Louisiana Transportation Research Center

Final Report 632

Evaluation of Pavement Service Life Extension Due to Asphalt Surface Treatment Interlayer over Soil-Cement Base

by

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16. Abstract

The Louisiana Department of Transportation and Development (DOTD) has been using asphalt surface treatment (AST) interlayers over soil-cement base courses for the last several years to control the reflective cracking of flexible pavements caused by soil-cement shrinkage. Even though DOTD has the specifications documents, the practice of AST interlayer use and application differs from district to district. Furthermore, there have been no studies conducted to determine the cost-effectiveness of AST interlayers over soil-cement bases. The service life extension or gain in service life of flexible pavements due to such practice is also unknown.

In this regard, the Louisiana Transportation Research Center (LTRC) initiated a research study that addresses the aforementioned issue. The main goal of the study was to evaluate the actual field performance of flexible pavements with and without AST interlayer over soil-cement bases using the PMS database. A comprehensive review of the state-of-the-practice of DOTD districts and other state highway agency about AST interlayers practices over soil-cement was conducted. A survey of DOTD district was launched to understand the state-of-the-practice and the construction procedures regarding such practices. Extensive data mining was commenced to identify pavement projects with and without AST interlayers with sufficient historical records and pavement performance data. Comprehensive evaluation of performances of the selected projects was performed based on the analysis of the time series distress data (roughness, cracking, and rutting) obtained from the pavement management system (PMS) database. Performance prediction models for each distress type with and without AST interlayer on soil-cement bases were also developed. Based on the pavement service life and area benefit concept, the cost of the treatment, the benefit/cost (B/C) was determined to assess the cost-effectiveness of AST interlay over soil cement bases. Finally, it was concluded that AST Interlayer is not a cost-effective option to mitigate reflective cracking over soil-cement bases in the state of Louisiana. On the contrary, cement treated design (CTD) bases without AST interlayer appeared to be the best cost-effective option for reflective crack mitigation.

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Each research project will have an advisory committee appointed by the LTRC Director. The Project Review Committee is responsible for assisting the LTRC Administrator or Manager in the development of acceptable research problem statements, requests for proposals, review of research proposals, oversight of approved research projects, and implementation of findings.

LTRC appreciates the dedication of the following Project Review Committee Members in guiding this research study to fruition.

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ABSTRACT

The Louisiana Department of Transportation and Development (DOTD) has been using asphalt surface treatment (AST) interlayers over soil-cement base courses for the last several years to control the reflective cracking of flexible pavements caused by soil-cement shrinkage. Even though DOTD has the specifications documents, the practice of AST interlayer use and application differs from district to district. Furthermore, there have been no studies conducted to determine the cost-effectiveness of AST interlayers over soil-cement bases. The service life extension or gain in service life of flexible pavements due to such practice is also unknown.

In this regard, the Louisiana Transportation Research Center (LTRC) initiated a research study that addresses the aforementioned issue. The main goal of the study was to evaluate the actual field performance of flexible pavements with and without AST interlayer over soil-cement bases using the PMS database. A comprehensive review of the state-of-the-practice of DOTD districts and other state highway agency about AST interlayers practices over soil-cement was conducted. A survey of DOTD district was launched to understand the state-of-the-practice and the construction procedures regarding such practices. Extensive data mining was commenced to identify pavement projects with and without AST interlayers with sufficient historical records and pavement performance data. Comprehensive evaluation of performances of the selected projects was performed based on the analysis of the time series distress data (roughness, cracking, and rutting) obtained from the pavement management system (PMS) database. Performance prediction models for each distress type with and without AST interlayer on soil-cement bases were also developed. Based on the pavement service life and area benefit concept, the cost of the treatment, the benefit/cost (B/C) was determined to assess the cost-effectiveness of AST interlay over soil cement bases. Finally, it was concluded that AST interlayer is not a cost-effective option to mitigate reflective cracking over soil-cement bases in the state of Louisiana. On the contrary, cement treated design (CTD) bases without AST interlayer appeared to be the best cost-effective option for reflective crack mitigation.

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Furthermore, the investigators extend their thanks to the University of Louisiana at Lafayette for providing the means and resources to conduct this research. Last but not least, the time and effort for this research accomplished by Mark LeBlanc (laboratory assistant) and Tommy and Jeremy (undergraduate assistants) are highly appreciated.

IMPLEMENTATION STATEMENT

This report includes the outcomes of all the project tasks and detailed discussion of the results and analyses followed by the conclusions and recommendation. The results of this study are immediately implementable through establishing adequate polices. The models and techniques developed during the course of the project have been documented in the report and can be utilized by PMS and pavement preservation, and other DOTD sections. Based on the analyses of results, it is recommended that CTD base with no AST interlayer is the most cost-effective option to mitigate reflective crack. On the contrary, due to the higher cost and marginal service life extension, the AST interlayer over soil-cement bases become the least cost-effective alternative.

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INTRODUCTION

The Louisiana Department of Transportation and Development (DOTD) has been using asphalt surface treatment (AST) interlayers over soil cement base courses as a means to mitigate shrinkage cracks from reflecting through the overlying asphaltic concrete pavement. This practice varies amongst the DOTD districts and there are currently no official DOTD guidelines or policies on this practice. Additionally, there have been no studies conducted to determine the cost-effectiveness of AST interlayers. The pavement service life (SL) and SL extension or gain in SL of pavement due to such practice is also not known.

In order to address the aforementioned problem, the LTRC launched a comprehensive study titled *Pavement Service Life Extension Due to Asphalt Surface Treatment Interlayer* under LTRC Project No: 16-5P. The main goal of the study was to evaluate the DOTD district practices and actual field performance of flexible pavements with and without AST interlayer over soil-cement bases. It should be noted that DOTD uses two types of soil-cement design processes: 150 psi unconfined compressive strength (USC) at 7 days and 300 psi USC at 7 days. Since the shrinkage behavior of each base type is different due to the cement content, it is expected that their cracking pattern—in particular, the reflective cracking—will be different too. A comprehensive research plan was devised by the research team to evaluate the performance of flexible pavement with and without AST interlayers. The research plan included an extensive review of the DOTD district practices; substantial data mining of every DOTD database to extract historical, cost, and pavement performance record; selection of candidate projects; determining the service life of each 1/10th log-mile section of selected projects; conducting statistical analyses; developing distress prediction performance models; and evaluating the cost-effective of such AST treatment for mitigating reflective cracking.

This report includes the outcomes of all the project tasks and detailed discussion of the results and analyses followed by the conclusions and recommendation. The results of this study are immediately implementable through establishing adequate polices. The findings of this study will enhance the DOTD capabilities in preserving and managing Louisiana pavement networks and facilitate cost-effective selection of AST interlayer over soil-cement base. The models and techniques developed during the course of the project have been documented in the report and can be utilized by the PMS and other DOTD sections for managing the pavements.

OBJECTIVE

The main objectives of this study were to:

1. Evaluate DOTD's current AST interlayer practice over soil-cement base courses.
2. Determine the effectiveness of the AST interlayer practice in terms of its costs and benefits.
3. Develop statistical performance prediction models for each distress type of flexible pavement with and without AST interlayer over.
4. Develop guidelines and recommendation for use of AST interlayers over soil-cement base of flexible pavements.
5. Report the effectiveness of stone interlayers in terms of costs and benefits, as few (only 5) stone interlayer projects are available in LA.

SCOPE

The scope of this proposed study was to use the DOTD time-dependent pavement management data to develop prediction models for each pavement distress type, to evaluate the performance of flexible pavement systems with and without AST interlayers over the soil-cement base. Such analyses will yield the cost-effectives of the treatment as well as provide guidelines and recommendations for effective use of the treatment. The scope of the study is summarized as below.

- Conduct a comprehensive review of the state-of-the-practice of DOTD districts and other US agencies about AST interlayers practices over soil-cement bases for flexible pavements and its performance.
- Identify pavement projects with and without AST interlayers over soil-cement bases for flexible pavements with good/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. In addition, identify projects with stone interlayers over soil-cement bases of flexible pavements.
- Perform extensive evaluation of performance of the selected projects with and without AST/stone 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 AST interlayer and its impact on the pavement service life and service life extension or gain in service life.
- Develop recommendation and guidelines for the implementation of cost-effective utilization of AST interlayer over soil-cement bases that would maximize the user and agency benefits and minimize their costs.

This research study will enhance the DOTD capabilities in preserving and managing Louisiana pavement networks and facilitate cost-effective selection of AST interlayer over soil-cement base.

METHODOLOGY

Research Approach

Recall, the main goal of the research study was to evaluate the performance of the flexible pavement with and without AST interlayer over soil-cement bases using the actual costs and field pavement distress data. To accomplish the objectives of the study a comprehensive and systematic research plan was designed containing several research tasks. The details of each research task are presented below.

Review of Literature and State-of-the-Practice

In this task, the research team conducted an extensive review and study of existing literature regarding the state-of-the-practice for the design, construction, quality control, and performance of AST/other interlayers over soil-cement/other bases of flexible pavements. The purpose of this task was to thoroughly review and synthesize the findings of previous and on-going research and case studies. This was accomplished through the review of refereed journals, proceedings of national and international conferences, findings of completed research project, and so forth. The literature review has been summarized in the results section of this report.

Review of DOTD State-of-the-Practice

This task included the evaluation of the state-of-the-practice of the various DOTD districts through a survey questionnaire and published DOTD specifications documents. The research team had conducted a comprehensive survey of the state-of-the-practice of each district within DOTD. The team also evaluated the DOTD state-of-the practice from the published documents of DOTD specifications for AST interlayer practice on soil-cement bases. In summary, the survey questionnaires included the following:

- The project scoping process and the factors affecting the selection of AST interlayer.
- The factors affecting the selection of construction methods.
- The preliminary investigation conducted to determine the AST interlayer selection.
- The possible service life and its extension with and without AST interlayer.
- The distress indices values at which the deteriorated pavements with and without AST would be considered for future treatments.
- The degree to which the PMS distress data are used in making decisions
- The thicknesses and the type of soil-cement and hot mix asphalt (HMA) used and the methodology used in determining the thicknesses.
- The process or procedures used by each district to construct such flexible pavements.
- The distribution, the average, and the standard deviation of the service life of each flexible pavement with and without AST interlayer.

- The cost of the original pavement construction.
- List of the flexible projects with control numbers and related information with and without AST interlayer treatment on soil cement bases.

The questionnaire was prepared by the research team and then mailed to all DOTD District Engineers of maintenance, design, and construction. The responses of all districts were compiled and then tabulated. The results of survey are summarized in the results section of this report. The survey questionnaire is also provided in the Appendix B section of the report.

Roadway Identification for Project Selection

The main objective of this task was to identify all roadways where flexible pavements were constructed with and without AST interlayer on soil-cement bases. This task was accomplished with the help of members of PRC, PMS office, and district engineers. In this task, the research team searched the entire pavement network database. Several variables controlling the cost and performance of the AST interlayer pavement were categorized. These variables include the method used by the district, the surface conditions of the deteriorated pavements after construction, traffic levels, the thickness of AST and HMA layers, and the type of materials used. This task was accomplished by the execution of the following:

Interviewing DOTD Engineers. The results of the survey helped the research team to gather information for new projects. Any shortcomings or deficiencies found in the survey was overcome by calling the districts to gather additional information.

Searching DOTD Mainframe Database. The data mining for all the related information for the flexible pavements' projects with and without AST interlay on soil-cement bases was conducted. Additional data such as material types, layer thicknesses (HMA or PCC surface layers, interlayers, base, subbase layers, and roadbed soil data), roadway geometry, traffic and other maintenance information was also found in other DOTD systems. Such systems include the Material Testing System (MATT), Tracking of Projects (TOPS), Letting of Projects (LETS), the Highway Needs Study (NEEDS), the Traffic & Planning Highway Inventory, the Maintenance Operations System, and the Traffic Volumes data sections of the mainframe database.

Searching DOTD PMS Database. The research team acquired all the available good pavement performance data for flexible pavements projects with and without AST interlayer treatment. It must be noted that DOTD had been collecting pavement distress data for each pavement section in the road network since 1995. The distress data has been collected for every two years and sorted for every 1/10th-mile section of a roadway. The distress data for all pavement sections (including alligator cracking, longitudinal and transverse cracks, international roughness index (IRI), and rutting) were obtained from PMS database. All such data were utilized to evaluate the performance of various pavement sections with and without AST interlayer. This evaluation has assisted the research team to compare the performance of pavement sections with and without AST interlayer and developing statistical-based distress prediction models.

Searching DOTD Pavement Design and System Preservation Database. Researchers utilized DOTD's databases of pavement design and system preservation section. The notion is to use all the available databases and obtain sufficient information for analysis.

Data Mining

The data relative to the pavement sections was obtained through a comprehensive search of the aforementioned DOTD database systems. All suitable information was then outlined and organized in user-friendly formats. For each pavement project, several tables were generated that included:

- Project/Section identification number (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, collectors, and local roads.
- Pavement performance data (all distress data).
- Type and cost of flexible pavement projects with and without AST interlayer treatment over soil cement bases.
- Type and thickness of AST and HMA layers and base pavement design (base thickness and base material (cement treated, cement stabilized) base compressive strength, roadbed soil type, etc.)
- Year/age of construction of treatments.
- Traffic data, (ADT, ADTT, ESAL, etc.). It should be noted that the ESAL/year would be one of the criteria for performance evaluation and modeling.

All the mined data for the projects are presented in Appendix A in a tabulated form.

Candidate Project Selection and Criteria

The tabulated information gathered from data mining was then used to select various pavement projects for analysis. Based on following criterion, the projects were selected for further analysis.

> *All pavement sections having, as a minimum, three or more distress points after treatment (CSD or CTD base with and without AST interlayers). Since performance evaluation of any treatment requires at least three data points, this criterion was chosen. Any project that did not meet the above mentioned criterion was not part of performance evaluation of with and without AST interlayer pavement system.*

Once the candidate projects were identified, the following criteria had to be met for the time-series distress data to accept a pavement section ($1/10^{th}$ log-mile) for use in the analyses. Any rejected pavement sections could not be used to evaluate pavement performance.

1. ***Minimum of three data points.*** A minimum of three data points was required to fit any non-linear model, as any model can be fit to two or to one data point. Hence, any pavement section ($1/10^{th}$ log-mile) that did not have a minimum of three data points was rejected for any further analysis.

2. ***Positive gain in distress based on the best-fit curve***. The appropriate model (Table 1) was fit to the data and the parameters of the model were determined. Negative best-fit slope value; β, ω, θ, or μ (depending on the model) implied that the distress was "healing" with time and consequently, the service life was infinite. Hence, any pavement section (1/10th mile) that had negative best-fit slope (β, ω, θ, or μ) were rejected from any further analysis.

Hence, the pavement sections that had at least three distress data points and positive gain over time were accepted for any analysis in this study. Figure 1 illustrates an example of rejection and acceptance based on the aforementioned criteria 1 and 2.

Table 1: Typical pavement condition models

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, I(A) (performance area)	$\left(\frac{\alpha}{\beta}\right)\exp^{(t\beta)}$	$\frac{\gamma t^{(\omega+1)}}{(\omega+1)}$	$Max\left\{t-\frac{\log\left[\exp^{(\theta+\mu t)}+1\right]}{\mu}\right\}$
Service Life (SL) = Time to reach threshold	$t=\frac{\ln\left(\frac{Threshold}{\alpha}\right)}{\beta}$	$t = exp\left[\frac{ln\left(\frac{Threshold}{\gamma}\right)}{\omega}\right]$	$t=\left[\frac{1}{\alpha}\left(\ln\left(\frac{Max}{Threshold}\right)-1\right)\right]-\left(\frac{\beta}{\alpha}\right)$
where, α, β, γ, ω, θ, and μ are regression parameters (α, γ, θ are intercepts and β, ω, μ are slopes) t = elapsed time (year), and Max = the maximum value of cracking			

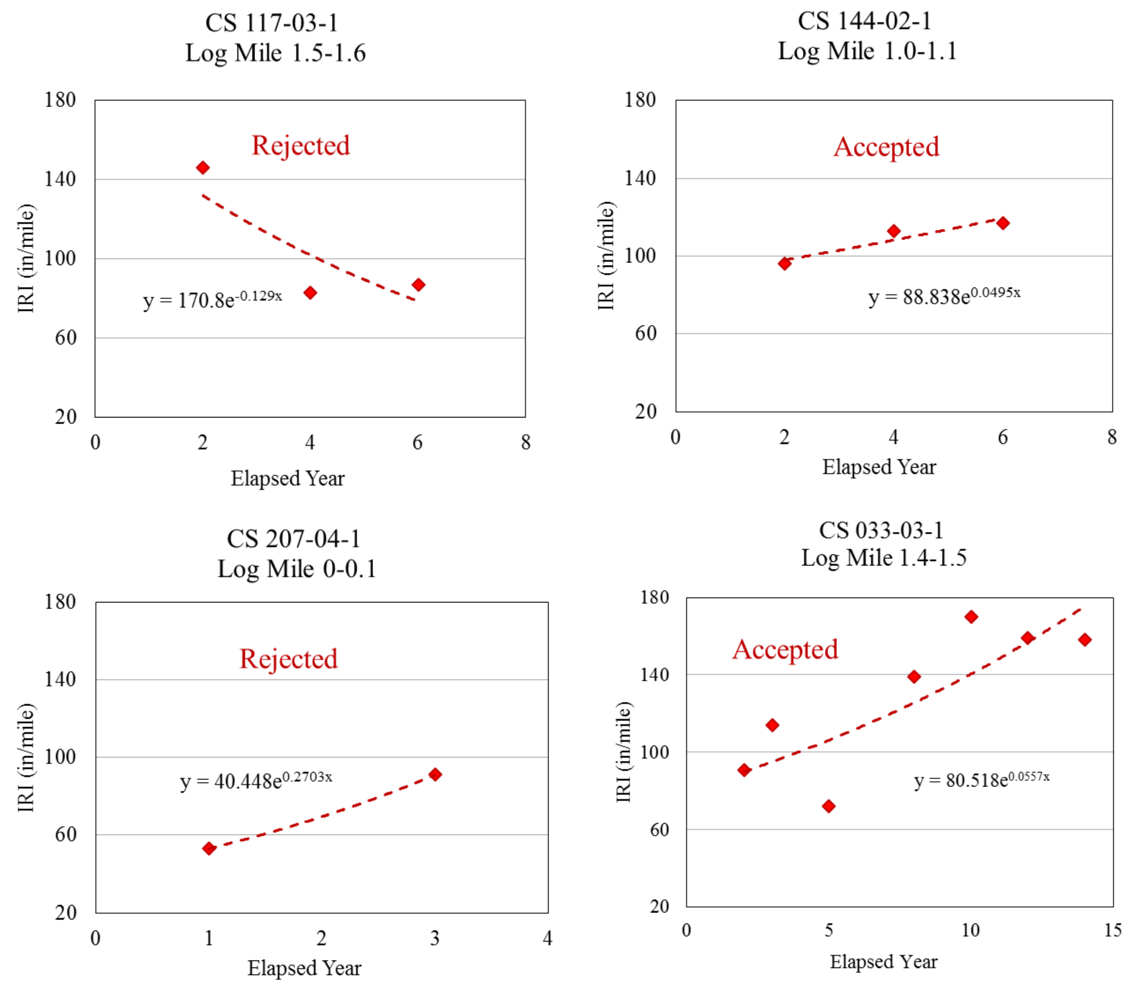


Figure 1: Acceptance criteria illustration

To increase the number of available data points without affecting the outcome of the data modeling, the initial data could be relatively accurately assumed. For example, immediately after a CSD or CTD project with or without interlayer, the rut depth and cracks were likely to be 0 or very near to 0; hence the rut depth and the length/area of cracks could be assumed as 0 at 0 time after construction. Exactly "0" value is typically not accepted by the functions used in Table 1 while modeling the data the initial values of transverse crack, longitudinal crack, alligator crack, IRI, and rut depth at first month (0.083 year- after construction) were assumed to be 0.26 ft, 0.26 ft, 0.26 ft^2, 42 in/mile, and 0.01 in. respectively. The value of initial crack is chosen as 0.26 unit as it provides better fit of the curve.

Service Life (SL) Computations

To compare the performance of AST interlayers projects with respect to no interlayer projects, a parameter that measures the behavior of pavements was required. Traditional service life (SL) of pavements was used as such performance parameter. For each of the selected pavement project with and without AST interlayers over soil-cement bases, the time dependent pavement distress data were used to calculate the SL of the 1/10th pavement sections relative to IRI, rut depth, alligator crack, transverse crack, and longitudinal crack. In general, the three forms of mathematical models listed in Table 1 were used to model the measured distress data and to facilitate the calculation of SL for each pavement section. Table 1 ascertains the mathematical models for all distress types, the equation for SL computations, the pavement rate of deterioration, and the area under the performance curve (a measure of benefits). It is worth mentioning that the SL for any pavement section is the time after construction to reach the threshold value for any distress. The threshold values of all distress types for SL computations are shown in Table 2.

Table 2: Threshold values of all distress types for SL computations

Distress Type	Threshold Values
Transverse Cracking	1,056 ft
Longitudinal Cracking	1,056 ft
Alligator Cracking	1,267 ft^2
IRI	200 in/mile
Rut	0.5 in

Based on SL of $1/10^{th}$ log-mile sections, ten brackets ranges were established to categorize the pavement sections for very poor to very good pavement condition as shown in Table 3. These brackets were necessary to evaluate and compare the distribution of SL for any particular categories of pavements. MATLAB 2016b and "MS Excel Visual Basics for Application (VBA) 2016" was utilized to gather and organize all the distress and condition data for all CSD and CTD base type projects with or without AST interlayers. With the best-fit curve shown in Table 1, the SL was computed for every single $1/10^{th}$ log-mile pavement section that passed the acceptance criteria. As the pavements were usually designed to have 20 years of SL, the maximum SL set for any pavement section was considered as 20 years. Hence, if any pavement sections' SL calculated (Table 1) were more than 20 years, it was considered as 20 years.

Table 3: Pavement brackets for range of service lives

Bracket Name	0B2	2B4	4B6	6B8	8B10	10B12	12B14	14B16	16B18	18B20
Service Life (Years)	0 - 2	2 - 4	4 - 6	6 - 8	8 - 10	10 - 12	12 - 14	14 - 16	16 - 18	18 - 20

Figure 2 illustrates two pavement sections with different deterioration rates based on IRI. Assume that pavement Section-1 is without AST interlayer treatment and pavement Section-2 with the application of AST interlayer treatment. For both pavement sections, 8 years of data was collected since its construction. Hence, the number of years since its construction to date will be referred as service age (SA) of pavement section. A best-fit exponential function was applied and distress values were than estimated until the IRI rehabilitation threshold of 175 in/mile. The RSL of a pavement section is the estimated/predicted number of years of service from any given date (usually the last distress data) to the time when the pavement section is expected to accumulate distress points equal to the threshold value. Here, RSL1 and RSL2 are the remaining service life of pavement Section-1 and Section-2, respectively.

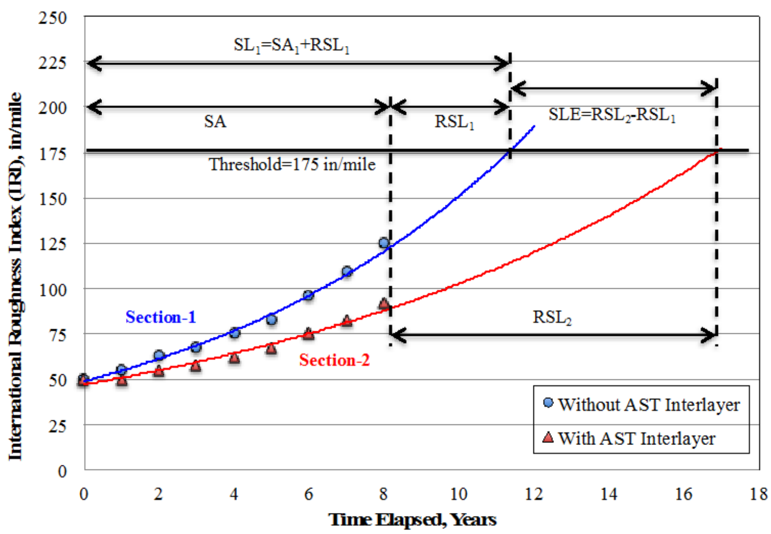


Figure 2: Illustration of service life (SL), and service life extension (SLE) or gain in service life (GainSL) of pavement sections with and without AST interlayer treatment

Hence, the service life (SL) is simply the addition of SA and RSL. Further, the service life extension (SLE) or gain in service life (GainSL) represents the pavement service life extension that can be achieved due the treatment. It is simply the difference in SL of with and without the AST treatment ($SLE=SL_2-SL_1$). In this study, the SLE or GSL concept was used to evaluate flexible pavement performance and benefits with and without AST interlayer treatments.

From the above-mentioned processes, it is well understood that any categories of projects will have a distribution of service lives (SL) for all its 1/10th log-mile pavement sections as shown in Figure 3. Hence, two different groups of projects' SL distribution could be compared to measure and compare their performance. For example, the CSD projects with and without AST interlayer are two different groups whose SL distributions could be compared to measure the performance of AST interlayer where CSD projects without interlayer are considered as control in this case. A similar comparison could be performed for CTD projects with and without AST interlayer. Moreover, only CSD and CTD projects (without interlayer) could also be compared. To clarify the SL distribution comparison, an example of SL distribution comparison is shown in Figure 4.

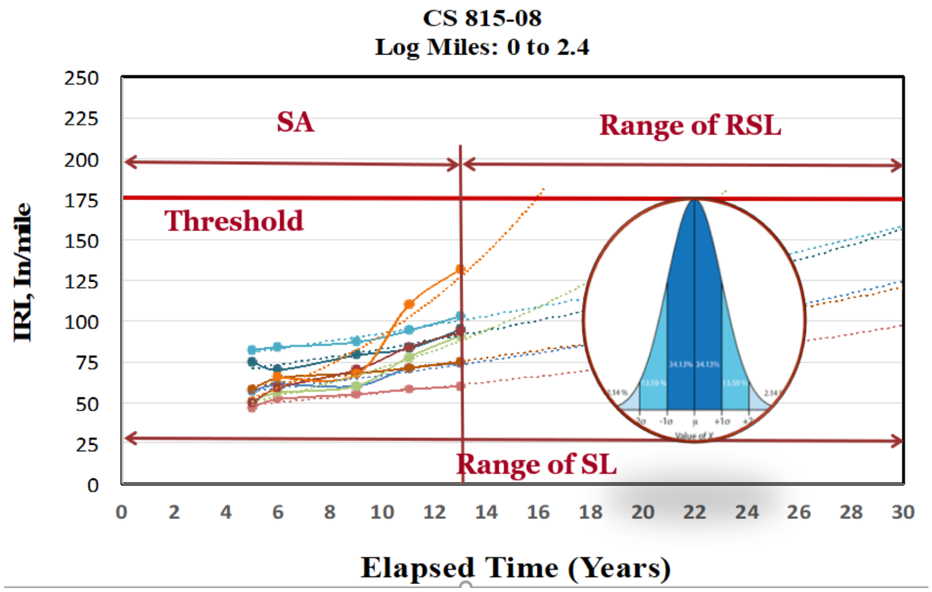


Figure 3: Distribution of service life (SL) for several 1/10th log-mile sections

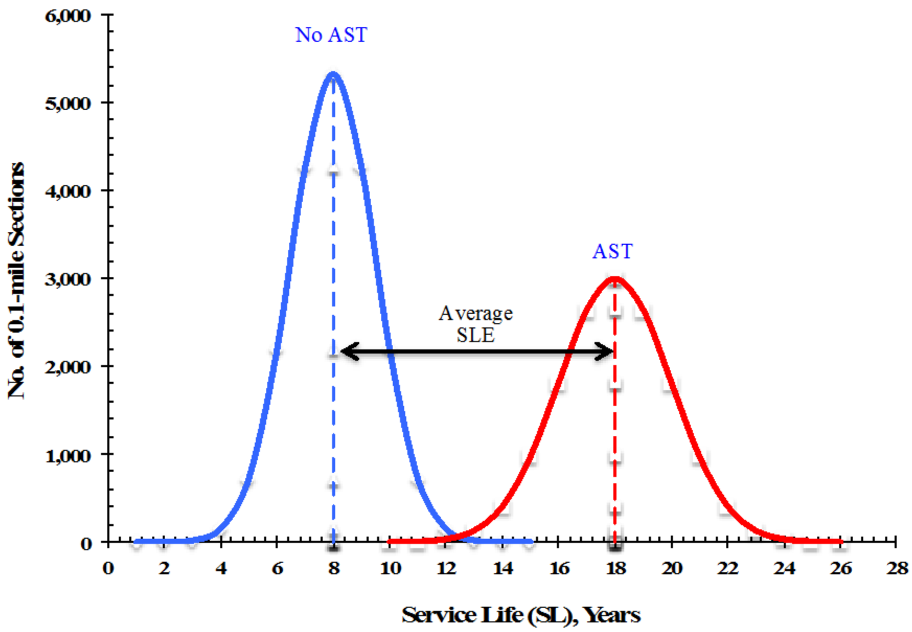
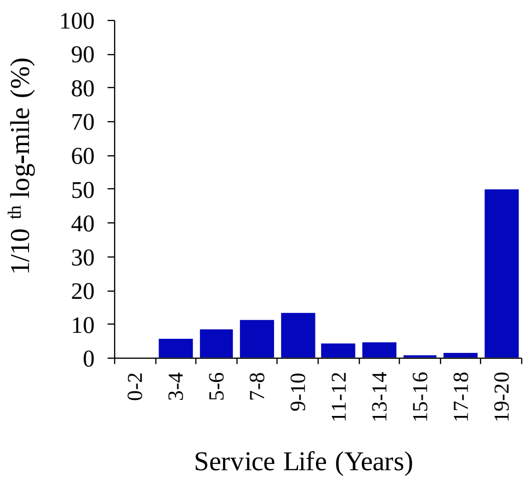


Figure 4: Service life (SL) distribution comparison of AST and no AST projects

As an example, the comparison of transverse cracks (TC) for CSD projects with and without interlayer is shown in Figure 5. All such distributions and the comparisons for all distress types were carried out by both MABLAB 2016b and Excel 2016 VBA (MatExVba) programs during the course of this project. From the comparison of SL distributions, the AST interlayer projects' performance was evaluated based on life cycle cost analysis.

AST INTERLAYER							NO INTERLAYER					
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev		N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
26	718	14.3	6.1	13.1	5.9		46	1785	11.6	4.6	10.5	4.7



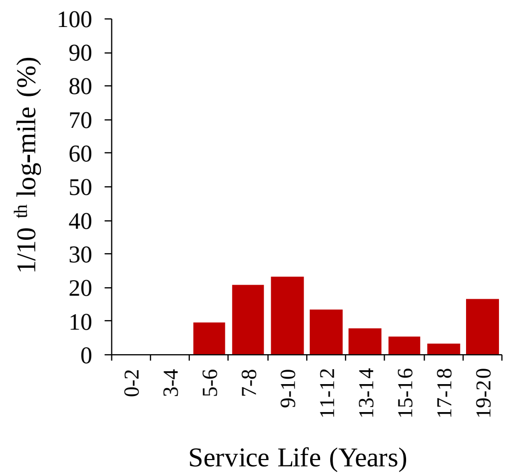


Figure 5: Comparison of SL distribution for CSD projects with and without interlayers

Pavement Performance Evaluation

Before further comparison of SL distribution were made the candidate projects were grouped based on with and without AST treatment, equivalent single axle load (ESAL) category, HMA thickness, base type (CSD, CTD), and surface age (SA) group as discussed below.

ESAL Category. The service life comparison analysis may or may not be dependent on ESAL experienced by the pavement sections. Hence, sensitivity of SL distribution with average SL should be checked for different ranges/categories of ESAL. Also, sufficient data may or may not be present for any particular ESAL category. Hence, projects should be categorized based on ESAL. Therefore, ESAL categories used by AASHTO flexible pavement design procedure was selected as an initial reference [1].

Similar to AASHTO ESAL category, the data availability related to number of projects (N(P)), number of 1/10th log-mile sections (N(S)), and SL distribution for projects with and without AST interlayers were compared for transverse cracks (TC) for ESAL range of (0-15,000), (15,001 – 30,000), (30,001 – 50,000), (50,001- 150,000), (150,001-500,000), (500,001-2,000,000) as shown in Table 4. Three different categories were chosen inside the lower ESAL categories to check the sensitivity of SL and data availability. Based on Table 4, it was found that the AST interlayer projects were mostly lower ESAL projects (0 to 30,000), very few projects for AST interlayers were present in ESAL range more than 30,000; no AST interlayer projects also had fewer number of projects for ESAL category range of (30,001- 2,000,000). For this reason, it was not possible to have reasonable comparison of SL for all the AASHTO categories. Therefore, only following two categories were selected for further analysis which was based on the availability of projects:

1. ESAL range: (0-30,000)
2. ESAL range: (30,001-2,000,000)

Table 4: Transverse crack service life comparison for different ESAL category

ESAL Category	AST INTERLAYER, CSD				NO INTERLAYER, CSD			
	No. of Projects, N(P)	No. of 1/10th log-mile section, N(S)	Avg. SL	StDev	No. of Projects, N(P)	No. of 1/10th log-mile section, N(S)	Avg. SL	StDev
0-15000	24	665	14.8	6.2	37	1487	12.0	4.8
15001-30000	7	214	15.7	5.3	9	298	9.8	3.3
30001-50000	2	48	17.2	4.8	9	418	12.4	5.2
50001-150000	3	54	7.6	2.3	5	312	15.0	4.6
150001-500000	3	58	14.1	7.3	2	124	10.1	2.7
500001-2000000	2	9	14.6	6.5	3	27	17.0	3.7
0-30000	31	879	15.0	6.0	46	1785	11.6	4.6
30001-2000000	10	169	12.9	6.6	19	881	13.1	5.0

StDev: Standard deviation, Avg: Average, SL: Service life

Thickness (Th) Category. Most of the AST interlayers had HMA thickness range from 2 to 4 in., which was mainly due to the fact interlayers were placed usually on low volume arterial, collector and local roads. Some AST interlayers pavements found to be more than 4 in. of HMA thickness. Hence, in this study two thickness ranges were selected for SL distribution comparison analysis:

1. Thickness range: $0 < Th \leq 4$ in.
2. Thickness range: $Th > 4$ in.

Surface Age Category. Most of the interlayer projects were newly constructed and they had only three data points available for modeling and benefit calculation (around 80%). These interlayer projects showed about 5-7 years of surface age (SA). But no AST interlayer projects were mostly old projects and had about 10 data points available for such analysis. As the models used in this analysis shown in Table 1, behaved very differently with the insertion of more data points, service lives were calculated for similar number of data points for comparison. Hence, for comparison of SL of projects with and without AST interlayer, the analyses were performed on the following two data point categories.

1. ***Three data points:*** Only the first three distress data points were chosen to build models

and SL computations for this category. Any data point after the third was truncated in these analyses. So, with the original data for 5-7 years of SA, the SL predicted were performed. These analyses included all CSD and CTD projects with or without AST interlayers, as all projects had a minimum of three data points.

2. ***Six data points:*** Only 13 projects with AST interlayers were found to have maximum six data points. Hence, these projects were categorized separately and their SL were compared to no AST interlayer projects with similar data points. In these analyses, both with and without AST interlayer projects had SA of 8-12 years.

Performance Evaluation Matrix

For the ESAL and thickness categories stated above, the performance of AST interlayer sections were determined by the SL distribution comparison with no AST interlayer sections. These analyses were performed for all categories described above. In Table 5, an experimental matrix is shown where all different types of categories are illustrated.

Table 5: Design matrix for performance evaluation

Base Type	HMA Thickness	AST Interlayer		No AST Interlayer		Data Points per (1/10th log-mile)
		ESAL Category 1 (Lower ESAL)	ESAL Category 2 (Higher ESAL)	ESAL Category 1 (Lower ESAL)	ESAL Category 2 (Higher ESAL)	
CSD	0-4 in	x1	x2	x5	x6	3
	>4 in	-	x4	-	x8	
CTD	0-4 in	x9	-	x13	x14	
	>4 in	-	-	-	x16	
CSD	0-4 in	x1'	-	x5'	x6'	6
	>4 in	-	x4'	-	x8'	
CTD	0-4 in	x9'	-	x13'	x14'	
	>4 in	-	-	-	x16'	

The distribution of SL for every 1/10th log-mile and for each category (shown in Table 5 by x1, x2, x3……,x16) were ascertained by MatExVba programs. For example, the MatExVba outputs for Category x1: TC for AST interlayer, ESAL (0-30,000), Th 0-4 in., and three data points are shown in Figure 6. All these categories are separately shown in Table 6 for further clarification.

It's worth mentioning that some stone interlayer projects' performances were also evaluated in this study as few projects (only 5) were available. Because of data unavailability, stone interlayer projects did not have the Category presented in the design matrix at Table 5, so they are not included. Stone interlayer projects were analyzed and compared separately in the results section.

For stone interlayer performance evaluation and comparison, four extra categories (x17 to x20) were created and those are shown in Table 6. Note that the stone interlayer sections have different thickness range (0 to 5 in.) and stone interlayer over CTD bases has different ESAL range: 0-150000, due to data unavailability (shown in Table 6: Category x17). As stone interlayers have different thickness and ESAL ranges, they were compared to no interlayer with CSD/CTD bases with same ranges. Hence two new no interlayer CSD/CTD base category (with same ESAL and thickness range of stone interlayer) were created: x19 and x20.

Table 6: All categories of projects for interlayer performance evaluation

Project Category		ESAL Range		Thickness Range		Base Type	Interlayer Type
3-data	6-data	Min	Max	Min	Max		
x1	x1'	0	30000	0	4	CSD	AST INT
x2	-	30001	2000000	0	4	CSD	AST INT
x4	x4'	30001	2000000	4.1	10	CSD	AST INT
x5	x5'	0	30000	0	4	CSD	NO INT
x6	x6'	30001	2000000	0	4	CSD	NO INT
x8	x8'	30001	2000000	4.1	10	CSD	NO INT
x9	x9'	0	30000	0	4	CTD	AST INT
x13	13'	0	30000	0	4	CTD	NO INT
x14	14'	30001	2000000	0	4	CTD	NO INT
x16	16'	30001	2000000	4.1	10	CTD	NO INT
x17		0	150000	0	5	CTD	STONE INT
x18		0	30000	0	5	CSD	STONE INT
x19		0	150000	0	5	CTD	NO INT
x20		0	30000	0	5	CSD	NO INT

For all the combinations of the matrix presented at Table 6, the MatExVba outputs are provided in the results and discussion chapter. Due to lack of data, some combinations were not present and shown by a dash (-) sign in the design matrix.

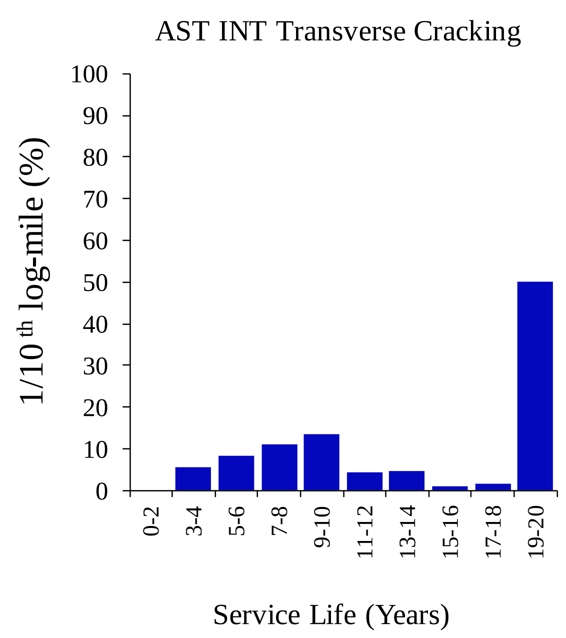
With the help of these MatExVba output figures, the comparison of two similar categories of pavements (such as: x1 vs x5) were conducted for the performance evaluation of AST interlayers. Examples of these comparisons includes not only the SL but also other area benefits along with the cost-benefit parameters. One of these comparison examples are explained after the description of area benefits and cost-benefit parameters.

Single Category Outputs. The MatExVba program outputs contained all the necessary information along with the SL and their distribution for any Category of projects. It also delivered the ESAL and ADT distributions for the corresponding sections by the minimum, 25th percentile, median, average, 75th percentile and maximum values. Moreover, it also calculates other area-benefits along with cost-benefit parameters.

AST INT Transverse Cracking (ft) Over CSD Bases								
ESAL	0	30000	Thickness	0	4	Data Range	3	
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives		
26	718	14.3	6.1	13.1	5.9	SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections

SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	40	5.6
5-6	60	8.4
7-8	80	11.1
9-10	96	13.4
11-12	32	4.5
13-14	33	4.6
15-16	7	1.0
17-18	11	1.5
19-20	359	50.0
TOTAL '0-20'	718	100.0

PARAMETER FOR ESAL/ADT Dist	ESAL Dist. for This Category	ADT Dist for This Category
MIN	603	91
25 PERCNTILE	2128	530
MEDIAN	6903	1400
AVERAGE	9415	1526
75 PERCNTILE	13569	1974
MAX	27494	3819



B/C (SL) =	67.4	Yrs / Dollar	Category
B/C (NBA) =	61.7	Ft-yr/ft/Dollar	x1

Figure 6: MatExVba output for TC of AST interlayer over CSD base

Here in Figure 6, the MatExVba program outputs for Category: Transverse Cracking, AST interlayer, ESAL 0-30000, Th $\leq$4 inches, 3 data points are shown.

In this figure, the following abbreviation were used.

N(P) = Number of Projects,
N(S) = Number of 1/10th log-miles section,
AvgSL= Arithmetic Mean of SL of all pavement sections in this category,
AvgNBA = Arithmetic mean of Normalized Benefit Area of all pavement sections
StDev = Standard Deviation of Service Lives/Normalized Benefit Area for that distribution,
B/C (SL) = Benefit Cost ratio for service lives, and
B/C (NBA) =Benefit cost ratio for NBA.

Histogram data for these categories of sections are shown in the right side of the figure. ESAL and ADT distributions are characterized by the minimum, 25th percentile, median, average, 75th percentile, and maximum values shown in the right side of the figure. For all categories, these MatExVba outputs and their benefits are discussed in the results section of this report.

Distress Performance Models

Linear regression models for each distress type were developed using the stepwise regression procedure. For such analysis, the model variables were selected based on the literature review, past experience, and the researchers' engineering judgment. In this study, simple regression models based on each distress (cracking, rutting, and IRI) as dependent variables and ESAL, time and pavement layer thickness as independent variables were used. It must be noted all such regression models are applicable only within the range of the data used for the development of the model and hence need to be calibrated after several years of performance data is further available.

Correlation Matrix. In order to understand the extent of relationship between the dependent and independent variable and also between the independent variable correlations' matrix is developed. Table 7 shows a typical example of correlation matrix. From the correlation matrix, it can be interpreted that the HMA thickness of pavements shows negative correlation, which supports the engineering judgments. Some other dependent variables show positive correlations and some of them have a very strong relationship with TC such as time.

Table 7. Typical correlation matrix of variables

	ln[(TC+1)/(M-TC-1)]	Time	CSD/CTD	Th-Base	Th-HMA	lnCESAL
ln[(TC+1)/(M-TC-1)]	1.00					
Time	0.63	1.00				
CSD/CTD	-0.37	-0.52	1.00			
Th-Base	0.12	0.24	-0.61	1.00		
Th-HMA	-0.31	-0.35	0.60	-0.45	1.00	
lnCESAL	0.39	0.33	-0.02	-0.17	0.23	1.00

Analysis of Variance (ANOVA). Linear regression analyses for the development of performance models yielded various outputs, as shown in Table 8. This includes the multiple R, R^2, adjusted R^2, standard error, the number of observations, and analysis of variance (ANOVA) table for the regression analyses. The output also summarizes the degrees of freedom, sum of squares, and mean sum of squares, F score, and p-value of F test. The final output consisted of coefficient data for models including coefficient, standard error, t-statistic, p-value, lower, and upper 95% confidence levels.

Table 8: Summary of regression output

Regression Statistics	
Multiple R	0.92
R Square	0.85
Adjusted R Square	0.85
Standard Error	1.95
Observations	162

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*	
Regression	3	3363.5	1121.18	294.26	1.954E-64	
Residual	158	602.0	3.81			
Total	161	3965.6				
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept (a_o)	-13.2927	1.2660	-10.50	6.8E-20	-15.7931	-10.7923
SR/T_h* (a_1)	3.9176	1.6837	2.33	2.1E-02	0.5921	7.2432
t (a_2)	0.4972	0.0187	26.58	3.4E-60	0.4603	0.5342
lnCESAL (a_3)	0.3501	0.0864	4.05	8.0E-05	0.1794	0.5208

*(*SR = CSD/CTD)*

International Roughness Index (IRI) Model

In general, the IRI performance model follows the shape of an exponential function with respect to time as shown below [2] - [5]:

$$IRI = \alpha \exp^{t\beta} \quad (1)$$

where, α and β are regression constants and *t* is the elapsed time or surface age of the treatment.

The measured IRI is the result of accumulation of damage due to repeated ESAL, so the cumulative ESAL was considered as an important parameter. Similarly, the thickness of HMA and base layers and type of base were considered which could also affect the intercept and the slope of the model.

Rut Model Development

Using power function, the rutting behavior of HMA layer was modeled. The equation for rutting is shown below:

$$Rut = \lambda t^{\beta} \quad (2)$$

The above equation can be written in a linear form as:

$$ln(Rut) = ln(\lambda) + \beta\, ln\, t \quad (3)$$

Rutting is caused by the accumulation of damage due to repeated ESAL, therefore the cumulative ESAL was one of the key variables in the model. Pavement layer thicknesses as well as the base type were considered since these variables also effect intercept and rate of rut accumulation.

Cracking Model Development

Cracking in flexible pavements are referred to alligator cracks, transverse cracks, and longitudinal cracks. Cracking is the major type of distress which is responsible for poor ride quality, driver's discomfort, increased operational and maintenance costs, and moisture related distresses [7] [8]. Cracking in flexible pavements follows the logistic (S-shaped) function as shown below [6] [9].

$$Crack = \frac{Max}{1 + exp^{(-X)}} \quad (4)$$

The above equation can be written as:

$$ln\left(\frac{Crack}{Max - Crack}\right) = X \quad (5)$$

where, *Max* = Maximum length of the crack in design life, and

$$X = a_o + a_1.x_1 + a_2.x_2 + a_3.x_3 + a_4.x_4 + \ldots\ldots\ldots\ldots$$

x_i = variables effecting cracking, such as ESAL, pavement layer thicknesses and their properties, environmental factors, etc.

The logistic function is a generalized linear model and linear regression analysis becomes possible. However, for crack = 0, the equation becomes undefined. Hence, a unit value of cracking per lane-mile in the U.S. customary unit was added with the actual crack value as shown below.

$$ln\left(\frac{Crack + 1}{Max - (Crack + 1)}\right) = X \quad (6)$$

The above-generalized linear form of logistic function was utilized to model transverse, longitudinal, and alligator cracking for both with and without AST interlayers over CSD or CTD bases of flexible pavements.

In order to utilize equation (6), the maximum magnitude of cracking (*Max*) for alligator, transverse, and longitudinal cracking needed to be determined as discussed below.

- The magnitude of maximum alligator crack level was set as 31,680 ft^2 /lane-mile which indicated that in a lane-mile, two-wheel paths with a width of 3 ft were fully cracked.
- The magnitude of maximum longitudinal crack level of 10,560 ft/lane-mile was used. This reflected two cracks along the entire mile-long pavement segment.
- The recommended maximum crack saturation level for transverse cracking was based on transverse crack spacing of about 3 ft. due to reflective cracks caused by soil cement shrinkage. This yielded 21,120 ft/lane-mile for 12 ft. wide lane.

The variables considered for cracking models included cumulative ESAL, thicknesses of HMA and base layers, and type of base layer (CSD, CTD) for flexible pavement with and without AST interlayer.

Cost Benefit Analysis

To evaluate the cost-effectiveness of AST interlayer, the benefits and costs of all projects with and without AST interlayers should be quantified first. After quantification of cost and benefits, AST interlayer projects could be compared with no interlayer projects for their cost-effectiveness. In this study, the benefits of interlayers were determined using the following two methods.

1. ***Average service life (AvgSL)***. The computation of SL has been discussed in previous sections. As SL are the primary form of benefits for any treatment, the arithmetic mean of all service lives (AvgSL) of all pavement sections are considered as one type of benefit for that category of projects. To evaluate cost-effectiveness of AST interlayer, this type of benefit is used in this study along with other benefits. The simple equation of determining the AvgSL is shown below:

$$AvgSL = \frac{\sum_{1}^{n} Service\ Life\ of\ each\ sections}{n} \quad (7)$$

   where, n = number of accepted $1/10^{th}$ log-mile sections of any category of projects

   The AvgSL for one group of projects could be used for comparison with another group of projects as a measure of performance. It is worth mentioning that this benefit does not include any cost parameter; hence, it cannot be relied for any final conclusion.

2. ***Average normalized benefit area (AvgNBA)***. Average benefit area is a comprehensive way to compare the benefits of AST interlayer with no AST interlayer projects. The performance curve of any $1/10^{th}$ log-mile section for any distress type could be different even though their

SL could be exactly same or similar. This scenario is illustrated in Figure 7. In the figure, the transverse crack (TC) behaviors of two pavement sections are shown. Even though the TC values reached the threshold at the same time, the pavement section "Section-2" had performed better than the section "Section-1" over time. This happened as the section "Section-2" had developed less cracks during the first few years and thus remained smoother, consequently providing better ride, less vehicle damage, and greater fuel efficiency. This implies that these two sections had exactly the same SL but distinctive, different performance and benefit over time. Hence, in many cases, testing only SL cannot capture the entire performance of the pavement section. To measure such performance benefit, the area above the performance curve (until threshold) of any distress type should be determined and compared to assess the overall pavement performance of particular treatment type. For any pavement section, more area above the performance curve indicates that the pavement section had lower damage for a longer period of time and performed better compared to other sections, even though they had the same SL. Here, the benefit area (BA) for the section "Section-1" is A1 and the benefit area for the section "Section-2" is A2 = A1+ ΔA.

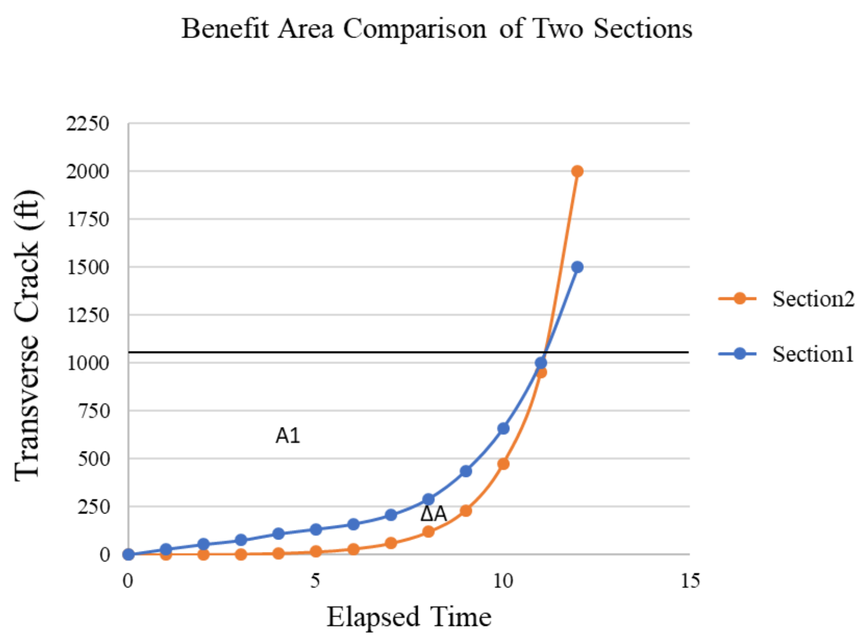


Figure 7: Benefit area illustration

Hence, as SL alone cannot measure the true extent of benefits for any treatment, the area above the performance curve has been calculated for all pavement sections and compared for the performance evaluation of AST interlayer or any other treatment. Benefit area was calculated for all distress types and pavement condition by the following formula:

$$BA = \{TH.t - I(A)\} \tag{8}$$

where, BA= Benefit area, TH = Threshold for any particular distress/condition, t = time in years required to reach the threshold or SL [When t <=20 years] , I(A) = Integral from 0 year to t year, calculated using Table 1 for corresponding distress/condition.

Since the benefit area is dependent on the threshold value and varies between distress to distress, it needs to be normalized. If the benefit area is divided by the threshold value then it normalizes and the area would be comparable for different distress types. Hence the y-axis (normalized distress) will always be between 0 to 1.Therefore, in this study, benefit area is normalized to create the term "Normalized Benefit Area (NBA)" that would be used for comparison. Hence, NBA is calculated as follows:

$$NBA = \frac{BA}{TH} \tag{9}$$

An example of NBA calculation is explained below for "Section-1" shown in Figure 7.
For Section-1:

Time to reach threshold, t =	11.5 yrs
The Integral Area calculated from Table 1, I(A)=	3055 ft-yr
Benefit Area, A1= Th*t-I(A) = 1056*11.5 - 3055 =	9089 ft-yr
NBA = 9089/1056 =	8.59 ft-yr/ft

In this study, NBA was calculated for every single 1/10th log-mile pavement sections just like SL. For one particular category of projects, the arithmetic mean of all 1/10th log-mile pavement sections' NBA, i.e., AvgNBA was calculated using the following equation:

$$\text{AvgNBA} = \frac{\sum_1^k Normalized\ Benefit\ Area\ of\ each\ sections}{k} \tag{10}$$

where, k= Number of pavement sections accepted for analysis.

Similar to AvgSL, the benefit parameter AvgNBA could be used to compare two groups of projects with and without AST interlayer. Moreover, these two parameters, AvgSL and AvgNBA, are only benefits without any cost parameters, hence these could not evaluate the cost-effectiveness of AST interlayer. The cost-effectiveness of AST interlayer would be evaluated by benefit to cost ratios described later in this report.

Comparison of Benefits

Based on the two benefits as described above, AvgSL and AvgNBA, the performance of AST interlayer projects with respect to no AST interlayer projects were evaluated. Two benefit terms (gain in SL [GainSL] and gain in NBA [GainNBA]) were used to assess the AST interlayer benefits with respect to no AST interlayer. GainSL and GainNBA were calculated for every type of distress using the following.

$$(GainSL)_d = (AvgSL)_I - (AvgSL)_{NI} \quad (11)$$

$$(GainNBA)_d = (AvgNBA)_I - (AvgNBA)_{NI} \quad (12)$$

where, $(GainSL)_d$ and $(GainNBA)_d$ are gains in service life and normalized benefit area for a distress type in question, respectively. $(AvgSL)_I$ and $(AvgNBA)_I$ are average service life and normalized benfit area for AST interlayer, respectively. Similarly, $(AvgSL)_{NI}$ and $(AvgNBA)_{NI}$ are average service life and normalized benfit area for no AST interlayer, respectively

In simple terms, GainSL is the increase in service life due to the AST interlayer application. Similarly, GainNBA is the improved area performance by using the AST interlayer. GainSL and GainNBA were always reported when two groups of projects were compared in this study. Sometimes, GainSL or GainNBA could be negative, which indicated that AST interlayer did not increase the service live/benefit areas, but rather it decreased it.

Cost Estimation

To determine the cost-effectiveness of AST interlayer, the original cost of interlayer projects and non-interlayer projects were required. The cost of every project present in this analysis was difficult to find as projects' cost information were not usually easily available in the database. Hence, through DOTD engineers' survey interview some CSD and CTD projects with and without AST interlayers' cost were obtained and these costs were used to evaluate cost-effectiveness of AST interlayers. As these projects had different treatment years, all such costs were converted to one treatment year (at 2010) using the following equation. Along with AST interlayer, some stone interlayers project costs were also estimated.

$$F = P'(1 + i)^n \quad (13)$$

where, F = Future Total Cost of treatment, P'= Present Total Cost of that treatment, I = inflation rate usually taken as 4%, and n = Difference of year between future and present year.

Using equation (13), the cost of treatment at its current year was converted to year 2010. These costs then became comparable, as all cost of treatment year were converted to one particular year. Table 9 shows the costs of CSD and CTD projects with and without interlayers at year 2010. The costs shown in Table 9 are costs data per square yard which were used to calculate the costs per 1-10th log-mile in Table 10.

Table 9: Project cost data of CSD and CTD base with AST/stone interlayer*

Project No.	Treatment Year (TY)	Year Difference From 2010	Per SQYD Cost at TY	Per SQYD Cost at Yr 2010	Type of Treatment for the Cost
408-02-0011	2012	2	$3.96	$3.66	AST interlayer
H.010526.6	2015	5	$4.01	$3.29	AST interlayer
H.010227.6	2013	3	$4.88	$4.34	AST interlayer
227-04-0018	2013	3	$4.72	$4.20	AST interlayer
H.010531	2014	4	$3.89	$3.33	AST interlayer
H.010533	2014	4	$3.54	$3.02	AST interlayer
H.011064	2014	4	$4.09	$3.49	AST interlayer
177-30-0021	2009	-1	$11.18	$11.62	Stone interlayer*
203-03-0016	2006	-4	$9.50	$11.11	Stone interlayer
316-01-0007	2012	2	$10.00	$9.25	CTD base
219-04-0018	2011	1	$7.00	$6.73	CTD base
132-03-0013	2005	-5	$4.55	$5.54	CTD base
033-03-0036	2004	-6	$4.65	$5.88	CTD base
300-30-0008	2012	2	$8.50	$7.86	CTD base
203-03-0016	2006	-4	$8.00	$9.36	CSD base
742-37-0023	2012	2	$12.00	$11.09	CSD base
742-37-0024	2012	2	$8.50	$7.86	CSD base
742-37-0025	2012	2	$13.00	$12.02	CSD base
742-37-0021	2012	2	$10.00	$9.25	CSD base

*4-inch stone interlayers cost are shown in the table.

