Development of Bridge Load Rating Techniques Using Physical Testing

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The Problem

- Posted bridges and bridges with unknown strength and behavior.
- Limited financial resources.
- Code equations that are usually very conservative at predicting bridge behavior.
The Problem

- Unknown bridge conditions
  - Load distribution.
  - End restraint.
  - Edge stiffening.
  - Composite action.
  - Effectiveness of specific bridge details.
  - Other details contributing to bridge capacity.
The Solution

- Use physical testing to understand the specific characteristics of each bridge.
- Use field collected data to calibrate a computer constructed model of the bridge.
- Use the accurate, calibrated computer model to determine bridge response to rating vehicles and other loads.
An Integrated Testing System

- Hardware and software suite.
- Integrated and seamless through all steps
  - Field testing.
  - Data presentation.
  - Model generation.
  - Model calibration.
  - Rating.
Data Collection Hardware

- Hardwired strain gages with variable gage lengths.
Data Collection Hardware

- Strain gage junction box
  - Balance and control strain gages.
  - Collect and temporarily store data.
  - Communicate with PC.
Data Collection Hardware

- Wireless truck position indicator.
Data Collection Hardware

- Power unit and PC
  - Power and control entire system.
Software Suite

• WinGRF
  - Relates truck position with strain data.
  - Prepare visual summaries of data
    » Strain.
    » Neutral axis location.
    » Curvature.
  - Allows engineer to study the data for behavioral interpretation.
Software Suite

• **WinGEN**
  - Construct bridge model
    » Overall geometry.
    » Material characteristics.
    » Section properties.
    » Support conditions.
  - Define loading conditions.
  - Establish optimization parameters.
  - Create analysis file.
Software Suite

- **WinSAC**
  - Performs analysis.
  - Performs optimization calculations
    » Linear least squares method of error reduction.
Hardwired strain gages

Wireless truck position indicator

Model analysis and optimization with field collected data

Accurate Assessment

Structural modeling

Engineering based data interpretation

Mid-Continent Transportation Symposium

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Diagnostic Testing of a bridge

- Boone County Bridge #11 on L Road.
- 38 ft - 10 in. single span.
- Eight girders with timber deck.
- Damaged exterior girder.
40 Intelliducers at 20 locations used.

Focused on:
- Composite action.
- End restraint.
- Load distribution.

Instrumented:
- Six of eight girders.
Load Position

- Three different load paths defined - loaded truck tandem axle dump truck.
- Each path addressing a key attribute.
Test Results-Minimal End Restraint

![Graph showing test results for Minimal End Restraint with Microstrain vs. Truck Position, ft. The graph includes multiple lines representing different locations (Bottom Flange, Location L4, Top Flange, Location L4, Bottom Flange, Location L8, Top Flange, Location L8).]
Test Results - Transverse Symmetry

Microstrain vs. Truck Position, ft

-250 -200 -150 -100 -50 0 50 100 150 200 250

0 10 20 30 40 50 60 70

-250 -200 -150 -100 -50 0 50 100 150

Top Flange, Path Y1, Location L10
Bottom Flange, Path Y1, Location L10
Bottom Flange, Path Y3, Location L5
Top Flange, Path Y3, Location L5
Modeling

- Model created using WinGen.
- Based on plan geometry and field measurements.
- 3 total element groups
  - Steel girder stiffness ($I_y$).
  - Timber deck stiffness ($E$).
  - Abutment stiffness ($K_y$).
Modeling Results

- All elements groups optimized
  - Girders found to have higher stiffness than code predicted.
  - Deck found to have less stiffness than code predicted.
  - Approximately 8% fixity.
- Resulted in 1.8% error when optimized.
Typical Modeling Results

![Graph showing typical modeling results with truck position on the x-axis and microstrain on the y-axis. The graph includes data for bottom flange analytical, top flange analytical, bottom flange experimental, and top flange experimental.]
Typical Modeling Results

-250
-200
-150
-100
-50
0
50
100
150
200
250
0 10 20 30 40 50 60 70
Truck Position, ft
0
-50
-100
-150
-200
-250
Microstrain

Top Flange Analytical
Bottom Flange Analytical
Top Flange Experimental
Bottom Flange Experimental
Rating

- Traditional AASHTO LFD Calculations.
- HS-20 Load Vehicle.
- Shear limit:
  - 3.94 Inventory.
  - 4.22 Operating.
- Flexural limit:
  - 0.92 Inventory.
  - 1.52 Operating.

- Physical Test Based Calculations.
- HS-20 Load Vehicle.
- Shear limit:
  - 4.78 Inventory.
  - 7.61 Operating.
- Flexural limit:
  - 1.31 Inventory.
  - 1.54 Operating.
Results of testing

- Impact of damaged member verified
- Increased rating
  - 42.4% for flexure
  - 21.3% for shear
Superload Evaluation

- Summer 2003 – Passage of 6 superloads ranging from 600,000 lb – 900,000 lb.
- Most bridges along route acceptable by traditional calculations.
- Hand calculations for one bridge – rating factor of approximately 0.5!
- Physical test needed.
Bridge Characteristics

- Six pre-stressed concrete girder lines.
- Critical span ~ 122 ft.
- 40 ft roadway carrying two lanes of traffic.
Initial Testing

- Tested with combinations of one and two loaded tandem axle dump trucks.
- Much learned about behavior
  - Composite action.
  - End restraint.
  - Load distribution
    » Improved load distribution characteristics improved hand calculations to above 0.9.
Analytical Modeling

- Bridge modeled using WinGEN
  - 7 element groups created and optimized.
- Less than 10% error.
Analysis with Superload

- Optimized model used to predict bridge behavior to anticipated load.
- Determined to be acceptable.
Monitoring During Passage
Accuracy of Prediction
Conclusions

- System is well suited to rating “typical” highway bridges
  - Materials
    » Steel.
    » Concrete.
    » Timber(?).
  - Type:
    » Simple span.
    » Continuous span.
    » Truss.
Conclusions

- System is well suited to evaluating bridges for the passage of superloads.