Pavement Service Life Extension
Due to Asphalt Surface Treatment (AST) Interlayer

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University of Louisiana at Lafayette

SESPA Conference
October 9-11, 2019
1. Research Need
2. Research Objectives
3. Research Work Plan
4. Results and Analysis
5. Conclusions and Recommendations
Research Need

College of Engineering

UNIVERSITY OF LOUISIANA
Lafayette
Reflective Cracking due to Soil-cement Base Mechanism

Soil Type, Cement Content, Curing, Compaction, Traffic, etc.
Research Need

Narrow Cracks

Wider Cracks
Research Need

Stress Relief Interlayers

$\sigma_t$: Tensile Stress, $S_t$: Tensile Strength of Material

AST Interlayer

Granular Interlayer
Soil-Cement Base (LA Design)

- **Cement Stabilized Design: (CSD)**
  - 300 psi 7-day Compressive Strength
  - Appx. 10% Cement Content

- **Cement Treated Design: (CTD)**
  - 150 psi 7-day Compressive Strength
  - Appx. 5% Cement Content
Research Need

Problem Statement

- DOTD has been using asphalt surface treatment (AST) interlayers over soil-cement base courses to mitigate shrinkage cracks from reflecting through the overlying asphaltic concrete (AC) pavement.

- No studies have been conducted to determine:
  - The service life extension (SLE) of AST interlayers
  - The cost effectiveness of AST interlayers

Systematic Research Study is Needed
Research Need

ustria Data
- DOTD’s Mainframe
- Material Testing System (MATT)
- Tracking of Projects (TOPS)
- Letting of Projects (LETS)
- Highway Needs, Traffic Volume, Pavement design and System Preservation databases.

Distress Data
- Distress data from PMS database
  - IRI, Rut, Fatigue, Longitudinal and Transverse cracking
- Recorded every two years by the automatic road analyzer (ARAN) for every 1/10th of a mile (1995-2016)
Research Objectives

1. Evaluate DOTD’s current practices on AST interlayer over soil-cement base

2. Determine the effectiveness of the AST interlayer practice in terms of its costs and benefits

3. Provide recommendation/guidelines for AST interlayers over soil-cement base
Research Approach and Work Plan
Research Work Plan

Research Tasks

- **Task 1**— Review of Literature and State-of-the-Practice
- **Task 2**— Review of LA DOTD State-of-the-Practice
- **Task 3**— Roadway Identification for Project Selection
- **Task 4**— Determination of Service life (SA) and Gain SL (SLE)
- **Task 5**— Cost Benefit Analysis
- **Task 6**— Guidelines
- **Task 7**— Final Report, Recommendation and Implementation
Task 1—Literature Review & State-of-the-Practice

- Several US States (LA, TX, CA, MS, VA, NM, GA) have been evaluating reflective cracks mitigating technique for soil-cement base pavements.
- Stress Relieving Interlayer, Micro-Cracking of Bases and Inverted Pavements (Stone Interlayers) are commonly used technique.
- Currently, Stone Interlayers are built over Soil-cement bases at VA, NM and GA for performance evaluation.
- LA also evaluated Stone Interlayer using ALF. The results indicated improvement in crack mitigation.
- Paving Fabrics (sometimes with chipseal) have been used by some US states and are found to be a capable interlayer to mitigate reflective cracking (over HMA/PCC/Soil-Cement bases).
- Micro-Cracking technique are on the process of evaluation in TX, CA and LA. Texas found significant crack mitigation by micro-crack however, LA did not find any improvement. CA has not reported the results, yet.
- Louisiana is currently using AST as interlayer over soil-cement bases. No other reports have been found in the literature where AST is used as solely as an Interlayer over soil-cement bases.
Task 2

Review of DOTD State-of-the-Practice

A. General
A.1 On average, how many lane miles of pavements receive the following interlayers over soil-cement bases in your district on a yearly basis?

<table>
<thead>
<tr>
<th>Interlayer Type</th>
<th>Number of Lane-Miles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flexible</td>
<td>Rigid</td>
</tr>
<tr>
<td>AST: Chip seal - Single layer</td>
<td></td>
</tr>
<tr>
<td>AST: Chip seal - Double layer</td>
<td></td>
</tr>
<tr>
<td>Micro-surfacing Interlayer</td>
<td></td>
</tr>
<tr>
<td>Aggregate Interlayer</td>
<td>Reclaimed Concrete Interlayer</td>
</tr>
<tr>
<td>Geotextile Interlayer</td>
<td>Other: 1)</td>
</tr>
<tr>
<td>Other: 2)</td>
<td></td>
</tr>
</tbody>
</table>

A.2 What is the current average life span (years) and cost per lane-mile of the following interlayers over soil-cement bases in your district?

