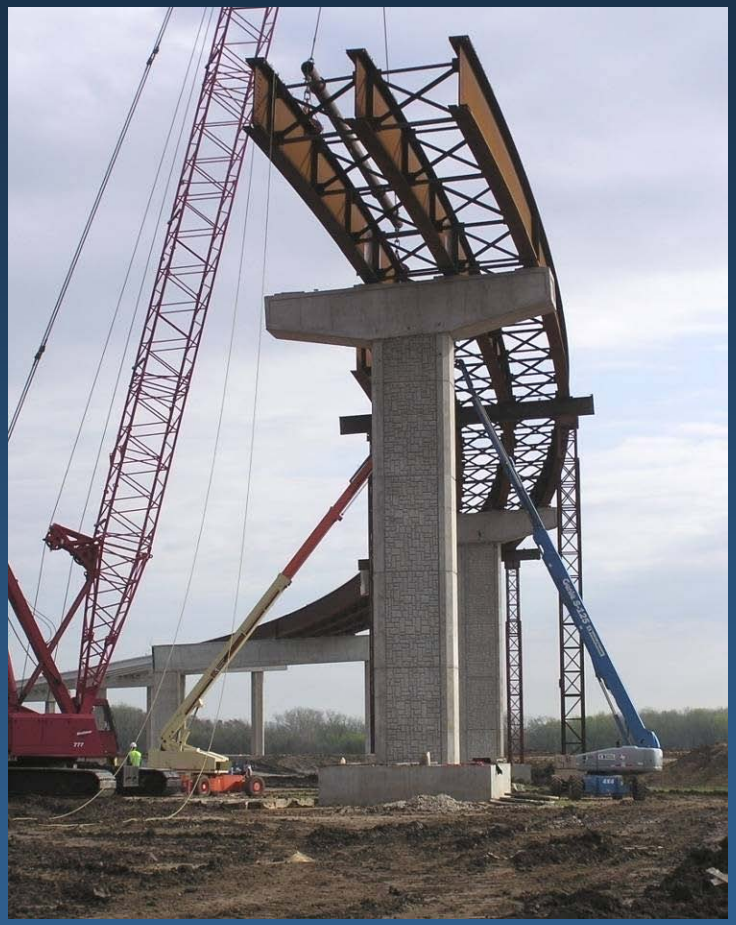
Welding Time Approx. =10- 20% of multiple pass weld

Minutes versus Hours


Steel
Construction
DAVIS
CRANE SERVICE

- Analyze girder system using grid analysis
- Predict the behavior of girder system once bridge is fully constructed

