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

Muhammad "Jamal" Khattak, Ph.D., P.E.

Mohammad "Reza" Ul Karim Bhuyan, GRA

University of Louisiana at Lafayette

SESPA Conference

October 9-11, 2019

Presentation Layout

1. Research Need
2. Research Objectives
3. Research Work Plan
4. Results and Analysis
5. Conclusions and Recommendations

Research Need

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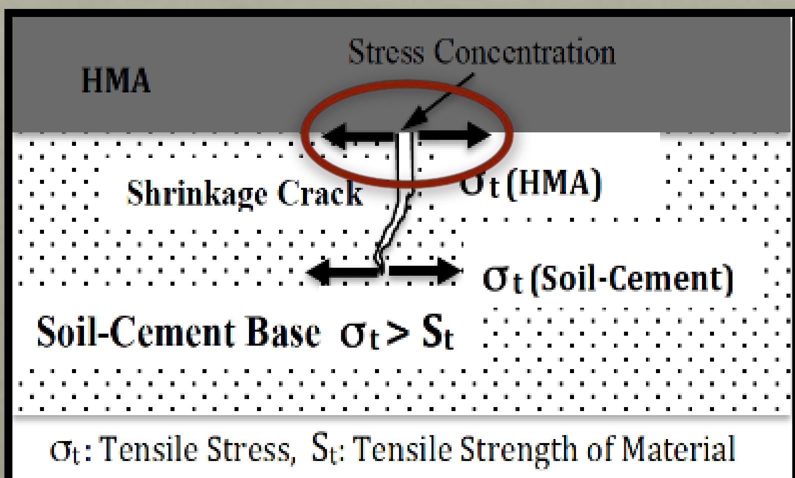
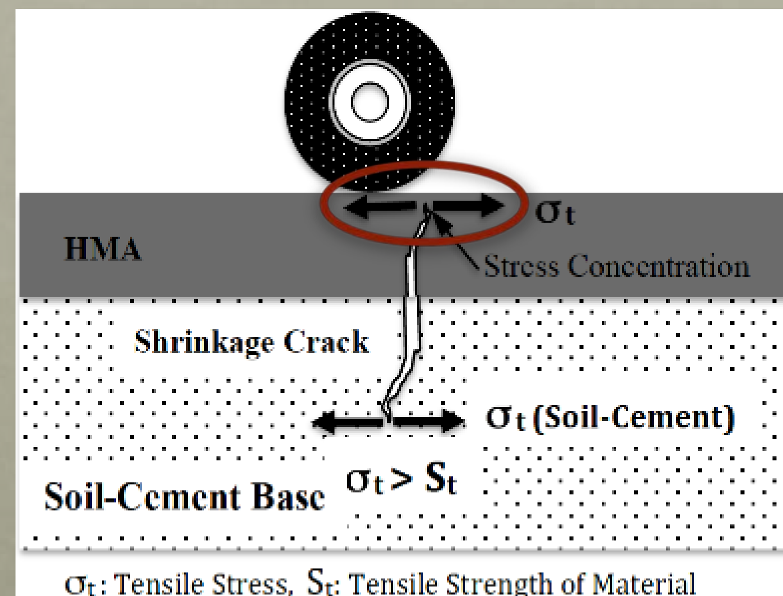
Research Need

Reflective Cracking due to Soil-cement Base
Mechanism





**Soil Type, Cement Content,
Curing, Compaction, Traffic, etc.**

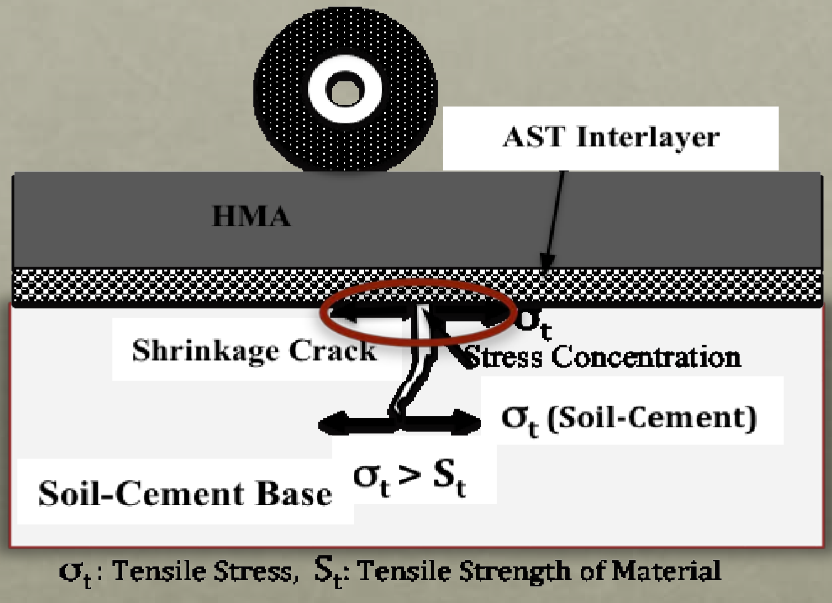
Research Need

Narrow Cracks

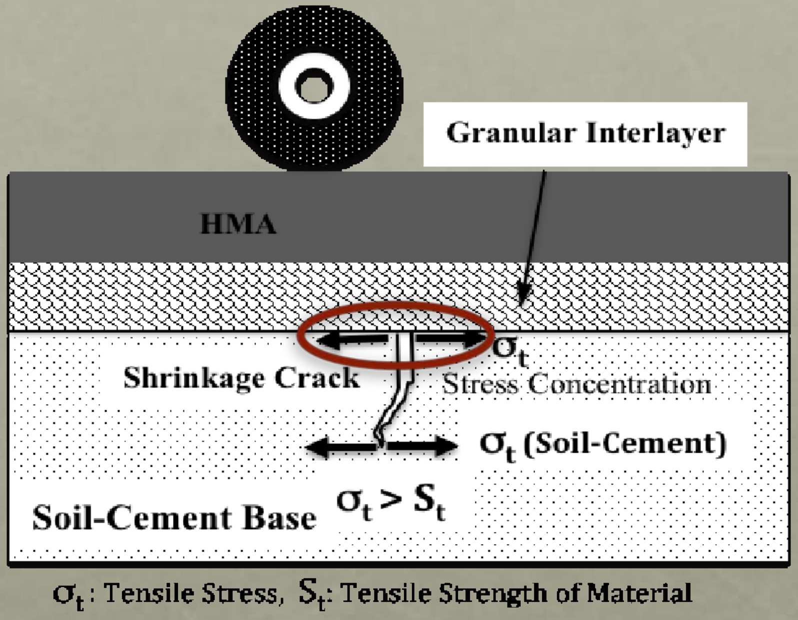
Wider Cracks

Research Need

Stress Relief Interlayers



AST Interlayer



Granular Interlayer

Research Need

Soil-Cement Base (LA Design)

- **<u>Cement Stabilized Design: (CSD)</u>**
  - 300 psi 7-day Compressive Strength
  - Appx. 10% Cement Content
- **<u>Cement Treated Design: (CTD)</u>**
  - 150 psi 7-day Compressive Strength
  - Appx. 5% Cement Content

Research Need

Problem Statement

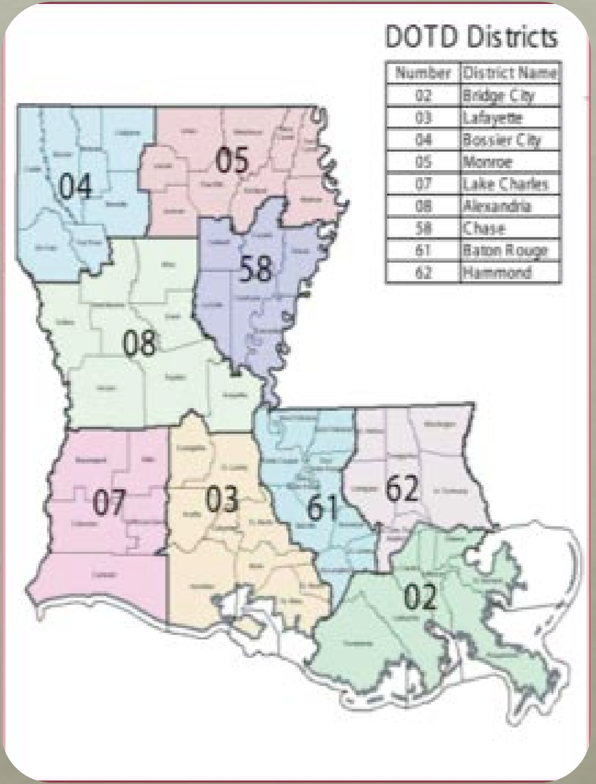
- DOTD has been using asphalt surface treatment (AST) interlayers over soil-cement base courses to mitigate shrinkage cracks from reflecting through the overlying asphaltic concrete (AC) pavement.

- 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

- ## Historical 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)



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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

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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*

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Research Work Plan

- **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

Survey 2016
Louisiana Transportation Research Center
LTRC Project No: 16-5P
"Pavement Service Life Extension due to Asphalt Surface Treatment (AST) Interlayer Over Soil- Cement Bases"

Conducted by: University of Louisiana at Lafayette (UL Lafayette)
Contact Person: Mohammad "Jamal" Khattak, Ph.D., P.E., Department of Civil Engineering, 254J-Madison Hall, Lafayette, LA 70504-2291. Phone No: (337) 482-5356, email: khattak@louisiana.edu

Name: First__________ Middle __________ Last __________
Title: __________ Phone No.__________
District Number: __________
Total Number of Lane-Miles: __________
Total Pavement-Related Yearly Budget (Construction, Rehabilitation, and Maintenance): $ __________

Please Respond to Each Question by Circling Yes or No or Check Mark or Appropriate Response

Note: This survey is related to Interlayers used on top of Soil-Cement Bases for Flexible Pavements to mitigate flexible pavement reflective cracking.

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

Interlayer Type	Number of lane-miles		
	Flexible	Rigid	Composite
AST- Chip seal- Single layer			
AST- Chip seal- Double layer			
Micro-surfacing Interlayer			
Aggregate Interlayer			
Reclaimed Concrete Interlayer			
Reclaimed Asphalt Interlayer			
Geotextiles Interlayer			
Other: 1)			
2)			

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?

Interlayer Type	Life Span (years)	Cost per lane- mile ($)
AST- Chip seal- Single layer		
AST- Chip seal- Double layer		
Micro-surfacing Interlayer		
Aggregate Interlayer		
Reclaimed Concrete Interlayer		
Reclaimed Asphalt Interlayer		
Geotextiles Interlayer		
Other: 1)		
2)		

A.3 What percentages of the following Interlayers over soil-cement bases are done by the District? Rate your experience with the contractor.

Interlayer Type	Percent Work by District	Contractor		
		Good	Fair	Poor
AST- Chip seal- Single layer				
AST- Chip seal- Double layer				
Micro-surfacing Interlayer				
Aggregate Interlayer				
Reclaimed Concrete Interlayer				
Reclaimed Asphalt Interlayer				
Geotextiles Interlayer				
Other: 1)				
2)				

B. Pavement Design

B.1 Does your District design thicknesses of pavement and Interlayers over soil-cement bases? □ Yes □ No

If you answered NO to B1, please skip to Question C.1

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)

Interlayer Type	AASHTO 1993	AASHTO 2002	In-house Experience	Others
AST- Chip seal- Single layer				
AST- Chip seal- Double layer				
Micro-surfacing Interlayer				
Aggregate Interlayer				
Reclaimed Concrete Interlayer				
Reclaimed Asphalt Interlayer				
Geotextiles Interlayer				
Other: 1)				
2)				

C. Project Scoping Process

C.1 Do you utilize the PMS Data in your project scoping process? □ Yes □ No

If No, then what method do you use? __________

C.2 What do you use to evaluate the existing pavement conditions? (Please check all that apply)

Pavement surface condition data-
- □ Distress data such as roughness, rutting, cracking, etc.
- □ Distress index
- □ Composite pavement index
- □ Remaining service life (RSL)
- □ Visual inspection
- □ Do not evaluate existing conditions
- □ Other method, please specify: __________

Forensic investigation-
- □ Destructive testing (coring, density, modulus, 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)
- □ Retard Reflective cracking due to soil cement bases
- □ PMS recommendations
- □ Political
- □ Retard aging
- □ Other reasons, please specify: __________

C.4 What type of soil-cement base requires the following Interlayers over soil-cement bases in your district?

Interlayer Type	Cement Treated Design (CTD) UCS@7days: 150 psi	Cement Stabilized Design (CSD) UCS@7days: 300 psi	Others
AST- Chip seal- Single layer			
AST- Chip seal- Double layer			
Micro-surfacing Interlayer			
Aggregate Interlayer			
Reclaimed Concrete Interlayer			
Reclaimed Asphalt Interlayer			
Geotextiles Interlayer			
Other: 1)			
2)			

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?

Interlayer Type	Average Daily Traffic	Average Daily Truck Traffic	Equivalent Single Axle Load
	ADT	ADTT	ESAL
AST- Chip seal- Single layer			
AST- Chip seal- Double layer			
Micro-surfacing Interlayer			
Aggregate Interlayer			
Reclaimed Concrete Interlayer			
Reclaimed Asphalt Interlayer			
Geotextiles Interlayer			
Other: 1)			
2)			

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

Treatment category	% of budget
Replacement	
Rehabilitation	
Preventive maintenance	
Routine maintenance	

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_____________, To construction_______________

b. Flexible pavement with Interlayers on soil-cement bases.

Range of elapsed time to design_____________, To construction_______________

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

a. Flexible pavement without Interlayers soil-cement bases, only. ☐ 1–3 ☐ 4–6 ☐ 7–9 ☐ Over 9

b. Flexible pavement with Interlayers on soil-cement bases. ☐ 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

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

Interlayer Type	Construction Season				
	Fall	Winter	Spring	Summer	Entire year
AST- Chip seal- Single layer					
AST- Chip seal- Double layer					
Micro-surfacing Interlayer					
Aggregate Interlayer					
Reclaimed Concrete Interlayer					
Reclaimed Asphalt Interlayer					
Geotextiles Interlayer					
Other: 1)					
2)					

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. If No, please proceed to section F below.

a. Do you use any specialized software for LCCA? If yes, what software?_______________

b. Does your district include User Costs in the analysis? If yes, in what ways does it consider it? _______________

c. What discount and /or inflation rates is used and how is it determined? _______________

d. What analysis period is used? (If not a fixed value, please explain briefly) _______________

e. What is the initial performance life assigned for reconstructed flexible pavement? _______________

f. Does your district use salvage value or remaining service life (RSL) value in its LCCA calculations? _______________

g. Does your district have any guidelines or policies regarding the pavement selection process? _______________

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 pavements? (Please check the 3 most important factors)

☐ Construction procedure ☐ Design method ☐ Better binder
☐ Better aggregates ☐ Quality control ☐ Traffic
☐ Underlying structure (Base/subbase ☐ Maintenance spending ☐ Roadbed Stabilization
☐ Moisture damage ☐ 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 dominant).

Interlayer Type	Distress type							
	Pothole	Bleeding	Corrugation	Raveling	Alligator cracks	Transverse cracks	Longitudinal cracks	Rutting
No Interlayers on Soil-cement								
AST- Chip seal- Single layer								
AST- Chip seal- Double layer								
Micro-surfacing Interlayer								
Aggregate Interlayer								
Reclaimed Concrete Interlayer								
Reclaimed Asphalt Interlayer								
Geotextiles Interlayer								
Other: 1) 2)								

F.3 Based on ride quality right after construction, assess the performance of flexible pavement with Interlayer on soil-cement bases as compared to the flexible pavement without Interlayers on soil-cement bases?

- ☐ 67% to 100% of projects showed improvement
- ☐ 33% to 67% of projects showed improvement
- ☐ 0% to 33% of projects showed improvement
- ☐ other:______________________________

F.4 Do you subcontract the quality assurance (QA)? ☐ Yes ☐ No

F. Project List *(Important for this Research Study!)*

F.1 Please list your district's flexible pavement projects that have received any of the above Interlayers over soil cement bases during time period 2000-2013 *(Attach a separate sheet, if required)*. This project list is key for the pavement performance evaluation and modeling for this research study.

Interlayer Type	Year	Project Number	Control Section	Route	Direction	Log-mile		Additional Important Information
						Begin	End	
With Interlayers on Soil-cement bases								
1.								
2.								
Add more projects ↓								
Without Interlayers on Soil-cement bases								
1.								
2.								
Add more projects ↓								

F.2. If there is anything that you would like to add that was not covered in this questionnaire, which you feel would benefit this study, please write your comments below *(See Attached Research Project Summary)*:

____

THANK YOU FOR SUPPORTING THIS IMPORTANT EFFORT!

Please Respond by December 14, 2016

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.

Summary
Survey Results

Items	Summary	Others
General	• The AST interlayer lane-mile varied from 0 to 60 lane-miles. • 4 districts do not use AST interlayer on soil-cement base.	Districts 2, 7, 58 and 62 does not use AST Interlayer
Pavement Design	• All districts do not do pavement design or AST interlayer recommendation. • All districts do not conduct any life cycle analysis.	Use Pavement Design Office Recommendation

Summary Survey Results

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

Summary
Survey Results

Items	Summary	Others
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 biding 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.	

