Railway Bridges Up-to-Date

Stephen Dick, PhD, SE
Senior Research Engineer
Bowen Laboratory
Lyle School of Civil Engineering
Railway Bridges Up To Date

- Railroad system in general
- Railroad environment
- Bridge design philosophy
- Bridge types
- Steel and fatigue
- New technologies
United States Railway System

• US rail network is 137,000 route miles
  - Indiana 3,786 route miles
• 200,000 employees (rr’s only)
• Three tiers of railroad (revenue)
  - Class I – $447,621,226  7 (+Amtrak)
  - Class II – $35,809,698   21
  - Class III – everything else  510
US Railway System
Class 1 Business Statistics – 2018

- Total revenue – $76.2 billion
- 26,000 locomotives (40,000 for all railroads)
- 1.67 million freight cars (total)
- Total reported asset base – $253.5 billion
- Capital Expenditures – $12.4 billion
Regulatory Environment

• Two main federal agencies
  • Surface Transportation Board (STB)
    • Financial and corporate regulation
  • Federal Railroad Administration (FRA)
    • Operations, maintenance, and safety enforcement
Regulatory Environment (2)

• Federal Railroad Administration (FRA)
  • Regulation of railroad bridges
    • Title 49 CFR Part 237 requires:
      • a Bridge Management Plan
      • a Load Rating for all bridges
      • annual bridge inspections
Self-Regulatory Environment

• Association of American Railroads (AAR)
  • Regulates the design and construction of freight railcars
  • Regulates some maintenance issues on railcars
  • Regulates and provides accounting services for interchange and other billings between railroads
Self-Regulatory Environment (2)

• Association of American Railroads (AAR)
  • Regulates the maximum axle weights and total railcar weights for the railroad system
  • Maintains minimum length and axle spacing requirements for railcars
• Federal Railroad Administration
  • Regulation of railroad bridges
    • Title 49 CFR Part 237 requires:
      • a Bridge Management Plan
      • a Load Rating for all bridges
      • annual bridge inspections
Historical Operating Data

Originated Carloads


15,000,000 25,000,000 35,000,000 45,000,000 55,000,000
Historical Operating Data (4)

Average Freight Car Capacity

- Data spans from 1915 to 2020
- Capacities range from 35.0 to 115.0

Graph showing the increase in average freight car capacity over time.
Historical Operating Data (5)

Average Tons per Carload


Tons per Carload: 20, 30, 40, 50, 60, 70
Railroad Train Loadings

- CURRENT CONDITIONS:
  - Heavy train conditions ≥ 50 trains per day
  - Train lengths – up to 10,000 feet are common
    - Increases in lengths are planned for some railroads
  - Train weights – 15,000 to 20,000 tons for bulk commodity trains, “light passenger trains” 500 -1,000 tons
  - Number of cars – unit trains 60 – 200 cars
    manifest (mixed) trains 100 – 150 cars
Railroad Train Loadings (2)

- Design Loading – Cooper E Loading system
  - Maximum 80,000 lb. axle loads (current E-80)

- Actual Loads:
  - Maximum car weight of 286,000 lbs. on four axles (interchange)
    - Up to 315,000 lbs and higher by special movements
  - Railcars designed to load to maximum weights
    - Railcar lengths from 42 – 95 feet
The Specialized Loads
And a Bad Day at the Office
Bridge Design Philosophy

• Highway Bridges
  • LRFD for all bridge designs
  • Specifications published by AASHTO
  • Integral abutments and other modern design details

• Railway Bridges
  • ASD for steel bridge designs
  • LFD or ASD for concrete bridge designs
  • Recommendations published by AREMA
  • Discrete construction without modern appurtenances installed

WHY?
Bridge Design Philosophy (2)

• LRFD – Highway Bridges
  • Advantageous in continuous spans
  • Dead load simple/live load continuous spans
  • Deflection to resist the loads on the bridge

• ASD – Railway Bridges
  • Simple spans
  • Deflection controls track surface requirements, not load
  • Deflection requirements are more stringent than load requirements
Bridge Design Philosophy (3)

• LRFD – Highway Bridges
  • LRFD provides sufficient strength but deflection must be checked
  • LRFD provides a safety margin for extreme events

• ASD – Railway Bridges
  • Stringent deflection requirements drive the section size with stresses from live loads easily handled
  • No advantage to using LRFD for simple spans
  • Railroad trains loading the bridge are the extreme event
Bridge Design Philosophy (4)

• Highway Bridges
  • Economy of section with continuous spans
  • Different measures for protection of bridge elements
    • i.e., we don’t intentionally salt railway bridges anymore

• Railway Bridges
  • Simple spans are easier and faster to maintain and replace
  • Reduction of maintenance and construction time “Time is money.”
  • Exposed elements easier to inspect
  • Accelerated bridge construction a fact of life for railroads to keep the track open for running trains.
Railroad Bridge Design Loads

- Live Load – Cooper E Load
  - Span Lengths 0 – 400 feet (130m)
- Cooper E80 Load

