Composite, or Thermally Insulated Concrete, Pavements

Prof. Lev Khazanovich
UMN, CEGE
ISCP Director
Acknowledgements

- TPF-5(149)
  - MnDOT, LRRB, Caltrans, WsDOT
  - FHWA
- TL: Tim Clyne
- UMN students and staff
  - Luke Johanneck (TRB 2010 award)
  - Priyam Saxena (TRB 2012 award)
  - Rita Lederle
  - Derek Tompkins
- John Harvey (UC Davis), Nick Santero (MIT), James Signore (UC Berkeley)
Outline

• Introduction
  – What is a Thermally Isolated Concrete Pavements (TICP)?
  – When should it be used?
  – Why do we call it TICP?

• Construction

• LCCA

• Design/Performance Prediction
What is TICP?

Thermally Insulated Concrete Pavement = asphalt layer over concrete pavement

- Newly constructed
- AC overlay over existing concrete pavement
  – Concrete layer is in good structural condition
Why do we call it TICP?

According to the Enhanced Integrated Climate Model (EICM), presence of the asphalt layer reduces temperature gradients in the concrete slab.
Thermal Gradients in PCC

ISCP Concrete Pavement Workshop
June 25, 2015
Introduction

When should a TICP be used?

- To achieve long life, premium ride and noise characteristics, rapid renewal - SHRP R21 project
- To achieve lower life cycle cost (LCC) - TPF-5(149)
Premium Pavement

Betonconstructie

50 mm ZOAB 0/16
Porous AC Friction Course

250 mm DGB
CRCP, 0.7% steel

60 mm GAB 0/32
AC Interlayer, Dense

250 mm AGRAC
Cement Bound Recycled Asphalt

Photo rotated to match cross-section at left

A50, Netherlands
AC/CRCP Cores

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Lower LCC

- Thinner concrete thickness
- Low cost concrete
  - Low cost aggregates
  - Recycled concrete aggregates
  - High percentage of SCM
- Lower construction cost
PCC Construction for TICP

- No change from regular PCC paving in terms of
  - Paver speed and control
  - Compaction
  - Joint sawing
- Changes from regular PCC paving in terms of
  - No need to finish
  - Different curing regime
  - No need to grind pavement smooth
PCC Construction for TICP

• Modified curing regime
  – Concrete surface must be able to bond with the AC layer
  – No wax based curing agents
  – Can use AC prime coat to seal surface, but it must dry quickly
  – Conventional cure compound may need to be sand blasted off to ensure bond
PCC Construction for TICP

• Contractor’s estimation of potential savings
  – two finishers at a cost of $1200/day or ~$0.10/sy
  – the rumble strip imprints ~$0.05/sy
  – pavement seals ~$1.00/sy
  – grinding for smoothness : $0.05-0.10/sy
RCC Construction for TICP

- Roller Compacted Concrete (RCC) is an attractive alternative to PCC
  - Use same equipment for placing RCC and AC
  - AC can be placed as soon as RCC joints are cut
  - No changes from regular RCC paving techniques

- RCC is not suitable in some situations
  - Heavy truck traffic
  - When dowels are required
AC Construction for TICP

• PCC surface must be properly prepared
  – Standard pre-overlay treatments to PCC
• Almost no changes from typical overlay construction
  – Must ensure joint sawing in AC is done ASAP to prevent reflective cracking
• Quality control and assurance
Importance of Joint Sawing

MnROAD cell with now joint sawing. Reflective cracking in less than 1 year.
Importance of Joint Sawing

MnROAD cell with saw-and sealing – no reflective cracking
Minnesota LCCA Case Study

- New two-lane, high-volume road
- MN LCCA decision metrics
  - When is the NPV of TICP and JPCP construction comparable?
  - Cost of initial construction
  - Cost of minor and major maintenance
  - Cost of rehabilitation regimens
### JPCP Maintenance Schedule

<table>
<thead>
<tr>
<th>Pavement Age</th>
<th>Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>initial construction</td>
</tr>
<tr>
<td>17</td>
<td>minor re-seal and minor CPR (partial depth repairs)</td>
</tr>
<tr>
<td>27</td>
<td>Minor CPR (partial depth repairs) and some full depth repairs</td>
</tr>
<tr>
<td>40</td>
<td>major CPR (Full depth repair and diamond grind)</td>
</tr>
<tr>
<td>50</td>
<td>end of analysis period (no residual value)</td>
</tr>
</tbody>
</table>

### TICP Maintenance Schedule

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<thead>
<tr>
<th>Pavement Age</th>
<th>Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>initial construction</td>
</tr>
<tr>
<td>7</td>
<td>crack fill</td>
</tr>
<tr>
<td>15</td>
<td>mill and overlay</td>
</tr>
<tr>
<td>20</td>
<td>crack fill</td>
</tr>
<tr>
<td>27</td>
<td>mill and overlay</td>
</tr>
<tr>
<td>32</td>
<td>crack fill</td>
</tr>
<tr>
<td>40</td>
<td>mill and overlay</td>
</tr>
<tr>
<td>45</td>
<td>crack fill</td>
</tr>
<tr>
<td>50</td>
<td>end of analysis period (no residual value)</td>
</tr>
</tbody>
</table>
Minnesota LCCA Case Study (3)