Critical Stages of Stability



- Girder Erection
- Before concrete deck placement

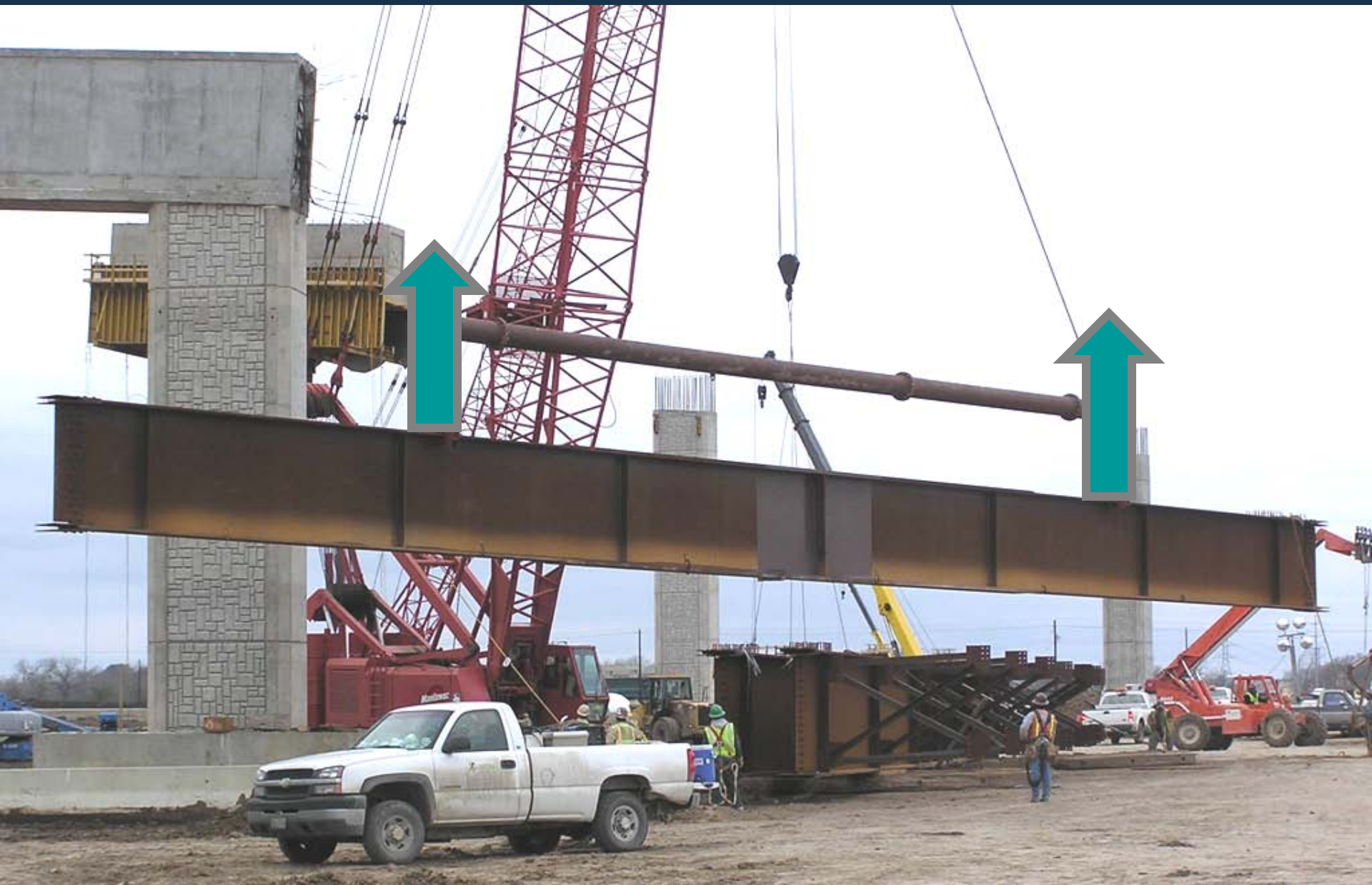
Research Study 0-5574

- Curved Plate Girder Design for Safe and Economical Construction
  - Justify recommendations in Preferred Practices
  - Create uniformity among analytical requirements of curved I-girders during early stages of construction
  - Girder erection and concrete slab placement

Research Study 0-5574

- Field Monitoring
- Parametric Finite Element Modeling
- Survey of Girder Erection Practices
- PC Based Analytical tools

