FDR Pavement Design/Technical Concepts

Andy Johnson, Ph.D., P.E.
Pavement Design Engineer
Southeast Cement Promotion Association

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What is a pavement supposed to do?

• Functional aspects:
  • Noise
  • Ride
  • Friction
  • Rutting
What is a pavement supposed to do?

• Structural aspects:
  • Protect the subgrade from permanent deformation
  • Have sufficient fatigue resistance to withstand repeated loading
Structural Pavement Aspects

- Protect subgrade from permanent deformation

![Diagram showing structural pavement aspects]

- Contact Radius: ~5 inches
- 100 PSI
- 45°
- 10-14”
- 2 to 3 times thickness of pavement
Structural Pavement Aspects

- Protect subgrade from permanent deformation

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”.
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.
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

• 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.
Sample Pavement Structure

2” Asphalt Surface
10” FDR

Subgrade

Horizontal Stress (psi)

Negative = Tension
Positive = Compression
## 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>
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<tr>
<td>6</td>
<td>100</td>
<td>0.71</td>
<td>1,200</td>
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<td>8</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
    - 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...
SC-311, Dorchester Co, SC
Age ~10 years
SC-311, Dorchester Co, SC
Age ~10 years
Crack Sealing?
Cracking is not limited to CTB

• Patching, milling, and overlay can also develop reflective cracking over patch boundaries and existing cracks.
• Unlike CTB-related shrinkage cracking, the reflected cracks are often promptly structural in nature.
• Need to consider the CTB 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.

Andy Johnson, Ph.D., P.E.
Pavement Design Engineer
ajohnson@seceement.org
(803) 556-2889