<table>
<thead>
<tr>
<th>Interlayer Type</th>
<th>Life Span (years)</th>
<th>Cost per Lane-Mile ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AST: Chip seal - Single layer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AST: Chip seal - Double layer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Micro-surfacing Interlayer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aggregate Interlayer</td>
<td>Reclaimed Concrete Interlayer</td>
<td></td>
</tr>
<tr>
<td>Geotextile Interlayer</td>
<td>Other: 1)</td>
<td></td>
</tr>
<tr>
<td>Other: 2)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

B. Pavement Design
B.1 Does your District design thickness of pavement and interlayers over soil-cement bases?

- Yes
- No

If you answered Yes to B1, please skip to Question C1.

B.2 What method do you use in the design of the thickness of the following interlayers over soil-cement bases?

(Please check all that apply)

<table>
<thead>
<tr>
<th>Interlayer Type</th>
<th>AASHTO 1993</th>
<th>AASHTO 2002</th>
<th>In-house Experience</th>
<th>Others</th>
</tr>
</thead>
<tbody>
<tr>
<td>AST: Chip seal - Single layer</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AST: Chip seal - Double layer</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Micro-surfacing Interlayer</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aggregate Interlayer</td>
<td>Reclaimed Concrete Interlayer</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Geotextile Interlayer</td>
<td>Other: 1)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other: 2)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

C. Project Scoping Process
C.1 Do you utilize the PMS Data in your project scoping process?

- Yes
- No

If Yes, please explain.

C.2 What method do you use to evaluate the existing pavement conditions?

(Please check all that apply)

- District data such as roughness, rutting, cracking, etc.
- District index
- Composite pavement index
- Remaining service life (RSL)
- Do not evaluate existing conditions
- Forensic investigation
- Destructive testing (tensile, etc.
- Nondestructive testing (FWD, etc.)
- Other method, please specify.

C.3 What are the major reasons for your District's decision to provide interlayers over soil-cement bases?

(Please check all that apply)

- Improve ride quality
- Improve structural capacity
- Retard distress propagation (cracking)
- Remaining service life (RSL)
- PMS recommendations
- Political
- Other reasons, please specify.
C.4 What type of soil-cement base requires the following interlayers over soil-cement bases in your district?

<table>
<thead>
<tr>
<th>Interlayer Type</th>
<th>Cement Treated Design (CTD) UCS@7days 160 psi</th>
<th>Cement Stabilized Design (CSD) UCS@7days 300 psi</th>
<th>Others</th>
</tr>
</thead>
<tbody>
<tr>
<td>AST - Chip seal - Single layer</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AST - Chip seal - Double layer</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aggregate Interlayer</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reclaimed Concrete Interlayer</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reclaimed Asphalt Interlayer</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Geotextiles Interlayer</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other: 1)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other: 2)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

C.5 What is the usual curing time (days) of soil-cement bases before the application of Interlayers for flexible pavements?

- 3  - 7  - 14  - 28  - over 28 days

C.6 What is the traffic volume that your district uses for the following Interlayers on soil-cement bases?

<table>
<thead>
<tr>
<th>Interlayer Type</th>
<th>Average Daily Traffic</th>
<th>Average Daily Truck Traffic</th>
<th>Equivalent Single Axle Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>AST - Chip seal - Single layer</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AST - Chip seal - Double layer</td>
<td></td>
<td></td>
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<tr>
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<td></td>
<td></td>
</tr>
<tr>
<td>Geotextiles Interlayer</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other: 1)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other: 2)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

C.7 What percent of the district’s yearly budget is spent on the following categories?

<table>
<thead>
<tr>
<th>Treatment category</th>
<th>% of budget</th>
</tr>
</thead>
<tbody>
<tr>
<td>Replacement</td>
<td></td>
</tr>
<tr>
<td>Rehabilitation</td>
<td></td>
</tr>
<tr>
<td>Preventive maintenance</td>
<td></td>
</tr>
<tr>
<td>Routine maintenance</td>
<td></td>
</tr>
</tbody>
</table>

D.4 What is your typical construction season? (Please check all that apply)

- Fall  - Winter  - Spring  - Summer  - Entire year

D.5 Does your district use Life-Cycle Cost Analysis (LCCA) as a part of the decision process for selecting pavement type?

- Yes  - No

If Yes, please answer the following questions.