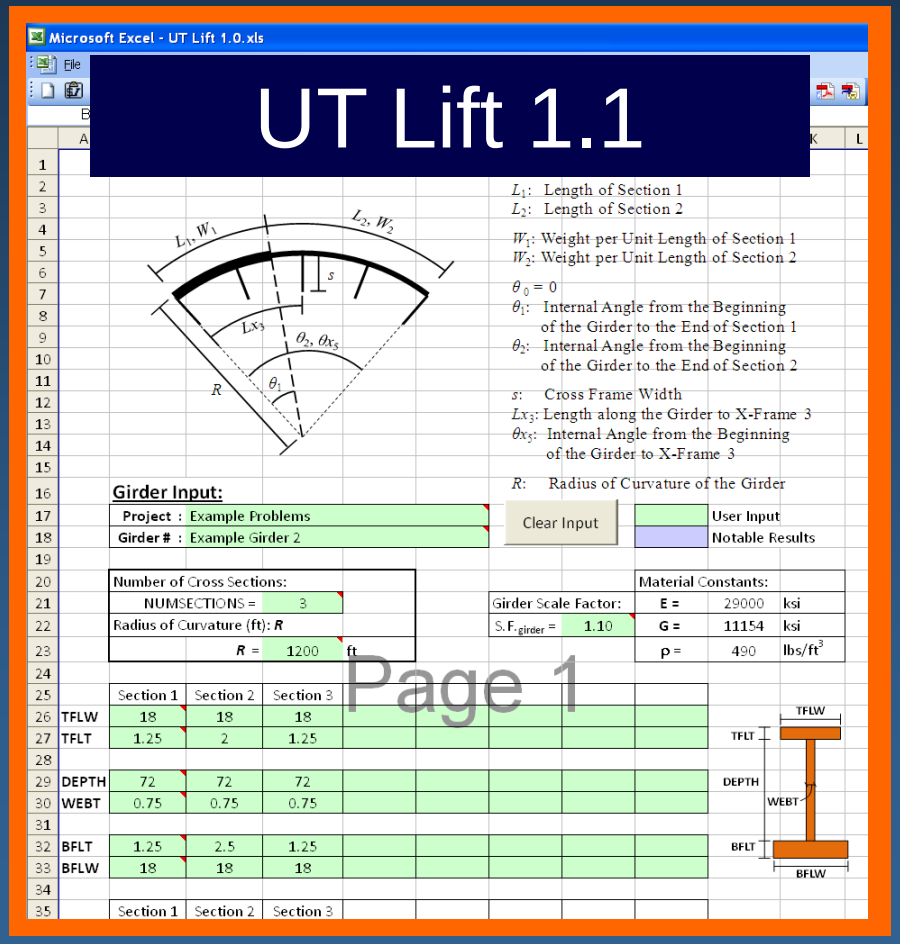
Lifting Point Locations



Shoring Issues

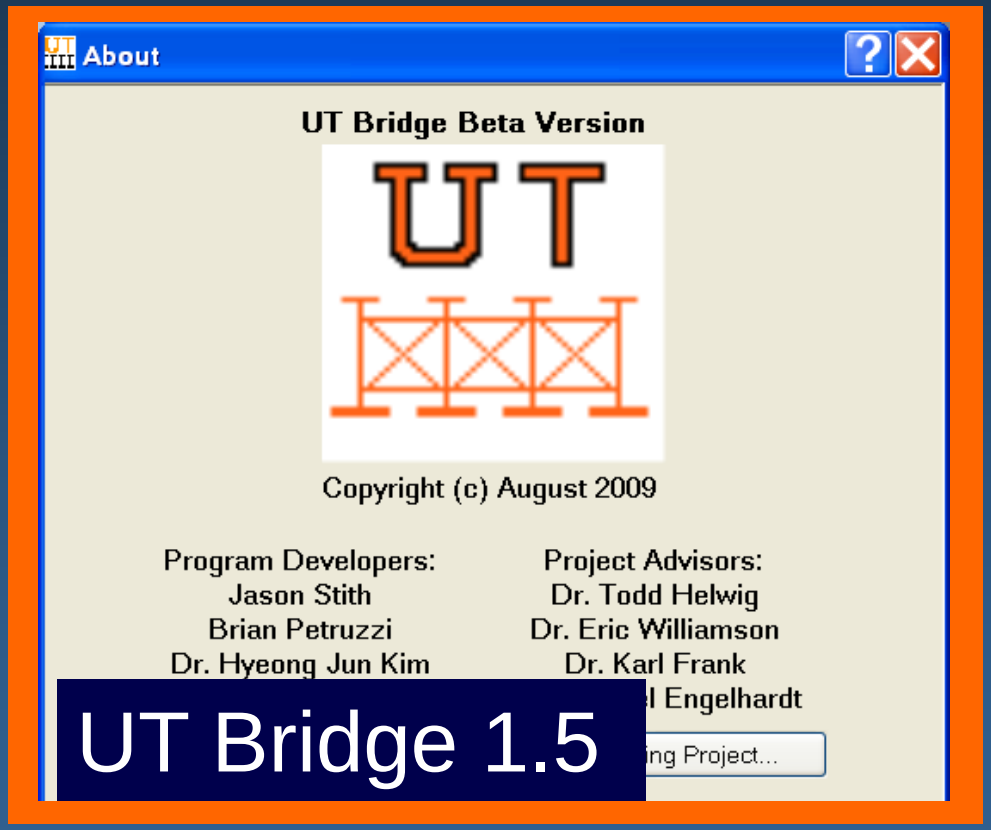
- High costs
- Premature removal
- Site access issues

