Evaluation of the true behaviour of the end supports in the Carbajal de la Legua Bridge

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Overview

1) Motivation

2) Bridge site

3) Preliminary studies

4) Testing and Measurements

5) Analysis of Results

6) Conclusions
**Motivation**

**Priority in 1970's & before:**

Durability is a hugely important issue – most bridges deteriorate well within their 100 year design lives.

**Ease of analysis & repair**

*But Bearings wear (teflon coating "flows") and need to be replaced*

*However they are sometimes necessary to allow for movement and for relieving stress*

- **Neoprene strips** (for inverted T-beam bridges)
- **Elastomeric bearings** (some resistance but allow translation & rotation; can be free, fixed or guided)
- **Spherical bearings**
Bridge structure over the river Bernesga in Carbajal de la Legua, a small town in the municipality of Sariegos, nearby Leon, Spain. The
Bridge site 2014

View from the North

View from the South

View From the West
How are these supports performing?

East support of South beam

a. Signs of damage at the support
b. Bearing detail

(1) To perform static tests on the third span by means of a five-axle truck.
(2) Data from these tests is collected using surveying techniques
(3) Data is used to calibrate a mathematical model of the structure. A variety of models is
Bridge Site 2014

Depth to Span ratio of 1 to 10

Inspected span

E 16.42 16.22 15.96 15.95 W
1.09 13.89 13.33 13.07 13.41
Span No. 1 Span No. 2 Span No. 3 Span No. 4

SECTION A-A'

SECTION B-B'

South Beam North Beam South Beam North Beam
MOMENTS IN BEAMS

LONGITUDINAL

TRANSVERSE

STRESSES IN SLAB

LONGITUDINAL

TRANSVERSE
MOMENTS IN BEAMS

LONGITUDINAL

STRESSES IN SLAB

LONGITUDINAL

TRANSVERSE

TRANSVERSE
Gross Vehicle Weight (GVW): 40.29 tonnes

Electronic tachymeter (TCRP1201)
Analysis of results

West

East

PINNED - PINNED

PINNED - FIXED

PINNED - FIXED

FIXED - FIXED

EI?

EI?

EI?

EI?
### Estimation of Stiffness for Beam Model with Pinning

<table>
<thead>
<tr>
<th>Stiffness (MN·m²)</th>
<th>NORTH BEAM</th>
<th>SOUTH BEAM</th>
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</thead>
<tbody>
<tr>
<td>Pin-pin (E)</td>
<td>4960</td>
<td>6077</td>
</tr>
<tr>
<td>Pin-fix (E)</td>
<td>2194</td>
<td>2689</td>
</tr>
<tr>
<td>Fix-pin (E)</td>
<td>1811</td>
<td>2209</td>
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<tr>
<td>Fix-fix (E)</td>
<td>959</td>
<td>1169</td>
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<table>
<thead>
<tr>
<th>Scenario</th>
<th>Case</th>
<th>Run</th>
<th>Run</th>
<th>Run</th>
<th>Run</th>
<th>Run</th>
<th>Case</th>
<th>Run</th>
<th>Run</th>
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<tbody>
<tr>
<td>A</td>
<td>4960</td>
<td>2194</td>
<td>1811</td>
<td>959</td>
<td>6077</td>
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<tr>
<td>B</td>
<td>6830</td>
<td>2642</td>
<td>3022</td>
<td>1430</td>
<td>5922</td>
<td>2324</td>
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<td>1255</td>
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<tr>
<td>C</td>
<td>4879</td>
<td>1770</td>
<td>2165</td>
<td>939</td>
<td>3579</td>
<td>1302</td>
<td>1592</td>
<td>694</td>
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<tr>
<td>D</td>
<td>4400</td>
<td>1929</td>
<td>1729</td>
<td>929</td>
<td>3770</td>
<td>1669</td>
<td>1474</td>
<td>801</td>
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<tr>
<td>Mean</td>
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<td>2134</td>
<td>2182</td>
<td>1064</td>
<td>4837</td>
<td>1996</td>
<td>1972</td>
<td>980</td>
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<td>Standard Dev</td>
<td>1071</td>
<td>3810</td>
<td>5913</td>
<td>2442</td>
<td>1344</td>
<td>6263</td>
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<tr>
<td>COV</td>
<td>0.0216</td>
<td>0.1827</td>
<td>0.2702</td>
<td>0.3023</td>
<td>0.2869</td>
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<tr>
<td>RMSE</td>
<td>1.519</td>
<td>1.515</td>
<td>1.519</td>
<td>1.513</td>
<td>1.511</td>
<td>1.511</td>
<td>1.511</td>
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</tbody>
</table>