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Do you use any specialized software for LCCA? If yes, what software?</td>
<td></td>
</tr>
<tr>
<td>b. Does your district use User Costs in the analysis? If yes, in what ways does it consider?</td>
<td></td>
</tr>
<tr>
<td>c. What discount and/or inflation rates are used and how is it determined?</td>
<td></td>
</tr>
<tr>
<td>d. What analysis period is used? (If not a fixed value, please explain briefly)</td>
<td></td>
</tr>
<tr>
<td>e. What is the initial performance life assigned for reconstructed flexible pavement?</td>
<td></td>
</tr>
<tr>
<td>f. Does your district use salvage value or remaining service life (RSI) value in the LCCA calculations?</td>
<td></td>
</tr>
<tr>
<td>g. Does your district have any guidelines or policies regarding the pavement selection process?</td>
<td></td>
</tr>
</tbody>
</table>

E. Performance and Evaluation

F.1 Which factors do you feel are the most important in minimizing pavement defects and extending the life of your flexible pavement?

- Construction procedure  - Design method  - Better aggregates  - Better binder
- Quality control  - Traffic  - Underlying structure (Base/subbase)  - Maintenance spending  - Roadside Stabilization  - Other

F.2 On the scale from 1 to 10, please rank the dominant distress types occurring after application of each of the interlayers over soil cement bases (a ranking of 1 is the most important).

<table>
<thead>
<tr>
<th>Distress type</th>
<th>Interlayer Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potholes</td>
<td></td>
</tr>
<tr>
<td>Blending</td>
<td></td>
</tr>
<tr>
<td>Corrugation</td>
<td></td>
</tr>
<tr>
<td>Raveling</td>
<td></td>
</tr>
<tr>
<td>Alligator cracks</td>
<td></td>
</tr>
<tr>
<td>Transverse cracks</td>
<td></td>
</tr>
<tr>
<td>Longitudinal cracks</td>
<td></td>
</tr>
<tr>
<td>Rating</td>
<td></td>
</tr>
</tbody>
</table>

D. Contracting and Costs

D.1 What is the range of elapsed time (in months) between pavement project identification, design, and construction for the following two groups of treatments?

a. Flexible pavement without interlayers soil-cement bases, only

- Range of elapsed time to design
- Range of elapsed time to construction

b. Flexible pavement with interlayers on soil-cement bases

- Range of elapsed time to design
- Range of elapsed time to construction

D.2 How many contractors typically bid on the listed jobs?

- 1-3  - 4-6  - 7-9  - Over 9

D.3 Do you feel that an adequate number of experienced contractors bid on your jobs?

- Yes  - No
SUMMARY OF RESEARCH PROJECT

The Louisiana Department of Transportation and Development (DOTD) has been using asphalt surface treatment (AST) and other interlayers over soil-cement base courses for the last several years to control the reflective cracking of flexible pavements caused by soil-cement shrinkage. This practice differs from district to district and there are currently no official DOTD guidelines or policies on such practice. Furthermore, there have been no studies conducted to determine the cost effectiveness of AST and other interlayers on soil cement bases. The gain in service life or service life extension of flexible pavements due to this practice is also unknown. It is proposed to conduct a systematic and comprehensive research analysis that focuses on the following:

- Conduct a comprehensive review of the state-of-the-practice of DOTD districts and other US State Highway Agencies (SHA) about interlayers practices over soil-cement bases for flexible pavements, its performance, and selection of candidate projects.
- Identify pavement projects with and without interlayers over soil-cement bases for flexible pavements with sufficient historical records (e.g., traffic, age, pavement structure and materials, cost data, etc.) and pavement performance data by exploring the information available in DOTD’s databases.
- Perform extensive evaluation of performance of the selected projects with and without interlayer treatment over soil cement bases. Such evaluation will be based on comprehensive analysis of the time series distress data (roughness, cracking, and rutting) available from the PMS database.
- Develop performance prediction models for each distress type based on the available pavement distress data. The models will make it possible to estimate the benefits and the life-cycle costs of the projects with and without interlayer and its impact on the pavement service life and remaining service life.
- Develop guidelines for the implementation of cost-effective utilization of interlayer that would maximize the user and agency benefits and minimize their costs.
- Develop implementation plan to integrate the developed performance models into the DOTD PMS, Pavement Preservation system, and Pavement design system.

This proposed research will enhance the DOTD capabilities in preserving and managing Louisiana pavement networks and facilitate cost effective selection of interlayer over soil-cement base. The models and techniques developed during the course of the project will be documented and provided to DOTD with proper training and technology transfer along with implementation plan.

THANK YOU FOR SUPPORTING THIS IMPORTANT EFFORT!