ANALYTICAL TOOLS



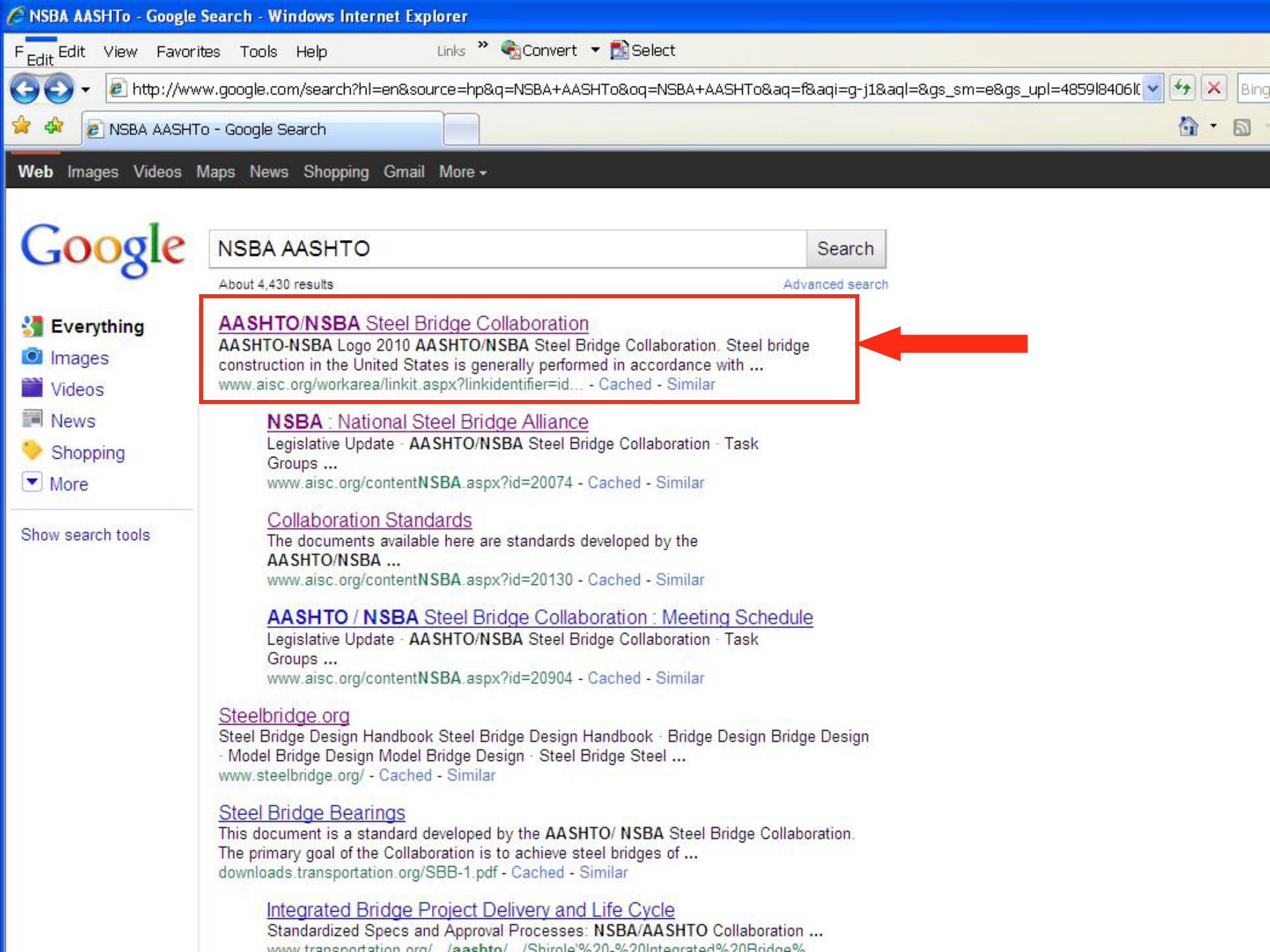
- Spreadsheet
- Behavior of girder segments during lifting
- Determines optimal lift locations
- Girder deformations
- Predicts girder twist

