NJDOT's Use of Underseals, Crack Attenuating Mixture and Interlayers (Oh, My!)

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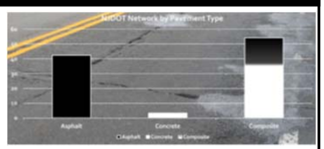
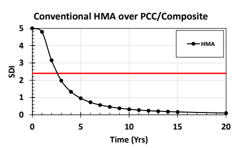
Composite Pavements in NJ

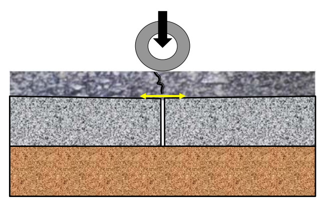
- Approximately 55% of NJDOT network consists of composite pavements
  - PMS data shows < 5 years before requiring rehab treatment
- Prior to 2007, NJDOT had tried paving fabrics and Strata
  - Paving fabrics delayed reflective cracking 1 year
    - Year 2 Control and fabric section looked identical
  - Strata (NJ Rt 10, 1997) - 4 to 5 years for Strata to achieve same cracking as Control





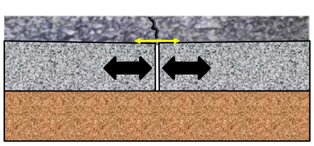
Mode 1 – Excessive Vertical Bending

- Mode 1 – Excessive Vertical Bending at PCC joint/crack (Classical Tensile Straining)
  - Applied axle load over the joint/crack area creates excessive bending
  - Generates high tensile strain at the bottom of the HMA layer
  - Cracking potential is a function of the flexural fatigue properties of the asphalt mixtures



Mode 2 – Excessive Vertical Bending

- Mode 2 – Horizontal Deflections (PCC slab expansion and contraction) due to environmental cycling
  - No traffic loading required
  - Temperature cycling
    - Most critical in colder temperatures with a significant cooling cycle
  - Function of the expansion/contraction properties of the PCC materials, slab dimension, PCC slab/base friction

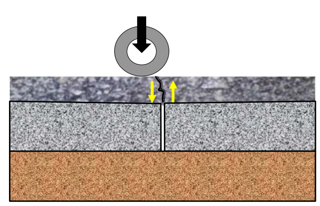


$$\Delta L = CTE(L)(\Delta T)(\beta)$$

ΔL = change in slab length; L = initial slab length
ΔT = rate of change in PCC temperature (24 hr);
β = slab/base friction coefficient

Mode 3 – Shear Due to Poor Load Transfer

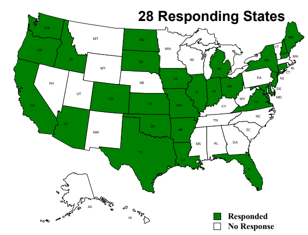
- Mode 3 – Shear Load Due to Poor Load Transfer
  - Research has shown to be a crack accelerator, not necessary an initiator
  - Poor load transfer applies a shear force that accelerates the crack growth of a crack
    - Example: Thick, folded paper – hard to start a tear, but once cut, tearing is much easier



National Survey on Composite Pavement Design - 2007

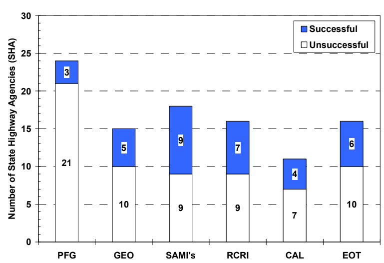
National Survey on Reflective Cracking

- Survey Overview
  - Time until reflective cracking occurs
  - Current PCC pavement characteristics (for composite pavement areas)
    - Joint spacing, joint type (contraction, expansion, etc)
    - PCC supporting base layer type
    - Traffic levels
  - HMA Overlay material characteristics
    - Typical mix designs and asphalt binder type
  - Pavement evaluation methods for design
  - Common PCC rehab prior to HMA overlay
  - Reflective cracking mitigation methods used and level of success