Please Respond by December 14, 2016
## Summary Survey Results

<table>
<thead>
<tr>
<th>Items</th>
<th>Summary</th>
<th>Others</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>General</strong></td>
<td>- The AST interlayer lane-mile varied from 0 to 60 lane-miles.</td>
<td>Districts 2, 7, 58 and 62 does not use AST Interlayer</td>
</tr>
<tr>
<td></td>
<td>- 4 districts do not use AST interlayer on soil-cement base.</td>
<td></td>
</tr>
<tr>
<td><strong>Pavement Design</strong></td>
<td>- All districts do not do pavement design or AST interlayer recommendation.</td>
<td>Use Pavement Design Office Recommendation</td>
</tr>
<tr>
<td></td>
<td>- All districts do not conduct any life cycle analysis.</td>
<td></td>
</tr>
</tbody>
</table>
# Summary
## Survey Results

<table>
<thead>
<tr>
<th>Items</th>
<th>Summary</th>
<th>Others</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Project Scoping</strong></td>
<td>• Most districts use Distress data and Visual inspection for evaluation. Some also use coring or NDT for evaluation.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Most districts based their decisions to apply AST to improve ride quality, retard distress, reflective cracks, and distress propagation.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Most districts use AST for CSD soil-cement and few also reported to use on CTD.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Most allow curing time of 7 days before AST application and some allow only 3 days.</td>
<td></td>
</tr>
</tbody>
</table>
### Project Contracting

- **AST Interlayers do not affect the contract elapsed time between project identification and construction.**
- The elapsed time varied from district to district, usually, *6 to 36 months*.
- Most reported that 1-3 contractors bid on the projects. In some districts *4-6 bids/project*.
- The quality of contractors bidding on the projects is fair to good (mostly good). Districts are also satisfied from their work.
- **Most districts do construction all year round.** However, fewer reported no construction during winter season.
### Performance and Evaluation

<table>
<thead>
<tr>
<th>Items</th>
<th>Summary</th>
<th>Others</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Most agreed that the performance of AST is affected by construction procedure, quality control, and moisture damage.</td>
<td></td>
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<tr>
<td></td>
<td>- The life span of AST interlayer on soil-cement project varied from 10 to 20 years.</td>
<td></td>
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<tr>
<td></td>
<td>- Most districts reported that about 33% of the sections improved after AST on soil-cement.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- AST and No AST soil-cement base are more susceptible to transverse followed by longitudinal and alligator cracking.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- In district 8 no improvement was observed. Mostly due to desiccation of soil-bases with larger crack widths.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Dist 08 recommended to put AST on top of HMA to extend its life after cracking.</td>
<td></td>
</tr>
</tbody>
</table>
## Summary

### District wise Projects

<table>
<thead>
<tr>
<th>District</th>
<th>AST Interlayer</th>
<th>Stone Interlayer</th>
<th>No Interlayer</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>-</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>36</td>
<td>3</td>
<td>23</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
<td>-</td>
<td>10</td>
</tr>
<tr>
<td>7</td>
<td>-</td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>8</td>
<td>17</td>
<td>-</td>
<td>7</td>
</tr>
<tr>
<td>58</td>
<td>-</td>
<td>1</td>
<td>22</td>
</tr>
<tr>
<td>61</td>
<td>4</td>
<td>-</td>
<td>23</td>
</tr>
<tr>
<td>62</td>
<td>-</td>
<td>-</td>
<td>27</td>
</tr>
</tbody>
</table>
Task 3
Roadway Identification & Project Selection

- Interviewing DOTD Engineers (Task 2)
- Searching DOTD Mainframe Database
  - Material Testing System (MATT), Tracking of Projects (TOPS), Letting of Projects (LETS), the Highway NEEDS, the Traffic & Planning Highway Inventory, the Maintenance Operations System, and the Traffic Volumes data sections of the mainframe database
- Searching DOTD PMS Database
  - Distress data from PMS database
  - IRI, Rut, Fatigue, Longitudinal and Transverse cracking
  - Recorded every two years by the automatic road analyzer (ARAN) for every 1/10th of a mile (2000-2017)
- Searching Pavement Design & Preservation Database
Task 3
Roadway Identification & Project Selection

Project Selection Criteria

- All Flexible Pavement Sections that has a soil-cement (CSD/CTD) base
  - Flexible Pavement sections that has AST Interlayer over soil-cement base
  - Flexible Pavement sections that has No Interlayer but the Base is soil-cement
- All Flexible Pavement Sections that has a soil-cement having a minimum of 3 distress points.
Task 3
Roadway Identification & Project Selection

Data Mining

- Data source
- Control section, log-mile, project number, etc.
- Route name and number (I-10, LA-1, US-90, etc).
- Roadway functional classification such as interstates, arterials, etc.
- Roadway classification including Interstates, NHS, SHS and RHS.
- Pavement performance data (distress data).
- Type and cost of flexible pavement projects
- Type and thickness of AST, HMA and base layers
- Year/age of construction of treatments
- Traffic data, (ADT, ADTT, ESAL, etc.).
- All possible maintenance actions (crack repair, grinding, milling, etc.).
Task 3
Roadway Identification & Project Selection