Based on a gross inertia of 0.228 m⁴ and a typical modulus of elasticity of reinforced concrete, solution expected to lay between 4560.
**Analysis of results**

Spring constants are considered to vary from $10^0 \text{ MN}\cdot\text{m}/\text{rad}$ to $10^6 \text{ MN}\cdot\text{m}/\text{rad}$.
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### Analysis of Results

Estimation of Section Stiffness and Spring Constants at the Supports

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Pin-Pin Stiffness (MN/m²)</th>
<th>K\text{West} (MN/m/rad)</th>
<th>K\text{East} (MN/m/rad)</th>
<th>Pin-Pin Stiffness (MN/m²)</th>
<th>K\text{West} (MN/m/rad)</th>
<th>K\text{East} (MN/m/rad)</th>
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<tbody>
<tr>
<td>A</td>
<td>4960</td>
<td>10^{0.2}</td>
<td>10^{2.3}</td>
<td>6077</td>
<td>10^{2.8}</td>
<td>10^{2.5}</td>
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<tr>
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<td>6830</td>
<td>10^{2.68}</td>
<td>10^{2.7}</td>
<td>5922</td>
<td>10^{3.3}</td>
<td>10^{0}</td>
</tr>
<tr>
<td>C</td>
<td>4879</td>
<td>10^{2.3}</td>
<td>10^{2.7}</td>
<td>3579</td>
<td>10^{0}</td>
<td>10^{1.5}</td>
</tr>
<tr>
<td>D</td>
<td>4400</td>
<td>10^{3.1}</td>
<td>3770</td>
<td>4837</td>
<td>10^{0}</td>
<td>10^{2.5}</td>
</tr>
<tr>
<td>Mean</td>
<td>52.67</td>
<td>17.4</td>
<td>67.4</td>
<td>42.85</td>
<td>67.6</td>
<td>16.6</td>
</tr>
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</table>

RMSE has decreased but there is a larger variability of the results and the values of EI are unrealistically low.
Pareto criterion is employed to decide which point represents the best combination of parameters for the beam models. There is a trade-off since COV decreases (from 0.34 to 0.09 in North beam and from 0.28 to 0.23 in South beam) but RMSE increases slightly (from 1.22 to 1.5 mm in North beam and from 1.45 to 1.6 mm South beam).

Values of $10^0 \text{ MN} \cdot \text{m} / \text{rad}$ for $K_{West}$, $10^{0.5} \text{ MN} \cdot \text{m} / \text{rad}$ for $K_{East}$ and $10^{0.375} \text{ MN} \cdot \text{m} / \text{rad}$ for $K_{West}$, $10^{0.25} \text{ MN} \cdot \text{m} / \text{rad}$ for $K_{East}$.
The health of an old bridge located near León (Spain), in particular its stiffness and support conditions, have been assessed via surveying measurement of deflections due to static loading tests.

The values of $EI$, $K_{East}$ and $K_{West}$ are relatively homogeneous for both beams, being the boundary conditions very similar to a simply supported beam. It is true that $EI$ of the South beam is slightly smaller than that of the North beam, which appears to be in agreement with a preliminary visual inspection, however, the impact on the structural response is not significant.

It is important to take into account the uncertainty associated to the measures when trying to assess the condition of the bridge.
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