Table 10: Selected cost for CSD/CTD projects with or without interlayer

Type	Cost per Sq Yd	Cost per $1/10^{th}$ log-mile (Only Base and Interlayer)	Total Cost (P) of Treatment with 3.5-inch overlying HMA per 1/10th log-mile
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

From the cost data shown in Table 9, average cost for any particular type of treatment was calculated and shown in Table 10. Now, as all these projects had overlying HMA, the cost of HMA should be added to calculate the total cost of construction for any treatment. Hence, the cost of overlying HMA per inch (of thickness) was ascertained from DOTD engineers by survey. The cost of HMA per inch was found to be $2909 in this study (at year 2010). As most of the AST interlayer and no interlayer projects had 3.5 in. HMA thickness, the cost of 3.5 in. HMA thickness (converted by equation (13) to year 2010) was added to the average cost of any treatment to calculate the total cost of constructions for that treatment. These total cost of construction (P) for different types of treatments for 1/10th log-mile along with cost per square yard are shown in Table 10. The cost of 1/10th log-mile was a necessity as benefits of AST interlayer (SL or NBA) were calculated for every $1/10^{th}$ log-mile because, if both the cost of all types of treatment and their benefits were available, the cost-effectiveness of AST interlayer could be evaluated through following methods.

Cost-effectiveness Evaluation by Benefit/Cost Ratio (B/C)

To evaluate the cost-effectiveness of any treatment, a parameter or criterion was necessary that would include both benefits and cost of the treament. Since two types of benefits were used, two types of benefit-cost ratios were developed in this study as cost-effectiveness parameters for AST interlayer performance evaluation.

B/C(SL). To incorporate costs with SL benefit, the equivalent uniform annual cost (EUAC) for the treatment could be determined and the AvgSL per EUAC could also be calculated for a comparison category. This (AvgSL/AvgEUAC) ratio would be a cost-effectiveness parameter based on SL to determine the worth of any treatment. In other words, this benefit was actually SL achieved by any treatment per dollar per year. If any treatment could provide more (AvgSL/AvgEUAC) ratio, that treatment would be more cost-effective. Moreover, (AvgSL/AvgEUAC) implied more SL for the same cost per year. In other words, if any particular type of treatment provided higher (AvgSL/AvgEUAC) than another type of treatment, the former was more cost-effective than the latter, as far as only SL was concerned.

Hence, this study determined (AvgSL/AvgEUAC) for each particular projects category for comparison. As this ratio was a benefit-cost ratio based on SL, this ratio was dubbed as "B/C-ratio-(SL)" in this study. The mathematical equation for "B/C(SL)" is shown below:

$$\text{B/C(SL)} = \frac{AvgSL}{AvgEUAC} * 10000 \qquad (14)$$

where, AvgSL = Average SL calculated for each 1/10th log-mile pavement sections, EUAC = Equivalent uniform annual cost for each 1/10th log-mile pavement sections

$$AvgSL = \frac{\sum_1^k Service\ Life(SL)\ of\ each\ sections}{k} \qquad (15)$$

$$EUAC = P.\ \frac{i.(1+i)^n}{(1+i)^n - 1} \qquad (16)$$

$$AvgEUAC = \frac{\sum_1^k Equivalent\ Uniform\ Annual\ Cost(EUAC)\ of\ each\ sections}{k} \qquad (17)$$

where, i= Inflation rate (4%), n= Time for the performance curve to reach threashold on an average, or service life (SL) one single pavement section, P= Present total cost of corresponding treatment considering 3.5 in HMA over the base, taken from Table 10, k=Number of Accepted Sections.

For all category of projects, B/C(SL) was calculated and their comparisons were evaluated as discussed in the results and discusssion section of this report.

B/C(NBA). In this method the NBA was considered as benefit and EUAC as appropriate cost. Hence, the (AvgNBA/AvgEUAC) could be the benefit-cost parameter B/C (NBA) that incorporates the overall area of distress curve. This indicated the benefit area per dollar for a particular treatment. Hence, the parameter B/C(NBA) was introduced and it was calculated by following equation:

$$B/C(NBA) = \frac{AvgNBA}{AvgEUAC} * 10000 \qquad (18)$$

$$AvgNBA = \frac{\sum_{1}^{k} Normalized\ Benefit\ Area(NBA)\ of\ each\ sections}{k} \quad (19)$$

For all category of projects, B/C(NBA) was calculated and their comparison were evaluated in the results and discusssion section. For simplicity, both benefit cost ratios were amplified by 10000 for ease of comparison of results.

Net B/C. For any category of projects, B/C(SL) and B/C(NBA) was calculated and their values were compared for cracking, rut, and IRI in the results and discusssion section. But any category of projects that may be beneficial for one distress may be non-beneficial for another distress. Hence, the net effect of all distresses should be captured by the B/C ratios for comparison. Hence the arithmetic mean of all B/C ratios for different distresses were calculated and reffered as Net B/C(SL) or Net AvgB/C(NBA) for any comparison. The equations for the Net B/C ratios are as follows:

$$Net\ B/C(SL) = \frac{\mathrm{B/C(SL)TC + B/C(SL)LC + B/C(SL)AC + B/C(SL)IRI + B/C(SL)RUT}}{n} \quad (20)$$

$$Net\ B/C(NBA) = \frac{\mathrm{B/C}(NBA)\mathrm{TC} + \mathrm{B/C}(NBA)\mathrm{LC} + \mathrm{B/C}(NBA)\mathrm{AC} + \mathrm{B/C}(NBA)\mathrm{IRI} + \mathrm{B/C}(NBA)\mathrm{RUT}}{n} \quad (21)$$

where, n is the number of distress parameter used in arithmetic mean, here n=5.

So, Net B/C(SL) and Net B/C(NBA) were finally used to compare any category's cost-effectiveness. If these two Net B/C ratios are higher than the control category, any reflective crack mitigation technique could be concluded as cost-effective.

In the results and discussion section, all comparison of B/C ratios for all distress types and their Net B/C ratios are compared for the evaluation of cost-effectiveness of any type of treatments.

Example Comparison from MatExVBA for Benefits and B/C Ratios

With the help of MatExVBA programing, the outputs for all categories were generated, which made it possible to compare two similar categories of pavement sections. This comparison aided in evaluating the effectiveness of AST interlayer. Table 11 shows combinations performed in this study to evaluate the effectiveness of AST interlayer. As CTD base is also another reflective crack mitigation technique, CTD bases' performance were also evaluated. Both AST interlayer and CTD bases were compared to CSD bases for their performance evaluation. In this case, CSD base performance acted as a control group for these evaluations. Moreover, AST interlayer over CTD bases were compared to CTD bases without any interlayer for the interlayer's performance evaluation. In this case, CTD base without any interlayer acted as control. Few stone interlayer projects (5 only) were also evaluated at the comparison section which was also shown in Table 11. Here, the comparison of service life, benefit area and their cost-effectiveness of CTD and CSD bases are shown (x13' vs x5') in Figure 8 for alligator cracking (AC).

Figure 8 compares all the parameters used in this study for CTD and CSD bases in case of alligator cracking. This figure evaluates CTD base as a crack mitigation technique. The distribution of SL are shown side by side inside the figure, where the right side has the control group (CSD) and the left side has the evaluating group (CTD) . This SL distribution was drawn for ESAL category (0-30,000), Thickness category 0-4 inch, Base category of CSD and Data points equal 6. Number of projects (N(P)), pavement sections (N(S)), AvgSL and its Standard Deviation are also shown in the figure in the top rows. Here, the GainSL for CTD is 0.1 years, and the GainNBA is 0.3 Ft-yrs/ft shown at the bottom of the figure. Hence, CTD behaves very similarly in terms of SL/NBA of pavement performance. But as CTD bases lead to cost reduction, only B/C ratios (SL based or NBA based) unfold the true cost-effective evaluation of CTD. As shown in Figure 8, the B/C (SL) values for CTD base and CSD base are 98.3 and 86.5 Yrs/Dollar, respectively, and B/C(NBA) are 89.2 and 77.3 Ft-yr/ft/Dollar, respectively. In both cases, CTD is more cost-effective than CSD bases for alligator cracking. It could be inferred from these B/C values that for SL based benefit-cost ratio, CTD bases are 13.7% more cost-effective then CSD bases. Also, CTD bases are 15.4% more cost effective than CSD bases for NBA based benefit-cost raito. It should be notified here that this analysis is performed by considering 8-12 years of surfage age data as number of data points for this analysis is 6.

Table 11: Comparison of different categories of projects for performance evaluation

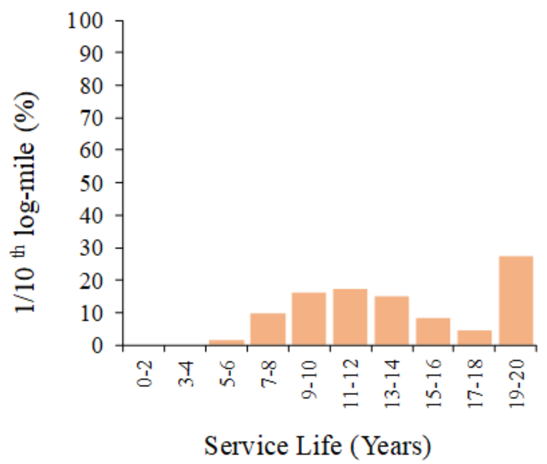
Comparison Matrix								
3 - data			Performance Evaluation Of	6 - data			Performance Evaluation Of
x1	vs	x5	AST INT (CSD)	x1'	vs	x5'	AST INT (CSD)
x2	vs	x6	AST INT (CSD)	-	-	-	-
x4	vs	x8	AST INT (CSD)	x4'	vs	x8'	AST INT (CSD)
x9	vs	x13	AST INT (CTD)	x9'	vs	x13'	AST INT (CTD)
x13	vs	x5	CTD BASE	x13'	vs	x5'	CTD BASE
x14	vs	x6	CTD BASE	x14'	vs	x6'	CTD BASE
x16	vs	x8	CTD BASE	x16'	vs	x8'	CTD BASE
x17	vs	x19	STONE INT (CTD)				
x18	vs	x20	STONE INT (CSD)				

ALLIGATOR CRACKING COMPARISON, No Int CTD vs No Int CSD Bases

ESAL Category	0	30000	ESAL		**Data Category**	6	Data points
Thickness Category	0	4	inches		**Base Category**		Soil Cement

NO INTERLAYER, CTD

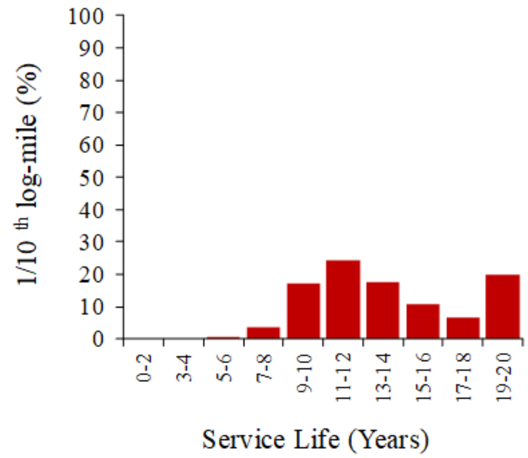
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
46	1478	13.9	4.4	12.7	4.7



B/C (SL) =	98.3	Yrs / Dollar
B/C (NBA) =	89.2	Ft-yr/ft/Dollar

NO INTERLAYER, CSD

N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
46	1789	13.8	3.8	12.4	4.0



B/C (SL) =	86.5	Yrs / Dollar
B/C (NBA) =	77.3	Ft-yr/ft/Dollar

Category:	Gain SL by AST Interlayer	=	0.1	Yrs	Category:
x13'	Gain NBA by AST Interlayer	=	0.3	Ft-yr/ft	x5'

Figure 8: Comparison of AC benefits, CTD vs CSD base (x13' vs x5')

RESULTS AND DISCUSSION

Review of Literature

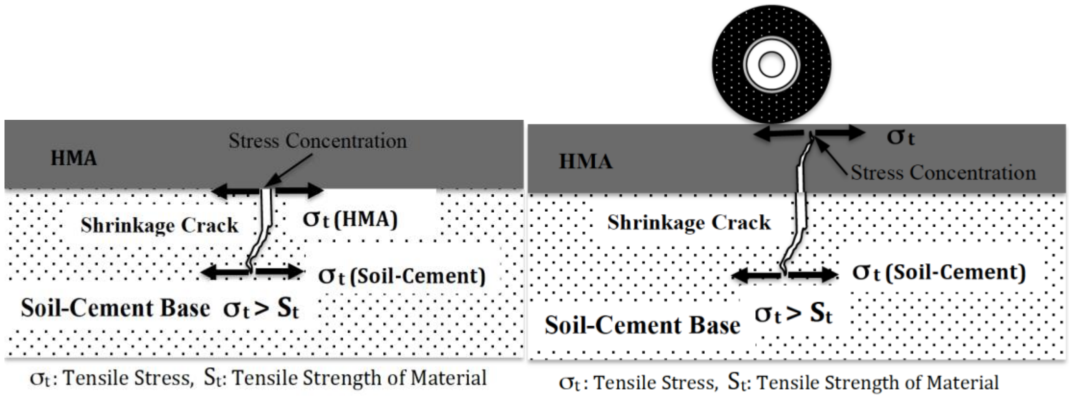
Introduction and Background

Soft surface soils present in many US states are incapable of bearing pavement and traffic loads. To mitigate this problem, many DOTs are utilizing soil-cement mixture as a base layer for flexible pavements. The soil-cement is comprised of in-situ soil and Portland cement along with water. Based on strength, the soil-cement base could be either stabilized or treated. Usually, stabilized soil-cement bases have more cement content and thus higher strength as compared to the treated soil-cement mixtures. Such cement stabilized/treated soil mixtures are durable and capable of sustaining heavy traffic loading under weak subgrade support. In addition, construction of the soil-cement base becomes quick and cost-effective. Hence, different DOTs used soil-cement base for flexible pavements for the last 50 or so years. Such practices have also been seen in other countries, where surface soils are weak and are unable to withstand heavy traffic loadings [10] [11] [12].

Even though the soil-cement mixture acts as an excellent base material, it has drawbacks. That is, soil-cement bases always have shrinkage cracks which consequently reflects to the top of HMA surface layer. Reflection of these shrinkage cracks usually result in significantly lower pavement service life. Several DOTs are trying to mitigate or prevent these reflective cracking to enhance the life of flexible pavement through different measures [11] [10] [13] [14] [15]. Now, with a goal to mitigate reflective cracking, researchers around the globe are studying the reason and mechanism of shrinkage cracking along with its reflection to HMA pavement layer. The following section briefly discusses the mechanism and process of reflective cracking due to the shrinkage of soil-cement bases of flexible pavements.

Mechanism of Reflective Crack

When soil-cement base underneath the asphalt layer starts shrinking, it creates hairline cracks initially. Over time, these hairline cracks widen and the above HMA layer loses support at that cracked area. Due to loss of support, extreme tensile stress develops at the bottom of HMA layer due to heavy traffic loads. A small micro-crack initiates at that a point in a HMA layer. With repeated traffic loads, that micro-crack becomes a wider macro crack and it propagates to the top and appears at the surface. Figure 9 illustrates this phenomenon for soil-cement bases. Figure 10 shows the original image of reflective cracks over soil-cement bases. As these cracks reflect from the bottom shrinkage crack of the bases, these are called reflective cracks. Usually, the reflective crack pattern at the surface of HMA follows the pattern of base shrinkage crack. In general, the transverse, alligator and block cracks present in the soil-cement based HMA layers are reflective. But there are instances where longitudinal cracks are also reported to be reflective for soil-cement bases.



(a) (b)

Figure 9: Mechanism of reflective crack development in flexible pavement with soil-cement base (a) stress concentration at bottom of HMA, (b) crack propagation and stress concentration in HMA [13]

Figure 10: Reflective cracking in flexible pavement due to underlying soil cement base [13]

Factor Affecting Shrinkage and Reflective Cracking

Primarily, it is the shrinkage of soil-cement base that causes the reflective crack in HMA layer. So, the reason and process of shrinkage crack should be understood first to diagnose the problem. Many researchers have already conducted several studies to determine the reason of shrinkage cracking in soil-cement bases. According to their findings shrinkage of soil-cement is influenced by the cement content of the soil, soil type and its grain size, moisture content, curing time along with additives used in the soil-cement mixture. The factors affecting the shrinkage of soil-cement base are illustrated below.

Cement Content. This is one of the primary reasons of wider shrinkage cracks. Higher cement content in the soil-cement mixture provides higher strength, but it also causes shrinkage at the time of curing and drying. Higher cement content requires more water for hydration and thus it creates wider cracks and smaller crack spacing during the drying process. The addition of cement cannot be avoided as it provides necessary strength to soil base to withstand traffic load. However, an optimum amount of cement content could be determined to minimize shrinkage cracks as reported by George (1968) [16]. This cement content reflects the cement dosage that provides necessary strength to the soil-cement base but does not create unnecessary shrinkage thus reduces reflective crack at the end. Sealing of the soil-cement just after construction by a prime coat also delays the drying process which reduces shrinkage [13, 14, 17, 18].

Soil Type and Grain Size. In general, clayey soils are more susceptible to shrinkage as compared to sandy or silty soils. Specifically, montmorillonite clay has more shrinkage than other types of clays. As finer soil particles require more cement to cover its surface area, it needs more cement which requires more water that eventually creates more shrinkage during drying process. Finer soils were found to experience short spaced shrinkage cracks (2-10 ft.), whereas coarser soils were found to have higher spaced shrinkage cracks (10-20 ft.). Finer soil also develops thin cracks whereas coarser soil develops wider cracks [13, 14, 18].

Density and Compaction. Past studies have confirmed that density and compaction has an effect over the shrinkage cracks. Properly compacted and dense soil-cement mixture has less void available which would allow shrinkage [19]. Adaska (2004) has shown that increasing density reduces the shrinkage of soil-cement for different soil types up to a certain point [13]. George (1968) suggested that if the soil is clayey, then it should not be compacted to higher density without decreasing the moisture content [16]. Bofinger et al. (1978) reported that autogenous shrinkage increases as density increases. Hence, higher compaction and density usually reduces shrinkage of soil-cement with some exception [20]. Adaska (2004) reported that compacting cement stabilized soil with modified proctor test instead of standard proctor test could reduce shrinkage up to 50%. Adaska (2004) also recommended pneumatic-tire rollers over vibratory rollers for compaction when shrinkage is an issue [13].

Moisture Content. Both pre-treatment moisture content and molding moisture content could be a useful factor regarding shrinkage. When cement and molding water were mixed into dry soil, shrinkage was found to be minimal. To reduce the shrinkage, cement treated bases should be compacted in a slight dry condition. As compacting the soil above optimum molding moisture could lead to more initial shrinkage, it is suggested that molding of soil-cement could be on the lower side of optimum moisture content, if any error occurs [16] [20].

Curing. Prolonged curing does not have much impact on shrinkage of soil-cement. Long time curing would rather increase both compressive and tensile strength of the soil-cement. Depending on soil type, long time curing could minutely increase or decrease the shrinkage. For clayey soils, moist curing was found to be helpful to reduce shrinkage [16]. Hence, longer curing time is usually recommended for soil-cement bases. Delaying the placement of overlay over the soil-cement bases would allow some hairline cracking to appear which reduces the reflective cracking [13] [21].

Additives. Some additives are found to be helpful to reduce shrinkage cracking in soil-cement. Shrinkage of clayey soil from montmorillonitic origin are reduced by a light addition (1%) of sodium chloride. In some cases, calcium chloride helps reduce shrinkage when it replaces a portion of cement (up to 0.5%) in the mixture. Lime was found to reduce shrinkage cracking and its intensity when it replaced cement content (up to 4%). Fly ash also minimizes shrinkage cracking in some cases, but it depends on soil and fly ash type. Sulfate salts also reduces shrinkage crack for some soil types, when added in a small amount (up to 1%) [22] [23].

Techniques to Mitigate Reflective Cracking / Shrinkage Crack for Soil-cement Bases

Mitigation of reflective crack in soil-cement pavements are performed in three different major fashion as described below.

Construction Practices of Soil-Cement Bases. As described above, shrinkage cracks could be minimized by reducing cement content from the conventional practices of many DOTs. Unnecessary strength of soil-cement would be reduced in this process but durability would increase because of less shrinkage. At the same time, moist curing of clay soil helps minimize shrinkage cracking too. Corresponding additives could also be added to the soil-cement mix to reduce shrinkage.

Several DOTs had already been using cement treated design (CTD) instead of cement stabilized design (CSD). Usually cement treated design yields 40-60% strength of cement stabilized design, but CTD needs lower cement content which reduces shrinkage crack significantly. CTD base usually has higher thickness as compared to CSD as it compensates some strength loss. It is worth mentioning here that CTD bases are strong enough to withstand the traffic load, but more durable as it is less susceptible to shrinkage crack. CTD soil-cement pavements also costs less, as it has low cement content. DOTs are also using several additives and fly ash which help minimizing shrinkage of soil-cement bases. Just after the construction, a prime coat layer is usually applied to seal the soil-cement bases. It decelerates soil-cement drying rate thus reducing shrinkage. Placement of HMA can also be delayed which allows the initial shrinkage to occur thus reduces the chance of reflection [24] [25] [26] [27]. Hence, the construction practices have changed over the years to minimize shrinkage crack. Even though, this minimization is not enough as those cracks eventually appear at the surface with some delay. For this reason, other techniques such as pre-cracking of base layer are necessary to retard the reflection of shrinkage crack in flexible pavements [14] [28] [29].

Micro-cracking. The concept of micro-cracking first initiated in Austria in 1995. Several passes of steel vibratory roller with high frequency and amplitude over the soil-cement base at short curing age (1 to 3 days) creates a network of thin hairline cracks. The soil-cement base would lose its compressive strength temporarily in this process, but eventually regains the strength after few months. This thin hairline network of crack prevents the base from creating wider shrinkage cracks, mitigating its reflection. As the nature of these cracking is micro and the pavement is cracked before overlay application, it is called micro-cracking of pre-cracking. Currently, TxDOT, DOTD, and CalTrans are performing micro-cracking on some of their pavements [14] [28] [29]. TxDOT has investigated and reported three field test sites crack performance to verify the effectiveness of micro-cracking. All three of those sections were micro-cracked and their performance evaluated over the course of 3 years. Just after micro-cracking, the reduction of base modulus is a major concern. So, all pavement sections inside the test sites were checked for their base modulus after micro-cracking. It was found that the base modulus decreased significantly after microcracking (40-60%), but recovered after several months. Hence, micro-cracking does not damage the pavement at all, if done properly. All test sites cracking performance were evaluated for 3 years. With little exception, most sections did not show any reflective cracking. The results demonstrated that micro-cracking delayed or mitigated the reflective cracking [28].

On three selected locations, DOTD constructed flexible pavements with micro-cracked base layer and monitored the performance for 3 years. Performance of such micro-cracked sections were compared with non-micro-cracked sections. For cement stabilized design, micro-cracked sections performed similar to conventional uncracked soil-cement bases. For cement treated design, micro-cracked sections performed worse than traditional soil-cement bases [29]. Caltrans also constructed some pavement sections with pre-cracked base. However, their performance has not been reported [14].

Stress Absorbing/Relieving Interlayer Membrane. As there is no real way to prevent shrinkage cracking for good and such cracks eventually reflect to the surface layer, a stress absorbing/relieving interlayer membrane could be placed over such bases to mitigate reflective cracking. This interlayer membrane usually traps the shrinkage crack and delays its propagation by providing a firm base for the overlying layer [30]. Several DOTs have used this technique on different types of interlayers over soil-cement bases to delay reflective cracking for long time.

Paving Fabrics. To retard reflective cracking, geotextile paving fabrics were being used as stress relieving interlayer since the 1930s in the US [31] . It should be noted that the paving fabrics could be placed along with a Chip seal as a surface dressing in many cases. Usually, paving fabrics were found to be a useful interlayer to mitigate reflective cracking for all types of bases. Researchers reported that reflective cracks from existing HMA or PCC bases were significantly deterred by paving fabrics [32]. Paving fabrics with chip seal were also found to be potential interlayer when used over subgrade soils directly as an interlayer [32]. In one study in

Australia, paving fabrics was placed over cement treated base as interlayer and it was able to retard reflective crack for one monsoon season, although the long term performance was not evaluated [33].

Mississippi also used paving fabrics over cement treated bases, but no performance evaluation of paving fabrics over soil-cement base was found [34]. TxDOT has evaluated paving fabrics performance over cement treated base for a 1200 ft. long test section for 24 months, where it was able to retard reflective cracking significantly as compared to control sections [35]. In most cases, paving fabrics acted as a capable interlayer to reduce reflective cracking on both existing HMA and PCC pavements. Also, in some cases these fabrics were unable to stop reflective cracking [31] [32] [34]**.**

Stone Interlayers/Inverted Pavements. When unbound compacted aggregates are placed between a cement treated base and HMA layer to create a pavement, it is called as an inverted pavement as its cross-section looks like an inverted anvil. South Africa first successfully implemented inverted pavement techniques with improved performance. The performance of inverted pavements was measured using Heavy Vehicle Simulator (HVS) testing where an inverted pavement with only 1.8 in unbound aggregate were able to withstand 50 million standard axles It must be noted that South Africa uses high quality crushed aggregate that could be compacted to 88% density for its inverted pavements. The unbound compacted aggregates of inverted pavements are nothing but an interlayer between soil cement base and HMA top surface. Hence, it could increase serviceability by entrapping the natural shrinkage cracks in cement treated or stabilized base. Hence, it is also called 'Stone Interlayer' in other parts of the world [36].

In the US, Louisiana has been using this technique to retard reflective cracking of soil-cement bases for flexible pavements. Under Accelerated Load Facilities (ALF), the stone interlayer performance was evaluated by DOTD on 8 test sections. Such interlayers exhibited significantly better performance to retard reflective cracking and rutting as compared to conventional bases [37]. To evaluate the field performance of stone interlayer, one stone interlayer test section was monitored for 10.2 years and compared with control section with no interlayer. Crack density, total crack, and roughness were found significantly lower on the stone interlayer pavement [10]. Instead of crushed stone, reclaimed asphalt pavement (RAP) was used to build stone interlayer in Louisiana and its performance as an interlayer was evaluated. Three test sections were made with RAP and traditional stone interlayers and their performance were compared by ALF test. The researchers concluded that there is no significant difference between the performances of RAP and crushed stone interlayer. As RAP is cheaper, the researchers concluded to use more RAP for inverted pavements [38]. Recently, many US States are on the process of building and evaluating stone interlayer (or inverted pavements) over cement treated bases due to its performance and cost-effectiveness. New Mexico, Georgia, and Virginia DOTs have already started building test sections to evaluate stone interlayers performance [39] [40] [41].

Chip Seal (Asphaltic Surface Treatment). Applying asphaltic surface treatment (AST) as an interlayer over soil-cement bases is relatively new. DOTD made 10 test sections in 1999, each 1000 ft. long, to evaluate shrinkage crack mitigation techniques. Two of these test sections consists of AST interlayers between soil-cement base and HMA surface. For eight years, these sections' cracking and rutting performance were evaluated and compared with soil-cement bases without interlayers. Sections with AST interlayer did not show any improvement in cracking or rutting performance. Contrarily, cement treated sections without an interlayer performed better than sections with AST interlayer in this study [17].

Techniques to Mitigate Reflective Cracking for Other Bases (PCC/HMA)

Soil cement bases has some degree of similarity with PCC, as it acts as a low strength concrete slab. PCC bases had usual transverse crack at a pre-defined place chosen by engineers at the time of construction. In contrast, soil-cement bases do not have any pre-defined transverse crack. Rather it has multiple shrinkage cracks all over the place mostly in the transverse direction. Moreover, shrinkage cracks width increases over time due to drying. The usual crack width in soil-cement is smaller compared to PCC bases. Because of the similarity of soil-cement and PCC bases, reflection of the cracks in both pavements could be delayed by the same interlayer. At the same time, reflective cracking is also present for pavements with existing HMA base. Even though HMA and soil-cement are two different bases, they both also reflect their base cracks. Hence, interlayers that are evaluated for PCC/HMA bases are briefly described below.

Paving Fabrics (over PCC/HMA). As described above, paving fabrics were found to be an effective interlayer to retard reflective cracking for pavements with PCC, HMA, or granular bases [32] [42] [43]. As it has good historical record, Mississippi has conducted a study by constructing 12 500-ft. long sections with paving fabrics over existing bases. Paving fabrics has proven its worth to mitigate reflective cracking as compared to control sections for a span of 7 years. A cost analysis where EUAC (equivalent annual cost) was compared for paving and non-paving sections found that paving fabrics with 1.5 in, overlay becomes most-cost effective over the span of 13 years analysis [44].

Asphalt Rubber Membrane Interlayer (ARMI). Long-term performance of ARMI was evaluated by TxDOT for three test sections and ARMI was found as an effective interlayer to reduce reflective cracking than no interlayer at all [45]. Florida DOT has been using ARMI as a reflective crack mitigation technique primarily for PCC pavements for more than three decades. A recent study showed that long term performance of ARMI test sections was not satisfactory and it did not effectively mitigate reflective cracking in Florida [46]. Arizona has assessed ARMI as a reflective crack mitigation technique for both rigid and flexible pavements. Eight projects with 47 test sections' performance were evaluated from pavement management database and ARMI was found to provide five to 10 years of life extensions [47]. ARMI was also used as an effective interlayer in the state of California to retard reflective cracking over both rigid and flexible pavements [48]. Along with ARMI, several other fiber reinforced stress absorbing membrane interlayer (SAM or SAMI) are being used in USA as a potential interlayer for both PCC and HMA pavements [15] [49].

Other Interlayers for PCC Bases. The state of Iowa has recently evaluated different techniques to mitigate reflective cracking by constructing several test sections. The performance of 16 test sites was evaluated. Stone interlayer over PCC pavements were able to reduce reflective cracking to a significant degree, hence recommended for further use [50]. Elseifi assessed the field performance of several interlayers to retard reflective cracking over composite pavements at Louisiana from PMS database. Four to 18 years of performance data was used for 50 different sites to evaluate chip seal, saw-seal, STRATA, and SAMI as an effective interlayer. Only chip seal and saw-seal were found to mitigate the reflective cracking for composite pavements. STRATA and SAMI exhibited mixed results and thus were not recommended for further use [51] .

Based on the above review of existing literature, it is clear that reflective cracks are one of the major concerns around the globe. There is a pressing need to continue research and grow new innovative techniques to mitigate or even prevent reflective cracking for all kind of bases. In an effort to evaluate the performance of asphaltic surface treatments (AST) or Chip seal as an interlayer over soil-cement bases, the Louisiana Transport Research Center (LTRC) has launched this research study. The goal of this study is to evaluate AST to extend service life of soil-cement (cement treated/stabilized) bases in Louisiana.

DOTD State-of-the-Practice

AST Interlayer Specifications

The Louisiana Department of Transportation and Development (DOTD) has been constructing AST interlayers over soil-cements for the last two decades with the intent to mitigate reflective cracking over soil-cement bases. The procedure for AST interlayer construction over soil-cement bases are found in the LA Specifications 2016 [52], Manual Survey and PMS database. In general, at first soil-cement bases were made ready prior to an AST interlayer installation. Usually, In-Place cement stabilized design (CSD) or cement treated design (CTD) are selected for soil-cement bases. In few cases, central plant mixed soil-cement bases are also used. Procedures for CSD or CTD bases along with AST interlayer installation are summarized below.

In-place Soil Cement Base Placement

CSDs are typically 8.5 in. thick soil-cement bases with design compressive strength 300 psi, whereas, CTDs are usually 12 in. thick with design compressive strength 150 psi. The Design Strengths are determined in accordance with DOTD TR 432, Method B or C. The CSD usually has more percentage of cement (8 to 12) and the CTD has less percentage (4 to 7) of cement in the soil-cement mix. [24]

Roadbed Preparation. First, all existing asphalt concrete surfacing is removed except the bottom inch prior to cement stabilization. The existing base is then scarified and pulverized to be mixed with materials below the surface. A uniform blend of pulverized materials is formed across the full width and depth of design base course. The roadbed shall be scarified and pulverized to at least 60 percent passing the no. 4 sieve prior to mixing with cement (in accordance with DOTD TR 431) [52]. Subsequently, the pulverized roadbed materials are compacted uniformly to at least 93.0 percent of maximum dry density. The dry density shall be determined in accordance with DOTD TR 401, TR 415, or TR 418 [52]. The compacted roadbed is shaped according to the required design dimensions.

Mixing with Cement. With a minimum of two passes with the mixer (stabilizer), the cement is then spread and mixed uniformly with the roadbed soil. Water is added through a spray bar by the mixer to achieve the optimum moisture content. Optimum moisture content is determined in accordance with DOTD TR 415 or TR 418. It's worth mentioning that the binder cement could be Portland cement, blended hydraulic cement, or Portland blast-furnace slag cement in accordance with lines, grades, thickness, and sections established or shown on the plans.

Compacting and Finishing. The mixture is immediately compacted to the specified depth and width shown in the plan. Initial compaction was performed by a sheepsfoot-type roller or a self-propelled tamping foot compactor-type roller in such a manner that no internal laminations occur in the completed base course. After the initial compaction, a pneumatic tire roller provides final compaction to the base. The base surface shall be kept uniformly moist during compaction and final finishing. It's worth mentioning that cement mixing operations starts within one hour of placement. Similarly, compaction and finishing operations shall be completed within three hours after initial mixing of cement with base materials.

Protection and Curing. The cement stabilized/treated compacted base has to be immediately protected against rapid drying which would create shrinkage crack. Hence an asphalt curing membrane is applied over the compacted base immediately after the completion of final finishing of the final lift of the surface. Public traffic or construction traffic should be not be allowed for a 72-hour curing period. Within 30 calendar days, any other asphalt concrete surfacing can cover the soil-cement base.

Samples were taken from the prepared roadbed to test all acceptance criteria of DOTD. The cement spread rate, moisture content, pulverization, and in-place density of the base were tested for compliance in accordance with DOTD TR 436, DOTD TR 403, DOTD TR 431, DOTD TR 415 or 418 accordingly*.

Even though DOTD usually prepares in-place soil cement bases, sometimes central plant mixed soil-cements are also used. Soils are selected for soil-cement mix in plant in accordance to DOTD TR 432. These soils must have liquid limit less than 35, plastic limit less than 15 and organic content less than 2 percent. Type I or II Portland cement is used as the cement source for soil-cement mix. In a mixing plant, within one hour of placement, the soils are combined with cement and water. After the mixed soil-cement placement on the site, compaction and finishing of the operations were performed within three hours.

Whether the soil-cement mix is in-place or plant mixed, it should be always either CSD or CTD based on the design of the roadway. (Detailed procedures and standards are present in Louisiana Standard Specification, 2016 [52]).

Asphalt Curing Membrane over Soil-Cement Bases

A curing membrane is necessary to protect the soil-cement base against rapid drying. Hence, an asphalt curing membrane is applied over the stabilized or treated base immediately after finishing. An emulsified asphalt or an emulsified petroleum resin (EPR -1) is used to cure the membrane, complying with section 1002 Louisiana Standard Specification, 2016 [52]. Emulsified asphalt curing membrane is applied uniformly over the base in accordance with the information of Table 12 [Table 12 is the Table 506-1 of DOTD Specifications].

Table 12: Asphalt curing membrane information [52]

Curing Membrane Type	Application Rate[1] Gal/Sq Yd	Application Temperature[2] °F
	Min.	Min.
EPR-1[3]	0.20	70
Emulsified Asphalt[4]	0.10	70

[1]Rates are minimum rates of undiluted asphalt emulsion. Dilution of the asphalt curing membrane is not permitted.
[2]Minimum application temperature or as recommended by the manufacturer.
[3]Undiluted EPR shall consist of 5 parts water and 1 part resin concentrate and comply with Section 1002.
[4]Shall comply with Section 1002.

The surface should be closed to traffic until the curing membrane is properly cured, unless otherwise directed by the engineer. Additional curing membrane at intervals could be provided to protect the surface when traffic is allowed.

Asphalt Surface Treatment Installation

Asphalt surface treatment (AST) is sometimes referred to as the 'Chip Seal' Treatment. This treatment could be applied on either both 'Cold' or 'Hot' condition based on design. This AST is a uniform application of liquid asphalt spread followed by an aggregate sprinkle. Usually, it is applied over the HMA overlaid surface to seal crack or improve surface friction of highway. This application could be placed over any surface multiple times. There are five different types of asphalt surface treatment used by DOTD: Type A, B, C, D, and E shown in Table 13 and Table 14 (Table 507-1 and 507-2 of LA Specifications, respectively). Only Type E AST applications are used as interlayers to mitigate reflective cracking over soil-cement bases. As this study is limited to interlayer application of AST, only interlayer application of AST is illustrated.

Table 13: AST requirements for cold application [52]

	Course No.	AST TYPE A		AST TYPE B		AST TYPE C	AST TYPE D			AST TYPE E (Interlayer)
Aggregate		Lightweight, Crushed Stone		Lightweight, Crushed Stone		Lightweight, Crushed Stone	Lightweight, Crushed Stone, Crushed Gravel			Crushed Stone, Crushed Gravel
Agg. Friction Rating		I, II		I, II, III		I, II, III	I, II, III, IV			I, II, III, IV
Asphalt Emulsion		CRS-2P		CRS-2P		CRS-2P	CRS-2P			CRS-2P
Application Temp. Minimum		160°F		160°F		160°F	160°F			160°F
Maximum		175°F		175°F		175°F	175°F			175°F
Number of Applications		2	1	2	1	1	3	2	1	2
Asphalt Emulsion[1] Application Rates Per Course	1	0.39	0.41	0.39	0.31	0.41	0.46	0.39	0.31	0.39
	2	0.29	—	0.29	—	—	0.36	0.29	—	0.29
	3	—	—	—	—	—	0.26	—	—	—
Aggregate size and Application Rates Per Course[2]	1	S2-0.0111	S2-0.0111	S2-0.0111	S3-0.0075	S2-0.0111	S1-0.0200	S2-0.0111	S3-0.0075	S2-0.0111
	2	S3-0.0075	—	S3-0.0075	—	—	S2-0.0111	S3-0.0075	—	S3-0.0075
	3	—	—	—	—	—	S3-0.0075	—	—	—

[1]Application rates are in gallons of asphalt emulsion per square yard of AST.
[2]Size aggregate and application rates. For example, S2 is Size 2 aggregate and 0.0111 is the application rate in cubic yards of aggregate per square yard of AST. S1A may be used in lieu of S1. Aggregate sizes for AST are shown in Table 1003-15.

Table 14: AST requirements for hot application [52]

	Course No.	AST TYPE A		AST TYPE B		AST TYPE C	AST TYPE D			AST TYPE E (Interlayer)
Aggregate		Lightweight, Crushed Stone		Lightweight, Crushed Stone		Lightweight, Crushed Stone	Lightweight, Crushed Stone, Crushed Gravel			Crushed Stone, Crushed Gravel
Agg. Friction Rating		I, II		I, II, III		I, II, III	I, II, III, IV			I, II, III, IV
Asphalt Cement[1]		PAC-15		PAC-15		PAC-15	PAC-15			PAC-15
Application Temp. Minimum		300°F		300°F		300°F	300°F			300°F
Maximum		360°F		360°F		360°F	360°F			360°F
Number of Applications		2	1	2	1	1	3	2	1	2
Asphalt Cement[2] Application Rates Per Course	1	0.30	0.31	0.30	0.24	0.31	0.36	0.30	0.24	0.30
	2	0.23	—	0.23	—	—	0.28	0.23	—	0.23
	3	—	—	—	—	—	0.20	—	—	—
Aggregate size and Application Rates Per Course[3]	1	S2-0.0111	S2-0.0111	S2-0.0111	S3-0.0075	S2-0.0111	S1-0.0200	S2-0.0111	S3-0.0075	S2-0.0111
	2	S3-0.0075	—	S3-0.0075	—	—	S2-0.0111	S3-0.0075	—	S3-0.0075
	3	—	—	—	—	—	S3-0.0075	—	—	—

[1]See Table 1002-11.
[2]Application rates are in gallons of asphalt cement per square yard of AST.
[3]Size aggregate and application rates. For example, S2 is Size 2 aggregate and 0.0111 is the application rate in cubic yards of aggregate per square yard of AST. S1A may be used in lieu of S1. Aggregate sizes for AST are shown in Table 1003-15.

Materials

Asphalt. The asphalt materials used in this treatment shall comply with section 1002 which are the approved material list products. Interlayer could be either hot or cold applied. When cold applications are used, asphalt shall comply with Table 13. If hot applications are used, asphalt shall comply with Table 14.

Aggregates. Crushed stones or crushed gravels are used as aggregates for interlayer applications. All aggregates used in interlayer applications, had to be precoated aggregates with a paving grade asphalt cement or a cationic emulsion. The residual asphalt content shall be a minimum of 1.4 percent by weight of the aggregate (for high absorption aggregates) and 0.5 percent minimum by weight (for low absorptions aggregates). It should be ensured that the precoated aggregate flows freely. If an emulsion is used for pre-coating, the stockpiled precoated aggregate must be cured prior to use. Aggregates' friction rating, size, and spread rate had to comply with Table 13 or Table 14. Aggregates' friction rating I, II, III or IV all are allowed for aggregates used in interlayers. Size of aggregates used in interlayers were Size 2 (S2) and Size 3 (S3). These gradations of these two sizes are presented in Table 15 (Table 1003-15 of LA Specifications).

Table 15: Gradation for asphalt surface treatment [52]

		Size 1		Size 1A	Size 2	Size 3
U. S. Sieve	Metric Sieve	Slag or Stone Aggregate (Size No. 5)	Crushed Gravel[1] or Lightweight Aggregate	Slag or Stone Aggregate	All Aggregate	All Aggregate
1 1/2 inch	37.5 mm	100	100	100	—	—
1 inch	25.0 mm	90-100	95-100	100	—	—
3/4 inch	19.0 mm	20-55	60-90	85-100	100	—
1/2 inch	12.5 mm	0-10	—	25-40	95-100	100
3/8 inch	9.5 mm	0-5	0-15	5-15	60- 80	95-100
No. 4	4.75 mm	—	0-5	—	0-5	20-50
No. 8	2.36 mm	—	—	—	0-2	0-2
No. 200[2]	75 µm[2]	0-1	0-1	0-1	—	—

[1] Uncrushed gravel may be used for Size 1 aggregate if more than one application of Asphalt Surface Treatment is required.
[2] If the material passing the No. 200 (75 µm) sieve consists of only dust from crushing and handling, and is essentially free of clay, then the percentage passing the No. 200 (75 µm) sieve shall be 0 - 2 percent.

Process of Installation. After the asphalt curing membrane is cured and maintained satisfactorily in accordance to section 505 and 506, the surface is ready for AST installation. With the help of a Power Asphalt Distributor, liquid asphalt is spread over the base surfaces. For cold applications, CRS-2P asphalt emulsion is used and the application temperatures are minimum 160^0F to maximum 175^0F. With an asphalt distributor, the asphalt emulsion is spread at a rate of 0.39 gallons (of asphalt)/Sq. Yd. (of AST) for first application. Aggregates are sprinkled immediately after asphalt spread with the help of self-propelled, pneumatic tire power spreader. S2 sized precoated aggregates are spread for the first application with a rate of 0.0111 Yd^3 (of Agg)/ Yd^2 (of AST). Interlayer applications usually had two applications. A minimum of 48 hours had to elapse between the two applications when it was a cold application. The second application is similar to first application with only a differing rate of asphalt and aggregate spread. For the second cold application, the asphalt emulsion application rate is 0.29 gallons (of asphalt)/Sq. Yd. (of AST). After the second asphalt emulsion application, aggregates of size 3(S3) are spread at a rate of 0.0075 Yd^3 (of Agg)/ Yd^2 (of AST).

For hot applications, PAC-15 asphalt cement is used as binder and the application temperatures for asphalt binder are minimum 300^0 F to maximum 360^0 F. The hot asphalt cement application rates are 0.30 and 0.23 gallons (of asphalt)/Sq. Yd. (of AST) for the first and second course, respectively. Size and application of aggregates are identical to the cold applications. The process of hot interlayer application is similar to the cold one, but for hot applications, two successive applications could be placed without delay.

Rolling and Brooming. Immediately after spreading aggregate over liquid asphalt cement or emulsion, the surface is rolled over by three passes of pneumatic tire rollers (weighing at least 12 tons). The first pass is made within approximately one minute of the aggregate spread. All the rolling operation is completed within 30 minutes of the last aggregate spread. The surface is lightly broomed or air-blown to remove loose material. For hot applications, light broom or blow could be performed immediately after rolling. For cold applications, light broom or blow is performed the next day of rolling, allowing for some curing time. Traffic is allowed after light broom or air-blow to the surface.

Survey Results: Review of District's Practices

A survey questionnaire was mailed to all districts of the DOTD; a copy is included in Appendix B of this report. The responses from the districts were analyzed and the results are summarized below. It should be noted that, in this document, the term "all districts" refers only to the districts who returned the survey.

District 02. The district reported that they do not use AST interlayer on soil-cement projects. However, the glass-grid interlayer was the most common interlayer used to mitigate reflecting cracking on composite pavements. Based on their experience, when the cracks finally appeared through the pavement, the cracks exhibited an irregular pattern, back and forth across the original crack location. In effect, the new cracks had a greater total length, indicating that the pavement is more susceptible to water in the long run.

District 03. District 03 provided detailed answers to all questions. In this district, 16 AST interlayer (55 lane-miles), 5 stone interlayers (20 lane-miles) and 40 no AST soil-cement base projects were obtained using the survey questionnaire. The average life span of the AST interlayer sections was reported on the average as 10 years. Both AST and no AST interlayer soil-cement projects were found to be more susceptible to transverse and longitudinal cracking followed by alligator cracking. Most AST interlayer projects did not exhibit any improvement; only 33% of AST interlayer projects were considered to have some improvement of service lives as reported by the district engineers.

District 04. In this district, only 6 lane-miles of pavement were found to have AST interlayer on soil-cement bases. Most AST interlayer projects did not show improvements; only 33% of AST interlayer projects exhibited increase in pavement service life. The average life span of 7 years was considered for single/double layer AST interlayer projects.

District 05. The district reported about 8 AST interlayer projects comprised of approximately 30 lane-miles. The engineers indicated that AST and no AST interlayer projects were more susceptible to transverse and longitudinal cracking. Most projects did not show any improvement in service life. Only 33% AST projects reflected improved service lives.

District 07. District 07 had not used AST interlayers on soil-cement bases until now. Hence, no information is available for this district.

District 08. This district provided information for 19 AST interlayer and 40 no AST interlayer projects. All such projects are expected to have about 60 lane-mile of data available. Both AST and no AST interlayer projects were found to be susceptible to longitudinal and transverse cracking. No improvement was observed for AST interlayers on soil-cement projects. Most pavement cracking in this district was due to desiccation. Crack widths were large and AST did not seem to be effective in mitigating such cracking.

District 58. District 58 had not yet used AST interlayers as a reflective crack mitigating technique. Hence, no information regarding AST interlayer performance was available.

District 61. About 5 AST interlayer projects with approximately 8 lane-miles were found in this district. Only 33% of projects showed any improvement according to the judgement of engineers. Soil-cement bases with or without AST interlayer were more susceptible to alligator cracking followed by longitudinal and transverse cracking.

District 62. District 62 had not yet used AST interlayers until now. Hence, no information regarding AST is available for this district.

Summary of District Survey

The results of districts practices are summarized in the following Table 16:

Table 16: Summary of survey results for DOTD districts

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 do 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
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.	
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 to 3 contractors bid on the projects. In some districts 4 to 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.	

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 interlayer was applied on soil-cement. • AST and no AST interlayer soil-cement base are more susceptible to transverse followed by longitudinal and alligator cracking. • In District 08 no improvement was observed. Mostly due to desiccation of soil-bases with larger crack widths. • District 08 recommended to install AST on top of HMA to extend its life after cracking.	

Pavement Performance Models

Based on the methodology adopted, the pavement distress prediction models for each type and for both with and without AST interlayers on soil-cement base were developed. The details of the performance models are provided below.

AST Interlayer over Soil-Cement Base

Transverse Cracking. In this study, 198.5 miles of flexible pavement with AST interlayer over base layer were analyzed and regression analyses were conducted on 141.1 miles of data for transverse cracking based on data availability and project acceptance criterion. Recall, the traverse cracking model follows the sigmoidal function which can be written as linear form to conduct linear regression analysis. The result of such regression yielded the following form of the equation.

$$\ln(TC^{*}) = ln\left(\frac{TC+1}{Max-(TC+1)}\right) = a_o + a_1\left(\frac{SR}{T_h}\right) + a_2 t + a_3 ln(CESAL) \tag{22}$$

where, *TC* equals transverse cracking (ft/mile), *Max* equals 21,120 ft/mile, *CESAL* equals cumulative ESAL, T_h equals thickness of HMA overlay (in), *t* equals to time in years, and *SR* represent the compressive strength ratio with respect to CTD strength of 150 psi. For CTD *SR* = 150/150= 1 and for CSD *SR* = 300/150= 2. The results of the statistical analysis are shown in Table 17.

After conducting the regression, the following equation was obtained to predict the actual transverse cracking.

$$TC = \frac{21120}{1+exp^{-\{\beta(-13.2927+3.9176(SR/Th)+0.4972(t)+0.3501(lnCESAL))\}}} - 1 \quad (23)$$

Here, *TC* equals transverse cracking (ft/lane-mile), β equals 1.179 for transverse crack is calibration factor obtained by minimizing the RMSE value using the above model.

The predicted versus the measured *ln(TC*)* value for AST interlayer on soil-cement base for flexible pavement is shown in Figure 11. It can be seen that there is a good agreement between the predicted and measured values, thus indicating that the model was able to predict the transverse cracking reasonably well. Furthermore, all the variables used in the models are statistically significant with p-value $\leq$0.05. Figure 12 depicts the predicted TC for both CTD and CSD base types. It is obvious that the TC values increases with the increase in time due to increase in cumulative ESALs. The CTD base exhibits low TC cracking relative to CSD for AST interlayer. This behavior is somewhat consistent with the SL analysis conducted in this study with slight increase of 2 years in SL for a TC threshold of 10,560 ft/lane-mile.

Table 17: Statistics of the regression analysis of TC model for AST interlayer over soil cement base of flexible pavements

Regression Statistics	
Multiple R	0.92
R Square	0.85
Adjusted R Square	0.85
Standard Error	1.95
Observations	162

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	3	3363.5	1121.18	294.26	1.95437E-64
Residual	158	602.0	3.81		
Total	161	3965.6			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept (a_o)	-13.2927	1.2660	-10.50	6.8E-20	-15.7931	-10.7923
SR/T_h (a_1)	3.9176	1.6837	2.33	2.1E-02	0.5921	7.2432
t (a_2)	0.4972	0.0187	26.58	3.4E-60	0.4603	0.5342
lnCESAL (a_3)	0.3501	0.0864	4.05	8.0E-05	0.1794	0.5208

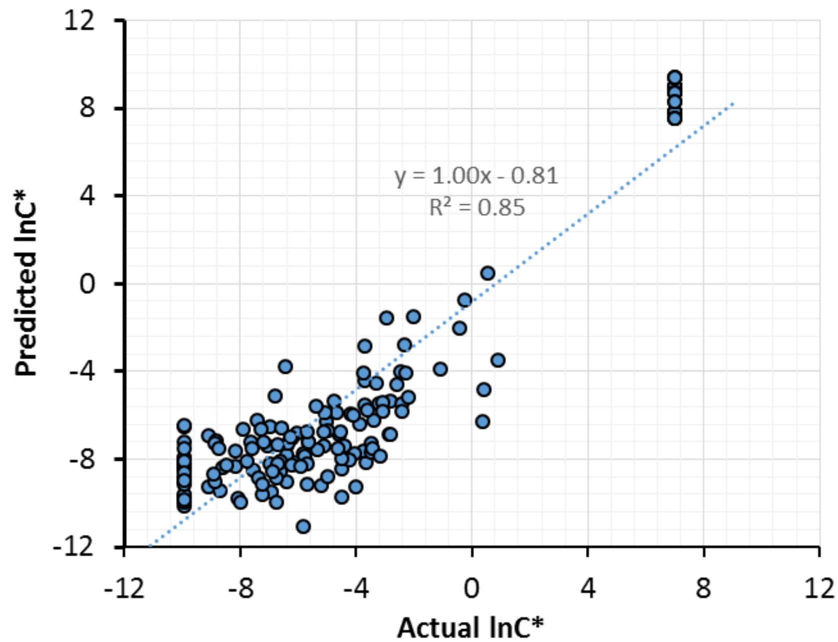


Figure 11: Predicted versus actual ln(TC*) for AST interlayer over soil-cement base

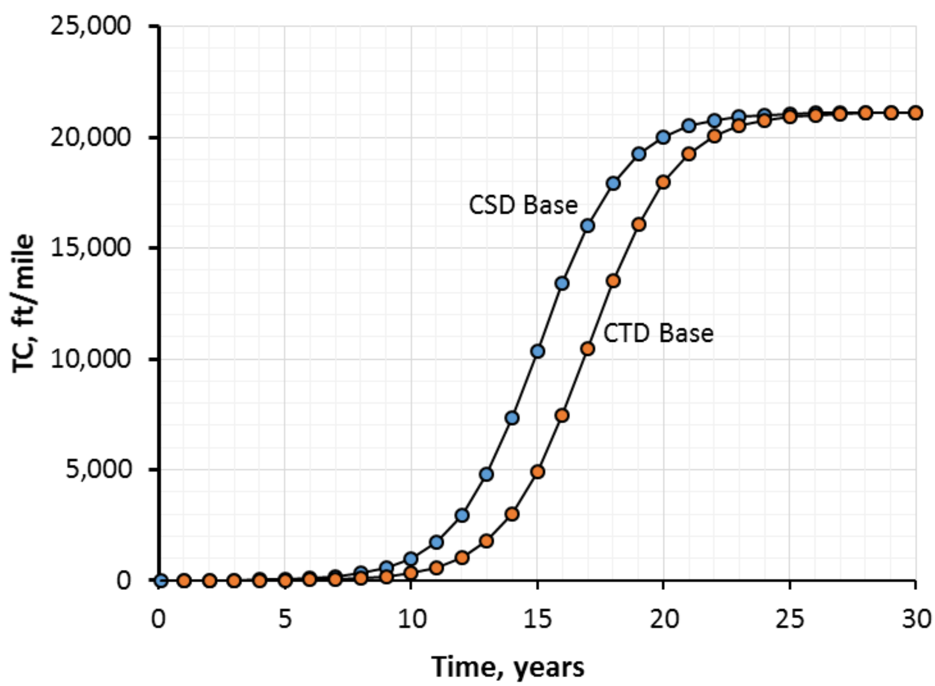


Figure 12: TC model behavior for AST interlayer over soil-cement base

Longitudinal Cracking. About 198.5 miles of flexible pavement with AST interlayer over base layer were analyzed for longitudinal cracking. However, the regression analyses were conducted on 137.8 of data for longitudinal cracking based on data availability and acceptance criteria. It should be noted that all cracking modes follow the sigmoidal function which were converted to a linear form for linear regression analysis. The result of the regression generated the following equation.

$$\ln(LC^{*}) = ln\left(\frac{LC+1}{Max-(LC+1)}\right) = a_o + a_1\left(\frac{SR}{T_h}\right) + a_2 t + a_3 ln(CESAL) \qquad (24)$$

where, *LC* equals transverse cracking (ft/mile), *Max* equals 10,560 ft/mile, *CESAL* equals cumulative ESAL, T_h equals thickness of HMA overlay (in), *t* equals to time in years, and *SR* represent the compressive strength ratio with respect to CTD (150 psi). For CTD *SR* = 1 and for CSD *SR* = 2. The results of the statistical analysis are shown in Table 18.

After conducting the regression, the following equations were obtained to predict the actual longitudinal cracking.

$$LC = \frac{10{,}560}{1+exp^{-\{\beta(-11.317+2.1484(SR/Th)+0.4596(t)+0.3057(lnCESAL))\}}} - 1 \qquad (25)$$

Here, *LC* equals longitudinal cracking (ft/lane-mile) β equals 1.205 for longitudinal crack is calibration factor obtained by minimizing the RMSE value using the above model.

The predicted versus the measured *ln(LC*)* value for AST interlayer on soil-cement base for flexible pavement is shown in Figure 13. It can be seen that there is a good agreement between the predicted and measured values, thus indicating that the model was able to predict the longitudinal cracking reasonably well. Furthermore, the variables used in the models are statistically significant with p-value ≤0.05, except for *SR/Th* which is significant with p-value of 0.13. Figure 14 depict the predicted LC for both CTD and CSD base types.