- **Data Mining**
  - Manual Sorting (Design PDF Files)
  - Development of Computer Programs
    - MATLAB-Program (All AST and No Interlayer)
    - VBA in MS Excel (All AST and No Interlayer)
    - Data mining for whole database at once

- **Merged Database**
  - Distress (IRI, Rut, cracking, etc)
  - ESAL
  - Historical data
## AST Interlayer Projects

<table>
<thead>
<tr>
<th>Control Section</th>
<th>District</th>
<th>BLM</th>
<th>ELM</th>
<th>L (mile)</th>
<th>Construction Year</th>
<th>Project No</th>
<th>Overlay HMA Thickness</th>
<th>ESAL</th>
<th>CTD or CSD</th>
</tr>
</thead>
<tbody>
<tr>
<td>093-02-1</td>
<td>04</td>
<td>0</td>
<td>7.3</td>
<td>7.3</td>
<td>2006</td>
<td>093-02-0007</td>
<td>2</td>
<td>9210</td>
<td>CTD</td>
</tr>
<tr>
<td>424-04-1</td>
<td>03</td>
<td>11.5</td>
<td>13.5</td>
<td>2</td>
<td>2009</td>
<td>424-04-0052</td>
<td>3.5</td>
<td>368103</td>
<td>CTD</td>
</tr>
<tr>
<td>217-02-1</td>
<td>03</td>
<td>2</td>
<td>3.1</td>
<td>1.1</td>
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<td>1.7</td>
<td>1.7</td>
<td>2009</td>
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<td>1.8</td>
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## Example
### Summary of Projects: No Interlayer

<table>
<thead>
<tr>
<th>Control Section</th>
<th>District</th>
<th>BLM</th>
<th>ELM</th>
<th>Length (mile)</th>
<th>Construction Year</th>
<th>Project Number</th>
<th>Overlay HMA Thickness</th>
<th>ESAL</th>
<th>CTD or CSD</th>
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<tr>
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<td>0.3</td>
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<tr>
<td>219-04-1</td>
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<td>4.6</td>
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<td>2012</td>
<td>281-04-0027</td>
<td>4.5</td>
<td>116821</td>
<td>CTD</td>
</tr>
</tbody>
</table>
Acceptance Criteria

- **Criterion 1**
  
  Three Data Points
  
  A minimum of 3 data points are required to fit any non-linear function, as any model can be fit to two or to one data point.

- **Criterion 2**
  
  Upward Trend (Positive slope)
  
  3 data points must have an upward trend to satisfy condition of calculating RSL
Acceptance Criteria

Graphs showing the IRI (In-Service Roughness Index) over elapsed years for different CS codes:

- **CS 117-03-1 (Log Mile 1.5-1.6)**: Rejected
  - $y = 170.8e^{-0.129x}$

- **CS 144-02-1 (Log Mile 1.0-1.1)**: Accepted
  - $y = 88.838e^{0.0495x}$

- **CS 207-04-1 (Log Mile 0-0.1)**: Rejected
  - $y = 40.448e^{0.2703x}$

- **CS 033-03-1 (Log Mile 1.4-1.5)**: Accepted
  - $y = 80.518e^{0.0557x}$
## Summary of All Sections

<table>
<thead>
<tr>
<th>Types of Interlayer</th>
<th>No. Accepted Projects</th>
<th>Miles</th>
<th>Accepted 1/10&lt;sup&gt;th&lt;/sup&gt; Log Miles</th>
</tr>
</thead>
<tbody>
<tr>
<td>AST Interlayer</td>
<td>49</td>
<td>141.1</td>
<td>1,411</td>
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<tr>
<td>No Interlayer</td>
<td>122</td>
<td>450.3</td>
<td>4,503</td>
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<tr>
<td>Stone Interlayer</td>
<td>6</td>
<td>15.7</td>
<td>157</td>
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</tbody>
</table>
Results and Analysis
Service Age (SA), Service Life (SL), Service Life Extension (SLE)

$SLE = SL_2 - SL_1$

(Gain SL)
# Mathematical Models (SL, SLE)

<table>
<thead>
<tr>
<th>Form of equation</th>
<th>Pavement distress type (model form)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Generic equation (modeling)</td>
<td>IRI (exponential)</td>
</tr>
<tr>
<td>$IRI = \alpha \exp^{t\beta}$</td>
<td>$Rut = \gamma t^\omega$</td>
</tr>
</tbody>
</table>

