Calibration of Mechanistic-Empirical Fatigue Models Using the PaveLab Heavy Vehicle Simulator
1. INTRODUCTION
1. INTRODUCTION

Real Time Load Testing (RTL) → significant time required (more than 10 years).

Costa Rican Accelerated Pavement Testing (APT) was implemented (PaveLab), relying on a Heavy Vehicle Simulator (HVS).

The PaveLab had to meet (Project Proposal 2010):

- Mobility
- Accelerated pavement evaluation
- Application of real loads
- Comparable results to similar equipment

Calibration of the CR-ME
1. INTRODUCTION
1. INTRODUCTION

Heavy vehicle simulator Mark VI (Dynatest)

Actual Test Settings:

- 20,000 bi-directional load repetitions per day
- Carriage speed: 10 km/hr
- Applied load: 40, 50, 60, 70, 80 kN
- Test tire: Dual 11R22-5
- Wheel wandering: 100 mm
- **Dry and wet condition**
- 23/6
PaveLab numbers....

- 9E6 load repetitions
- 70E6 ESALs
- 10 test sections
1. INTRODUCTION

The effect of moisture is fundamental in determining pavement response. The effect becomes more important when high levels of moisture and precipitation are present → COSTA RICA
1. INTRODUCTION

1200 – 8000 Raining mm/year
1. INTRODUCTION

To capture the effect of moisture on pavement performance:

- 4 APT test sections under optimum moisture
- 4 APT test sections under high saturation conditions
2. PAVELAB TEST SECTIONS
2. PAVELAB TEST SECTIONS

<table>
<thead>
<tr>
<th>Section Properties</th>
<th>001AC1</th>
<th>003AC2</th>
<th>008AC1</th>
<th>007AC2</th>
</tr>
</thead>
<tbody>
<tr>
<td>AC Thickness (H1), cm</td>
<td>6.1</td>
<td>6.3</td>
<td>6.1</td>
<td>6.3</td>
</tr>
<tr>
<td>Base Thickness (H2), cm</td>
<td>21.9</td>
<td>21.2</td>
<td>21.9</td>
<td>21.2</td>
</tr>
<tr>
<td>Subbase Thickness (H3), cm</td>
<td>30.1</td>
<td>30.1</td>
<td>30.1</td>
<td>30.1</td>
</tr>
<tr>
<td>AC Modulus (E1), MPa [@ 25 °C, 1.5 Hz]</td>
<td>3500</td>
<td>3500</td>
<td>3500</td>
<td>3500</td>
</tr>
<tr>
<td>Base Modulus (E2), MPa</td>
<td>1200</td>
<td>115</td>
<td>1750</td>
<td>300</td>
</tr>
<tr>
<td>Subbase Modulus (E3), MPa</td>
<td>142</td>
<td>75</td>
<td>500</td>
<td>100</td>
</tr>
</tbody>
</table>
3. INSTRUMENTATION

- Asphalt strain gauges
- Pressure cells
- MDDs
- Moisture probes
- Temperature probes

Section Length = 6.0 m
4. SATURATION OF THE TEST TRACKS

- Constant water table → 70 cm
- Subgrade Saturation → 87%
- Base and subbase saturation → 43%
MODULI VARIATION WITHLOADING
5. PROPOSED FATIGUE MODEL

\[
\text{Damage} = A \times MN^\alpha \times \left( \frac{\text{resp}}{\text{resp}_{\text{ref}}} \right)^\beta \times \left( \frac{E}{E_{\text{ref}}} \right)^\gamma \times e^{\delta T}
\]

Where:

- MN = the number of load repetitions (ESAL) in millions
- \text{resp} = the response (stress or strain)
- \text{resp}_{\text{ref}} = a reference response (can be related to strength)
- E = the modulus of the material (adjusted for climate and damage)
- E_{\text{ref}} = a reference modulus
- A, \alpha, \beta, and \gamma are model constants.
6. RESULTS

Four Point Bending Beam (4PBB) Fatigue Tests

\[ \omega = 0.189 \times (MN)^{0.271} \times \left( \frac{\varepsilon}{200} \right)^{1.07} \times \left( \frac{E}{3000} \right)^{0.535} \times e^{(0.035 \times T)} \]

Where:
- \( MN \) = the number of load repetitions in millions
- \( \varepsilon \) = tensile micro strain
- \( E \) = material modulus
- \( T \) = temperature.

<table>
<thead>
<tr>
<th>Mix</th>
<th>Coefficient</th>
<th>Value</th>
<th>Std. Error</th>
<th>T-stat.</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laboratory</td>
<td>A</td>
<td>0.189</td>
<td>0.0079</td>
<td>65.85</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td></td>
<td>( \alpha )</td>
<td>0.271</td>
<td>0.0014</td>
<td>162.82</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td></td>
<td>( \beta )</td>
<td>1.070</td>
<td>0.0084</td>
<td>117.12</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td></td>
<td>( \gamma )</td>
<td>0.535</td>
<td>0.0081</td>
<td>19.23</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td></td>
<td>( \delta )</td>
<td>0.035</td>
<td>0.0005</td>
<td>32.29</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Residual Standard Error</td>
<td>0.04897 for 25,172 degrees of freedom</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
6. RESULTS

Backcalculated Layer Moduli

- RSD deflection data to determine the pavement layer moduli
- Based on Method of Equivalent Thickness (MET)
- Stress, strains and deflections calculation was realized using Boussinesq theory

Damage determined for the laboratory tests as well as each individual test section → 5 locations

- Three deflection measurements were performed at each location
6. RESULTS

- Temperature records at mid depth of the asphalt layer were also recorded to correct the modulus of the temperature-susceptible layers.

- A single adjustment factor might not be adequate for predicting fatigue damage.
6. RESULTS

- Fatigue cracking
- Rutting
- Longitudinal cracking
- Pumping
6. RESULTS

\[ MN = k_1 \left( \frac{\epsilon}{200} \right)^{k_2} \left( \frac{E}{3000} \right)^{k_3} \]

Where
- \( k_1, k_2, k_3 \) and \( k_4 \) = regression coefficients corrected with HVS data,
- MN: ESALs millions.
6. RESULTS

Damage on AC1 dry condition

Damage vs. Mesal

- AC1 layer damage
- Damage laboratory regression
- Calibration with HVs data

Damage on AC1 wet condition

Damage vs. Mesal

- AC1 layer damage
- Damage laboratory regression
- Calibration with HVs data
6. RESULTS

<table>
<thead>
<tr>
<th>Section AC1 Dry conditions</th>
<th>Section AC1 Wet conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Coefficients</strong></td>
<td><strong>Damage level</strong></td>
</tr>
<tr>
<td></td>
<td>60%</td>
</tr>
<tr>
<td>$k_1$</td>
<td>0.040</td>
</tr>
<tr>
<td>$k_2$</td>
<td>-3.006</td>
</tr>
<tr>
<td>$k_3$</td>
<td>-1.503</td>
</tr>
<tr>
<td>$k_4$</td>
<td>-0.099</td>
</tr>
</tbody>
</table>
7. CONCLUSIONS

- Fatigue models accounted for different conditions: materials and humidity.
- Field calibration is still required (CR-LTPP project).
- Fatigue models were calibrated for strain levels corresponding to the pavement sections AC1 and AC2. Future tests sections will expand the strain level range.
- Fatigue model coefficients calibration between 4PBB and APT sections are satisfactory for each of the test tracks was statistically satisfactory.
8. REFERENCES


8. REFERENCES


8. REFERENCES


THANKS FOR YOUR ATTENTION!

luis.loriasalazar@ucr.ac.cr