Summary
Survey Results

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

Summary
District wise Projects

District	AST Interlayer	Stone Interlayer	No Interlayer
2	-	-	1
3	36	3	23
4	2	1	2
5	1	-	10
7	-	1	10
8	17	-	7
58	-	1	22
61	4	-	23
62	-	-	27

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

Example
Summary of Projects: AST Interlayer

AST Interlayer Projects

Control Section	District	BLM	ELM	L (mile)	Construction Year	Project No	Overlay HMA Thickness	ESAL	CTD or CSD
093-02-1	04	0	7.3	7.3	2006	093-02-0007	2	9210	CTD
424-04-1	03	11.5	13.5	2	2009	424-04-0052	3.5	368103	CTD
217-02-1	03	2	3.1	1.1	2009	217-02-0014	4	16161	CSD
316-01-1	05	0	1.7	1.7	2009	316-01-0007	2	53812	CTD
218-30-1	03	0	1.8	1.8	2010	218-30-0005	4.5	72608	CSD
801-29-1	03	0	2.1	2.1	2010	801-29-0005	4	13876	CSD
408-02-1	03	5.8	10.8	5	2011	408-02-0011	5	443	CTD
144-02-1	03	1	2	1	2011	H.009068.6	4	748	CSD
213-08-1	03	0	4.3	4.3	2012	H.002147.6	4.5	65571	CSD
857-63-1	03	3	10.9	7.9	2012	H.008443.6	4	24361	CSD
217-02-1	03	3.1	8.3	5.2	2012	H.002161.6	5	15814	CSD
801-10-1	03	0	6.2	6.2	2012	H.007837.6	4	10102	CSD
857-11-1	03	0	3.1	3.1	2012	H.009995.6	3.5	5225	CSD

Example
Summary of Projects: No Interlayer

No Interlayer Projects

Control Section	District	BLM	ELM	Length (mile)	Construction Year	Project Number	Overlay HMA Thickness	ESAL	CTD or CSD
185-01-1	05	0	11.4	11.4	2000	185-01-0013	3.5	5621	CSD
815-08-1	58	0	2.4	2.4	2002	815-08-0008	3.5	7373	CSD
178-02-1	58	5.9	9.6	3.7	2002	178-02-0020	3.5	24092	CSD
367-01-1	08	0	4.7	4.7	2003	367-01-0015	3.5	10099	CTD
033-03-1	08	0.9	2.3	1.4	2004	033-03-0036	4	127765	CTD
163-02-1	05	0.1	3.3	3.2	2004	163-02-0012	2	11398	CTD
156-02-1	05	3.3	4.5	1.2	2007	156-02-0013	3.5	35383	CTD
165-02-1	58	0	2.8	2.8	2007	165-02-0027	3.5	1819	CTD
863-02-1	61	0	6.9	6.9	2008	863-02-0029	3.5	20132	CTD
428-01-1	61	6.6	12.2	5.6	2008	428-01-0016	3.5	25040	CTD
197-02-1	07	0.2	0.5	0.3	2011	197-02-0022	6	98545	CSD
219-04-1	61	3.1	4.6	1.5	2011	219-04-0017	3.5	9683	CTD
270-05-1	62	5.9	10.8	4.9	2012	270-05-0015	3.5	21656	CTD
281-04-1	62	0	7.5	7.5	2012	281-04-0027	4.5	116821	CTD

Acceptance Criteria

- **Criterion 1**

Three Data Points

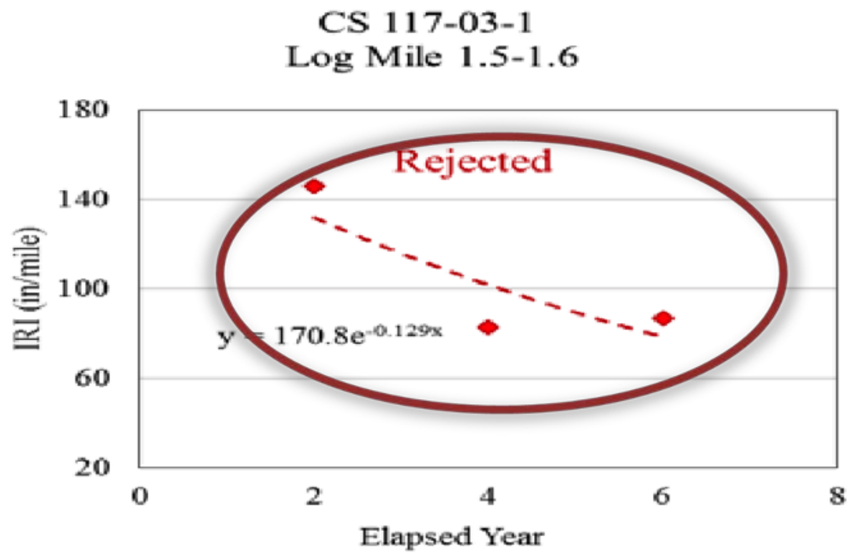
A minimum of 3 data points are required to fit any non-linear function, as any model can be fit to two or to one data point.

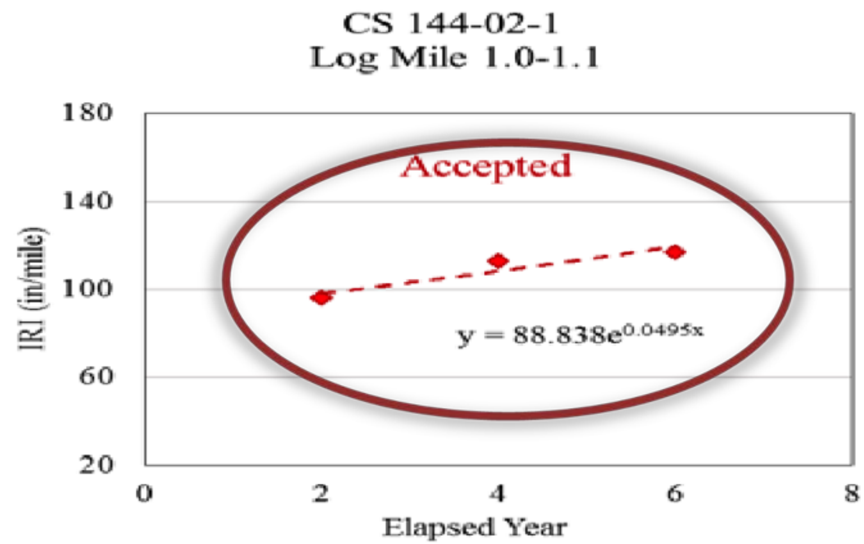
- **Criterion 2**

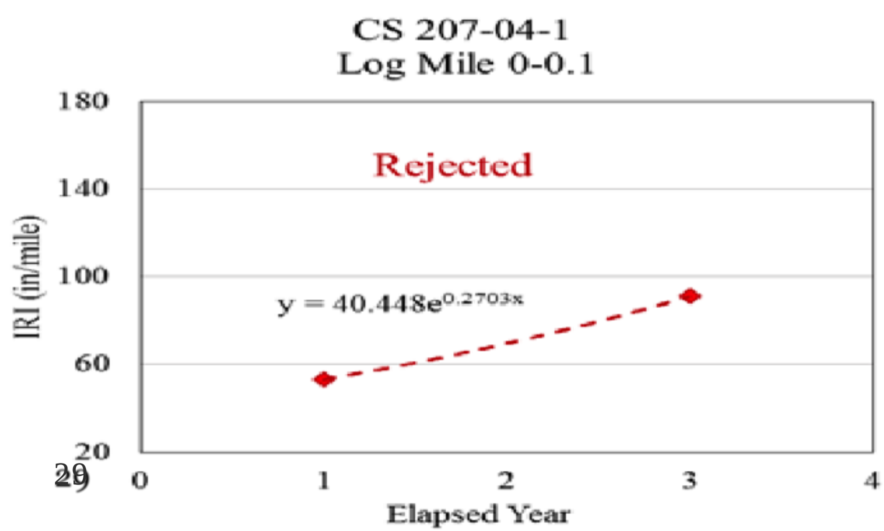
Upward Trend (Positive slope)

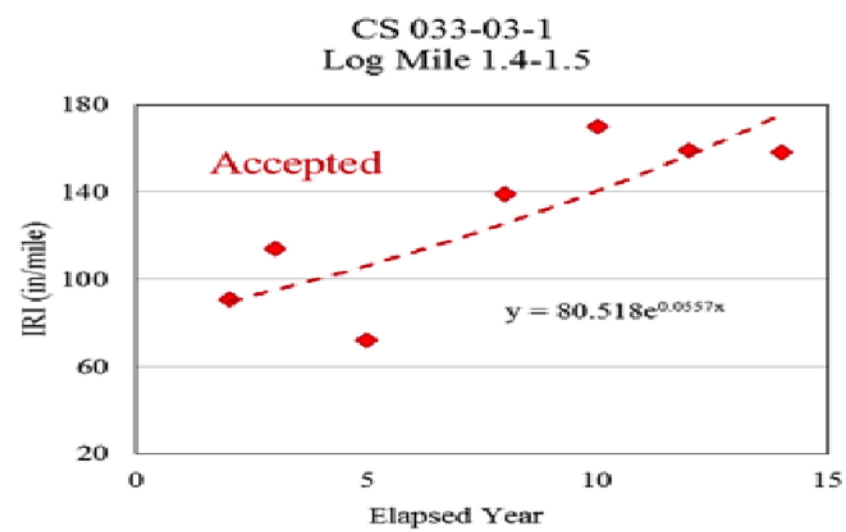
3 data points must have an upward trend to satisfy condition of calculating RSL

Acceptance Criteria









Summary of All Sections

Types of Interlayer	No. Accepted Projects	Miles	Accepted 1/10th Log Miles
AST Interlayer	49	141.1	1,411
No Interlayer	122	450.3	4,503
Stone Interlayer	6	15.7	157

Results and Analysis

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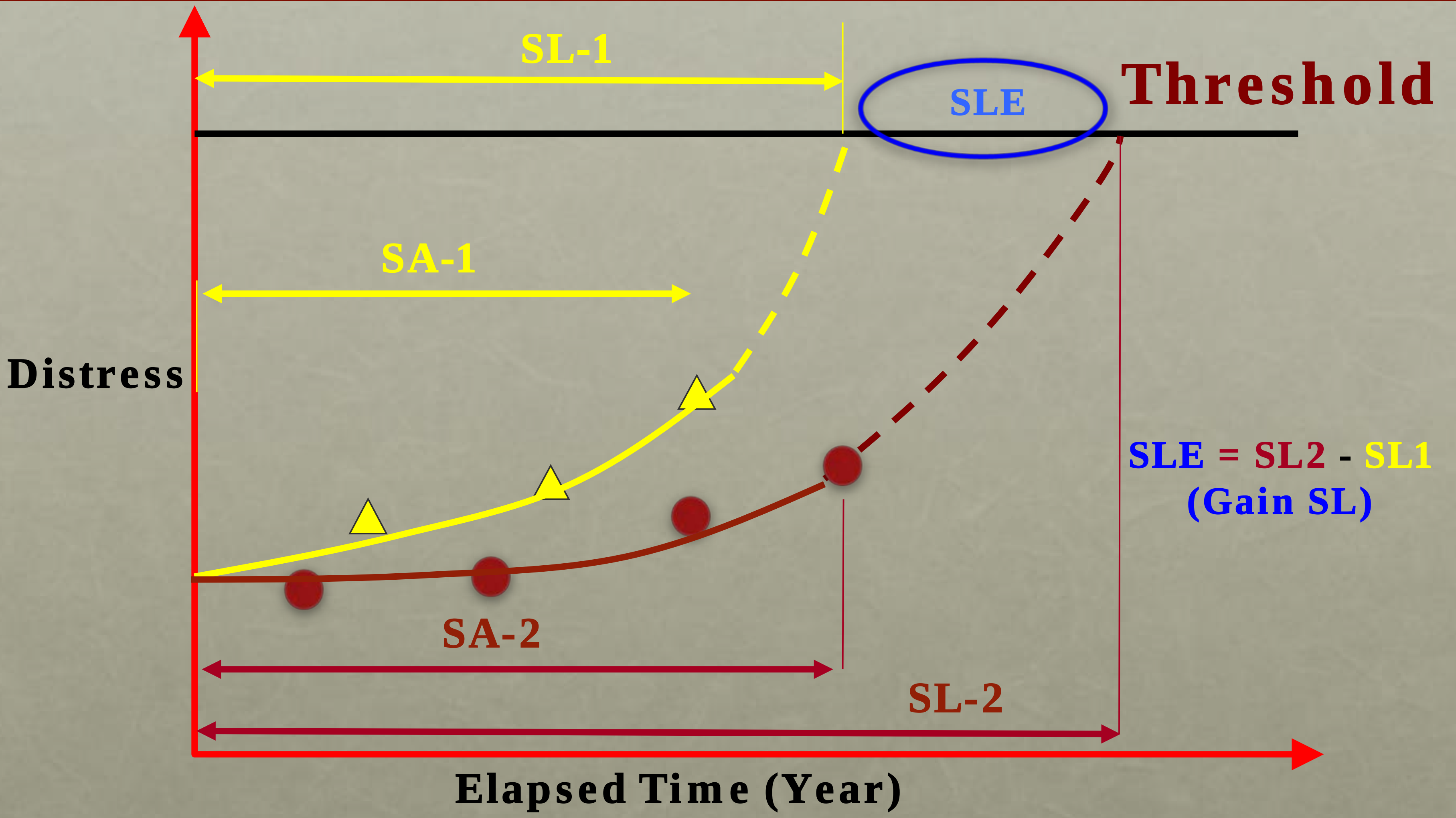
Service Age (SA), Service Life (SL), Service Life Extension (SLE)



Mathematical Models (SL, SLE)

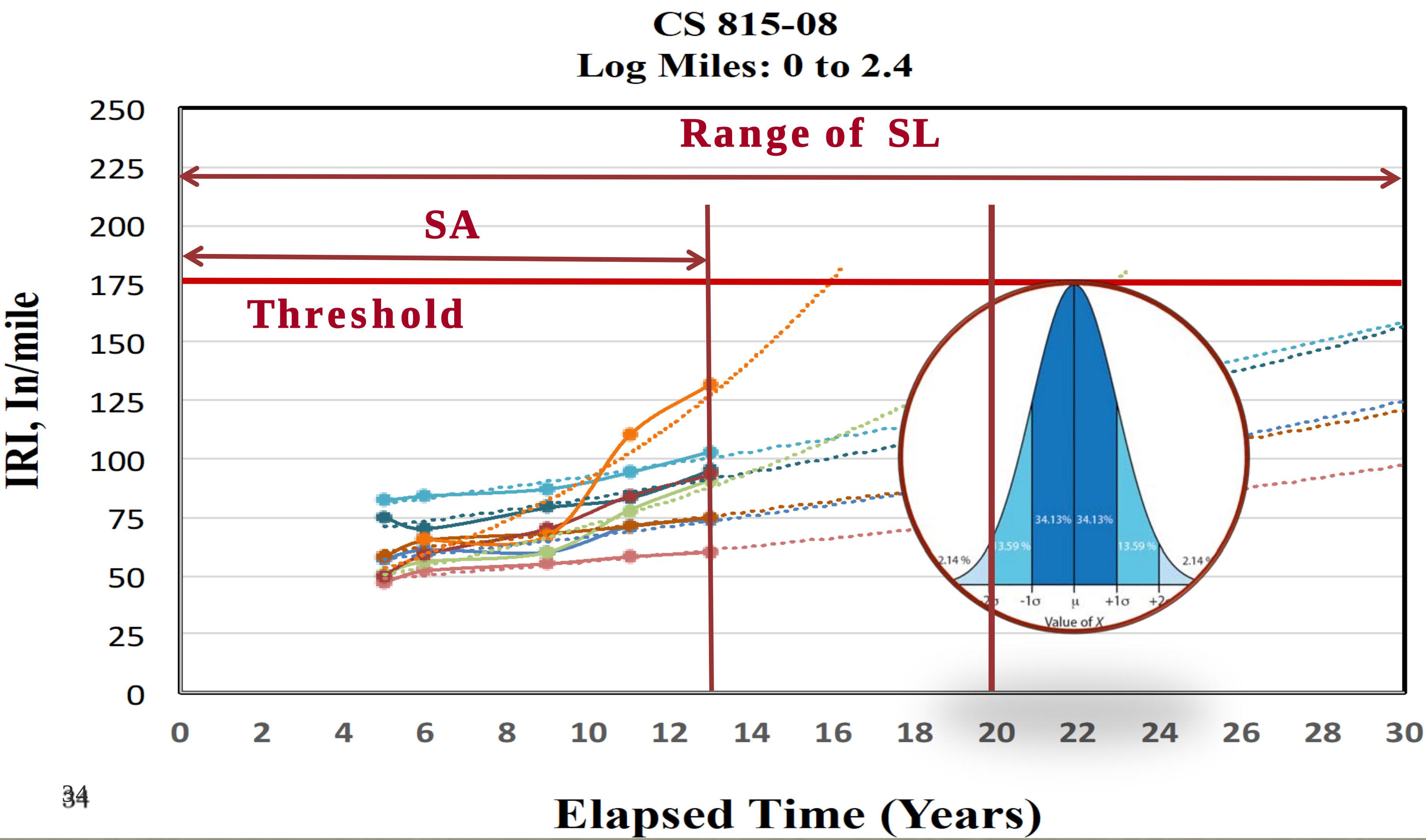
Form of equation	Pavement distress type (model form)		
	IRI (exponential)	Rut depth (power)	Cracking (Logistic (S-shaped))
Generic equation (modeling)	$IRI = \alpha \exp^{t\beta}$	$Rut = \gamma\, t^{\omega}$	$Crack = \frac{Max}{1+\exp^{(\theta+\mu t)}}$
Derivative (slope)	$\alpha\beta \exp^{(t\beta)}$	$\gamma\omega t^{(\omega-1)}$	$-\frac{Max\,\mu \exp^{(\theta+\mu t)}}{\left[\exp^{(\theta+\mu t)}+1\right]^2}$
Integral (performance area)	$\left(\frac{\alpha}{\beta}\right)\exp^{(t}$ [illegible]		[illegible] $t - \frac{\log\left[\exp^{(\theta+\mu t)}+1\right]}{\mu}\Big\}$
Time to reach threshold (LE)	$t = \frac{\ln\left(\frac{Thresho}{\alpha}\right.}{\beta}$ [illegible]	[illegible]	[illegible] $\left(\frac{Max}{Threshold}\right)-1\Big)\Big] - \left(\frac{\beta}{\alpha}\right)$