Table 18: Statistics of the regression analysis of LC model for AST interlayer over soil cement base of flexible pavements

Regression Statistics	
Multiple R	0.91
R Square	0.83
Adjusted R Square	0.83
Standard Error	1.89
Observations	162

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*	
Regression	3	2795.2	931.73	261.83	4.51004E-61	
Residual	158	562.3	3.56			
Total	161	3357.4				
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept (a_o)	-11.3170	1.0854	-10.43	1.1E-19	-13.4608	-9.1732
SR/T$_h$ (a_1)	2.1484	1.4111	1.52	1.3E-01	-0.6386	4.9354
t (a_2)	0.4596	0.0184	24.96	1.1E-56	0.4232	0.4959
Ln(CESAL) (a_3)	0.3057	0.0800	3.82	1.9E-04	0.1477	0.4637

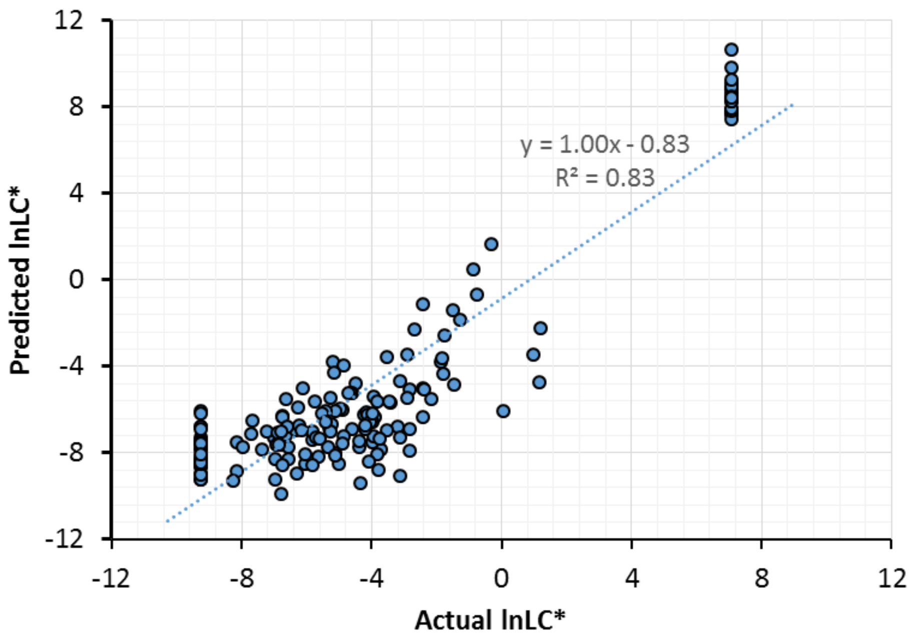


Figure 13: Predicted versus actual ln(LC*) for AST interlayer over soil-cement base

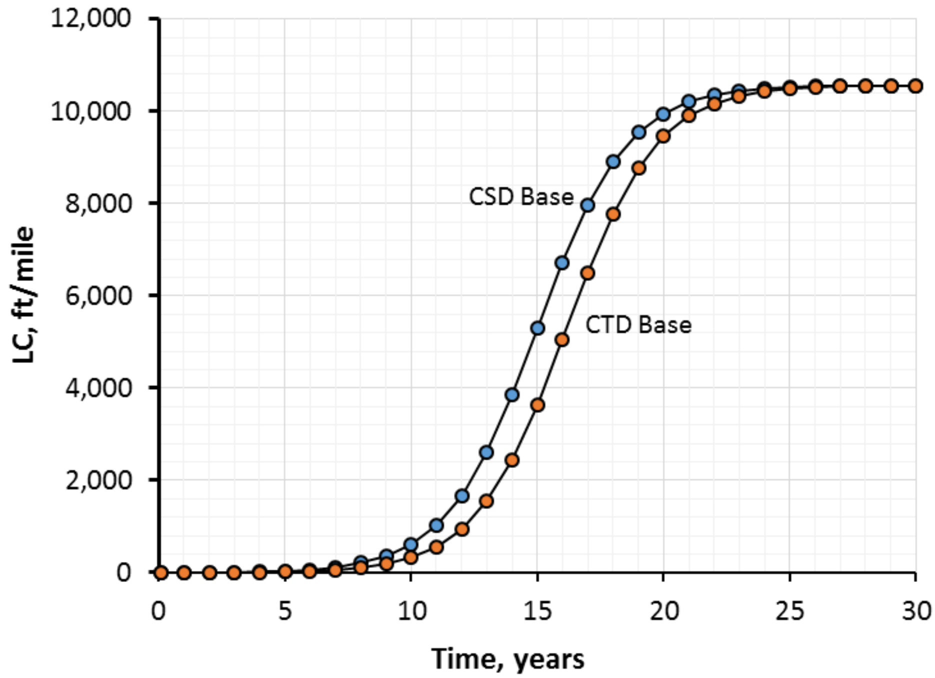


Figure 14: LC model behavior for AST interlayer over soil-cement base

Alligator Cracking. Approximately 198.5 miles of flexible pavement with AST interlayer over base layer were extracted for alligator cracking. Based on data availability and acceptance criteria, the regression analyses were conducted on 142.6 miles of data. Similar to the other cracking the alligator model also followed the sigmoidal function. The function was then reduced to a linear equation for linear regression analysis. The result of the regression produced the following equation.

$$\ln(AC) = ln\left(\frac{AC+1}{Max-(AC+1)}\right) = a_o + a_1(T_h) + a_2(T_h)(T_b) + a_3(SR)(T_h) + a_4(SR)(T_b) + a_5\ln(CESAL).t \quad (26)$$

where, *AC* equals alligator cracking (ft^2/mile), *Max* equals 31,680 ft^2/lane-mile *CESAL* equals cumulative ESAL, *t* equals to time in years, T_h and T_b equals thickness of HMA and base layers in inches, respectively, and *SR* represents the compressive strength ratio with respect to CTD (150 psi). In this study, for CTD *SR* = 1 and for CSD *SR* = 2. The results of the statistical analysis are shown in Table 19.

Table 19: Statistics of the regression analysis of AC model for AST interlayer over soil cement base of flexible pavements

Regression Statistics	
Multiple R	0.88
R Square	0.77
Adjusted R Square	0.76
Standard Error	2.21
Observations	163

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*	
Regression	5	2531.3	506.26	103.58	6.96028E-48	
Residual	157	767.4	4.89			
Total	162	3298.7				
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept (a_o)	0.9863	3.6292	0.27	7.9E-02	-6.1820	8.1546
T_h (a_1)	-5.6915	2.3976	-2.37	1.9E-02	-10.4272	-0.9558
(T_h).(T_b) (a_2)	0.3030	0.1182	2.56	1.1E-02	0.0696	0.5364
(SR).(T_h) (a_3)	1.2467	0.7459	1.67	9.7E-02	-0.2266	2.7201
(SR).(T_b) (a_4)	-0.4255	0.2335	-1.82	7.0E-02	-0.8867	0.0357
Ln(CESAL).t (a_5)	0.0349	0.0019	18.09	3.0E-40	0.0311	0.0388

After the regression analysis, the following equation was obtained to predict the actual alligator cracking.

$$AC = \frac{31{,}680}{1+exp^{-\{\beta(\gamma+a_o+a_1(T_h)+a_2(T_h)(T_b)+a_3(SR)(T_h)+a_4(SR)(T_b)+a_5\ln(CESAL).t)\}}} - 1 \qquad (27)$$

Here, *AC* equals alligator cracking (ft^2/lane-mile), $\beta = 1.308$ and $\gamma = 1.288$ are calibration factors obtained by minimizing the RMSE value using the above model.

The predicted versus the measured *ln(AC*)* value for AST interlayer on soil-cement base for flexible pavement is shown in Figure 15. It can be seen that there is a good agreement between the predicted and measured values, thus indicating that the model was able to predict the alligator crack reasonably well. Additionally, the variables used in the models are statistically significant with p-value ≤0.10. Figure 16 depicts the predicted LC for both CTD and CSD base types at low and medium ESAL levels. It is evident that there is no impact of base type on alligator cracking; however, it is significantly higher values for medium ESAL category.

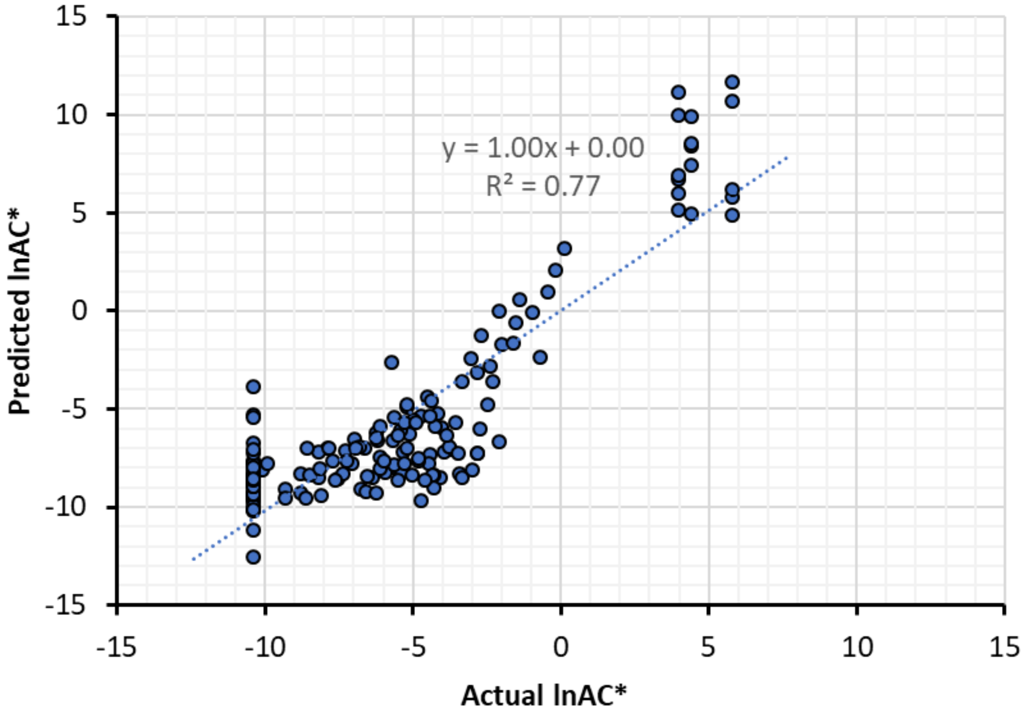


Figure 15: Predicted versus actual ln(AC*) of AST interlayer over soil-cement base

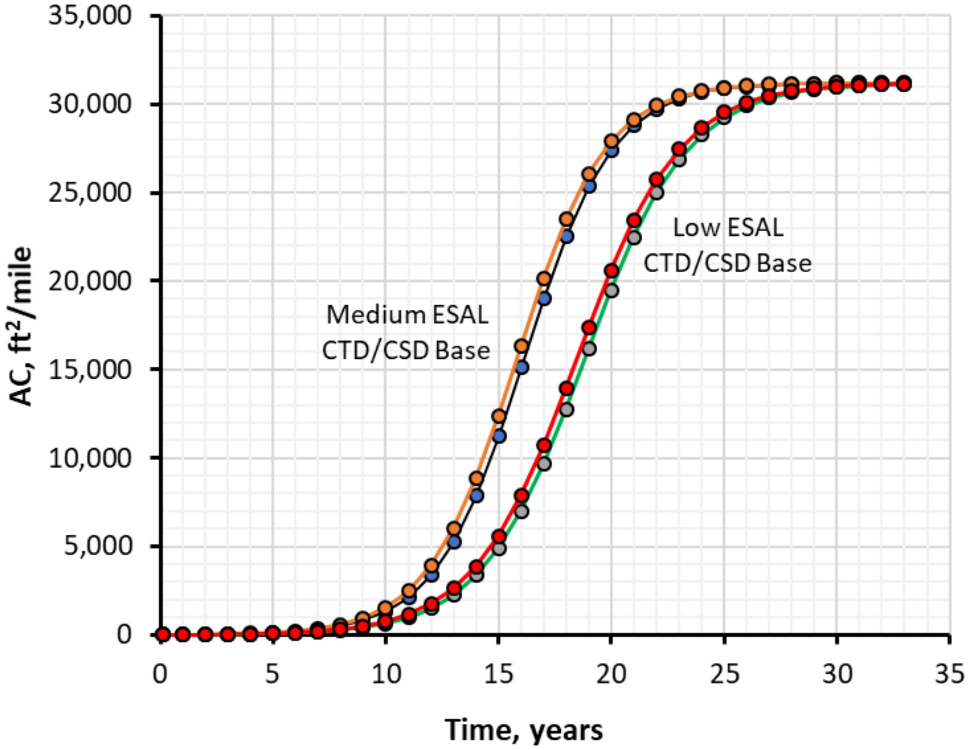


Figure 16: AC model behavior for AST interlayer over soil-cement base

International Roughness Index (IRI). In this study, 198.5 miles of flexible pavement with AST interlayer over base layer were analyzed and regression analyses were conducted on 118.5 miles of data for IRI based on data availability and project acceptance criterion. Recall, the IRI model follows the exponential function which can be written as linear form to conduct linear regression analysis. The result of such regression yielded the following form of the equation.

$$\ln(\mathrm{IRI}) = \mathrm{a_o} + \mathrm{a_1 t} + \mathrm{a_2}\left(\frac{\mathrm{SR}.Th}{\mathrm{Tb}}\right) + \mathrm{a_3}\ln(ESAL) \tag{28}$$

where, IRI equals IRI (in/mile), ESAL equals ESAL/year, t equals to time in years, T_h and T_b refers to thickness of HMA and base layer in inches, respectively. SR represents the compressive strength ratio with respect to CTD strength of 150 psi. For CTD SR = 150/150= 1 and for CSD SR = 300/150= 2. The results of the statistical analysis are shown in Table 20.

After conducting the regression, the following equation was obtained to predict the actual IRI.

$$IRI = exp^{\beta\{\gamma+3.6940+0.0353\mathrm{t}-0.1471\left(\frac{\mathrm{SR.Th}}{\mathrm{Tb}}\right)+0.0610\ln(ESAL)\}} \tag{29}$$

Here, *IRI* equals International Roughness Index(in/mile), $\beta = 1.4913$ and $\gamma = -1.4109$ are calibration factors for the above model.

The predicted versus the measured IRI value for AST interlayer on soil-cement base for flexible pavement is shown in Figure 17. It can be seen that there is a fair agreement between the predicted and measured values, thus indicating that the model was able to predict IRI fairly. Furthermore, all the variables used in the models are statistically significant with p-value ≤0.05. Figure 18 depicts the predicted IRI for both CTD and CSD base types. It is obvious that the IRI behaves similarly for CTD and CSD base types, which is consistent with the SL analysis of IRI for both bases. From Figure 17, it is also seen that few data points are not predicted properly. It happens as these models do not include any environmental factors such as any temperature or precipitation indexes. Due to lack of environmental information, those indexes could not be included in this model. However, this is somewhat acceptable model as no better models were found from the existing data.

Table 20: Statistics of the regression analysis of IRI model for AST interlayer over soil cement base of flexible pavements

SUMMARY OUTPUT

Regression Statistics	
Multiple R	*0.49*
R Square	*0.24*
Adjusted R Square	*0.23*
Standard Error	*0.29*
Observations	*177*

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	*3*	*4.8*	*1.60*	*18.69*	*1.51E-10*
Residual	*173*	*14.8*	*0.09*		
Total	*176*	*19.6*			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept (a_0)	*3.6940*	*0.1163*	*31.77*	*4.1E-74*	*3.4645*	*3.9235*	*3.4645*	*3.9235*

t (a_1)	*0.0353*	*0.0075*	*4.68*	*5.8E-06*	*0.0204*	*0.0502*	*0.0204*	*0.0502*
*SR*Th/Tb (a_2)*	*-0.1471*	*0.0671*	*-2.19*	*3.0E-02*	*-0.2796*	*-0.0147*	*-0.2796*	*-0.0147*
ln(ESAL) (a_3)	*0.0610*	*0.0128*	*4.78*	*3.7E-06*	*0.0358*	*0.0862*	*0.0358*	*0.0862*

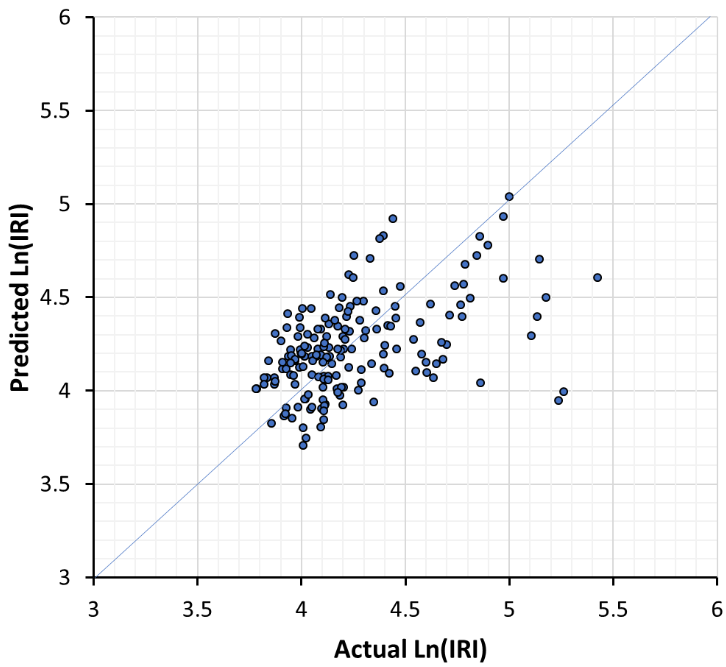


Figure 17: Predicted versus actual ln(IRI) for AST interlayer over soil-cement base

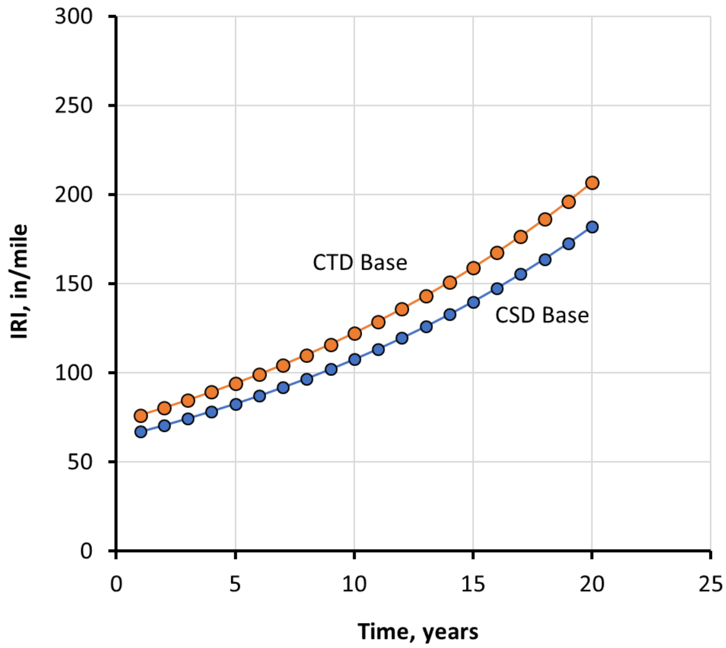


Figure 18: IRI model behavior for AST interlayer over soil-cement base

Rut Depth. In this study, 198.5 miles of flexible pavement with AST interlayer over base layer were analyzed and regression analyses were conducted on 143.1 miles of data for rut depth based on data availability and project acceptance criterion. Recall, the rut model follows the power function which can be written as linear form to conduct linear regression analysis. The result of such regression yielded the following form of the equation.

$$\ln(Rut) = a_o + a_1\,(\ln(t)\,) + a_2\left(\frac{SR*Tb}{Th}\right) + a_3\left(\frac{\ln(CESAL)*SR}{Th+Tb}\right) \qquad (30)$$

where, *Rut* equals Rut Depth (in), C*ESAL* equals cumulative ESAL, T_h *and* T_b refer to thickness of HMA overlay (in) and Base (in), *t* equals to time in years, and *SR* represent the compressive strength ratio with respect to CTD strength of 150 psi. For CTD *SR* = 150/150= 1 and for CSD *SR* = 300/150= 2. The results of the statistical analysis are shown in Table 21.

After conducting the regression, the following equation was obtained to predict the actual Rut Depth.

$$Rut = exp^{\beta\{\gamma - 3.7160 + 0.5722\ln(t) + 0.0825\frac{SR*Tb}{Th} + 0.2928\left(\frac{\ln(CESAL)*SR}{Th+Tb}\right)\}} \qquad (31)$$

Here, *Rut* equals Rut depth (inches), $\beta = 1.2013$ and $\gamma = 0.3792$ are calibration factors for the above model.

The predicted versus the measured ln(Rut) value for AST interlayer on soil-cement base for flexible pavement is shown in Figure 19. All the variables used in the models are statistically significant with p-value ≤0.05. Figure 20 depicts the predicted Rut behavior for both CTD and CSD base types. It is obvious that the CSD bases higher Rut from the CSD bases as described in the previous section. The CTD base exhibits less rutting to CSD for AST interlayer. It's worth mentioning here that there are only 6 CTD projects for AST interlayer which is included in Rut analysis. This behavior is consistent with the SL analysis conducted in this study. In Figure 19, it is shown that rut is not always predicted with a fair margin, as there is some difference between the actual and predicted rut for some data points. It may happen as this model does not include any environmental factors such as any temperature or precipitation indexes. Due to the lack of environmental information, those indexes could not be included in this model. However, this is a somewhat acceptable model as no better models were not found from the existing data.

Table 21: Statistics of the regression analysis of Rut model for AST interlayer over soil cement base of flexible pavements

SUMMARY OUTPUT

Regression Statistics	
Multiple R	*0.89*
R Square	*0.79*
Adjusted R Square	*0.79*
Standard Error	*0.51*
Observations	*179*

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	*3*	*176.9*	*58.97*	*223.40*	*1.3577E-59*
Residual	*175*	*46.2*	*0.26*		
Total	*178*	*223.1*			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	*-3.7160*	*0.2184*	*-17.02*	*6.1E-39*	*-4.1471*	*-3.2850*	*-4.1471*	*-3.2850*
ln(t)	*0.5722*	*0.0248*	*23.12*	*4.5E-55*	*0.5233*	*0.6210*	*0.5233*	*0.6210*
*SR*Tb/Th*	*0.0825*	*0.0351*	*2.35*	*2.0E-02*	*0.0132*	*0.1519*	*0.0132*	*0.1519*
*ln(CESAL)*SR/(Th+Tb)*	*0.2928*	*0.0891*	*3.28*	*1.2E-03*	*0.1169*	*0.4688*	*0.1169*	*0.4688*

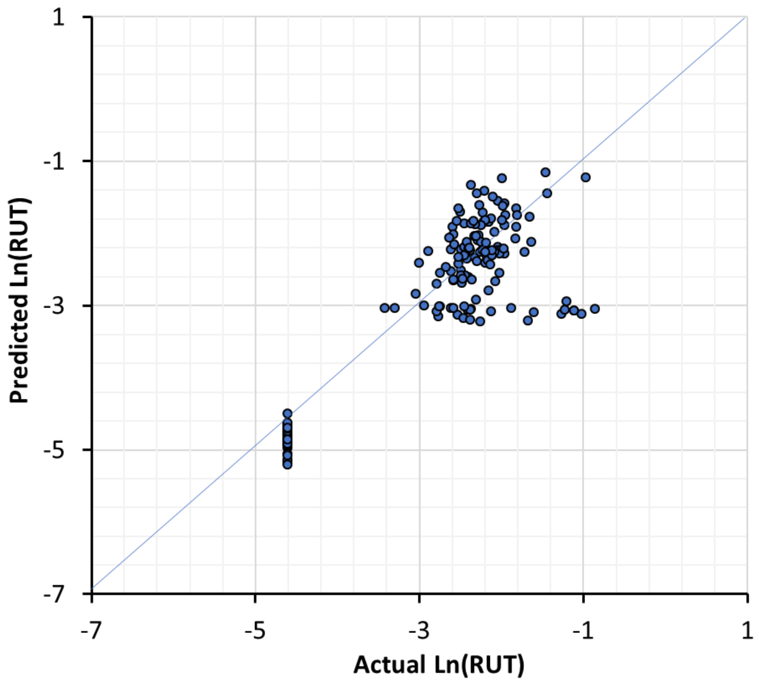


Figure 19: Predicted versus actual ln(Rut) for AST interlayer over soil-cement base

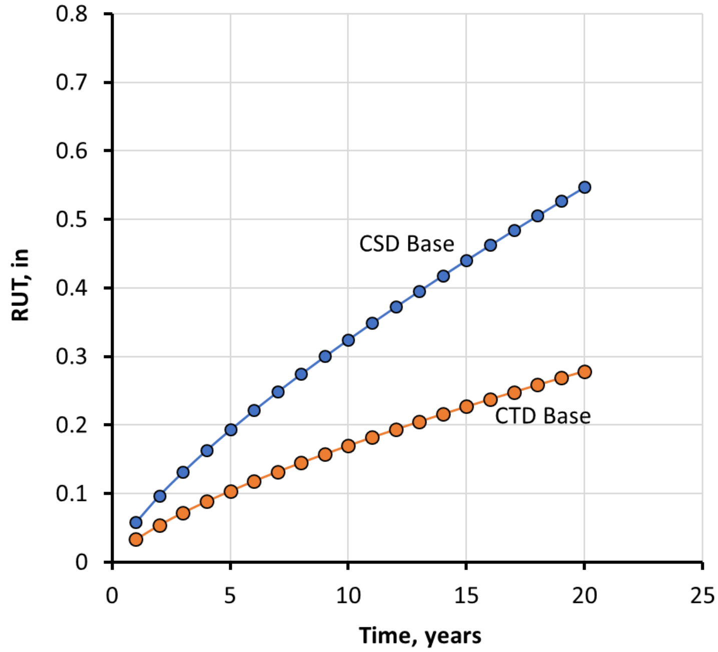


Figure 20: Rut model behavior for AST interlayer over soil-cement base

No AST Interlayer Over Soil-Cement Base

Transverse Cracking. The linear regression analysis was conducted to develop TC cracking models for flexible pavements without any AST interlayer on soil-cement base. About, 452.5 miles of flexible pavement data without AST interlayer over base layer were obtained and analyzed. The regression analyses were conducted on 441.0 miles of data for transverse cracking based on data availability and acceptance criteria. The linear regression analysis yielded the following equation.

$$\ln(TC^*) = ln\left(\frac{TC+1}{Max-(TC+1)}\right) = a_o + a_1\left(\frac{SR}{T_h}\right) + a_2 t + a_3 ln(CESAL) \quad (32)$$

where, *TC* equals transverse cracking (ft/mile), *Max* equals 21,120 ft/mile, *CESAL* equals cumulative ESAL, T_h equals thickness of HMA overlay (in), *t* equals to time in years, and *SR* represent the compressive strength ratio with respect to CTD (150 psi). For CTD *SR* = 1 and for CSD *SR* = 2. The results of the statistical analysis are shown in Table 22.

The above equation was reduced to the following equation to predict the actual transverse cracking.

$$TC = \frac{21120}{1+exp^{-\{\beta(\gamma-9.5933+2.8682(SR/Th)+0.4665(t)+0.0794(lnCESAL))\}}} - 1 \quad (33)$$

Here, *TC* equals transverse cracking (ft/lane-mile), $\beta = 1.47$ and $\gamma = 1.09$ are calibration factor obtained by minimizing the RMSE value using the above model.

The predicted versus the measured *ln (TC*)* value for AST interlayer on soil-cement base for flexible pavement is shown in Figure 21. It can be seen that there is a good agreement between the predicted and measured values, thus indicating that the model was able to predict the transverse cracking reasonably well. Furthermore, all the variables used in the models are statistically significant with p-value $\leq$0.05. Figure 22 depicts the predicted TC for both CTD and CSD base types. It is obvious that the TC values increases with the increase in time due to increase in cumulative ESAL. The CTD base exhibits low TC cracking relative to CSD for no AST interlayer. This behavior is consistent with the SL analysis conducted in this study with slight increase of 2 years in SL for CTD bases at TC threshold of 10,560 ft/lane-mile.

Table 22: Statistics of the regression analysis of TC model for no AST interlayer over soil cement base of flexible pavements

Regression Statistics	
Multiple R	0.83
R Square	0.68
Adjusted R Square	0.68
Standard Error	1.79
Observations	794

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	3	5418.3	1806.09	562.60	1.4924E-195
Residual	790	2536.1	3.21		
Total	793	7954.4			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept (a_o)	-9.5933	0.3908	-24.55	2.5E-99	-10.3605	-8.8261
SR/T$_h$ (a_1)	2.8682	0.4551	6.30	4.9E-10	1.9748	3.7616
t (a_2)	0.4665	0.0128	36.46	1.8E-171	0.4414	0.4916
lnCESAL (a_3)	0.0794	0.0328	2.42	1.6E-02	0.0151	0.1437

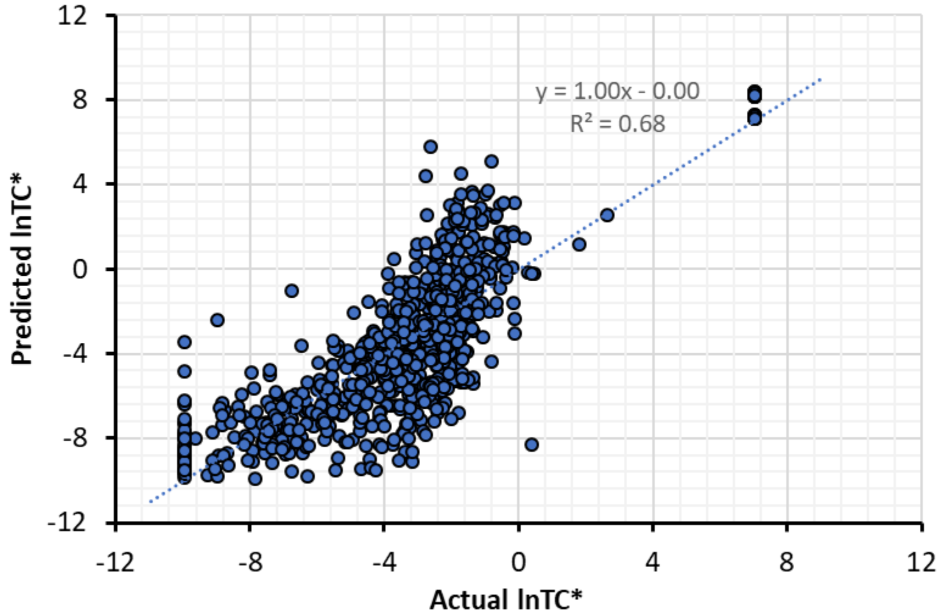


Figure 21: Predicted versus actual ln(TC*)

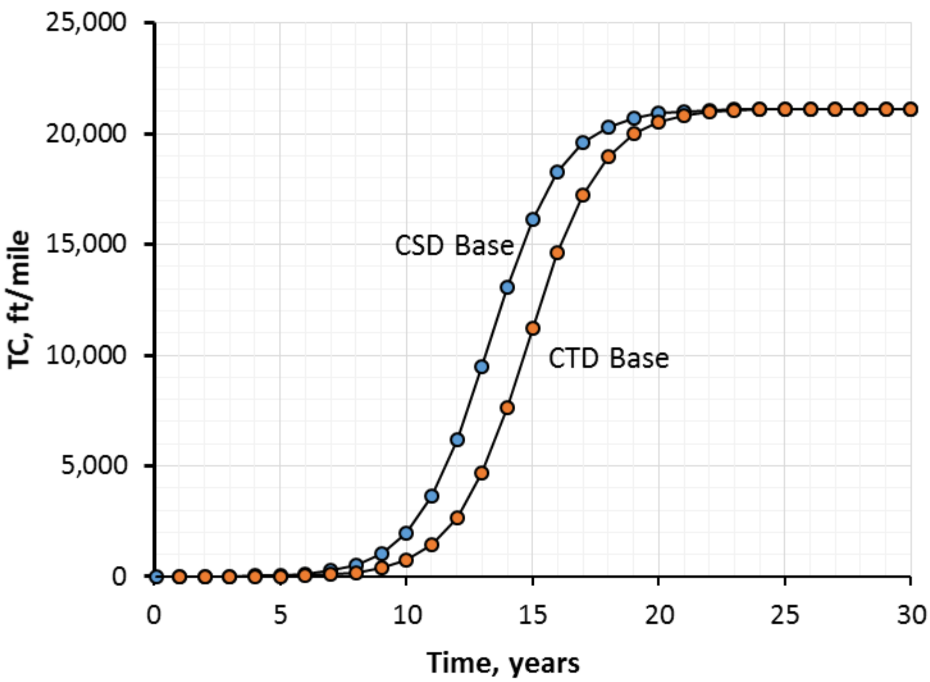


Figure 22: TC model behavior for no AST interlayer over soil-cement base

Longitudinal Cracking. About 452.5 miles of flexible pavement with no AST interlayer over base layer were analyzed for longitudinal cracking. However, the regression analyses were conducted on 447.2 miles of data for longitudinal cracking based on data availability and acceptance criteria. It should be noted that all cracking models followed the sigmoidal function which were converted to the following form for linear regression analysis.

$$\ln(LC^{*}) = ln\left(\frac{LC+1}{Max-(LC+1)}\right) = a_o + a_1\left(\frac{SR}{T_h}\right) + a_2 t + a_3 ln(ESAL).t \quad (34)$$

where, LC equals transverse cracking (ft/mile), Max equals 10,560 ft/mile, $ESAL$ equals ESAL/year, T_h equals thickness of HMA overlay (in), t equals to time in years, and SR represent the compressive strength ratio with respect to CTD (150 psi). For CTD SR = 1 and for CSD SR = 2. The results of the statistical analysis are shown in Table 23.

Table 23: Statistics of the regression analysis of LC model for no AST interlayer over soil cement base of flexible pavements

Regression Statistics	
Multiple R	0.84
R Square	0.70
Adjusted R Square	0.70
Standard Error	2.08
Observations	930

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	3	9458.4	3152.80	729.31	2.8024E-243
Residual	926	4003.1	4.32		
Total	929	13461.5			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept (a_o)	-7.1225	0.2516	-28.31	1.5E-127	-7.6162	-6.6288
SR/T_h (a_1)	-1.1995	0.4916	-2.44	1.5E-02	-2.1643	-0.2346
t (a_2)	0.1910	0.0312	6.12	1.4E-09	0.1298	0.2523
*Ln(ESAL)*t* (a_3)	0.0267	0.0028	9.38	5.1E-20	0.0211	0.0322

After conducting the regression, the following equations were obtained to predict the actual longitudinal cracking.

$$LC = \frac{10{,}560}{1+exp^{-\{\beta(\gamma-7.1225-1.1995(SR/Th)+0.1910(t)+0.0267(lnESAL)t)\}}} - 1 \quad (35)$$

Here, *LC* equals longitudinal cracking (ft/lane-mile), β = 1.429 and γ = 0.93 calibration factors obtained by minimizing the RMSE value using the above model.

The predicted versus the measured *ln(LC*)* value for no AST interlayer on soil-cement base for flexible pavement is shown in Figure 23. It can be seen that there is a good agreement between the predicted and measured values, thus indicating that the model was able to predict the transverse cracking reasonably well. Furthermore, the variables used in the models are statistically significant with p-value ≤0.05. Figure 24 depicts the predicted LC behavior for both CTD and CSD base types. It seems that the base type has not much effect on the LC of no interlayer system.

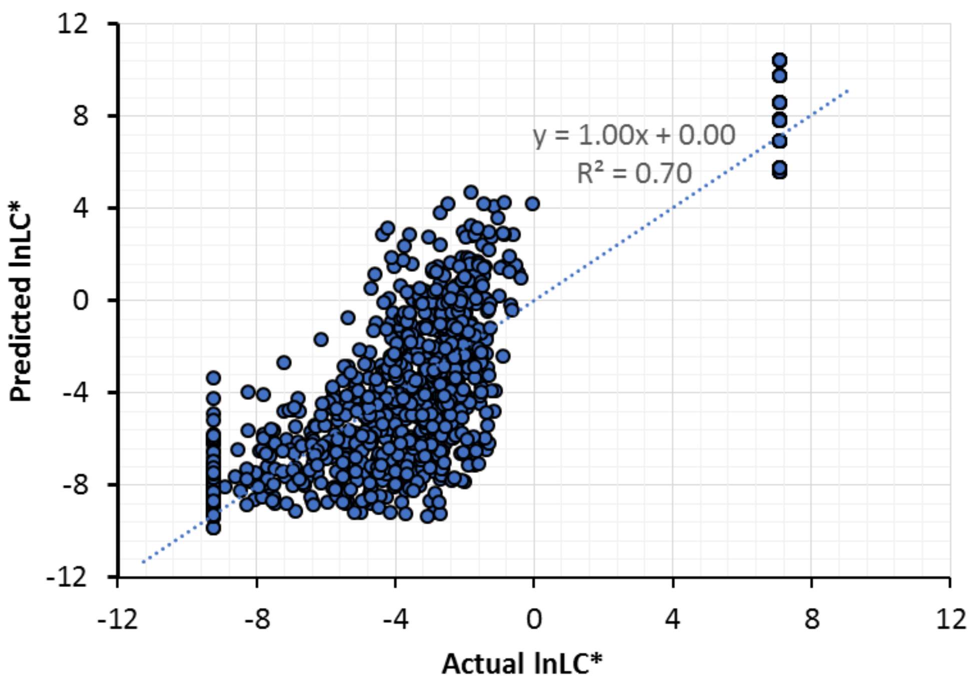


Figure 23: Predicted versus actual ln(LC*) for no AST interlayer pavements

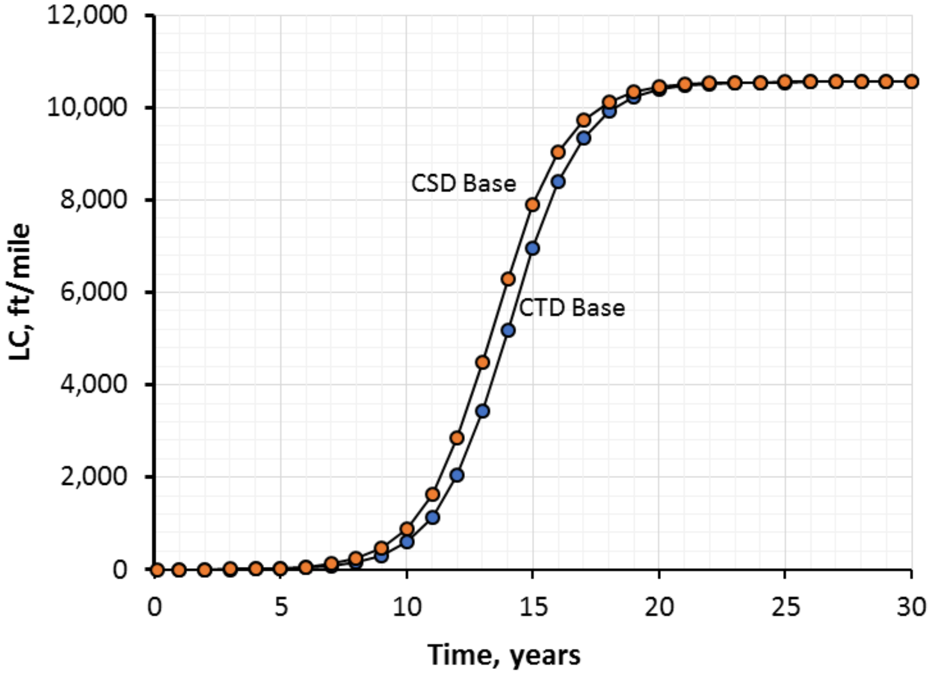


Figure 24: LC model behavior for no AST interlayer over soil-cement base

Alligator Cracking. Approximately 452.5 miles of flexible pavement with no AST interlayer over base layer were extracted for alligator cracking analysis. Based on data availability and acceptance criteria the regression analyses were conducted on 434.9 miles of data. Similar to the other cracking, the alligator model also followed the sigmoidal function. The function was then reduced to a linear equation for linear regression analysis. The result of the regression produced the following equation.

$$\ln(AC^*) = ln\left(\frac{AC+1}{Max-(AC+1)}\right) = a_o + a_1(T_h) + a_2(T_b) + a_3(SR)(T_b) + a_4 \ln(CESAL)\,.\,t \qquad (36)$$

where, AC equals alligator cracking (ft/mile), Max equals 31,680 ft^2/lane-mile $CESAL$ equals cumulative ESAL, t equals to time in years, T_h and T_b equals thickness of HMA and base layers in inches, respectively, and SR represents the compressive strength ratio with respect to CTD (150 psi). In this study, for CTD $SR = 1$ and for CSD $SR = 2$. The results of the statistical analysis are shown in Table 24.

After the regression analysis, the following equation was obtained to predict the actual alligator cracking.

$$AC = \frac{31{,}680}{1+exp^{-\{\beta(\gamma+a_o+a_1(T_h)+a_2(T_b)+a_3(SR)(T_b)+a_4\ln(CESAL).t)\}}} - 1 \qquad (37)$$

Here, *AC* equals alligator cracking (ft^2/lane-mile), $\beta = 1.709$ and $\gamma = 1.1$ are calibration factors obtained by minimizing the RMSE value using the above model.

The predicted versus the measured *ln(AC*)* value for AST interlayer on soil-cement base for flexible pavement is shown in Figure 25. It can be seen that there is a good agreement between the predicted and measured values, thus indicating that the model was able to predict the alligator crack reasonably well. Additionally, the variables used in the models are statistically significant with p-value ≤0.05, except the variable (SR)(T_b). For the variable (SR)(T_b), the statistical significance for p-value is allowed to be ≤ 0.20, because of the importance of the variable. Also, no better model is found for this case. Figure 26 depicts the predicted AC behavior for both CTD and CSD base types for no AST interlayer. It is clear that there is no significant impact of base type on alligator cracking.

Table 24: Statistics of the regression analysis of AC model for no AST interlayer over soil cement base of flexible pavements

Regression Statistics	
Multiple R	0.76
R Square	0.59
Adjusted R Square	0.58
Standard Error	2.40
Observations	958

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	5	2531.3	506.26	103.58	6.96028E-48
Residual	157	767.4	4.89		
Total	162	3298.7			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept (a_o)	-5.2443	1.0801	-4.86	1.4E-06	-7.3641	-3.1246
T_h (a_1)	-0.8847	0.2080	-4.25	2.3E-05	-1.2928	-0.4765
T_b (a_2)	0.1185	0.0499	2.38	1.8E-02	0.0207	0.2164
(SR).(T_b) (a_3)	0.0321	0.0246	1.31	1.9E-01	-0.0162	0.0805
Ln(CESAL).t (a_4)	0.0318	0.0009	35.53	8.E-177	0.0301	0.0336

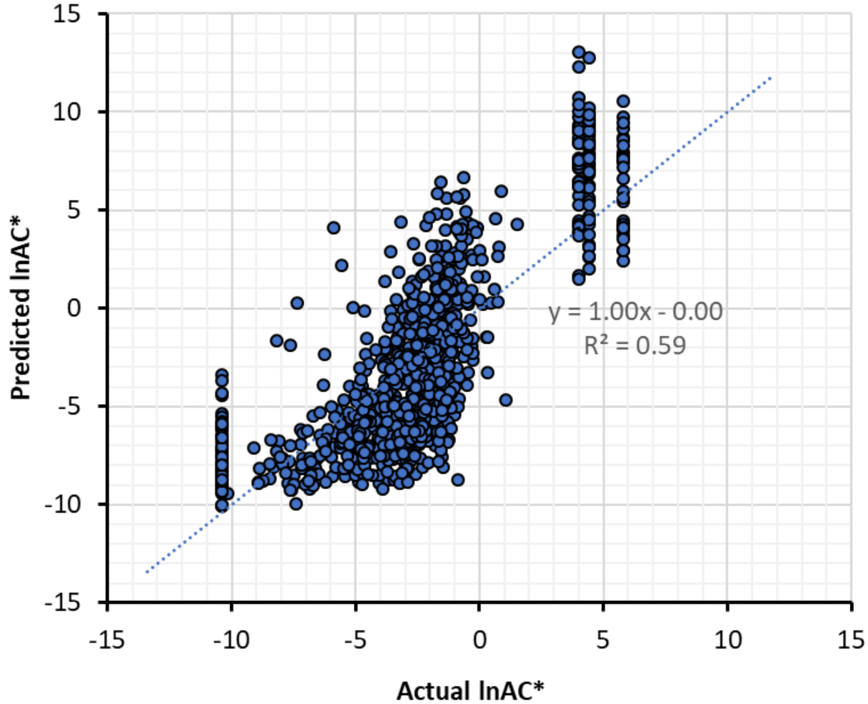


Figure 25: Predicted versus actual ln(AC*) for no AST interlayer

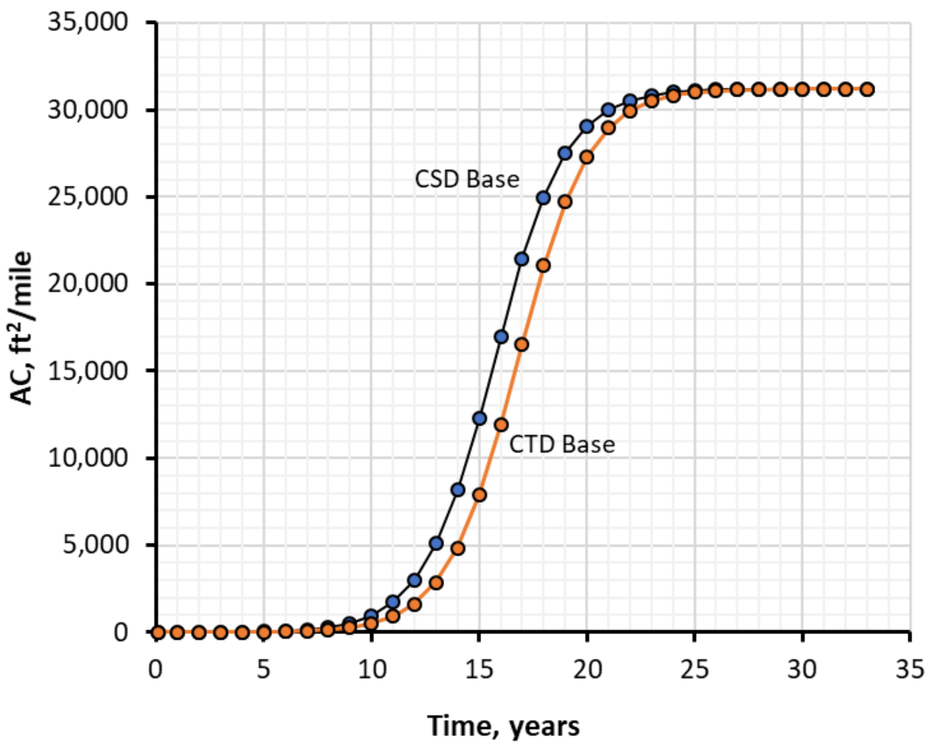


Figure 26: AC model behavior for no AST interlayer over soil-cement base

International Roughness Index (IRI). In this study, 452.5 miles of flexible pavement with No AST interlayer over base layer were analyzed and regression analyses were conducted on 420.2 miles of data for IRI based on data availability and project acceptance criterion. Recall, the IRI model follows the exponential function which can be written as linear form to conduct linear regression analysis. The result of such regression yielded the following form of the equation.

$$\ln(\mathrm{IRI}) = \mathrm{a_o} + \mathrm{a_1}.\mathrm{SR} + \mathrm{a_2}.Th + \mathrm{a_3}Tb + \mathrm{a_4}t + \mathrm{a_5}\ln(ESAL)\,.\,t \quad (38)$$

where, IRI equals IRI (in/mile), ESAL equals ESAL/year, t equals to time in years, T_h and T_b refers to thickness of HMA and Base layer in inches, respectively. SR represents the compressive strength ratio with respect to CTD strength of 150 psi. For CTD SR = 150/150= 1 and for CSD SR = 300/150= 2. The results of the statistical analysis are shown in Table 25.

After conducting the regression, the following equation was obtained to predict the actual IRI.

$$IRI = exp^{\beta\{\gamma + 4.0384 - 0.1026\mathrm{SR} + 0.1031Th - 0.0148Tb + 0.0170t + 0.0015\ln(ESAL).t\}} \quad (39)$$

Here, *IRI* equals International Roughness Index (in/mile), $\beta = 1.9306$ and $\gamma = -2.0873$ are calibration factors for the above model.

The predicted versus the measured IRI value for No AST interlayer on soil-cement base for flexible pavement is shown in Figure 27. It can be seen that there is a good agreement between the predicted and measured values, thus indicating that the model was able to predict IRI fairly. Furthermore, all the variables used in the models are statistically significant with p-value ≤0.05. Figure 28 depicts the predicted IRI for both CTD and CSD base types. It is obvious that the IRI behaves similarly for CTD and CSD base types, which is consistent with the SL analysis of IRI for both bases.

Table 25: Statistics of the regression analysis of IRI model for no AST interlayer over soil cement base of flexible pavements

SUMMARY OUTPUT

Regression Statistics	
Multiple R	*0.64*
R Square	*0.41*

Adjusted R Square	*0.41*
Standard Error	*0.21*
Observations	*1001*

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	*5*	*31.0*	*6.21*	*138.13*	*3E-111*
Residual	*995*	*44.7*	*0.04*		
Total	*1000*	*75.7*			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	*4.0384*	*0.0954*	*42.35*	*7.4E-225*	*3.8513*	*4.2256*	*3.8513*	*4.2256*
SR	*-0.1026*	*0.0167*	*-6.14*	*1.2E-09*	*-0.1354*	*-0.0698*	*-0.1354*	*-0.0698*
Th	*0.1031*	*0.0180*	*5.72*	*1.4E-08*	*0.0677*	*0.1385*	*0.0677*	*0.1385*
Tb	*-0.0148*	*0.0051*	*-2.88*	*4.1E-03*	*-0.0249*	*-0.0047*	*-0.0249*	*-0.0047*
t	*0.0170*	*0.0034*	*4.9248*	*9.9E-07*	*0.0102*	*0.0237*	*0.0102*	*0.0237*
*ln(ESAL)*t*	*0.0015*	*0.0004*	*4.0495*	*5.5E-05*	*0.0008*	*0.0022*	*0.0008*	*0.0022*

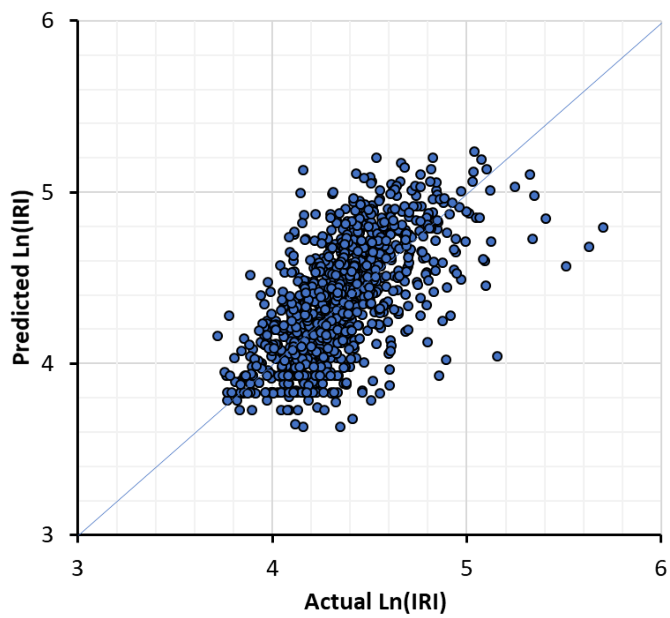


Figure 27: Predicted versus actual ln(IRI) for no AST interlayer over soil-cement

base

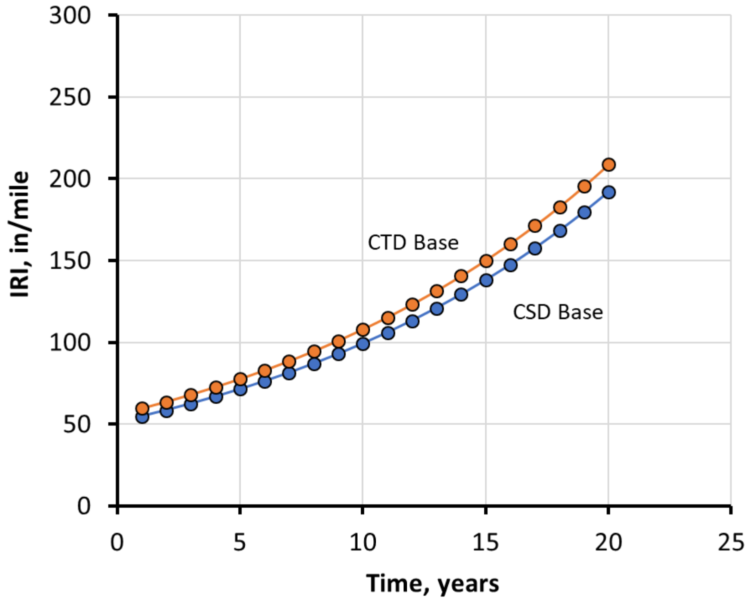


Figure 28: IRI model behavior for no AST interlayer over soil-cement base

Rut Depth. In this study, 452.5 miles of flexible pavement with no AST interlayer over base layer were analyzed and regression analyses were conducted on 451.7 miles of data for rut depth based on data availability and project acceptance criterion. Recall, the rut model follows the power function which can be written as linear form to conduct linear regression analysis. The result of such regression yielded the following form of the equation.

$$\ln(Rut) = a_o + a_1\,(\ln(t)) + a_2\left(\frac{\ln(CESAL)}{Th+Tb}\right) + a_3\left(\frac{SR*Th}{Tb}\right) \quad (40)$$

where, *Rut* equals rut depth (in.), C*ESAL* equals cumulative ESAL, T_h *and* T_b refers to thickness of HMA overlay (in.) and base (in.), *t* equals to time in years, and *SR* represents the compressive strength ratio with respect to CTD strength of 150 psi. For CTD *SR* = 150/150= 1 and for CSD *SR* = 300/150= 2. The results of the statistical analysis are shown in Table 26.

After conducting the regression, the following equation was obtained to predict the actual rut depth.

$$Rut = exp^{\beta\{\gamma - 3.3196 + 0.4755(\ln(t)\,) + 0.3185\left(\frac{\ln(CESAL)}{Th+Tb}\right) - 0.1692\left(\frac{SR*Th}{Tb}\right)\}} \quad (41)$$

Here, *Rut* equals rut depth (in.), $\beta = 1.1909$ and $\gamma = 0.4129$ are calibration factors for the above model.

The predicted versus the measured ln(Rut) value for no AST interlayer on soil-cement base for flexible pavement is shown in Figure 29. All the variables used in the models are statistically significant with p-value ≤0.05. Figure 30 depicts the predicted rut for both CTD and CSD base types. It is obvious that the CSD bases and CTD bases behaves similarly in this case. This behavior is somewhat consistent with the SL analysis conducted in this study. Figure 29 shows that rut is not always predicted with a fair margin because these models do not include any environmental factors such as any temperature or precipitation indexes. Due to this lack of environmental information, those indexes could not be included in this model. However, this is somewhat acceptable model and could be used for prediction.

Table 26: Statistics of the regression analysis of rut model for no AST interlayer over soil cement base of flexible pavements

SUMMARY OUTPUT

Regression Statistics	
Multiple R	*0.88*
R Square	*0.78*
Adjusted R Square	*0.78*
Standard Error	*0.42*
Observations	*988*

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	*3*	*623.8*	*207.92*	*1155.18*	*0*
Residual	*984*	*177.1*	*0.18*		
Total	*987*	*800.9*			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*
Intercept(a_0)	*-3.3196*	*0.0543*	*-61.14*	*0.0E+00*	*-3.4262*	*-3.2131*	*-3.4262*
ln(t)(a_1)	*0.4755*	*0.0111*	*42.95*	*7.6E-228*	*0.4538*	*0.4973*	*0.4538*
ln(CESAL)/(Th+Tb)(a_2)	*0.3185*	*0.0962*	*3.31*	*9.6E-04*	*0.1297*	*0.5072*	*0.1297*
*SR*Th/Tb(a_3)*	*-0.1692*	*0.0632*	*-2.68*	*7.6E-03*	*-0.2933*	*-0.0451*	*-0.2933*

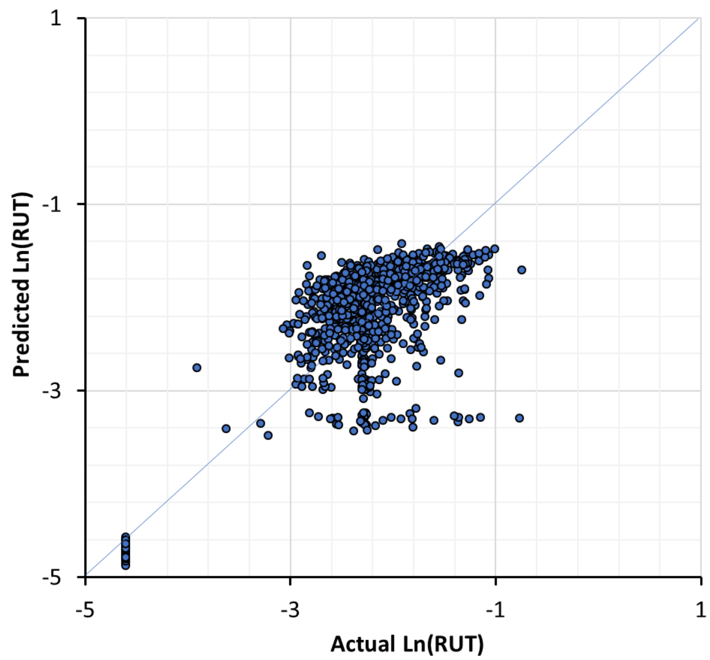


Figure 29: Predicted versus actual ln(Rut) for no AST interlayer over soil-cement base

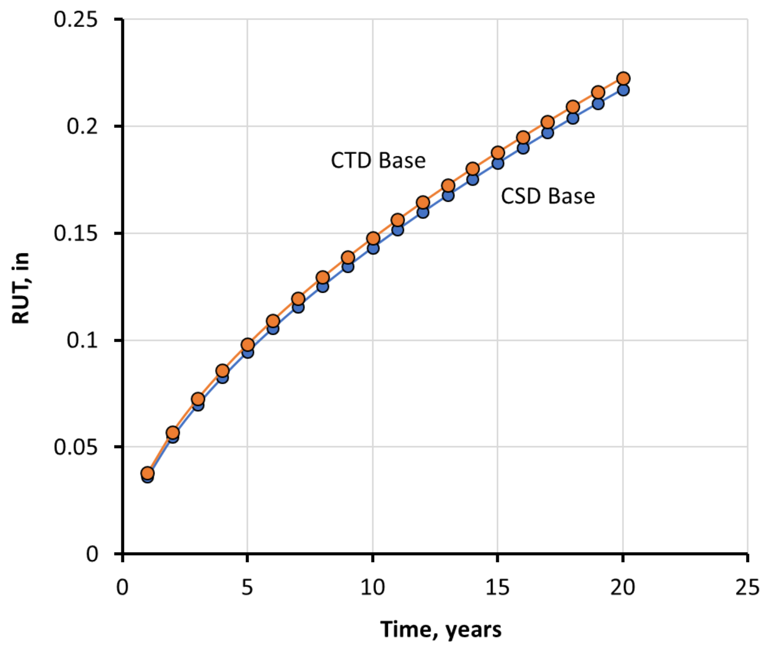


Figure 30: Rut model behavior for no AST interlayer over soil-cement base

Performance Evaluation of AST and No AST Interlayers

The performance of all AST and no AST interlayer sections were evaluated for all distress types using the aforementioned methodology with the help of MatExVba programs developed during the study.