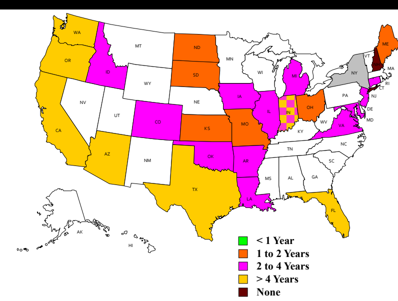
National Survey on Reflective Cracking

- Reflective cracking mitigation techniques and success rate
  - > 5 years before reflective cracking observed
  - Asphalt interlayer applications had best success rate



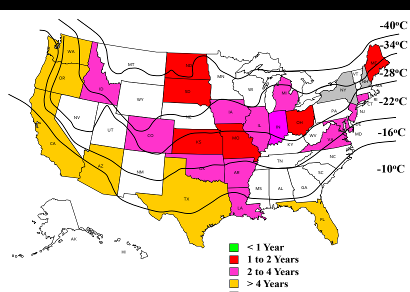
National Survey on Reflective Cracking

- Typical time after overlay until reflective cracking observed
  - Reflective cracking observed earlier in northern states compared to states with milder climates



National Survey on Reflective Cracking

- LTPPBind low temperature asphalt binder PG Grade recommendations
  - Longer delay in reflective cracking with better low temperature binder properties



National Survey on Reflective Cracking

- Reflective cracking appeared to occur equally at different traffic levels and base types – which means both load and non-load associated conditions initiate reflective cracking
  - General trends to greater reflective cracking life at stronger base materials and shorter joint spacing
    - Lower magnitude of vertical and horizontal deflections
- HMA overlay material (asphalt binder type) had large impact on reflective cracking
  - HMA overlay needs to be resistant to cracking at low temperatures
  - Using one grade or more less than LTPPbind was more successful

NJDOT/Rutgers Field Research Sections

NJDOT/Rutgers Field Research Sections

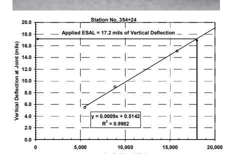
- 2006 to 2010 looked at a number of field sections
  - Interlayers
  - Different HMA designs (AC%, binder grades)
  - Portable WIM's for traffic
  - FWD at joints/cracks
  - Field cores of PCC for Coefficient of Thermal Expansion (CTE)

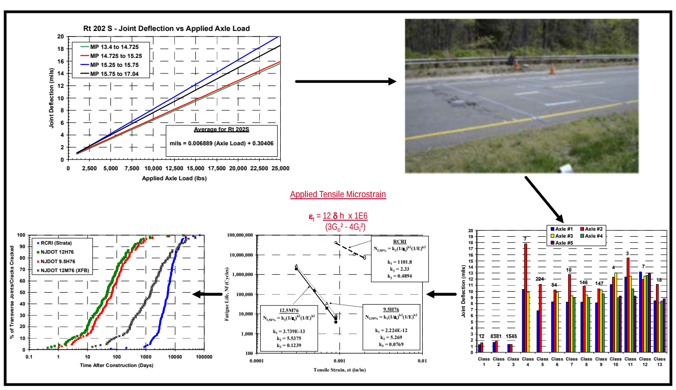
Evaluating Material Properties for Composite Pavement Design

- NJDOT/Rutgers test sections provide wide range of materials to begin investigating how to simulate field movements in the laboratory for characterization
  - Experience from research sections
    - Mode 1 – Vertical
    - Mode 2 – Horizontal

Evaluating Material Properties for Composite Pavement Design - Mode 1

- The vertical deflection at the PCC joint/crack is a function of the applied axle load
- Magnitude of vertical deflection can be evaluated using Falling Weight Deflectometer (FWD) at different loads
- Combined with measured traffic/axle loading, a "Deflection Spectra" can be developed specifically for the pavement



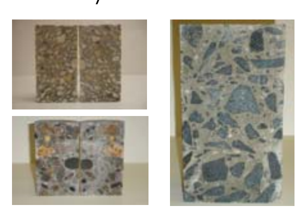


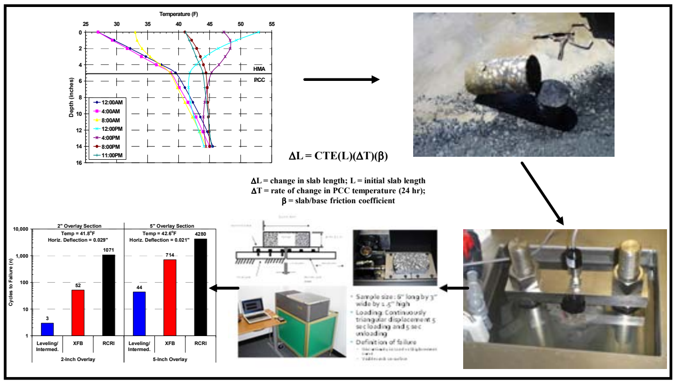
Evaluating Material Properties for Composite Pavement Design - Mode 2

