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Re: DESIGN OF BEARINGS FOR TYPICAL STEEL GIRDER FORESTRY BRIDGES

Dear Mr. Chow:

Associated Engineering is pleased to submit a technical memorandum summarising our review of the design of plain natural rubber elastomeric bearing pads. In addition to suggesting that the Ministry adopt the methodology included in CAN/CSA-S6-00, we have included recommendations regarding the detailing of a typical bearing assemblies and the use of reinforced laminated bearing pads for spans exceeding 40 m.

If you have any further questions, please feel free to contact me at your convenience.

Respectfully submitted

ASSOCIATED ENGINEERING

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Reviewed by:

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JH/mceeb
SUMMARY OF BEARING DESIGN IN ACCORDANCE WITH CAN/CSA-S6-00, AASHTO LRFD 1998 AND BS-5400

The following briefly summarises the various design methods that could be adopted for the design of plain natural rubber elastomeric bearing pads. The limiting criteria are summarised in Table 1.

**CAN/CSA-S6-00**
Maximum allowable stress is limited to a function based the bearing pad shape factor to a maximum value of 7 MPa. Vertical strain is limited to 0.07 and no uplift is allowed when the bearing is subject to a rotational displacement.

**AASHTO**
Maximum allowable stress is limited to 5.5 MPa. To accommodate rotational displacements without uplift, a minimum allowable stress is also defined based on the bearing pad shape factor and shear modulus of the elastomer.

**BS-5400**
Maximum allowable stress is limited to function based on the shape factor of the pad and the shear modulus of the elastomer. A typical allowable bearing stress is about 3 MPa. To accommodate rotational displacements without uplift, a minimum vertical deflection is defined.

To compare these methods, sample bearing designs were completed and the results summarised in Table 2. The designs all assumed 4.8 m wide composite concrete decks and 60 durometer plain rubber bearing pads. S6-00 SLS loads were assumed when considering designs based on BS-5400.
Table 1  
**Summary of Limiting Parameters**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>CAN/CSA-S6-00</th>
<th>AASHTO LRFD 1998</th>
<th>BS5400</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shape Factor</td>
<td>$\frac{W \times L}{2 \times t \times (W + L)}$</td>
<td>$\frac{W \times L}{2 \times t \times (W + L)}$</td>
<td>$\frac{W \times L}{2 \times (1.8 \times t) \times (W + L)}$</td>
</tr>
<tr>
<td>Limiting SLS Stress (MPa)</td>
<td>$1.95 \times S - 3.6 \leq 7^2$</td>
<td>5.5</td>
<td>$G \times S \leq 5 \times G$</td>
</tr>
<tr>
<td>Vertical deflection</td>
<td>$0.07t$</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Rotation¹</td>
<td>No uplift</td>
<td>$f_x \geq 0.5GS \times \left(\frac{L}{t}\right)^2 \times \theta$</td>
<td>$\Delta \geq \frac{L\theta}{3}$</td>
</tr>
</tbody>
</table>

Note:
1. AASHTO requires the inclusion of an additional 0.005 rad to account for fabrication/installation irregularities.
2. Numerical approximation of limits defined graphically in S6-00.