Transverse Cracking Evaluation (3 data points)

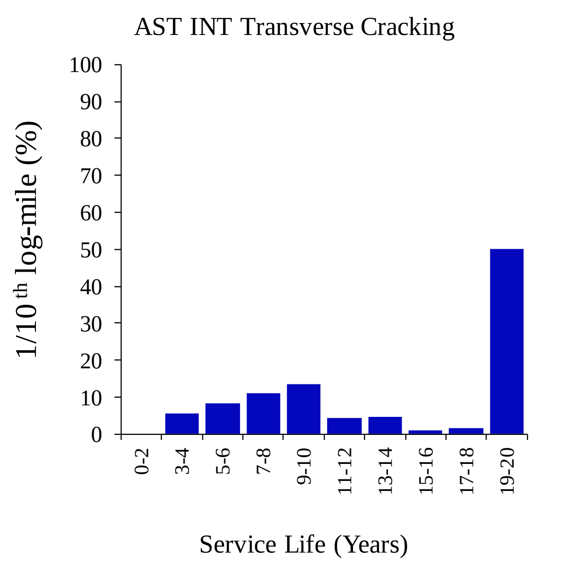
AST/No Interlayer over CSD Bases. All pavement sections for AST interlayer over CSD bases were analyzed and the resulting MatExVba outputs are shown in this section. Figure 31 is the MatExVba outputs illustrating the transverse cracking (TC) evaluation for AST interlayer over CSD bases. This group has HMA thickness (Th) range of 0-4 in. and ESAL range from 0-30,000 (which is Category x1). All such sections have 3 data points indicating 5 to 7 years of surface age. All this information is presented at the top three rows of the Figure 31. The average service life (AvgSL) and average net benefit area (AvgNBA) for this category is found to be 14.3 years and 13.1 ft-yr/ft, respectively. The number of projects (N(P) and pavement sections (N(S)) analyzed are 26 and 718, respectively. All this information is shown at the fourth row (from the top) of Figure 31. The distribution of ESAL for this category could be understood from various parameters listed on the bottom right side of Figure 31. The minimum, 25th percentile, median, average, 75th percentile, and maximum values for ESAL are 603, 2128, 6903, 9415, 13569, and 27494, respectively. Similarly, the corresponding ADT values for this category are reported as 91, 530, 1400, 1526, 1974, and 3819. The SL for all these sections are shown by histogram distribution on the middle left side of this figure. The distribution plot represents the percent of the total 1/10th log-mile sections in certain SL bracket. The percentage of sections present in each bracket of SL are shown at the middle right of the figure. The benefit cost ratio based on SL and net benefit area (NBA), as reported on the bottom left of the figure, are 67.4 Yrs/dollar and 61.7 Ft-yr/ft/Dollar, respectively. In this distribution, most sections (about 50%) have SL equal or greater than 20 years. The SL of rest of the sections are distributed from 3 to 18 years. This category of AST interlayer will be compared with a similar category of no interlayer sections to determine the effectiveness of AST interlayer as discussed in the next section of this report.

Figure 32 describes Category x2 where TC of AST interlayer over CSD with ESAL 30,001-2,000,000, HMA thickness 0-4 in. is shown. In this category, very few AST interlayer projects were available (N(P)=2), so these results are not conclusive. However, these projects have lower benefits and service lives in general to the previous lower ESAL Category x1 shown in Figure 31. These results were expected as higher ESAL is supposed to reduce benefits and service lives.

Figure 33 shows Category x4 where TC of AST interlayer over CSD with ESAL 30,001-2,000,000, HMA thickness (Th) range > 4 in. is illustrated. In this category, fewer AST interlayer projects were available (N(P)=8) with higher ESAL and higher thicknesses. As higher ESAL are compensated by higher thickness, these projects behave somewhat similarly to lower ESAL AST interlayer projects. Moreover, the higher ESAL projects had slightly less benefits (B/C(SL)=58.8 and B/C(NBA)=53.1) as compared to lower ESAL projects Category x1 as shown in Figure 31.

AST INT Transverse Cracking (ft) Over CSD Bases							
ESAL	0	30000	Thickness	0	4	Data Range	3
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives	
26	718	14.3	6.1	13.1	5.9		

SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	40	5.6
5-6	60	8.4
7-8	80	11.1
9-10	96	13.4
11-12	32	4.5
13-14	33	4.6
15-16	7	1.0
17-18	11	1.5
19-20	359	50.0
TOTAL '0-20'	718	100.0

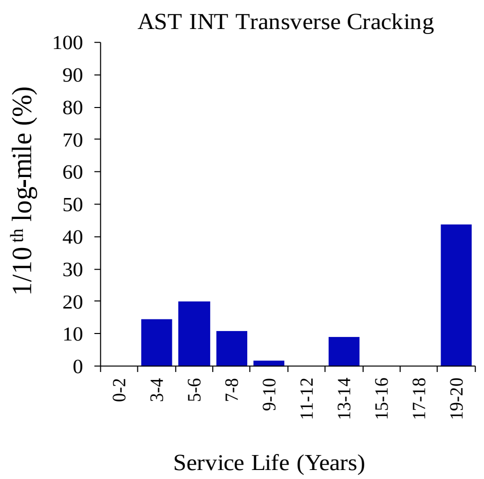


Parameters	ESAL Distribution	ADT Distribution
MIN	603	91
25 PERCNTILE	2128	530
MEDIAN	6903	1400
AVERAGE	9415	1526
75 PERCNTILE	13569	1974
MAX	27494	3819

B/C (SL) =	67.4	Yrs / Dollar	Category
B/C (NBA) =	61.7	Ft-yr/ft/Dollar	x1

Figure 31: Evaluation of TC for AST interlayer over CSD base, (Cat. x1)

AST INT Transverse Cracking (ft) Over CSD Bases								
ESAL	30001	2E6	Thickness	0	4	Data Range	3	
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives		
2	55	12.5	7.1	11.0	6.4	SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections



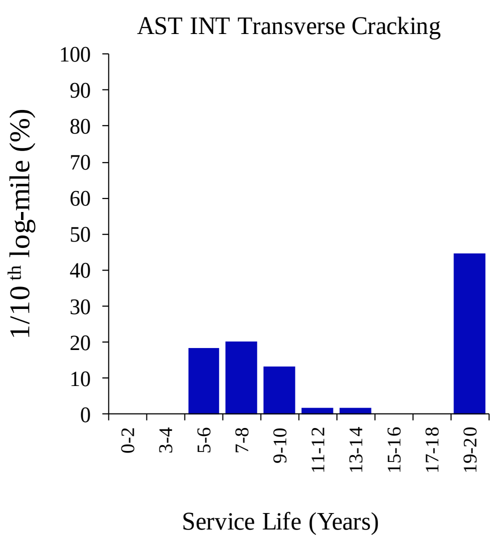
SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	8	14.5
5-6	11	20.0
7-8	6	10.9
9-10	1	1.8
11-12	0	0.0
13-14	5	9.1
15-16	0	0.0
17-18	0	0.0
19-20	24	43.6
TOTAL '0-20'	55	100.0

Parameters	ESAL Distribution	ADT Distribution
MIN	33693	1090
25 PERCNTILE	33693	1090
MEDIAN	33693	1090
AVERAGE	143136	10096
75 PERCNTILE	368103	28609
MAX	368103	28609

B/C (SL) =	47.2	Yrs / Dollar	Category
B/C (NBA) =	41.7	Ft-yr/ft/Dollar	x2

Figure 32: Evaluation of TC for AST interlayer over CSD base, (Cat. x2)

AST INT Transverse Cracking (ft) Over CSD Bases								
ESAL	30001	2E6	Thickness	4.1	10	Data Range	3	
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives		
8	114	13.2	6.3	11.9	6.0	SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections



SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	0	0.0
5-6	21	18.4
7-8	23	20.2
9-10	15	13.2
11-12	2	1.8
13-14	2	1.8
15-16	0	0.0
17-18	0	0.0
19-20	51	44.7
TOTAL '0-20'	114	100.0

Parameters	ESAL Distribution	ADT Distribution
MIN	43959	1750
25 PERCNTILE	63643	2350
MEDIAN	71889	3900
AVERAGE	140088	4499
75 PERCNTILE	181101	3900
MAX	523334	31600

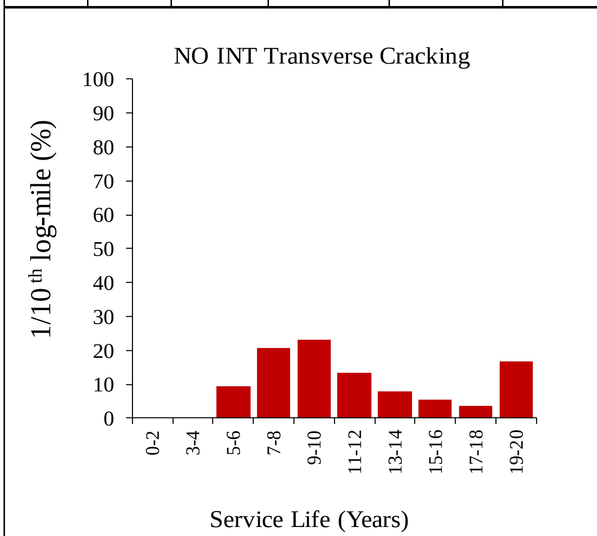
B/C (SL) =	58.8	Yrs / Dollar	Category
B/C (NBA) =	53.1	Ft-yr/ft/Dollar	x4

Figure 33: Evaluation of TC for AST interlayer over CSD base, (Cat. x4)

Figure 34 illustrates Category x5 which is the MatExVba output for TC of no interlayer, CSD base, HMA thickness (Th) range 0-4 in., and ESAL range 0-30000. To avoid repetition, this figure is not further explained. From the figure, it is clear that the no AST interlayer sections have less average service life (AvgSL) and net benefit areas (AvgNBA) as compared to the AST interlayer sections. But, as no interlayer sections is cheaper, at the end it results into slightly more benefits for AST interlayer in terms of B/C(SL) and B/C(NBA). Detailed comparison between the AST and no interlayer sections for B/C are provided later in this report.

Figure 35 demonstrates Category x6 which is the results of no interlayer projects for higher ESAL (>30000) and lower HMA thickness Category (0-4 in.) for CSD projects. Similarly, Figure 36 illustrates the no interlayer projects for higher ESAL and greater HMA thickness for CSD projects (Category x8). It is worth mentioning that due to less data points (N(P) = 2), the results of Figure 36 are not conclusive.

NO INT Transverse Cracking (ft) Over CSD Bases							
ESAL	0	30000	Thickness	0	4	Data Range	3
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev		
46	1785	11.6	4.6	10.5	4.7		

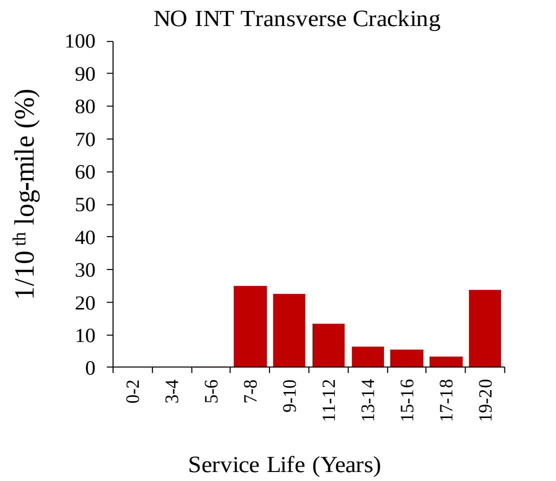


HISTOGRAM DATA of Service Lives		
SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	0	0.0
5-6	170	9.5
7-8	371	20.8
9-10	413	23.1
11-12	237	13.3
13-14	139	7.8
15-16	95	5.3
17-18	62	3.5
19-20	298	16.7
TOTAL '0-20'	1785	100.0
Parameters	ESAL Distribution	ADT Distribution
MIN	56	159
25 PERCNTILE	1508	679
MEDIAN	4664	1185
AVERAGE	7981	1478
75 PERCNTILE	13877	2028
MAX	28790	8012

B/C (SL) =	60.3	Yrs / Dollar	Category
B/C (NBA) =	54.5	Ft-yr/ft/Dollar	x5

Figure 34: Evaluation of TC for no interlayer over CSD base, (Cat. x5)

NO INT Transverse Cracking (ft) Over CSD Bases								
ESAL	30001	2E6	Thickness	0	4	Data Range	3	
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives		
17	773	12.6	4.8	11.5	5.0	SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections

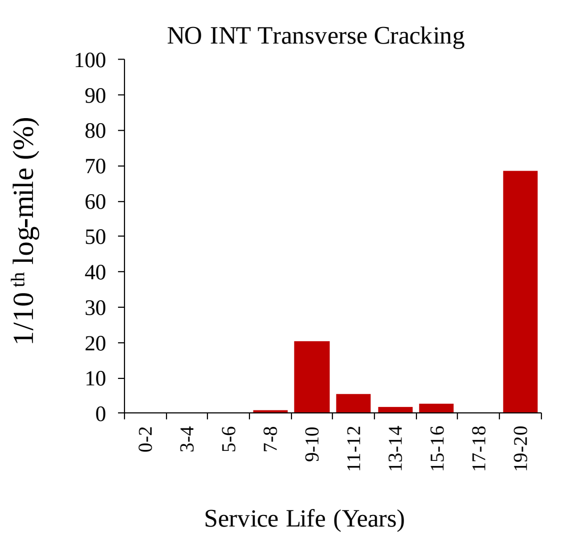


SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	0	0.0
5-6	1	0.1
7-8	194	25.1
9-10	175	22.6
11-12	103	13.3
13-14	49	6.3
15-16	42	5.4
17-18	25	3.2
19-20	184	23.8
TOTAL '0-20'	773	100.0
Parameters	ESAL Distribution	ADT Distribution
MIN	30494	455
25 PERCNTILE	37822	1152
MEDIAN	45871	2368
AVERAGE	112750	3942
75 PERCNTILE	84069	3849
MAX	1431101	54792

B/C (SL) =	69.9	Yrs / Dollar	Category
B/C (NBA) =	64.0	Ft-yr/ft/Dollar	x6

Figure 35: Evaluation of TC for no interlayer over CSD bases, (Cat. x6)

NO INT Transverse Cracking (ft) Over CSD Bases								
ESAL	30001	2E6	Thickness	4.1	10	Data Range	3	
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives		
2	108	17.0	4.5	15.9	4.6	SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections



SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	0	0.0
5-6	0	0.0
7-8	1	0.9
9-10	22	20.4
11-12	6	5.6
13-14	2	1.9
15-16	3	2.8
17-18	0	0.0
19-20	74	68.5
TOTAL '0-20'	108	100.0
Parameters	ESAL Distribution	ADT Distribution
MIN	31695	4084
25 PERCNTILE	31695	4084
MEDIAN	62459	4656
AVERAGE	54483	4508
75 PERCNTILE	62459	4656
MAX	62459	4656

B/C (SL) =	122.1	Yrs / Dollar	Category
B/C (NBA) =	114.3	Ft-yr/ft/Dollar	x8

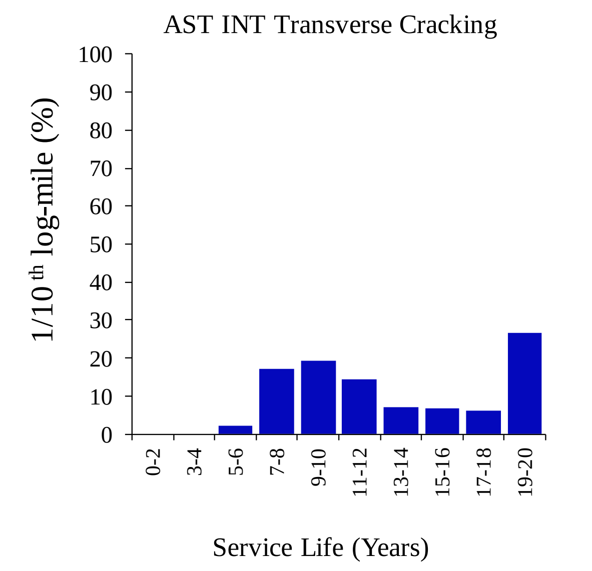
Figure 36: Evaluation of TC for no interlayer over CSD base, (Cat x8)

AST/No interlayer over CTD bases. Figure 37 depicts Category x9, the MatExVba output for AST interlayer over CTD bases for HMA thickness (Th) range 0-4 in., and ESAL range 0-30000. The AvgSL and AvgNBA for this category is 13.3 years and 12.2 Ft-yr/ft on average, respectively. The benefit cost ratio based on SL and NBA are 74.7 Yrs/Dollar and 68.5 Ft-yr/ft/Dollar, respectively.

If the results of AST interlayer over CTD and CSD are compared, it becomes obvious that these two types of base underneath AST interlayer behave similarly as they have similar AvgSL and AvgNBA values (Figure 31 and 37). The interesting finding is the B/C comparison between these two bases. According to the cost chart, the CTD sections costs less than the CSD sections. Hence, the CTD sections have slightly more B/C then CSD sections due to the fact that they have similar benefits in terms of SL and NBA. Detailed comparisons of these two base types are discussed later in this report.

AST INT Transverse Cracking (ft) Over CTD Bases

ESAL	0	30000	Thickness	0	4	Data Range	3
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives	
6	347	13.3	4.8	12.2	5.0		



SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	0	0.0
5-6	8	2.3
7-8	60	17.3
9-10	67	19.3
11-12	50	14.4
13-14	25	7.2
15-16	24	6.9
17-18	21	6.1
19-20	92	26.5
TOTAL '0-20'	347	100.0

Parameters	ESAL Distribution	ADT Distribution
MIN	81	360
25 PERCNTILE	3467	411
MEDIAN	9210	667
AVERAGE	10231	809
75 PERCNTILE	16965	1360
MAX	18718	1440

B/C (SL) =	74.7	Yrs / Dollar	Category
B/C (NBA) =	68.5	Ft-yr/ft/Dollar	x9

Figure 37: Evaluation of TC for AST interlayer over CTD base, (Cat. x9)

Figure 38 explains Category x13, which is the MatExVba output for no interlayer over CTD sections for lower ESAL and less thickness. Unlike the AST interlayer sections, no interlayer sections have sufficient projects for this CTD category (N(P)>40). From the comparison of CTD and CSD sections for No Interlayer sections, it is evident that CTD bases are much more cost-effective as they have significant higher B/C ratio from CSD bases. As CTD has less cost but provides higher life, it ends up with significant higher benefit-cost ratio in compared to CSD.

Figure 39 and Figure 40 illustrates the summary of results of no interlayer CTD sections for higher ESAL and thickness.

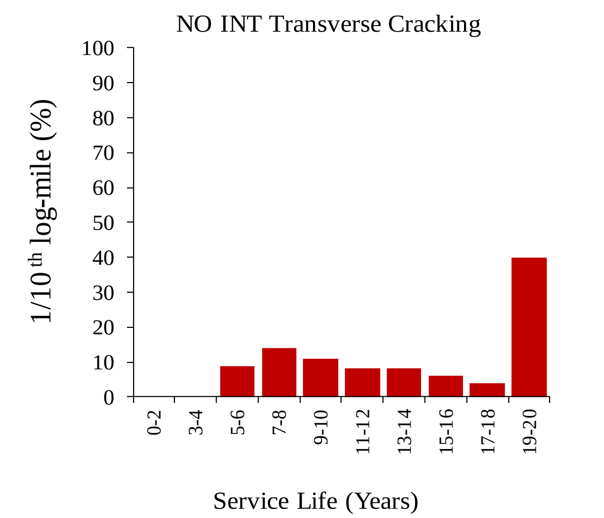
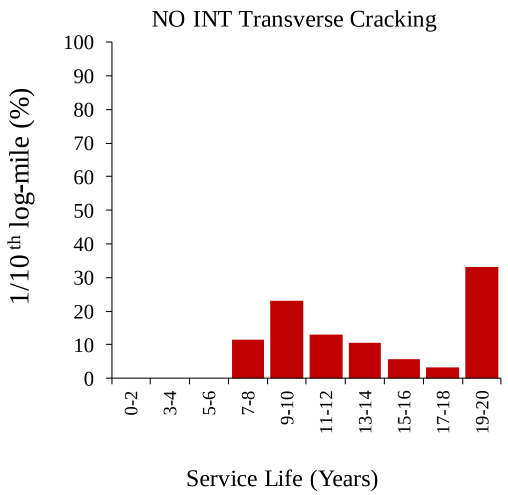
NO INT Transverse Cracking (ft) Over CTD Bases								
ESAL	0	30000	Thickness	0	4	Data Range	3	
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives		
46	1476	14.2	5.4	13.3	5.7	SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
						0-2	0	0.0
						3-4	0	0.0
						5-6	129	8.7
						7-8	205	13.9
						9-10	161	10.9
						11-12	123	8.3
						13-14	120	8.1
						15-16	91	6.2
						17-18	56	3.8
						19-20	591	40.0
						TOTAL '0-20'	1476	100.0
						Parameters	ESAL Distribution	ADT Distribution
						MIN	148	115
						25 PERCNTILE	1451	500
						MEDIAN	7339	1040
						AVERAGE	9661	1454
B/C (SL) =		95.6	Yrs / Dollar		Category	75 PERCNTILE	17083	1576
B/C (NBA) =		89.3	Ft-yr/ft/Dollar		x13	MAX	28551	10210

Figure 38: Evaluation of TC for no interlayer over CTD base, (Cat. x13)

NO INT Transverse Cracking (ft) Over CTD Bases								
ESAL	30001	2E6	Thickness	0	4	Data Range	3	
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives		
6	209	14.0	4.7	13.0	5.0	SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections



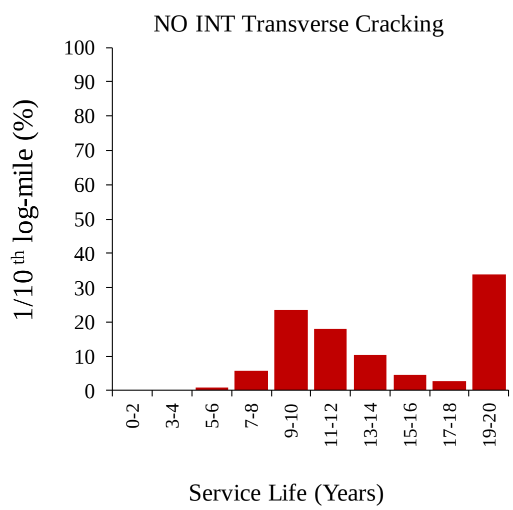
SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	0	0.0
5-6	0	0.0
7-8	24	11.5
9-10	48	23.0
11-12	27	12.9
13-14	22	10.5
15-16	12	5.7
17-18	7	3.3
19-20	69	33.0
TOTAL '0-20'	209	100.0

Parameters	ESAL Distribution	ADT Distribution
MIN	36661	1761
25 PERCNTILE	36661	1896
MEDIAN	51834	3538
AVERAGE	57268	3731
75 PERCNTILE	76200	3931
MAX	134609	8861

B/C (SL) =	98.4	Yrs / Dollar	Category
B/C (NBA) =	91.1	Ft-yr/ft/Dollar	x14

Figure 39: Evaluation of TC for no interlayer over CTD bases, (Cat. x14)

NO INT Transverse Cracking (ft) Over CTD Bases								
ESAL	30001	2E6	Thickness	4.1	10	Data Range	3	
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives		
3	106	14.1	4.7	13.1	5.0	SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections



SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	0	0.0
5-6	1	0.9
7-8	6	5.7
9-10	25	23.6
11-12	19	17.9
13-14	11	10.4
15-16	5	4.7
17-18	3	2.8
19-20	36	34.0
TOTAL '0-20'	106	100.0

Parameters	ESAL Distribution	ADT Distribution
MIN	113385	5500
25 PERCNTILE	113385	5500
MEDIAN	113385	5500
AVERAGE	209500	9169
75 PERCNTILE	378875	13851
MAX	387171	16602

B/C (SL) =	100.5	Yrs / Dollar	Category
B/C (NBA) =	93.4	Ft-yr/ft/Dollar	x16

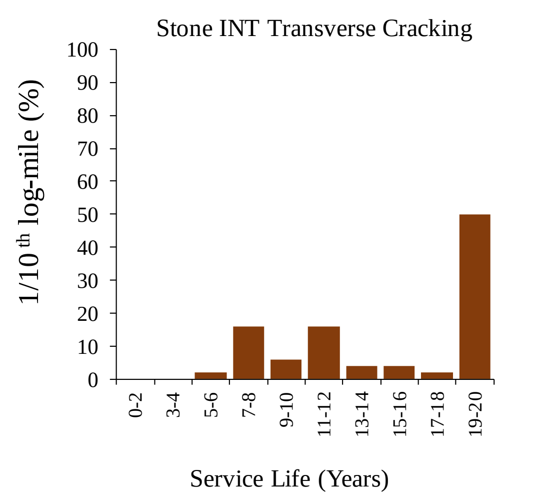
Figure 40: Evaluation of TC for no interlayer over CTD bases, (Cat. x16)

All MatExVba outputs were compared to evaluate the cost-effectiveness of AST interlayer in the next section.

Stone Interlayer over CSD/CTD Bases. As few stone interlayer projects are available, those projects were analyzed and their results are shown in Figures 41 and 42. Figures 41 and 42 (Category x17 and x18, respectively) illustrate the transverse cracking for stone interlayer sections over CTD and CSD bases, respectively. It should be remembered that stone interlayer over CTD and CSD has a slightly different range; for CTD: ESAL range (0-150000), for both CTD and CSD, thickness range (0-5 in.) because of data unavailability. Hence, for performance evaluation, a new control group of no interlayer with this same range is necessary. For this reason, the researchers created two extra no interlayer categories with the exact same range for stone interlayer performance evaluations corresponding to CTD and CSD. These two extra no interlayer categories' results are shown in Figure 43 and Figure 44 where the performance of no interlayer over CTD and CSD bases are shown, respectively.

Stone interlayer over CSD bases shows promising results in Figure 42 where 80% of sections is showing 20 years of service lives, which means these sections did not show up any crack or very few cracks until 7 years of surface age, whereas the control group (no interlayer sections), in Figure 44, shows only 16.7% of sections had 20 years of service lives. The AvgSL for stone interlayer over CSD is 18.3 years whereas it is 11.6 for no interlayer over CSD. Hence, the gain SL is 6.7 years. Even though stone interlayer is expensive, the benefit cost ratio in this case is more for stone interlayer. Stone interlayer has 91.5 ft/yrs of B/C (SL) with respect to 60.3 ft/yrs of no interlayer for CSD bases. It should be noted that due to limited projects (N(P) = 3) of stone interlayers, these results are preliminary rather than conclusive. Stone interlayer projects over CTD bases did not show up these promising results. Detailed comparison is provided later in the comparison sections.

Stone Int Transverse cracking (ft) Over CTD Bases								
ESAL	0	150000	Thickness	0	5	Data Range	3	
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives		
2	50	15.3	5.1	14.4	5.5	SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections



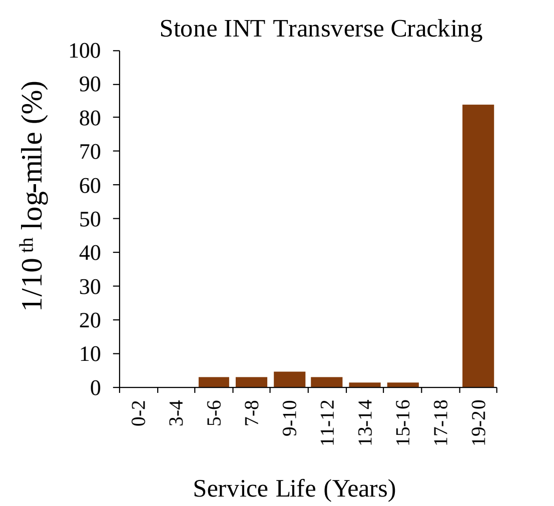
SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	0	0.0
5-6	1	2.0
7-8	8	16.0
9-10	3	6.0
11-12	8	16.0
13-14	2	4.0
15-16	2	4.0
17-18	1	2.0
19-20	25	50.0
TOTAL '0-20'	50	100.0

Parameters	ESAL Distribution	ADT Distribution
MIN	28551	1355
25 PERCNTILE	28551	1355
MEDIAN	28551	1355
AVERAGE	48126	1664
75 PERCNTILE	28551	1355
MAX	137299	3071

B/C (SL)=	70.8	Yrs / Dollar	Category
B/C (NBA)=	66.8	Ft-yr/ft/Dollar	x17

Figure 41: Evaluation of TC for stone interlayer over CTD bases, (Cat. x17)

Stone Int Transverse cracking (ft) Over CSD Bases								
ESAL	0	30000	Thickness	0	5	Data Range	3	
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives		
3	68	18.3	4.1	17.5	4.2	SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections



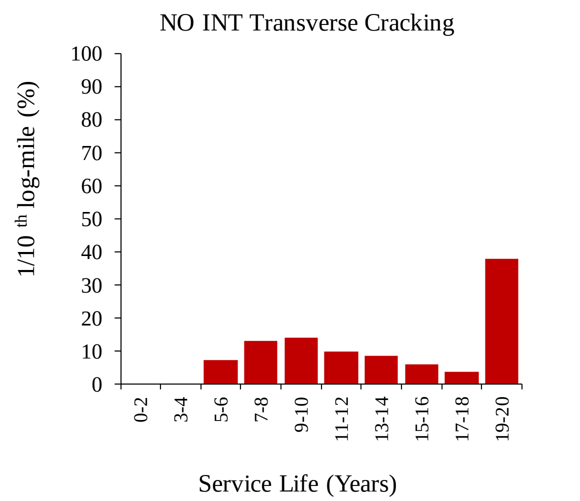
SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	0	0.0
5-6	2	2.9
7-8	2	2.9
9-10	3	4.4
11-12	2	2.9
13-14	1	1.5
15-16	1	1.5
17-18	0	0.0
19-20	57	83.8
TOTAL '0-20'	68	100.0

Parameters	ESAL Distribution	ADT Distribution
MIN	15932	2800
25 PERCNTILE	15932	2800
MEDIAN	15932	2800
AVERAGE	19704	4556
75 PERCNTILE	24152	3800
MAX	29340	11214

B/C (SL)=	91.5	Yrs / Dollar	Category
B/C (NBA)=	87.3	Ft-yr/ft/Dollar	x18

Figure 42: Evaluation of TC for stone interlayer over CSD bases, (Cat. x18)

NO INT Transverse Cracking (ft) Over CTD Bases							
ESAL	0	150000	Thickness	0	5	Data Range	3
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives	
55	1799	14.1	5.3	13.1	5.6		

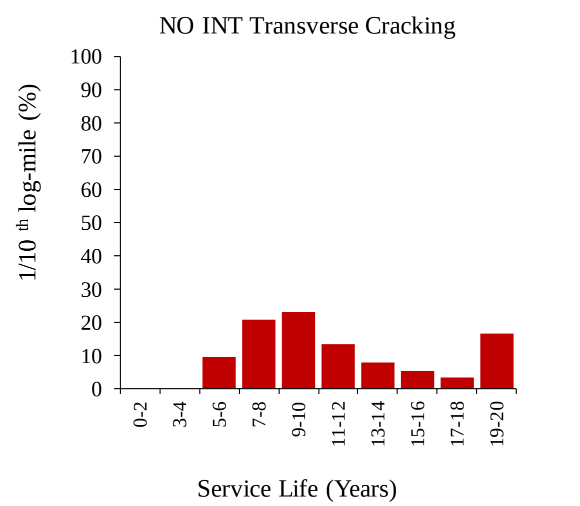


SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	0	0.0
5-6	130	7.2
7-8	236	13.1
9-10	249	13.8
11-12	174	9.7
13-14	156	8.7
15-16	107	5.9
17-18	67	3.7
19-20	680	37.8
TOTAL '0-20'	1799	100.0
Parameters	ESAL Distribution	ADT Distribution
MIN	148	115
25 PERCNTILE	1819	693
MEDIAN	9723	1159
AVERAGE	19428	1860
75 PERCNTILE	23409	2403
MAX	134609	10210

B/C (SL) =	95.0	Yrs / Dollar	Category
B/C (NBA) =	88.6	Ft-yr/ft/Dollar	x19

Figure 43: Evaluation of TC for no interlayer over CTD bases, (Cat. x19)

NO INT Transverse Cracking (ft) Over CSD Bases							
ESAL	0	30000	Thickness	0	5	Data Range	3
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives	
46	1785	11.6	4.6	10.5	4.7		



SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	0	0.0
5-6	170	9.5
7-8	371	20.8
9-10	413	23.1
11-12	237	13.3
13-14	139	7.8
15-16	95	5.3
17-18	62	3.5
19-20	298	16.7
TOTAL '0-20'	1785	100.0
Parameters	ESAL Distribution	ADT Distribution
MIN	56	159
25 PERCNTILE	1508	679
MEDIAN	4664	1185
AVERAGE	7981	1478
75 PERCNTILE	13877	2028
MAX	28790	8012

B/C (SL) =	60.3	Yrs / Dollar	Category
B/C (NBA) =	54.5	Ft-yr/ft/Dollar	x20

Figure 44: Evaluation of TC for no interlayer over CSD bases, (Cat. x20)

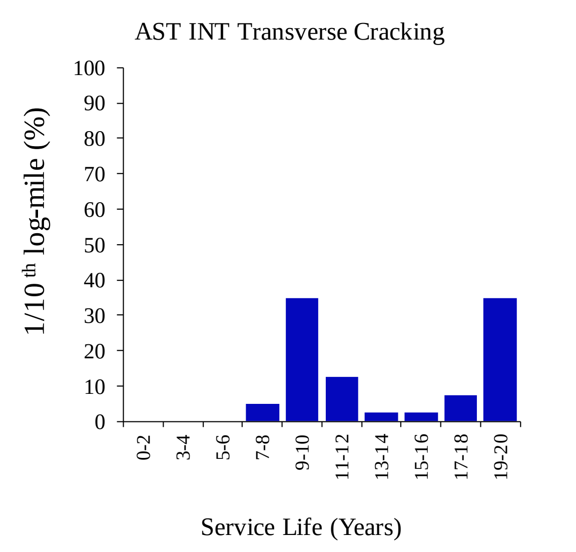
Transverse Cracking Evaluation (6 data points)

In this section, results of all the categories presented above are shown again for 6 data points. Category x1' to x16' captures all the groups of AST and no interlayer projects regarding 6 data points. It should be noted that AST interlayer projects do not have sufficient sections for 6 data points range, hence these results are not as conclusive as before. However, these results follow the conclusion gained from the 3 data points' range in general, thus strengthening the conclusion of the results of the previous sections. Moreover, the no interlayer CSD sections and CTD sections has significant data for 6 data points (Category x5' and x13') and conclusive results could be found. Hence, these 6 data points analyses are very useful to evaluate the crack mitigation potential of CTD sections. Also, due to the unavailability of data, stone interlayers were not evaluated for 6 data points.

AST/No Interlayer over CSD Bases. Figure 45 to Figure 49 illustrates the evaluation of transverse cracking for CSD bases (6 data points). It is important to remember that only categories x5' and x6' (shown in Figure 47 and Figure 48) have significant data for conclusive results for these 6 data points analyses.

AST INT Transverse cracking (ft) Over CSD Bases

ESAL	0	30000	Thickness	0	4	Data Range	6
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev		
3	40	14.0	5.0	13.1	5.5		



HISTOGRAM DATA of Service Lives

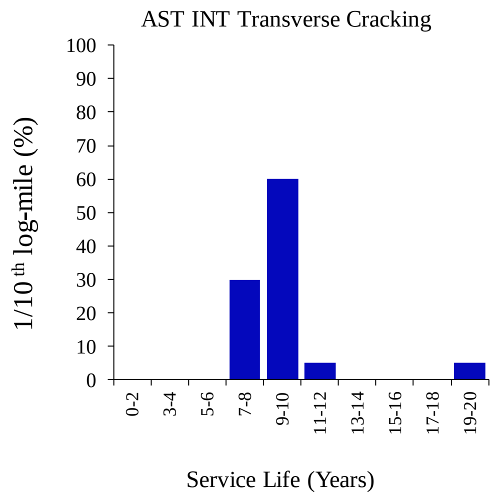
SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	0	0.0
5-6	0	0.0
7-8	2	5.0
9-10	14	35.0
11-12	5	12.5
13-14	1	2.5
15-16	1	2.5
17-18	3	7.5
19-20	14	35.0
TOTAL '0-20'	40	100.0

Parameters	ESAL Distribution	ADT Distribution
MIN	734	530
25 PERCNTILE	9583	794
MEDIAN	12533	882
AVERAGE	10490	1528
75 PERCNTILE	13440	1616
MAX	16161	3819

B/C (SL) =	73.5	Yrs / Dollar	Category
B/C (NBA) =	68.8	Ft-yr/ft/Dollar	x1'

Figure 45: Evaluation of TC for AST interlayer over CSD bases, (Cat. x1')

AST INT Transverse cracking (ft) Over CSD Bases							
ESAL	30001	2E6	Thickness	4.1	10	Data Range	6
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives	
2	20	9.4	2.6	8.3	2.8		



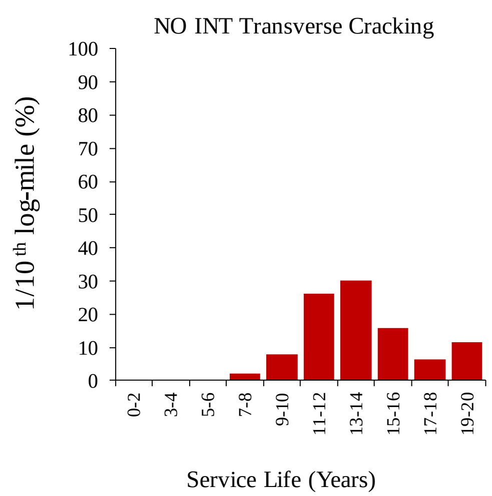
SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	0	0.0
5-6	0	0.0
7-8	6	30.0
9-10	12	60.0
11-12	1	5.0
13-14	0	0.0
15-16	0	0.0
17-18	0	0.0
19-20	1	5.0
TOTAL '0-20'	20	100.0

Parameters	ESAL Distribution	ADT Distribution
MIN	71889	6197
25 PERCNTILE	71889	6197
MEDIAN	71889	6197
AVERAGE	137383	10007
75 PERCNTILE	71889	6197
MAX	508514	31600

B/C (SL) =	38.4	Yrs / Dollar	Category
B/C (NBA) =	33.8	Ft-yr/ft/Dollar	x4'

Figure 46: Evaluation of TC for AST interlayer over CSD bases, (Cat. x4')

NO INT Transverse cracking (ft) Over CSD Bases							
ESAL	0	30000	Thickness	0	4	Data Range	6
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives	
46	1789	13.9	3.0	12.1	3.1		



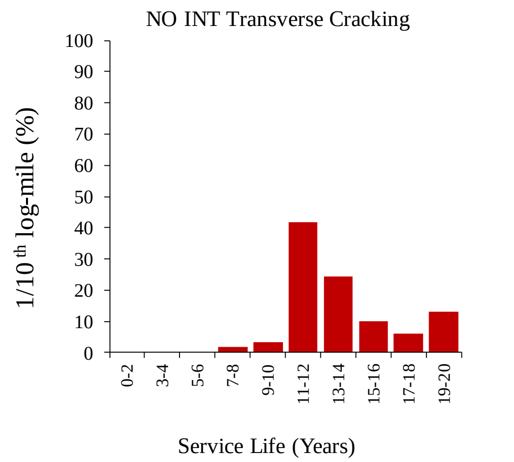
SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	0	0.0
5-6	0	0.0
7-8	36	2.0
9-10	140	7.8
11-12	470	26.3
13-14	537	30.0
15-16	285	15.9
17-18	113	6.3
19-20	208	11.6
TOTAL '0-20'	1789	100.0

Parameters	ESAL Distribution	ADT Distribution
MIN	56	159
25 PERCNTILE	1508	679
MEDIAN	4664	1185
AVERAGE	7973	1476
75 PERCNTILE	13877	2028
MAX	28790	8012

B/C (SL) =	89.3	Yrs / Dollar	Category
B/C (NBA) =	77.8	Ft-yr/ft/Dollar	x5'

Figure 47: Evaluation of TC for no interlayer over CSD bases, (Cat. x5')

NO INT Transverse cracking (ft) Over CSD Bases								
ESAL	30001	2E6	Thickness	0	4	Data Range	6	
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives		
17	773	13.7	3.0	12.1	3.2	SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections



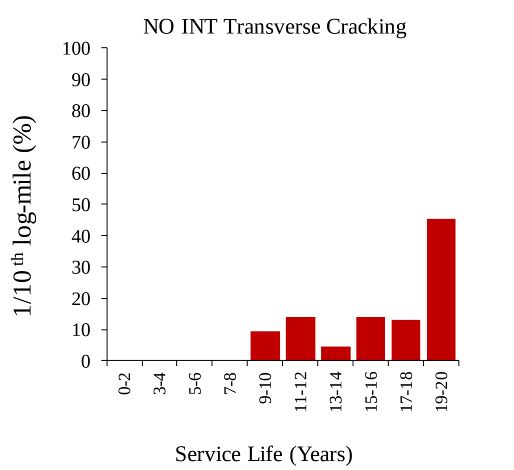
SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	0	0.0
5-6	0	0.0
7-8	14	1.8
9-10	25	3.2
11-12	322	41.7
13-14	188	24.3
15-16	77	10.0
17-18	46	6.0
19-20	101	13.1
TOTAL '0-20'	773	100.0

Parameters	ESAL Distribution	ADT Distribution
MIN	30494	455
25 PERCNTILE	37822	1152
MEDIAN	45871	2368
AVERAGE	112750	3942
75 PERCNTILE	84069	3849
MAX	1431101	54792

B/C (SL) =	87.4	Yrs / Dollar	Category
B/C (NBA) =	77.0	Ft-yr/ft/Dollar	x6'

Figure 48: Evaluation of TC for no interlayer over CSD bases, (Cat. x6')

NO INT Transverse cracking (ft) Over CSD Bases								
ESAL	30001	2E6	Thickness	4.1	10	Data Range	6	
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives		
2	108	16.5	3.7	14.9	3.7	SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections



SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	0	0.0
5-6	0	0.0
7-8	0	0.0
9-10	10	9.3
11-12	15	13.9
13-14	5	4.6
15-16	15	13.9
17-18	14	13.0
19-20	49	45.4
TOTAL '0-20'	108	100.0

Parameters	ESAL Distribution	ADT Distribution
MIN	31695	4084
25 PERCNTILE	31695	4084
MEDIAN	62459	4656
AVERAGE	54483	4508
75 PERCNTILE	62459	4656
MAX	62459	4656

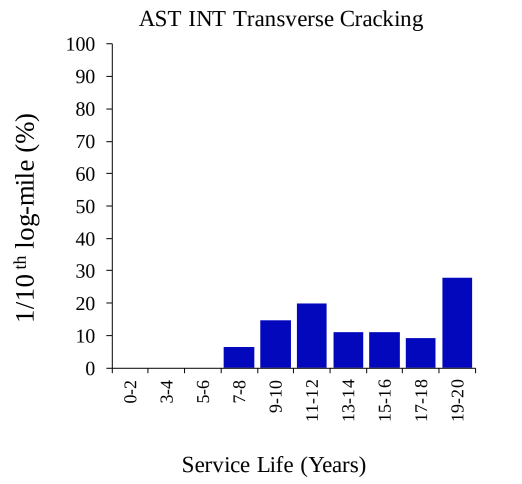
B/C (SL) =	119.5	Yrs / Dollar	Category
B/C (NBA) =	108.2	Ft-yr/ft/Dollar	x8'

Figure 49: Evaluation of TC for no interlayer over CSD bases, (Cat. x8')

AST/No Interlayer over CTD Bases. Transverse cracking evaluation for CTD bases are shown in Figure 50 to Figure 53. Amongst all the figures in this section, only Figure 51

(Category x13') had sufficient data for conclusive results.

AST INT Transverse cracking (ft) Over CTD Bases								
ESAL	0	30000	Thickness	0	4	Data Range	6	
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives		
6	347	14.5	4.2	13.2	4.3	SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections



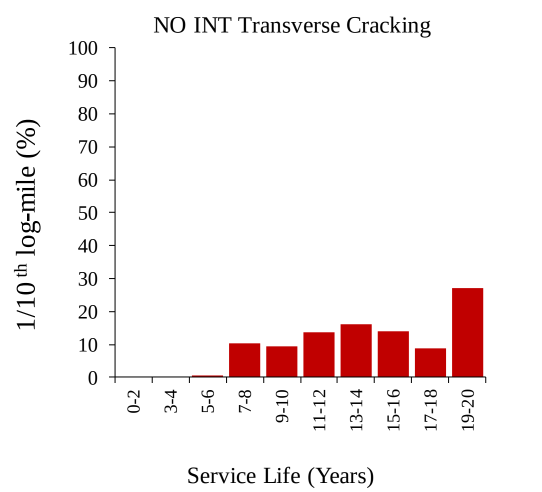
SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	0	0.0
5-6	0	0.0
7-8	22	6.3
9-10	51	14.7
11-12	69	19.9
13-14	38	11.0
15-16	38	11.0
17-18	32	9.2
19-20	97	28.0
TOTAL '0-20'	347	100.0

Parameters	ESAL Distribution	ADT Distribution
MIN	81	360
25 PERCNTILE	3467	411
MEDIAN	9210	667
AVERAGE	10231	809
75 PERCNTILE	16965	1360
MAX	18718	1440

B/C (SL) =	90.4	Yrs / Dollar	Category
B/C (NBA) =	82.0	Ft-yr/ft/Dollar	x9'

Figure 50: Evaluation of TC for AST interlayer over CTD bases, (Cat. x9')

NO INT Transverse cracking (ft) Over CTD Bases								
ESAL	0	30000	Thickness	0	4	Data Range	6	
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives		
46	1483	14.6	4.3	13.2	4.4	SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections



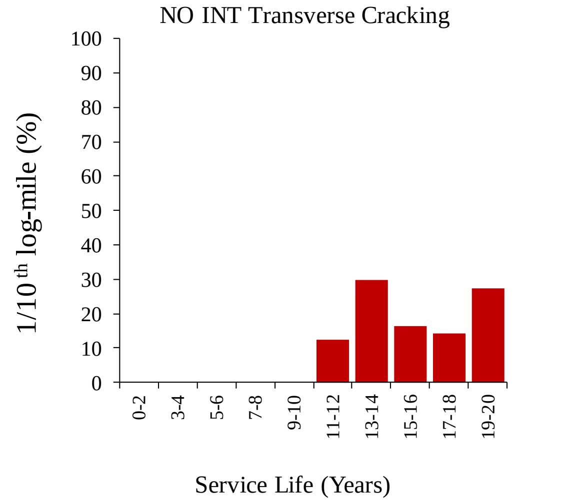
SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	0	0.0
5-6	7	0.5
7-8	155	10.5
9-10	138	9.3
11-12	202	13.6
13-14	240	16.2
15-16	209	14.1
17-18	130	8.8
19-20	402	27.1
TOTAL '0-20'	1483	100.0

Parameters	ESAL Distribution	ADT Distribution
MIN	148	115
25 PERCNTILE	1451	500
MEDIAN	7339	1040
AVERAGE	9664	1455
75 PERCNTILE	17083	1576
MAX	28551	10210

B/C (SL) =	106.6	Yrs / Dollar	Category
B/C (NBA) =	96.3	Ft-yr/ft/Dollar	x13'

Figure 51: Evaluation of TC for no interlayer over CTD bases, (Cat. x13')

NO INT Transverse cracking (ft) Over CTD Bases								
ESAL	30001	2E6	Thickness	0	4	Data Range	6	
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives		
6	209	15.9	2.9	14.3	3.3	SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections



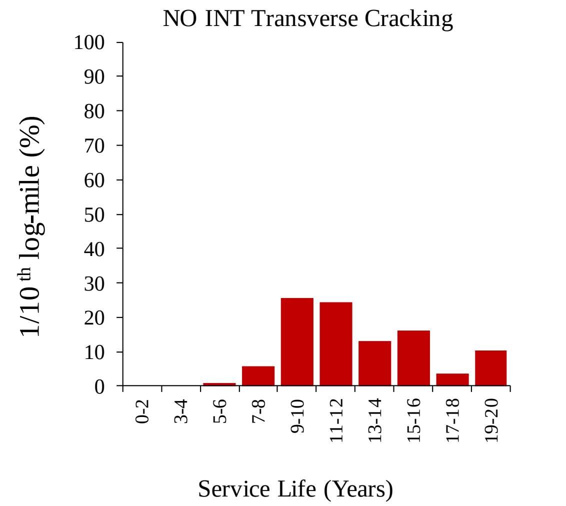
SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	0	0.0
5-6	0	0.0
7-8	0	0.0
9-10	0	0.0
11-12	26	12.4
13-14	62	29.7
15-16	34	16.3
17-18	30	14.4
19-20	57	27.3
TOTAL '0-20'	209	100.0

Parameters	ESAL Distribution	ADT Distribution
MIN	36661	1761
25 PERCNTILE	36661	1896
MEDIAN	51834	3538
AVERAGE	57268	3731
75 PERCNTILE	76200	3931
MAX	134609	8861

B/C (SL) =	131.5	Yrs / Dollar	Category
B/C (NBA) =	118.2	Ft-yr/ft/Dollar	x14'

Figure 52: Evaluation of TC for no interlayer over CTD bases, (Cat. x14')

NO INT Transverse cracking (ft) Over CTD Bases								
ESAL	30001	2E6	Thickness	4.1	10	Data Range	6	
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives		
3	106	12.7	3.6	11.3	3.5	SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections



SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	0	0.0
5-6	1	0.9
7-8	6	5.7
9-10	27	25.5
11-12	26	24.5
13-14	14	13.2
15-16	17	16.0
17-18	4	3.8
19-20	11	10.4
TOTAL '0-20'	106	100.0

Parameters	ESAL Distribution	ADT Distribution
MIN	113385	5500
25 PERCNTILE	113385	5500
MEDIAN	113385	5500
AVERAGE	209500	9169
75 PERCNTILE	378875	13851
MAX	387171	16602

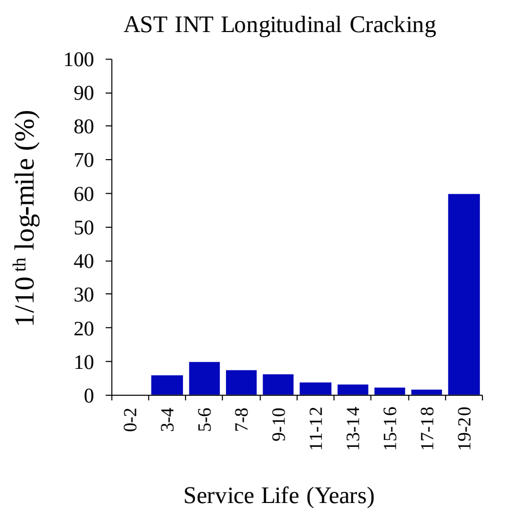
B/C (SL) =	85.2	Yrs / Dollar	Category
B/C (NBA) =	76.3	Ft-yr/ft/Dollar	x16'

Figure 53: Evaluation of TC for no interlayer over CTD bases, (Cat. x16')

Longitudinal Crack Evaluation (3 data points)

AST/No Interlayer over CSD Bases. In Figure 54 to 59, longitudinal cracks performance is evaluated over CSD bases for 3 data points. Categories x1, x5, and x6 (shown in Figures 54, 57, and 58, respectively) have sufficient data for comparison shown in the next section. Category x4 (shown in Figure 56) also has some projects available (N(P)=8) for longitudinal cracking.