Where, α, β, γ, ω, θ, and μ are regression parameters (a, g, q are intercepts and b, ω, m are slopes) t = elapsed time (year), and Max = the maximum value of cracking

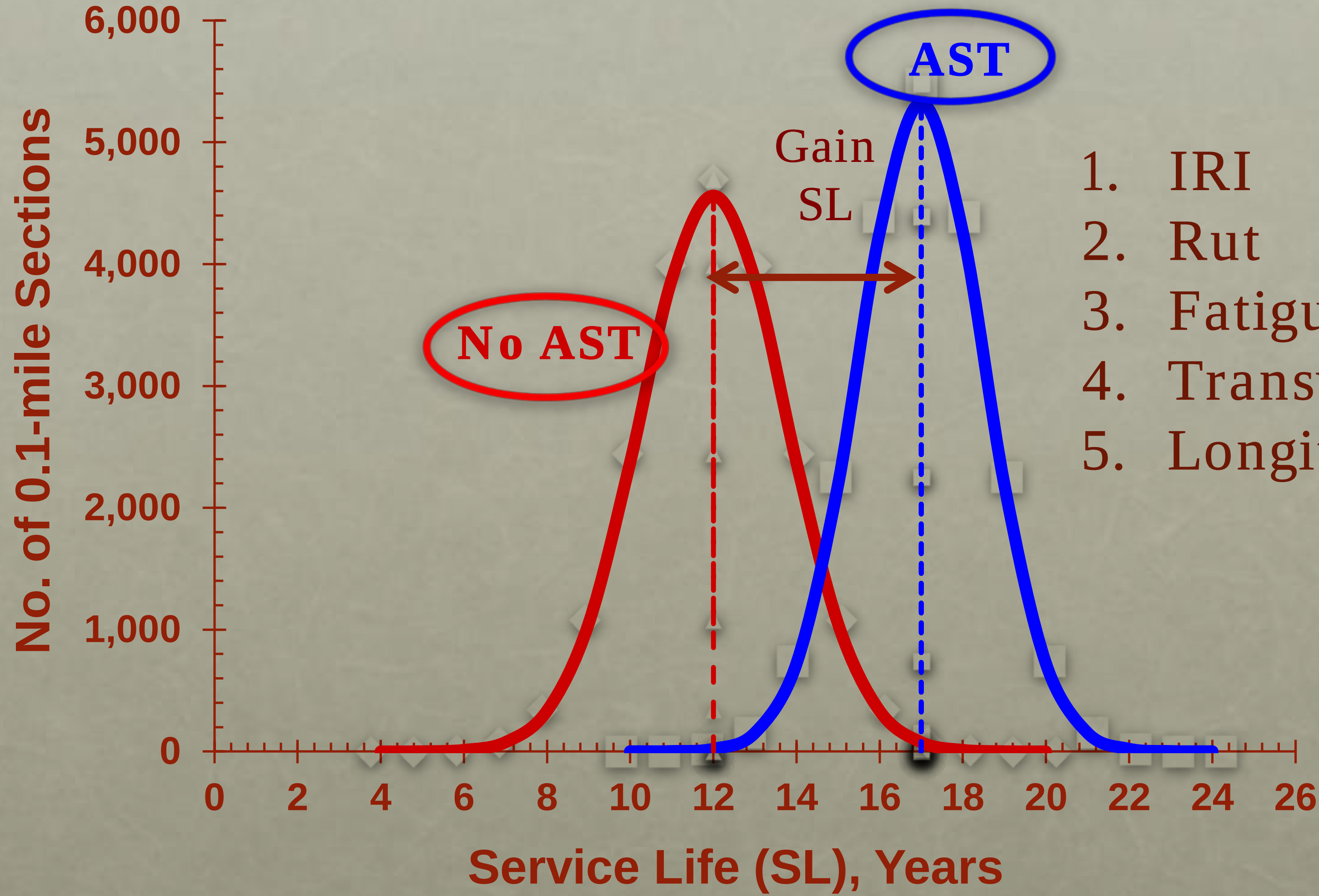
Every 1/10th log-mile

MATLAB, VBA, EXCEL Programs Were Used!

Distribution of SL



Comparison of SL



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

Analysis Matrix

Base Type	HMA Thickness (in)	AST Interlayer		No Interlayer		No. Data Points/ (SA)
		ESAL <30k	ESAL >30k	ESAL <30k	ESAL >30k	
CSD	0-4	x	x	x	x	3/ (5-7 yr)
	>4	x	x	x	x	
CTD	0-4	x	x	x	x	
	>4	x	x	x	x	
CSD						6/ (12-14 yr)
CTD						
	>4	x	x	x	x	

<u>Majority</u>

<u><=4 in, <=30k ESAL</u>

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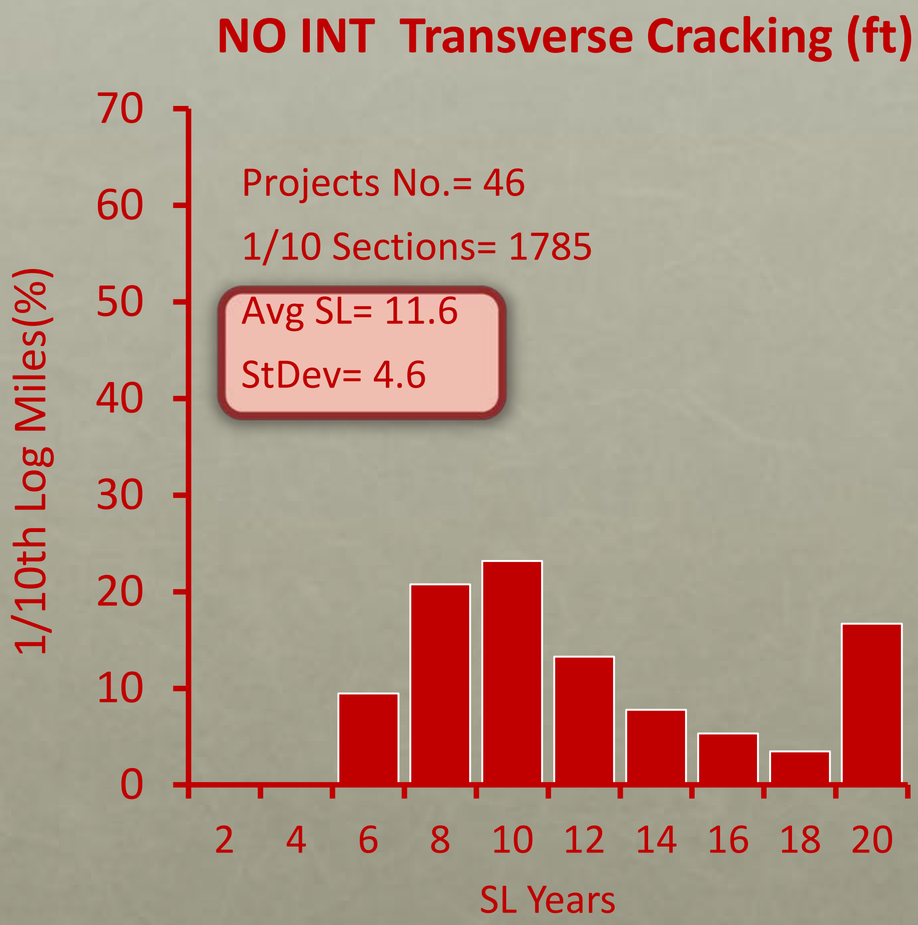
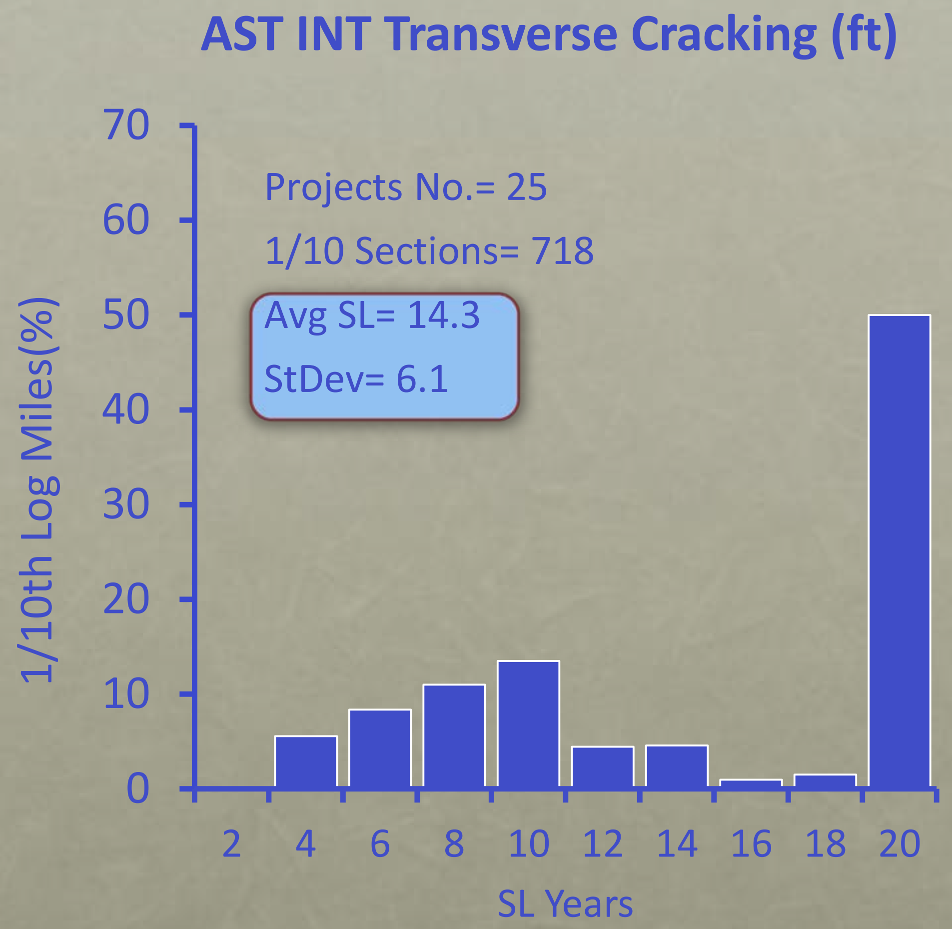
SL Distribution (TC)
ESAL<30K, Th<4 in, CSD Base

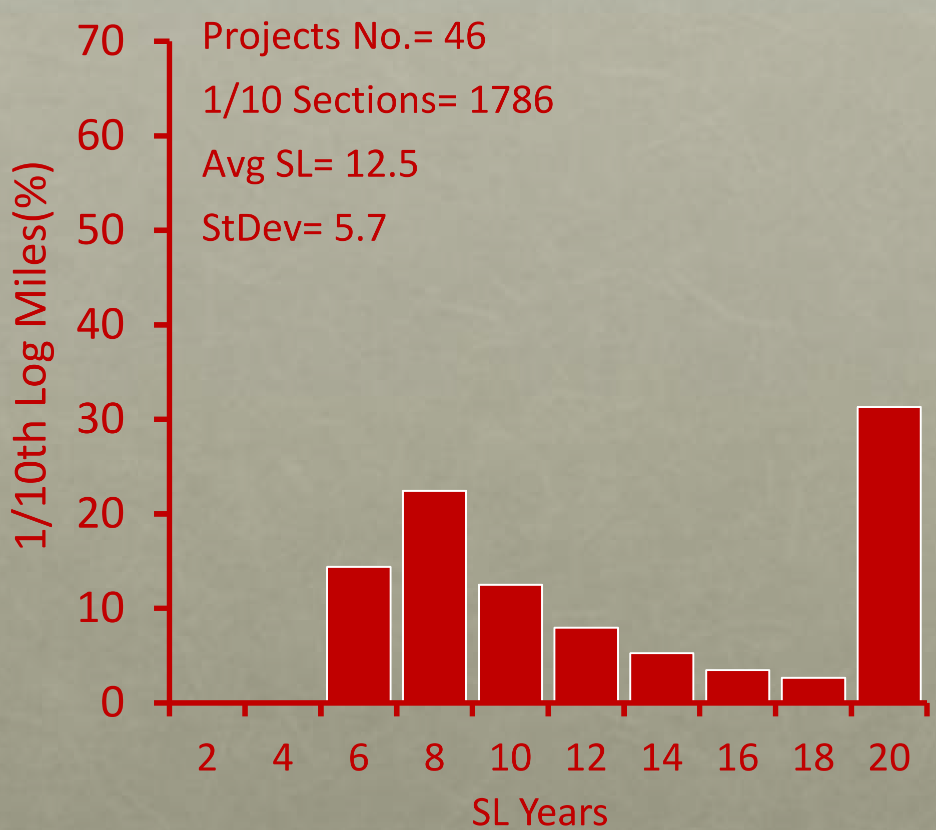




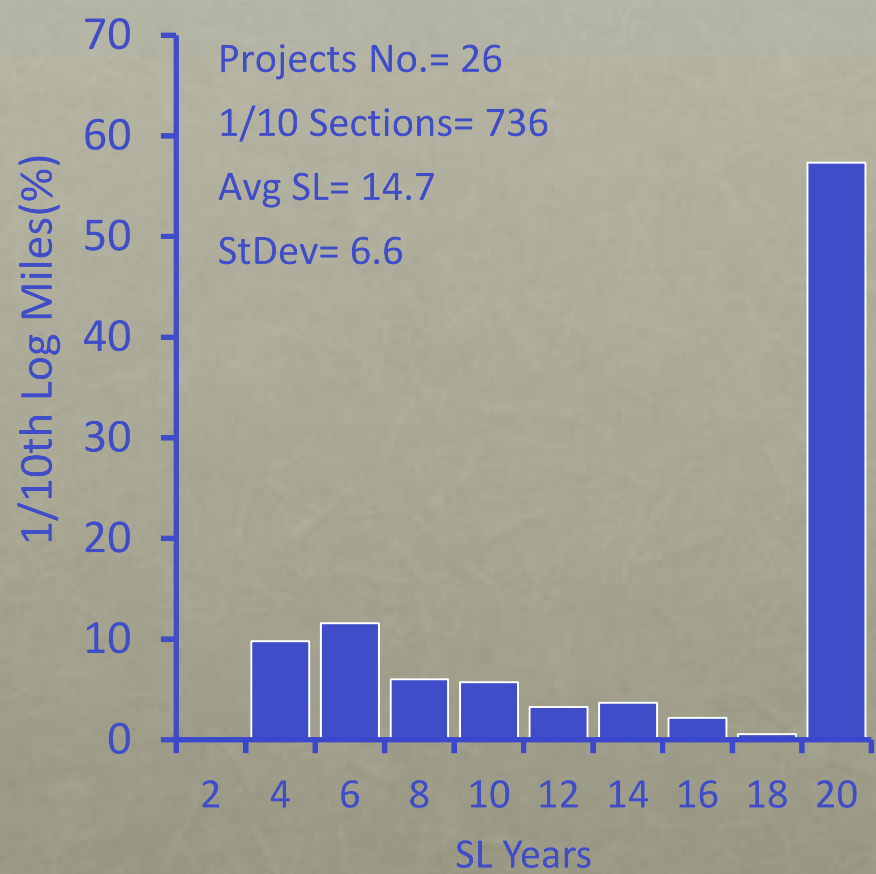
Gain SL = 2.7 yrs

SL Distribution (AC)
ESAL<30K, Th<4 in, CSD Base

NO INT Alligator Crack (Sq. ft)



AST INT Alligator Crack (Sq. ft)