### Derivative (slope)

- $\alpha \beta \exp^{(t\beta)}$
- $\gamma \omega \exp^{(\omega-1)}$
- $\frac{Max \mu \exp^{(\theta + \mu)}}{\exp^{(\theta + \mu)} + 1}$
- $t = \frac{\log\left(\exp^{(\theta + \mu)} + 1\right)}{\mu}$

### Integral (performance area)

- $\left(\frac{\alpha}{\beta}\right) \exp^{(t\beta)}$
- $\left(\frac{\alpha}{\beta}\right) \exp^{(t\beta)}$
- $\left(\frac{Max}{Threshold} - 1\right) - \left(\frac{\beta}{\alpha}\right)$

### Time to reach threshold (LE)

- $t = \left(\frac{Threshold}{\alpha}\right) - \left(\frac{\beta}{\alpha}\right)$

Where, $\alpha$, $\beta$, $\gamma$, $\omega$, $\theta$, and $\mu$ are regression parameters ($a$, $g$, $q$ are intercepts and $b$, $o$, $m$ are slopes) $t =$ elapsed time (year), and Max = the maximum value of cracking.

---

**Every 1/10th log-mile**

**MATLAB, VBA, EXCEL Programs Were Used!**
Distribution of SL

CS 815-08
Log Miles: 0 to 2.4

Range of SL

SA

Threshold
Comparison of SL

1. IRI
2. Rut
3. Fatigue cracking
4. Transverse cracking
5. Longitudinal cracking
## Analysis Matrix

<table>
<thead>
<tr>
<th>Base Type</th>
<th>HMA Thickness (in)</th>
<th>AST Interlayer</th>
<th>No Interlayer</th>
<th>No. Data Points/ (SA)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>ESAL &lt;30k</td>
<td>ESAL &gt;30k</td>
<td>ESAL &lt;30k</td>
</tr>
<tr>
<td>CSD</td>
<td>0-4</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>&gt;4</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>CTD</td>
<td>0-4</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>&gt;4</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>CSD</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CTD</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Majority**

≤4 in, ≤30k ESAL
SL Distribution (TC)
ESAL<30K, Th<4 in, **CSD** Base

**NO INT Transverse Cracking (ft)**
- Projects No. = 46
- 1/10 Sections = 1785
- Avg SL = 11.6
- StDev = 4.6

**AST INT Transverse Cracking (ft)**
- Projects No. = 25
- 1/10 Sections = 718
- Avg SL = 14.3
- StDev = 6.1

**Gain SL = 2.7 yrs**
SL Distribution (AC)
ESAL<30K, Th<4 in, CSD Base

NO INT Alligator Crack (Sq. ft)

Projects No.= 46
1/10 Sections= 1786
Avg SL= 12.5
StDev= 5.7

AST INT Alligator Crack (Sq. ft)

Projects No.= 26
1/10 Sections= 736
Avg SL= 14.7
StDev= 6.6

Gain SL= 2.2 yrs
SL Distribution (LC)  
ESAL<30K, Th<4 in, CSD Base

NO INT Longitudinal Crack (ft)

- Projects No. = 45
- 1/10 Sections = 1718
- Avg SL = 16.0
- StDev = 5.0

AST INT Longitudinal Crack (ft)

- Projects No. = 25
- 1/10 Sections = 695
- Avg SL = 15.3
- StDev = 6.2

No Gain SL
SL Distribution (IRI)
ESAL<30K, Th<4 in, **CSD Base**

**NO INT IRI (in/mile)**

- Projects No.: 46
- 1/10 Sections: 1584
- Avg SL: 19.7
- StDev: 1.5

**AST INT IRI (in/mile)**

- Projects No.: 19
- 1/10 Sections: 570
- Avg SL: 18.3
- StDev: 3.7

**No Gain SL**
SL Distribution (RUT)  
ESAL<30K, Th<4 in, CSD Base

NO INT RUT
- Projects No.= 46
- 1/10 Sections= 1789
- Avg SL= 19.5
- StDev= 2.3

AST INT RUT
- Projects No.= 30
- 1/10 Sections= 979
- Avg SL= 15.5
- StDev= 5.0

Gain SL= -4.0 yrs
SL Distribution (TC)
ESAL<30K, Th<4 in, CTD Base

NO INT Transverse Cracking (ft)

Projects No.= 45
1/10 Sections= 1476
Avg SL= 14.2
StDev= 5.4

AST INT Transverse Cracking (ft)

Projects No.= 6
1/10 Sections= 347
Avg SL= 13.3
StDev= 4.8

No Gain SL
SL Distribution (TC)