AST INT Longitudinal Cracking (ft) Over CSD Bases							
ESAL	0	30000	Thickness	0	4	Data Range	3
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives	
26	695	15.3	6.2	14.3	6.1		

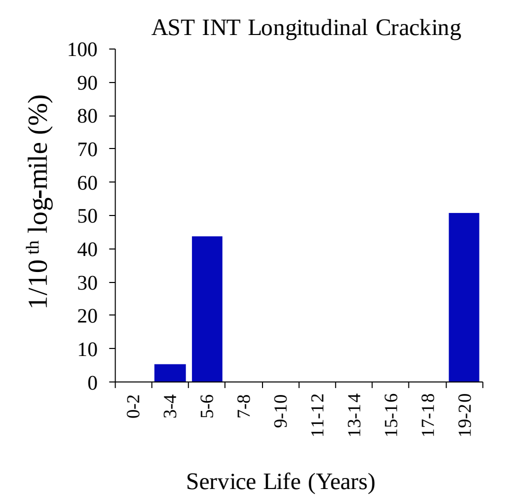


SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	40	5.8
5-6	69	9.9
7-8	51	7.3
9-10	44	6.3
11-12	27	3.9
13-14	21	3.0
15-16	15	2.2
17-18	12	1.7
19-20	416	59.9
TOTAL '0-20'	695	100.0
Parameters	ESAL Distribution	ADT Distribution
MIN	603	91
25 PERCNTILE	2128	570
MEDIAN	7035	1400
AVERAGE	9608	1551
75 PERCNTILE	13569	2030
MAX	27494	3819

B/C (SL) =	75.0	Yrs / Dollar	Category
B/C (NBA) =	69.8	Ft-yr/ft/Dollar	x1

Figure 54: Evaluation of LC for AST interlayer over CSD base, (Cat. x1)

AST INT Longitudinal Cracking (ft) Over CSD Bases								
ESAL	30001	2E6	Thickness	0	4	Data Range	3	
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives		
2	55	12.6	7.6	11.2	6.9	SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections



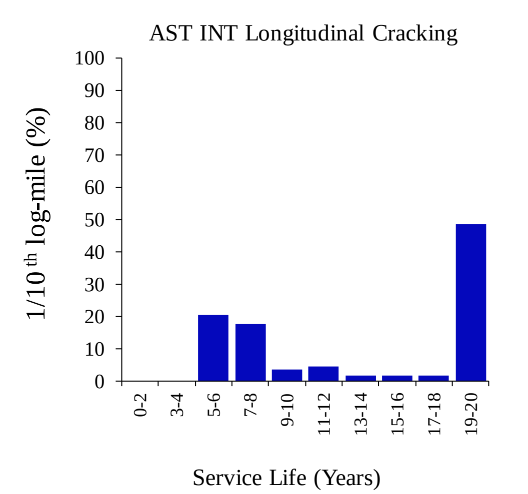
SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	3	5.5
5-6	24	43.6
7-8	0	0.0
9-10	0	0.0
11-12	0	0.0
13-14	0	0.0
15-16	0	0.0
17-18	0	0.0
19-20	28	50.9
TOTAL '0-20'	55	100.0

Parameters	ESAL Distribution	ADT Distribution
MIN	33693	1090
25 PERCNTILE	33693	1090
MEDIAN	33693	1090
AVERAGE	143136	10096
75 PERCNTILE	368103	28609
MAX	368103	28609

B/C (SL) =	46.0	Yrs / Dollar	Category
B/C (NBA) =	40.8	Ft-yr/ft/Dollar	x2

Figure 55: Evaluation of LC for AST interlayer over CSD base, (Cat. x2)

AST INT Longitudinal Cracking (ft) Over CSD Bases								
ESAL	30001	2E6	Thickness	4.1	10	Data Range	3	
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives		
8	113	13.8	6.4	12.6	6.2	SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections



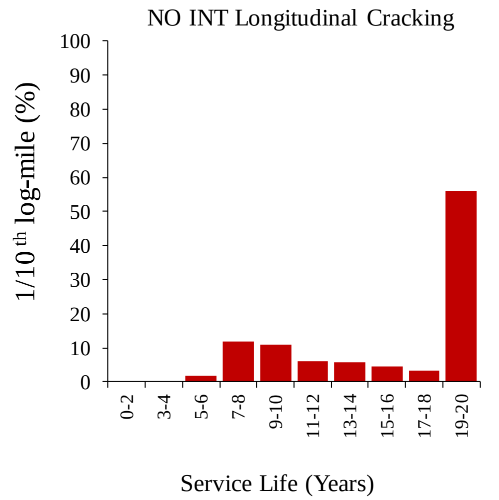
SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	0	0.0
5-6	23	20.4
7-8	20	17.7
9-10	4	3.5
11-12	5	4.4
13-14	2	1.8
15-16	2	1.8
17-18	2	1.8
19-20	55	48.7
TOTAL '0-20'	113	100.0

Parameters	ESAL Distribution	ADT Distribution
MIN	43959	1750
25 PERCNTILE	63643	2350
MEDIAN	71889	3900
AVERAGE	140692	4484
75 PERCNTILE	181101	3900
MAX	523334	31600

B/C (SL) =	63.2	Yrs / Dollar	Category
B/C (NBA) =	57.7	Ft-yr/ft/Dollar	x4

Figure 56: Evaluation of LC for AST interlayer over CSD base, (Cat. x4)

NO INT Longitudinal Cracking (ft) Over CSD Bases								
ESAL	0	30000	Thickness	0	4	Data Range	3	
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives		
45	1718	16.0	5.0	15.2	5.4	SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections



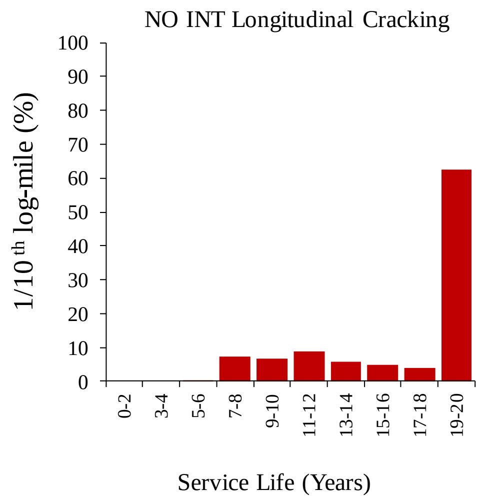
SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	0	0.0
5-6	33	1.9
7-8	201	11.7
9-10	186	10.8
11-12	103	6.0
13-14	98	5.7
15-16	79	4.6
17-18	56	3.3
19-20	962	56.0
TOTAL '0-20'	1718	100.0

Parameters	ESAL Distribution	ADT Distribution
MIN	56	159
25 PERCNTILE	1508	679
MEDIAN	4664	1185
AVERAGE	7679	1481
75 PERCNTILE	13877	2028
MAX	28790	8012

B/C (SL) =	106.2	Yrs / Dollar	Category
B/C (NBA) =	101.0	Ft-yr/ft/Dollar	x5

Figure 57: Evaluation of LC for no interlayer over CSD base, (Cat. x5)

NO INT Longitudinal Cracking (ft) Over CSD Bases								
ESAL	30001	2E6	Thickness	0	4	Data Range	3	
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives		
17	768	16.9	4.4	16.2	4.9	SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections



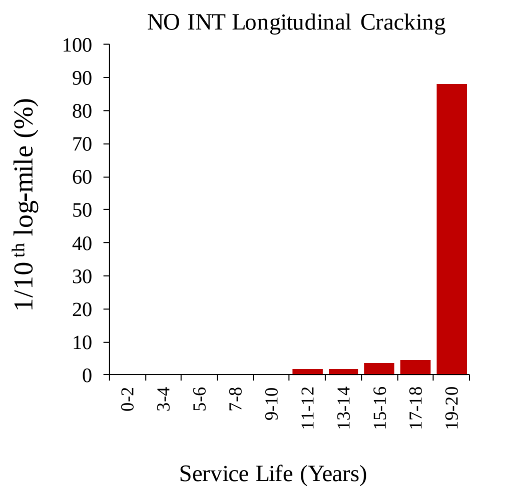
SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	0	0.0
5-6	1	0.1
7-8	56	7.3
9-10	51	6.6
11-12	67	8.7
13-14	44	5.7
15-16	37	4.8
17-18	31	4.0
19-20	481	62.6
TOTAL '0-20'	768	100.0

Parameters	ESAL Distribution	ADT Distribution
MIN	30494	455
25 PERCNTILE	37822	1152
MEDIAN	45871	2368
AVERAGE	114431	3997
75 PERCNTILE	84069	3849
MAX	1431101	54792

B/C (SL) =	121.1	Yrs / Dollar	Category
B/C (NBA) =	115.7	Ft-yr/ft/Dollar	x6

Figure 58: Evaluation of LC for no interlayer over CSD bases, (Cat. x6)

NO INT Longitudinal Cracking (ft) Over CSD Bases								
ESAL	30001	2E6	Thickness	4.1	10	Data Range	3	
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives		
2	108	19.4	1.6	18.7	2.2	SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections



SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	0	0.0
5-6	0	0.0
7-8	0	0.0
9-10	0	0.0
11-12	2	1.9
13-14	2	1.9
15-16	4	3.7
17-18	5	4.6
19-20	95	88.0
TOTAL '0-20'	108	100.0

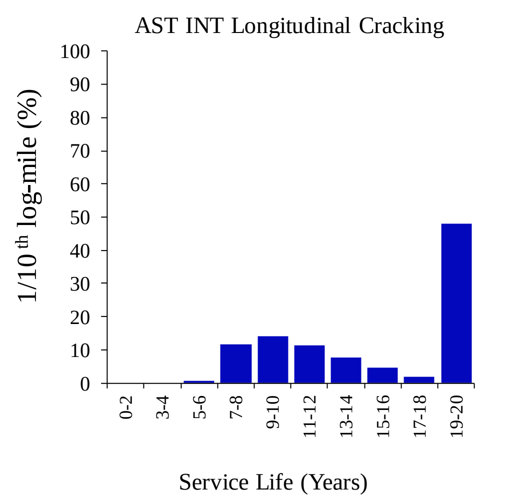
Parameters	ESAL Distribution	ADT Distribution
MIN	31695	4084
25 PERCNTILE	31695	4084
MEDIAN	62459	4656
AVERAGE	54483	4508
75 PERCNTILE	62459	4656
MAX	62459	4656

B/C (SL) =	163.8	Yrs / Dollar	Category
B/C (NBA) =	157.5	Ft-yr/ft/Dollar	x8

Figure 59: Evaluation of LC for no interlayer over CSD bases, (Cat. x8)

AST/No interlayer over CTD Sections. In this section, the performance of AST/no interlayer over CTD base is shown from Figure 60 to Figure 63 for longitudinal cracking (3 data points). Like transverse cracking, only Category x13 (shown in Figure 61) has sufficient data in this case. Category x9 and x14 have more than five projects (N(P)>5), hence these results are somewhat acceptable.

AST INT Longitudinal Cracking (ft) Over CTD Bases							
ESAL	0	30000	Thickness	0	4	Data Range	3
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev		
6	344	15.3	5.0	14.4	5.4		
B/C (SL) =	95.3	Yrs / Dollar	Category				
B/C (NBA) =	90.0	Ft-yr/ft/Dollar	x9				

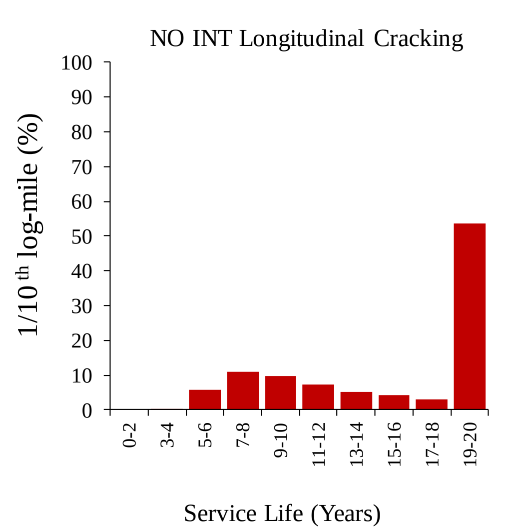


HISTOGRAM DATA of Service Lives		
SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	0	0.0
5-6	2	0.6
7-8	40	11.6
9-10	49	14.2
11-12	39	11.3
13-14	27	7.8
15-16	16	4.7
17-18	6	1.7
19-20	165	48.0
TOTAL '0-20'	344	100.0

Parameters	ESAL Distribution	ADT Distribution
MIN	81	360
25 PERCNTILE	3467	411
MEDIAN	9210	667
AVERAGE	10266	813
75 PERCNTILE	16965	1360
MAX	18718	1440

Figure 60: Evaluation of LC for AST interlayer over CTD bases, (Cat. x9)

NO INT Longitudinal Cracking (ft) Over CTD Bases							
ESAL	0	30000	Thickness	0	4	Data Range	3
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev		
46	1463	15.5	5.4	14.7	5.7		
B/C (SL) =	112.1	Yrs / Dollar	Category				
B/C (NBA) =	106.6	Ft-yr/ft/Dollar	x13				

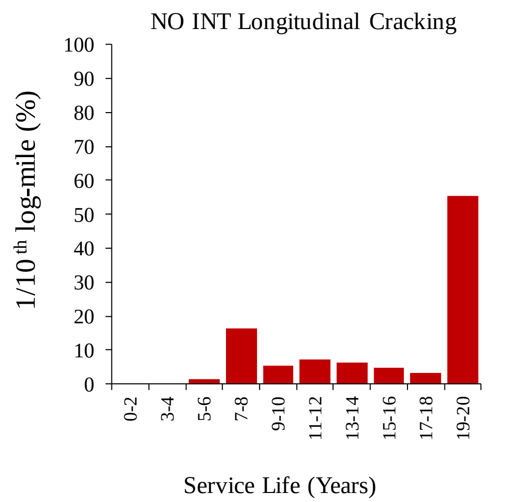


HISTOGRAM DATA of Service Lives		
SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	4	0.3
5-6	86	5.9
7-8	161	11.0
9-10	140	9.6
11-12	105	7.2
13-14	76	5.2
15-16	61	4.2
17-18	46	3.1
19-20	784	53.6
TOTAL '0-20'	1463	100.0

Parameters	ESAL Distribution	ADT Distribution
MIN	148	115
25 PERCNTILE	1451	500
MEDIAN	7339	1040
AVERAGE	9617	1451
75 PERCNTILE	17083	1576
MAX	28551	10210

Figure 61: Evaluation of LC for no interlayer over CTD bases, (Cat. x13)

NO INT Longitudinal Cracking (ft) Over CTD Bases								
ESAL	30001	2E6	Thickness	0	4	Data Range	3	
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives		
6	208	15.8	5.2	15.0	5.5	SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections



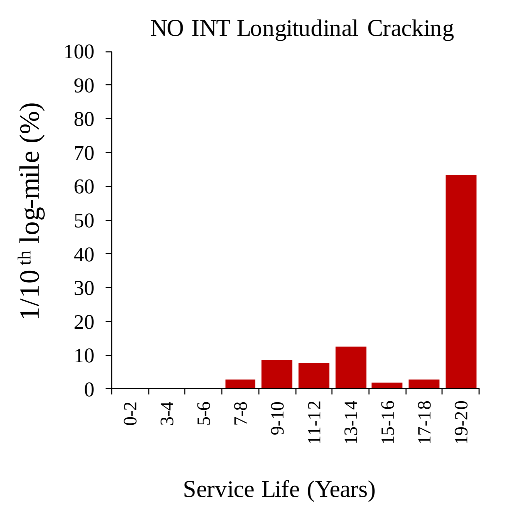
SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	0	0.0
5-6	3	1.4
7-8	34	16.3
9-10	11	5.3
11-12	15	7.2
13-14	13	6.3
15-16	10	4.8
17-18	7	3.4
19-20	115	55.3
TOTAL '0-20'	208	100.0

Parameters	ESAL Distribution	ADT Distribution
MIN	36661	1761
25 PERCNTILE	36661	1896
MEDIAN	51834	3405
AVERAGE	57280	3730
75 PERCNTILE	76200	3931
MAX	134609	8861

B/C (SL) =	118.6	Yrs / Dollar	Category
B/C (NBA) =	112.2	Ft-yr/ft/Dollar	x14

Figure 62: Evaluation of LC for no interlayer over CTD bases, (Cat. x14)

NO INT Longitudinal Cracking (ft) Over CTD Bases								
ESAL	30001	2E6	Thickness	4.1	10	Data Range	3	
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives		
3	104	17.1	4.1	16.3	4.5	SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections



SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	0	0.0
5-6	0	0.0
7-8	3	2.9
9-10	9	8.7
11-12	8	7.7
13-14	13	12.5
15-16	2	1.9
17-18	3	2.9
19-20	66	63.5
TOTAL '0-20'	104	100.0

Parameters	ESAL Distribution	ADT Distribution
MIN	113385	5500
25 PERCNTILE	113385	5500
MEDIAN	113385	5500
AVERAGE	211348	9239
75 PERCNTILE	378875	14539
MAX	387171	16602

B/C (SL) =	144.3	Yrs / Dollar	Category
B/C (NBA) =	137.0	Ft-yr/ft/Dollar	x16

Figure 63: Evaluation of LC for no interlayer over CTD bases, (Cat. x16)

Stone Interlayer over CTD/CSD Bases. Evaluation of longitudinal cracks for stone interlayer for CTD and CSD bases are shown in Figures 64 and 65, respectively. The corresponding no interlayer sections for comparison with stone interlayer are shown in Figure 66 and 67, as both CTD and CSD sections have more than 18 years of AvgSL. Hence, stone interlayer shows good improvements for longitudinal cracking also.

Stone Int Longitudinal cracking (ft) Over CTD Bases								
ESAL	0	150000	Thickness	0	5	Data Range	3	
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives		
2	50	18.9	2.7	18.4	3.2	SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
						0-2	0	0.0
						3-4	0	0.0
						5-6	0	0.0
						7-8	0	0.0
						9-10	0	0.0
						11-12	4	8.0
						13-14	1	2.0
						15-16	1	2.0
						17-18	2	4.0
						19-20	42	84.0
						TOTAL '0-20'	50	100.0
						Parameters	ESAL Distribution	ADT Distribution
						MIN	28551	1355
						25 PERCNTILE	28551	1355
						MEDIAN	28551	1355
						AVERAGE	48126	1664
B/C (SL) =		111.5	Yrs / Dollar		Category	75 PERCNTILE	28551	1355
B/C (NBA) =		108.7	Ft-yr/ft/Dollar		x17	MAX	137299	3071

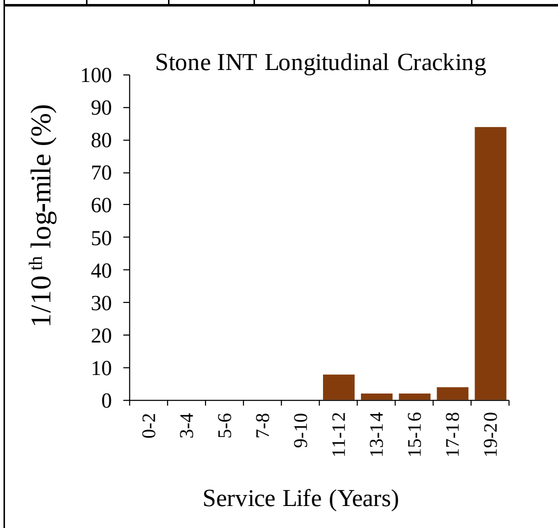
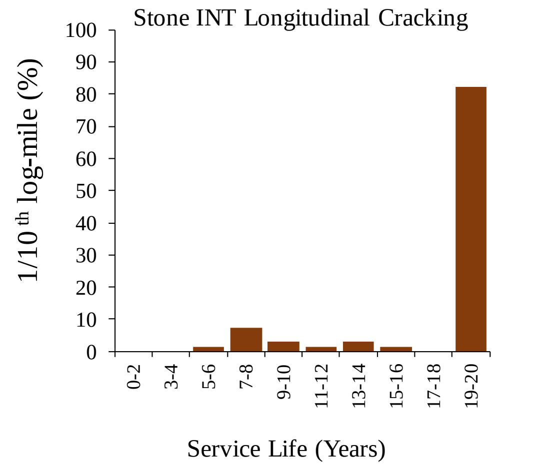


Figure 64: Evaluation of LC for stone interlayer over CTD bases, (Cat. x17)

Stone Int Longitudinal cracking (ft) Over CSD Bases							
ESAL	0	30000	Thickness	0	5	Data Range	3
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives	
3	68	18.2	4.2	17.3	4.3		



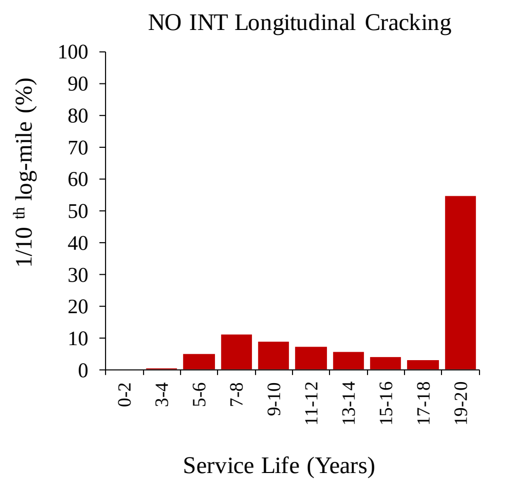
SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	0	0.0
5-6	1	1.5
7-8	5	7.4
9-10	2	2.9
11-12	1	1.5
13-14	2	2.9
15-16	1	1.5
17-18	0	0.0
19-20	56	82.4
TOTAL '0-20'	68	100.0

Parameters	ESAL Distribution	ADT Distribution
MIN	15932	2800
25 PERCNTILE	15932	2800
MEDIAN	15932	2800
AVERAGE	19704	4556
75 PERCNTILE	24152	3800
MAX	29340	11214

B/C (SL) =	90.0	Yrs / Dollar	Category
B/C (NBA) =	86.0	Ft-yr/ft/Dollar	x18

Figure 65: Evaluation of LC for stone interlayer over CSD bases, (Cat. x18)

NO INT Longitudinal Cracking (ft) Over CTD Bases							
ESAL	0	150000	Thickness	0	5	Data Range	3
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives	
55	1783	15.7	5.3	14.9	5.6		



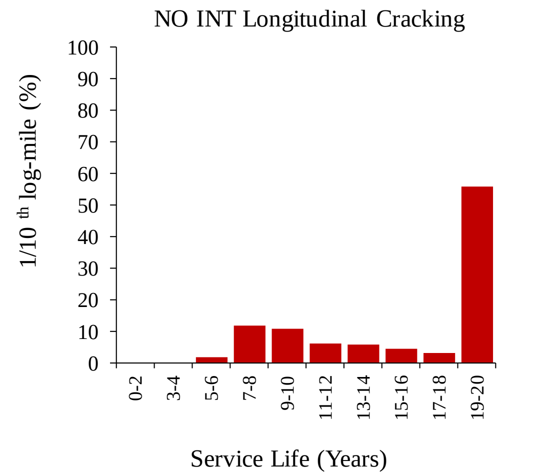
SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	4	0.2
5-6	89	5.0
7-8	198	11.1
9-10	160	9.0
11-12	127	7.1
13-14	100	5.6
15-16	73	4.1
17-18	56	3.1
19-20	976	54.7
TOTAL '0-20'	1783	100.0

Parameters	ESAL Distribution	ADT Distribution
MIN	148	115
25 PERCNTILE	1819	693
MEDIAN	9723	1159
AVERAGE	19338	1854
75 PERCNTILE	21801	2403
MAX	134609	10210

B/C (SL) =	114.9	Yrs / Dollar	Category
B/C (NBA) =	109.3	Ft-yr/ft/Dollar	x19

Figure 66: Evaluation of LC for no interlayer over CTD bases, (Cat. x19)

NO INT Longitudinal Cracking (ft) Over CSD Bases								
ESAL	0	30000	Thickness	0	5	Data Range	3	
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives		
45	1718	16.0	5.0	15.2	5.4	SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections



SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	0	0.0
5-6	33	1.9
7-8	201	11.7
9-10	186	10.8
11-12	103	6.0
13-14	98	5.7
15-16	79	4.6
17-18	56	3.3
19-20	962	56.0
TOTAL '0-20'	1718	100.0

Parameters	ESAL Distribution	ADT Distribution
MIN	56	159
25 PERCNTILE	1508	679
MEDIAN	4664	1185
AVERAGE	7679	1481
75 PERCNTILE	13877	2028
MAX	28790	8012

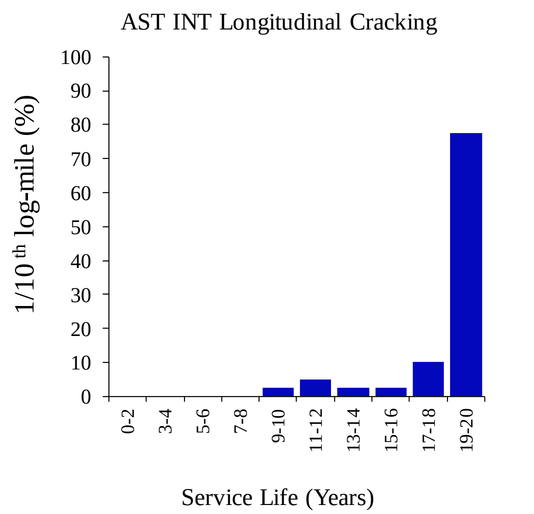
B/C (SL) =	106.2	Yrs / Dollar	Category
B/C (NBA) =	101.0	Ft-yr/ft/Dollar	x20

Figure 67: Evaluation of LC for no interlayer over CSD bases, (Cat. x20)

Longitudinal Crack Evaluation (6 data points)

AST/No Interlayer over CSD Bases. Figure 68 to Figure 72 illustrates the evaluation of longitudinal cracking for CSD bases. It should be noted here that only x5' and x6' (shown in Figure 70 and 71) had sufficient data for any conclusion.

AST INT Longitudinal cracking (ft) Over CSD Bases								
ESAL	0	30000	Thickness	0	4	Data Range	6	
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives		
3	40	18.8	2.7	18.1	3.2	SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections



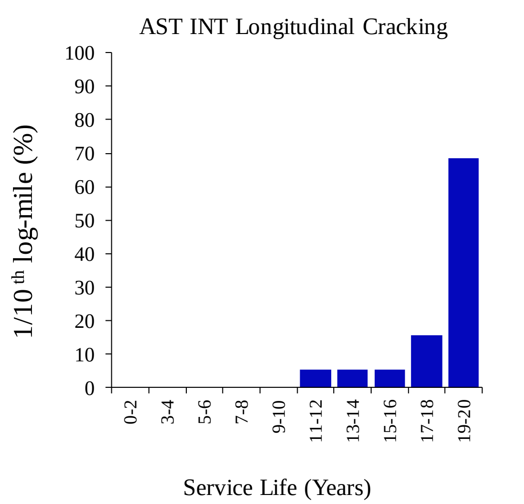
SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	0	0.0
5-6	0	0.0
7-8	0	0.0
9-10	1	2.5
11-12	2	5.0
13-14	1	2.5
15-16	1	2.5
17-18	4	10.0
19-20	31	77.5
TOTAL '0-20'	40	100.0

Parameters	ESAL Distribution	ADT Distribution
MIN	734	530
25 PERCNTILE	9583	794
MEDIAN	12533	882
AVERAGE	10490	1528
75 PERCNTILE	13440	1616
MAX	16161	3819

B/C (SL) =	131.4	Yrs / Dollar	Category
B/C (NBA) =	126.6	Ft-yr/ft/Dollar	x1'

Figure 68: Evaluation of LC for AST interlayer over CSD base, (Cat. x1')

AST INT Longitudinal cracking (ft) Over CSD Bases								
ESAL	30001	2E6	Thickness	4.1	10	Data Range	6	
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives		
2	19	18.6	2.5	17.7	3.2	SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections



SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	0	0.0
5-6	0	0.0
7-8	0	0.0
9-10	0	0.0
11-12	1	5.3
13-14	1	5.3
15-16	1	5.3
17-18	3	15.8
19-20	13	68.4
TOTAL '0-20'	19	100.0

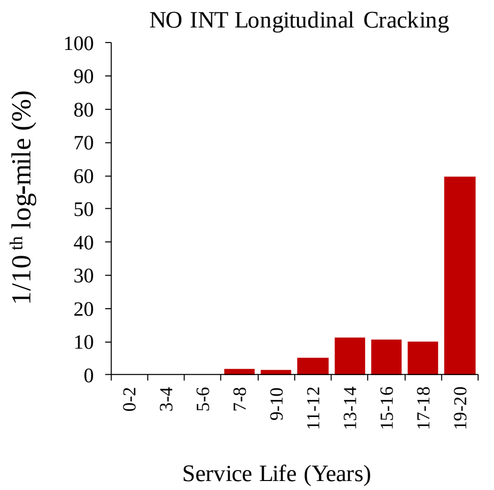
Parameters	ESAL Distribution	ADT Distribution
MIN	71889	6197
25 PERCNTILE	71889	6197
MEDIAN	71889	6197
AVERAGE	140830	10208
75 PERCNTILE	71889	6197
MAX	508514	31600

B/C (SL) =	130.2	Yrs / Dollar	Category
B/C (NBA) =	123.8	Ft-yr/ft/Dollar	x4'

Figure 69: Evaluation of LC for AST interlayer over CSD base, (Cat. x4')

NO INT Longitudinal cracking (ft) Over CSD Bases								
ESAL	0	30000	Thickness	0	4	Data Range	6	
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives		
45	1745	17.7	3.2	16.4	3.7	SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections

SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	0	0.0
5-6	0	0.0
7-8	31	1.8
9-10	25	1.4
11-12	89	5.1
13-14	194	11.1
15-16	188	10.8
17-18	177	10.1
19-20	1041	59.7
TOTAL '0-20'	1745	100.0



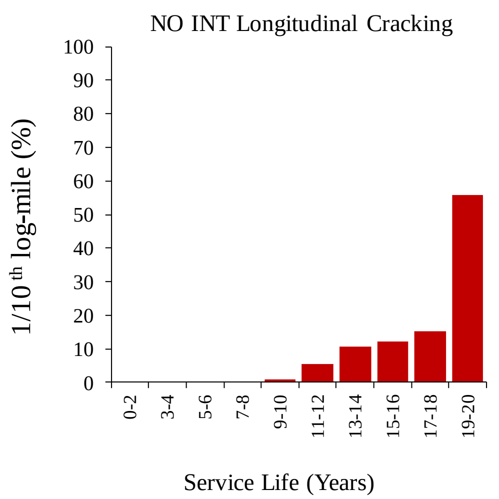
Parameters	ESAL Distribution	ADT Distribution
MIN	56	159
25 PERCNTILE	1508	679
MEDIAN	4664	1185
AVERAGE	7719	1483
75 PERCNTILE	13877	2028
MAX	28790	8012

B/C (SL) =	136.5	Yrs / Dollar	Category
B/C (NBA) =	126.7	Ft-yr/ft/Dollar	x5'

Figure 70: Evaluation of LC for no interlayer over CSD base, (Cat. x5')

NO INT Longitudinal cracking (ft) Over CSD Bases								
ESAL	30001	2E6	Thickness	0	4	Data Range	6	
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives		
17	772	17.8	2.8	16.5	3.4	SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections

SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	0	0.0
5-6	0	0.0
7-8	0	0.0
9-10	6	0.8
11-12	42	5.4
13-14	82	10.6
15-16	94	12.2
17-18	117	15.2
19-20	431	55.8
TOTAL '0-20'	772	100.0



Parameters	ESAL Distribution	ADT Distribution
MIN	30494	455
25 PERCNTILE	37822	1152
MEDIAN	45871	2368
AVERAGE	114015	3981
75 PERCNTILE	84069	3849
MAX	1431101	54792

B/C (SL) =	139.6	Yrs / Dollar	Category
B/C (NBA) =	128.9	Ft-yr/ft/Dollar	x6'

Figure 71: Evaluation of LC for no interlayer over CSD bases, (Cat. x6')

NO INT Longitudinal cracking (ft) Over CSD Bases								
ESAL	30001	2E6	Thickness	4.1	10	Data Range	6	
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives		
2	107	19.8	0.9	19.5	1.3	SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
						0-2	0	0.0
						3-4	0	0.0
						5-6	0	0.0
						7-8	0	0.0
						9-10	0	0.0
						11-12	0	0.0
						13-14	1	0.9
						15-16	2	1.9
						17-18	0	0.0
						19-20	104	97.2
						TOTAL '0-20'	107	100.0
						Parameters	ESAL Distribution	ADT Distribution
						MIN	31695	4084
						25 PERCNTILE	31695	4084
						MEDIAN	62459	4656
						AVERAGE	54409	4506
B/C (SL) =		170.3	Yrs / Dollar		Category	75 PERCNTILE	62459	4656
B/C (NBA) =		167.8	Ft-yr/ft/Dollar		x8'	MAX	62459	4656

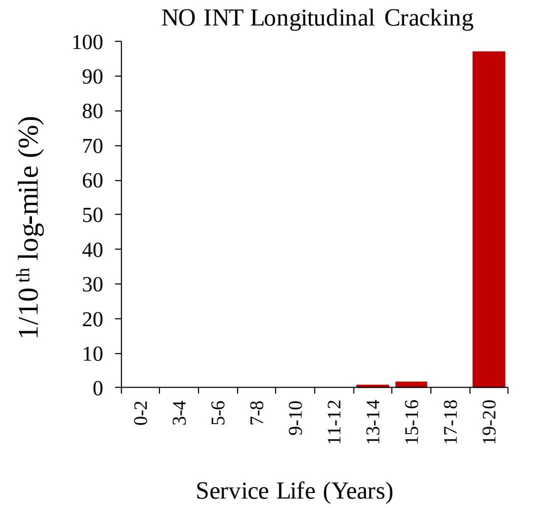


Figure 72: Evaluation of LC for no interlayer over CSD bases, (Cat. x8')

AST/No Interlayer over CTD Bases. Longitudinal cracking evaluation for CTD bases are shown below by Figure 73 to Figure 76. Amongst all the figures in this section, only Figure 74 (Category x13') had sufficient data for conclusive results.

AST INT Longitudinal cracking (ft) Over CTD Bases								
ESAL	0	30000	Thickness	0	4	Data Range	6	
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives		
6	344	16.8	3.7	15.7	4.2	SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
						0-2	0	0.0
						3-4	0	0.0
						5-6	0	0.0
						7-8	7	2.0
						9-10	9	2.6
						11-12	48	14.0
						13-14	49	14.2
						15-16	29	8.4
						17-18	27	7.8
						19-20	175	50.9
						TOTAL '0-20'	344	100.0
						Parameters	ESAL Distribution	ADT Distribution
						MIN	81	360
						25 PERCNTILE	3467	411
						MEDIAN	9210	667
						AVERAGE	10266	813
B/C (SL) =		119.6	Yrs / Dollar		Category	75 PERCNTILE	16965	1360
B/C (NBA) =		111.6	Ft-yr/ft/Dollar		x9'	MAX	18718	1440

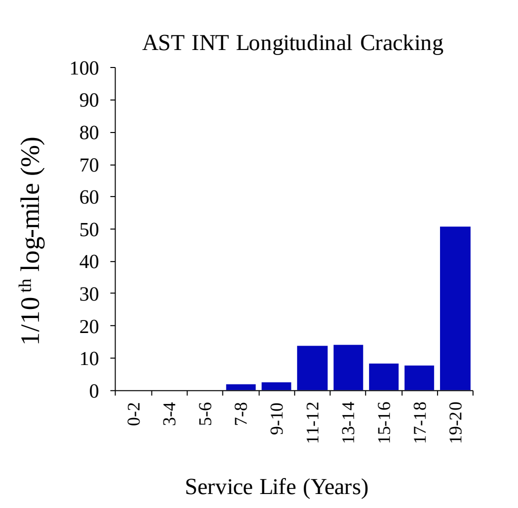


Figure 73: Evaluation of LC for AST interlayer over CTD bases, (Cat. x9')

NO INT Longitudinal cracking (ft) Over CTD Bases								
ESAL	0	30000	Thickness	0	4	Data Range	6	
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives		
46	1477	16.8	4.0	15.7	4.4	SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
						0-2	0	0.0
						3-4	0	0.0
						5-6	11	0.7
						7-8	48	3.2
						9-10	79	5.3
						11-12	143	9.7
						13-14	170	11.5
						15-16	125	8.5
						17-18	110	7.4
						19-20	791	53.6
						TOTAL '0-20'	1477	100.0
						Parameters	ESAL Distribution	ADT Distribution
						MIN	148	115
						25 PERCNTILE	1451	500
						MEDIAN	8671	1040
						AVERAGE	9678	1454
B/C (SL) =		139.4	Yrs / Dollar		Category	75 PERCNTILE	17083	1576
B/C (NBA) =		130.1	Ft-yr/ft/Dollar		x13'	MAX	28551	10210

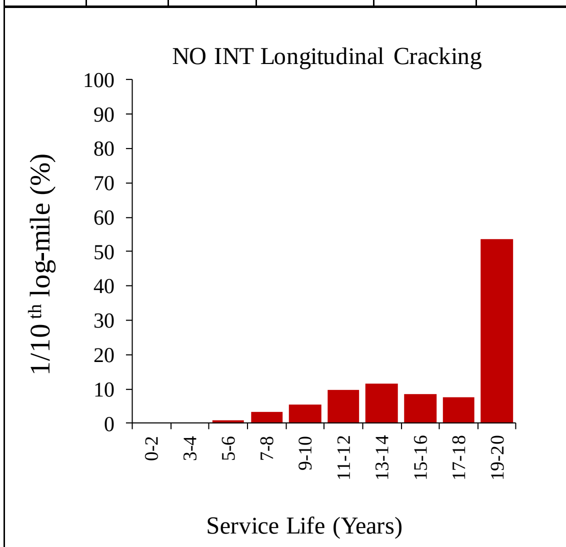
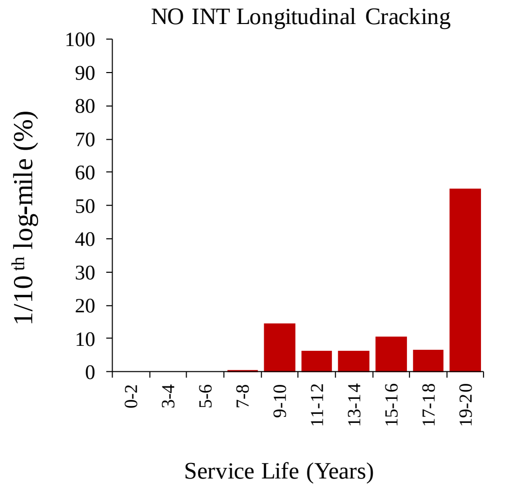


Figure 74: Evaluation of LC for no interlayer over CTD bases, (Cat. x13')

NO INT Longitudinal cracking (ft) Over CTD Bases							
ESAL	30001	2E6	Thickness	0	4	Data Range	6
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives	
6	207	16.8	4.0	15.7	4.4		

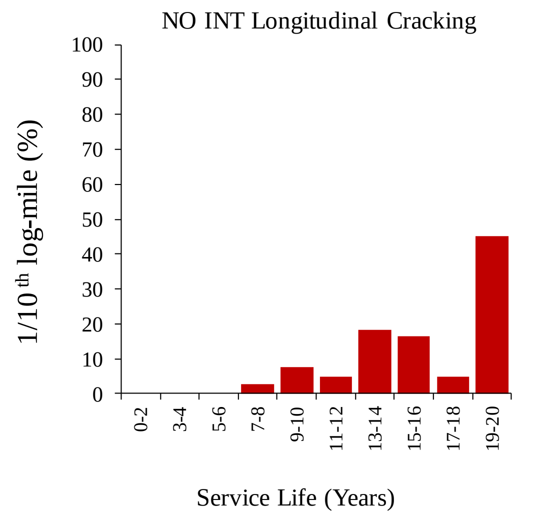


SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	0	0.0
5-6	0	0.0
7-8	1	0.5
9-10	30	14.5
11-12	13	6.3
13-14	13	6.3
15-16	22	10.6
17-18	14	6.8
19-20	114	55.1
TOTAL '0-20'	207	100.0
Parameters	ESAL Distribution	ADT Distribution
MIN	36661	1761
25 PERCNTILE	36661	1896
MEDIAN	51834	3538
AVERAGE	57380	3739
75 PERCNTILE	76200	3931
MAX	134609	8861

B/C (SL) =	140.2	Yrs / Dollar	Category
B/C (NBA) =	130.4	Ft-yr/ft/Dollar	x14'

Figure 75: Evaluation of LC for no interlayer over CTD bases, (Cat. x14')

NO INT Longitudinal cracking (ft) Over CTD Bases							
ESAL	30001	2E6	Thickness	4.1	10	Data Range	6
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives	
3	104	16.4	3.8	15.2	4.2		



SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	0	0.0
5-6	0	0.0
7-8	3	2.9
9-10	8	7.7
11-12	5	4.8
13-14	19	18.3
15-16	17	16.3
17-18	5	4.8
19-20	47	45.2
TOTAL '0-20'	104	100.0
Parameters	ESAL Distribution	ADT Distribution
MIN	113385	5500
25 PERCNTILE	113385	5500
MEDIAN	113385	5500
AVERAGE	211348	9239
75 PERCNTILE	378875	14539
MAX	387171	16602

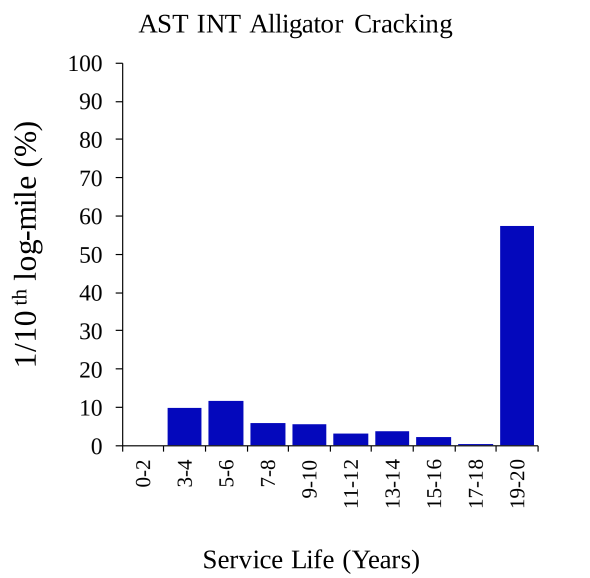
B/C (SL) =	134.8	Yrs / Dollar	Category
B/C (NBA) =	125.1	Ft-yr/ft/Dollar	x16'

Figure 76: Evaluation of LC for no interlayer over CTD bases, (Cat. x16')

Alligator Cracking Evaluation (3 data points)

AST/No Interlayer over CSD Bases. From Figure 77 to 82 shown below, the performance of alligator cracking over CSD bases performance was evaluated for 3 data points. Categories x1, x5, and x6 (shown in Figure 77, 80, and 81, respectively) have sufficient data for comparison shown in the next section. Category x4 (shown in Figure 79) also has reasonable data for alligator cracking (N(P)=8).

AST INT Alligator Cracking (Sq. ft) Over CSD Bases							
ESAL	0	30000	Thickness	0	4	Data Range	3
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives	
27	736	14.7	6.6	13.8	6.5		



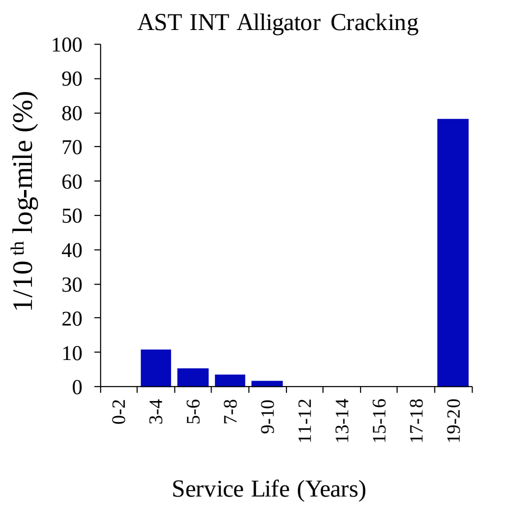
SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	72	9.8
5-6	85	11.5
7-8	44	6.0
9-10	42	5.7
11-12	24	3.3
13-14	27	3.7
15-16	16	2.2
17-18	4	0.5
19-20	422	57.3
TOTAL '0-20'	736	100.0

Parameters	ESAL Distribution	ADT Distribution
MIN	603	91
25 PERCNTILE	2128	530
MEDIAN	6969	1400
AVERAGE	9323	1530
75 PERCNTILE	13569	1845
MAX	27494	3819

B/C (SL) =	66.2	Yrs / Dollar	Category
B/C (NBA) =	62.0	Ft-yr/ft/Dollar	x1

Figure 77: Evaluation of AC for AST interlayer over CSD base, (Cat. x1)

AST INT Alligator Cracking (Sq. ft) Over CSD Bases								
ESAL	30001	2E6	Thickness	0	4	Data Range	3	
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives		
2	55	16.8	6.2	15.8	6.1	SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections



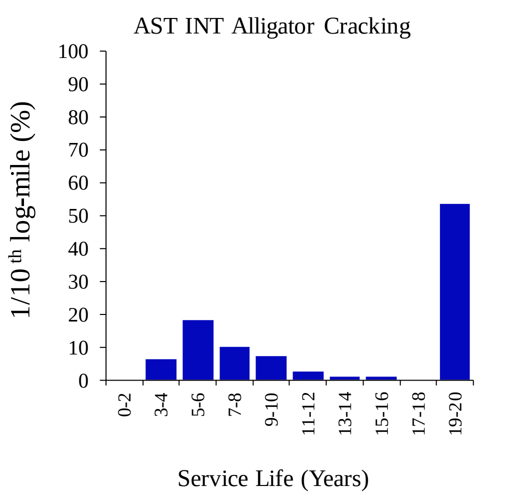
SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	6	10.9
5-6	3	5.5
7-8	2	3.6
9-10	1	1.8
11-12	0	0.0
13-14	0	0.0
15-16	0	0.0
17-18	0	0.0
19-20	43	78.2
TOTAL '0-20'	55	100.0

Parameters	ESAL Distribution	ADT Distribution
MIN	33693	1090
25 PERCNTILE	33693	1090
MEDIAN	33693	1090
AVERAGE	143136	10096
75 PERCNTILE	368103	28609
MAX	368103	28609

B/C (SL) =	84.3	Yrs / Dollar	Category
B/C (NBA) =	79.5	Ft-yr/ft/Dollar	x2

Figure 78: Evaluation of AC for AST interlayer over CSD base, (Cat. x2)

AST INT Alligator Cracking (Sq. ft) Over CSD Bases								
ESAL	30001	2E6	Thickness	4.1	10	Data Range	3	
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives		
8	110	14.0	6.7	13.1	6.6	SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections



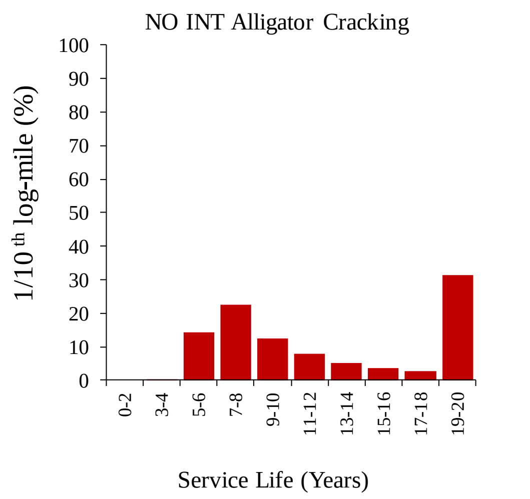
SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	7	6.4
5-6	20	18.2
7-8	11	10.0
9-10	8	7.3
11-12	3	2.7
13-14	1	0.9
15-16	1	0.9
17-18	0	0.0
19-20	59	53.6
TOTAL '0-20'	110	100.0

Parameters	ESAL Distribution	ADT Distribution
MIN	43959	1750
25 PERCNTILE	63643	2350
MEDIAN	71889	3900
AVERAGE	142568	4437
75 PERCNTILE	181101	3900
MAX	523334	31600

B/C (SL) =	61.4	Yrs / Dollar	Category
B/C (NBA) =	57.3	Ft-yr/ft/Dollar	x4

Figure 79: Evaluation of AC for AST interlayer over CSD base, (Cat. x4)

NO INT Alligator Cracking (Sq. ft) Over CSD Bases								
ESAL	0	30000	Thickness	0	4	Data Range	3	
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives		
46	1786	12.5	5.7	11.7	5.9	SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections



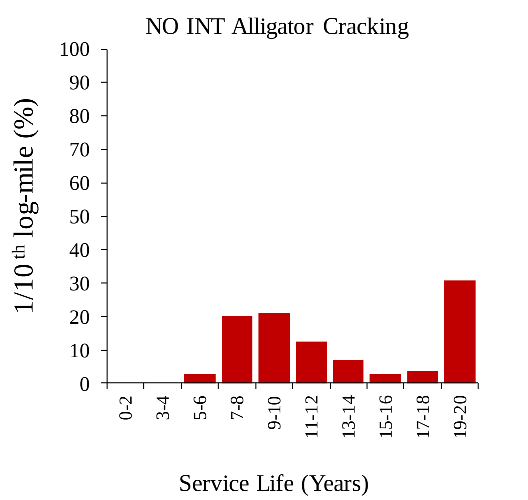
SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	1	0.1
5-6	257	14.4
7-8	401	22.5
9-10	223	12.5
11-12	142	8.0
13-14	94	5.3
15-16	62	3.5
17-18	47	2.6
19-20	559	31.3
TOTAL '0-20'	1786	100.0

Parameters	ESAL Distribution	ADT Distribution
MIN	56	159
25 PERCNTILE	1508	679
MEDIAN	4664	1185
AVERAGE	7980	1478
75 PERCNTILE	13877	2028
MAX	28790	8012

B/C (SL) =	65.1	Yrs / Dollar	Category
B/C (NBA) =	60.9	Ft-yr/ft/Dollar	x5

Figure 80: Evaluation of AC for no interlayer over CSD base, (Cat. x5)

NO INT Alligator Cracking (Sq. ft) Over CSD Bases								
ESAL	30001	2E6	Thickness	0	4	Data Range	3	
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives		
17	757	13.1	5.1	12.2	5.4	SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections



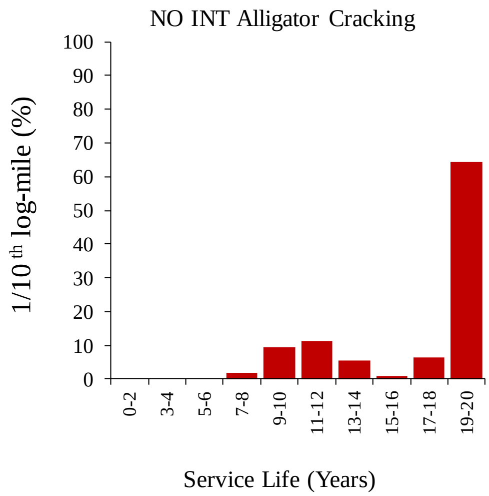
SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	0	0.0
5-6	20	2.6
7-8	153	20.2
9-10	159	21.0
11-12	94	12.4
13-14	52	6.9
15-16	20	2.6
17-18	27	3.6
19-20	232	30.6
TOTAL '0-20'	757	100.0

Parameters	ESAL Distribution	ADT Distribution
MIN	30494	455
25 PERCNTILE	37822	1152
MEDIAN	57684	2368
AVERAGE	115713	4015
75 PERCNTILE	84069	3849
MAX	1431101	54792

B/C (SL) =	74.3	Yrs / Dollar	Category
B/C (NBA) =	69.0	Ft-yr/ft/Dollar	x6

Figure 81: Evaluation of AC for no interlayer over CSD bases, (Cat. x6)

NO INT Alligator Cracking (Sq. ft) Over CSD Bases							
ESAL	30001	2E6	Thickness	4.1	10	Data Range	3
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives	
2	107	17.2	4.1	16.4	4.4		



SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	0	0.0
5-6	0	0.0
7-8	2	1.9
9-10	10	9.3
11-12	12	11.2
13-14	6	5.6
15-16	1	0.9
17-18	7	6.5
19-20	69	64.5
TOTAL '0-20'	107	100.0

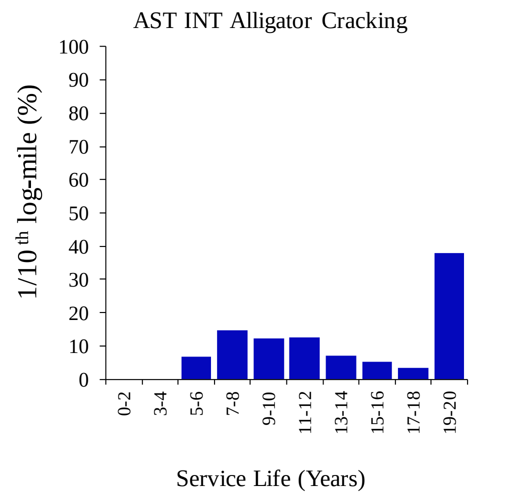
Parameters	ESAL Distribution	ADT Distribution
MIN	31695	4084
25 PERCNTILE	31695	4084
MEDIAN	62459	4656
AVERAGE	54409	4506
75 PERCNTILE	62459	4656
MAX	62459	4656

B/C (SL) =	127.3	Yrs / Dollar	Category
B/C (NBA) =	120.7	Ft-yr/ft/Dollar	x8

Figure 82: Evaluation of AC for no interlayer over CSD bases, (Cat. x8)

AST/No Interlayer over CTD Bases. The performance of AST and no interlayer sections over CTD bases for alligator cracking are shown from Figure 83 to Figure 86.

AST INT Alligator Cracking (Sq. ft) Over CTD Bases							
ESAL	0	30000	Thickness	0	4	Data Range	3
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev		
6	346	14.0	5.3	13.1	5.6		



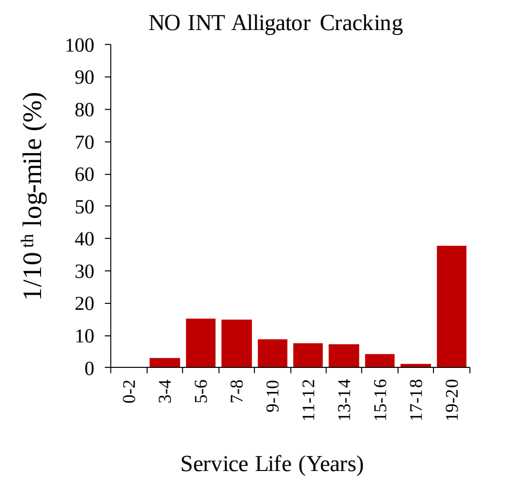
HISTOGRAM DATA of Service Lives		
SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	0	0.0
5-6	23	6.6
7-8	51	14.7
9-10	42	12.1
11-12	44	12.7
13-14	25	7.2
15-16	18	5.2
17-18	12	3.5
19-20	131	37.9
TOTAL '0-20'	346	100.0

Parameters	ESAL Distribution	ADT Distribution
MIN	81	360
25 PERCNTILE	3467	411
MEDIAN	9210	667
AVERAGE	10211	807
75 PERCNTILE	16965	1360
MAX	18718	1440

B/C (SL) =	80.0	Yrs / Dollar	Category
B/C (NBA) =	75.0	Ft-yr/ft/Dollar	x9

Figure 83: Evaluation of AC for AST interlayer over CTD bases, (Cat. x9)

NO INT Alligator Cracking (Sq. ft) Over CTD Bases							
ESAL	0	30000	Thickness	0	4	Data Range	3
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev		
46	1458	13.2	6.0	12.4	6.2		



HISTOGRAM DATA of Service Lives		
SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	42	2.9
5-6	223	15.3
7-8	218	15.0
9-10	129	8.8
11-12	112	7.7
13-14	105	7.2
15-16	62	4.3
17-18	18	1.2
19-20	549	37.7
TOTAL '0-20'	1458	100.0

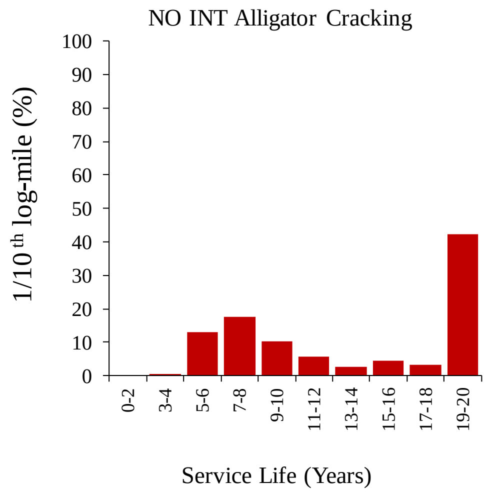
Parameters	ESAL Distribution	ADT Distribution
MIN	148	115
25 PERCNTILE	1798	500
MEDIAN	7339	1040
AVERAGE	9592	1438
75 PERCNTILE	17083	1576
MAX	28551	10210

B/C (SL) =	78.5	Yrs / Dollar	Category
B/C (NBA) =	73.9	Ft-yr/ft/Dollar	x13

Figure 84: Evaluation of AC for no interlayer over CTD bases, (Cat. x13)

NO INT Alligator Cracking (Sq. ft) Over CTD Bases								
ESAL	30001	2E6	Thickness	0	4	Data Range	3	
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives		
5	154	13.7	6.0	13.0	6.3	SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections

SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	1	0.6
5-6	20	13.0
7-8	27	17.5
9-10	16	10.4
11-12	9	5.8
13-14	4	2.6
15-16	7	4.5
17-18	5	3.2
19-20	65	42.2
TOTAL '0-20'	154	100.0



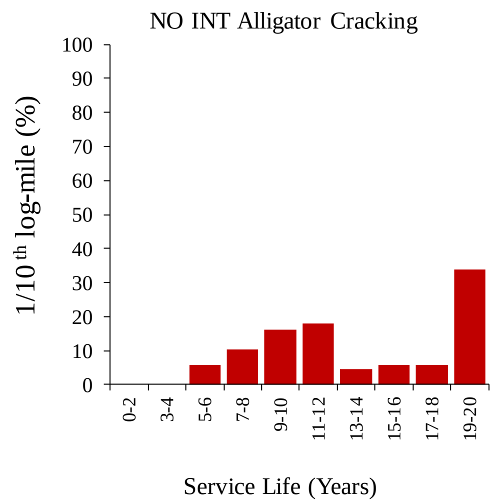
Parameters	ESAL Distribution	ADT Distribution
MIN	41466	1761
25 PERCNTILE	51834	3271
MEDIAN	54675	3538
AVERAGE	64510	4373
75 PERCNTILE	76200	3931
MAX	134609	8861

B/C (SL) =	85.8	Yrs / Dollar	Category
B/C (NBA) =	81.0	Ft-yr/ft/Dollar	x14

Figure 85: Evaluation of AC for no interlayer over CTD bases, (Cat. x14)

NO INT Alligator Cracking (Sq. ft) Over CTD Bases								
ESAL	30001	2E6	Thickness	4.1	10	Data Range	3	
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives		
3	106	14.0	5.1	13.0	5.3	SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections

SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	0	0.0
5-6	6	5.7
7-8	11	10.4
9-10	17	16.0
11-12	19	17.9
13-14	5	4.7
15-16	6	5.7
17-18	6	5.7
19-20	36	34.0
TOTAL '0-20'	106	100.0



Parameters	ESAL Distribution	ADT Distribution
MIN	113385	5500
25 PERCNTILE	113385	5500
MEDIAN	113385	5500
AVERAGE	209500	9169
75 PERCNTILE	378875	13851
MAX	387171	16602

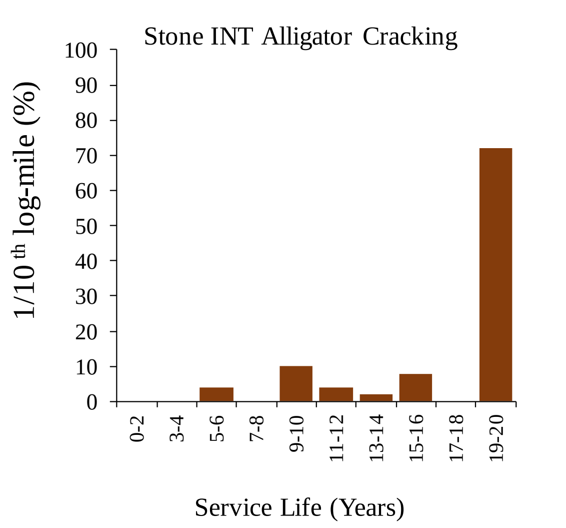
B/C (SL) =	95.4	Yrs / Dollar	Category
B/C (NBA) =	89.0	Ft-yr/ft/Dollar	x16

Figure 86: Evaluation of AC for no interlayer over CTD bases, (Cat. x16)

Stone Interlayer over CSD/CTD Bases. Evaluation of alligator cracks for CTD and CSD bases are shown in Figures 87 and 88, respectively for stone interlayer. The corresponding no interlayer sections for comparison with stone interlayer are shown in Figure 89 and 90, as both CTD and CSD sections had about 18 years of AvgSL. Hence, stone interlayer shows significant improvement for alligator cracking too.