Gain SL= 2.2 yrs

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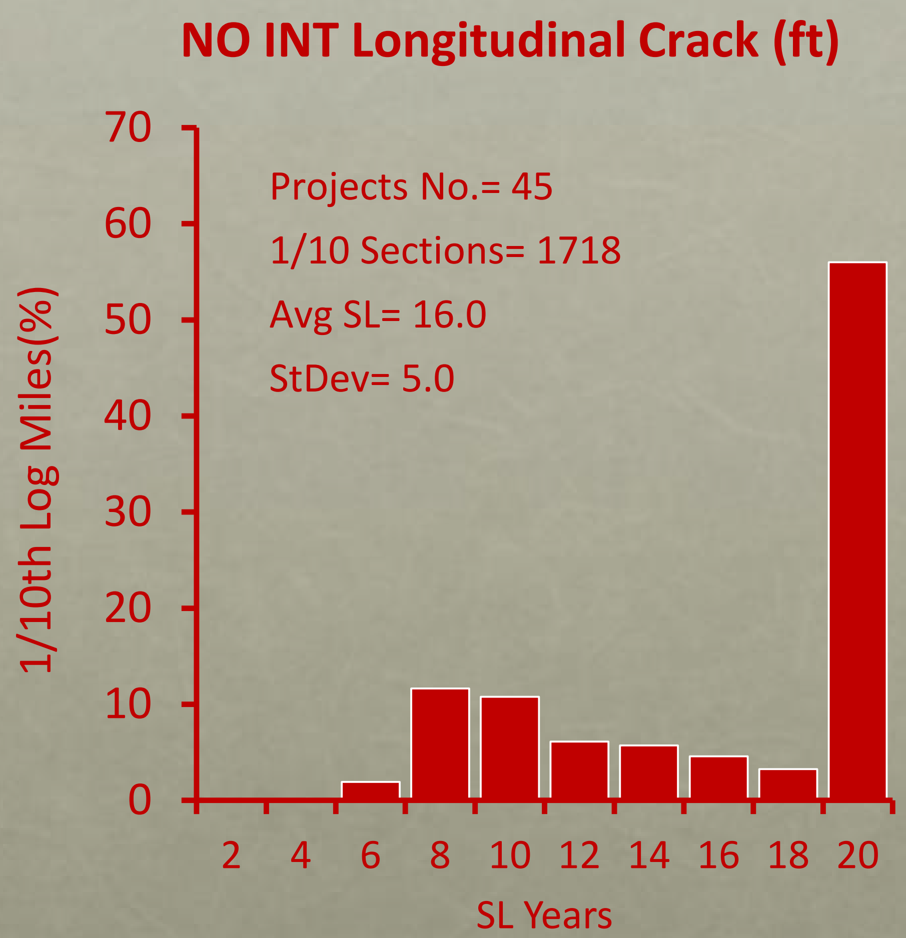
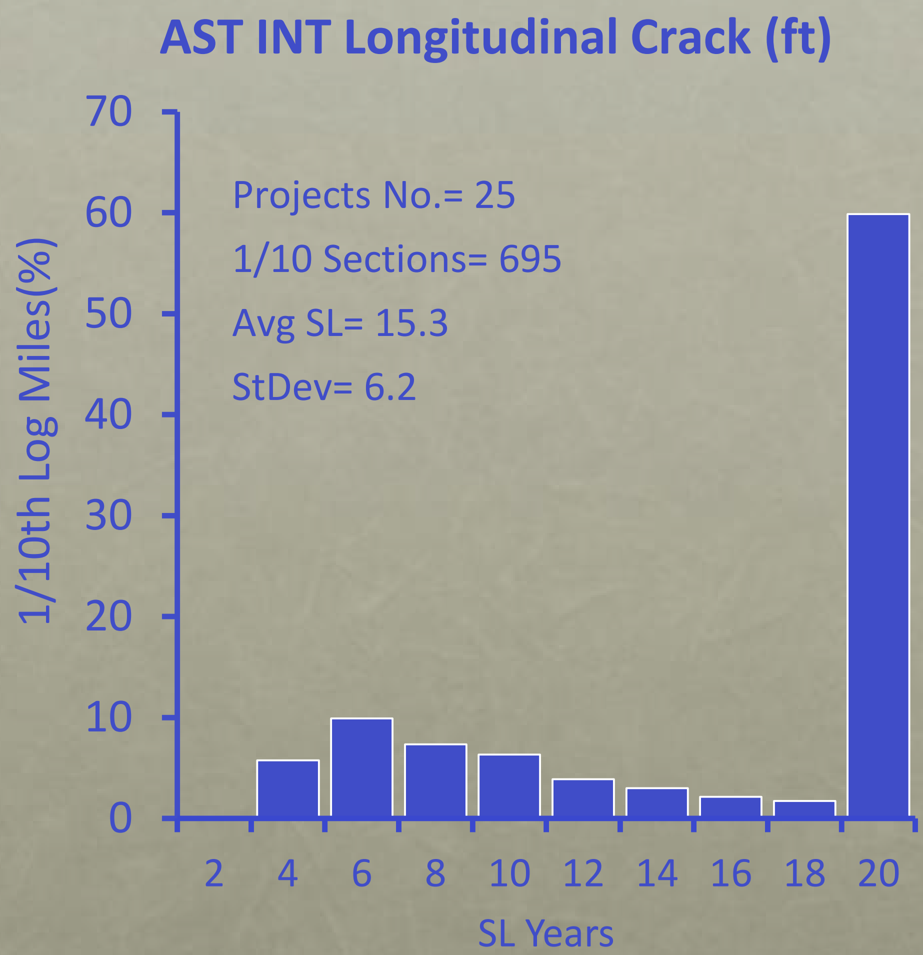
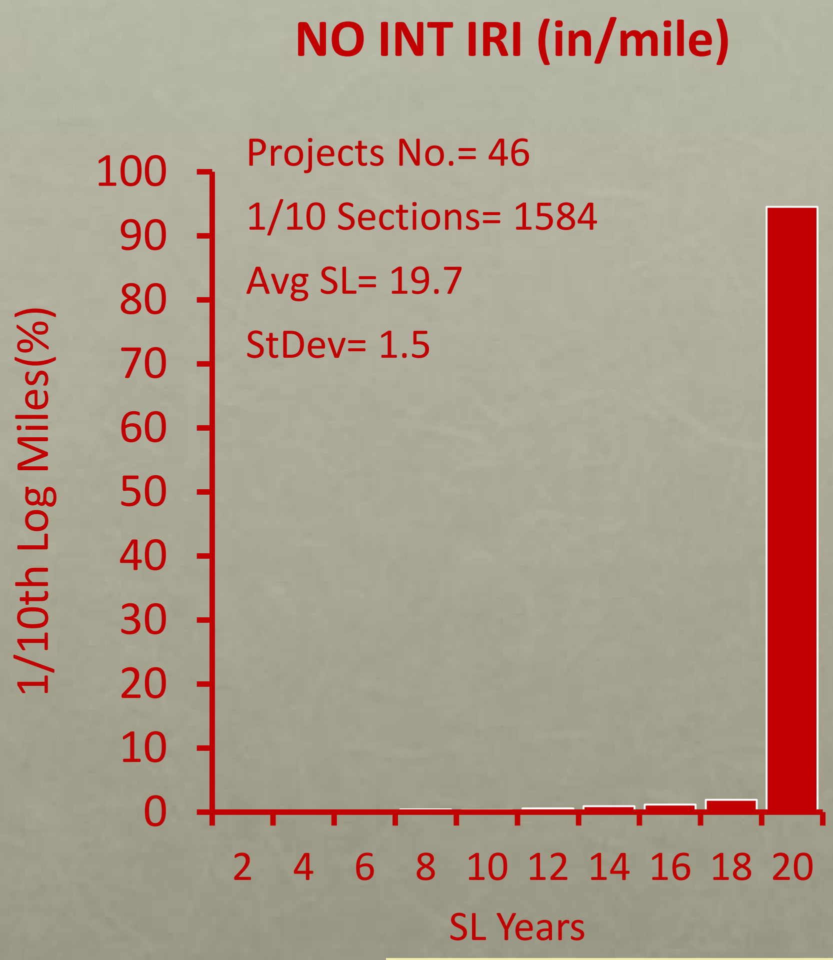
SL Distribution (LC)
ESAL<30K, Th<4 in, CSD Base

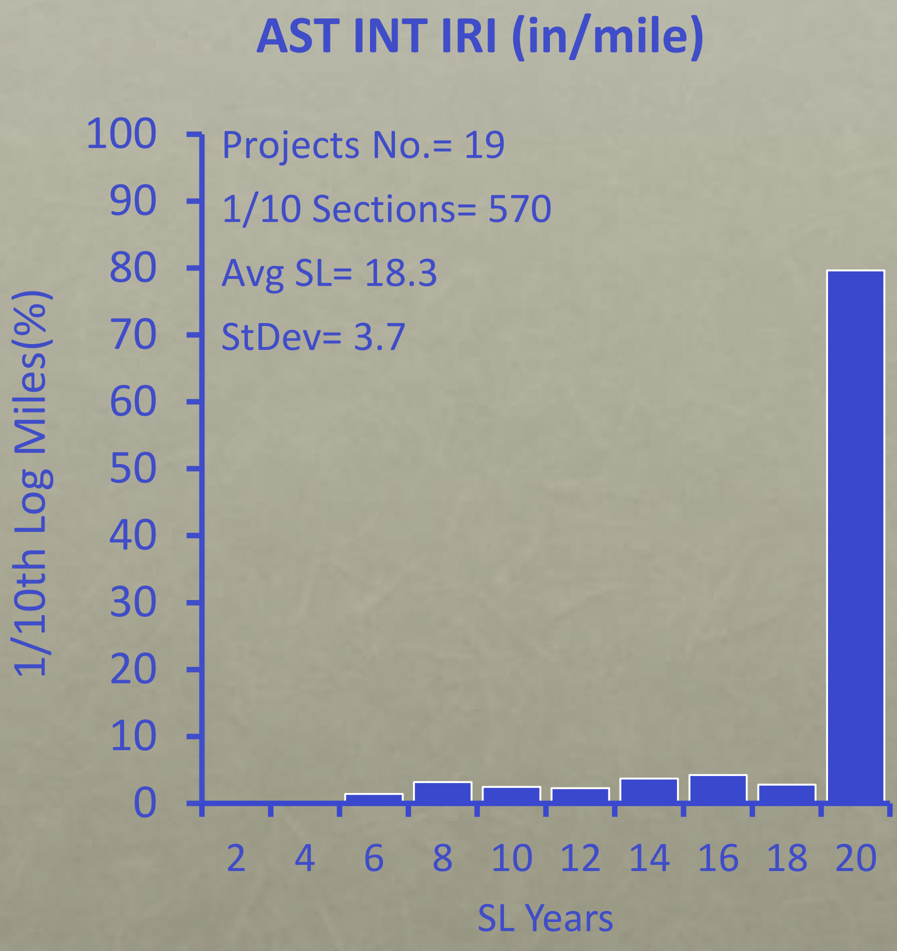




No Gain SL

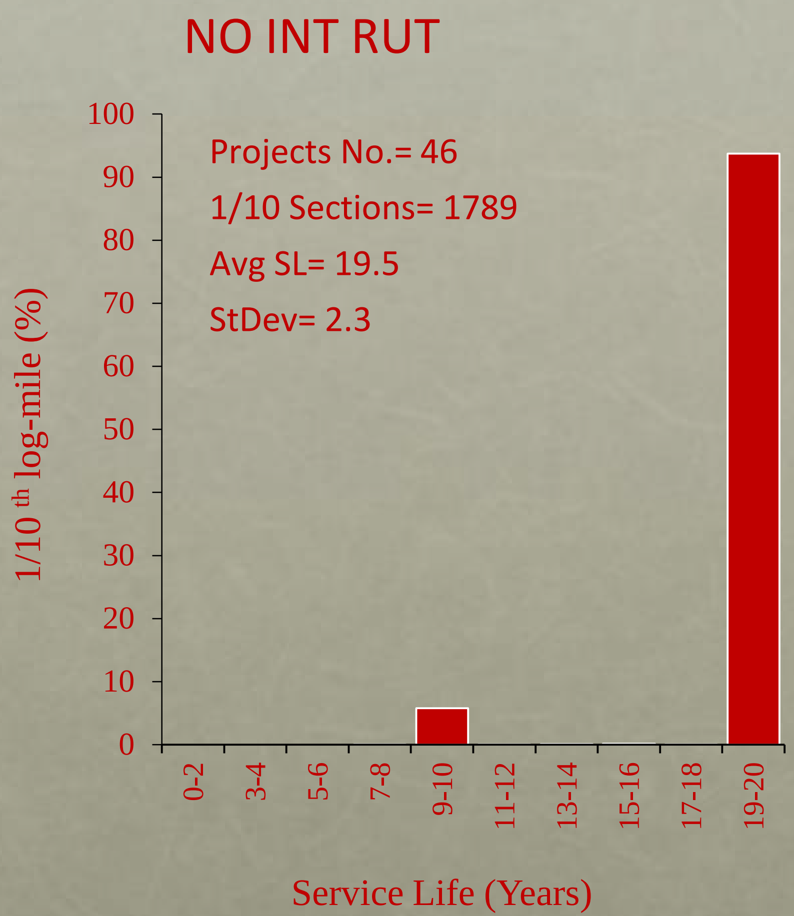
SL Distribution (IRI)
ESAL<30K, Th<4 in, CSD Base

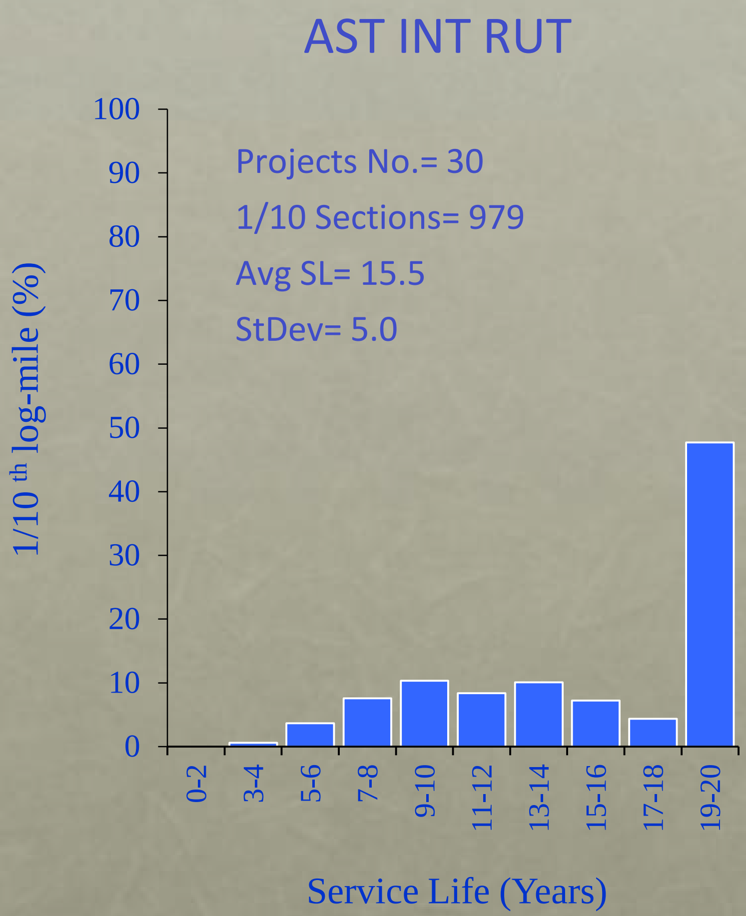




No Gain SL

SL Distribution (RUT)
ESAL<30K, Th<4 in, CSD Base

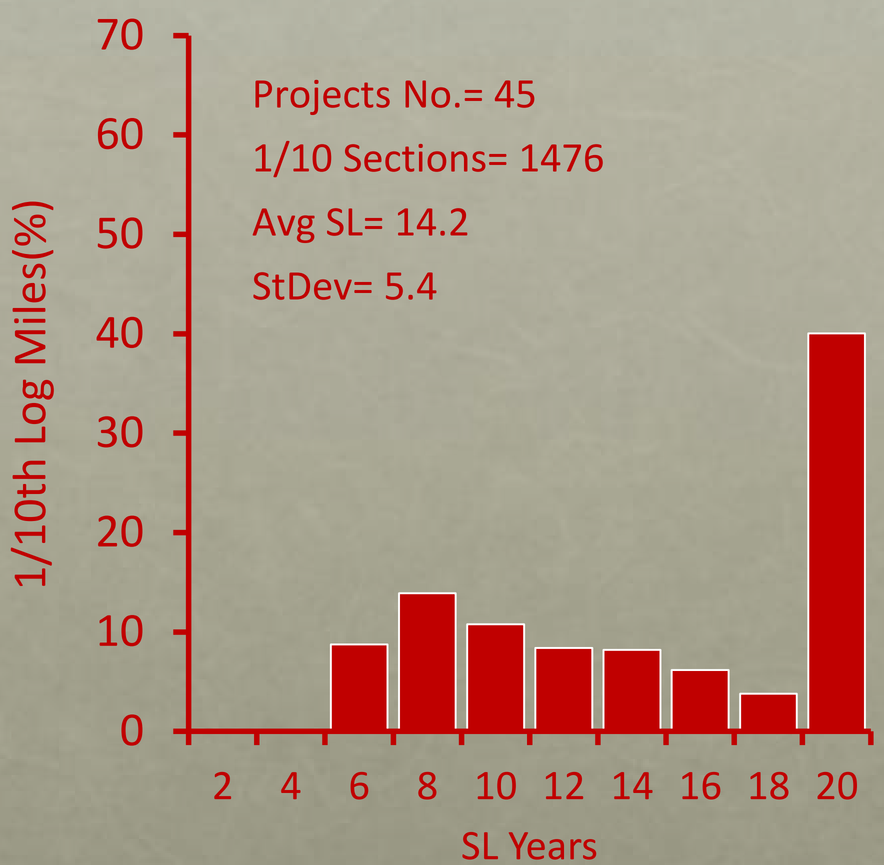




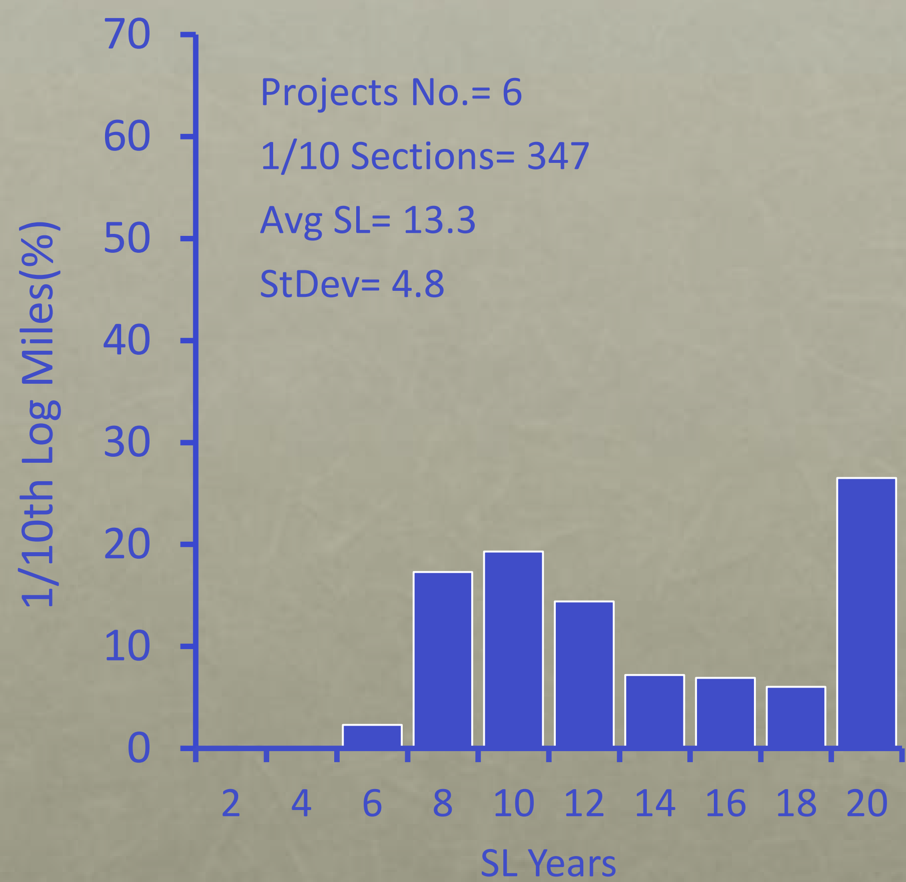
Gain SL= -4.0 yrs

SL Distribution (TC)
ESAL<30K, Th<4 in, CTD Base

NO INT Transverse Cracking (ft)