- Three levels of concrete and asphalt costs
- Cost of TICP concrete could be 25%, 50%, 75%, or 100% the cost of the JPCP concrete

<table>
<thead>
<tr>
<th>Concrete or Asphalt $ per yd$^3$ (m$^3$)</th>
<th>Price designation</th>
</tr>
</thead>
<tbody>
<tr>
<td>38 (50)</td>
<td>Low</td>
</tr>
<tr>
<td>115 (150)</td>
<td>Medium</td>
</tr>
<tr>
<td>230 (300)</td>
<td>High</td>
</tr>
</tbody>
</table>
A reduction in cost of the TICP PCC layer could be accomplished by

- Use of RCC
- Increasing the percentage of supplementary cementitious materials
- Substituting recycled concrete aggregates for conventional coarse aggregates
- Allowing a higher percentage of fine, soft, spall, or slate in the coarse aggregate.
- Decreasing the cost of concrete is not limited to these examples
• Cost of concrete (H, M, L)
• Cost of asphalt (H, M, L)
• Cost of concrete in TICP relative to the cost of concrete in JPCP (25%, 75%, 100%)
• Discount rate (2.5% & 5.0%)
MN LCCA: Influence of Material Cost

<table>
<thead>
<tr>
<th>DR = 2.8</th>
<th>Asphalt Cost: Low</th>
<th>Asphalt Cost: Medium</th>
<th>Asphalt Cost: High</th>
</tr>
</thead>
<tbody>
<tr>
<td>[Graphs showing cost percentages for different asphalt costs and DR values]</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>DR = 5.0</th>
<th>Asphalt Cost: Low</th>
<th>Asphalt Cost: Medium</th>
<th>Asphalt Cost: High</th>
</tr>
</thead>
<tbody>
<tr>
<td>[Graphs showing cost percentages for different asphalt costs and DR values]</td>
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<td></td>
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</table>
MN LCCA Conclusions

• TICP becomes more cost competitive with JPCP when/as . . .
  – The cost of concrete increases
  – The cost of asphalt is low and the cost of concrete is high or medium
  – The cost of concrete for TICPs decrease relative to the cost of JPCP concrete
  – The discount rate increases
Analysis procedures
  - Enhanced Integrated Climatic Model
  - FE program

Design Procedures:
  - MEPDG
  - NCHRP 1-41
  - TPF-5(149)

Performance models
• Presence of an AC overlay reduces temperature gradients in the PCC layer
• EICM qualitatively captures this effect
  • Climate data quality is very important!
• High quality MnROAD data provide an opportunity to calibrate and validate the EICM
More than 10 million temperature measurements from PCC and AC/PCC

Data was filtered using a program developed by Dr. Randal Barnes, UMN

Subjected field data to 14 different tests to identify missing and insufficient data, sensors outliers, subset outliers

Suspect data were flagged
MnROAD Data vs. MEPDG Default

Note: MnROAD data for July
PCC Thermal Conductivity = 1.25 BTU/hr-ft-°F
Good qualitative agreement, but the MEPDG underestimates frequencies of positive and negative temperature gradients.

Possible explanation is the MEPDG default thermal conductivity value is too high.

Action:
- Adjust thermal conductivity to minimize the discrepancy for July.
- Verify the model for other months.
PCC Thermal Conductivity = 0.94 BTU/hr-ft-°F

Note: MnROAD data for July
PCC Thermal Conductivity = 0.94 BTU/hr-ft-°F

Note: MnROAD data for March
Performance Models

- Pavement-ME
  - PCC cracking model
  - PCC joints faulting model = unavailable
  - AC rutting model
  - AC reflective cracking model = placeholder

- NCHRP 1-41 reflective cracking model is a positive development, but needs to be better integrated with the Pavement-ME

- TPF-5(149) models: need to be integrated with
  - JPCP faulting model
  - Reflective cracking model
  - AC rutting model
Based on the MEPDG JPCP faulting model
Accounts for the effect of AC layer on PCC temperature and PCC joints load transfer efficiency
• Combines MEPDG EICM analysis with CalME HMA rutting modeling
• Two-stages
  – Crack propagation resulting in low-severity (L) cracking
  – Crack deterioration resulting in medium- and high-severity cracking (M+H)
• Crack propagation modeling
  – Based on CalME damage analysis corrected for the effect of joint/crack load transfer and damage due to PCC thermal movement
• Crack deterioration modeling
  \[ RC_{MH} = \frac{RC_{LMH}}{1 + (a_2 \sum DE)^{b_2}} \]
  
  \( DE = \) differential energy of subgrade deformation
TPF-5(149) Reflective Cracking

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Conclusions

• TICP can be an attractive cost-effective design alternative for any traffic volume roads
• Presence of the top asphalt layer not only improves ride quality but also protects the concrete layer from environmental effects
• If use of dowels is not required then RCC is an attractive option for the PCC layer
• MEPDG with some modifications provides a reliable design methodology for TICP pavements