Stone Int Alligator cracking (ft) Over CTD Bases

ESAL	0	150000	Thickness	0	5	Data Range	3
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev		
2	50	17.6	4.3	17.0	4.8		



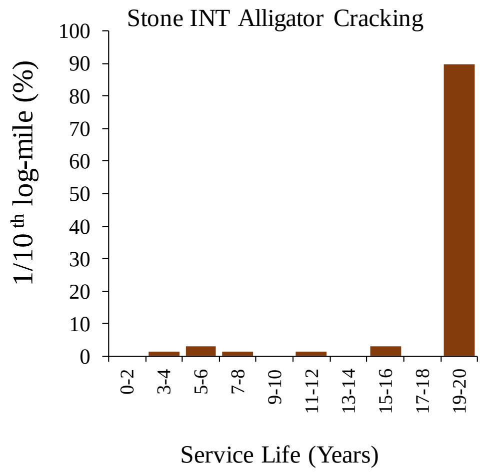
HISTOGRAM DATA of Service Lives		
SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	0	0.0
5-6	2	4.0
7-8	0	0.0
9-10	5	10.0
11-12	2	4.0
13-14	1	2.0
15-16	4	8.0
17-18	0	0.0
19-20	36	72.0
TOTAL '0-20'	50	100.0

Parameters	ESAL Distribution	ADT Distribution
MIN	28551	1355
25 PERCNTILE	28551	1355
MEDIAN	28551	1355
AVERAGE	48126	1664
75 PERCNTILE	28551	1355
MAX	137299	3071

B/C (SL) =	93.1	Yrs / Dollar	Category
B/C (NBA) =	90.2	Ft-yr/ft/Dollar	x17

Figure 87: Evaluation of AC for stone interlayer over CTD bases, (Cat. x17)

Stone Int Alligator cracking (ft) Over CSD Bases								
ESAL	0	30000	Thickness	0	5	Data Range	3	
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives		
3	68	18.9	3.5	18.2	3.6	SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections



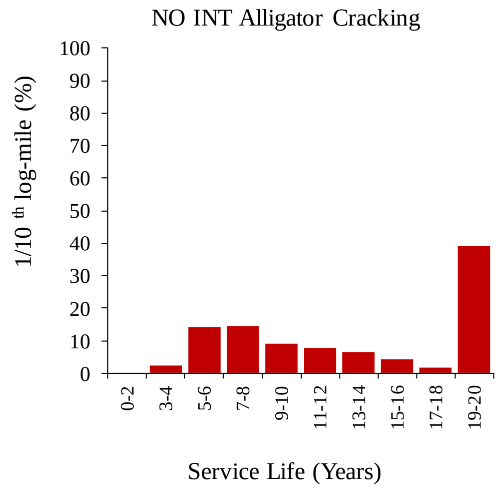
SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	1	1.5
5-6	2	2.9
7-8	1	1.5
9-10	0	0.0
11-12	1	1.5
13-14	0	0.0
15-16	2	2.9
17-18	0	0.0
19-20	61	89.7
TOTAL '0-20'	68	100.0

Parameters	ESAL Distribution	ADT Distribution
MIN	15932	2800
25 PERCNTILE	15932	2800
MEDIAN	15932	2800
AVERAGE	19704	4556
75 PERCNTILE	24152	3800
MAX	29340	11214

B/C (SL) =	97.2	Yrs / Dollar	Category
B/C (NBA) =	93.4	Ft-yr/ft/Dollar	x18

Figure 88: Evaluation of AC for stone interlayer over CSD bases, (Cat. x18)

NO INT Alligator Cracking (Sq. ft) Over CTD Bases								
ESAL	0	150000	Thickness	0	5	Data Range	3	
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives		
54	1726	13.4	6.0	12.7	6.2	SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections



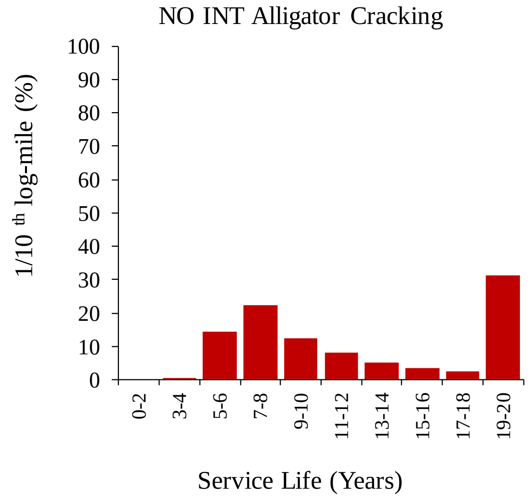
SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	43	2.5
5-6	244	14.1
7-8	250	14.5
9-10	159	9.2
11-12	137	7.9
13-14	114	6.6
15-16	74	4.3
17-18	29	1.7
19-20	676	39.2
TOTAL '0-20'	1726	100.0

Parameters	ESAL Distribution	ADT Distribution
MIN	148	115
25 PERCNTILE	1819	693
MEDIAN	9510	1159
AVERAGE	18912	1848
75 PERCNTILE	20192	2403
MAX	134609	10210

B/C (SL) =	81.7	Yrs / Dollar	Category
B/C (NBA) =	77.0	Ft-yr/ft/Dollar	x19

Figure 89: Evaluation of AC for no interlayer over CTD bases, (Cat. x19)

NO INT Alligator Cracking (Sq. ft) Over CSD Bases							
ESAL	0	30000	Thickness	0	5	Data Range	3
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives	
46	1786	12.5	5.7	11.7	5.9		



SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	1	0.1
5-6	257	14.4
7-8	401	22.5
9-10	223	12.5
11-12	142	8.0
13-14	94	5.3
15-16	62	3.5
17-18	47	2.6
19-20	559	31.3
TOTAL '0-20'	1786	100.0

Parameters	ESAL Distribution	ADT Distribution
MIN	56	159
25 PERCNTILE	1508	679
MEDIAN	4664	1185
AVERAGE	7980	1478
75 PERCNTILE	13877	2028
MAX	28790	8012

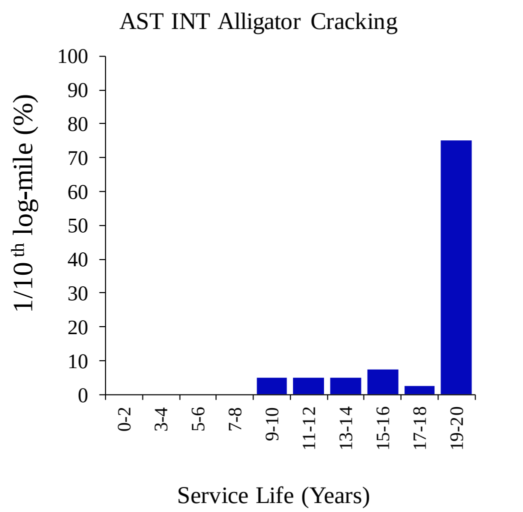
B/C (SL) =	65.1	Yrs / Dollar	Category
B/C (NBA) =	60.9	Ft-yr/ft/Dollar	x20

Figure 90: Evaluation of AC for no interlayer over CSD bases, (Cat. x20)

Alligator Cracking Evaluation (6 data points)

AST/No Interlayer over CSD Bases. Figure 91 to Figure 95 illustrates the evaluation of alligator cracking for CSD bases. It should be recalled here that only x5' and x6' (shown in Figure 93 and 94, respectively) had sufficient data for any conclusive remarks.

AST INT Alligator cracking (Sq. ft) Over CSD Bases								
ESAL	0	30000	Thickness	0	4	Data Range	6	
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives		
3	40	18.4	3.0	18.0	3.6	SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections

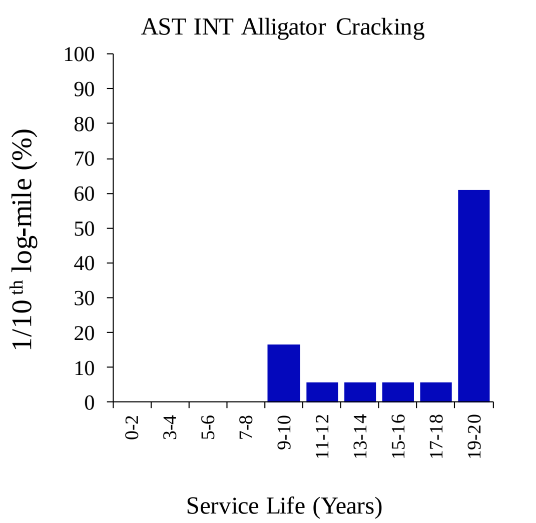


SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	0	0.0
5-6	0	0.0
7-8	0	0.0
9-10	2	5.0
11-12	2	5.0
13-14	2	5.0
15-16	3	7.5
17-18	1	2.5
19-20	30	75.0
TOTAL '0-20'	40	100.0
Parameters	ESAL Distribution	ADT Distribution
MIN	734	530
25 PERCNTILE	9583	794
MEDIAN	12533	882
AVERAGE	10490	1528
75 PERCNTILE	13440	1616
MAX	16161	3819

B/C (SL) =	126.3	Yrs / Dollar	Category
B/C (NBA) =	123.3	Ft-yr/ft/Dollar	x1'

Figure 91: Evaluation of AC for AST interlayer over CSD base, (Cat. x1')

AST INT Alligator cracking (Sq. ft) Over CSD Bases								
ESAL	30001	2E6	Thickness	4.1	10	Data Range	6	
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives		
2	18	16.9	4.3	16.0	4.6	SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections

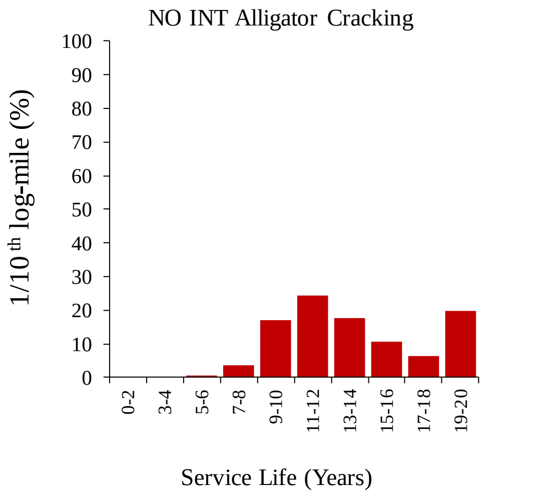


SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	0	0.0
5-6	0	0.0
7-8	0	0.0
9-10	3	16.7
11-12	1	5.6
13-14	1	5.6
15-16	1	5.6
17-18	1	5.6
19-20	11	61.1
TOTAL '0-20'	18	100.0
Parameters	ESAL Distribution	ADT Distribution
MIN	71889	6197
25 PERCNTILE	71889	6197
MEDIAN	71889	6197
AVERAGE	144660	10431
75 PERCNTILE	71889	6197
MAX	508514	31600

B/C (SL) =	105.6	Yrs / Dollar	Category
B/C (NBA) =	99.6	Ft-yr/ft/Dollar	x4'

Figure 92: Evaluation of AC for AST interlayer over CSD base, (Cat. x4')

NO INT Alligator cracking (Sq. ft) Over CSD Bases								
ESAL	0	30000	Thickness	0	4	Data Range	6	
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives		
46	1789	13.8	3.8	12.4	4.0	SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections



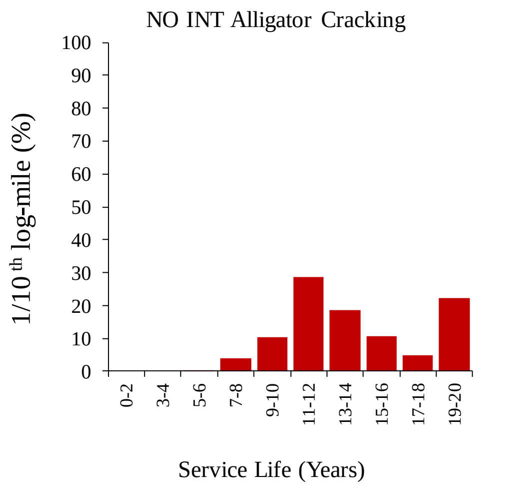
SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	0	0.0
5-6	11	0.6
7-8	63	3.5
9-10	307	17.2
11-12	433	24.2
13-14	313	17.5
15-16	192	10.7
17-18	116	6.5
19-20	354	19.8
TOTAL '0-20'	1789	100.0

Parameters	ESAL Distribution	ADT Distribution
MIN	56	159
25 PERCNTILE	1508	679
MEDIAN	4664	1185
AVERAGE	7972	1476
75 PERCNTILE	13877	2028
MAX	28790	8012

B/C (SL) =	86.5	Yrs / Dollar	Category
B/C (NBA) =	77.3	Ft-yr/ft/Dollar	x5'

Figure 93: Evaluation of AC for no interlayer over CSD base, (Cat. x5')

NO INT Alligator cracking (Sq. ft) Over CSD Bases								
ESAL	30001	2E6	Thickness	0	4	Data Range	6	
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives		
17	769	14.0	3.8	12.6	4.0	SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections



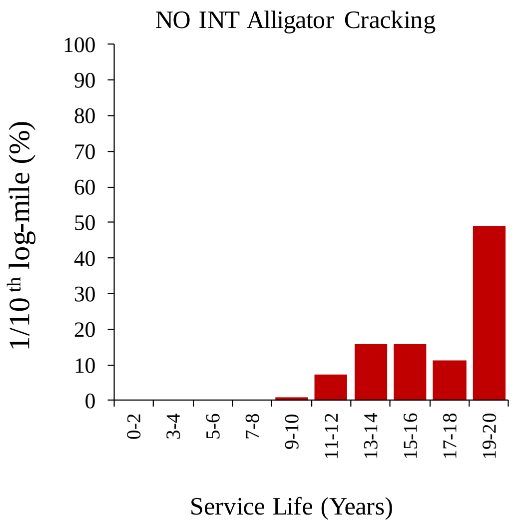
SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	0	0.0
5-6	2	0.3
7-8	31	4.0
9-10	79	10.3
11-12	221	28.7
13-14	144	18.7
15-16	83	10.8
17-18	37	4.8
19-20	172	22.4
TOTAL '0-20'	769	100.0

Parameters	ESAL Distribution	ADT Distribution
MIN	30494	455
25 PERCNTILE	37822	1152
MEDIAN	45871	2368
AVERAGE	112637	3946
75 PERCNTILE	84069	3849
MAX	1431101	54792

B/C (SL) =	89.4	Yrs / Dollar	Category
B/C (NBA) =	80.2	Ft-yr/ft/Dollar	x6'

Figure 94: Evaluation of AC for no interlayer over CSD bases, (Cat. x6')

NO INT Alligator cracking (Sq. ft) Over CSD Bases								
ESAL	30001	2E6	Thickness	4.1	10	Data Range	6	
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives		
2	108	17.2	3.1	15.9	3.4	SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections



SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	0	0.0
5-6	0	0.0
7-8	0	0.0
9-10	1	0.9
11-12	8	7.4
13-14	17	15.7
15-16	17	15.7
17-18	12	11.1
19-20	53	49.1
TOTAL '0-20'	108	100.0

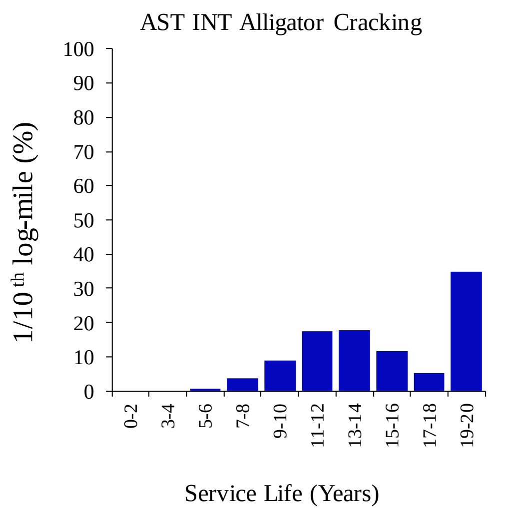
Parameters	ESAL Distribution	ADT Distribution
MIN	31695	4084
25 PERCNTILE	31695	4084
MEDIAN	62459	4656
AVERAGE	54483	4508
75 PERCNTILE	62459	4656
MAX	62459	4656

B/C (SL) =	130.3	Yrs / Dollar	Category
B/C (NBA) =	120.3	Ft-yr/ft/Dollar	x8'

Figure 95: Evaluation of AC for no interlayer over CSD bases, (Cat. x8')

AST/No Interlayer over CTD Sections. Alligator cracking evaluation for CTD bases are shown below from Figure 96 to Figure 99. Among all these figures, only Category x13' (shown in Figure 97) had sufficient data for conclusive results. Category x9' and x14' (shown in Figure 96 and figure 98) had at least five projects, hence their results are somewhat acceptable.

AST INT Alligator cracking (Sq. ft) Over CTD Bases								
ESAL	0	30000	Thickness	0	4	Data Range	6	
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives		
6	346	15.2	4.1	14.0	4.5	SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections



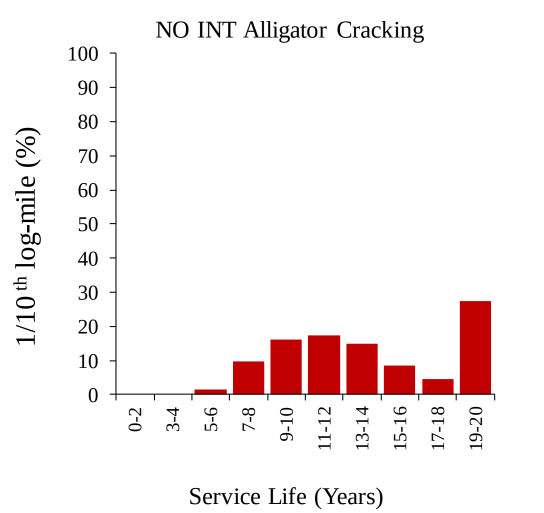
SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	0	0.0
5-6	2	0.6
7-8	13	3.8
9-10	31	9.0
11-12	60	17.3
13-14	61	17.6
15-16	40	11.6
17-18	18	5.2
19-20	121	35.0
TOTAL '0-20'	346	100.0

Parameters	ESAL Distribution	ADT Distribution
MIN	81	360
25 PERCNTILE	3467	411
MEDIAN	9210	667
AVERAGE	10211	807
75 PERCNTILE	16965	1360
MAX	18718	1440

B/C (SL) =	98.7	Yrs / Dollar	Category
B/C (NBA) =	91.1	Ft-yr/ft/Dollar	x9'

Figure 96: Evaluation of AC for AST interlayer over CTD bases, (Cat. x9')

NO INT Alligator cracking (Sq. ft) Over CTD Bases								
ESAL	0	30000	Thickness	0	4	Data Range	6	
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives		
46	1478	13.9	4.4	12.7	4.7	SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections



SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	0	0.0
5-6	24	1.6
7-8	142	9.6
9-10	236	16.0
11-12	257	17.4
13-14	221	15.0
15-16	125	8.5
17-18	66	4.5
19-20	407	27.5
TOTAL '0-20'	1478	100.0

Parameters	ESAL Distribution	ADT Distribution
MIN	148	115
25 PERCNTILE	1798	500
MEDIAN	8671	1040
AVERAGE	9699	1452
75 PERCNTILE	17083	1576
MAX	28551	10210

B/C (SL) =	98.3	Yrs / Dollar	Category
B/C (NBA) =	89.2	Ft-yr/ft/Dollar	x13'

Figure 97: Evaluation of AC for no interlayer over CTD bases, (Cat. x13')

NO INT Alligator cracking (Sq. ft) Over CTD Bases								
ESAL	30001	2E6	Thickness	0	4	Data Range	6	
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives		
5	154	14.7	3.9	13.3	4.2	SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
						0-2	0	0.0
						3-4	0	0.0
						5-6	3	1.9
						7-8	2	1.3
						9-10	16	10.4
						11-12	32	20.8
						13-14	31	20.1
						15-16	18	11.7
						17-18	10	6.5
						19-20	42	27.3
						TOTAL '0-20'	154	100.0
						Parameters	ESAL Distribution	ADT Distribution
						MIN	41466	1761
						25 PERCNTILE	51834	3271
						MEDIAN	54675	3538
						AVERAGE	64510	4373
B/C (SL) =		110.4	Yrs / Dollar		Category	75 PERCNTILE	76200	3931
B/C (NBA) =		99.9	Ft-yr/ft/Dollar		x14'	MAX	134609	8861

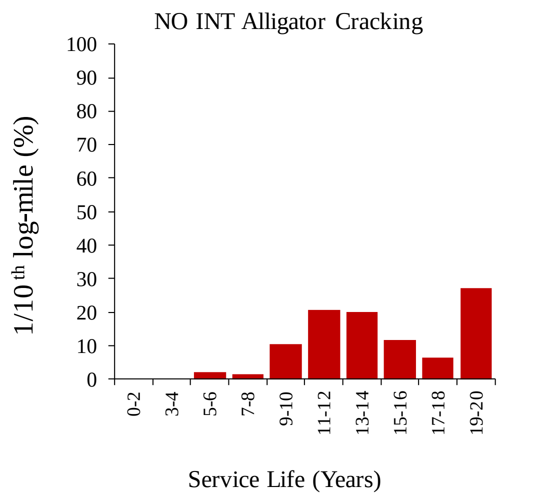


Figure 98: Evaluation of AC for no interlayer over CTD bases, (Cat. x14')

NO INT Alligator cracking (Sq. ft) Over CTD Bases								
ESAL	30001	2E6	Thickness	4.1	10	Data Range	6	
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives		
3	106	13.2	4.3	12.1	4.6	SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
						0-2	0	0.0
						3-4	0	0.0
						5-6	1	0.9
						7-8	5	4.7
						9-10	28	26.4
						11-12	35	33.0
						13-14	5	4.7
						15-16	2	1.9
						17-18	5	4.7
						19-20	25	23.6
						TOTAL '0-20'	106	100.0
						Parameters	ESAL Distribution	ADT Distribution
						MIN	113385	5500
						25 PERCNTILE	113385	5500
						MEDIAN	113385	5500
						AVERAGE	209500	9169
B/C (SL) =		89.9	Yrs / Dollar		Category	75 PERCNTILE	378875	13851
B/C (NBA) =		82.7	Ft-yr/ft/Dollar		x16'	MAX	387171	16602

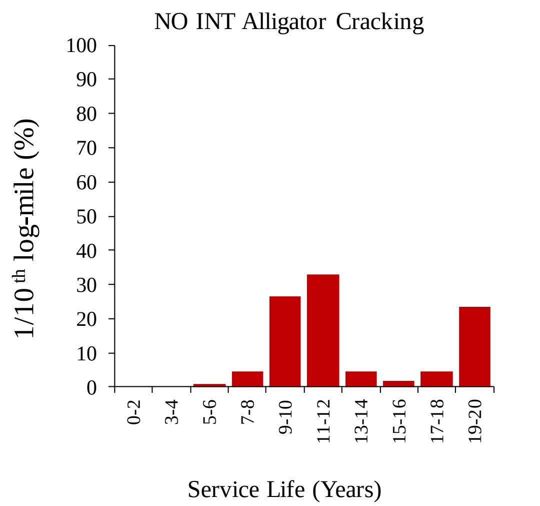


Figure 99: Evaluation of AC for no interlayer over CTD bases, (Cat. x16')

IRI Evaluation (3 data points)

AST/No Interlayer over CSD Bases. In Figure 100 to Figure 105, the IRI performance over CSD bases are evaluated. From these figures, it is found that IRI performance is not generally affected by interlayer. Hence, IRI behaves differently that cracking for these categories. It worth mentioning here that some categories (such as: x2 and x8) may show less AvgSL for IRI, but those categories have a very few projects, hence these results are inconclusive.

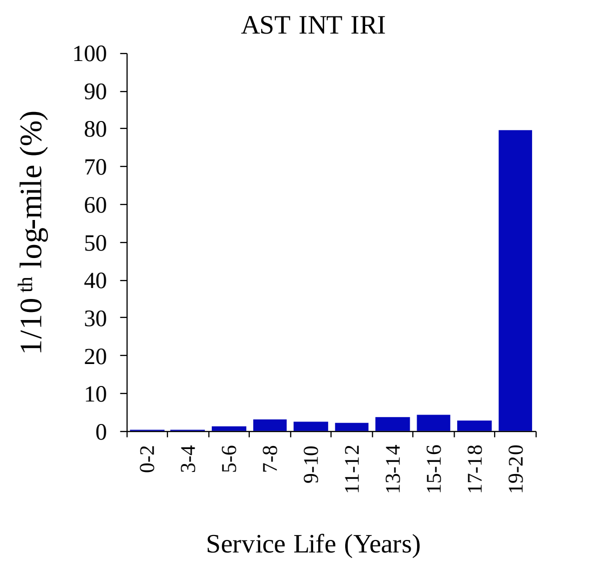
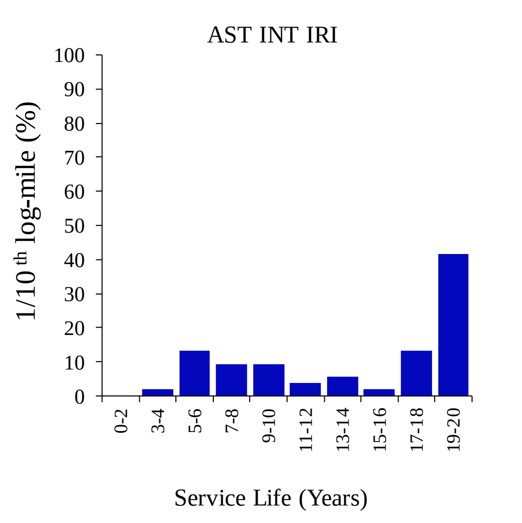
AST INT IRI (in/mi) Over CSD Bases								
ESAL	0	30000	Thickness	0	4	Data Range	3	
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives		
19	570	18.3	3.7	11.0	3.5	SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
						0-2	1	0.2
						3-4	1	0.2
						5-6	8	1.4
						7-8	18	3.2
						9-10	14	2.5
						11-12	13	2.3
						13-14	21	3.7
						15-16	24	4.2
						17-18	16	2.8
						19-20	454	79.6
						TOTAL '0-20'	570	100.0
						Parameters	ESAL Distribution	ADT Distribution
						MIN	603	91
						25 PERCNTILE	952	680
						MEDIAN	5280	1400
						AVERAGE	9033	1505
B/C (SL) =		118.7	Yrs / Dollar		Category	75 PERCNTILE	13569	1500
B/C (NBA) =		71.4	Ft-yr/ft/Dollar		x1	MAX	27494	3819

Figure 100: Evaluation of IRI for AST interlayer over CSD base, (Cat. x1)

AST INT IRI (in/mi) Over CSD Bases

ESAL	30001	2E6	Thickness	0	4	Data Range	3
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives	
2	53	14.2	6.2	6.2	3.9		



SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	1	1.9
5-6	7	13.2
7-8	5	9.4
9-10	5	9.4
11-12	2	3.8
13-14	3	5.7
15-16	1	1.9
17-18	7	13.2
19-20	22	41.5
TOTAL '0-20'	53	100.0

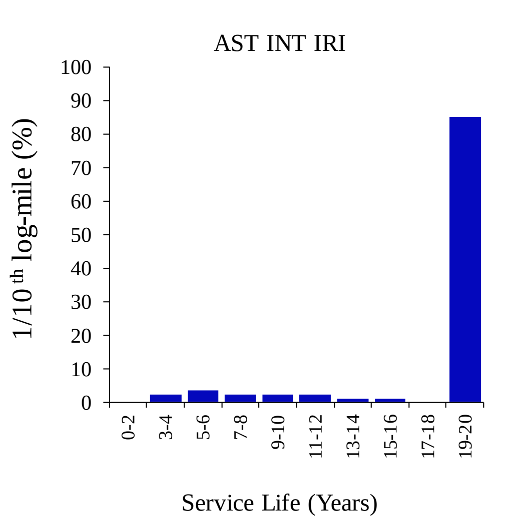
Parameters	ESAL Distribution	ADT Distribution
MIN	33693	1090
25 PERCNTILE	33693	1090
MEDIAN	33693	1090
AVERAGE	145163	10263
75 PERCNTILE	368103	28609
MAX	368103	28609

B/C (SL) =	81.0	Yrs / Dollar	Category
B/C (NBA) =	35.5	Ft-yr/ft/Dollar	x2

Figure 101: Evaluation of IRI for AST interlayer over CSD base, (Cat. x2)

AST INT IRI (in/mi) Over CSD Bases

ESAL	30001	2E6	Thickness	4.1	10	Data Range	3
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives	
8	87	18.3	4.3	10.9	3.7		



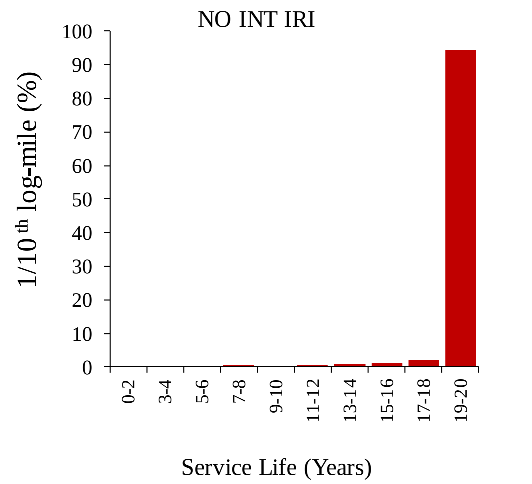
SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	2	2.3
5-6	3	3.4
7-8	2	2.3
9-10	2	2.3
11-12	2	2.3
13-14	1	1.1
15-16	1	1.1
17-18	0	0.0
19-20	74	85.1
TOTAL '0-20'	87	100.0

Parameters	ESAL Distribution	ADT Distribution
MIN	43959	1750
25 PERCNTILE	63643	2350
MEDIAN	71889	2350
AVERAGE	150238	4678
75 PERCNTILE	181101	6197
MAX	523334	31600

B/C (SL) =	114.1	Yrs / Dollar	Category
B/C (NBA) =	68.3	Ft-yr/ft/Dollar	x4

Figure 102: Evaluation of IRI for AST interlayer over CSD base, (Cat. x4)

NO INT IRI (in/mi) Over CSD Bases								
ESAL	0	30000	Thickness	0	4	Data Range	3	
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives		
46	1584	19.7	1.5	12.1	2.3	SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections



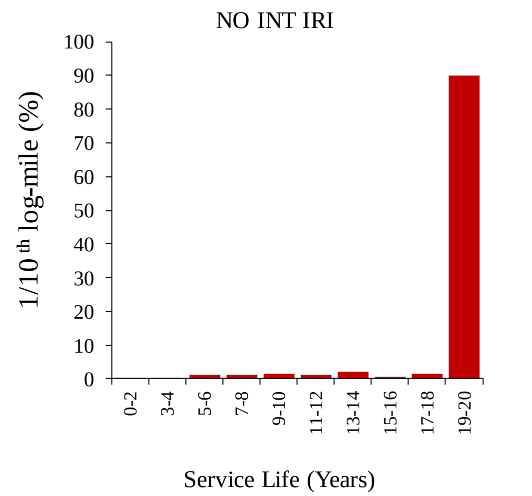
SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	0	0.0
5-6	1	0.1
7-8	7	0.4
9-10	5	0.3
11-12	9	0.6
13-14	15	0.9
15-16	19	1.2
17-18	31	2.0
19-20	1497	94.5
TOTAL '0-20'	1584	100.0

Parameters	ESAL Distribution	ADT Distribution
MIN	56	159
25 PERCNTILE	1508	690
MEDIAN	4664	1180
AVERAGE	8005	1480
75 PERCNTILE	13877	2028
MAX	28790	8012

B/C (SL) =	167.2	Yrs / Dollar	Category
B/C (NBA) =	103.1	Ft-yr/ft/Dollar	x5

Figure 103: Evaluation of IRI for no interlayer over CSD base, (Cat. x5)

NO INT IRI (in/mi) Over CSD Bases								
ESAL	30001	2E6	Thickness	0	4	Data Range	3	
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives		
17	702	19.0	3.2	11.7	3.1	SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections



SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	2	0.3
3-4	3	0.4
5-6	8	1.1
7-8	9	1.3
9-10	10	1.4
11-12	8	1.1
13-14	14	2.0
15-16	5	0.7
17-18	11	1.6
19-20	632	90.0
TOTAL '0-20'	702	100.0

Parameters	ESAL Distribution	ADT Distribution
MIN	30494	455
25 PERCNTILE	37822	1575
MEDIAN	57684	2368
AVERAGE	116076	4148
75 PERCNTILE	84069	3849
MAX	1431101	54792

B/C (SL) =	150.9	Yrs / Dollar	Category
B/C (NBA) =	92.9	Ft-yr/ft/Dollar	x6

Figure 104: Evaluation of IRI for no interlayer over CSD bases, (Cat. x6)

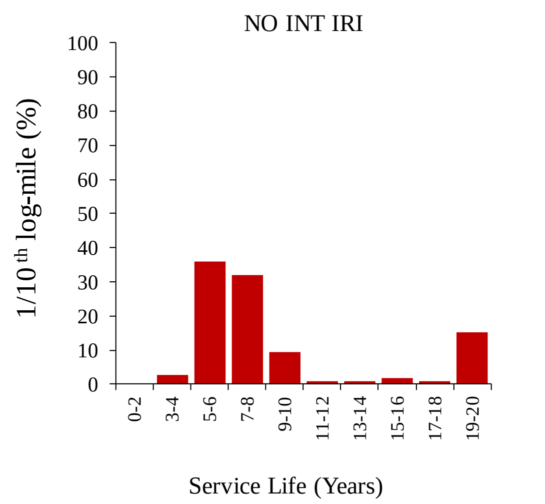
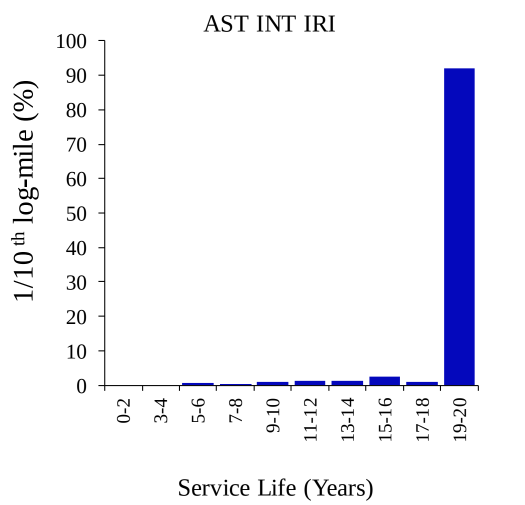
NO INT IRI (in/mi) Over CSD Bases								
ESAL	30001	2E6	Thickness	4.1	10	Data Range	3	
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives		
2	106	9.1	5.1	4.4	2.8	SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
						0-2	0	0.0
						3-4	3	2.8
						5-6	38	35.8
						7-8	34	32.1
						9-10	10	9.4
						11-12	1	0.9
						13-14	1	0.9
						15-16	2	1.9
						17-18	1	0.9
						19-20	16	15.1
						TOTAL '0-20'	106	100.0
						Parameters	ESAL Distribution	ADT Distribution
						MIN	31695	4084
						25 PERCNTILE	31695	4084
						MEDIAN	62459	4656
						AVERAGE	54333	4505
B/C (SL) =		36.3	Yrs / Dollar		Category	75 PERCNTILE	62459	4656
B/C (NBA) =		17.5	Ft-yr/ft/Dollar		x8	MAX	62459	4656

Figure 105: Evaluation of IRI for no interlayer over CSD bases, (Cat. x8)

AST/No Interlayer over CTD Bases. For IRI, CTD behaves similarly as CSD bases for both AST and no interlayer. Figure 106 to Figure 109 shows this trend for CTD base sections for IRI.

AST INT IRI (in/mi) Over CTD Bases					
ESAL	0	30000	Thickness	0	4
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
6	314	19.4	2.2	11.5	2.7

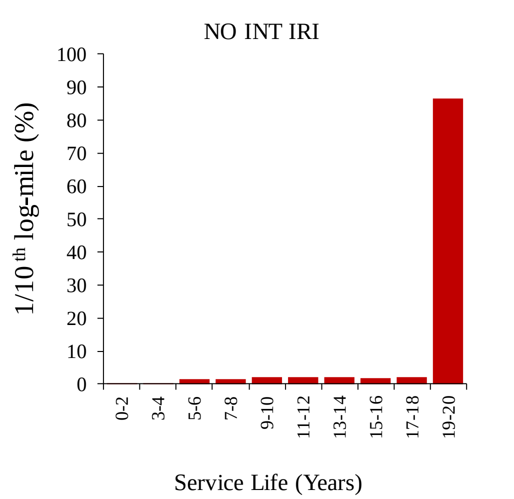


Data Range	3	
HISTOGRAM DATA of Service Lives		
SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	0	0.0
5-6	2	0.6
7-8	1	0.3
9-10	3	1.0
11-12	4	1.3
13-14	4	1.3
15-16	8	2.5
17-18	3	1.0
19-20	289	92.0
TOTAL '0-20'	314	100.0
Parameters	ESAL Distribution	ADT Distribution
MIN	81	360
25 PERCNTILE	3467	411
MEDIAN	9210	667
AVERAGE	10697	822
75 PERCNTILE	18718	1360
MAX	18718	1440

B/C (SL) =	156.5	Yrs / Dollar	Category
B/C (NBA) =	92.3	Ft-yr/ft/Dollar	x9

Figure 106: Evaluation of IRI for AST interlayer over CTD bases, (Cat. x9)

NO INT IRI (in/mi) Over CTD Bases					
ESAL	0	30000	Thickness	0	4
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
44	1178	18.8	3.8	11.5	3.2

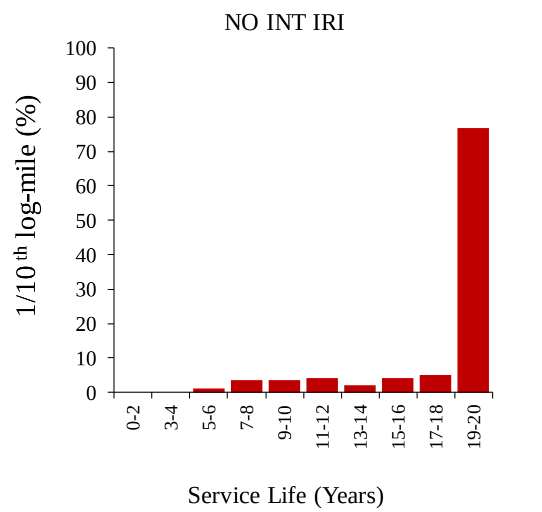


Data Range	3	
HISTOGRAM DATA of Service Lives		
SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	1	0.1
3-4	4	0.3
5-6	16	1.4
7-8	16	1.4
9-10	25	2.1
11-12	25	2.1
13-14	26	2.2
15-16	21	1.8
17-18	23	2.0
19-20	1021	86.7
TOTAL '0-20'	1178	100.0
Parameters	ESAL Distribution	ADT Distribution
MIN	148	115
25 PERCNTILE	1451	500
MEDIAN	7339	1040
AVERAGE	9570	1526
75 PERCNTILE	16798	1903
MAX	28551	10210

B/C (SL) =	167.4	Yrs / Dollar	Category
B/C (NBA) =	102.4	Ft-yr/ft/Dollar	x13

Figure 107: Evaluation of IRI for no interlayer over CTD bases, (Cat. x13)

NO INT IRI (in/mi) Over CTD Bases								
ESAL	30001	2E6	Thickness	0	4	Data Range	3	
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives		
6	197	18.2	3.7	10.4	3.3	SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections



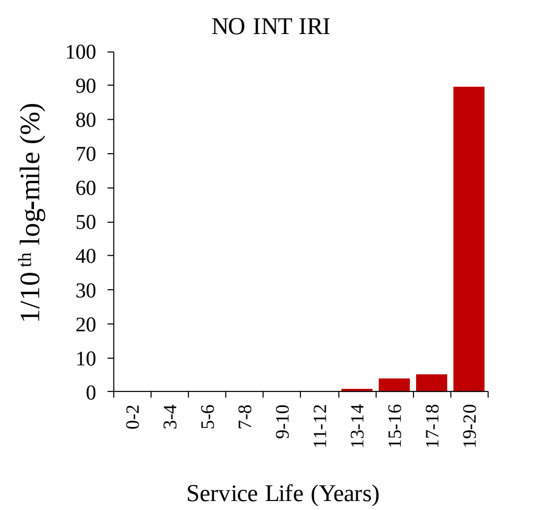
SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	0	0.0
5-6	2	1.0
7-8	7	3.6
9-10	7	3.6
11-12	8	4.1
13-14	4	2.0
15-16	8	4.1
17-18	10	5.1
19-20	151	76.6
TOTAL '0-20'	197	100.0

Parameters	ESAL Distribution	ADT Distribution
MIN	36661	1761
25 PERCNTILE	36661	1896
MEDIAN	51834	3538
AVERAGE	56140	3784
75 PERCNTILE	76200	3931
MAX	134609	8861

B/C (SL) =	161.3	Yrs / Dollar	Category
B/C (NBA) =	92.4	Ft-yr/ft/Dollar	x14

Figure 108: Evaluation of IRI for no interlayer over CTD bases, (Cat. x14)

NO INT IRI (in/mi) Over CTD Bases								
ESAL	30001	2E6	Thickness	4.1	10	Data Range	3	
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives		
3	98	19.6	1.3	9.6	2.8	SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections



SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	0	0.0
5-6	0	0.0
7-8	0	0.0
9-10	0	0.0
11-12	0	0.0
13-14	1	1.0
15-16	4	4.1
17-18	5	5.1
19-20	88	89.8
TOTAL '0-20'	98	100.0

Parameters	ESAL Distribution	ADT Distribution
MIN	113385	5500
25 PERCNTILE	113385	5500
MEDIAN	113385	5500
AVERAGE	211843	9270
75 PERCNTILE	378875	15914
MAX	387171	16602

B/C (SL) =	190.9	Yrs / Dollar	Category
B/C (NBA) =	93.8	Ft-yr/ft/Dollar	x16

Figure 109: Evaluation of IRI for no interlayer over CTD bases, (Cat. x16)

Stone Interlayer over CSD/CTD Bases. For stone interlayer, IRI evaluation for CTD and CSD bases are shown in Figure 110 and 111, respectively. The corresponding no interlayer sections for comparison with Stone Interlayer are shown in Figure 112 and 113. It is clear from these figures that stone interlayer behaves similarly to no interlayer for IRI.

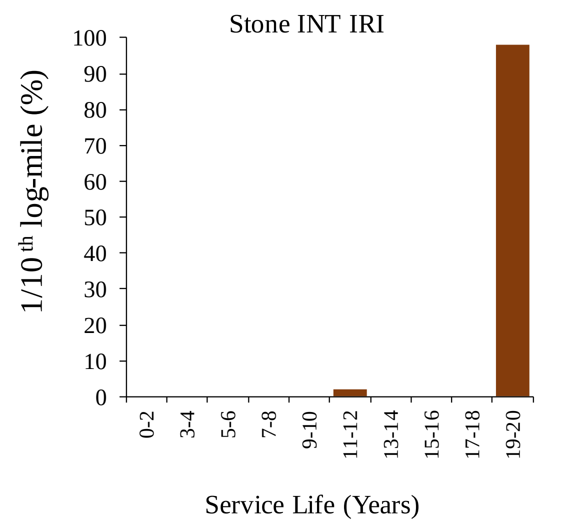
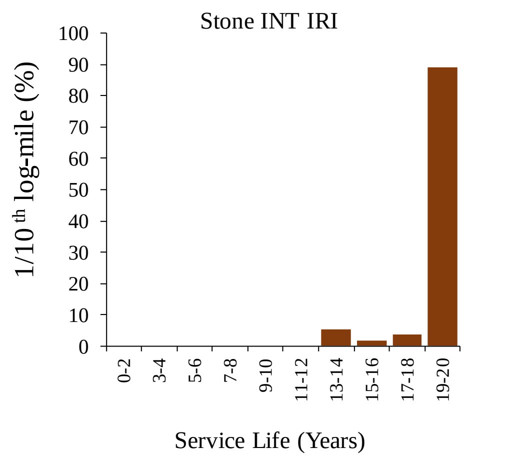
Stone Int IRI (in/mi) Over CTD Bases								
ESAL	0	150000	Thickness	0	5	Data Range	3	
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives		
2	49	19.8	1.1	12.3	1.6	SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
						0-2	0	0.0
						3-4	0	0.0
						5-6	0	0.0
						7-8	0	0.0
						9-10	0	0.0
						11-12	1	2.0
						13-14	0	0.0
						15-16	0	0.0
						17-18	0	0.0
						19-20	48	98.0
						TOTAL '0-20'	49	100.0
						Parameters	ESAL Distribution	ADT Distribution
						MIN	28551	1355
						25 PERCNTILE	28551	1355
						MEDIAN	28551	1355
						AVERAGE	46306	1635
B/C (SL) =		123.3	Yrs / Dollar		Category	75 PERCNTILE	28551	1355
B/C (NBA) =		76.7	Ft-yr/ft/Dollar		x17	MAX	137299	3071

Figure 110: Evaluation of IRI for stone interlayer over CTD bases, (Cat. x17)

Stone Int IRI (in/mi) Over CSD Bases								
ESAL	0	30000	Thickness	0	5	Data Range	3	
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives		
3	55	19.4	1.7	11.6	2.5	SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections



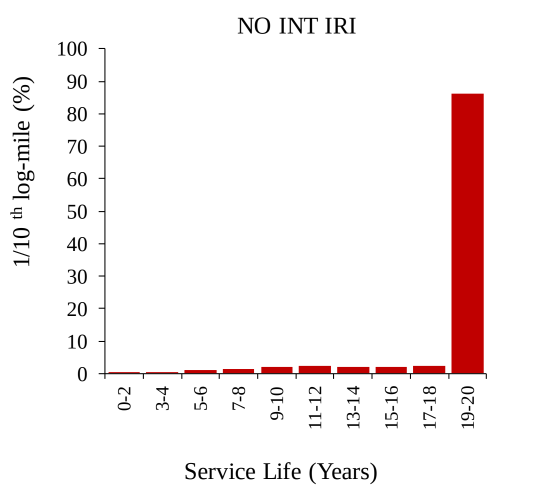
SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	0	0.0
5-6	0	0.0
7-8	0	0.0
9-10	0	0.0
11-12	0	0.0
13-14	3	5.5
15-16	1	1.8
17-18	2	3.6
19-20	49	89.1
TOTAL '0-20'	55	100.0

Parameters	ESAL Distribution	ADT Distribution
MIN	15932	2800
25 PERCNTILE	15932	2800
MEDIAN	15932	2800
AVERAGE	20352	4817
75 PERCNTILE	24152	3800
MAX	29340	11214

B/C (SL) =	108.4	Yrs / Dollar	Category
B/C (NBA) =	65.0	Ft-yr/ft/Dollar	x18

Figure 111: Evaluation of IRI for stone interlayer over CSD bases, (Cat. x18)

NO INT IRI (in/mi) Over CTD Bases								
ESAL	0	150000	Thickness	0	5	Data Range	3	
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives		
53	1480	18.8	3.7	11.4	3.1	SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections



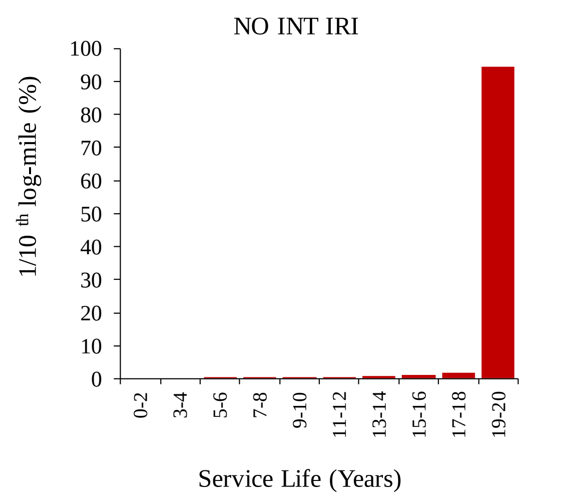
SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	1	0.1
3-4	4	0.3
5-6	18	1.2
7-8	23	1.6
9-10	32	2.2
11-12	33	2.2
13-14	30	2.0
15-16	29	2.0
17-18	33	2.2
19-20	1277	86.3
TOTAL '0-20'	1480	100.0

Parameters	ESAL Distribution	ADT Distribution
MIN	148	115
25 PERCNTILE	2039	693
MEDIAN	9723	1212
AVERAGE	20476	1977
75 PERCNTILE	23411	2462
MAX	134609	10210

B/C (SL) =	168.6	Yrs / Dollar	Category
B/C (NBA) =	101.7	Ft-yr/ft/Dollar	x19

Figure 112: Evaluation of IRI for no interlayer over CTD bases, (Cat. x19)

NO INT IRI (in/mi) Over CSD Bases							
ESAL	0	30000	Thickness	0	5	Data Range	3
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives	
46	1584	19.7	1.5	12.1	2.3		



SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	0	0.0
5-6	1	0.1
7-8	7	0.4
9-10	5	0.3
11-12	9	0.6
13-14	15	0.9
15-16	19	1.2
17-18	31	2.0
19-20	1497	94.5
TOTAL '0-20'	1584	100.0

Parameters	ESAL Distribution	ADT Distribution
MIN	56	159
25 PERCNTILE	1508	690
MEDIAN	4664	1180
AVERAGE	8005	1480
75 PERCNTILE	13877	2028
MAX	28790	8012

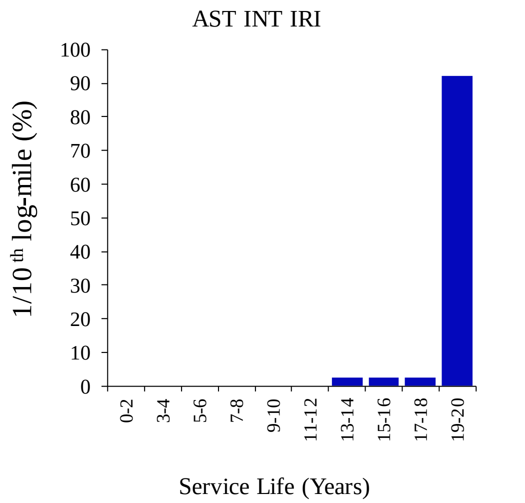
B/C (SL) =	167.2	Yrs / Dollar	Category
B/C (NBA) =	103.1	Ft-yr/ft/Dollar	x20

Figure 113: Evaluation of IRI for no interlayer over CSD bases, (Cat. x20)

IRI Evaluation (6 data points)

AST/No Interlayer over CSD Bases. Figure 114 to Figure 118 illustrates the evaluation of IRI for CSD bases for 6 data points. It should be recalled here that only x5' and x6' (shown in Figures 116 and 117, respectively) had sufficient data for any conclusive remarks; therefore, these 6 data points results are similar to the 3 data points results shown before.

AST INT IRI (in/mi) Over CSD Bases							
ESAL	0	30000	Thickness	0	4	Data Range	6
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives	
3	38	19.6	1.3	12.3	2.3		



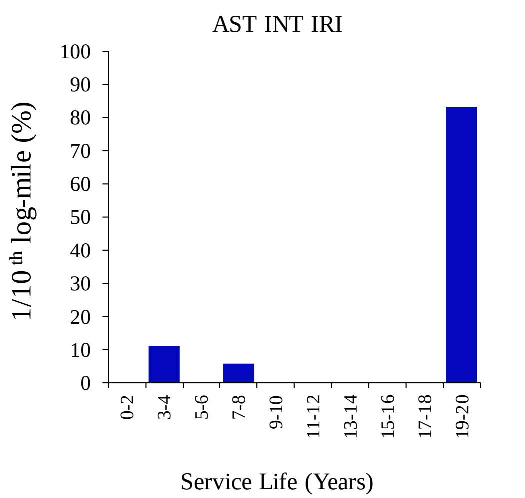
SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	0	0.0
5-6	0	0.0
7-8	0	0.0
9-10	0	0.0
11-12	0	0.0
13-14	1	2.6
15-16	1	2.6
17-18	1	2.6
19-20	35	92.1
TOTAL '0-20'	38	100.0

Parameters	ESAL Distribution	ADT Distribution
MIN	734	530
25 PERCNTILE	3684	618
MEDIAN	12533	882
AVERAGE	10383	1562
75 PERCNTILE	15254	3085
MAX	16161	3819

B/C (SL) =	143.8	Yrs / Dollar	Category
B/C (NBA) =	89.8	Ft-yr/ft/Dollar	x1'

Figure 114: Evaluation of IRI for AST interlayer over CSD base, (Cat. x1')

AST INT IRI (in/mi) Over CSD Bases							
ESAL	30001	2E6	Thickness	4.1	10	Data Range	6
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives	
2	18	17.5	5.9	9.1	4.0		



SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	2	11.1
5-6	0	0.0
7-8	1	5.6
9-10	0	0.0
11-12	0	0.0
13-14	0	0.0
15-16	0	0.0
17-18	0	0.0
19-20	15	83.3
TOTAL '0-20'	18	100.0

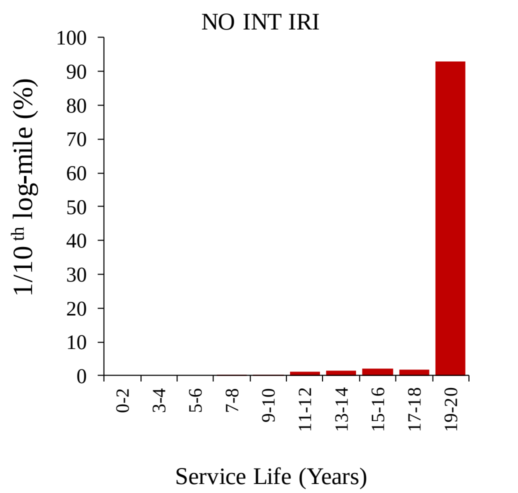
Parameters	ESAL Distribution	ADT Distribution
MIN	71889	6197
25 PERCNTILE	71889	6197
MEDIAN	71889	6197
AVERAGE	144660	10431
75 PERCNTILE	71889	6197
MAX	508514	31600

B/C (SL) =	91.6	Yrs / Dollar	Category
B/C (NBA) =	47.6	Ft-yr/ft/Dollar	x4'

Figure 115: Evaluation of IRI for AST interlayer over CSD base, (Cat. x4')

NO INT IRI (in/mi) Over CSD Bases							
ESAL	0	30000	Thickness	0	4	Data Range	6
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives	
46	1710	19.6	1.9	12.0	2.4		

SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	0	0.0
5-6	0	0.0
7-8	1	0.1
9-10	7	0.4
11-12	18	1.1
13-14	26	1.5
15-16	34	2.0
17-18	32	1.9
19-20	1592	93.1
TOTAL '0-20'	1710	100.0



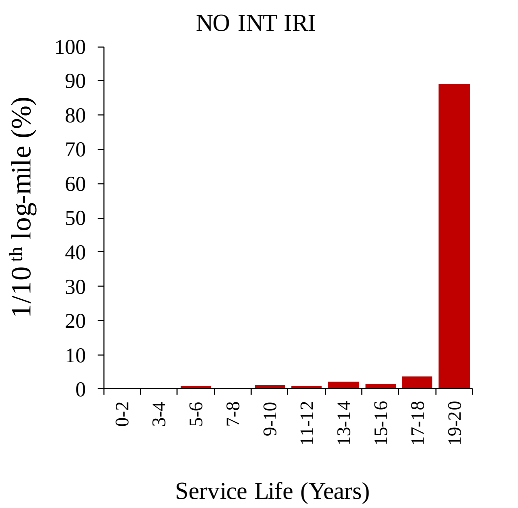
Parameters	ESAL Distribution	ADT Distribution
MIN	56	159
25 PERCNTILE	1508	679
MEDIAN	4664	1174
AVERAGE	8094	1484
75 PERCNTILE	13877	2028
MAX	28790	8012

B/C (SL) =	166.5	Yrs / Dollar	Category
B/C (NBA) =	101.7	Ft-yr/ft/Dollar	x5'

Figure 116: Evaluation of IRI for no interlayer over CSD base, (Cat. x5')

NO INT IRI (in/mi) Over CSD Bases							
ESAL	30001	2E6	Thickness	0	4	Data Range	6
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives	
17	758	19.2	2.8	11.4	3.0		

SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	1	0.1
3-4	2	0.3
5-6	6	0.8
7-8	2	0.3
9-10	10	1.3
11-12	7	0.9
13-14	17	2.2
15-16	12	1.6
17-18	27	3.6
19-20	674	88.9
TOTAL '0-20'	758	100.0

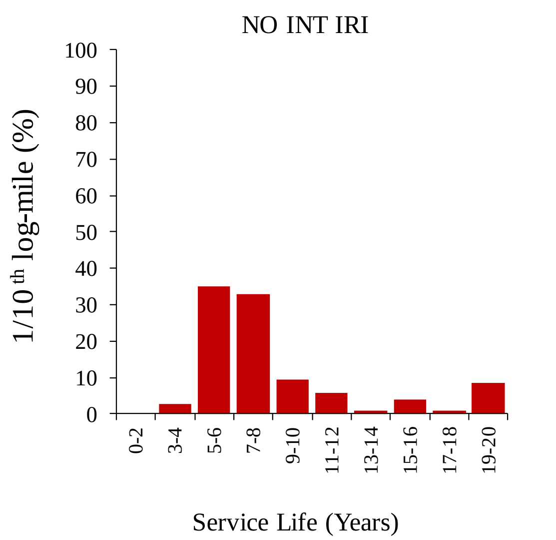


Parameters	ESAL Distribution	ADT Distribution
MIN	30494	455
25 PERCNTILE	37822	1152
MEDIAN	51778	2368
AVERAGE	113813	3971
75 PERCNTILE	84069	3849
MAX	1431101	54792

B/C (SL) =	158.6	Yrs / Dollar	Category
B/C (NBA) =	94.3	Ft-yr/ft/Dollar	x6'

Figure 117: Evaluation of IRI for no interlayer over CSD bases, (Cat. x6')

NO INT IRI (in/mi) Over CSD Bases								
ESAL	30001	2E6	Thickness	4.1	10	Data Range	6	
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives		
2	106	8.6	4.3	4.0	2.2	SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections



SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	3	2.8
5-6	37	34.9
7-8	35	33.0
9-10	10	9.4
11-12	6	5.7
13-14	1	0.9
15-16	4	3.8
17-18	1	0.9
19-20	9	8.5
TOTAL '0-20'	106	100.0

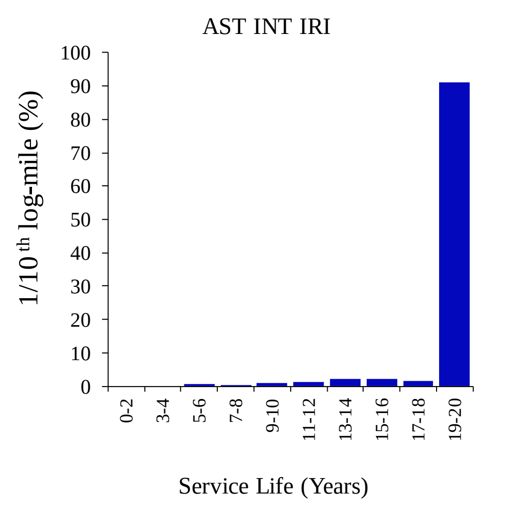
Parameters	ESAL Distribution	ADT Distribution
MIN	31695	4084
25 PERCNTILE	31695	4084
MEDIAN	62459	4656
AVERAGE	54333	4505
75 PERCNTILE	62459	4656
MAX	62459	4656

B/C (SL) =	34.0	Yrs / Dollar	Category
B/C (NBA) =	15.9	Ft-yr/ft/Dollar	x8'

Figure 118: Evaluation of IRI for no interlayer over CSD bases, (Cat. x8')

AST/No Interlayer over CTD Bases. In Figures 119 to 122, CTD bases performance are evaluated for IRI for 6 data points.

