I-81 over Preble Road Bridge Hit

Coordinated Emergency Response and Retrofit
Project Location
What Happened?

• Tractor Trailer With Over-Height Backhoe
• Impacts Girders
  – Removes large sections of bottom flange
  – Deforms bottom flange
  – Bends Web
  – Cracked local welds in transverse stiffeners
• Traffic Stopped
• Bridge Load Posted
G-2 2nd Connection Plate Crack

04/27/2012
How to Determine Load Capacity?

• 4 of 5 Steel Beams Are Compromised

• Section Properties Changed
  • Bottom flanges have loss of section
  • Cracking introduced
  • Bottom flanges bent
  • Webs bent
  • Beams not symmetrical about vertical axis

• Steel Properties Changed
The stress-strain curve shows the mechanical properties of a material. The curve starts in the linear region, which is followed by a perfect plasticity or yielding region (AB). This is followed by a strain hardening region (BC), where the material resists further deformation. The curve reaches a peak stress at point C, indicating the ultimate stress. Beyond point C, the material begins to neck, which is followed by fracture (DE), leading to material failure.
How To Determine Capacity?

• Proof Load Test
  – Physical Non-Destructive Test

• Finite Element Analysis
  – Mathematical computer model – Ryan Lund

• Mathematical Analysis
  – Computational method based on formulas
Proof Load Test

• Provides Lower-Bound Limit for True Capacity
• Requires Larger Load Than Legal Load
• Target Proof Load Factor, $X_p$
  – Minimum of 40% higher than legal load
  – Could be less for single-trip permit loads
• In This Case, The Short Span Required:
  – Loads too high for truck axle
  – More than 7 layers of concrete barrier
Finite Element Analysis

• Requires Estimation
  – Boundary Condition
  – Material Properties
  – Girder Condition
  – Damage Locations/Severity

• Highly Accurate If The Estimates Are Correct
• Provides False Comfort/Worry If Incorrect
Mathematical Analysis

• Cannot Use Standard AASHTO Formulas
  – Damage invalidates most formula assumptions

• *Evaluation of Steel Bridge Girders Damaged by Over-Height Vehicle Collision*, Dawson, et al, August 2005
  – It is possible to determine the plastic moment capacity of a damaged girder.
  – *If the section properties of that damaged girder can be accurately determined.*
LIDAR Survey

- **Light Detection And Ranging**
- Uses Laser Direction and Time to Locate Points
- Points Become ‘Cloud’
- CADD Uses Point Cloud to Locate Lines and Surfaces
- Video of LIDAR Point Cloud
LIDAR Determined Beam Shape
# Damaged Girder Properties Using STAAD-Pro Section Wizard

<table>
<thead>
<tr>
<th>Section element</th>
<th>Rotation Angle</th>
<th>Material</th>
<th>E (kip/inch^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sheet 3.93701 x 0.551181</td>
<td>75.0</td>
<td>Steel</td>
<td>29732.747</td>
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<td>Sheet 5.90551 x 0.551181</td>
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<tr>
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<td>85.0</td>
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<tr>
<td>Sheet 6.49606 x 0.551181</td>
<td>85.0</td>
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<tr>
<td>Sheet 10.4724 x 0.748031</td>
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<tr>
<td>Sheet 2.625 x 0.75</td>
<td>-23.0</td>
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<td>29732.747</td>
</tr>
<tr>
<td>Sheet 5.25 x 0.75</td>
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<tr>
<td>Sheet 6 x 0.75</td>
<td>-23.0</td>
<td>Steel</td>
<td>29732.747</td>
</tr>
<tr>
<td>Sheet 2.625 x 0.75</td>
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<td>Steel</td>
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</tr>
</tbody>
</table>

Angle between Y-Z and U-V axes: \(-11.41\) degrees

\(Z_{pl,u}\) Plastic modulus about U-axis: \(397.22\) inch^3

\(Z_{pl,v}\) Plastic modulus about V-axis: \(55.93\) inch^3
Span 2 Right Elevation

04/30/2012
Determining Moment Capacities

\[ M_{pl_u} := F_y \cdot Z_u \]
This is about the axis that lies almost horizontal

\[ M_{pl_v} := F_y \cdot Z_v \]
This is about the axis that lies almost vertical

The angle from local axis to global axis is \( \alpha \).

\[ \alpha := 11.41^\circ \]

The plastic moment capacity of the beam along the global axes (X-Y) is determined to be:

\[ M_{pl_x} := \frac{M_{pl_u}}{\cos(\alpha)} \quad M_{pl_x} = 1 \text{ kip}\cdot\text{in} \]

\[ M_{pl_y} := \frac{M_{pl_v}}{\sin(\alpha)} \quad M_{pl_y} = 1 \text{ kip}\cdot\text{in} \]
Determining Rating Factor

The LRFR Operating Rating for the beam subjected to the Type 7 loading can be determined by:

\[
M_{LL\_Type\_7} := 1044 \text{kip\cdot in per axle}
\]

\[
M_{LL\_Type\_7\_I} = M_{LL\_Type\_7} \cdot LLDF \cdot I = 1.019 \times 10^3 \cdot \text{kip\cdot in}
\]

\[
\gamma_{DC\_mod\_7} := 1.25 \quad \gamma_{DW\_mod\_7} := 1.25 \quad \gamma_{LL\_mod\_7} := 1.2
\]

\[
OR_7 := \frac{\phi \cdot \phi_c \cdot \phi_s \cdot \left(\min\left(M_{pl\_x}, M_{pl\_y}\right)\right) - \gamma_{DC\_mod\_7} M_{DC} - \gamma_{DW\_mod\_7} M_{DW}}{\gamma_{LL\_mod\_7} \left(M_{LL\_Type\_7\_I} + M_{DLL}\right)}
\]

\[
OR_7 = 1.073
\]
tani of 11
New int. stiffeners
Place as shown - 5 x 1/2" (typ.)

Total of 10
New Brdg. stiffeners
2 - 5 x 5/16" (typ.)

DE = Existing diaphragm
DN = New diaphragm
Area to be Removed

2.5" (min.)

Example Crack

2" min Radius

Note: All crack tips to be cut-out and ground smooth.
Timeline

• April 27: Bridge Damaged
• April 28: Region 3 Maintenance Shores Structure/Load Posting Issued
• May 9: Region Calls TR&BD – Structures Unit
• May 21: Initial Response From TR&DB – Structures Unit
• June 8: NYSDOT Photogrammetry Completes LIDAR Modeling
• June 11: Final Details from TR&DB – Structures Unit
• June 29: Repairs Completed/Load Posting Removed
Conclusion

• Region called TR&DB-Structures Unit Because:
  – Contracting out takes too long
  – Contracting out costs too much
  – Analysis is not straight-forward
  – There is no other unit in NYSDOT that does what the TR&DB-Structures Unit does
    • Specific knowledge/skills
    • Specific equipment/training
1) The Modulus of Elasticity changes after the material yields (T/F)

2) The three methods for determining the capacity of a damaged beam are _____, _____, _____?

3) LIDAR stands for Light Detection and Reading (T/F)

4) AASHTO formulas are appropriate for damaged girders (T/F)

5) Contracting out services for emergencies is more efficient and cost-effective than having those services in-house (T/F)