ANALYTICAL TOOLS



- 3D Finite Element Program
- Partially constructed girder systems
- Staged deck placement

National Steel Bridge Alliance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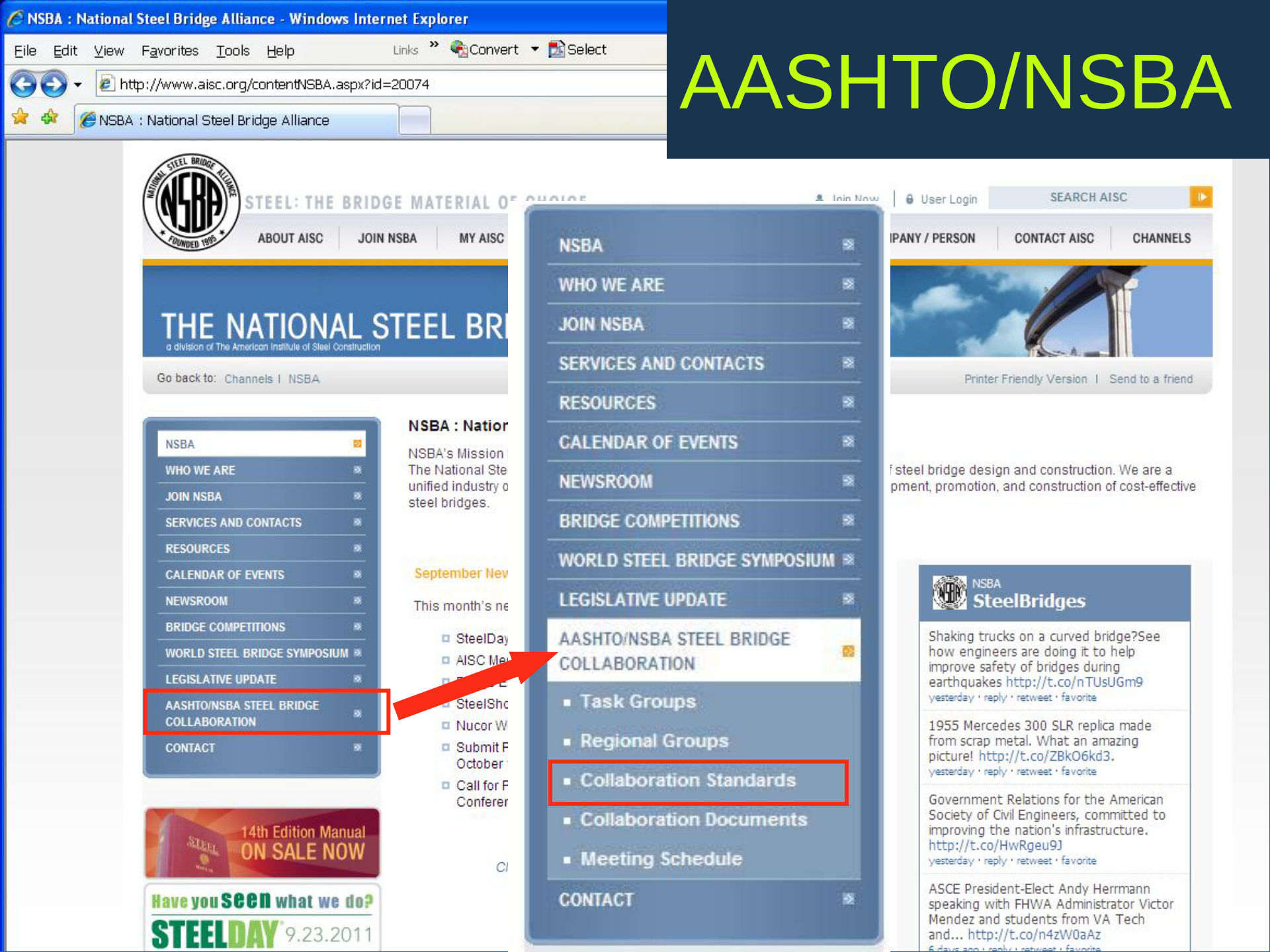
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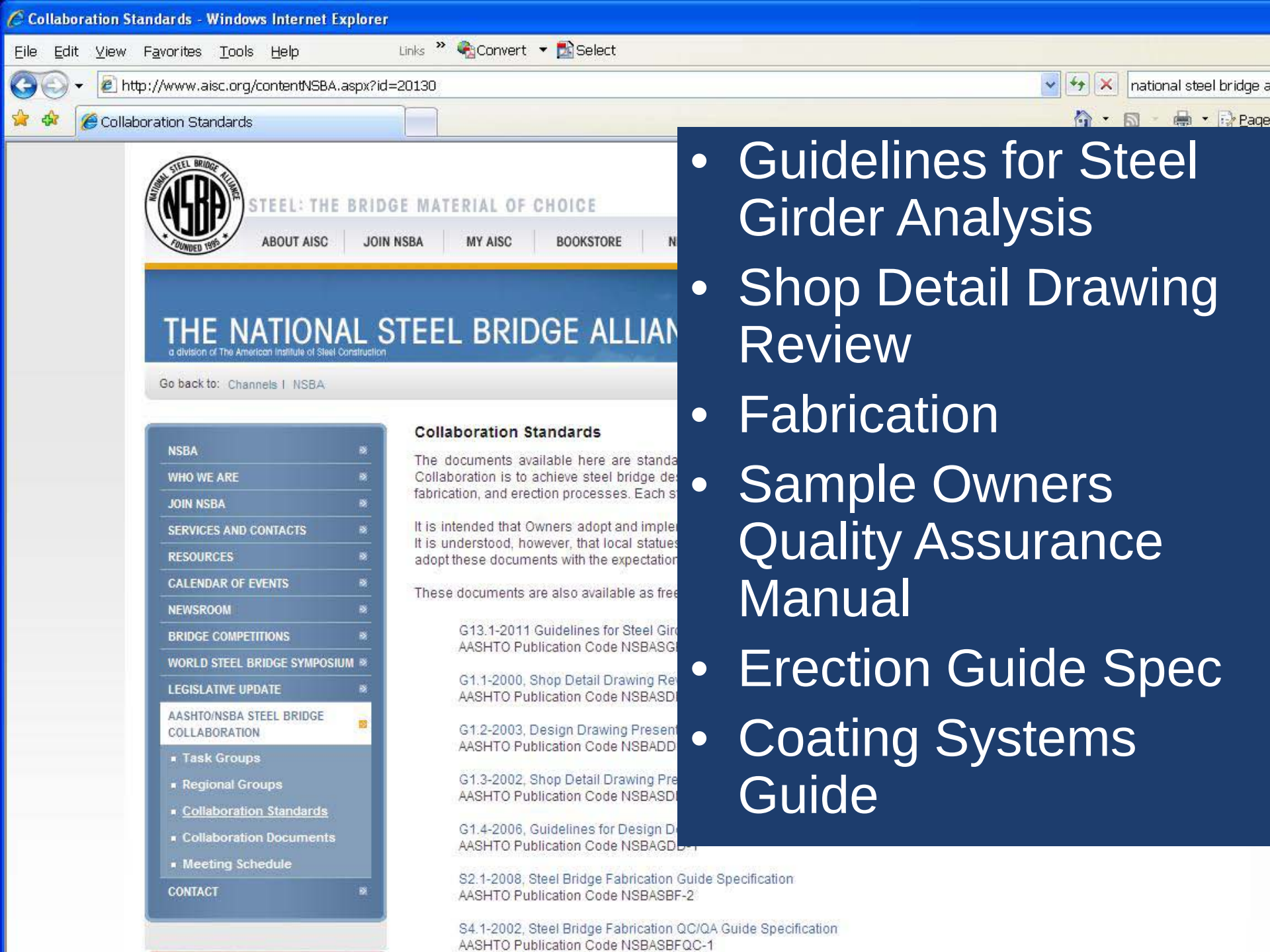