AST INT IRI (in/mi) Over CTD Bases								
ESAL	0	30000	Thickness	0	4	Data Range	6	
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives		
6	320	19.4	2.2	11.4	2.9	SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections



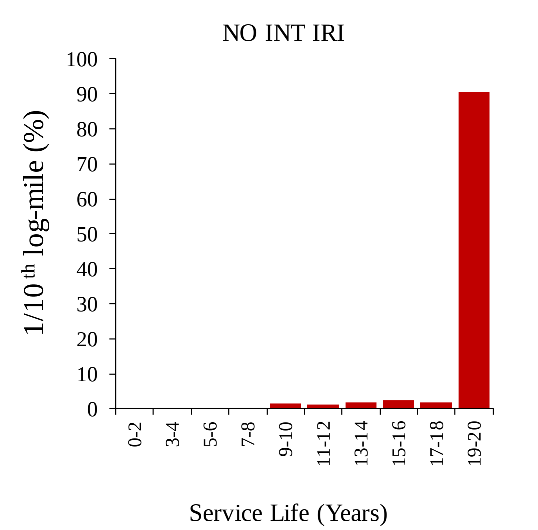
SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	0	0.0
5-6	2	0.6
7-8	1	0.3
9-10	3	0.9
11-12	4	1.3
13-14	7	2.2
15-16	7	2.2
17-18	5	1.6
19-20	291	90.9
TOTAL '0-20'	320	100.0

Parameters	ESAL Distribution	ADT Distribution
MIN	81	360
25 PERCNTILE	3467	411
MEDIAN	9210	667
AVERAGE	10708	816
75 PERCNTILE	18718	1360
MAX	18718	1440

B/C (SL) =	155.6	Yrs / Dollar	Category
B/C (NBA) =	91.9	Ft-yr/ft/Dollar	x9'

Figure 119: Evaluation of IRI for AST interlayer over CTD bases, (Cat. x9')

NO INT IRI (in/mi) Over CTD Bases								
ESAL	0	30000	Thickness	0	4	Data Range	6	
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives		
44	1288	19.3	3.2	11.8	2.7	SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections



SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	1	0.1
5-6	0	0.0
7-8	3	0.2
9-10	20	1.6
11-12	17	1.3
13-14	24	1.9
15-16	32	2.5
17-18	24	1.9
19-20	1167	90.6
TOTAL '0-20'	1288	100.0

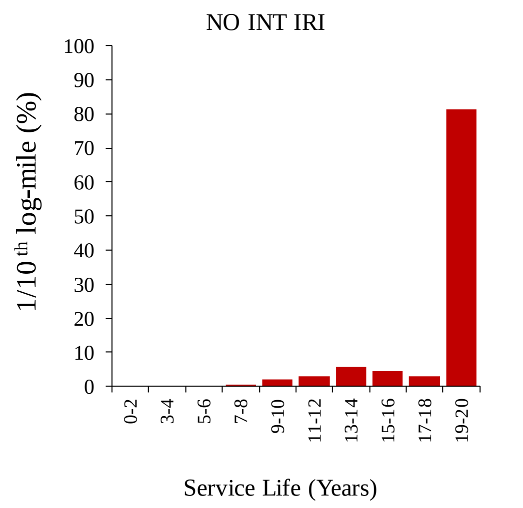
Parameters	ESAL Distribution	ADT Distribution
MIN	148	115
25 PERCNTILE	1798	500
MEDIAN	8671	1159
AVERAGE	9742	1511
75 PERCNTILE	17083	1903
MAX	28551	10210

B/C (SL) =	185.4	Yrs / Dollar	Category
B/C (NBA) =	113.1	Ft-yr/ft/Dollar	x13'

Figure 120: Evaluation of IRI for no interlayer over CTD bases, (Cat. x13')

NO INT IRI (in/mi) Over CTD Bases

ESAL	30001	2E6	Thickness	0	4	Data Range	6
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives	
6	197	18.8	2.7	11.1	3.1		



SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	0	0.0
5-6	0	0.0
7-8	1	0.5
9-10	4	2.0
11-12	6	3.0
13-14	11	5.6
15-16	9	4.6
17-18	6	3.0
19-20	160	81.2
TOTAL '0-20'	197	100.0

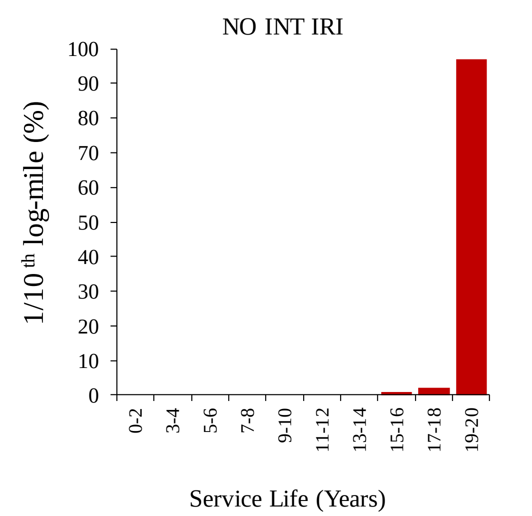
Parameters	ESAL Distribution	ADT Distribution
MIN	36661	1761
25 PERCNTILE	36661	1896
MEDIAN	51834	3271
AVERAGE	56816	3734
75 PERCNTILE	76200	3931
MAX	134609	8861

B/C (SL) =	174.9	Yrs / Dollar	Category
B/C (NBA) =	103.3	Ft-yr/ft/Dollar	x14'

Figure 121: Evaluation of IRI for no interlayer over CTD bases, (Cat. x14')

NO INT IRI (in/mi) Over CTD Bases

ESAL	30001	2E6	Thickness	4.1	10	Data Range	6
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives	
3	99	19.9	0.6	10.1	2.4		



SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	0	0.0
5-6	0	0.0
7-8	0	0.0
9-10	0	0.0
11-12	0	0.0
13-14	0	0.0
15-16	1	1.0
17-18	2	2.0
19-20	96	97.0
TOTAL '0-20'	99	100.0

Parameters	ESAL Distribution	ADT Distribution
MIN	113385	5500
25 PERCNTILE	113385	5500
MEDIAN	113385	5500
AVERAGE	213614	9316
75 PERCNTILE	378875	15227
MAX	387171	16602

B/C (SL) =	196.7	Yrs / Dollar	Category
B/C (NBA) =	99.4	Ft-yr/ft/Dollar	x16'

Figure 122: Evaluation of IRI for no interlayer over CTD bases, (Cat. x16')

Rut Depth Evaluation (3 data points)

AST/No Interlayer over CSD Bases. The performance of rut depth is shown from Figure 123 to Figure 128 for CSD bases. Unexpectedly, rut behavior for the AST interlayer sections varies greatly from the no interlayer sections (from the comparison of Category x1 vs x5 shown in Figure 123 vs Figure 126 and similar others). From these figures, it is obvious that AST interlayer creates unnecessary rutting for the overlying HMA layers. Detailed comparisons are provided in the next section.

AST INT Rut Depth (in) Over CSD Bases								
ESAL	0	30000	Thickness	0	4	Data Range	3	
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives		
24	724	16.8	4.6	9.5	3.9	SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
						0-2	0	0.0
						3-4	3	0.4
						5-6	22	3.0
						7-8	36	5.0
						9-10	48	6.6
						11-12	37	5.1
						13-14	69	9.5
						15-16	41	5.7
						17-18	23	3.2
						19-20	445	61.5
						TOTAL '0-20'	724	100.0
						Parameters	ESAL Distribution	ADT Distribution
						MIN	603	91
						25 PERCNTILE	1683	530
						MEDIAN	6903	1400
						AVERAGE	9356	1546
B/C (SL) =		100.6	Yrs / Dollar		Category	75 PERCNTILE	13569	2030
B/C (NBA) =		57.0	Ft-yr/ft/Dollar		x1	MAX	27494	3819

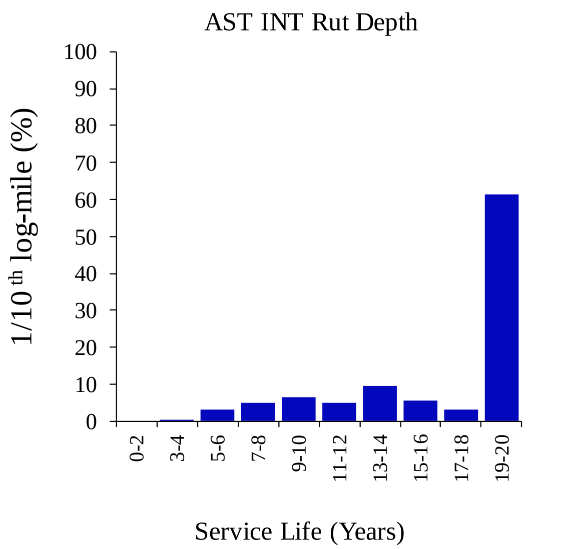
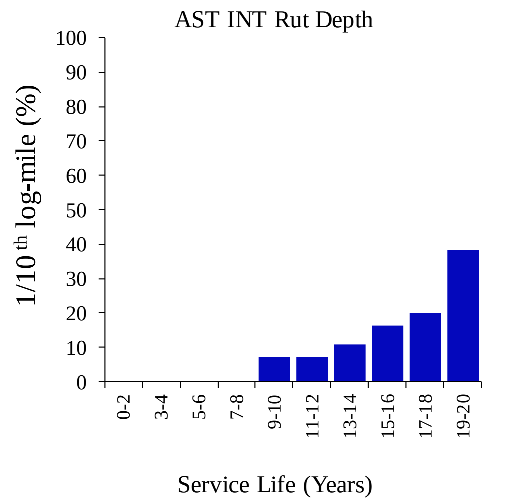


Figure 123: Evaluation of RUT for AST interlayer over CSD base, (Cat. x1)

AST INT Rut Depth (in) Over CSD Bases								
ESAL	30001	2E6	Thickness	0	4	Data Range	3	
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives		
2	55	16.7	3.5	7.8	2.2	SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections



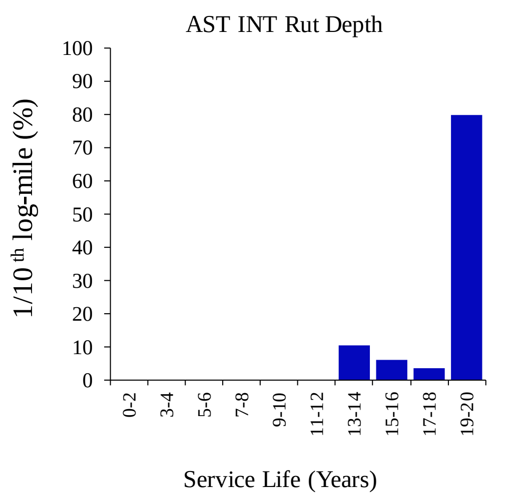
SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	0	0.0
5-6	0	0.0
7-8	0	0.0
9-10	4	7.3
11-12	4	7.3
13-14	6	10.9
15-16	9	16.4
17-18	11	20.0
19-20	21	38.2
TOTAL '0-20'	55	100.0

Parameters	ESAL Distribution	ADT Distribution
MIN	33693	1090
25 PERCNTILE	33693	1090
MEDIAN	33693	1090
AVERAGE	143136	10096
75 PERCNTILE	368103	28609
MAX	368103	28609

B/C (SL) =	105.2	Yrs / Dollar	Category
B/C (NBA) =	49.2	Ft-yr/ft/Dollar	x2

Figure 124: Evaluation of RUT for AST interlayer over CSD base, (Cat. x2)

AST INT Rut Depth (in) Over CSD Bases								
ESAL	30001	2E6	Thickness	4.1	10	Data Range	3	
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives		
8	114	19.0	2.1	11.0	3.0	SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections



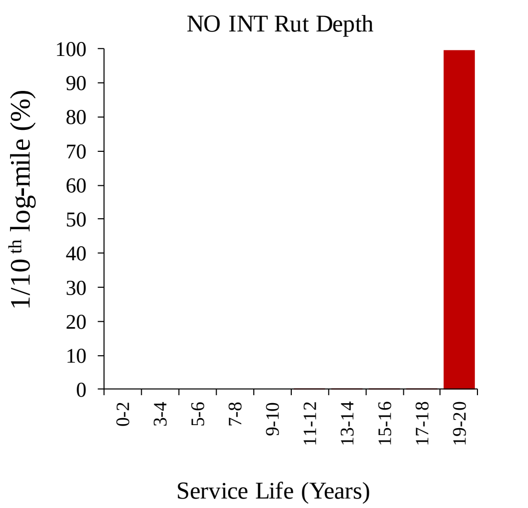
SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	0	0.0
5-6	0	0.0
7-8	0	0.0
9-10	0	0.0
11-12	0	0.0
13-14	12	10.5
15-16	7	6.1
17-18	4	3.5
19-20	91	79.8
TOTAL '0-20'	114	100.0

Parameters	ESAL Distribution	ADT Distribution
MIN	43959	1750
25 PERCNTILE	63643	2350
MEDIAN	71889	3900
AVERAGE	140088	4499
75 PERCNTILE	181101	3900
MAX	523334	31600

B/C (SL) =	135.0	Yrs / Dollar	Category
B/C (NBA) =	78.1	Ft-yr/ft/Dollar	x4

Figure 125: Evaluation of RUT for AST interlayer over CSD base, (Cat. x4)

NO INT Rut Depth (in) Over CSD Bases								
ESAL	0	30000	Thickness	0	4	Data Range	3	
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives		
46	1789	20.0	0.4	14.1	1.6	SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections

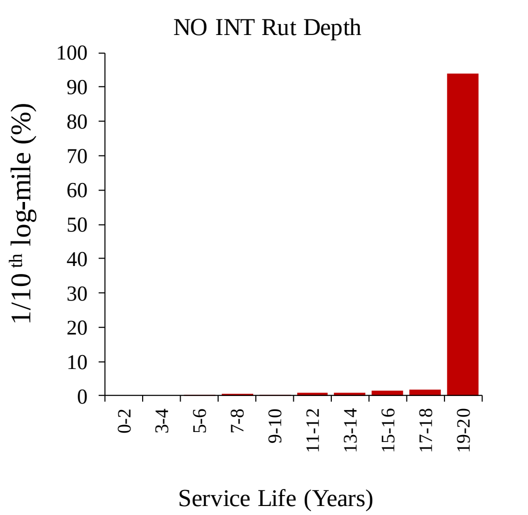


SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	0	0.0
5-6	0	0.0
7-8	0	0.0
9-10	0	0.0
11-12	1	0.1
13-14	2	0.1
15-16	3	0.2
17-18	1	0.1
19-20	1782	99.6
TOTAL '0-20'	1789	100.0
Parameters	ESAL Distribution	ADT Distribution
MIN	56	159
25 PERCNTILE	1508	679
MEDIAN	4664	1185
AVERAGE	7972	1475
75 PERCNTILE	13877	2028
MAX	28790	8012

B/C (SL) =	172.6	Yrs / Dollar	Category
B/C (NBA) =	121.5	Ft-yr/ft/Dollar	x5

Figure 126: Evaluation of RUT for no interlayer over CSD base, (Cat. x5)

NO INT Rut Depth (in) Over CSD Bases								
ESAL	30001	2E6	Thickness	0	4	Data Range	3	
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives		
17	774	19.6	1.7	13.3	2.8	SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections

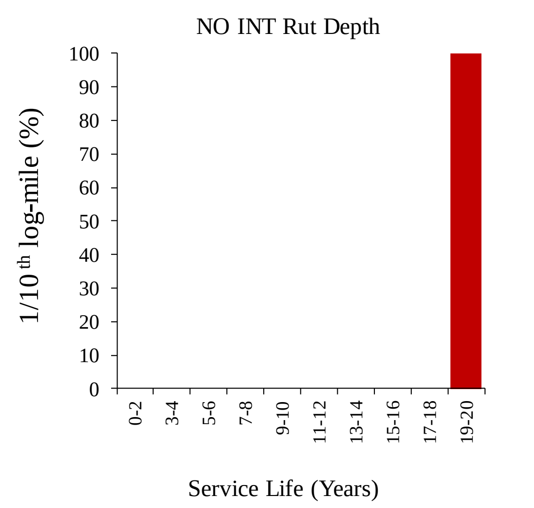


SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	0	0.0
5-6	1	0.1
7-8	4	0.5
9-10	3	0.4
11-12	7	0.9
13-14	8	1.0
15-16	12	1.6
17-18	13	1.7
19-20	726	93.8
TOTAL '0-20'	774	100.0
Parameters	ESAL Distribution	ADT Distribution
MIN	30494	455
25 PERCNTILE	37822	1152
MEDIAN	45871	2368
AVERAGE	114002	3978
75 PERCNTILE	84069	3849
MAX	1431101	54792

B/C (SL) =	165.8	Yrs / Dollar	Category
B/C (NBA) =	112.6	Ft-yr/ft/Dollar	x6

Figure 127: Evaluation of RUT for no interlayer over CSD bases, (Cat. x6)

NO INT Rut Depth (in) Over CSD Bases								
ESAL	30001	2E6	Thickness	4.1	10	Data Range	3	
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives		
2	108	20.0	0.0	12.4	2.1	SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections



SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	0	0.0
5-6	0	0.0
7-8	0	0.0
9-10	0	0.0
11-12	0	0.0
13-14	0	0.0
15-16	0	0.0
17-18	0	0.0
19-20	108	100.0
TOTAL '0-20'	108	100.0

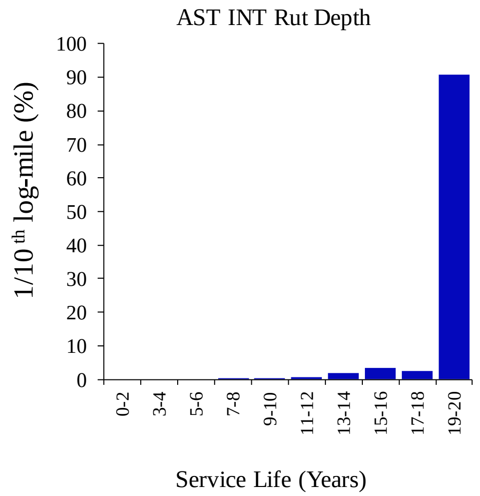
Parameters	ESAL Distribution	ADT Distribution
MIN	31695	4084
25 PERCNTILE	31695	4084
MEDIAN	62459	4656
AVERAGE	54483	4508
75 PERCNTILE	62459	4656
MAX	62459	4656

B/C (SL) =	173.0	Yrs / Dollar	Category
B/C (NBA) =	107.1	Ft-yr/ft/Dollar	x8

Figure 128: Evaluation of RUT for no interlayer over CSD bases, (Cat. x8)

AST/No Interlayer over CTD Bases. The performance of AST and no interlayer sections over CTD bases for rut depths are shown from Figure 129 to Figure 132.

AST INT Rut Depth (in) Over CTD Bases							
ESAL	0	30000	Thickness	0	4	Data Range	3
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev		
6	347	19.5	1.6	13.7	2.9		



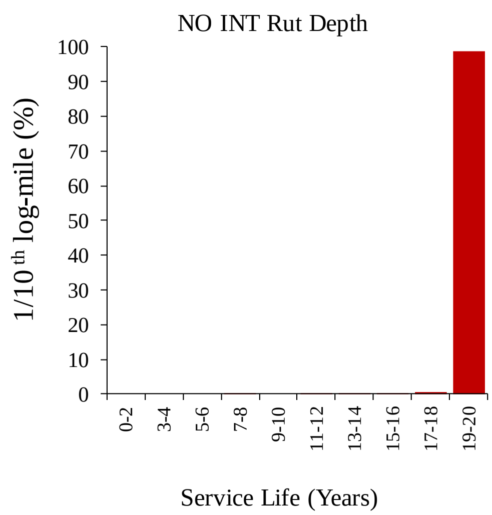
HISTOGRAM DATA of Service Lives		
SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	0	0.0
5-6	0	0.0
7-8	1	0.3
9-10	1	0.3
11-12	2	0.6
13-14	7	2.0
15-16	12	3.5
17-18	9	2.6
19-20	315	90.8
TOTAL '0-20'	347	100.0

Parameters	ESAL Distribution	ADT Distribution
MIN	81	360
25 PERCNTILE	3467	411
MEDIAN	9210	667
AVERAGE	10231	809
75 PERCNTILE	16965	1360
MAX	18718	1440

B/C (SL) =	159.8	Yrs / Dollar	Category
B/C (NBA) =	112.1	Ft-yr/ft/Dollar	x9

Figure 129: Evaluation of RUT for AST interlayer over CTD bases, (Cat. x9)

NO INT Rut Depth (in) Over CTD Bases							
ESAL	0	30000	Thickness	0	4	Data Range	3
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev		
46	1484	19.9	0.6	14.3	2.3		



HISTOGRAM DATA of Service Lives		
SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	0	0.0
5-6	0	0.0
7-8	1	0.1
9-10	0	0.0
11-12	1	0.1
13-14	6	0.4
15-16	3	0.2
17-18	9	0.6
19-20	1464	98.7
TOTAL '0-20'	1484	100.0

Parameters	ESAL Distribution	ADT Distribution
MIN	148	115
25 PERCNTILE	1451	500
MEDIAN	8005	1040
AVERAGE	9670	1455
75 PERCNTILE	17083	1576
MAX	28551	10210

B/C (SL) =	197.2	Yrs / Dollar	Category
B/C (NBA) =	141.3	Ft-yr/ft/Dollar	x13

Figure 130: Evaluation of RUT for no interlayer over CTD bases, (Cat. x13)

NO INT Rut Depth (in) Over CTD Bases								
ESAL	30001	2E6	Thickness	0	4	Data Range	3	
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives		
6	209	20.0	0.3	14.2	1.6	SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
						0-2	0	0.0
						3-4	0	0.0
						5-6	0	0.0
						7-8	0	0.0
						9-10	0	0.0
						11-12	0	0.0
						13-14	0	0.0
						15-16	1	0.5
						17-18	1	0.5
						19-20	207	99.0
						TOTAL '0-20'	209	100.0
						Parameters	ESAL Distribution	ADT Distribution
						MIN	36661	1761
						25 PERCNTILE	36661	1896
						MEDIAN	51834	3538
						AVERAGE	57268	3731
B/C (SL) =		198.0	Yrs / Dollar		Category	75 PERCNTILE	76200	3931
B/C (NBA) =		140.9	Ft-yr/ft/Dollar		x14	MAX	134609	8861

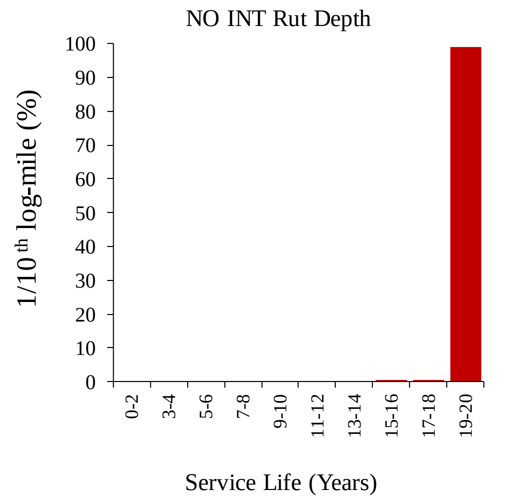


Figure 131: Evaluation of RUT for AST interlayer over CTD bases, (Cat. x14)

NO INT Rut Depth (in) Over CTD Bases								
ESAL	30001	2E6	Thickness	4.1	10	Data Range	3	
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives		
3	106	19.3	1.8	12.9	3.3	SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
						0-2	0	0.0
						3-4	0	0.0
						5-6	0	0.0
						7-8	0	0.0
						9-10	1	0.9
						11-12	1	0.9
						13-14	3	2.8
						15-16	2	1.9
						17-18	9	8.5
						19-20	90	84.9
						TOTAL '0-20'	106	100.0
						Parameters	ESAL Distribution	ADT Distribution
						MIN	113385	5500
						25 PERCNTILE	113385	5500
						MEDIAN	113385	5500
						AVERAGE	209500	9169
B/C (SL) =		185.5	Yrs / Dollar		Category	75 PERCNTILE	378875	13851
B/C (NBA) =		124.1	Ft-yr/ft/Dollar		x16	MAX	387171	16602

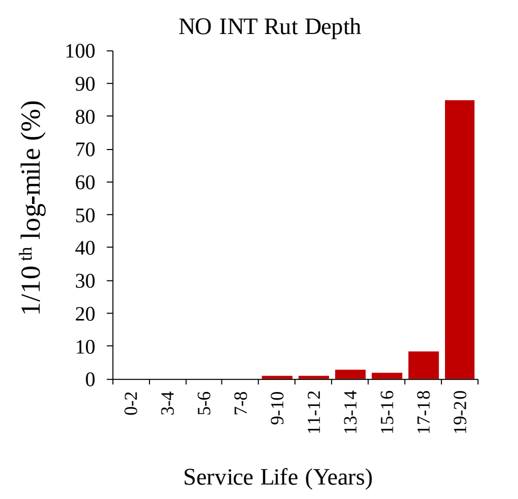
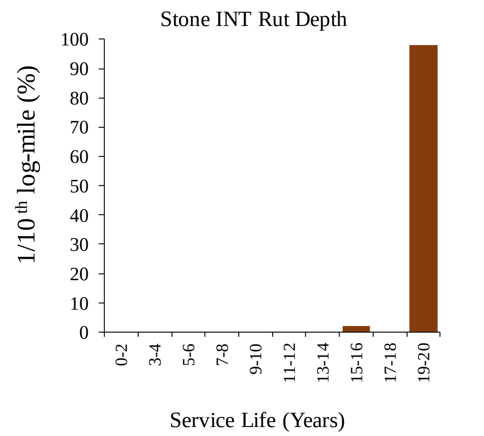


Figure 132: Evaluation of RUT for AST interlayer over CTD bases, (Cat. x16)

Stone Interlayer over CSD/CTD Bases. For the evaluation of stone interlayer, Figure 133 to Figure 136 shows Category x17 to x20 for rut.

Stone Int Rut Depth (in) Over CTD Bases								
ESAL	0	150000	Thickness	0	5	Data Range	3	
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives		
2	50	19.9	0.5	12.0	1.9	SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections



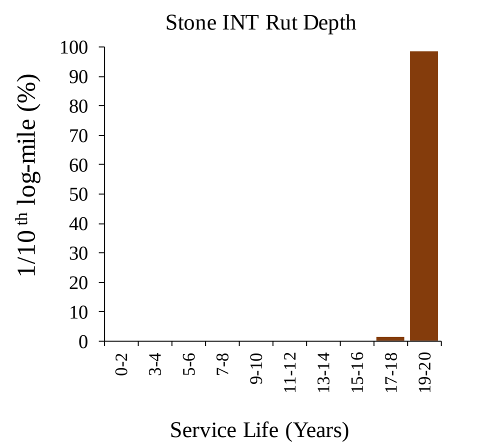
SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	0	0.0
5-6	0	0.0
7-8	0	0.0
9-10	0	0.0
11-12	0	0.0
13-14	0	0.0
15-16	1	2.0
17-18	0	0.0
19-20	49	98.0
TOTAL '0-20'	50	100.0

Parameters	ESAL Distribution	ADT Distribution
MIN	28551	1355
25 PERCNTILE	28551	1355
MEDIAN	28551	1355
AVERAGE	48126	1664
75 PERCNTILE	28551	1355
MAX	137299	3071

B/C (SL) =	124.5	Yrs / Dollar	Category
B/C (NBA) =	75.3	Ft-yr/ft/Dollar	x17

Figure 133: Evaluation of RUT for stone interlayer over CTD bases, (Cat. x17)

Stone Int Rut Depth (in) Over CSD Bases								
ESAL	0	30000	Thickness	0	5	Data Range	3	
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives		
3	68	20.0	0.2	13.1	1.6	SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections



SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	0	0.0
5-6	0	0.0
7-8	0	0.0
9-10	0	0.0
11-12	0	0.0
13-14	0	0.0
15-16	0	0.0
17-18	1	1.5
19-20	67	98.5
TOTAL '0-20'	68	100.0

Parameters	ESAL Distribution	ADT Distribution
MIN	15932	2800
25 PERCNTILE	15932	2800
MEDIAN	15932	2800
AVERAGE	19704	4556
75 PERCNTILE	24152	3800
MAX	29340	11214

B/C (SL) =	114.3	Yrs / Dollar	Category
B/C (NBA) =	74.9	Ft-yr/ft/Dollar	x18

Figure 134: Evaluation of RUT for stone interlayer over CSD bases, (Cat. x18)

NO INT Rut Depth (in) Over CTD Bases								
ESAL	0	150000	Thickness	0	5	Data Range	3	
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives		
55	1807	19.9	0.6	14.3	2.3	SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
						0-2	0	0.0
						3-4	0	0.0
						5-6	0	0.0
						7-8	1	0.1
						9-10	0	0.0
						11-12	1	0.1
						13-14	6	0.3
						15-16	5	0.3
						17-18	10	0.6
						19-20	1784	98.7
						TOTAL '0-20'	1807	100.0
						Parameters	ESAL Distribution	ADT Distribution
						MIN	148	115
						25 PERCNTILE	1929	693
						MEDIAN	9723	1159
						AVERAGE	19393	1858
B/C (SL) =		197.3	Yrs / Dollar		Category	75 PERCNTILE	23409	2403
B/C (NBA) =		141.9	Ft-yr/ft/Dollar		x19	MAX	134609	10210

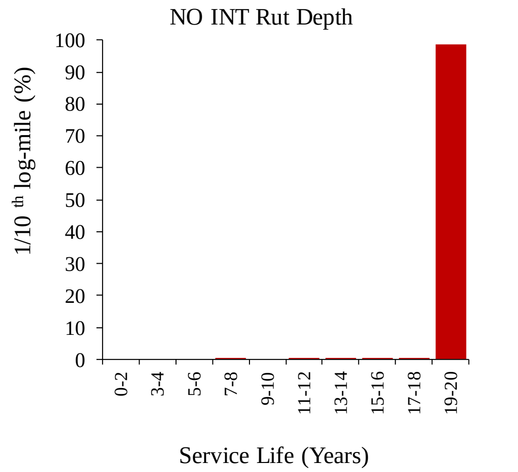


Figure 135: Evaluation of RUT for no interlayer over CTD bases, (Cat. x19)

NO INT Rut Depth (in) Over CSD Bases								
ESAL	0	30000	Thickness	0	5	Data Range	3	
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives		
46	1789	20.0	0.4	14.1	1.6	SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
						0-2	0	0.0
						3-4	0	0.0
						5-6	0	0.0
						7-8	0	0.0
						9-10	0	0.0
						11-12	1	0.1
						13-14	2	0.1
						15-16	3	0.2
						17-18	1	0.1
						19-20	1782	99.6
						TOTAL '0-20'	1789	100.0
						Parameters	ESAL Distribution	ADT Distribution
						MIN	56	159
						25 PERCNTILE	1508	679
						MEDIAN	4664	1185
						AVERAGE	7972	1475
B/C (SL) =		172.6	Yrs / Dollar		Category	75 PERCNTILE	13877	2028
B/C (NBA) =		121.5	Ft-yr/ft/Dollar		x20	MAX	28790	8012

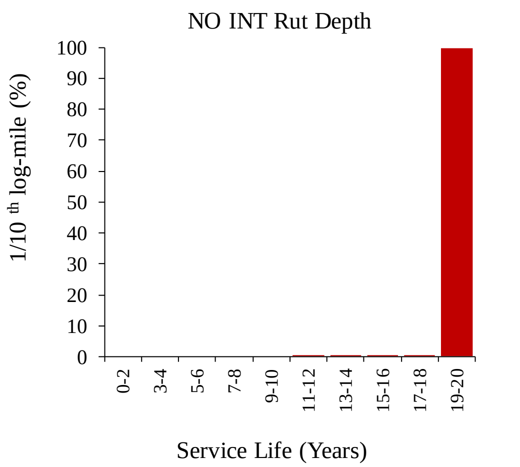


Figure 136: Evaluation of RUT for no interlayer over CSD bases, (Cat. x20)

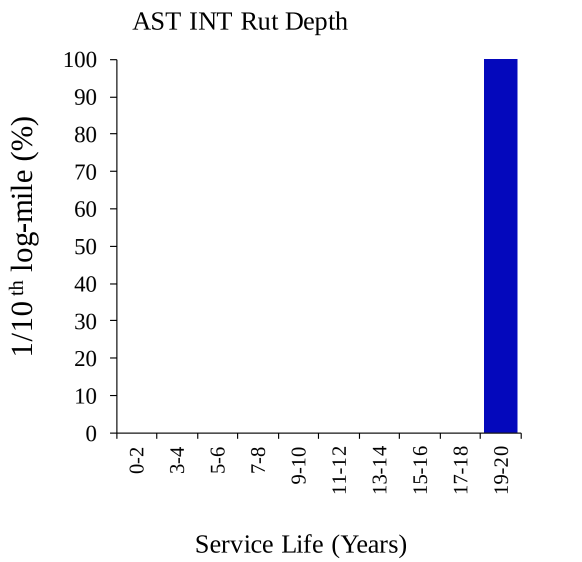
Rut Depth Evaluation (6 data points)

AST/No Interlayer over CSD Bases. Figure 137 to Figure 141 illustrates the evaluation of rut for CSD bases for 6 data points. It should be recalled here that only x5' and x6' (shown in Figures 139 and 140) had sufficient data for any conclusive remarks. As these analyses are for 6 data points, the Category x1' (shown in Figure 137) had very few projects (N(P)=3); hence it does not present the rut problem in the corresponding 3 data points Category (Category x1, shown in Figure 123).

AST INTRut Depth (in) Over CSD Bases

ESAL	0	30000	Thickness	0	4	Data Range	6
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev		
3	40	20.0	0.0	13.7	1.2		

HISTOGRAM DATA of Service Lives		
SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	0	0.0
5-6	0	0.0
7-8	0	0.0
9-10	0	0.0
11-12	0	0.0
13-14	0	0.0
15-16	0	0.0
17-18	0	0.0
19-20	40	100.0
TOTAL '0-20'	40	100.0

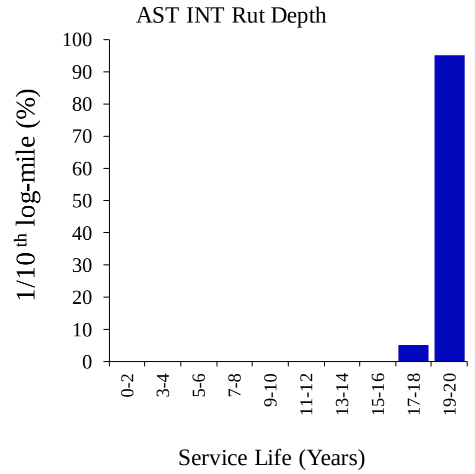


Parameters	ESAL Distribution	ADT Distribution
MIN	734	530
25 PERCNTILE	9583	794
MEDIAN	12533	882
AVERAGE	10490	1528
75 PERCNTILE	13440	1616
MAX	16161	3819

B/C (SL) =	148.9	Yrs / Dollar	Category
B/C (NBA) =	101.8	Ft-yr/ft/Dollar	x1'

Figure 137: Evaluation of RUT for AST interlayer over CSD base, (Cat. x1')

AST INT Rut Depth (in) Over CSD Bases							
ESAL	30001	2E6	Thickness	4.1	10	Data Range	6
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives	
2	20	19.9	0.3	12.3	2.1		



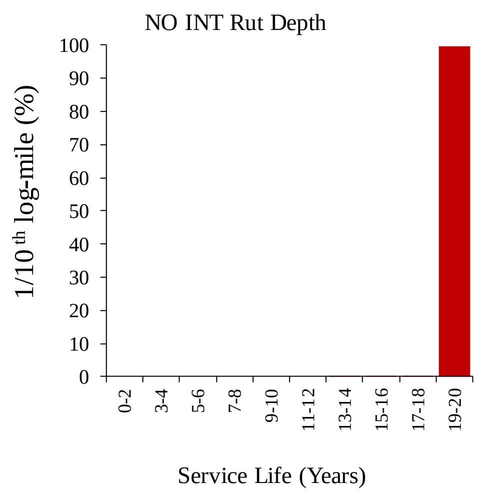
SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	0	0.0
5-6	0	0.0
7-8	0	0.0
9-10	0	0.0
11-12	0	0.0
13-14	0	0.0
15-16	0	0.0
17-18	1	5.0
19-20	19	95.0
TOTAL '0-20'	20	100.0

Parameters	ESAL Distribution	ADT Distribution
MIN	71889	6197
25 PERCNTILE	71889	6197
MEDIAN	71889	6197
AVERAGE	137383	10007
75 PERCNTILE	71889	6197
MAX	508514	31600

B/C (SL) =	147.9	Yrs / Dollar	Category
B/C (NBA) =	91.0	Ft-yr/ft/Dollar	x4'

Figure 138: Evaluation of RUT for AST interlayer over CSD base, (Cat. x4')

NO INT rut depth (in) Over CSD Bases							
ESAL	0	30000	Thickness	0	4	Data Range	6
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives	
46	1789	20.0	0.2	15.4	1.5		



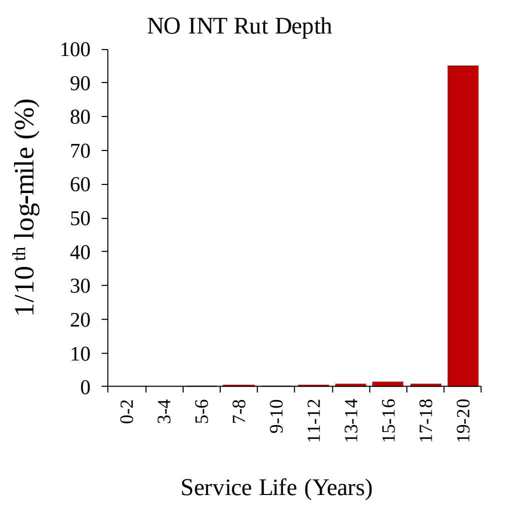
SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	0	0.0
5-6	0	0.0
7-8	0	0.0
9-10	0	0.0
11-12	0	0.0
13-14	1	0.1
15-16	2	0.1
17-18	1	0.1
19-20	1785	99.8
TOTAL '0-20'	1789	100.0

Parameters	ESAL Distribution	ADT Distribution
MIN	56	159
25 PERCNTILE	1508	679
MEDIAN	4664	1185
AVERAGE	7972	1475
75 PERCNTILE	13877	2028
MAX	28790	8012

B/C (SL) =	172.9	Yrs / Dollar	Category
B/C (NBA) =	133.3	Ft-yr/ft/Dollar	x5'

Figure 139: Evaluation of RUT for no interlayer over CSD base, (Cat. x5')

NO INT Rut Depth (in) Over CSD Bases								
ESAL	30001	2E6	Thickness	0	4	Data Range	6	
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives		
17	774	19.7	1.6	14.3	2.7	SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections



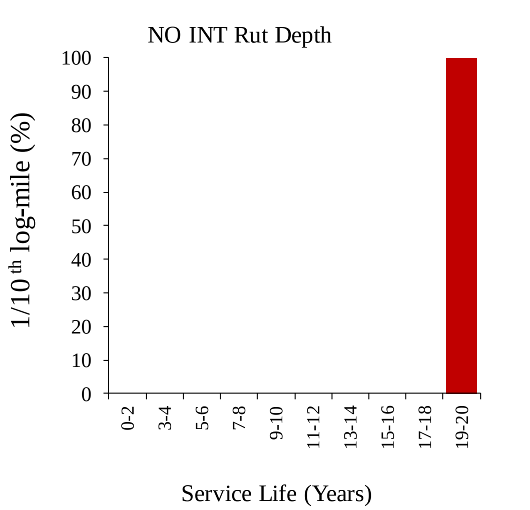
SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	0	0.0
5-6	1	0.1
7-8	4	0.5
9-10	3	0.4
11-12	5	0.6
13-14	6	0.8
15-16	11	1.4
17-18	7	0.9
19-20	737	95.2
TOTAL '0-20'	774	100.0

Parameters	ESAL Distribution	ADT Distribution
MIN	30494	455
25 PERCNTILE	37822	1152
MEDIAN	45871	2368
AVERAGE	114002	3978
75 PERCNTILE	84069	3849
MAX	1431101	54792

B/C (SL) =	166.8	Yrs / Dollar	Category	75 PERCNTILE	84069	3849
B/C (NBA) =	120.8	Ft-yr/ft/Dollar	x6'	MAX	1431101	54792

Figure 140: Evaluation of RUT for no interlayer over CSD bases, (Cat. x6')

NO INT Rut Depth (in) Over CSD Bases								
ESAL	30001	2E6	Thickness	4.1	10	Data Range	6	
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives		
2	108	20.0	0.0	13.7	1.8	SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections



SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	0	0.0
5-6	0	0.0
7-8	0	0.0
9-10	0	0.0
11-12	0	0.0
13-14	0	0.0
15-16	0	0.0
17-18	0	0.0
19-20	108	100.0
TOTAL '0-20'	108	100.0

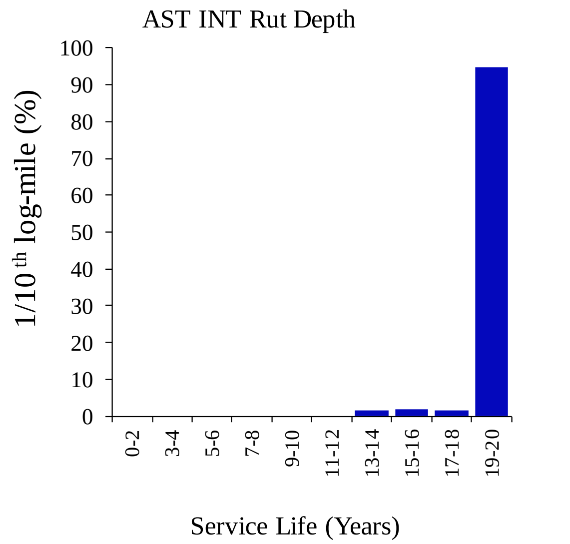
Parameters	ESAL Distribution	ADT Distribution
MIN	31695	4084
25 PERCNTILE	31695	4084
MEDIAN	62459	4656
AVERAGE	54483	4508
75 PERCNTILE	62459	4656
MAX	62459	4656

B/C (SL) =	173.0	Yrs / Dollar	Category	75 PERCNTILE	62459	4656
B/C (NBA) =	118.2	Ft-yr/ft/Dollar	x8'	MAX	62459	4656

Figure 141: Evaluation of RUT for no interlayer over CSD bases, (Cat. x8')

AST/No Interlayer over CTD Bases. Rut Depth evaluation for CTD bases are shown below in Figure 142 to Figure 145.

AST INT Rut Depth (in) Over CTD Bases								
ESAL	0	30000	Thickness	0	4	Data Range	6	
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives		
6	347	19.8	1.0	14.2	2.5	SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections



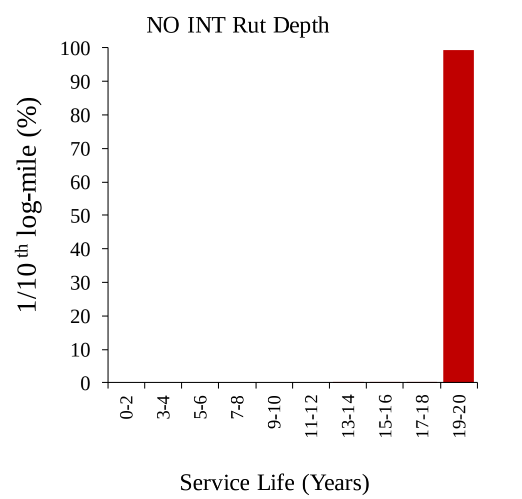
SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	0	0.0
5-6	0	0.0
7-8	0	0.0
9-10	0	0.0
11-12	0	0.0
13-14	5	1.4
15-16	7	2.0
17-18	6	1.7
19-20	329	94.8
TOTAL '0-20'	347	100.0

Parameters	ESAL Distribution	ADT Distribution
MIN	81	360
25 PERCNTILE	3467	411
MEDIAN	9210	667
AVERAGE	10231	809
75 PERCNTILE	16965	1360
MAX	18718	1440

B/C (SL) =	163.9	Yrs / Dollar	Category
B/C (NBA) =	117.5	Ft-yr/ft/Dollar	x9'

Figure 142: Evaluation of RUT for AST interlayer over CTD bases, (Cat. x9')

NO INT Rut Depth (in) Over CTD Bases								
ESAL	0	30000	Thickness	0	4	Data Range	6	
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives		
46	1485	20.0	0.4	15.0	1.7	SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections

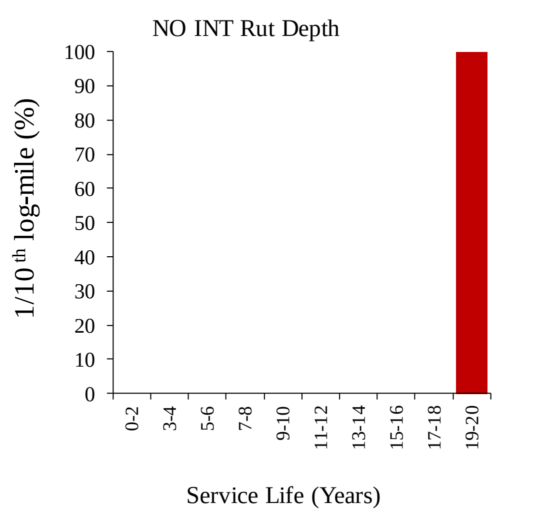


SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	0	0.0
5-6	0	0.0
7-8	0	0.0
9-10	0	0.0
11-12	0	0.0
13-14	3	0.2
15-16	2	0.1
17-18	3	0.2
19-20	1477	99.5
TOTAL '0-20'	1485	100.0
Parameters	ESAL Distribution	ADT Distribution
MIN	148	115
25 PERCNTILE	1451	500
MEDIAN	7339	1040
AVERAGE	9664	1455
75 PERCNTILE	17083	1576
MAX	28551	10210

B/C (SL) =	198.1	Yrs / Dollar	Category
B/C (NBA) =	149.1	Ft-yr/ft/Dollar	x13'

Figure 143: Evaluation of RUT for no interlayer over CTD bases, (Cat. x13')

NO INT Rut Depth (in) Over CTD Bases								
ESAL	30001	2E6	Thickness	0	4	Data Range	6	
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives		
6	209	20.0	0.0	14.7	1.3	SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections

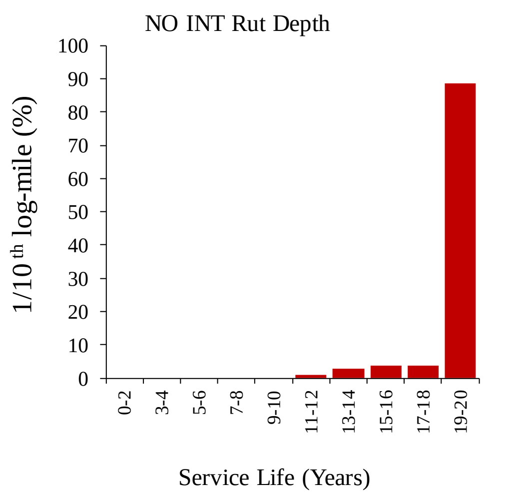


SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	0	0.0
5-6	0	0.0
7-8	0	0.0
9-10	0	0.0
11-12	0	0.0
13-14	0	0.0
15-16	0	0.0
17-18	0	0.0
19-20	209	100.0
TOTAL '0-20'	209	100.0
Parameters	ESAL Distribution	ADT Distribution
MIN	36661	1761
25 PERCNTILE	36661	1896
MEDIAN	51834	3538
AVERAGE	57268	3731
75 PERCNTILE	76200	3931
MAX	134609	8861

B/C (SL) =	198.5	Yrs / Dollar	Category
B/C (NBA) =	146.1	Ft-yr/ft/Dollar	x14'

Figure 144: Evaluation of RUT for no interlayer over CTD bases, (Cat. x14')

NO INT Rut Depth (in) Over CTD Bases							
ESAL	30001	2E6	Thickness	4.1	10	Data Range	6
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	HISTOGRAM DATA of Service Lives	
3	106	19.4	1.7	12.8	3.1		



SL YEAR BRACKET	Number of 1/10th Log mile section	Percent of Sections
0-2	0	0.0
3-4	0	0.0
5-6	0	0.0
7-8	0	0.0
9-10	0	0.0
11-12	1	0.9
13-14	3	2.8
15-16	4	3.8
17-18	4	3.8
19-20	94	88.7
TOTAL '0-20'	106	100.0

Parameters	ESAL Distribution	ADT Distribution
MIN	113385	5500
25 PERCNTILE	113385	5500
MEDIAN	113385	5500
AVERAGE	209500	9169
75 PERCNTILE	378875	13851
MAX	387171	16602

B/C (SL) =	187.6	Yrs / Dollar	Category
B/C (NBA) =	124.0	Ft-yr/ft/Dollar	x16'

Figure 145: Evaluation of RUT for no interlayer over CTD bases, (Cat. x16')

Comparison of Benefits

To evaluate the performance of AST interlayer, the AST interlayer sections had to be compared with no interlayer sections by the same base category. Hence, for all distress types, AST interlayer sections are compared with no interlayer sections by the above-mentioned outputs as shown in the methodology.

Transverse Cracking Comparison (3 data points)

AST Interlayer Evaluation (Over CSD). There are three available comparisons for AST interlayer evaluation over CSD bases: Category x1 vs x5, Category x2 vs x6, and Category x4 vs x8. Now, from these three categories, only the first one (Category x1 vs x5) provides conclusive information as it has sufficient data for both sides. The other two comparisons have fewer data points (N(P)<5, for any side), hence results from those comparisons may not have much confidence.

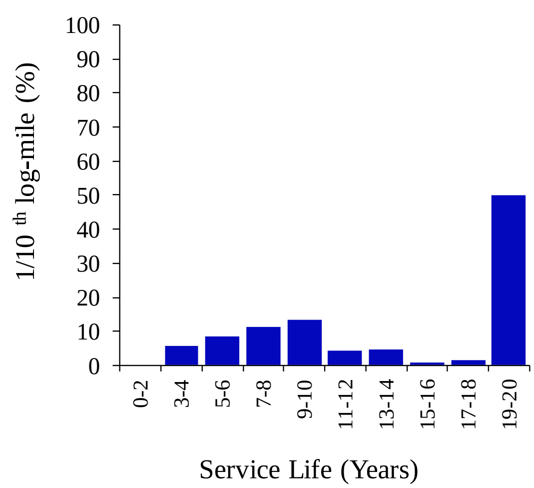
Now, both the x1 and x5 categories consist of CSD bases, ESAL 0-30000, and HMA thickness of 0-4 in.; the only difference is that x1 has an AST interlayer and x5 has no interlayer. Hence, Category x1 vs x5 is the evaluation of AST interlayer for lower ESAL and less thickness category for CSD bases. Similarly, Category x2 vs x6 is the evaluation of AST interlayer for higher ESAL (>30000) and less thickness (0-4 in.) over CSD bases. Category x4 vs x8 is the evaluation of AST interlayer for higher ESAL (>30000) and more thickness (Th>4 in.) category. As Category x1 vs x5 has sufficient data points on both side, this is the major comparison category for AST interlayer over CSD.

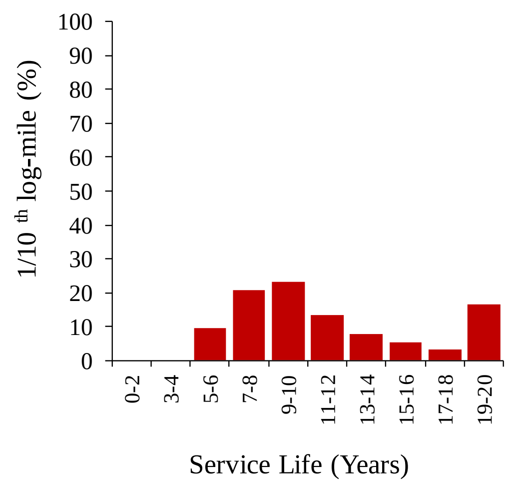
Figure 146 shows the comparison of Category x1 vs x5, which is the comparison of AST vs no interlayer over CSD bases for transverse cracking (for lower ESAL and less thickness). In the figure, the AvgSL and AvgNBA for the AST interlayer sections are 14.3 years and 13.1 years Ft-yr/ft whereas the AvgSL and AvgNBA for no interlayer sections are 11.6 years and 10.5 Ft-yr/ft. Hence, the GainSL and GainNBA for AST interlayer for CSD sections are 2.7 years and 2.6 Ft-yr/ft, which is shown at the middle center of the figure. From the histogram comparison, it is seen that the AST interlayer sections have a slightly better histogram with respect to the no interlayer sections. About 50% of AST interlayer sections have 20 years of service life, whereas only about 17% of sections for no interlayer sections has 20 years of service life. So, the AST interlayer did delay transverse crack development for 2.7 years on an average. Hence, the B/C ratios are slightly better for AST interlayer with respect to no interlayer. The B/C(SL) and B/C(NBA) values for AST interlayer are 67.4 Yrs/Dollar and 61.7 Ft-yr/ft/Dollar, whereas for no interlayer, those values are 60.3 Yrs/Dollar and 54.5 Ft-yr/ft/Dollar. So, if only TC (with no other distress types) is considered, AST interlayer is slightly cost-effective compared to no interlayer for CSD bases for lower ESAL and less thickness category.

TRANSVERSE CRACKING COMPARISON, CSD Bases, AST vs NO Interlayer

ESAL Category	0	30000	ESAL		**Data Category**	3	Data points
Thickness Category	0	4	inches		**Base Category**	CSD	Soil Cement

AST INTERLAYER						NO INTERLAYER					
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
26	718	14.3	6.1	13.1	5.9	46	1785	11.6	4.6	10.5	4.7





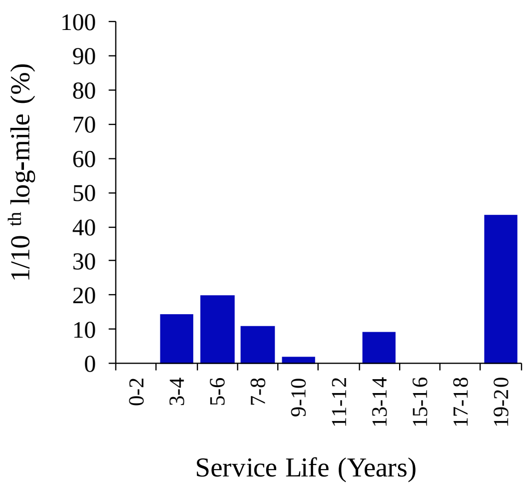
B/C (SL) =	67.4	Yrs / Dollar		B/C (SL) =	60.3	Yrs / Dollar
B/C (NBA) =	61.7	Ft-yr/ft/Dollar		B/C (NBA) =	54.5	Ft-yr/ft/Dollar
Category:	Gain SL by AST Interlayer	=	2.7	Yrs	Category:	
x1	Gain NBA by AST Interlayer	=	2.6	Ft-yr/ft	x5	

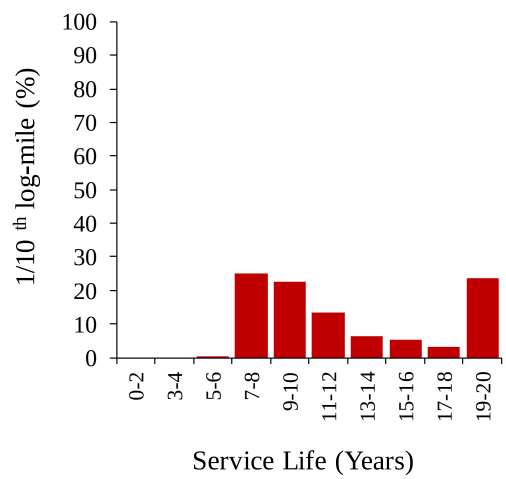
Figure 146: TC comparison for AST vs no interlayer, CSD base (Cat. x1 vs x5)

Figure 147 shows the TC comparison for AST vs no interlayer over CSD bases for Category x2 vs x6 (higher ESAL and less thickness). Both x2 and x6 had similar AvgSL and AvgNBA in this comparison, even though the histograms differed. There is a slightly negative GainSL and GainNBA for this comparison. But, as N(P) = 2 for the x2 (for AST interlayer sections), these results are not conclusive.