![Diagram showing load distribution for different span lengths with 8,000 lb per lin ft]
Railroad Bridge Design Loads (2)

- Live Load – Alternate Load (Steel Bridges Only)
  - Axle load 25% greater than Cooper E80
  - Useful for short spans, floor systems
  - Creates maximum design moment up to 50 feet
  - Better representation of actual loadings
# AAR Railcar Minimum Requirements

<table>
<thead>
<tr>
<th></th>
<th>Gross Rail Load - 220,000 lbs</th>
<th>Gross Rail Load - 286,000 lbs</th>
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<tbody>
<tr>
<td>Overall Length</td>
<td>35 ft 0-1/2 in</td>
<td>41 ft 10-1/2 in</td>
</tr>
<tr>
<td>Truck Centers</td>
<td>20 ft 6 in</td>
<td>27 ft 4 in</td>
</tr>
<tr>
<td>Truck Wheelbase</td>
<td>5 ft 8 in</td>
<td>5 ft 10 in</td>
</tr>
</tbody>
</table>
# AREA/AREMA Bridge Design Levels

<table>
<thead>
<tr>
<th>Time Period</th>
<th>Design Level (Cooper)</th>
<th>Impact Equation (Year)</th>
<th>Allowable Stress (ksi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1906-1919</td>
<td>E40</td>
<td>1906</td>
<td>16</td>
</tr>
<tr>
<td>1920-1934</td>
<td>E60</td>
<td>1920</td>
<td>16</td>
</tr>
<tr>
<td>1935-1947</td>
<td>E72</td>
<td>1935</td>
<td>18</td>
</tr>
<tr>
<td>1948-1967</td>
<td>E72</td>
<td>1948</td>
<td>18</td>
</tr>
<tr>
<td>1968- present</td>
<td>E80</td>
<td>1968</td>
<td>20</td>
</tr>
</tbody>
</table>
Steel Bridge Design Impact

![Graph showing impact vs. span length for different steel bridge designs with labels: 1920 E60 Hammer Blow, 1948 E72 Hammer Blow, 1935 E72 Hammer Blow, 1906 E40 Hammer Blow, and Rolling Impact. The x-axis represents span length in feet, and the y-axis represents impact percentage.]
Girder Section Modulus Requirements

![Graph showing girder section modulus requirements vs. span length, with different curves for different years: E72 1935, E72 1948, E60 1920, E40 1906, E80 1968.](image)
Approximately 1600 miles of bridge
On the Class 1 system

Estimated 1/3 of all bridges are steel riveted deck girders
Timber Bridges

• Timber trestles are the vast majority of the timber bridges still in inventory

• Population is declining due to multiple factors
  • Lack of quality timber
  • Loading increases makes wood insufficient to handle the required loads and stresses
  • Creosote treatment is a hazardous material

• Eventually will be gone from Class I railroads
Timber Bridges
Timber Bridges (2)
Sometimes a fire problem exists
Did I mention that they burn?
Concrete Railway Bridges

- Currently, the main use of concrete for railway bridges is:
  - Specialty cast-in-place structures
  - Prestressed concrete beams for superstructure
  - Precast concrete elements for substructure
  - Timber trestle replacements also as a standard
Concrete Railway Bridges (2)

• Prestressed superstructure elements:
  • Slab beams for trestle replacement
  • Double-voided box beams for trestle replacement
  • AASHTO section I-beams for longer spans
  • Tall Tee beams for the longest spans
  • Maximum practical span length for Cooper E80 is about 100 feet for Tee Beams
Concrete Railway Bridges (3)
Concrete Railway Bridges (4)
Concrete Railway Bridges (5)
Concrete Railway Bridges (6)
Concrete Railway Bridges (7)
Steel Railway Bridges

• The largest part of the bridge inventory
• Used for beams, girders, and trusses
• Riveted deck girders are the main type
• Eyebar-Pin trusses are still great in number
  • Built mainly before World War I
  • Load capacity could be an issue
Steel Girder Bridges

Deck Girder

Through Girder
Steel Girder Construction
Steel Girder Rule of 75’s

• Approximately 75% are 75 years old or older
• Approximately 50% are 100 years old or older
• Most are riveted (Fatigue Category D)

• Approximately 1/3 of all railway bridges are steel deck girders
• Typically two girders per track for older spans
Modern Steel Girders – 200 feet long
Modern Steel Girders – 200 feet long (2)
Modern Steel Girders – 200 feet long (3)
Modern Steel Girders
Hillman Composite Beam (HCB®)

• A new technology
  • A tied concrete arch inside a box
  • Box is fiberglass
  • Prestressing strand used to tie the arch
  • Proprietary technology
Hillman Composite Beam (HCB®)

• Light weight alternative
• Requires only one crane for lift
• Replaces three trestle spans versus two for prestressed concrete
Hillman Composite Beam (HCB®)
Hillman Composite Beam (HCB®) (2)
Hillman Composite Beam (HCB®)
Hillman Composite Beam (HCB®)
Thank You!