TPF(5)-169, Development of an Improved Design Procedure for Unbonded Concrete Overlays

Task 4. Cracking Models

Prof. Lev Khazanovich
Cracking Model development

• 6x6 slabs
  – Develop Neural Networks
  – Climate characterization
  – Damage modeling- MEPDG cracking model with adjusted strength, if necessary
  – Model validation
• **Interlayer analysis**: Validated Task 3 Totsky
  – Confirmed $k_{totsky}$ for HMA and Fabric

• **Mesh and interlayer values**: Effect of mesh refinement and interlayer $k$-value on stress at critical location
  – 18-kip load + no thermal load and no axle load + thermal load

• **Existing crack**: Batch runs for 1L undamaged system of varied slab thickness and 2L with existing crack
  – Assumes 18 kip load, no thermal load in 6x6 and 12x15
  – 6-on-6 performs equivalently to ~6.6" either with or without crack
Totsky approach for interlayer modeling

- Totsky approach models “cushioning” property of the interlayer using springs
- Estimate Totsky coefficients for HMA and fabric interlayers from lab data
- Investigate 2-layer system with varied $k_{tot}$ versus 1-layer system with varied $k_{sub}$
MinneALF

Load LVDTs LT, LB
LVDTs ET, EB
LVDTs CT, CB

CT, CB

ET, EB

LB, LT

Load

N
After 4 million load repetitions

$k_{int} \approx 500 \text{ psi}$
Task 4, 1L/2L equivalent w cracking

1L_Cracked (by thickness)

1L_NoCrack (by thickness)

2L_Cracked (6-on-6, by k_tot)

2L_NoCrack (6-on-6, by k_tot)
Task 4, Investigations (2)

- **6x6 stress response**: Factorial of 216 cases varied by $D_1/D_2$, $kt/ks$, $(D_1/kt)^{0.25}$ for stress response of 6x6, 2L system
  - 18-kip load, no thermal, 6-on-10 inch system
• **6x6 stress response**: Factorial of 1650 cases varied by D1/D2, kt/ks, \((D1/kt)^{0.25}\) for response of 6x6, 2L system

  – 18-kip load, no thermal, 6-on-8 inch system
Similarity Concept
Similarity Concept

Two pavement structures are similar if

\[
\frac{L_{x1}}{\ell_1} = \frac{L_{x2}}{\ell_2} \quad \frac{L_{y1}}{\ell_1} = \frac{L_{y2}}{\ell_2} \quad \frac{AGG_1}{k_1\ell_1} = \frac{AGG_2}{k_2\ell_2} \\
\frac{a_1}{\ell_1} = \frac{a_2}{\ell_2} \quad \frac{P_1}{\gamma_1 h_1} = \frac{P_2}{\gamma_2 h_2} \quad \varphi_1 = \varphi_2
\]

\[
\varphi = \frac{2\alpha(1 + \mu)\ell^2}{h^2} \frac{k}{\gamma} \Delta T
\]

\[
\Delta T = h \int_{h}^{\infty} (T(z) - T_0)E(z) z \, dz
\]

\[
\sigma_2 = \frac{h_1\gamma_2\ell_2^2}{h_2\gamma_1\ell_1^2} \sigma_1 + \Delta\sigma_{NLT}
\]

\(\gamma\) = unit weight

Korenev’s (1962) nondimensional temperature gradient

Temperature difference for the linear strain component of the temperature distribution

(Khazanovich et al. 2001)
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<th>Slab size, ft</th>
<th>Elastic Modulus, psi</th>
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<th>Lane/Shoulder LTE, %</th>
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Task 4, Building database of responses

- Stress response in slab according to EPCC, offset, joint LTE for 4500+ cases
Task 4, Edge vs joint stresses

Edge stress/Joint stress ratio

Joint LTE, percent

Ratio

0.00 0.20 0.40 0.60 0.80 1.00 1.20
0 20 40 60 80 100
Task 4, Edge vs joint stresses

Edge stress/Joint stress ratio

Ratio vs. Radius of Relative Stiffness

UBOL, Task 4, 20 Dec 2016
Task 4, Building database of responses

- Response of 6x6 panel system with asphalt shoulder to axle loading at midslab
- Response of 6x6 panel system with AC shoulder to axle loading at joint with interlayer void
- Additional factorials to be conducted with PCC shoulders
• Database of 170k MEPDG 1.1 projects summarizing:
  – 7 climates, 8 PCC overlay thicknesses
  – 2 existing PCC thicknesses, 2 subgrade types
  – 2 lane widths, 2 joint spacing
  – Interpolate for EPCC, Mod Rupture, COTE

• Determine single-layer equivalent of two-layer UBOL systems, use with database to evaluate top-down/bottom-up damage
Remaining work

• Finalize NNs, correct void analysis
• Integrate with erosion in the faulting model
• Assemble the model
Contract modification will be required:

• To allow more time to complete the project
• To account for PI’s move to another institution
  – Move project to UPitt
  – Appoint an interim PI at the University of Minnesota and modify the contract with UPitt
Remaining work

• Task 4: UBOL procedure development – April 30, 2017
• Task 5: Procedure user guide development – July 31, 2017
• Task 6: Evaluate guidelines on suitability of UBOL – August 31, 2017
• Task 7: Draft final report – September 30, 2017
• Task 8: Final report – December 31, 2017