VALIDATION OF FDOT AUTOMATED FAULTING METHOD

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Roanoke, VA
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Outline

• Background
• Goal & Objectives
• Automated Faulting Program
• Test Equipment
• Data Collection
• Results
• Analysis
• Conclusion
• Recommendation
Background

What is Faulting?

“...the difference in elevation across a transverse joint or a transverse crack..” Ref. AASHTO R-36
Faulting is ...

- a key distress in jointed concrete pavements
- an important performance indicator
- a critical factor in the life-cycle cost of a pavement
Background

Source: Pavement Interactive – http://pavementinteractive.org
Background

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Background

Catalysts for the study …

- HPMS reassessment requirements
- Need to leverage profile data
- Lack of validation information
- Safety
Automated Faulting Program
Automated Faulting Program

TRB Publication 10-1868, 2010
Goal and Objectives

Validate automated faulting method
  • Phase 1 – Faulting simulation
  • Phase 2 – Field validation

Automated faulting precision
  • Repeatability
  • Accuracy
  • Reproducibility
Test Equipment

Georgia Faultmeter

[Image of Test Equipment with labels: Leave Slab, Approach Slab, Direction of Traffic]
Test Equipment

Five High Speed Profilers (HSP)
# Test Equipment

IRI Filtered Cross Correlation

<table>
<thead>
<tr>
<th>HSP</th>
<th>Interval (in)</th>
<th>Left</th>
<th>Right</th>
</tr>
</thead>
<tbody>
<tr>
<td>29748</td>
<td>0.8</td>
<td>93</td>
<td>94</td>
</tr>
<tr>
<td>30330</td>
<td>0.7</td>
<td>92</td>
<td>96</td>
</tr>
<tr>
<td>30781</td>
<td>0.9</td>
<td>62</td>
<td>84</td>
</tr>
<tr>
<td>29863</td>
<td>0.8</td>
<td>94</td>
<td>97</td>
</tr>
<tr>
<td>30392</td>
<td>0.7</td>
<td>97</td>
<td>97</td>
</tr>
</tbody>
</table>
Test Equipment

Faulting Simulation Device
Software

• Automated Faulting Program – Major Steps
  • Remove user-defined exclusions from collected data
  • Set default sensitivity factor (SF)
  • Find valleys (negative slopes) and peaks (positive slopes) meeting minimum SF
  • Calculate distance between consecutive peak and valley
  • Distance has to be less than 2.5 inch to consider the couple as joint
  • Calculate faulting based on AASHTO R36-04 criteria
  • Check if the calculated faulting is more than 1/64\textsuperscript{th} inch (FDOT PCS spec) → YES → temporary save location of the joint
This is a test page!

• Automated Faulting Program – Major Steps
  • Repeat previous steps for all the points in the given profile
  • Check distance between consecutive joints to be more than 14.8 in → NO → keep one with deeper fault
  • Count number of joints
  • Repeat all previous steps for different SF
  • Keep SF which has largest number of found joints meeting all previous described criteria
  • Recalculate joint location and fault magnitude for the chosen SF
  • Save results
Data Collection

Phase 1: Simulated Faulting

- “controlled” conditions (eliminates effects of pavement texture and vehicle wander)
- Asses HSIP’s ability to collect accurate and repeatable elevation data in a dynamic mode
- Middle laser was used to collect elevation data
- Average of left and right accelerometer readings was used to correct middle laser sensor height data
Data Collection

Phase 1- Simulated Faulting

• 5 HSP
  ➢ 0.68 to 0.91 inch interval
• Faulting simulation device (reference)
  ➢ 13, 11.89, 10.07, 7.00, 5.05, 2.01, 0.91 (mm)
• 6 speeds
  ➢ 20, 30, 40, 50, 60, and 70 mph
• 3 replicate runs per speed
Data Collection

Phase 1 - Simulated Faulting

Run 60 MPH, pass 2, vehicle 28330
Data Collection

Phase 1- Simulated Faulting (defective sensor)
Data Collection

Phase 2- Field Validation

• SR-331 (Waldo Road)
  ➢ PCP, 20 ft slabs, burlap drag texture, 50 joints
• 5 HSP
  ➢ 0.68” to 0.91” sampling interval
  ➢ 3 runs @ 40 MPH
  ➢ Right laser/accelerometer
• Georgia Faultmeter (reference)
  ➢ 9 readings across right wheelpath
Results

