Behavior of Plain Elastomeric Pads

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Acknowledgments

- AASHTO
- MN DOT
Plain Elastomeric Pads – the Problem.

- Plain pads are made from unreinforced sheets of elastomer (Natural Rubber or Neoprene.)
- MN DOT found plain pads bulging out from the plates that they support.
- Was something wrong with the rubber?
- Are the AASHTO design values at fault?
MNDOT bearing

- Girder
- Steel rocker
- Elastomeric pad
- Welded studs
- Concrete pier cap
MNDOT bearing
MNDOT bearing
Plain Pad in Compression
Plain Pad in Compression
Plain Pad in Compression

- Slip
- No slip
- Slip
Comparison with Steel-Laminated Bearing
Comparison with Steel-Laminated Bearing

No lateral expansion – bonded to internal plates
Plain Pad in Compression

*Rubber volume stays constant.*

*Lateral expansion implies vertical deflection.*

*Expansion resisted by friction ($\mu$) and rubber stiffness, $G$.***
Compression Stiffness.

- Reinforced (bonded) Bearing

\[ K_c = \text{stiffness} \]
\[ A = \text{plan area} \]
\[ t = \text{rubber thickness} \]
\[ E_c = \text{Effective modulus} \]
\[ S = \text{Shape Factor} \]

\[ K_c = E_c \frac{A}{t} \]
\[ E_c \approx 4GS^2 \]
\[ S = \frac{LW}{2t_i(L + W)} \]
Compression Stiffness.

Plain pad

\[ K_c = E_c \frac{A}{t} \]

\[ E_{c,\text{PEP}} = \int K E_{c,\text{LRB}} \]

\[ f_K \approx 0.75\mu \]

(Nasty math. Depends on slip/no slip boundary).

Assumes:

- Incompressible material.
- \( W = \text{infinite (strip bearing)} \).
- Constant \( \mu \) (independent of contact pressure).
Test Plan

Compression test variables:

- Elastomer material
- Contact surface (may affect friction)
- Shape factor
- Aspect ratio
- Loading type and level

Friction test variables

- Contact pressure
## Compression Test Matrix

<table>
<thead>
<tr>
<th>Test Name</th>
<th>Rubber Material</th>
<th>Contact Surface</th>
<th>Length (inch)</th>
<th>Width (inch)</th>
<th>S</th>
<th>AR</th>
<th>Loading</th>
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<td>2</td>
<td>Creep</td>
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<td>8</td>
<td>2</td>
<td>Offset</td>
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</table>
Test set up

- Loading beam
- Galvanized plate
- Rubber pad
- Concrete block on steel plate

CROSS-SECTION
Instrumentation.

**Horizontal potentiometer**

**Vertical potentiometer**

**PLAN**
Loading Protocol.
Test Results – Vertical Strain.

- Zero for strain difficult to define: “bedding in”.
- $\varepsilon_{el} \approx 12\%$ at 800 psi
- Large “creep” strains
Test Results - Lateral Strain.

- Lateral strain = average slip on long sides/short dimension.
- Strain zero does not need adjustment.
- Lateral strain ≈ vertical strain (constant volume).
Test Results - Lateral Strain.
Compression Test Results.

Marks on rubber showing slip region.
No cracks or other damage.
Compression Test Results.

Cyclic loading & creep cause additional deflection. Total strain comparable to galvanized (1.GG.24.12).
Test Results.

High Aspect Ratio (11.0), Low S (2.0).
High elastic strains, lower creep strains.
Test Results - Creep.

Creep increases significantly above 400 psi (= 0.5GS)
Test Results – Creep Rate.


Compression Test Results - Summary.

- Elastomer: Negligible effect.
- Contact Surface: Little effect.
- Shape Factor: High S → higher elastic stiffness.
- Aspect Ratio: Little effect. (High AR → less stiff).
- Loading: Large effect. Creep and cyclic load: large increase in deflections.
Friction tests

3 steel plates (24” x 12”). (2 galvanized, 1 as-rolled).
2 rubber pads (6” x 3”).
Contact pressures: 200, 400, 600 psi.
Friction tests
Friction tests

Friction Test: 600 psi

Elastic shear deformation

Sliding
Friction tests

Previous studies have also found that rubber friction varies with contact pressure. Similar to PTFE.
Data Analysis

- Quantify the effects of the various parameters on compression stiffness.
- Use the measured friction coefficients in the analytical model to compare predicted and measured compression stiffnesses.
Data Analysis

Contact Surface (Concrete, Steel, Galvanized)

Laterals strain shown includes creep.
Bare steel has lowest friction, highest lateral strain.
Differences are small.
Data Analysis

Shape Factor, S.

For 24” x 12” pad, rubber squeezed out from plates.
For smaller pads, rubber remained between plates.
Data Analysis

Effect of Aspect Ratio

Larger AR gives slightly higher strains. Difference is quite small.
Comparison with Theory.

Plain pad

\[ E_{c,PEP} \approx f_K E_{c,LRB} \]

\[ f_K \approx 0.75 \mu \quad \text{Use} \quad \mu_{ave} = 0.44. \quad \text{Then} \quad f_K \approx 0.33 \]

Stiffness of a plain pad should be expected to be about \(1/3\) of that of a reinforced bearing with the same \(S\). However, this does not include creep deflections.
Tentative Design Criteria.

- Design plain pads using criteria similar to those for steel-reinforced bearings, but with lower values.
- No long-term damage to pads occurred, so difficult to link design criteria to potential damage.
- Consider a limiting compression strain, and generate a stress criterion from it.
Tentative Design Criteria.

Example:

• If strain limited to 10%, \( \sigma \leq 0.6GS \)

Governed here by bearings with \( S = 8 \).
Outcomes for Users.

- Plain pad strips under rectangular box beams: make pad wider.

- Leveling pad (e.g. MNDOT): present pads are at ≈ 800 psi (would need $S = 16$, thus $\frac{1}{4}”$ thick pad). Potential problems unless stiffer material used (70 durometer?).

- Use under prestressed girders. Problems similar to leveling pads.

- Others?
Preliminary Conclusions

- Additional strain due to creep and cyclic load is significant, controls behavior.
- Present AASHTO LRFD stress of 800 psi is much too high.
- Stress limit should be related to S.
- Before recommending changes to AASHTO LRFD Spec, need to check other conditions (e.g. higher durometer pads).