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AN IMPLEMENTABLE FRAMEWORK FOR STANDARDIZING NATIONAL PAVEMENT CRACK MEASURES

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Background

- **Cracking is one of the most common types of pavement surface distresses** and an important symptom of potential pavement failure. Crack evaluation is an necessary component in most pavement surface condition surveys:
  - Required by the Highway Performance Monitoring System (HPMS);
  - Suggested to AASHTO as part of pavement performance measures to fulfill the need of MAP-21;
  - Commonly used in state DOT’s survey practice to support their pavement management.

- However, due to the significant diversity among the federal and state DOT’s pavement distress protocols, it remains a challenge to establish nationwide consistent crack measures.
  - State DOTs have invested major resources to collect and maintain their **legacy data over decades for pavement management**, and are not willing to change their distress protocol.
  - Collecting crack data following both DOT’s legacy protocols and an irrelevant national standard requires extra resources, which is not optimal given the current and projected budgetary constraints.
The automatic crack survey is gradually replacing traditional manual field survey in many highway agencies.
Automatic Crack Measurement/Evaluation

Data Acquisition

Crack Detection

Crack Classification

3 Steps of Crack Measurement/Evaluation
The objective of this study is to propose an implementable framework for standardizing national pavement crack measures, which

- Utilizes the data derived from emerging 2D imaging and 3D technology
- Characterizes pavement surface cracks in a systematic and comprehensive manner;
- Converts flexibly and easily among different crack protocols (crack types and severity levels).
Crack pattern is crucial for differentiating crack types and severity levels.

A multi-scale CFE model is developed, which provides rich crack properties at three scales:

- **Fundamental crack properties**: fundamental and physical characteristics of each basic crack line;
- **Aggregated crack properties**: crack patterns, representing how cracks interact with each other;
- **Clustered CFE geometrical properties**: overall properties of clustered CFE.
Crack Properties at Three Scales


Framework for Sensor-based Standardized Crack Measures

Sensor-based Pavement Data Collection

Crack Map Generation

Multi-Scale Topological Crack Representation Using Crack Fundamental Element

- **Fundamental Crack Properties**
  - (crack width, crack length, crack depth, etc.)

- **Aggregated Crack Properties**
  - (crack intersection, crack polygon, crack density, etc.)

- **CFE Geometrical Properties**
  - (CFE location, CFE orientation, CFE extent, etc.)

Standardized Crack Measures Among Agencies

Crack Classification and Quantification based on Agency’s Distress Protocol
Illustration of abstracting crack properties from the data and transforming them into specific distress protocol

**Real-World Crack Characteristics**

**Multi-Scale Crack Representation**

- **CFE Cluster Geometrical Properties**
  - Clustered CFEs (CFE location, CFE orientation, and CFE extent)

- **Aggregated Crack Properties**
  - Crack Network (location, density of curves and pieces)
  - Crack Piece (polygon or spall type, angle and area)
  - Crack Intersection (number and location of key points)

- **Fundamental Crack Properties**
  - Predominant Crack Curve (location, extent, width, depth, and orientation)
  - Initial CFEs

**Criteria & Interpretation Methods**

- **Federal & State DOT’s Crack Definitions**
  - GDOT Load Cracking
    - Severity Level 4
  - Severity Level 3
  - Severity Level 2
  - Severity Level 1

Consistency & Flexibility!
Flexible Shell Applications

Invariant Multi-scale Crack Characteristics

4.1 Small-Scale Crack Network
(location, density of curves and pieces)

4.2 Medium-Scale Crack Network
(density of curves and pieces)

4.3 Large-Scale Crack Network
(Extent)

3. Crack Piece
 polygon or spall type, angle and area

2. Crack Intersection
(number and location of key points)

1. Predominant Crack Curve
(location, extent, width, depth, and orientation)

0. Fundamental Crack Element

Various Shell Applications

Standardized Pavement Crack Measures
(e.g. wheelpath crack, intensity 20%)

Agencies’ legacy Protocols (LTTP, GDOT, etc)
(e.g. GDOT load cracking, severity level 2, 10%)
GDOT - B/T Cracking (crack type and severity level)

Severity Level 1

Severity Level 2

Severity Level 3
Implementation with GDOT’s protocol

*Measurement Unit: Foot*
Implementation with GDOT’s protocol (cont’d)

<table>
<thead>
<tr>
<th>Wheelpath Type</th>
<th>Level 1</th>
<th>Level 3</th>
<th>Level 4</th>
<th>Level 1</th>
<th>Level 3</th>
<th>Level 4</th>
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<tr>
<td>Left Wheelpath</td>
<td>12.6</td>
<td>15.9</td>
<td>14.7</td>
<td>0</td>
<td>15.9</td>
<td>4.1</td>
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<td>Right Wheelpath</td>
<td>12.6</td>
<td>15.9</td>
<td>14.7</td>
<td>0</td>
<td>15.9</td>
<td>4.1</td>
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<tr>
<td>Non Wheelpath</td>
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<td>18.8</td>
<td>4.1</td>
<td>0</td>
<td>18.8</td>
<td>4.1</td>
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</table>

*Measurement Unit: Foot*
### Implementation with GDOT’s protocol (cont’d)

<table>
<thead>
<tr>
<th></th>
<th>Left Wheelpath</th>
<th>None</th>
<th>0</th>
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<tbody>
<tr>
<td>Right Wheelpath</td>
<td>None</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Non Wheelpath</td>
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<td></td>
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<td>0</td>
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<tr>
<td></td>
<td>Non Wheelpath</td>
<td>BT Level 3</td>
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</table>

*Measurement Unit: Foot*
## In-field Comparison Results (1)

### SR 236 Site #1

<table>
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<tr>
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<th>Field Measurement</th>
<th>Automatic Evaluation</th>
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<tbody>
<tr>
<td></td>
<td>Extent(%)</td>
<td>Deduct</td>
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<tr>
<td><strong>Load Lvl 1</strong></td>
<td>56</td>
<td>15</td>
</tr>
<tr>
<td><strong>B/T Lvl 1</strong></td>
<td>100</td>
<td>18</td>
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<td><strong>Overall</strong></td>
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### SR 236 Site #2

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<td></td>
<td>Extent(%)</td>
<td>Deduct</td>
</tr>
<tr>
<td><strong>Load Lvl 1</strong></td>
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<td>13</td>
</tr>
<tr>
<td><strong>Load Lvl 2</strong></td>
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<td>2</td>
</tr>
<tr>
<td><strong>B/T Lvl 1</strong></td>
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<td>18</td>
</tr>
<tr>
<td><strong>Overall</strong></td>
<td>31</td>
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</table>

*Note: the total deduct value is computed using the predominant deduct value for each crack type, following PACES.*
The average absolute difference for four sections is 3.25.

The overall performance is promising, within the error tolerance in GDOT’s decision making practice (5 deduct points).
Conclusions and Recommendations

- The concept of multi-scale crack analysis using Crack Fundamental Element (CFE) model is proposed. Based on this concept, this study develops a framework that can flexibly and easily convert among different crack protocols. It
  - Provides nationwide consistent crack measures to fulfill the need of MAP-21; and also
  - Maintains the legacy of state DOT’s historical data and pavement management practice.

- Methods and procedures need to be developed to transform the multi-scale crack properties into agency’s crack definitions, i.e. automatic crack classification using federal and state DOT’s distress protocols.
Thank you for your attention!

Questions?