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- Shop Detail Drawing Review
- Fabrication
- Sample Owners Quality Assurance Manual
- Erection Guide Spec
- Coating Systems Guide

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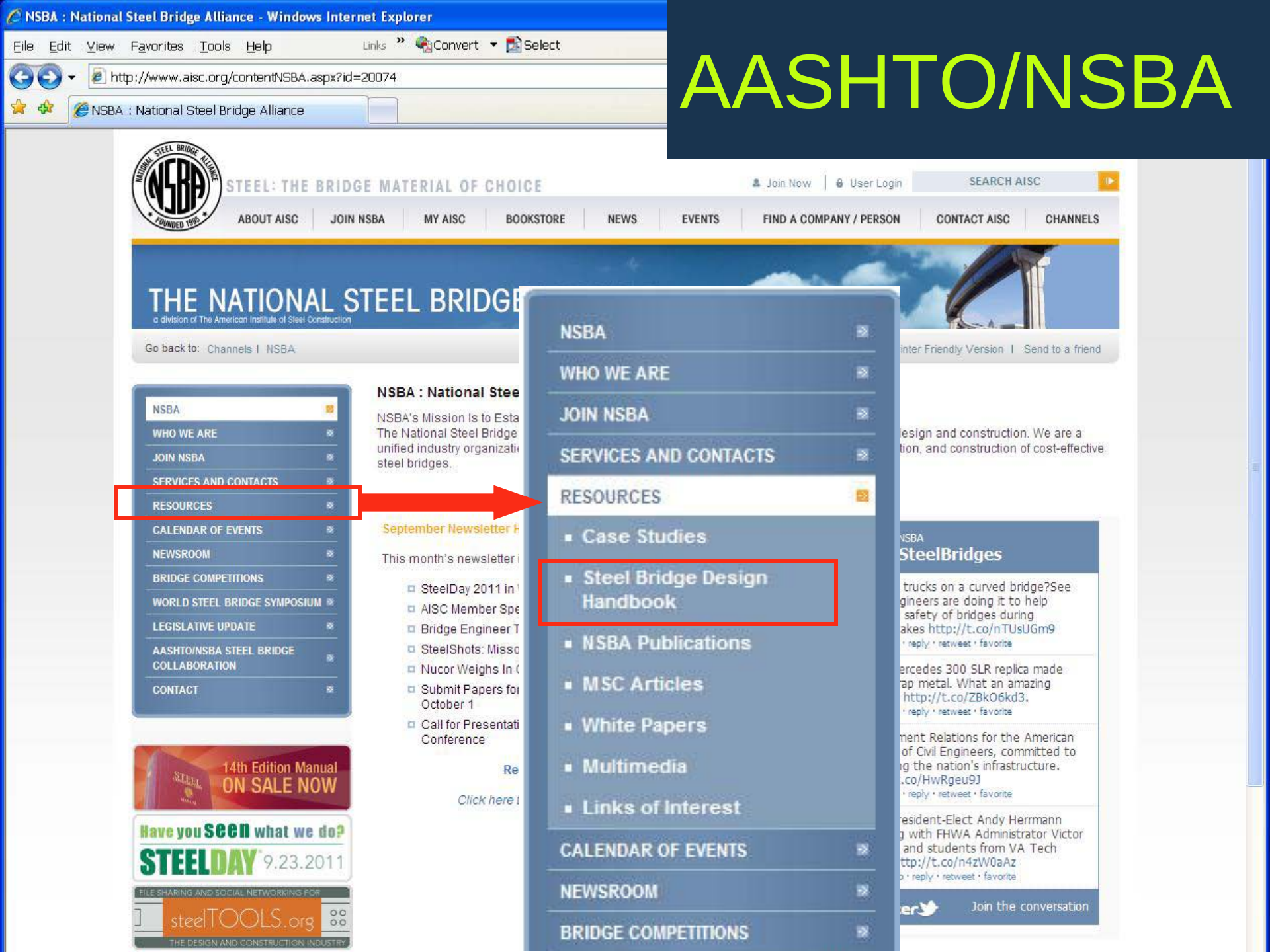