CSD/CTD, No Interlayer

NO INT TC, CSD

Projects No. = 46
1/10 Sections = 1785
Avg SL = 11.6
StDev = 4.6

NO INT TC, CTD

Projects No. = 45
1/10 Sections = 1476
Avg SL = 14.2
StDev = 5.4

Gain SL = 2.6 yrs, same as AST INT
NO INT AC, CSD
Projects No.= 46
1/10 Sections= 1786
Avg SL= 12.5
StDev= 5.7

NO INT AC, CTD
Projects No.= 45
1/10 Sections= 1458
Avg SL= 13.2
StDev= 6.0

CTD IS BETTER/SIMILAR TO CSD
Summary Service Life (SL)

Transverse Crack SL COMPARISON

<table>
<thead>
<tr>
<th></th>
<th>AST CSD</th>
<th>AST CTD</th>
<th>No AST CSD</th>
<th>No AST CTD</th>
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<tbody>
<tr>
<td>Average SL</td>
<td>14.3</td>
<td>13.3</td>
<td>11.6</td>
<td>14.2</td>
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Alligator Crack SL COMPARISON

<table>
<thead>
<tr>
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<th>AST CTD</th>
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<th>No AST CTD</th>
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</thead>
<tbody>
<tr>
<td>Average SL</td>
<td>14.7</td>
<td>14.0</td>
<td>12.5</td>
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Longitudinal Crack SL COMPARISON

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<th>AST CTD</th>
<th>No AST CSD</th>
<th>No AST CTD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average SL</td>
<td>15.3</td>
<td>19.5</td>
<td>19.4</td>
<td>19.9</td>
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Rut Depth SL COMPARISON

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<th>AST CTD</th>
<th>No AST CSD</th>
<th>No AST CTD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average SL</td>
<td>15.5</td>
<td>19.5</td>
<td>19.4</td>
<td>19.9</td>
</tr>
</tbody>
</table>
SL Distribution (TC)  
ESAL>30K, CSD Base

NO INT TC, ESAL>30K

Projects No. = 19  
1/10 Sections = 881  
Avg SL = 13.1  
StDev = 5.0

AST INT TC, ESAL>30K

Projects No. = 10  
1/10 Sections = 169  
Avg SL = 12.9  
StDev = 6.6

No Gain SL
STONE INT SL Distribution (TC)
ESAL<150K, Th<0-5in, CSD Bases

NO INT TC

- Projects No. = 60
- 1/10 Sections = 2515
- Avg SL = 12.2
- StDev = 4.9

AST INT TC

- Projects No. = 37
- 1/10 Sections = 981
- Avg SL = 14.7
- StDev = 6.1

STONE INT TC

- Projects No. = 3
- 1/10 Sections = 68
- Avg SL = 18.3
- StDev = 4.1
Cost-Benefit Analysis

Benefit Analysis

Benefit Area (No AST)

Net Benefit Area

SL\textsubscript{(No AST)}

SLE

\( B/C = \frac{\text{Benefit Area}}{\text{Cost}} \)

(No AST)

Time Elapsed, Years

Benefit Area

0 2 4 6 8 10 12 14 16 18 20

0 25 50 75 100 125 150 175 200 225 250
Cost-Benefit Analysis

Cost-effectiveness Evaluation

**Benefit/Cost Ratio (B/C):**

\[
B/C(SL) = \frac{SL}{EUAC} \times 10000
\]

\[
B/C(NBA) = \frac{NBA}{EUAC} \times 10000
\]

\[
EUAC = P \cdot \frac{i(1+i)^n}{(1+i)^n - 1}
\]

EUAC = Equivalent uniform annual cost

P = Present cost, of entire pavement system, considering 3.5 in HMA

i = inflation (4%)
## Cost-Benefit Analysis

### Cost for CSD/CTD Projects With or Without Interlayer

<table>
<thead>
<tr>
<th>Type</th>
<th>Cost per Sq Yd</th>
<th>Cost per 1/10th log-mile</th>
<th>Total Cost of Treatment (P) (Including Overlying 3.5 in HMA cost)</th>
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</thead>
<tbody>
<tr>
<td>AST Interlayer, only</td>
<td>$3.62</td>
<td>$2,547</td>
<td>-</td>
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<tr>
<td>AST Interlayer over CTD</td>
<td>$10.67</td>
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<tr>
<td>AST Interlayer over CSD</td>
<td>$13.53</td>
<td>$9,528</td>
<td>$19,709</td>
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<td>Stone Interlayer over CSD</td>
<td>$21.28</td>
<td>$14,984</td>
<td>$25,165</td>
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<tr>
<td>CTD base, only</td>
<td>$7.05</td>
<td>$4,964</td>
<td>$15,145</td>
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<td>CSD base, only</td>
<td>$9.92</td>
<td>$6,981</td>
<td>$17,162</td>
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</table>
Cost-Benefit Analysis