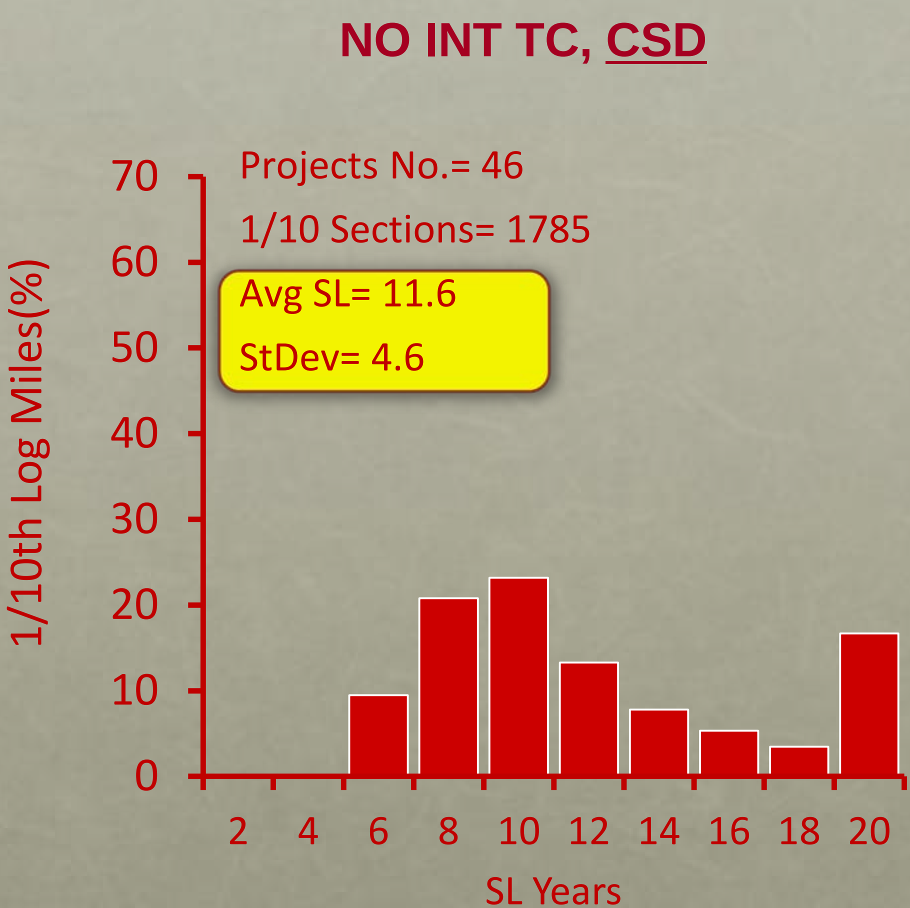
AST INT Transverse Cracking (ft)

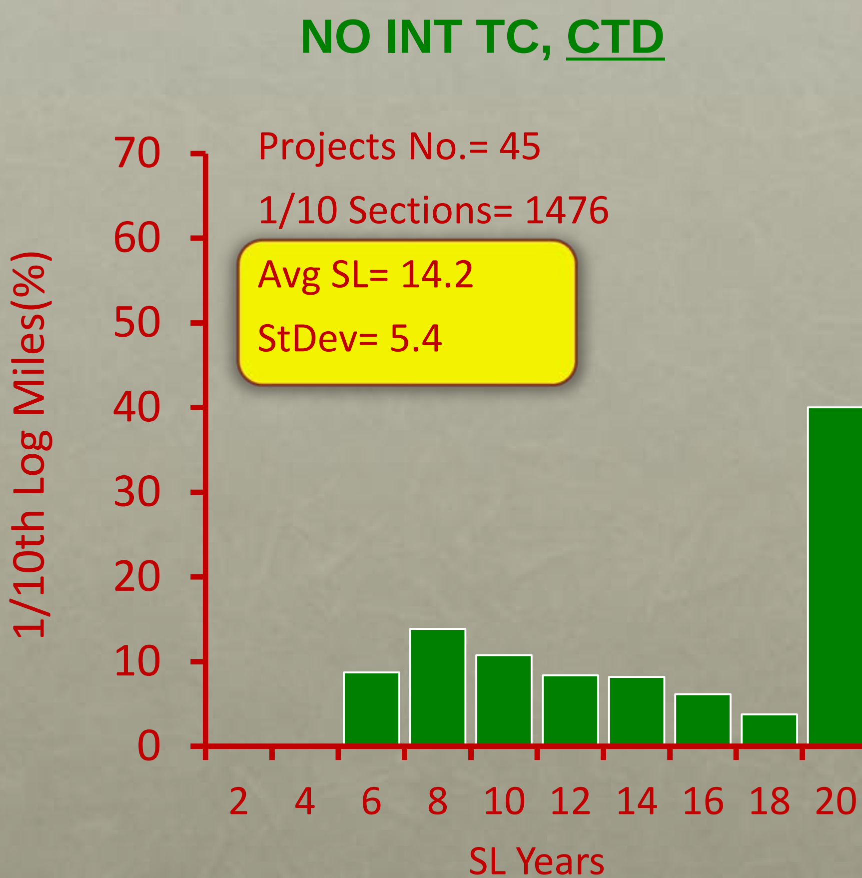


No Gain SL

SL Distribution (TC)

CSD/CTD, No Interlayer





Gain SL = 2.6 yrs, same as AST INT

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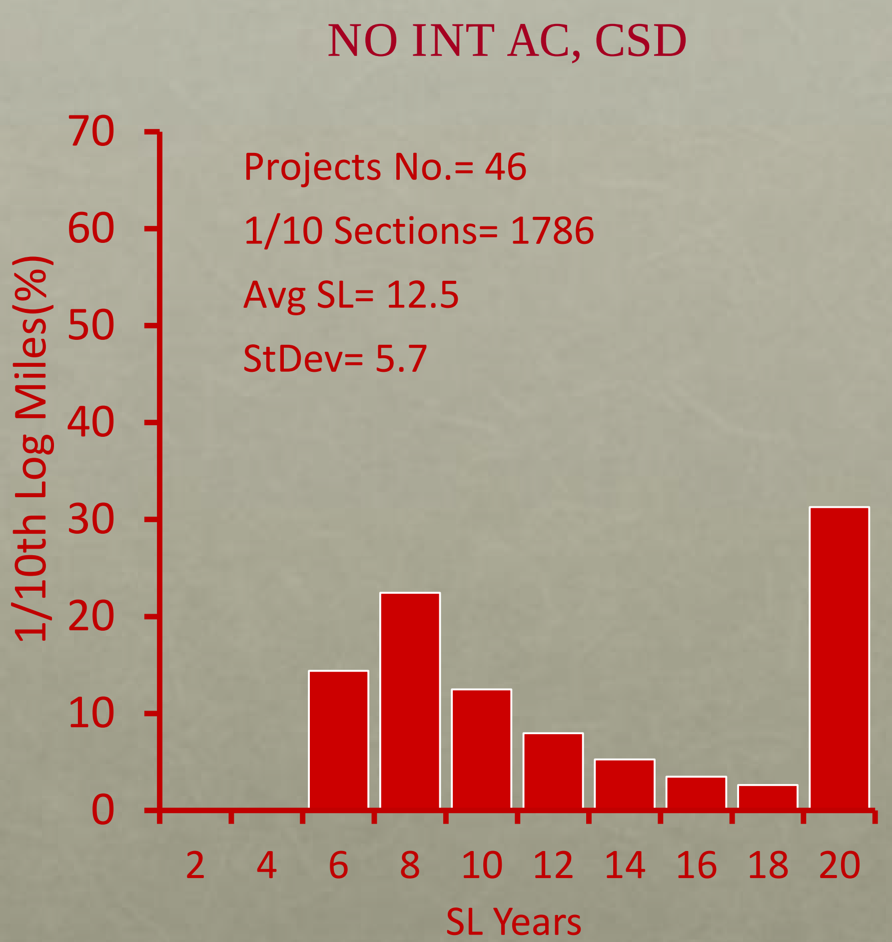
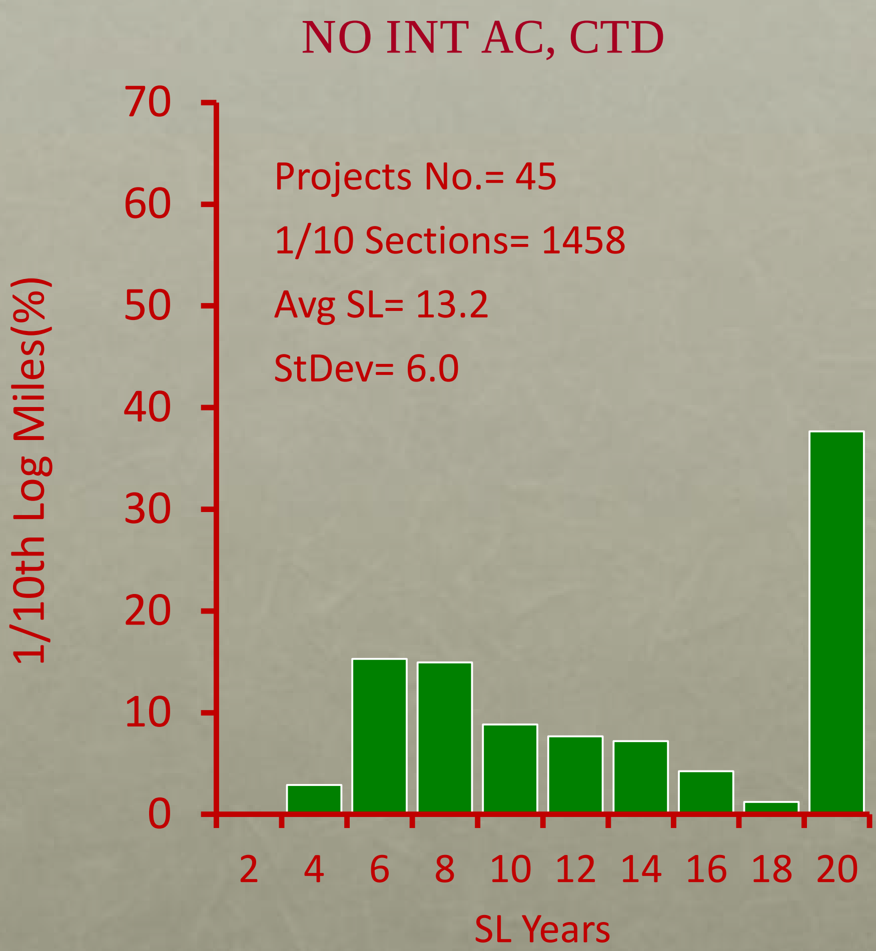
SL Distribution (AC)

CSD/CTD, No Interlayer





CTD IS BETTER/SIMILAR TO CSD

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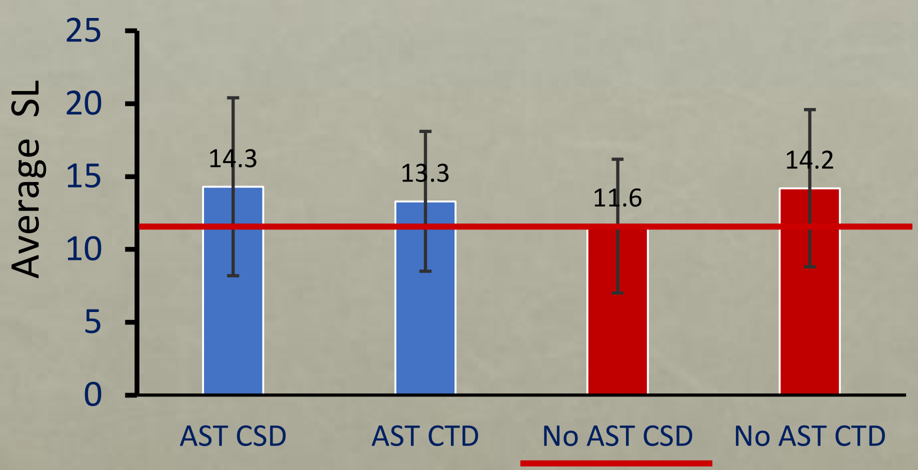
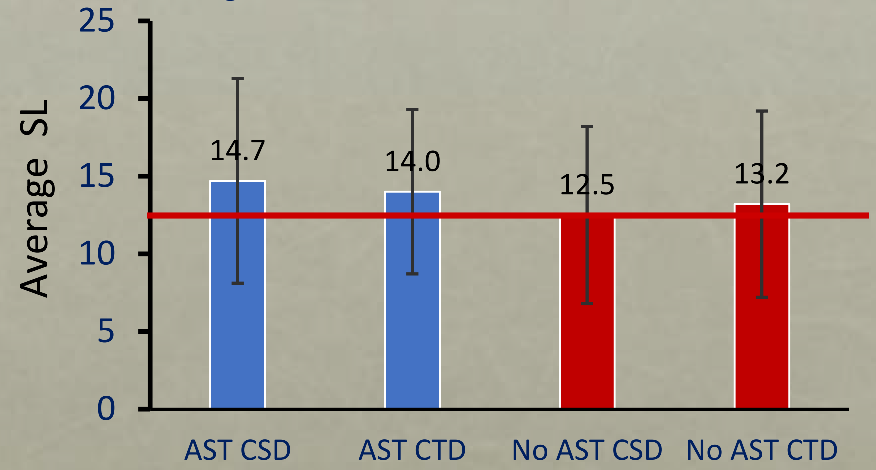
Summary Service Life (SL)