- Expansion and contraction at PCC joint creates zone of tensile stress at bottom of asphalt overlay
- Horizontal deflection (ΔL) can be determined by:

$$\Delta L = CTE(L)(\Delta T)(\beta)$$

ΔL = change in slab length; L = initial slab length
ΔT = rate of change in PCC temperature (24 hr);
β = slab/base friction coefficient





Lessons Learned

NJDOT/Rutgers Field Research Sections – Lessons Learned

- Material selection!
  - Interlayers work, but still need good overlays!
    - Composite pavement design needs to be thought of as a "system approach"
      - Asphalt immediately over PCC needs to be able to withstand horizontal and vertical deflection
      - Surface course must still be able to withstand vertical deformation
        - Compatibility is required between asphalt materials – can not have very flexible overlaid by very stiff
    - Example: Massachusetts I495

NJDOT/Rutgers Field Research Sections – Lessons Learned

- Material selection!
  - "Crack jumping" on MA I495
  - Interlayer worked, leveling course and intermediate layer cracked with 7 months of paving!
    - Too stiff to withstand horizontal deflections (leveling course) and residual vertical deflections (intermediate course)
    - Stress Absorbing Membrane Interlayers (SAMI's)
      - Is this term misleading?

NJDOT/Rutgers Field Research Sections – Lessons Learned

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    - ~~Stress Absorbing Membrane Interlayers (SAMI's)~~
    - Strain Tolerant Asphalt Materials (STAM's)

NJDOT/Rutgers Field Research Sections – Lessons Learned Interlayer Thickness Influence

NJDOT/Rutgers Field Research Sections – Lessons Learned - Interlayer Thickness Influence

5 Cycles (0 inches)

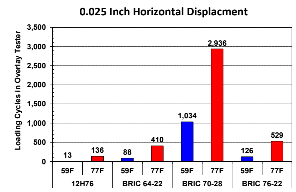
0.035" Opening
15°C (59°F)

>2,800 Cycles (1.0 inches)

278 Cycles (0.5 inches)

Bituminous Rich Intermediate Layer (BRIC)

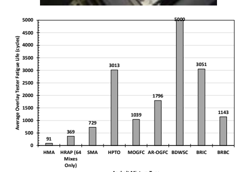
- Originally based off TxDOT Crack Attenuating Mix (CAM)
  - Placed at 1" thick
  - 4.75mm NMAS; No natural sand
  - PG70-28 asphalt binder
  - Minimum Asphalt Content 7%
- Performance Testing
  - Originally APA only (binder grade, AC% & VMA controlling fatigue)
  - Incorporated Overlay Tester after experience – eliminated binder grade requirement
    - Acceptance (design, test strip, production) based solely on performance testing results



Design Approach for Composite Pavements

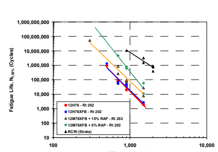
Design Approach for Composite Pavements

- Assumptions
  - Good construction and not using excessive overlay thickness (EOT)
- Step 1: Find material to withstand expected horizontal deflections (Mode 2)
  - Analysis of field sections in NJ found this to be controlling factor
  - Originally used Strata – found too flexible
  - Developed a "poor man's" Strata – Bituminous Rich Intermediate Course (BRIC)



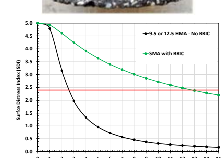
Design Approach for Composite Pavements

- Step 2: Find surface/intermediate course capable of withstanding residual vertical deflections
  - Analysis found compatibility of asphalt layers important
    - Flexural fatigue and rut resistant
    - Thicker asphalt overlays will have lower flexural fatigue requirements due to reduction in vertical deflections
      - Obviously vice versa!



