So ... you want to design a steel bridge

• How and where do you start?
• Lots of important decisions to make
  • span layout
  • girder spacing
  • splice locations
  • cross frame locations
  • preliminary girder sizing
  • ...and no hard math
First ... Let’s Pick the Bridge Type

**Steel I-Beams**

- The most common steel bridge by far

**Steel Box Beams (Tub Girders)**

- Less common
- More frequently used for curved applications

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I-Girder Bridges ... some useful considerations

- If you “color inside these lines” simple analyses like line girder methods are applicable. (*important for later discussions on SIMON*)

<table>
<thead>
<tr>
<th>Concrete Deck or Filled Grid, Partially Filled Grid, or Unfilled Grid Deck Composite with Reinforced Concrete Slab on Steel or Concrete Beams; Concrete T-beams, T- and Double T-sections</th>
<th>a, e, k and also i, j if sufficiently connected to act as a unit</th>
<th>One Design Lane Loaded:</th>
<th>Two or More Design Lanes Loaded:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>(0.06 + \left(\frac{S}{14}\right)^{0.64} \left(\frac{S}{L}\right)^{0.3} \left(\frac{K_e}{12.0 L t_i^3}\right)^{0.1})</td>
<td>(0.075 + \left(\frac{S}{9.5}\right)^{0.6} \left(\frac{S}{L}\right)^{0.2} \left(\frac{K_e}{12.0 L t_i^3}\right)^{0.1})</td>
</tr>
</tbody>
</table>

- 3.5 \(\leq S \leq 16.0\)
- 4.5 \(\leq t \leq 12.0\)
- 20 \(\leq L \leq 240\)
- \(N_b \geq 4\)
- \(10,000 \leq K_e \leq 7,000,000\)

- Beam spacing \(\leq 16\) ft ... Common
- Span Length \(\leq 240\) ft ... Common
- 4 or more beams ... Common
Preliminary Design Resources

AASHTO / NSBA Design for Constructibility

Guidance and Rules of Thumb

- Spacing
- Plate Thickness
- Material Availability
- Flange & Web Sizing
- Bracing
- Details
NSBA Online Resources

Design Resources
NSBA provides a number of resources to help engineers during the preliminary design phase. These resources work from various levels of refinement toward the goal of generating economical steel solutions. Most coarse are the Steel Span to Weight Curves which provide steel weights, in pounds per square foot of bridge deck, for various span arrangements. The next level of refinement is the Continuous Span Standards. The Standards include pertinent steel information, such as plate sizes, steel weights, and camber diagrams, for three-span bridges. Finally, NSBA's LRFD Simon design and analysis software, is the most refined resource and is a powerful tool for generating preliminary designs that meet project constraints.

STEEL SPAN TO WEIGHT CURVES
The Steel Span to Weight Curves are the quickest way to determine the weight of steel per square foot of bridge deck for straight, low skew, plate girder bridges. They are also a great way to compare various span arrangements and girder spacings. With very little effort the weight per square foot can easily be converted to a potential dollar value for the steel superstructure.

CONTINUOUS SPAN STANDARDS
The Continuous Span Standards represent an excellent starting point for 3-span continuous steel plate girder design. They serve to help reduce the time required for preliminary bridge superstructure layout, girder plate sizing, and more.

From the Continuous Span Standards
Note – some predesigned layouts are available
• Narrowest spacing 7’-6”
• Widest Spacing 12’-0”

Many span choices with center spans from 150 – 300’
Spans assume end span = 78% of center span

For a given spacing and overhang, each drawing presents solutions for eleven different span-length systems. Four of the drawings represent homogeneous solutions (A709-50 or A709-50W steel), and four represent corresponding solutions for hybrid girders (A709-50 or A709-50W and A709-HPS70W steel). The general characteristics of the girder systems are:

● Four homogeneous and four hybrid drawings based upon 7’-6”, 9’-0”, 10’-6”, and 12’-0” girder spacings.
● Eleven conceptual solutions per drawing based upon 150’-0”, 165’-0”, 180’-0”, 195’-0”, 210’-0”, 225’-0”, 240’-0”, 255’-0”, 270’-0”, 285’-0”, and 300’-0” center spans.
● End span lengths based upon center span ratio = 78%.
● Included on each conceptual solution are tables presenting girder plate sizes, diaphragm spacings, intermediate stiffener sizes and locations, shear connectors.
Sample Design (I know you can't read this)

COMPOSITE PLATE GIRDER
12'-0" SPACING, 3'-6" OVERHANG
HYBRID
April 2015  DO NOT SCALE

FHWA Resources
Bridge Layout

- Let’s start at the beginning
  - How wide?
    - Generally “we” don’t decide
    - There are “highway engineers” for that
  - How long?
    - Many possible constraints to consider
  - How many spans?
    - Simple / continuous / etc.

