Longitudinal Joint Permeability: Case Study of Mississippi Ultra-Thin Asphalt Pavements
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Ben C. Cox
Doctoral Student & Recipient of Ergon Asphalt & Emulsions Distinguished Doctoral Fellowship

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- Mark Holley

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Permeability

- Why is it important?
  - Permeability is directly related to durability
- What factors affect permeability?
  - NMAS, t/NMAS, gradation (coarse vs. fine)

Darcy’s $k$ Calculations

$$k = \frac{aL}{At} \ln \left( \frac{h_1}{h_2} \right)$$

Where,
- $k$ = hydraulic conductivity (cm/s)
- $a$ = inside cross-sectional area (cm$^2$)
- $A$ = cross-sectional contact area (cm$^2$)
- $L$ = thickness of specimen (cm)
- $t$ = elapsed time between $h_1$ and $h_2$ (s)
- $h_1$ = initial head across specimen (cm)
- $h_2$ = final head across specimen (cm)

Darcy’s Law

- Requires one-directional flow
- Requires known specimen dimensions

Conclusion: Darcy’s $k$ is essentially only a relative indicator of permeability, but it has been argued that it is at least an indicator.

Common Permeameters

- ASTM PS 129
- NCAT

Permeability by NMAS

<table>
<thead>
<tr>
<th>Air Voids (%)</th>
<th>Permeability (10$^{-5}$ cm/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.5</td>
<td>5.0</td>
</tr>
<tr>
<td>25 mm</td>
<td>7.0</td>
</tr>
<tr>
<td>19 mm</td>
<td>7.5</td>
</tr>
<tr>
<td>12.5 mm</td>
<td>11.5</td>
</tr>
<tr>
<td>5.5 mm</td>
<td></td>
</tr>
<tr>
<td>4.7 mm</td>
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</table>

Cooley et al. (2002), Cooley (2003), Cross & Bhusal (2009), Megawer et al. (2002), West et al. (2011)
Longitudinal Joints

- Longstanding concern for long-term performance
- Research has shown permeability provides reasonable discrimination between joints of various quality
- Permeability has also become a tool to measure the effectiveness of various joint construction techniques

Joint Permeability

- Joint permeability provides reasonable discrimination between joints of various quality
- Permeability has also become a tool to measure the effectiveness of various joint construction techniques

Thin-Lift Overlays

- Typically <1.5” thick with 4.75 mm NMAS
- Can be used as a leveling mix, low-volume overlays
- Provide use for screenings stockpiles
- Could extend service life 3-24 years (Labi et al., 2005)
- Currently used in states such as Alabama, Georgia, and others

Public perception: new road ☺

Mississippi’s Ultra-Thin Overlays

- Natural sand: <30%
- RAP (-1/2’’): <25%
- Design $V_o$: 4-6%
- Roll to refusal

<table>
<thead>
<tr>
<th>Route</th>
<th>Length (mi)</th>
<th>AADT</th>
<th>Design Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>370</td>
<td>1.5</td>
<td>1200</td>
<td>3/4”</td>
</tr>
<tr>
<td>Lee/Prentiss Co.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>370</td>
<td>2.9</td>
<td>1000</td>
<td>1/2”</td>
</tr>
<tr>
<td>Inwasamba Co.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>371</td>
<td>1.1</td>
<td>1500</td>
<td>1”</td>
</tr>
<tr>
<td>Prentiss Co.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total AC: 6.8%</td>
<td></td>
<td></td>
<td>Built November, 2010</td>
</tr>
</tbody>
</table>

UTAP Construction

Photo credit: Mark Holley
Longitudinal Joint Close-ups

Good Joint Quality  Moderate Joint Quality  Poor Joint Quality

Joint Sealant

• RePLAY Agricultural Oil Seal & Preservation Agent was placed on joints of the 3/4" and 1" sections (July 11, 2011).
• Application rates were 0.26 gal/yd² and on the 3/4" section and 0.32 gal/yd² on the 1" section.
• The material was sprayed in a 2’ swath covering 1’ on each side of the joint.
• Cost of the in-place material was approximately $1,600 per mile of joint.

Sealant Application

Test Plan

Select test locations (Good, Moderate, Poor)  Seal Joints (RePLAY)  Test (At Joint, 1’ offset, 2’ offset)

Hwy 370 (3/4” Overlay)

Permeability Equipment

2” I.D. permeameter  Truck-mounted permeameter support frame

Permeameter Development

• Standpipe developed at US Army Corps of Engineers by Dr. Thomas White in 1970s
• Equipment refined and packaged into portable system at MSU over past several years
• Total cost of entire equipment package: ~$3,800
• Full list of materials available on request
Permeability Equipment

Calculations

• Infiltration rate (cm/min) is used to characterize a mix’s permeability rather than Darcy’s $k$
• Infiltration rate does not consider head

$$Inf = \frac{a}{At} (h_1 - h_2)$$

Conversion: 1 cm/min = 1,667 (10^{-5}) cm/sec

Note that this does not convert between infiltration and Darcy’s $k$. Infiltration in units of $(10^{-5})$ cm/sec ≠ Darcy’s $k$ in units of $(10^{-5})$ cm/sec.

Possible Benefits of Approach Presented

• Ease of testing procedure
• Can test same spot repeatedly
• Adaptable for lab or field testing
• No laws or assumptions are violated because there are none
• Can be used for OGFC, DGA, SMA
• Can test mats, longitudinal joints, cracks

Permeability At Joint

Permeability of the Mat
Conclusions

• Generally, permeability has decreased with time.
  – A combination of hot weather, traffic, and high asphalt contents likely led to closure of some surface voids.
  – Locations 6 & 9 are exceptions – permeability is increasing again as longitudinal joint cracking is appearing.

• Sections treated with RePLAY do not appear distinguishably different from those untreated to date.

• The permeability device/method presented could warrant further consideration.

References


Questions?

Ben C. Cox
bcc115@msstate.edu