Phase 1 - Simulated Faulting
## Results

### Phase 1 - Simulated Faulting

<table>
<thead>
<tr>
<th>Speed (mph)</th>
<th>Slope (mm)</th>
<th>Intercept (mm)</th>
<th>$R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>0.978</td>
<td>0.568</td>
<td>0.999</td>
</tr>
<tr>
<td>30</td>
<td>1.007</td>
<td>0.299</td>
<td>0.999</td>
</tr>
<tr>
<td>40</td>
<td>1.010</td>
<td>0.153</td>
<td>0.998</td>
</tr>
<tr>
<td>50</td>
<td>1.008</td>
<td>0.196</td>
<td>0.999</td>
</tr>
<tr>
<td>60</td>
<td>0.989</td>
<td>0.354</td>
<td>0.999</td>
</tr>
<tr>
<td>70</td>
<td>0.991</td>
<td>0.459</td>
<td>0.999</td>
</tr>
</tbody>
</table>
Results

Phase 1 - Simulated Faulting

• Accuracy
  ➢ maximum bias between HSP and simulated faulting device

• Repeatability
  ➢ maximum range within a HSP
## Results

### Phase 1 - Simulated Faulting

<table>
<thead>
<tr>
<th>Accuracy (mm)</th>
<th>Repeatability (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.60</td>
<td>0.65</td>
</tr>
</tbody>
</table>
Results

Phase 2 – Faulting Field Validation

• Accuracy
  ➢ maximum bias between HSP and Georgia Faultmeter

• Repeatability
  ➢ maximum range within a HSP

• Reproducibility
  ➢ maximum range among all HSPs
Results

Phase 2 – Joint Detection

• True Positives
  ➢ existing joints detected

• True Negatives
  ➢ existing joints not detected

• False Positives
  ➢ non-existing joints falsely detected
Results

Joint Detection Rate (\%) = \frac{(# \ True \ Positives) \times 100}{(# \ True \ Positives + # \ True \ Negatives)}
## Results

### Phase 2 – True Positives

<table>
<thead>
<tr>
<th></th>
<th>29748</th>
<th>29863</th>
<th>30330</th>
<th>30781</th>
<th>30392</th>
</tr>
</thead>
<tbody>
<tr>
<td>Count</td>
<td>41</td>
<td>42</td>
<td>40</td>
<td>37</td>
<td>47</td>
</tr>
<tr>
<td>Accuracy</td>
<td>82%</td>
<td>84%</td>
<td>80%</td>
<td>74%</td>
<td>94%</td>
</tr>
</tbody>
</table>
## Results

### Phase 2 – True Negatives

<table>
<thead>
<tr>
<th></th>
<th>29748</th>
<th>29863</th>
<th>30330</th>
<th>30781</th>
<th>30392</th>
</tr>
</thead>
<tbody>
<tr>
<td>Count</td>
<td>9</td>
<td>8</td>
<td>10</td>
<td>13</td>
<td>3</td>
</tr>
<tr>
<td>%</td>
<td>18%</td>
<td>16%</td>
<td>20%</td>
<td>26%</td>
<td>6%</td>
</tr>
</tbody>
</table>
# Results

## Phase 2 – False Positives

<table>
<thead>
<tr>
<th></th>
<th>29748</th>
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<th>30330</th>
<th>30781</th>
<th>30392</th>
</tr>
</thead>
<tbody>
<tr>
<td>Count</td>
<td>9</td>
<td>8</td>
<td>8</td>
<td>7</td>
<td>16</td>
</tr>
<tr>
<td>Percent</td>
<td>18%</td>
<td>16%</td>
<td>16%</td>
<td>14%</td>
<td>32%</td>
</tr>
</tbody>
</table>
## Results

### Phase 2 - Automated Faulting

<table>
<thead>
<tr>
<th>“Precision” (mm)</th>
<th>Accuracy</th>
<th>Repeatability</th>
<th>Reproducibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.2</td>
<td>1.1</td>
<td>0.5</td>
<td></td>
</tr>
</tbody>
</table>

Analysis

Phase 1- Simulated faulting

- Speed gradient had an upward bias at all speeds.
- Simulated faulting accuracy estimated at 0.6 mm.
- Simulated faulting repeatability estimated at 0.65mm.
Analysis

Phase 2 Field validation

- Positive joint detection was 80 to 90%
- Automated faulting accuracy was 1.2 mm.
- Automated faulting repeatability was 1.1 mm.
- Automated faulting reproducibility was 0.5 mm.
Conclusions

• The simulated faulting device is an effective tool to test an inertial profiler system’s ability to make accurate height measurements in dynamic mode.

• The FDOT Automated Faulting Method provides a safe, fast, accurate, and cost effective method faulting measurement method.
Recommendations

Additional validations work…

• Range of joint widths
• Different joint and slab conditions
• Range of slab lengths and geometry
• Various profile filters
Recommendations

Improve the algorithm by …

• Enhancing positive joint detection
• Reducing false positives, and
• Increasing program efficiency
<table>
<thead>
<tr>
<th>Mississippi Data – True Positives</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Carroll</strong></td>
</tr>
<tr>
<td>160</td>
</tr>
<tr>
<td>74%</td>
</tr>
</tbody>
</table>
Thank you!