Bridge Layout

How many beams / what spacing?
Spacing & Overhangs

Goal – relative force / material balance between beams

General Thoughts on Beam Spacing

From the NSBA G12 Document consider the following:

- Owner preferences and limitations
- Cost of steel fabrication, transportation, and erection
- Deck thickness and forming methods
- Provisions for future widening
- Vertical clearances

Also provisions for redecking (beam in the middle ?)
Typical Transverse Section

Example cross-section

- 40 ft roadway + 2 barriers at 1.5 ft = 43 ft out to out
- “X” beams @ “S” on center + 2 overhangs @ 0.28-0.35 “S”
- For a 4-beam section
  - 3 beams at “S”
  - 2 OH at 0.28 – 0.35 S
  - S max = 12’-1” S min = 11’-7”
- For a 5-beam section
  - 4 beams at “S”
  - 2 OH at 0.28 – 0.35 S
  - S max = 9’-5” S min = 9’-2”

From the NSBA Span Weight Curves
Girder Spacing – Some Final Thoughts

• Always provide the same size interior/exterior girder
• Wider beam spacing tends to be more economical
  • Balance this with the deck costs
• Use tools like SIMON (presented later) to explore different numbers of beams and determine a reasonable solution
• There is rarely a “best” solution
• Find several “good” ones and make a choice

Span Layout – the “Balanced Span” Arrangement

Continuous spans preferred for multi-span bridge
In a balanced span, positive moments are nearly equal

Balanced Span Arrangement

“Balance” is achieved with end spans 75% - 82% of center span
**Balanced Span Example – 3 Spans, 616 ft Total Length**

**Solid Red Line – Balanced**
- End span length ≈ 0.8 center span
- +M in end span ≈ 1.2 center span value

**Blue Dashed Line – Unbalanced**
- End span length ≈ 0.93 center span
- +M in end span ≈ 2.5 center span value
- +M in end span ≈ 33% greater than balanced span value

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**What Size is the Girder?**

- A function of span
- A function of available depth
- A function of spacing
- A function of fabrication and shipping limitations
Depth to Span Ratio
Composite Section

Suggested minimum overall depth of composite I-beam:

- **0.040L** for Simple spans
- **0.032L** for Continuous spans

\[ L = \text{total span length} \]

*AASHTO LRFD Article 2.5.2.6.3*

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Depth to Span Ratio
Bare Girder

Suggested minimum depth of I-beam portion only:

- **0.033L** for Simple spans
- **0.027L** for Continuous spans

\[ L = \text{total span length} \]

- *These rules – and those on the prior page – generally lead to girders too shallow to be economical*
- *Make the girder deeper if possible, but be practical (less than 10ft deep)*

*AASHTO LRFD Article 2.5.2.6.3*
**Minimum Web Thickness**

\[ (t_w)_{\text{min}} = \frac{7}{16}''; \]

\[ \frac{1}{2}'' \text{ preferred} \]

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**Flange Proportioning Limits**

\[ \frac{b_f}{2t_f} \leq 12 \]

\[ b_f \geq \frac{D}{6} \]

\[ 0.1 \leq \frac{I_{yc}}{I_{yt}} \leq 10 \]

\[ b_f \geq \frac{L}{85} \]

- *AASHTO LRFD* Article 6.10.2.2
- *AASHTO / NSBA Suggestion*
Bracing Considerations

- Determine a suitable brace type
- Determine a functional layout
- Old rules still good rules
  - i.e. the old 25 ft rule

Selection of Beam Bracing

Brace spacing influences flexural strength

But don’t go crazy
Spacing Requirements

<table>
<thead>
<tr>
<th>Closer Spacing</th>
<th>Larger Spacing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower cross-frame forces</td>
<td>Larger cross-frame forces</td>
</tr>
<tr>
<td>Lower lateral flange moments</td>
<td>Larger lateral flange moments</td>
</tr>
<tr>
<td>Higher compression-flange capacity</td>
<td>Lower compression-flange capacity</td>
</tr>
<tr>
<td>Higher cross-frame cost</td>
<td>Lower cross-frame cost</td>
</tr>
</tbody>
</table>

Spacing Requirements

Preliminary Spacing – Straight I-Girder Bridges

<table>
<thead>
<tr>
<th>Simple Spans &amp; Positive Moment Regions in End Spans</th>
<th>18 to 25 ft</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positive Moment Regions in Interior Spans</td>
<td>24 to 30 ft</td>
</tr>
<tr>
<td>Negative Moment Regions</td>
<td>18 to 24 ft</td>
</tr>
</tbody>
</table>
### Layout

Skews ≤ 20 degrees, may be placed parallel to supports

Skews > 20 degrees, must be placed perpendicular to girders and typically placed in a contiguous pattern

AASHTO LRFD Article 6.7.4.2

### Field Sections / Splice Locations

Again from G12

2.2.5 Girder Field Section Length

Use piece lengths that can be shipped by truck and allow the fabricator to add or move splices to optimize delivery. Girders can readily be shipped in lengths up to 120’. Depending on route and site constraints, pieces over 150’ and even approaching 175’ can be delivered.
People generally say the splice goes “at the point of inflection”

What does that mean?

FHWA SBDH Example 1

- 3-span continuous steel I-beam bridge
- 140-175-140
- 40’ roadway (43’ out to out)
- 4 beams @ 12’ center and 3’-6” overhangs

- Does this make sense?
Typical Section

43'-0"

40'-0" Roadway

1'-6"

2'-0"

10"

3'-6"

3 1/2"

3 1/2"

3 Spa at 12'-0" = 36'-0"

3'-6"

3.5' = 0.29S

9 1/2" Slab w/ 1/2" Integral Wearing Surface

F.W.S. at 25.0 psf

Span Layout

3 Spans, 140-175-140 (0.8L – L – 0.8L)

Balanced Span Arrangement

End spans 75% - 82% of center span
Field Section Lengths

Conclusion

• Major design decisions we just made drive the cost of the entire project
• Once these choices are made, the engineer has just locked in a major component of the price of the job
• Important to spend time “optimizing” this aspect of the design
• To reiterate, there isn’t a “perfect” solution. Study a few “good” ones and make a choice
THE BASICS OF STEEL BRIDGE DESIGN WORKSHOP