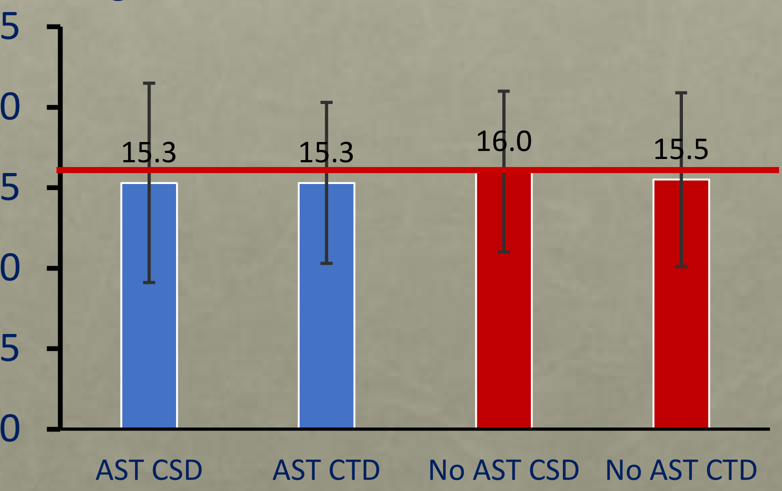
Transverse Crack SL COMPARISON



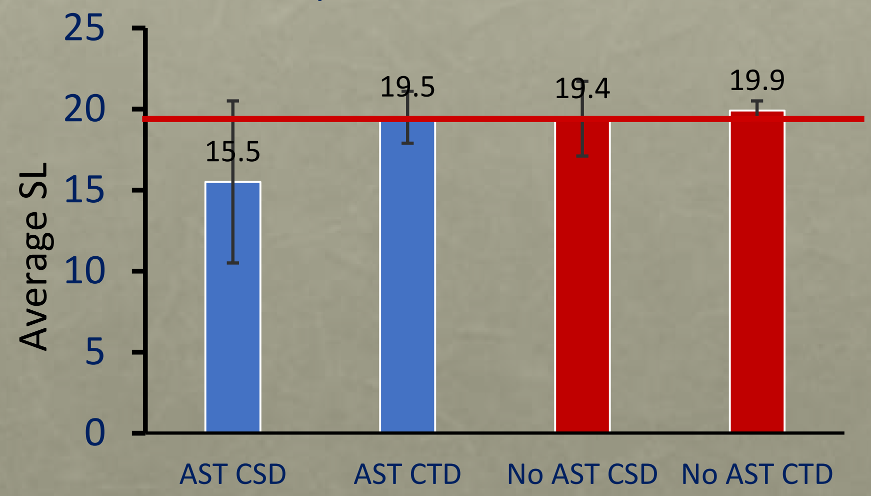
Alligator Crack SL COMPARISON



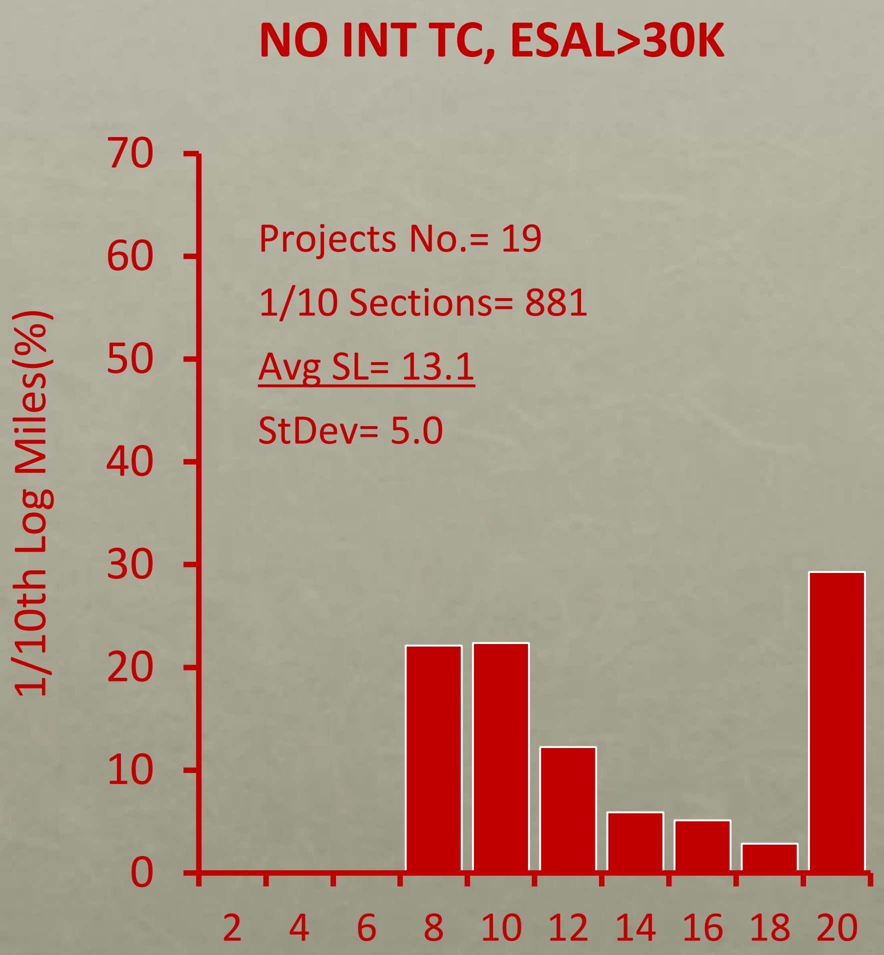
Longitudinal Crack SL COMPARISON

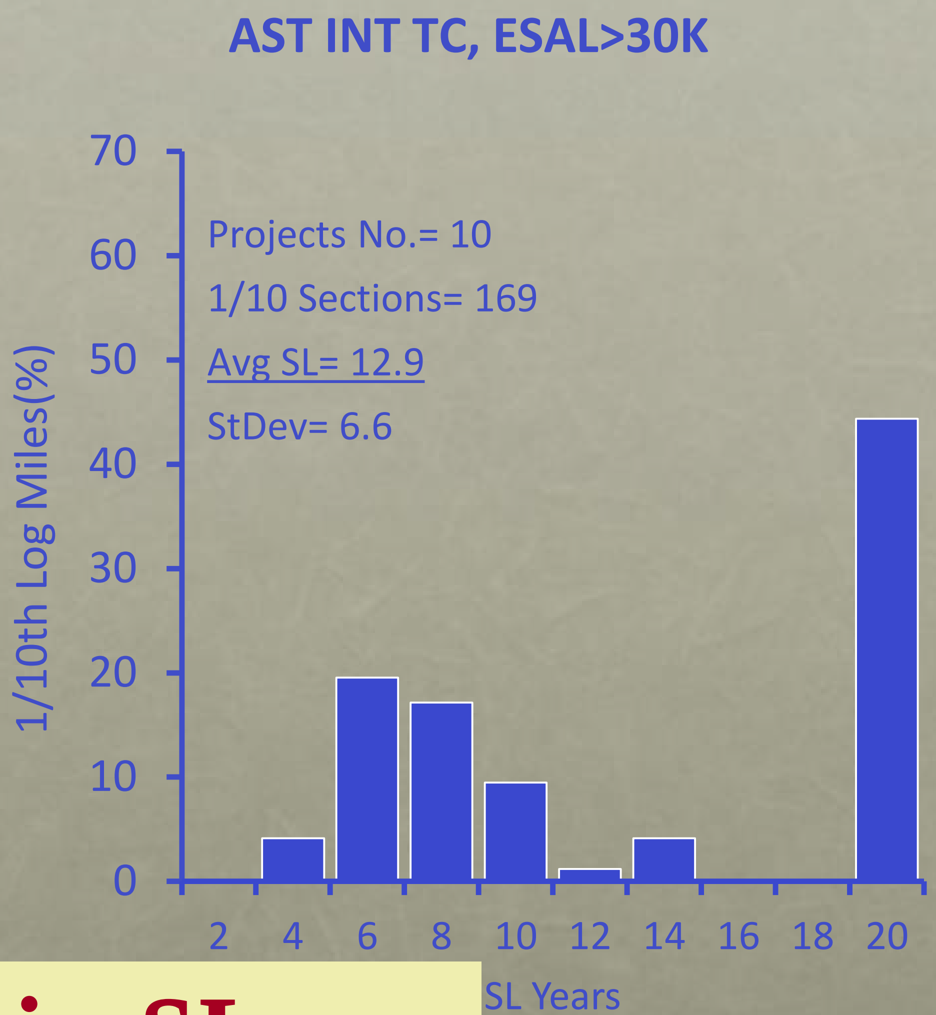


Rut Depth SL COMPARISON



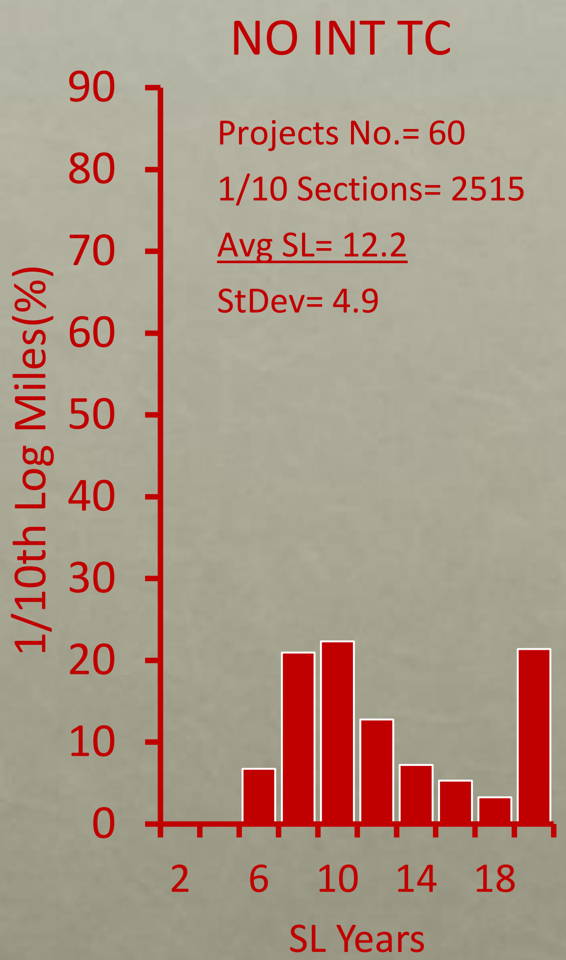
SL Distribution (TC)
ESAL>30K, CSD Base

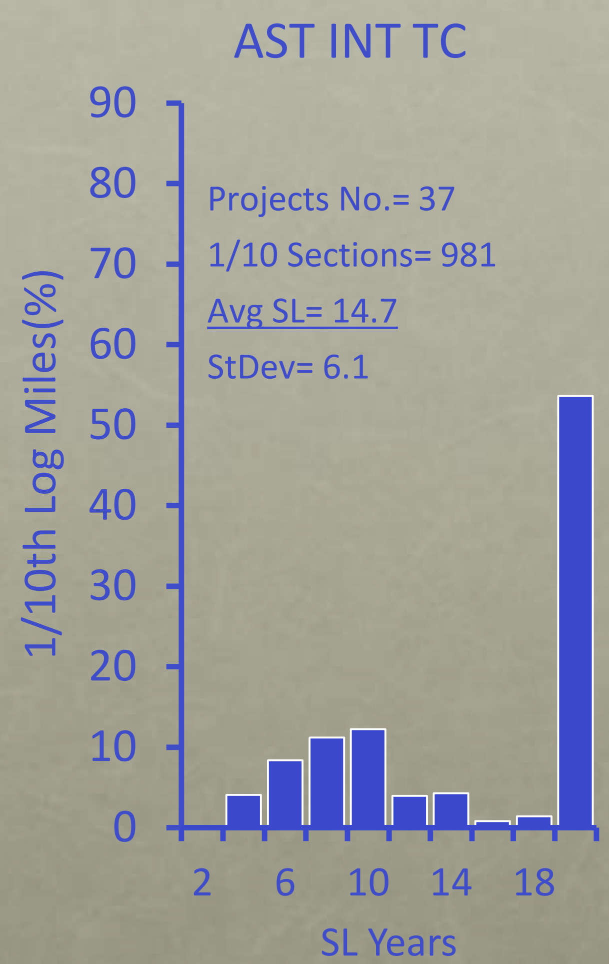


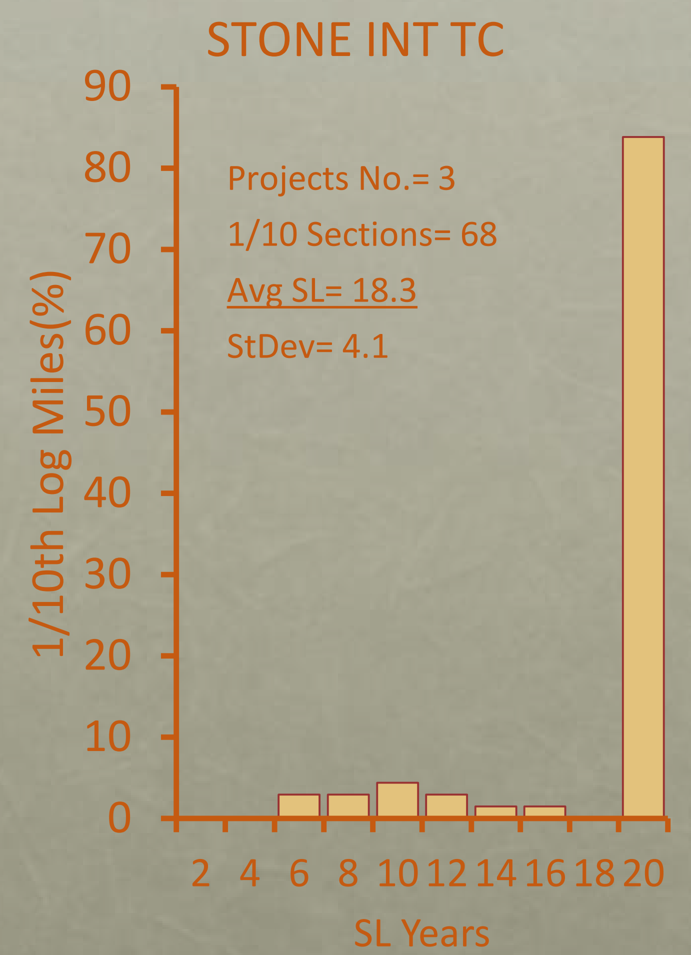


No Gain SL

STONE INT SL Distribution (TC) ESAL<150K, Th<0-5in, CSD Bases

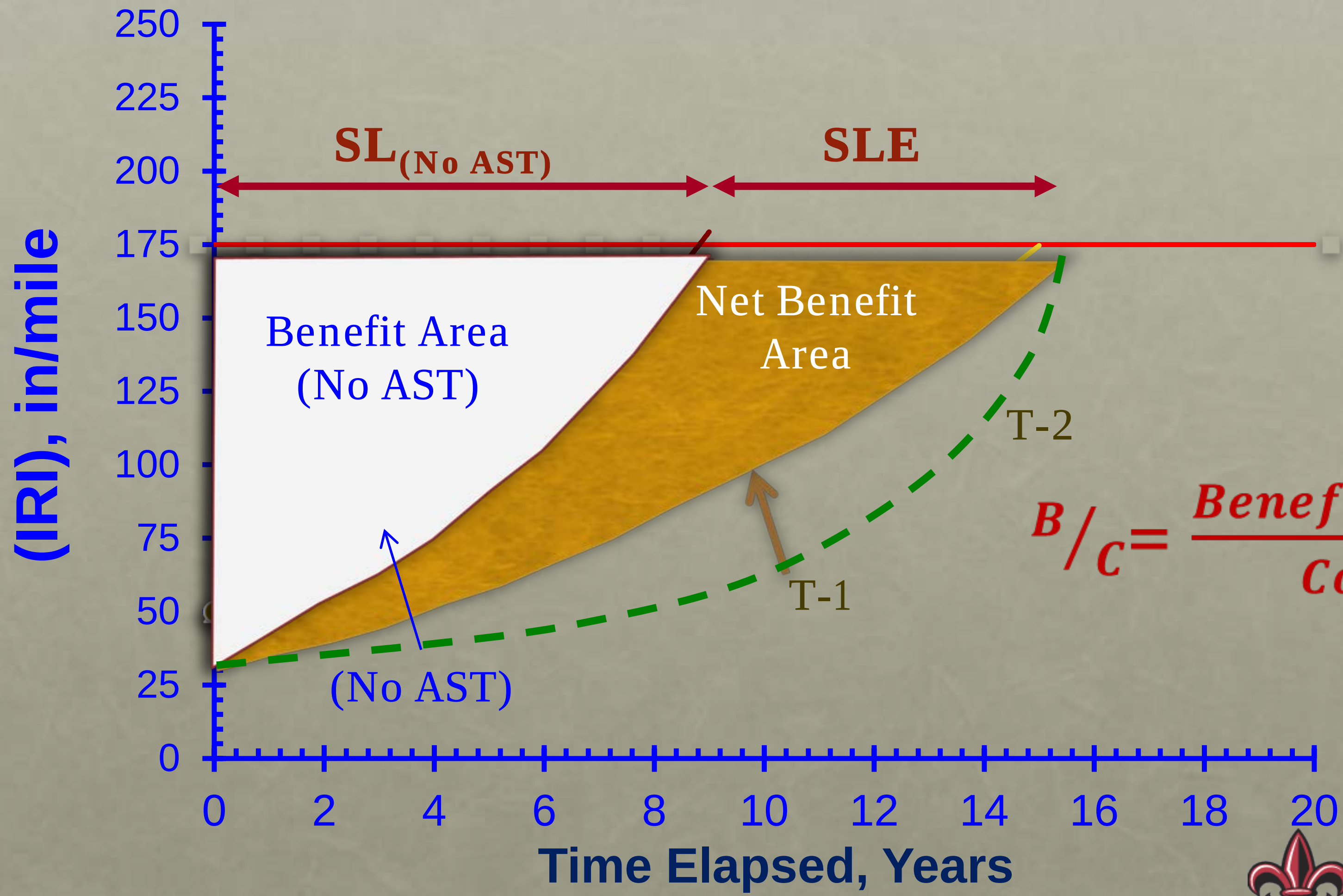






Cost-Benefit Analysis

Benefit Analysis



$$B/C = \frac{\textit{Benefit Area}}{\textit{Cost}}$$

Cost-Benefit Analysis

Cost-effectiveness Evaluation

Benefit/Cost Ratio (B/C):