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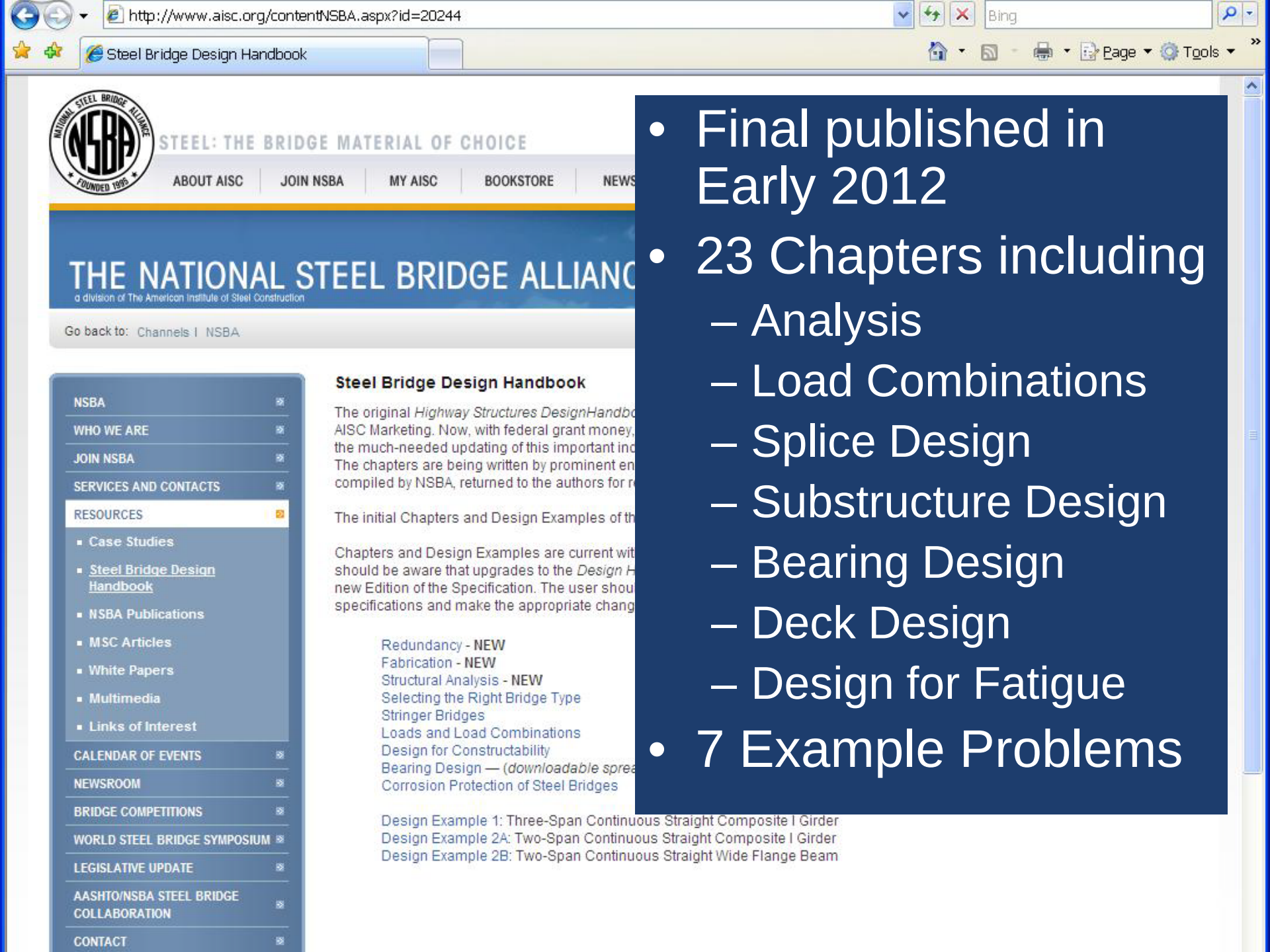

- Final published in Early 2012
- 23 Chapters including
  - Analysis
  - Load Combinations
  - Splice Design
  - Substructure Design
  - Bearing Design
  - Deck Design
  - Design for Fatigue
- 7 Example Problems

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Thank you!