Automated Cross-Slope and Drainage Path Method
Presentation Outline:

• Contributing factors to Hydroplaning
• Traditional and Automated Survey Methods
• Multi-Purpose Survey Vehicle (MPSV) and Subsystems
• Automated Cross-Slope Analysis Program (ACAP)
• Field Validation
• Examples
• Conclusion
Factors that contribute to hydroplaning:

- Driver
- Vehicle
- Environment
- Pavement Surface (geometry, condition, drainage)
Pavement

- Cross-slope
  *Facilitates/hampers drainage*

- Grade
  *Affects drainage path (DP)*

- Rutting
  *Increases water retention*
Traditional Survey Methods

• Slow and labor intensive
• Expose crew to hazardous conditions
• Require traffic control
• Cause inconvenience to traveling public
• Costly
Automated Survey Methods

- Fast (highway speed)
- Safe (no traffic control required)
- Efficient (simultaneous data collection)
- Cost-Effective
Automated Cross-Slope and Drainage Path Method

• Multi-Purpose Survey Vehicle (MPSV) to collect pavement data, and

• Automated Cross-Slope Analysis Program (ACAP) to analyze data
Multi-Purpose Survey Vehicle (MPSV)

- Inertial Profiling System
- Position and Orientation System (POS)
Multi-Purpose Survey Vehicle (MPSV)

- Inertial Profiling System
- Position and Orientation System (POS)
Inertial Profiling System

- Three height laser sensors
- Two accelerometers
- Distance Measurement Indicator (DMI)
- Automatic Trigger System
Multi-Purpose Survey Vehicle (MPSV)

- Inertial Profiling System
- Position and Orientation System (POS)
Position and Orientation System (POS)

- Differential Global Positioning System (DGPS)
- Inertial Measurement Unit (IMU)
- Distance Measurement Indicator (DMI)
- POS Computer
Differential Global Position System (DGPS)

- Roof antennas
- Receiver (12 channel)
- Differential correction signal
Inertial Measurement Unit (IMU)

- Generates tilt, roll and yaw data
- 3 accelerometers
- 3 gyroscopes
Distance Measuring Indicator (DMI)

• Linear distance referencing
POS Computer

- Data storage and processing
Input Data from MPSV

- Cross-Slope
- Grade
- Rutting
- Linear Reference (Distance)
Automated Cross-Slope Analysis Program (ACAP)

- Imports MPSV data (cross-slope, grade, rutting, distance)
- Calculates drainage path length
- Generates outputs (tabular and graphical)
Automated Cross-Slope Analysis Program (ACAP)
Drainage Path Length Calculation

\[ DP^2 = (W_C^2)[1+(S_G/S_C)^2] \quad (1) \]

- \( W_C \) = pavement width (ft)
- \( S_G \) = grade (ft/ft)
- \( S_C \) = cross-slope (ft/ft)

Automated Cross-Slope Analysis Program (ACAP) Text Report

<table>
<thead>
<tr>
<th>REPORT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Road Number</strong></td>
</tr>
<tr>
<td><strong>Road Name and County</strong></td>
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<tr>
<td><strong>Direction</strong></td>
</tr>
<tr>
<td><strong>FIN Number</strong></td>
</tr>
<tr>
<td><strong>Project Limit (Start)</strong></td>
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<tr>
<td><strong>Project Limit (End)</strong></td>
</tr>
<tr>
<td><strong>Note</strong></td>
</tr>
<tr>
<td><strong>Survey Date</strong></td>
</tr>
</tbody>
</table>

Section: 2 (MP 3.95 to MP 3.2). L1, L2, and L3, L4 decceleration lane begins at MP 3.458 and ends at MP 3.358:

**Super-Elevation.**
L1 Cross-slope: Min= -3.2 %, Max= 2.3 %, Mean= -2.1 %, St Dev = 1.4 %.
L1 Drainage Path: Min= 12 ft, Max= 1130.2 ft, Mean= 40 ft.
L1 Rutting: Min= 0.00 inch, Max= 0.21 inch, Mean= 0.13 in, St Dev= 0.05 in.
L2 Cross-slope: Min= -3.4 %, Max= 1.8 %, Mean= -2 %, St Dev = 1.23 %.
L2 Drainage Path: Min= 13.5 ft, Max= 1200.1 ft, Mean= 29.8 ft.
L2 Rutting: Min= 0.00 inch, Max= 0.37 inch, Mean= 0.21 in, St Dev= 0.05 in.
L3 Cross-slope: Min= -2.4 %, Max= 2.8 %, Mean= -1.1 %, St Dev = 0.93 %.
L3 Drainage Path: Min= 12 ft, Max= 1092.1 ft, Mean= 21.7 ft.
L3 Rutting: Min= 0.00 inch, Max= 0.3 inch, Mean= 0.18 in, St Dev= 0.07 in.
L4 Cross-slope: Min= 0.6 %, Max= 4.4 %, Mean= 3.2 %, St Dev = 1.02 %.
L4 Drainage Path: Min= 12.2 ft, Max= 29.2 ft, Mean= 13.4 ft.
L4 Rutting: Min= 0.07 inch, Max= 0.48 inch, Mean= 0.17 in, St Dev= 0.12 in.
L4 Average Vertical Grade= -1.1 %.

**User Note:** L3 lane is not fully superelivated (Cross slope is between 1% and 2%). Rutting in all lanes is up to 0.25 inch with L2 up to 0.35 inch. Cross-slope in L3 steadily rises from 0.5% up to 6% and splits off L1 lane which has negative Cross-slope.
Automated Cross-Slope Analysis Program (ACAP) Tabular Output

<table>
<thead>
<tr>
<th>Milepost (MP)</th>
<th>Cross-slope (%)</th>
<th>Longitudinal Grade (%)</th>
<th>Drainage Path (ft)</th>
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<tbody>
<tr>
<td>6.32</td>
<td>2.36</td>
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<tr>
<td>6.33</td>
<td>2.62</td>
<td>-1.61</td>
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<td>6.34</td>
<td>3.11</td>
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<td>3.29</td>
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<td>6.36</td>
<td>3.44</td>
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<tr>
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<td>2.62</td>
<td>-0.79</td>
<td>13</td>
</tr>
<tr>
<td>6.49</td>
<td>3.50</td>
<td>-0.91</td>
<td>12</td>
</tr>
</tbody>
</table>
Automated Cross-Slope Analysis Program (ACAP)
2D Graphical Output
Automated Cross-Slope Analysis Program (ACAP)
3D Graphical Output (work in progress)

(a) MP = 4.088
(b) MP = 4.503
(c) MP = 4.877
(d) MP = 5.286

positive cross-slope
negative cross-slope
Field Validation

SR-222 (37 points)
MPSV Cross-Slope Precision

- **Repeatability:** 0.06%
- **Accuracy:** ±0.13%
Case Example 1

Problem:
Shallow cross-slope within super elevation of interstate

Consequence:
Vehicle departures reported
Cross-Slope Comparisons

All Lanes

Before

After

Notice This Zero Value

Distance / Station

EBPL (Before)  EBTL (Before)  EBPL (After)  EBTL (After)
Case Example 2

Problem:  
Poor pavement drainage reported on 6-lane rural interstate

Consequence:  
Roadway departures reported
Before Corrective Action
Short-Term Preventive Action
Short-Term Preventive Action
Short-Term Solution
Long-term Solution

- Milling
- Overbuild
Observations

• Substantial cross-slope improvement

• Smoother transition in and out of super-elevation

• Elimination of surface drainage problem

• No new roadway departures reported
Automated Cross-Slope and Drainage Path Method

- Identifies areas of pavement prone to hydroplaning
- For design, construction and safety projects
- Assists in developing short and long term solutions
- Safe, fast and very effective
Thank You!