$$B/C(SL) = \frac{SL}{EUAC} * 10000 \qquad B/C(NBA) = \frac{NBA}{EUAC} * 10000$$

$$EUAC = P.\frac{i.(1+i)^n}{(1+i)^n - 1}$$

NBA= Normalized Benefit Area

EUAC = Equivalent uniform annual cost

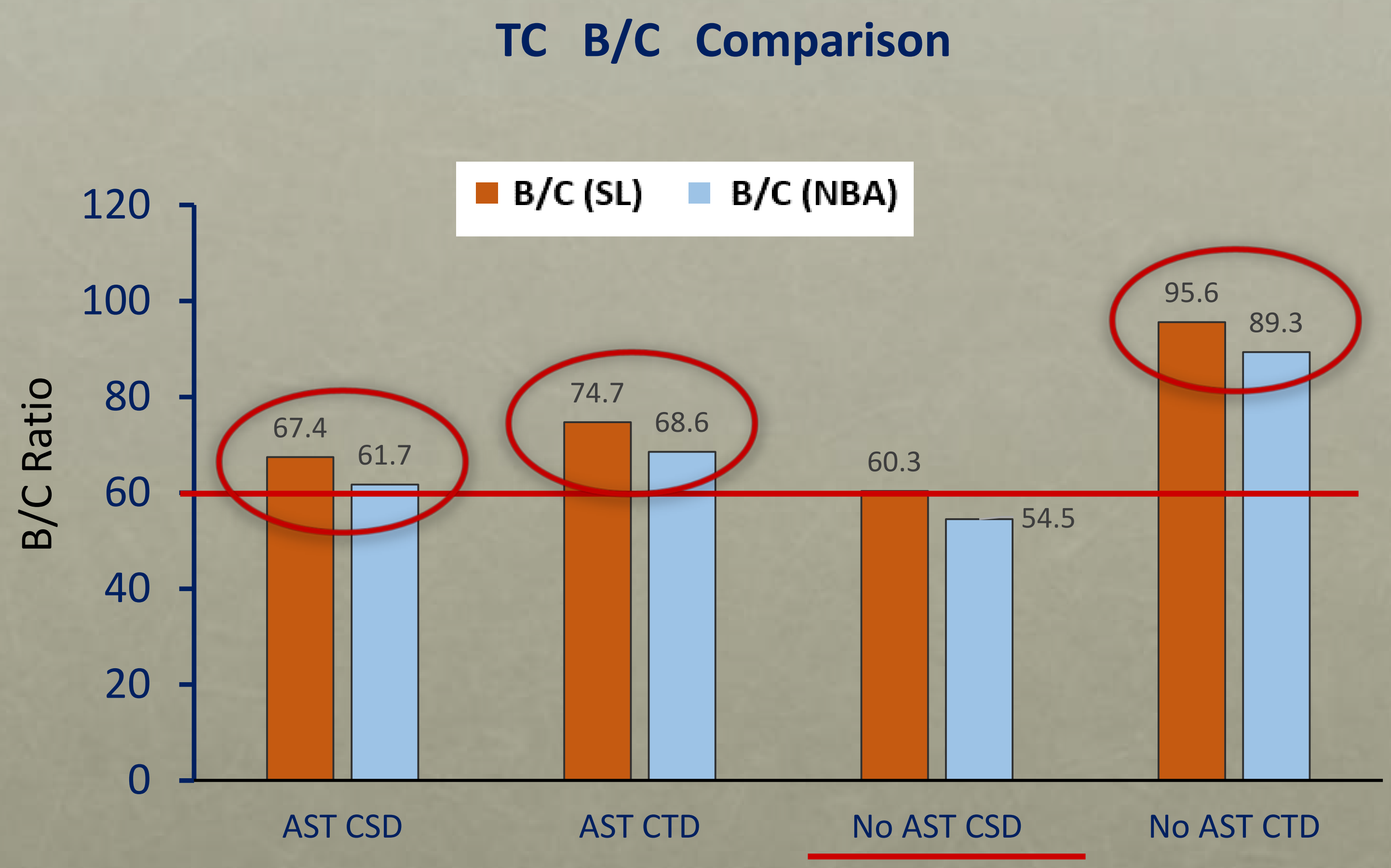
P= Present cost, of entire pavement system, considering 3.5 in HMA
i= inflation (4%)

Cost-Benefit Analysis

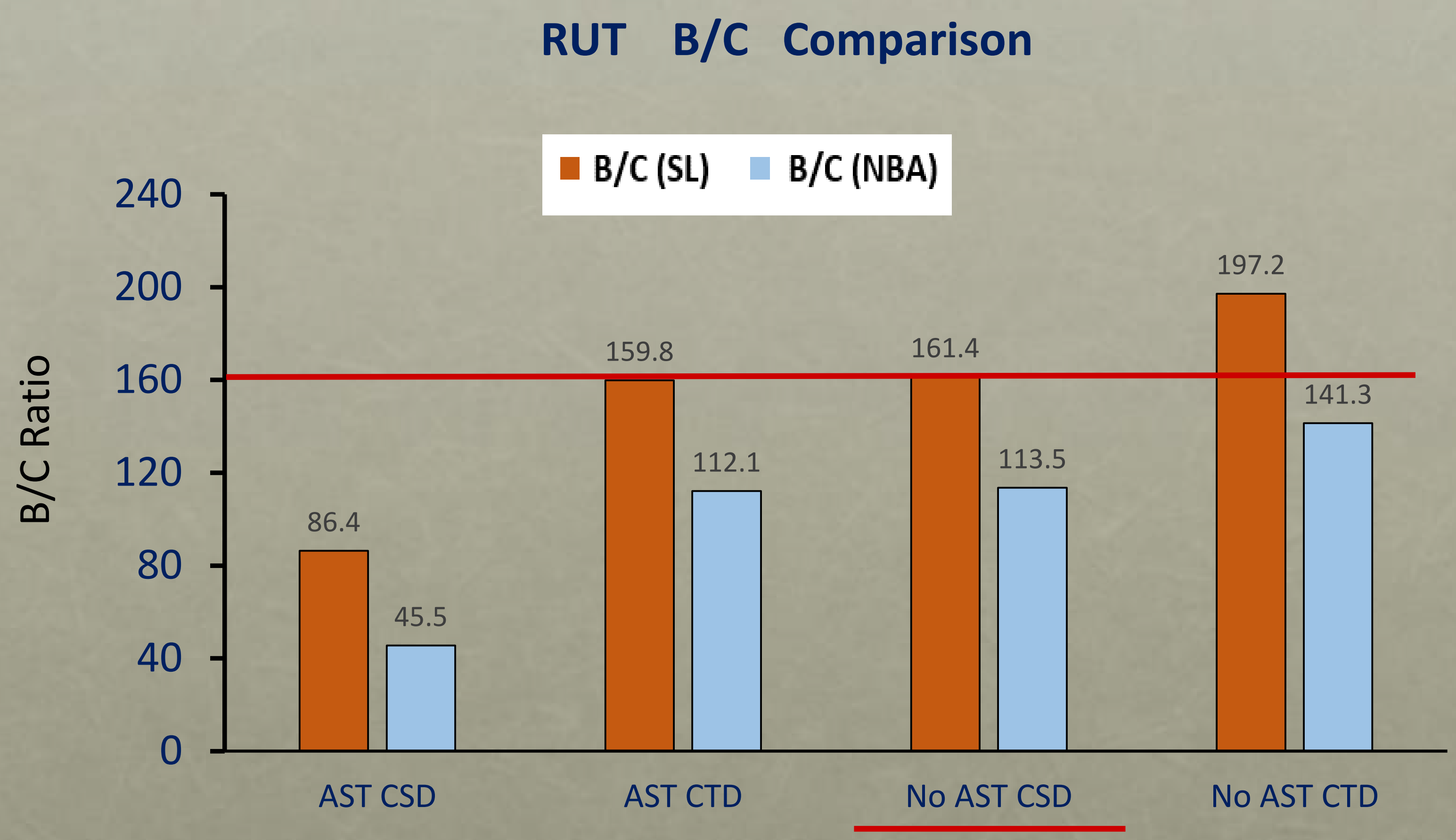
Cost for CSD/CTD Projects With or Without Interlayer

Type	Cost per Sq Yd	Cost per 1/10th log-mile	Total Cost of Treatment (P) (Including Overlying 3.5 in HMA cost)
AST Interlayer, only	$3.62	$2,547	-
AST Interlayer over CTD	$10.67	$7,511	$17,692
AST Interlayer over CSD	$13.53	$9,528	$19,709
Stone Interlayer over CSD	$21.28	$14,984	$25,165
CTD base, only	$7.05	$4,964	$15,145
CSD base, only	$9.92	$6,981	$17,162

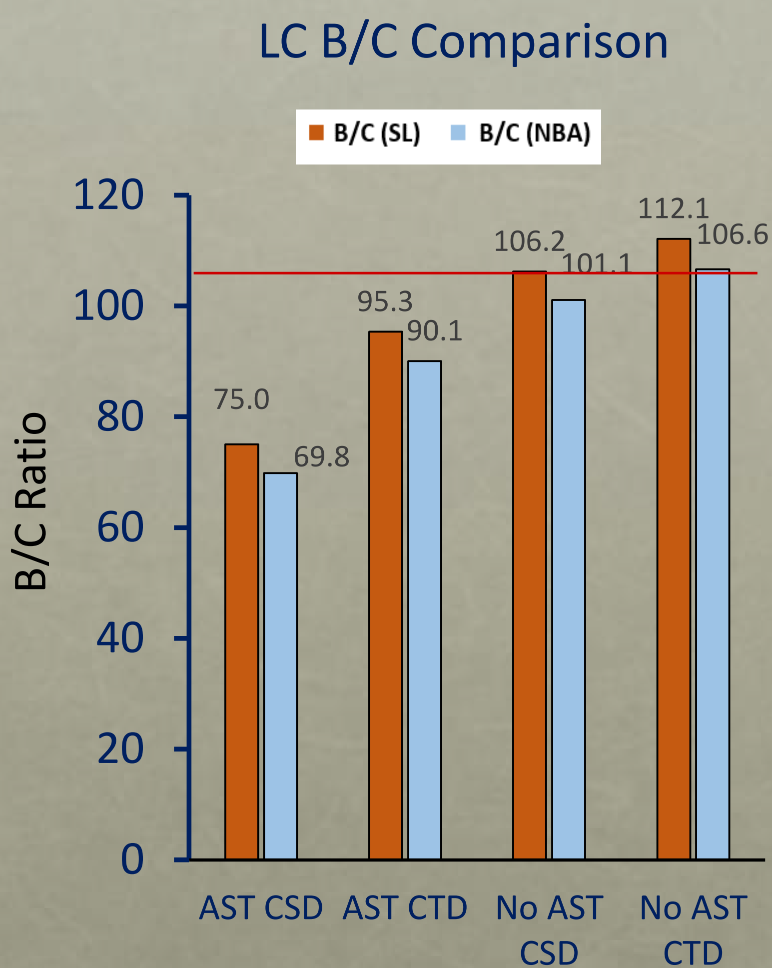
Cost-Benefit Analysis

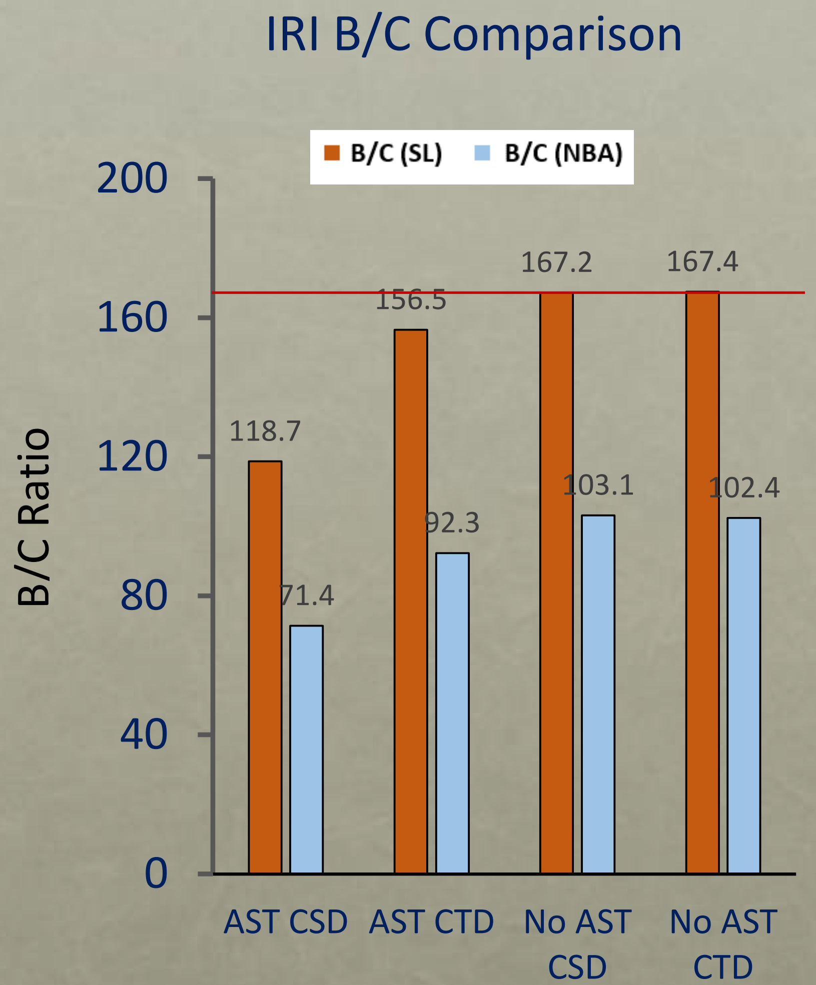


Cost-Benefit Analysis



Cost-Benefit Analysis





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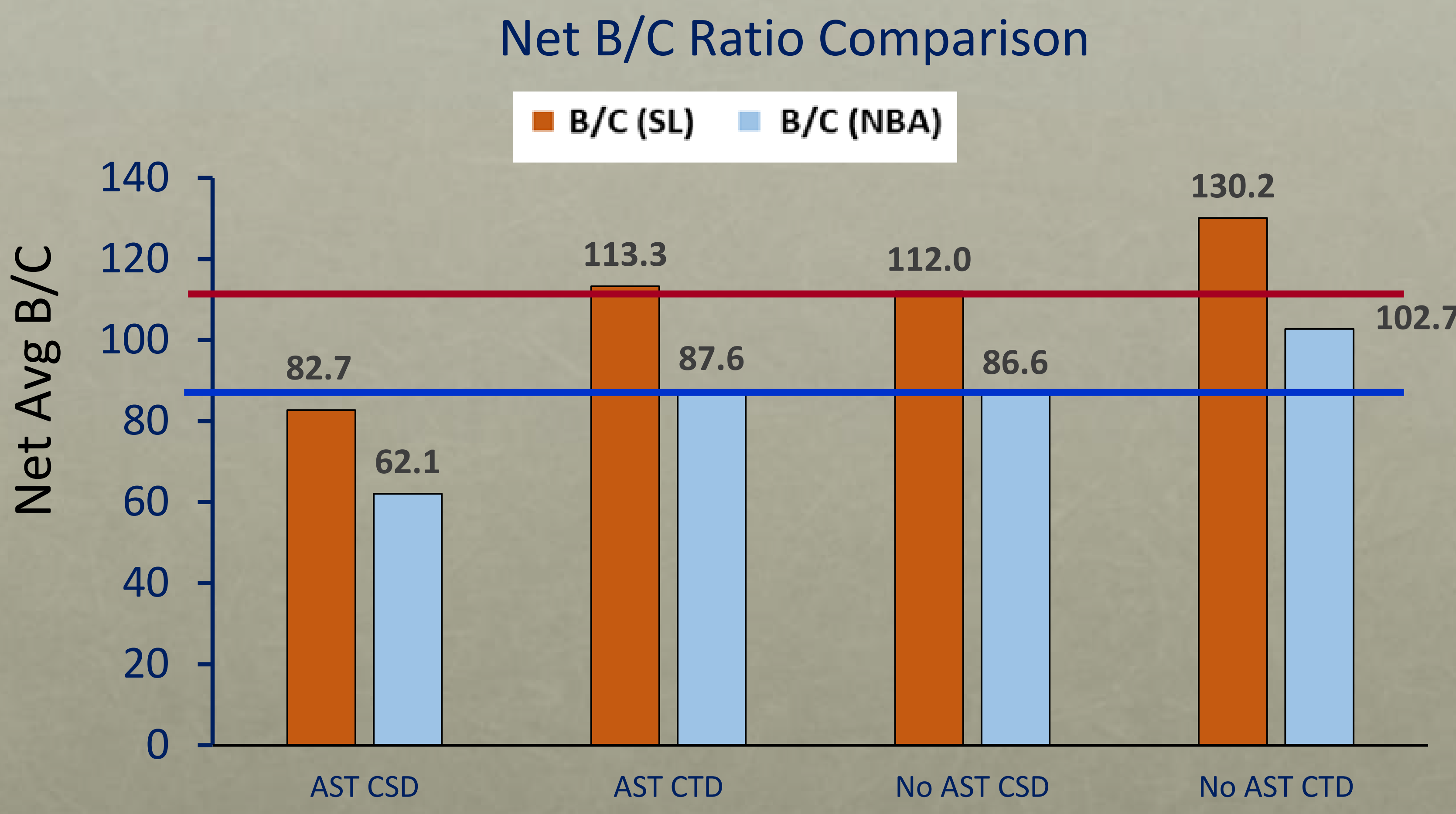
Cost-Benefit Analysis



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

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

- Since the <u>AST interlayer</u> of all soil-cement became least cost-effective option, therefore, it is recommended that it <u>should not be used as an interlayer</u> over soil-cement to minimize the reflective cracking.

Thanks!