Table 2  
**Sample Bearing Designs**

<table>
<thead>
<tr>
<th>Bridge</th>
<th>S6-00 (modified)</th>
<th>AASHTO LRFD (1998)</th>
<th>BS-5400</th>
</tr>
</thead>
<tbody>
<tr>
<td>18 m L75</td>
<td>400 x 375 x 25</td>
<td>400 x 300 x 25</td>
<td>550 x 475 x 25</td>
</tr>
<tr>
<td>30 m L75</td>
<td>425 x 400 x 25</td>
<td>400 x 400 x 30</td>
<td>550 x 525 x 25</td>
</tr>
<tr>
<td>39 m L75</td>
<td>500 x 375 x 25</td>
<td>450 x 400 x 30</td>
<td>600 x 550 x 25</td>
</tr>
<tr>
<td>18 m L100</td>
<td>450 x 375 x 25</td>
<td>450 x 325 x 25</td>
<td>550 x 500 x 25</td>
</tr>
<tr>
<td>30 m L100</td>
<td>500 x 400 x 25</td>
<td>475 x 400 x 30</td>
<td>600 x 550 x 25</td>
</tr>
<tr>
<td>39 m L100</td>
<td>525 x 400 x 25</td>
<td>550 x 400 x 35</td>
<td>600 x 600 x 25</td>
</tr>
<tr>
<td>18 m L165</td>
<td>500 x 400 x 25</td>
<td>525 x 400 x 25</td>
<td>600 x 600 x 25</td>
</tr>
<tr>
<td>30 m L165</td>
<td>600 x 400 x 25</td>
<td>650 x 450 x 35</td>
<td>700 x 600 x 25</td>
</tr>
<tr>
<td>39 m L165</td>
<td>600 x 500 x 30</td>
<td>600 x 475 x 45</td>
<td>700 x 650 x 25</td>
</tr>
</tbody>
</table>

A review of the sample designs indicates the following:

- As span lengths increase there are greater live load rotational and translational displacement demands on the bearings. To accommodate these, the bearing pad thickness must be increased.

- Given the additional 0.005 rad rotational allowance that AASHTO specifies, bearings pads designed in accordance with AASHTO are typically thicker than those designed in
acCORDANCE WITH S6-00.

- Bearings designed in accordance with BS-5400 are typically larger than those design in accordance with S6-00 or AASHTO given the very low allowable design stresses (typically 50% of those based on S6-00 and AASHTO).

- For the longer spans (> 39 m), the plain pads are very large when compared to typical flange widths. For these span lengths, it may be more appropriate to consider the use of reinforced laminated pads. These pads are typically smaller than plain rubber pads and able to resist higher vertical loads and displacement demands.

**Proposed design methodology for plain elastomeric bearing pads**

We propose the following methodology for the design of plain elastomeric bearing pads:

1. **Bearing design should be completed in accordance with CAN/CSA-S6-00.**

2. **When checking the rotational capacity of the bearings, only the live load rotation need be considered if the dead load rotations are accommodated in the construction methodology. The live load rotational demand can be estimated as**

\[
\theta_{ll} = \frac{M_{ll} \times l}{3 \times E \times I}
\]

where \(M_{ll}\) = maximum factored live load moment

\(l\) = span length

3. **Typically shear deformation need not be considered if the connection between the two bearing plates does not allow for a significant shear displacement (e.g. by use of anchor bolts for shear connection). If the bearing plates allow for a shear displacement, this deformation must be included in the bearing design.**

4. **Where spans exceed 40 m, reinforced laminated bearing pads should be used to accommodate the increased vertical loads and associated deformations.**

5. **Revise the standard bearing drawings to include continuous keepers on both the top and bottom bearing plates (as shown on the attached sketch) to help restrain the elastomeric pad.**

6. **Require that upon the completion of bridge installation, the bearings be inspected and if required, reset to relieve any unintended shear and rotational deformations that may have been applied during the construction of the bridge.**
2-32\( \phi \) ASTM A325 BOLTS C/W NUTS AND WASHERS

BEARING PLATE C/W 2-36\( \phi \) HOLES ON C AND F.B. 6x6 CONT. KEEPERS

BEARING PLATE C/W 2-34\( \phi \) HOLES ON C AND F.B. 6x6 CONT. KEEPERS

NATURAL RUBBER BEARING PAD, GRADE 5, TO CAN/CSA-S6-88, 60 DURO

BEARING DETAIL

6x6 CONT. KEEPER, TYP.

PLAN ON KEEPERS

MINISTRY OF FOREST

DETAILING OF PLAIN ELASTOMERIC BEARING PADS