What is a pavement supposed to do?

• Functional aspects:
  – Noise
  – Ride
  – Friction
  – Rutting
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Structural Pavement Aspects

- Protect subgrade from permanent deformation
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100 psi

8” Cement Treated Layer

Pressure ~3 to 7 psi

+/- 20 ft
Structural Pavement Aspects

• Resist fatigue damage from repeated traffic loading

Critical Stress/Strain
Pavement Design

- For most pavements consisting of bound materials, fatigue damage is the controlling factor.
- The larger the stress or strain at the critical point, the fewer load repetitions to failure.
- The relationship between material response and damage is referred to as a transfer function.
Pavement Design

• At one extreme, a pavement can fail in one load repetition. This is a consideration for airfield pavement, but not so much for highways.
• At the other extreme, the load-induced response in the pavement can be so low that the fatigue life is “infinite”.

Pavement Design

• For asphalt, the “infinite” condition is determined by the endurance limit and expressed in microstrain.

• Researchers differ somewhat on what the endurance limit is, but the range is generally 70 to 200 microstrain and depends on the mix design.
Pavement Design

• For concrete and cement-treated bases, the fatigue life is generally expressed as the ratio of horizontal stress to the modulus of rupture.
• It is often assumed that if the ratio is less than 0.45 to 0.40, the fatigue life is also infinite.
Sample Pavement Structure

2” Asphalt Surface

10” FDR

Subgrade

Unconfined compressive strength
= 400 psi at 8 days

Modulus of Rupture
= 139 psi at 28 days

Modulus of Elasticity
= 595,000 at 28 days
Sample Pavement Structure

- 2” Asphalt Surface
- 10” FDR
- Subgrade

Horizontal Stress (psi)

- Negative = Tension
- Positive = Compression
Sample Pavement Structure

- Horizontal stress in our example is -57 psi.
- Horizontal Stress/Modulus of Rupture = 0.41.
- Using AASHTO MEPDG transfer function, this would give unlimited repetitions to failure.
- Estimated asphalt strain is 88 microstrain, below typical endurance limits for fatigue.
- Vertical stress on the subgrade is 5.5 psi.
## Effect of Base Thickness

<table>
<thead>
<tr>
<th>Base Thickness (inches)</th>
<th>Tensile Stress (psi)</th>
<th>Stress Ratio</th>
<th>Loads to failure (MEPDG)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>181</td>
<td>1.3</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>100</td>
<td>0.71</td>
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<td>8</td>
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<td>0.51</td>
<td>389,000</td>
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<td>9</td>
<td>61</td>
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<tr>
<td>12</td>
<td>40</td>
<td>0.29</td>
<td>196,700,000</td>
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</tbody>
</table>
Pavement thickness design procedures

- “New” AASHTO Design Guide
  - Mechanistic-Empirical Design
  - Evaluates effects of pavement materials, traffic loading conditions, environmental factors, design features, and construction practices
  - Must be calibrated to local conditions
Pavement thickness design procedures

- 1993 AASHTO Pavement Design Guide
  - Structural Numbers
  - Layer coefficients
    - NCDOT – 0.20/inch
    - SCDOT – 0.26/inch
    - VDOT – 0.30/inch
    - NCAT – 0.37/inch
What’s the catch?

• Reflective cracking:
  – When Portland cement and water cure, the resulting product has a slightly lower volume than what went in.
  – The pavement is restrained by friction to its original length. It wants to shrink, but can’t.
  – This creates tensile stresses in the pavement.
  – If the tensile stresses exceed the tensile strength at a given point in time and space, the pavement will crack.
What’s the catch?

• Reflective cracking:
  – These cracks are NOT the same as fatigue cracks and have high load transfer efficiency.
  – Concern is that these cracks will lose their LTE over time, water will get into pavement and subgrade. This water could lead to softening of the subgrade and damage.
  – Also the cracks reflect through the asphalt overlay and may allow water damage.
Dealing with reflective cracking

• Several strategies available
  – Stress absorbing interlayer
  – Geosynthetics
  – Pre-cracking/microcracking
  – Crack sealing
  – Use lower cement content/greater depth
  – Don’t worry about it…
Bethlehem Church Road, Cabarrus Co.
Bethlehem Church Road, Cabarrus Co.
Bethlehem Church Road, Cabarrus Co.
Bethlehem Church Road, Cabarrus Co.
SC-311, Dorchester Co, SC
Age ~10 years
Old Pardue Rd
Lancaster Co, SC
Age ~10 years

Crack
Crack Sealing?
Cracking is not limited to FDR

- Patching, milling, and overlay can also develop reflective cracking over patch boundaries and existing cracks.
- Unlike FDR-related shrinkage cracking, the reflected cracks are often promptly structural in nature.
- Need to consider the FDR cracking behavior in perspective with the alternatives.
Conclusions

- FDR can provide a very long-lasting base, even under high traffic conditions.
- In mild climates reflected shrinkage cracks are primarily an aesthetic issue.
- Shrinkage cracking may be mitigated by a variety of means, if necessary.
Thank you.

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