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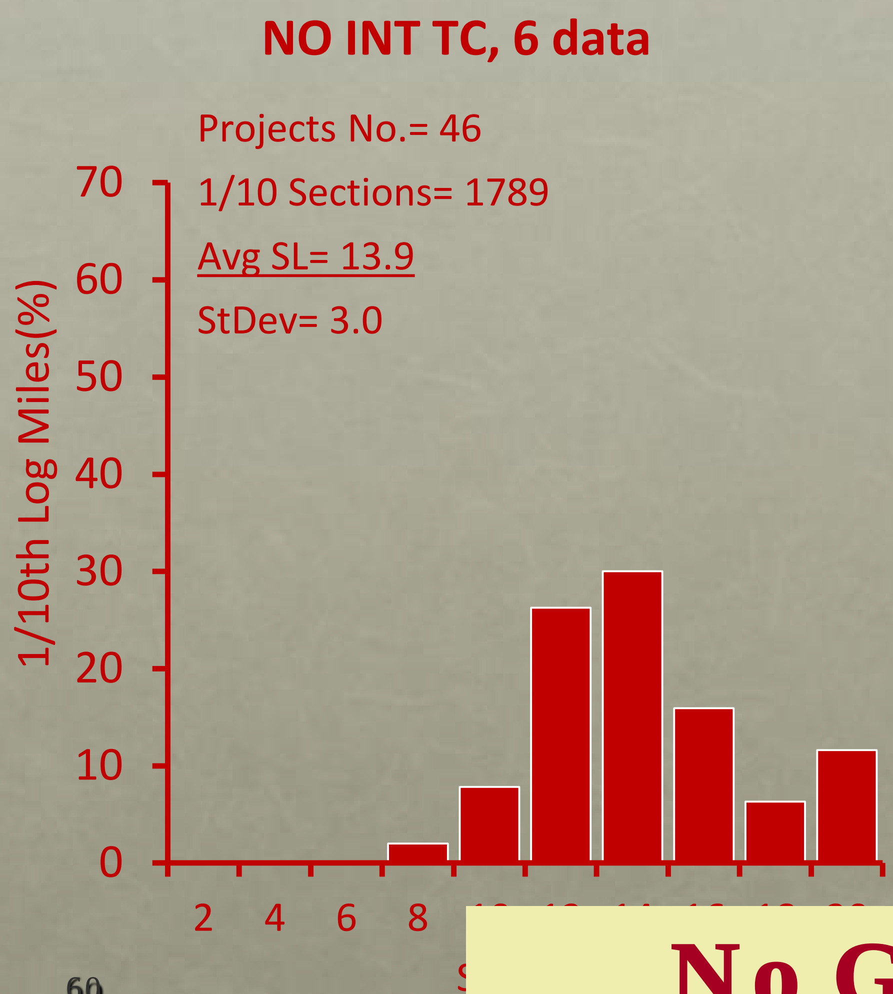
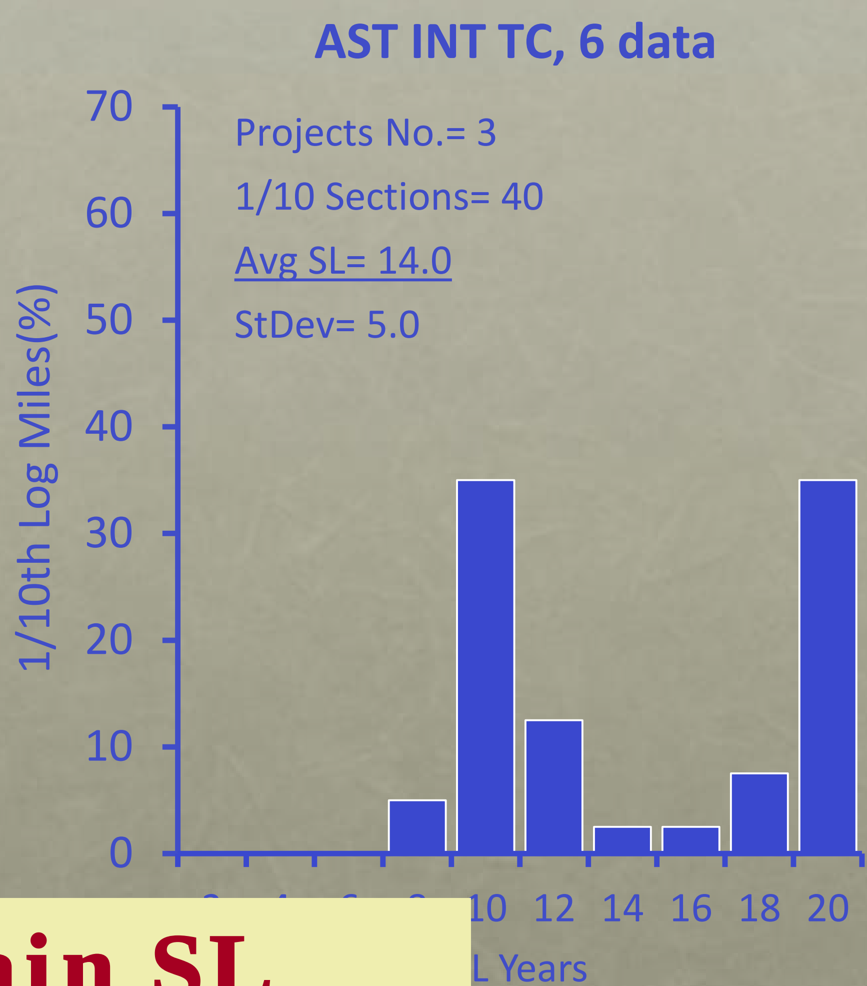
Additional Slides

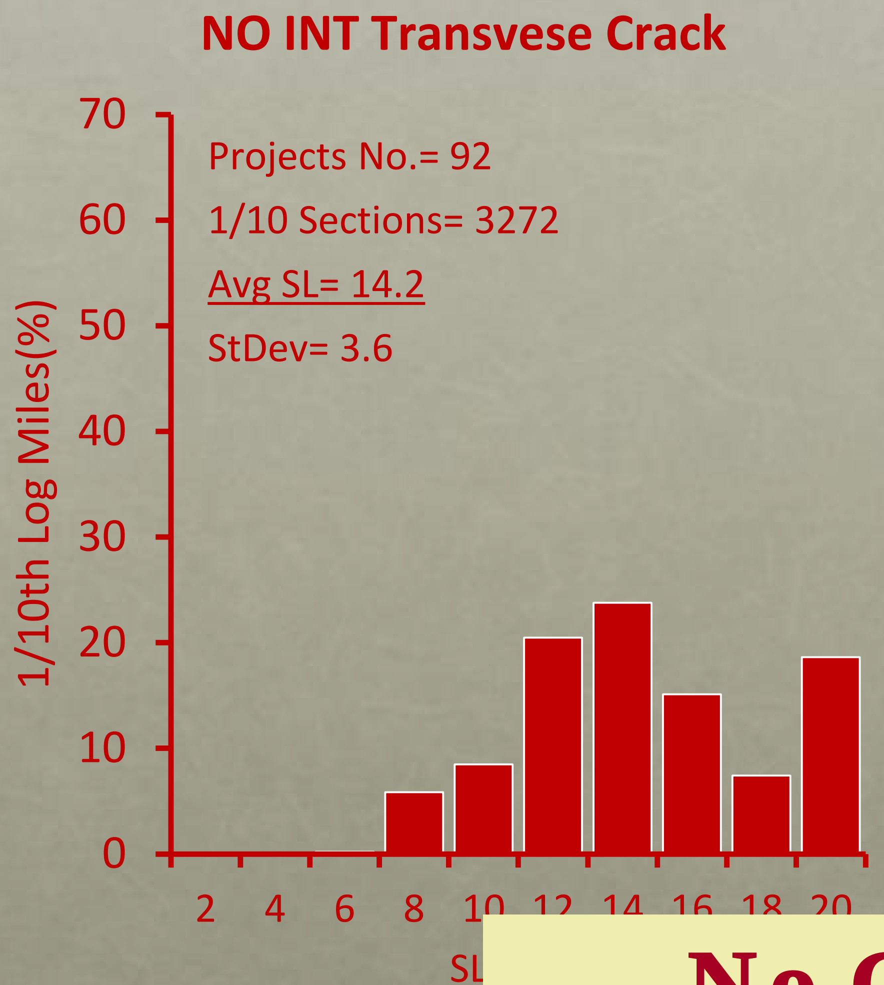
SL Distribution (TC)
ESAL<30K, CSD Base, 10-14 yr data

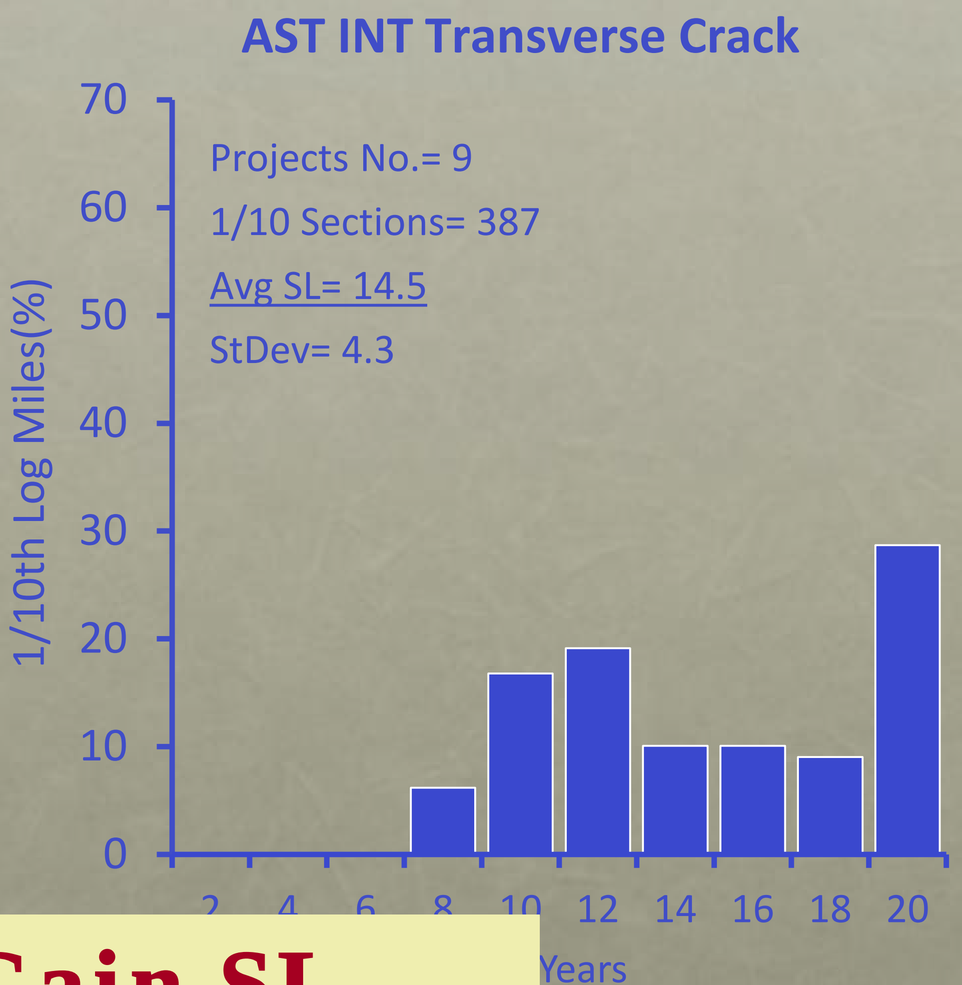




No Gain SL

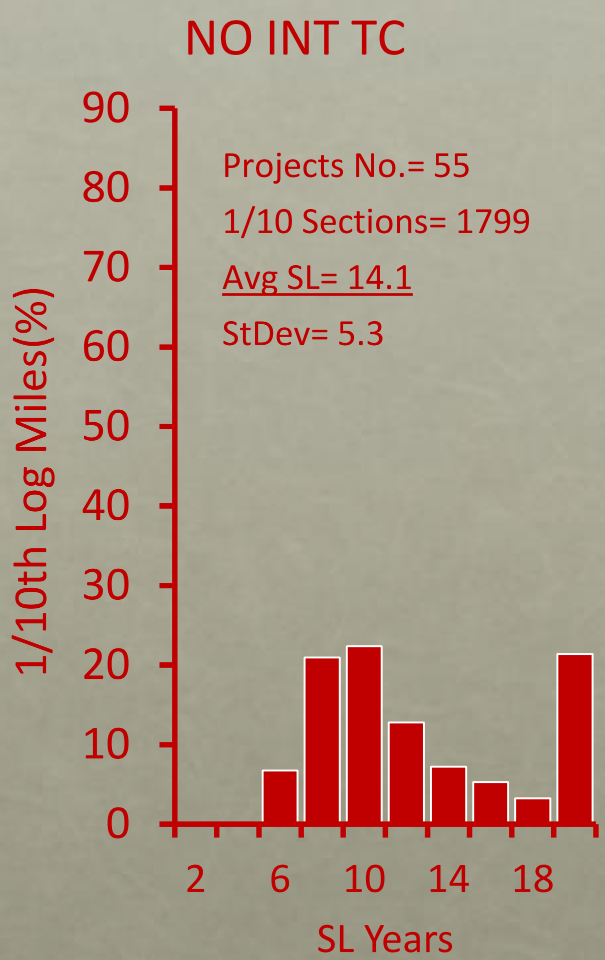
SL Distribution (TC)
ESAL<30K, CSD&CTD Base, 10-14 yr

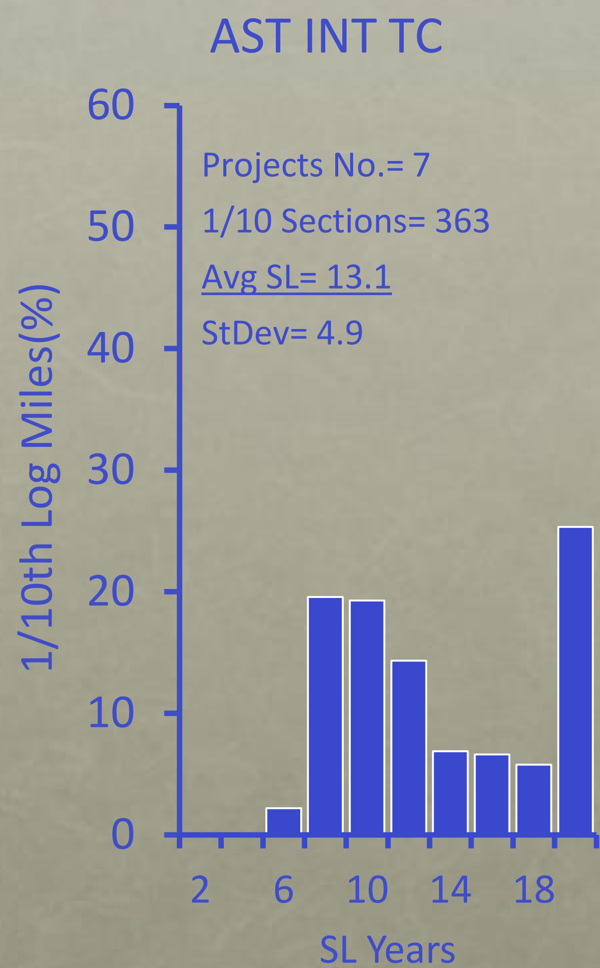


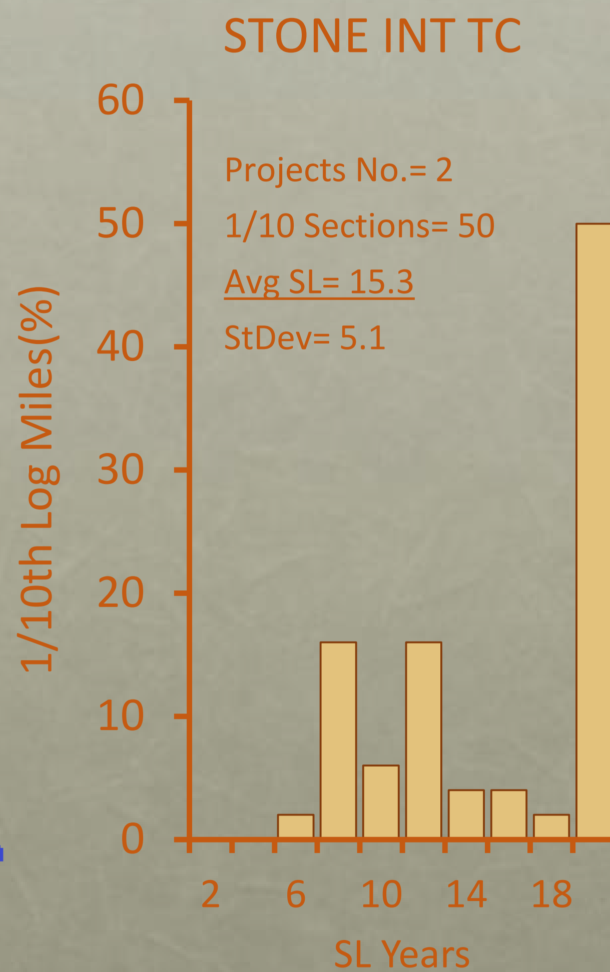


No Gain SL

STONE INT SL Distribution (TC)
ESAL<150K, Th<0-5in, CTD Bases







Cost-Benefit Analysis: Bar Chart