Design Approach for Composite Pavements

- Developed an Excel macro for NJDOT on asphalt mixture selection
- Considered horizontal and vertical movements
- Due to overlay thickness restrictions and deflections magnitude, majority of composite pavements in NJ are constructed with;
  - 2" SMA Surface
    - Good rutting & flexural fatigue resistance
    - Stiffness compatible with BRIC
  - 1" BRIC
    - Excellent at withstanding horizontal deflections



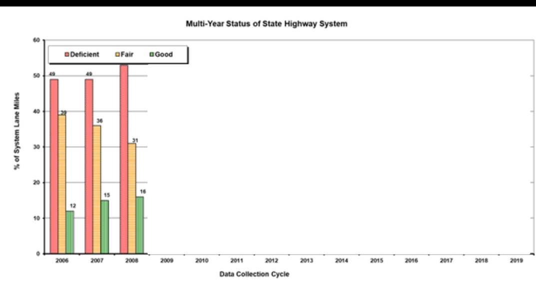
Examples: Rt 9 – Ocean County

- 20 year ESAL's = 5 million
- Existing 2-3" HMA over 8" JRCP
  - Built 1920's with 50' joint spacing
  - SDI = 2.1; IRI = 222 in/mile
- Resurface in 2011
  - Mill 3"
  - 2" SMA over 1" BRIC
  - SDI = 5.0; IRI = 78 in/mile
- 2020 PMS Data
  - SDI = 4.6; IRI = 83 in/mile

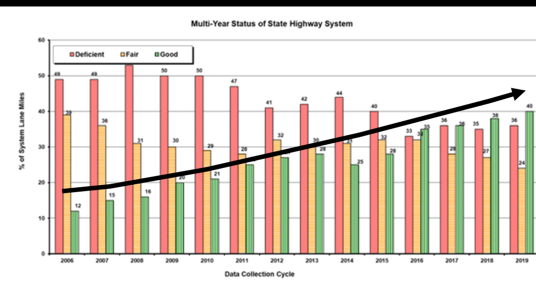
Examples: Rt 1 & 9 – Hudson County

- 20 year ESAL's = 80 million
- Existing 3-4" HMA over 10" JRCP
  - Built 1930/40's with 56' joint spacing
  - SDI = 0.67; IRI = 165 in/mile
- Resurface in 2011
  - Mill 3"
  - 2" SMA over 1" BRIC
  - SDI = 5.0; IRI = 59 in/mile
- 2020 PMS Data
  - SDI = 3.4; IRI = 93 in/mile

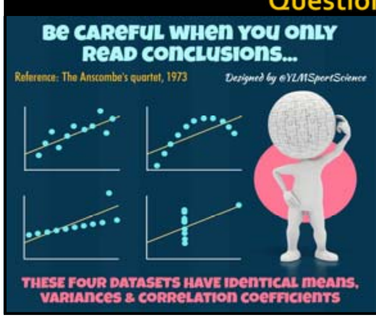
NJDOT Pavement System – How it started



NJDOT Pavement System – How it's going



Thank you for your time! Questions?



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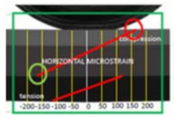
NJDOT/Rutgers Field Research Sections – Lessons Learned

- Construction
  - Can have significant impact on performance (duh!)
    - However, due to higher deflections, even more critical in composite pavements
      - True "flexible" pavements
    - Thickness of interlayers
    - Bonding of layers
    - "1 inch = 1 year"

NJDOT/Rutgers Field Research Sections – Lessons Learned - Bonding of Asphalt Layers

- Proper tack coat/bond strength
  - Composite pavements have high vertical deflections at PCC joints/crack
  - Important to ensure good bonding to properly distribute stress
    - If unbonded, surface lift will take majority of applied stress and bottom-up cracking will occur in that lift solely



NJDOT/Rutgers Field Research Sections – Lessons Learned "1 Inch = 1 Extra Year"

- An old composite pavement design approach – "For every extra inch of HMA, you get 1 extra year"
  - Why?
  - Two factors
    - Thermal insulation of PCC
    - Reduces tensile strain magnitude at bottom of HMA
    - Can we use strain tolerate materials instead of extra thickness?