TC B/C Comparison

B/C Ratio

<table>
<thead>
<tr>
<th></th>
<th>B/C (SL)</th>
<th>B/C (NBA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AST CSD</td>
<td>67.4</td>
<td>61.7</td>
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<tr>
<td>AST CTD</td>
<td>74.7</td>
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<td>No AST CSD</td>
<td>60.3</td>
<td>54.5</td>
</tr>
<tr>
<td>No AST CTD</td>
<td>95.6</td>
<td>89.3</td>
</tr>
</tbody>
</table>
Cost-Benefit Analysis

RUT B/C Comparison

- **B/C Ratio**
  - AST CSD: 86.4 (B/C (SL)), 45.5 (B/C (NBA))
  - AST CTD: 159.8 (B/C (SL)), 112.1 (B/C (NBA))
  - No AST CSD: 161.4 (B/C (NBA))
  - No AST CTD: 197.2 (B/C (SL)), 141.3 (B/C (NBA))

The red line represents the threshold for profitability.
Cost-Benefit Analysis

LC B/C Comparison

IRI B/C Comparison
Cost-Benefit Analysis

Net B/C Ratio Comparison

<table>
<thead>
<tr>
<th></th>
<th>B/C (SL)</th>
<th>B/C (NBA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AST CSD</td>
<td>82.7</td>
<td>62.1</td>
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<tr>
<td>AST CTD</td>
<td>113.3</td>
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<td>112.0</td>
<td>86.6</td>
</tr>
<tr>
<td>No AST CTD</td>
<td>130.2</td>
<td>102.7</td>
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</tbody>
</table>
Conclusions

- Transverse cracking was the controlling distress followed by fatigue cracking.
- Based on Transverse cracking, AST interlayer on CSD showed Gain in SL of 2.7 yr.
- Similar results were shown for Alligator cracking with Gain in SL of 2.2 yr.
- No Gain in SL was observed for LC and IRI.
- SL based on RUT for AST interlayer showed decreased values of about 4.0 years relative to No AST interlayer.
- CTD base exhibited similar or better SL then CSD base.
Conclusions

- Net B/C ratio in terms of SL and NBA revealed that on average the AST interlayer showed 27% less B/C than the CSD bases only.

- CTD base only, exhibited around 18% more B/C then CSD base only.

- In general, due to higher cost associated with AST interlayer and the loss of SL in RUT, the AST interlayer proved to be least cost-effective option.
Recommendations

- CTD base only became the most cost-effective options for all cases. Therefore, it is recommended that the DOTD continue using the CTD bases for flexible pavements for low ESAL.

- Since the AST interlayer of all soil-cement became least cost-effective option, therefore, it is recommended that it should not be used as an interlayer over soil-cement to minimize the reflective cracking.
Thanks!
SL Distribution (TC)
ESAL < 30K, CSD Base, 10-14 yr data

NO INT TC, 6 data
- Projects No. = 46
- 1/10 Sections = 1789
- Avg SL = 13.9
- StDev = 3.0

AST INT TC, 6 data
- Projects No. = 3
- 1/10 Sections = 40
- Avg SL = 14.0
- StDev = 5.0

No Gain SL
SL Distribution (TC)  
ESAL<30K, CSD&CTD Base,  

**NO INT Transverse Crack**
- Projects No.= 92
- 1/10 Sections= 3272
- Avg SL= 14.2
- StDev= 3.6

**AST INT Transverse Crack**
- Projects No.= 9
- 1/10 Sections= 387
- Avg SL= 14.5
- StDev= 4.3

**No Gain SL**
STONE INT SL Distribution (TC)
ESAL<150K, Th<0-5in, CTD Bases

NO INT TC

- Projects No. = 55
- 1/10 Sections = 1799
- Avg SL = 14.1
- StDev = 5.3

AST INT TC

- Projects No. = 7
- 1/10 Sections = 363
- Avg SL = 13.1
- StDev = 4.9

STONE INT TC

- Projects No. = 2
- 1/10 Sections = 50
- Avg SL = 15.3
- StDev = 5.1
Cost-Benefit Analysis: Bar Chart

Net B/C Ratio Comparison

<table>
<thead>
<tr>
<th></th>
<th>B/C (SL)</th>
<th>B/C (NBA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AST CSD</td>
<td>62.1</td>
<td>82.7</td>
</tr>
<tr>
<td>AST CTD</td>
<td>87.6</td>
<td>113.3</td>
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<tr>
<td>No AST CSD</td>
<td>86.6</td>
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<tr>
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<tr>
<td>STONE CSD</td>
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<tr>
<td>STONE CTD</td>
<td>83.5</td>
<td>104.6</td>
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</tbody>
</table>

Avg B/C Ratio