TRANSVERSE CRACKING COMPARISON, CSD Bases, AST vs NO Interlayer							
ESAL Category	30001	2E6	ESAL		**Data Category**	3	Data points
Thickness Category	0	4	inches		**Base Category**	CSD	Soil Cement

AST INTERLAYER							NO INTERLAYER					
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev		N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
2	55	12.5	7.1	11.0	6.4		17	773	12.6	4.8	11.5	5.0





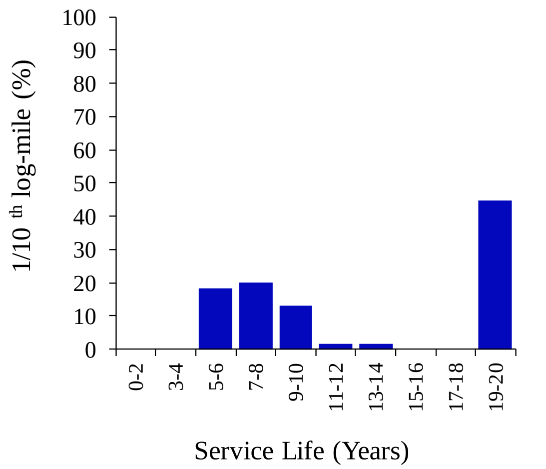
B/C (SL) =	47.2	Yrs / Dollar		B/C (SL) =	69.9	Yrs / Dollar
B/C (NBA) =	41.7	Ft-yr/ft/Dollar		B/C (NBA) =	64.0	Ft-yr/ft/Dollar
Category:	Gain SL by AST Interlayer		=	-0.1	Yrs	Category:
x2	Gain NBA by AST Interlayer		=	-0.5	Ft-yr/ft	x6

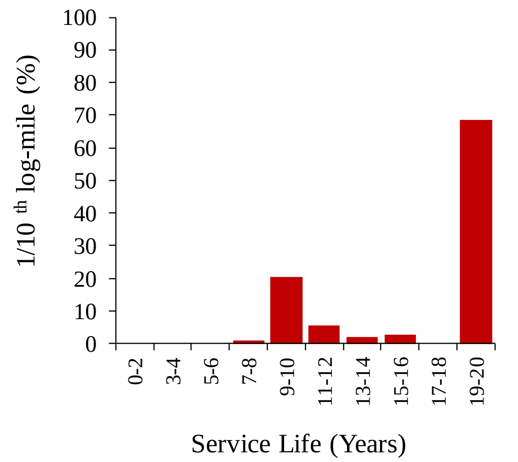
Figure 147: TC comparison for AST vs no interlayer, CSD base (Cat. x2 vs x6)

Figure 148 shows the TC comparison for AST vs no interlayer over CSD bases for Category x4 vs x8 (higher ESAL and more thickness). Here, AST Interlayer has -3.8 years of GainSL, which means that AST did not extend pavement service life for TC, instead reducing it in this case.

TRANSVERSE CRACKING COMPARISON, CSD Bases, AST vs NO Interlayer						
ESAL Category	30001	2E6	ESAL	**Data Category**	3	Data points
Thickness Category	4.1	10	inches	**Base Category**	CSD	Soil Cement

AST INTERLAYER							NO INTERLAYER					
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev		N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
8	114	13.2	6.3	11.9	6.0		2	108	17.0	4.5	15.9	4.6





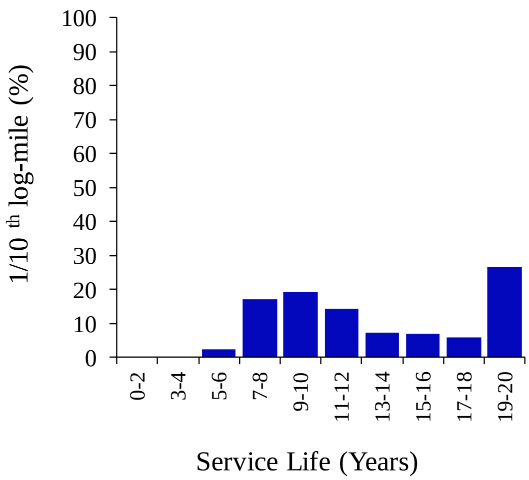
B/C (SL) =	58.8	Yrs / Dollar		B/C (SL) =	122.1	Yrs / Dollar
B/C (NBA) =	53.1	Ft-yr/ft/Dollar		B/C (NBA) =	114.3	Ft-yr/ft/Dollar
Category:	Gain SL by AST Interlayer		=	-3.8 Yrs	Category:	
x4	Gain NBA by AST Interlayer		=	-4.0 Ft-yr/ft	x8	

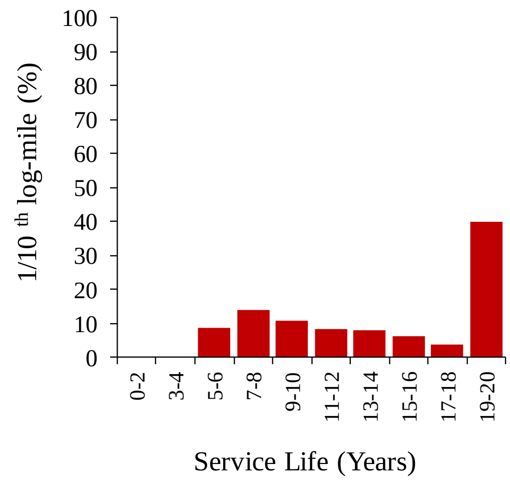
Figure 148: TC comparison for AST vs no interlayer, CSD base (Cat. x4 vs x8)

AST Interlayer Evaluation (Over CTD). There is only one comparison category for AST interlayer over CTD base performance: Category x9 vs x13, which is shown in Figure 149. From the figure, it is clear that AST interlayer over CTD behaved somewhat similarly to no interlayer over CTD bases. Both histograms are similar in nature with slightly negative GainSL and GainNBA values. Hence, AST interlayer did not extend pavement service life in this case.

TRANSVERSE CRACKING COMPARISON, CTD Bases, AST vs NO Interlayer							
ESAL Category	0	30000	ESAL		**Data Category**	3	Data points
Thickness Category	0	4	inches		**Base Category**	CTD	Soil Cement

AST INTERLAYER							NO INTERLAYER					
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev		N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
6	347	13.3	4.8	12.2	5.0		46	1476	14.2	5.4	13.3	5.7





B/C (SL) =	74.7	Yrs / Dollar		B/C (SL) =	95.6	Yrs / Dollar
B/C (NBA) =	68.5	Ft-yr/ft/Dollar		B/C (NBA) =	89.3	Ft-yr/ft/Dollar
Category:	Gain SL by AST Interlayer		=	-0.9 Yrs	Category:	
x9	Gain NBA by AST Interlayer		=	-1.1 Ft-yr/ft	x13	

Figure 149: TC comparison for AST vs no interlayer, CTD base (Cat. x9 vs x13)

CTD bases Evaluation. As CTD base itself is a reflective crack mitigation technique, the performance of CTD bases were compared with CSD bases; the CSD base acted as the control group. There are three comparison categories for CTD bases for any distress type: Category x13 vs x5, Category x14 vs x6, and Category x16 vs x8. Figure 150 to Figure 152 shows these three comparisons to evaluate CTD bases performance with respect to CSD bases as a reflective crack control method, respectively. The first comparison Category x13 vs x5 (Figure 150) has sufficient data (N(P)>45 for both sides) for any conclusive decision. The second comparison Category x14 vs x6 (Figure 151) has reasonable number of data points (N(P)>5, for both sides) with somewhat acceptable results. The third comparison Category x16 vs x8 (Figure 152) has few projects (N(P)<=3 for both sides), hence results for this category are inconclusive.

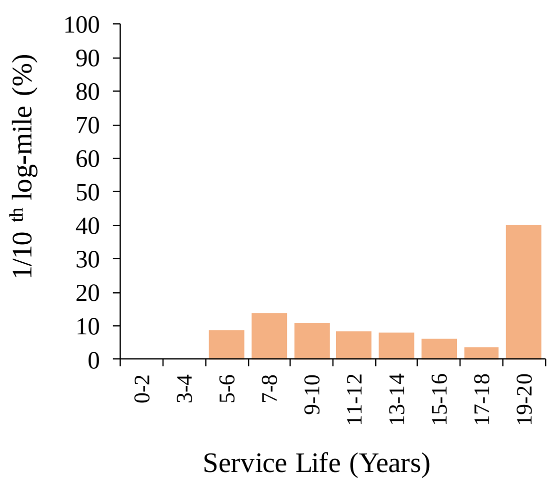
Figure 150 shows the transverse cracking comparison for CTD and CSD bases for lower ESAL

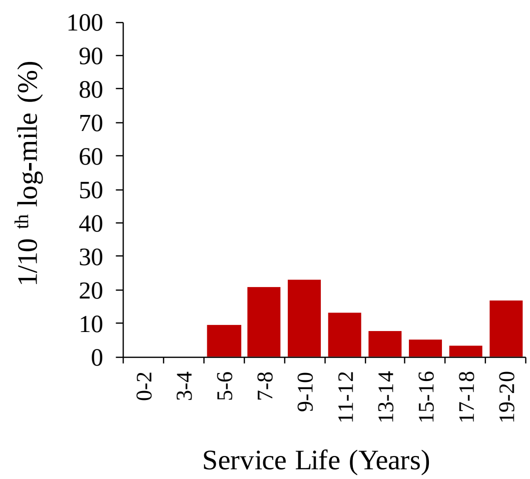
(<30000) and less thickness (Th: 0-4 in.) category. Here the AvgSL for CTD bases and CSD bases are 14.2 years and 11.6 years, respectively. Hence the GainSL by CTD bases are 2.6 years for transverse cracking. Similarly, GainNBA value for CTD bases is 2.8 Ft-yr/ft. It's worth mentioning here that AST interlayer has almost similar GainSL and GainNBA values for this category (as shown in Figure 146). Hence, CTD bases provide the same benefit as AST interlayer but CTD bases are inexpensive with respect to AST interlayer. For this reason, the benefit cost ratios (B/C(SL) and B/C(NBA) for CTD bases are way higher in comparison to AST interlayer for transverse cracking. The B/C(SL) and B/C(NBA) for CTD bases are 95.6 Yrs/Dollar and 89.3 Ft-yr/ft/Dollar, respectively, whereas these two values for CSD bases are 60.3 Yrs/Dollar and 54.5 Ft-yr/ft/Dollar. For the AST interlayer, these two values are 67.4 Yrs/Dollar and 61.7 Ft-yr/ft/Dollar (from Figure 146). Hence, CTD bases becomes the most cost-effective option for this lower ESAL and less thickness category.

TRANSVERSE CRACKING COMPARISON, No Int CTD vs No Int CSD Bases

ESAL Category	0	30000	ESAL		**Data Category**	3	Data points
Thickness Category	0	4	inches		**Base Category**		Soil Cement

NO INTERLAYER, CTD							NO INTERLAYER, CSD					
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev		N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
46	1476	14.2	5.4	13.3	5.7		46	1785	11.6	4.6	10.5	4.7



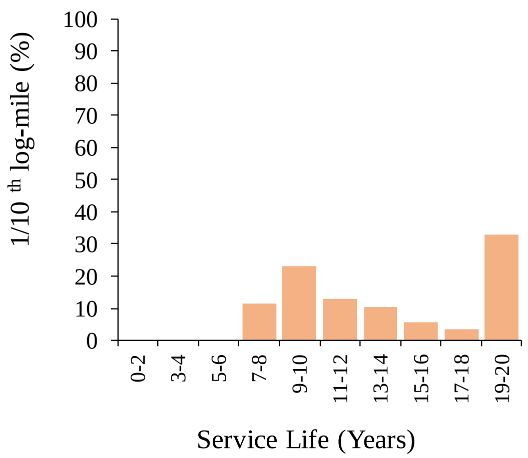


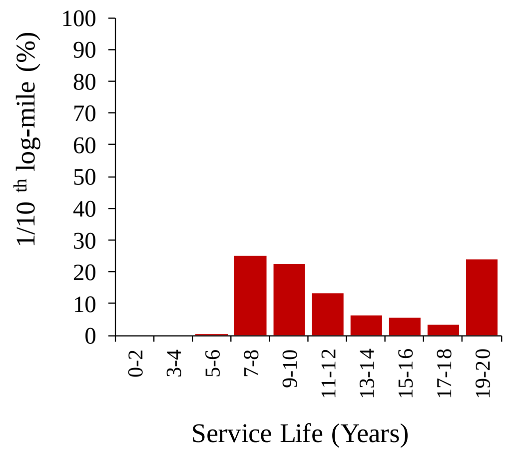
B/C (SL) =	95.6	Yrs / Dollar		B/C (SL) =	60.3	Yrs / Dollar
B/C (NBA) =	89.3	Ft-yr/ft/Dollar		B/C (NBA) =	54.5	Ft-yr/ft/Dollar
Category:	Gain SL by CTD Base		=	2.6	Yrs	Category:
x13	Gain NBA by CTD Base		=	2.8	Ft-yr/ft	x5

Figure 150: TC comparison, CTD vs CSD base (Cat. x13 vs x5)

TRANSVERSE CRACKING COMPARISON, No Int CTD vs No Int CSD Bases							
ESAL Category	30001	2E6	ESAL		**Data Category**	3	Data points
Thickness Category	0	4	inches		**Base Category**		Soil Cement

NO INTERLAYER, CTD							NO INTERLAYER, CSD					
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev		N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
6	209	14.0	4.7	13.0	5.0		17	773	12.6	4.8	11.5	5.0





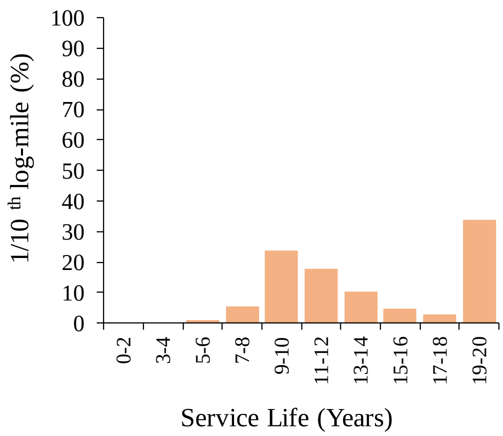
B/C (SL) =	98.4	Yrs / Dollar		B/C (SL) =	69.9	Yrs / Dollar
B/C (NBA) =	91.1	Ft-yr/ft/Dollar		B/C (NBA) =	64.0	Ft-yr/ft/Dollar
Category:	Gain SL by CTD Base		=	1.4	Yrs	Category:
x14	Gain NBA by CTD Base		=	1.5	Ft-yr/ft	x6

Figure 151: TC comparison, CTD vs CSD base (Cat. x14 vs x6)

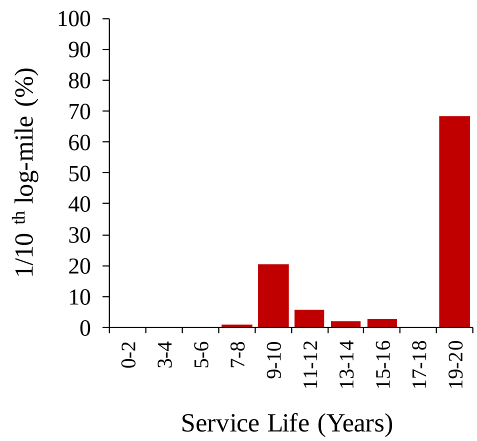
Figure 151 illustrates the CTD bases evaluation for transverse cracking with respect to CSD bases for higher ESAL and less thickness category. CTD bases has 1.4 years of GainSL 1.5 Ft-yr/ft GainNBA in this case, which means, CTD bases work even in higher ESAL category. The histogram of the two bases are similar in nature with slightly better lives for CTD. Figure 152 shows the CTD bases evaluation for higher ESAL and more thickness category (x16 vs x8). Even though CTD has negative GainSL for this category, these results are not conclusive because of lack of data on both sides.

TRANSVERSE CRACKING COMPARISON, No Int CTD vs No Int CSD Bases							
ESAL Category	30001	2E6	ESAL		**Data Category**	3	Data points
Thickness Category	4.1	10	inches		**Base Category**		Soil Cement

NO INTERLAYER, CTD					
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
3	106	14.1	4.7	13.1	5.0



NO INTERLAYER, CSD					
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
2	108	17.0	4.5	15.9	4.6



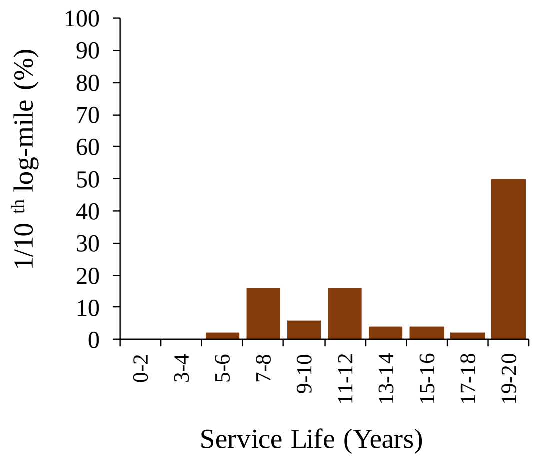
B/C (SL) =	100.5	Yrs / Dollar		B/C (SL) =	122.1	Yrs / Dollar
B/C (NBA) =	93.4	Ft-yr/ft/Dollar		B/C (NBA) =	114.3	Ft-yr/ft/Dollar
Category:	Gain SL by CTD Base		=	-2.8 Yrs	Category:	
x16	Gain NBA by CTD Base		=	-2.7 Ft-yr/ft	x8	

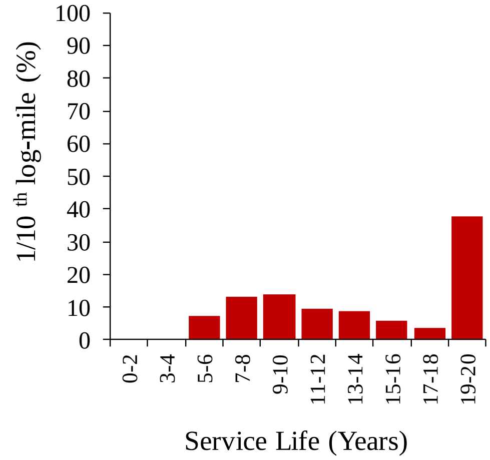
Figure 152: TC comparison, CTD vs CSD base (Cat. x16 vs x8)

Stone Interlayer Evaluation. There are two comparison categories for stone interlayer performance evaluation for any distress type: Category x17 vs x19 and Category x18 vs x20. The first one evaluates stone interlayer for CTD bases, the second for CSD base evaluation. Figure 153 evaluates stone interlayer for CTD bases for transverse cracking as it compares stone interlayer over CTD sections with no interlayer over CTD sections. Unfortunately, there are only two projects available for stone interlayer for CTD pavements. Hence it should be remembered that the results of Figure 153 are not conclusive but instead preliminary. From Figure 153, it is clear that stone interlayer over CTD has 1.2 years of GainSL and 1.3 Ft-yr/ft of GainNBA with respect to no interlayer CTD pavements. For B/C ratio comparison, stone interlayer over CTD is not effective, as the cost of stone interlayer is much higher than its service life gain.

TRANSVERSE CRACKING COMPARISON, CTD Bases, Stone vs No Interlayer							
ESAL Category	0	150000	ESAL		**Data Category**	3	Data points
Thickness Category	0	5	inches		**Base Category**	CTD	Soil Cement

STONE INTERLAYER, CTD							NO INTERLAYER, CTD					
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev		N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
2	50	15.3	5.1	14.4	5.5		55	1799	14.1	5.3	13.1	5.6





B/C (SL) =	70.8	Yrs / Dollar		B/C (SL) =	95.0	Yrs / Dollar
B/C (NBA) =	66.8	Ft-yr/ft/Dollar		B/C (NBA) =	88.6	Ft-yr/ft/Dollar
Category:	Gain SL by Stone Interlayer		=	1.2 Yrs		Category:
x17	Gain NBA by Stone Interlayer		=	1.3 Ft-yr/ft		x19

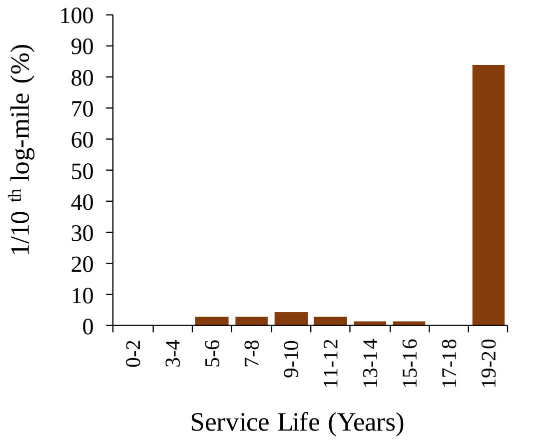
Figure 153: TC comparison for stone interlayer, CTD base (Cat. x17 vs x19)

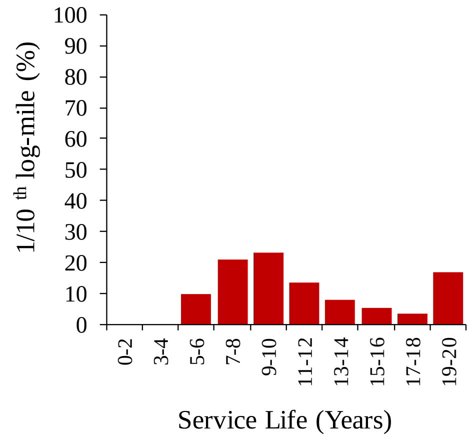
Figure 154 illustrates the transverse cracking comparison for Category x18 vs x20, which evaluates stone interlayer over CSD bases. In this case, stone interlayer shows surprisingly better results. From the histogram at the left, it is seen that almost no sections for stone interlayer had any transverse crack developed, hence about 90% sections had 20 years of service life whereas no interlayer over CSD had only about 18% with 20 years of service life. The GainSL and GainNBA values for stone interlayer over CSD bases are 6.7 years and 6.9 Ft-yr/ft, respectively. As stone interlayer over CSD provides significant GainSL and GainNBA values, it appeared to be very cost effective at the end despite the higher cost of stone interlayer. The B/C ratios for stone interlayer over CSD are 91.5 Yrs/Dollar and 87.3 Ft-yr/ft/Dollar whereas only CSD bases without interlayer had 60.3 Yrs/Dollar and 54.5 Ft-yr/ft/Dollar of B/C ratios, respectively. It's worth mentioning here that stone interlayer over CSD has only three projects with 6.8 miles of roadway, and so these results should be regarded as preliminary rather than decisive.

TRANSVERSE CRACKING COMPARISON, CSD Bases, Stone vs No Interlayer

ESAL Category	0	30000	ESAL		**Data Category**	3	Data points
Thickness Category	0	5	inches		**Base Category**	CSD	Soil Cement

STONE INTERLAYER, CSD							NO INTERLAYER, CSD					
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev		N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
3	68	18.3	4.1	17.5	4.2		46	1785	11.6	4.6	10.5	4.7





B/C (SL) =	91.5	Yrs / Dollar		B/C (SL) =	60.3	Yrs / Dollar
B/C (NBA) =	87.3	Ft-yr/ft/Dollar		B/C (NBA) =	54.5	Ft-yr/ft/Dollar
Category:	Gain SL by Stone Interlayer		=	6.7	Yrs	Category:
x18	Gain NBA by Stone Interlayer		=	6.9	Ft-yr/ft	x20

Figure 154: TC comparison for stone interlayer, CSD base (Cat. x18 vs x20)

Transverse Cracking Comparison (6 data points)

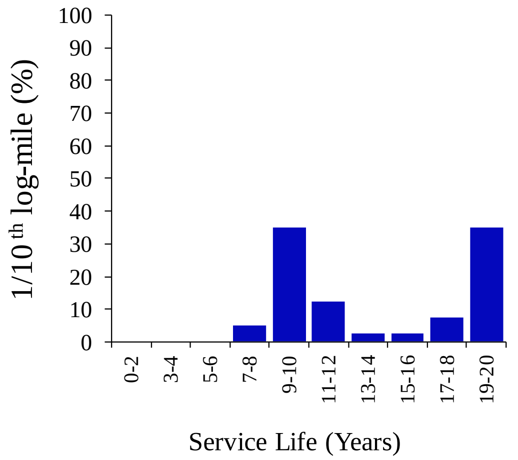
AST Interlayer Evaluation (Over CSD). Figure 155 and Figure 156 illustrate the transverse cracking comparison for Category x1' vs x5' and Category x4' vs x8' for 6 data points, respectively. For the lower ESAL and less thickness Category x1' vs x5' (as shown in Figure 155), AST interlayer over CSD provides a similar service life as no interlayer over CSD. The GainSL and GainNBA values for AST interlayer are only 0.2 years and 1.1 Ft-yr/ft. It should be remembered also that only three projects were available for AST interlayer over CSD for this comparison, hence this result is not conclusive.

TRANSVERSE CRACKING COMPARISON, CSD Bases, AST vs NO Interlayer

ESAL Category	0	30000	ESAL		**Data Category**	6	Data points
Thickness Category	0	4	inches		**Base Category**	CSD	Soil Cement

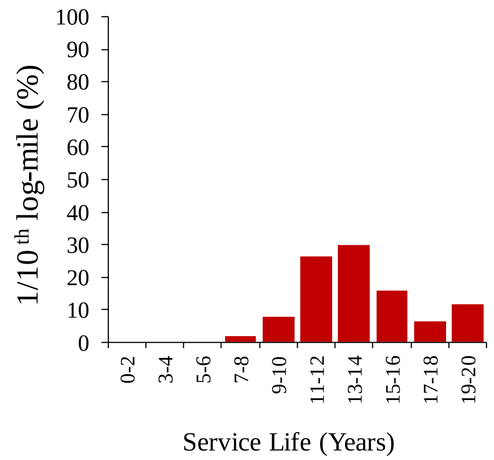
AST INTERLAYER

N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
3	40	14.0	5.0	13.1	5.5



NO INTERLAYER

N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
46	1789	13.9	3.0	12.1	3.1

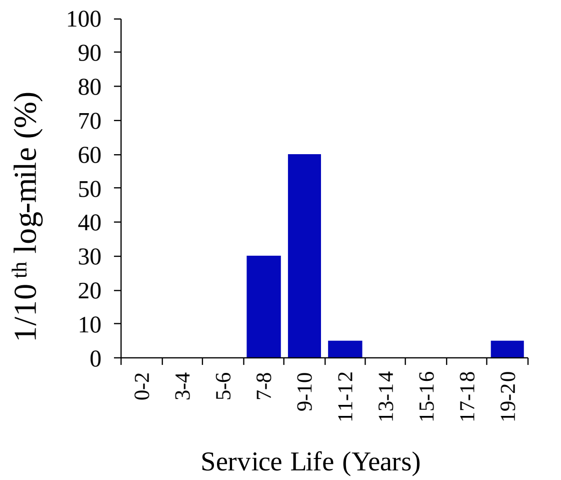


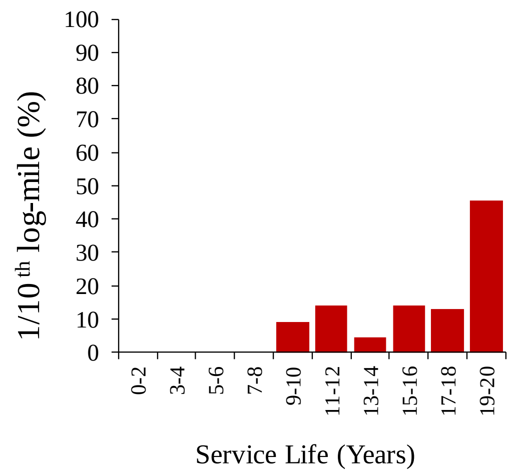
B/C (SL) =	73.5	Yrs / Dollar		B/C (SL) =	89.3	Yrs / Dollar
B/C (NBA) =	68.8	Ft-yr/ft/Dollar		B/C (NBA) =	77.8	Ft-yr/ft/Dollar
Category:	Gain SL by AST Interlayer		=	0.2	Yrs	Category:
x1'	Gain NBA by AST Interlayer		=	1.1	Ft-yr/ft	x5'

Figure 155: TC comparison for AST vs no interlayer, CSD base (Cat. x1' vs x5')

TRANSVERSE CRACKING COMPARISON, CSD Bases, AST vs NO Interlayer							
ESAL Category	30001	2E6	ESAL		**Data Category**	6	Data points
Thickness Category	4.1	10	inches		**Base Category**	CSD	Soil Cement

AST INTERLAYER							**NO INTERLAYER**					
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev		N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
2	20	9.4	2.6	8.3	2.8		2	108	16.5	3.7	14.9	3.7





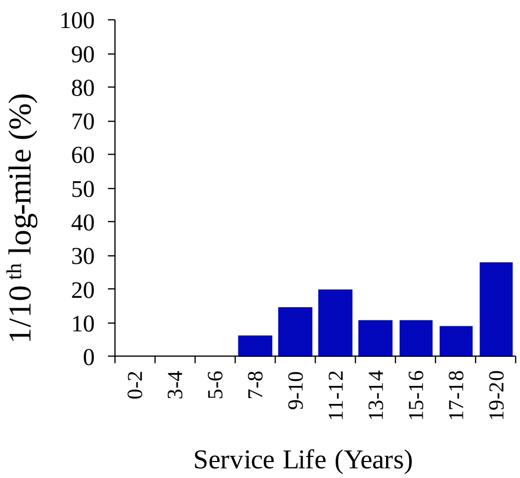
B/C (SL) =	38.4	Yrs / Dollar		B/C (SL) =	119.5	Yrs / Dollar
B/C (NBA) =	33.8	Ft-yr/ft/Dollar		B/C (NBA) =	108.2	Ft-yr/ft/Dollar
Category:	Gain SL by AST Interlayer		=	-7.1	Yrs	Category:
x4'	Gain NBA by AST Interlayer		=	-6.6	Ft-yr/ft	x8'

Figure 156: TC comparison for AST vs no interlayer, CSD base (Cat. x4' vs x8')

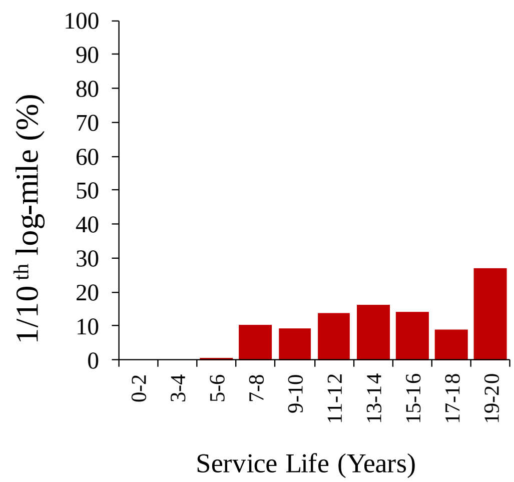
AST Interlayer Evaluation (Over CTD*).* Figure 157 compares AST interlayer over CTD with no interlayer over CTD sections for transverse cracking. Here, both cases had similar AvgSL and AvgNBA, hence the GainSL and GainNBA became zero in this case. AST interlayer did not increase service life for CTD pavements, hence the B/C ratios for AST interlayer is lower with respect to control in this case.

TRANSVERSE CRACKING COMPARISON, CTD Bases, AST vs NO Interlayer							
ESAL Category	0	30000	ESAL		**Data Category**	6	Data points
Thickness Category	0	4	inches		**Base Category**	CTD	Soil Cement

AST INTERLAYER					
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
6	347	14.5	4.2	13.2	4.3



NO INTERLAYER					
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
46	1483	14.6	4.3	13.2	4.4



B/C (SL) =	90.4	Yrs / Dollar		B/C (SL) =	106.6	Yrs / Dollar
B/C (NBA) =	82.0	Ft-yr/ft/Dollar		B/C (NBA) =	96.3	Ft-yr/ft/Dollar
Category:	Gain SL by AST Interlayer	=	0.0	Yrs	Category:	
x9'	Gain NBA by AST Interlayer	=	0.0	Ft-yr/ft	x13'	

Figure 157: TC comparison for AST vs no interlayer, CTD base (Cat. x9' vs x13')

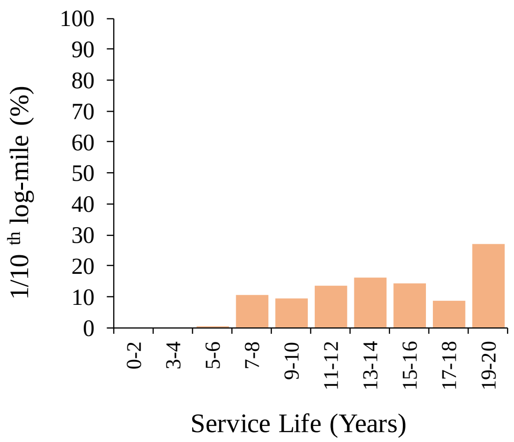
CTD Bases Evaluation. There are three categories present for CTD base evaluation for different ESAL and thickness category for 6 data points. All three comparison categories are shown from Figure 158 to Figure 160. Figure 158 has sufficient data and Figure 159 has acceptable data at both sides for any conclusion. From these two figures it is evident that the CTD base itself is a cost-effective option for reflective crack mitigation and that it works on higher ESAL also. CTD bases had more B/C ratios and positive GainSL and GainNBA for both Figure 158 and Figure 159.

Figure 160 shows comparison Category x16' vs x8', but this comparison does not provide conclusive decision due to lack of sufficient data points.

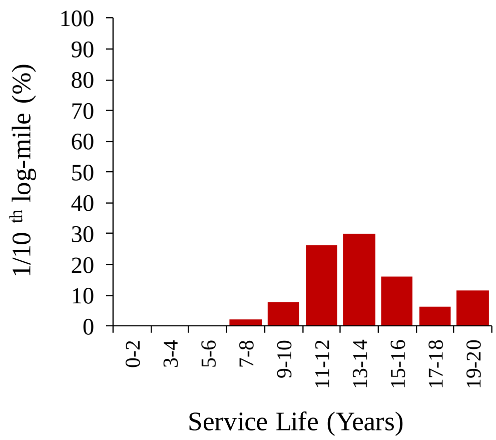
TRANSVERSE CRACKING COMPARISON, No Int CTD vs No Int CSD Bases

ESAL Category	0	30000	ESAL		**Data Category**	6	Data points
Thickness Category	0	4	inches		**Base Category**		Soil Cement

NO INTERLAYER, CTD					
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
46	1483	14.6	4.3	13.2	4.4



NO INTERLAYER, CSD					
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
46	1789	13.9	3.0	12.1	3.1



B/C (SL) =	106.6	Yrs / Dollar	B/C (SL) =	89.3	Yrs / Dollar
B/C (NBA) =	96.3	Ft-yr/ft/Dollar	B/C (NBA) =	77.8	Ft-yr/ft/Dollar

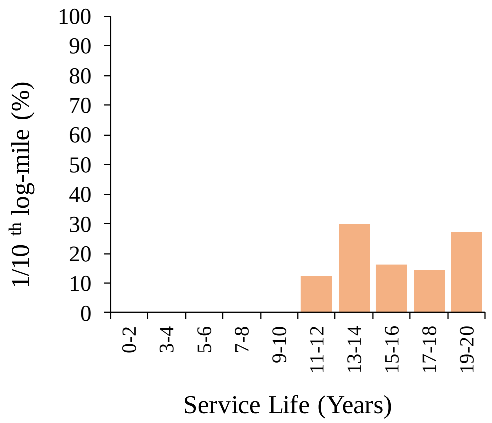
Category:	Gain SL by AST Interlayer	=	0.7	Yrs	Category:
x13'	Gain NBA by AST Interlayer	=	1.1	Ft-yr/ft	x5'

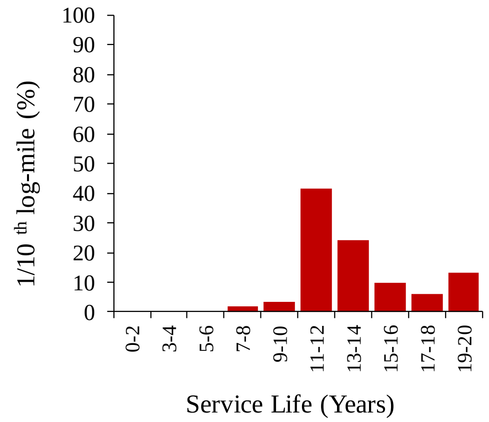
Figure 158: TC comparison, CTD vs CSD base (Cat. x13' vs x5')

TRANSVERSE CRACKING COMPARISON, No Int CTD vs No Int CSD Bases

ESAL Category	30001	2E6	ESAL		**Data Category**	6	Data points
Thickness Category	0	4	inches		**Base Category**		Soil Cement

NO INTERLAYER, CTD							**NO INTERLAYER, CSD**					
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev		N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
6	209	15.9	2.9	14.3	3.3		17	773	13.7	3.0	12.1	3.2

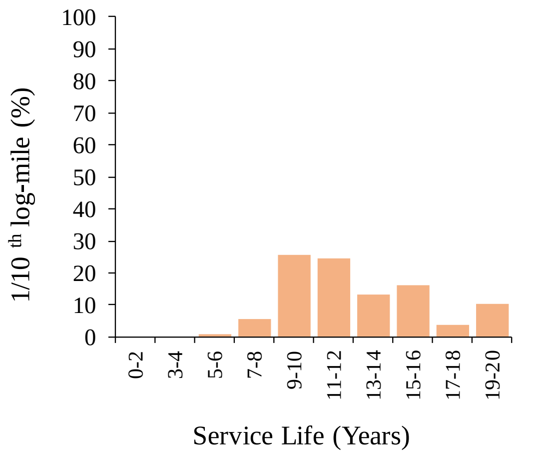


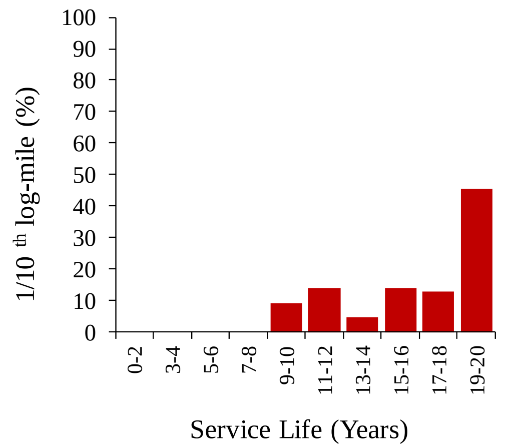


B/C (SL) =	131.5	Yrs / Dollar		B/C (SL) =	87.4	Yrs / Dollar
B/C (NBA) =	118.2	Ft-yr/ft/Dollar		B/C (NBA) =	77.0	Ft-yr/ft/Dollar
Category:	Gain SL by AST Interlayer		=	2.2	Yrs	Category:
x14'	Gain NBA by AST Interlayer		=	2.2	Ft-yr/ft	x6'

Figure 159: TC comparison, CTD vs CSD base (Cat. x14' vs x6')

TRANSVERSE CRACKING COMPARISON, No Int CTD vs No Int CSD Bases												
ESAL Category	30001	2E6	ESAL				**Data Category**	6	Data points			
Thickness Category	4.1	10	inches				**Base Category**		Soil Cement			
NO INTERLAYER, CTD							**NO INTERLAYER, CSD**					
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev		N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
3	106	12.7	3.6	11.3	3.5		2	108	16.5	3.7	14.9	3.7





B/C (SL) =	85.2	Yrs / Dollar		B/C (SL) =	119.5	Yrs / Dollar
B/C (NBA) =	76.3	Ft-yr/ft/Dollar		B/C (NBA) =	108.2	Ft-yr/ft/Dollar
Category:	Gain SL by AST Interlayer		=	-3.8	Yrs	Category:
x16'	Gain NBA by AST Interlayer		=	-3.6	Ft-yr/ft	x8'

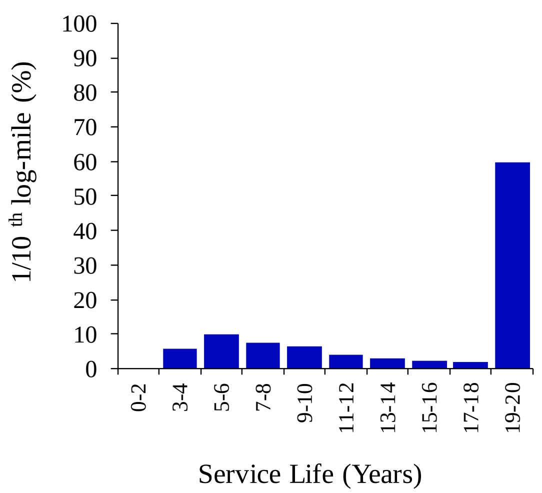
Figure 160: TC comparison, CTD vs CSD base (Cat. x16' vs x8')

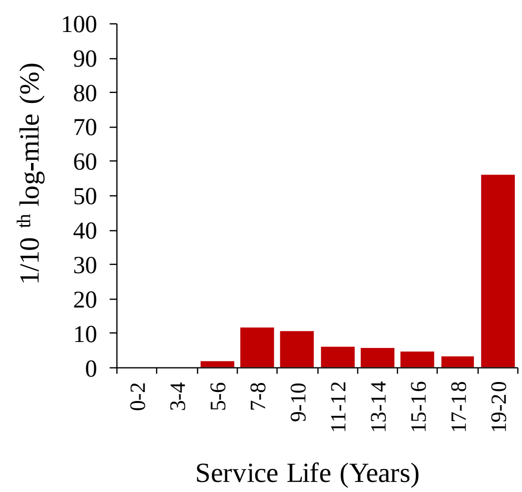
Longitudinal Cracking Comparison (3 data points)

AST Interlayer Evaluation (Over CSD). Figure 161 to Figure 163 illustrates longitudinal cracking comparison for AST interlayer over CSD bases for the above-mentioned categories. Figure 161 shows the comparison Category x1 vs x5 for longitudinal cracking. AST interlayer sections behave similarly to the no interlayer sections in this case. As AST interlayer has a slightly negative GainSL and GainNBA, becoming less cost-effective in this case which is confirmed by the B/C ratios. Figure 162 and Figure 163 had similar results with negative GainSL and GainNBA. The comparison shown in Figure 162 and 163 is not conclusive as one side had very few (N(P)=2) projects.

LONGITUDINAL CRACKING COMPARISON, CSD Bases, AST vs NO Interlayer							
ESAL Category	0	30000	ESAL		**Data Category**	3	Data points
Thickness Category	0	4	inches		**Base Category**	CSD	Soil Cement

AST INTERLAYER							NO INTERLAYER					
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev		N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
26	695	15.3	6.2	14.3	6.1		45	1718	16.0	5.0	15.2	5.4





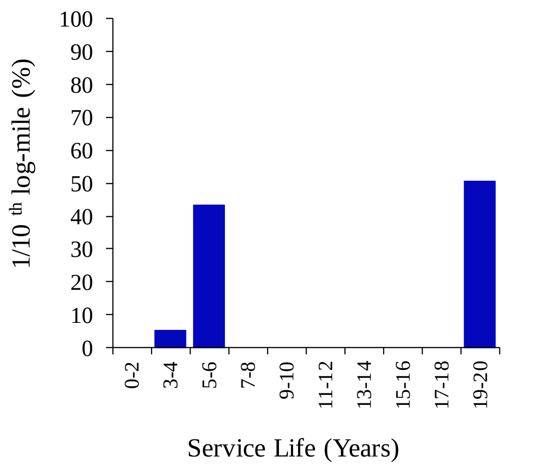
B/C (SL) =	75.0	Yrs / Dollar		B/C (SL) =	106.2	Yrs / Dollar
B/C (NBA) =	69.8	Ft-yr/ft/Dollar		B/C (NBA) =	101.0	Ft-yr/ft/Dollar
Category:	Gain SL by AST Interlayer		=	-0.6	Yrs	Category:
x1	Gain NBA by AST Interlayer		=	-0.9	Ft-yr/ft	x5

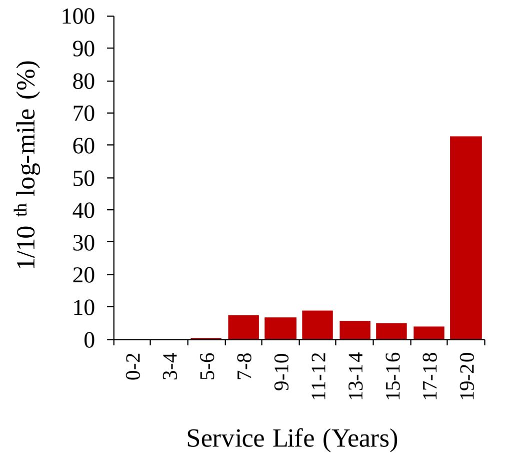
Figure 161: LC comparison for AST vs no interlayer, CSD base (Cat. x1 vs x5)

LONGITUDINAL CRACKING COMPARISON, CSD Bases, AST vs NO Interlayer

ESAL Category	30001	2E6	ESAL		**Data Category**	3	Data points
Thickness Category	0	4	inches		**Base Category**	CSD	Soil Cement

AST INTERLAYER						NO INTERLAYER					
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
2	55	12.6	7.6	11.2	6.9	17	768	16.9	4.4	16.2	4.9



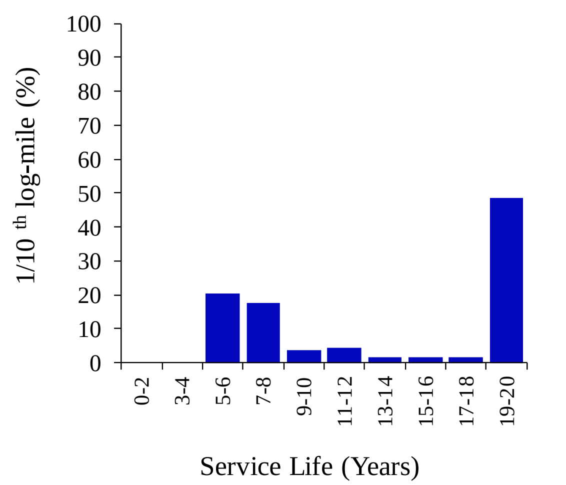


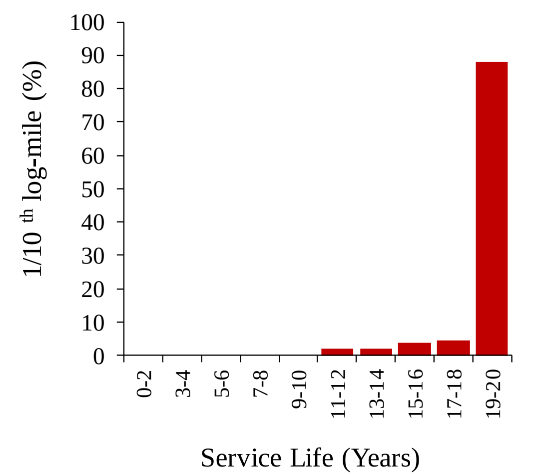
B/C (SL) =	46.0	Yrs / Dollar		B/C (SL) =	121.1	Yrs / Dollar
B/C (NBA) =	40.8	Ft-yr/ft/Dollar		B/C (NBA) =	115.7	Ft-yr/ft/Dollar
Category:	Gain SL by AST Interlayer	=	-4.3	Yrs	Category:	
x2	Gain NBA by AST Interlayer	=	-5.0	Ft-yr/ft	x6	

Figure 162: LC comparison for AST vs no interlayer, CSD base (Cat. x2 vs x6)

LONGITUDINAL CRACKING COMPARISON, CSD Bases, AST vs NO Interlayer							
ESAL Category	30001	2E6	ESAL		**Data Category**	3	Data points
Thickness Category	4.1	10	inches		**Base Category**	CSD	Soil Cement

AST INTERLAYER						NO INTERLAYER					
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
8	113	13.8	6.4	12.6	6.2	2	108	19.4	1.6	18.7	2.2





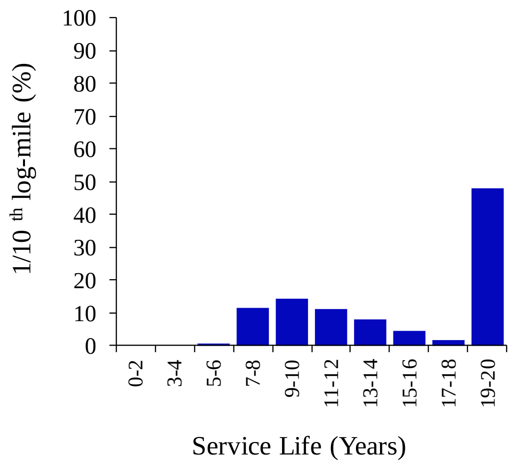
B/C (SL) =	63.2	Yrs / Dollar		B/C (SL) =	163.8	Yrs / Dollar
B/C (NBA) =	57.7	Ft-yr/ft/Dollar		B/C (NBA) =	157.5	Ft-yr/ft/Dollar
Category:	Gain SL by AST Interlayer		=	-5.6 Yrs	Category:	
x4	Gain NBA by AST Interlayer		=	-6.1 Ft-yr/ft	x8	

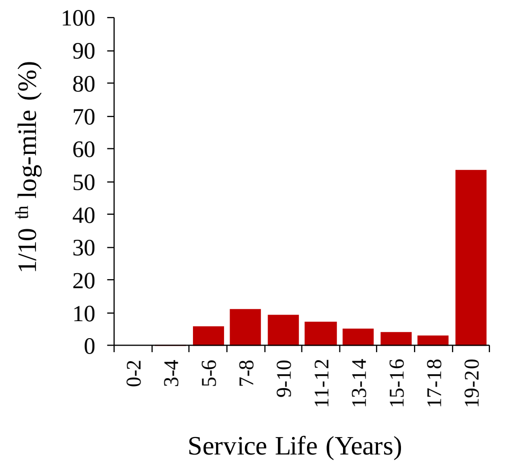
Figure 163: LC comparison for AST vs no interlayer, CSD base (Cat. x4 vs x8)

AST Interlayer Evaluation (Over CTD). Figure 164 shows the only comparison category for AST interlayer over CTD base performance: Category x9 vs x13. Here, from Figure 164, it is clear that AST interlayer over CTD behaves somewhat similarly to no interlayer over CTD bases. Both histograms are similar in nature and GainSL and GainNBA values are slightly negative. Hence, AST interlayer did not extend pavement service life in this case.

LONGITUDINAL CRACKING COMPARISON, CTD Bases, AST vs NO Interlayer							
ESAL Category	0	30000	ESAL		**Data Category**	3	Data points
Thickness Category	0	4	inches		**Base Category**	CTD	Soil Cement

AST INTERLAYER							NO INTERLAYER					
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev		N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
6	344	15.3	5.0	14.4	5.4		46	1463	15.5	5.4	14.7	5.7





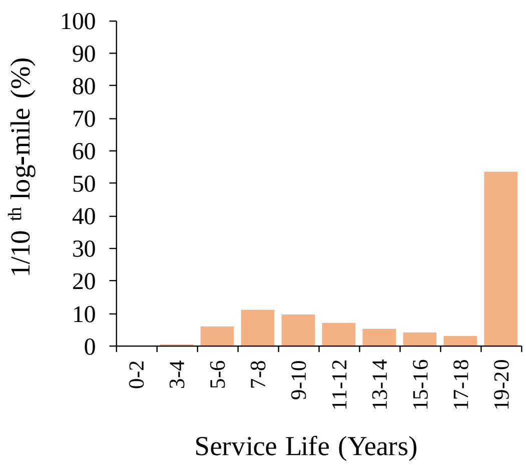
B/C (SL) =	95.3	Yrs / Dollar		B/C (SL) =	112.1	Yrs / Dollar
B/C (NBA) =	90.0	Ft-yr/ft/Dollar		B/C (NBA) =	106.6	Ft-yr/ft/Dollar
Category:	Gain SL by AST Interlayer		=	-0.3 Yrs	Category:	
x9	Gain NBA by AST Interlayer		=	-0.3 Ft-yr/ft	x13	

Figure 164: LC comparison for AST vs no interlayer, CTD base (Cat. x9 vs x13)

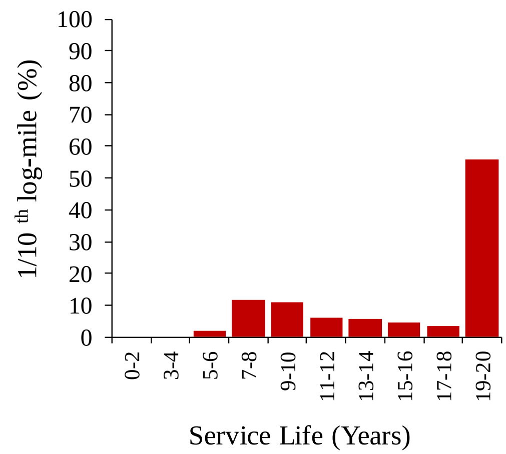
CTD Bases Evaluation. For longitudinal cracking, the three comparison categories are shown from Figure 165 to Figure 167. Figure 165 has sufficient data and Figure 166 has acceptable data from both sides for any conclusion. From these two figures, it is evident that CTD base behaves analogous to CSD bases for both ESAL categories. The comparison Category x16' vs x8' is shown in Figure 167, but this comparison does not provide a conclusive decision as sufficient data points are not present on both sides.

LONGITUDINAL CRACKING COMPARISON, No Int CTD vs No Int CSD Bases							
ESAL Category	0	30000	ESAL		**Data Category**	3	Data points
Thickness Category	0	4	inches		**Base Category**		Soil Cement

NO INTERLAYER, CTD					
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
46	1463	15.5	5.4	14.7	5.7



NO INTERLAYER, CSD					
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
45	1718	16.0	5.0	15.2	5.4



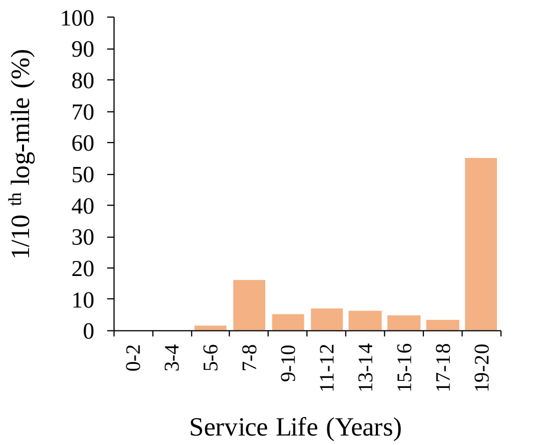
B/C (SL) =	112.1	Yrs / Dollar		B/C (SL) =	106.2	Yrs / Dollar
B/C (NBA) =	106.6	Ft-yr/ft/Dollar		B/C (NBA) =	101.0	Ft-yr/ft/Dollar
Category:	Gain SL by CTD Base		=	-0.5	Yrs	Category:
x13	Gain NBA by CTD Base		=	-0.4	Ft-yr/ft	x5

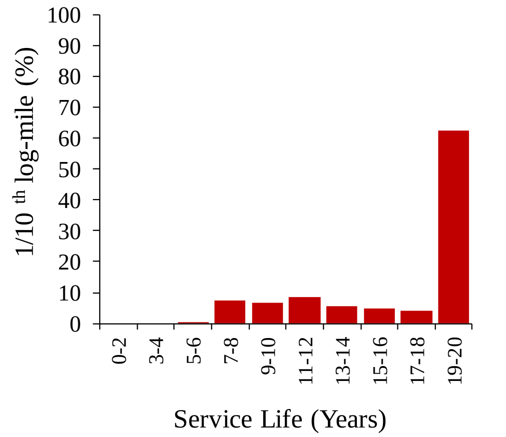
Figure 165: LC comparison, CTD vs CSD base (Cat. x13 vs x5)

LONGITUDINAL CRACKING COMPARISON, No Int CTD vs No Int CSD Bases

ESAL Category	30001	2E6	ESAL		**Data Category**	3	Data points
Thickness Category	0	4	inches		**Base Category**		Soil Cement

NO INTERLAYER, CTD							NO INTERLAYER, CSD					
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev		N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
6	208	15.8	5.2	15.0	5.5		17	768	16.9	4.4	16.2	4.9



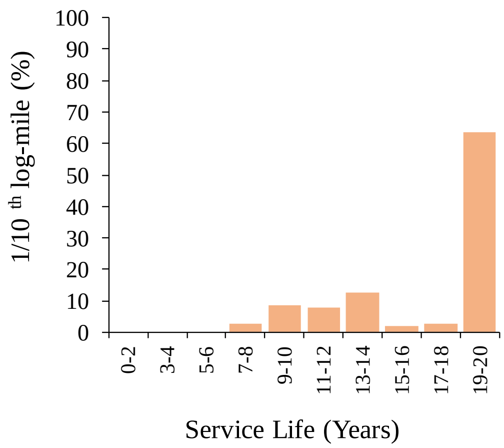


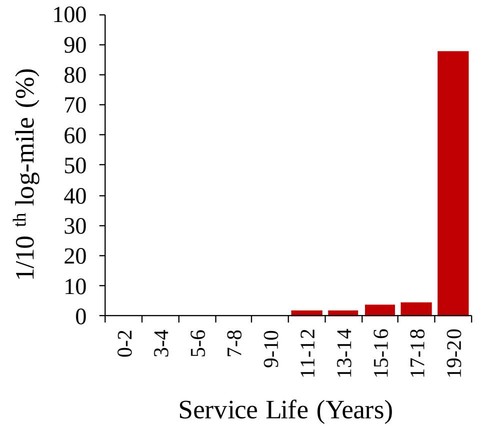
B/C (SL) =	118.6	Yrs / Dollar		B/C (SL) =	121.1	Yrs / Dollar
B/C (NBA) =	112.2	Ft-yr/ft/Dollar		B/C (NBA) =	115.7	Ft-yr/ft/Dollar
Category:	Gain SL by CTD Base		=	-1.1 Yrs		Category:
x14	Gain NBA by CTD Base		=	-1.2 Ft-yr/ft		x6

Figure 166: LC comparison, CTD vs CSD base (Cat. x14 vs x6)

LONGITUDINAL CRACKING COMPARISON, No Int CTD vs No Int CSD Bases							
ESAL Category	30001	2E6	ESAL		**Data Category**	3	Data points
Thickness Category	4.1	10	inches		**Base Category**		Soil Cement

NO INTERLAYER, CTD							**NO INTERLAYER, CSD**					
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev		N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
3	104	17.1	4.1	16.3	4.5		2	108	19.4	1.6	18.7	2.2





B/C (SL) =	144.3	Yrs / Dollar		B/C (SL) =	163.8	Yrs / Dollar
B/C (NBA) =	137.0	Ft-yr/ft/Dollar		B/C (NBA) =	157.5	Ft-yr/ft/Dollar
Category:	Gain SL by CTD Base		=	-2.3 Yrs	Category:	
x16	Gain NBA by CTD Base		=	-2.4 Ft-yr/ft	x8	

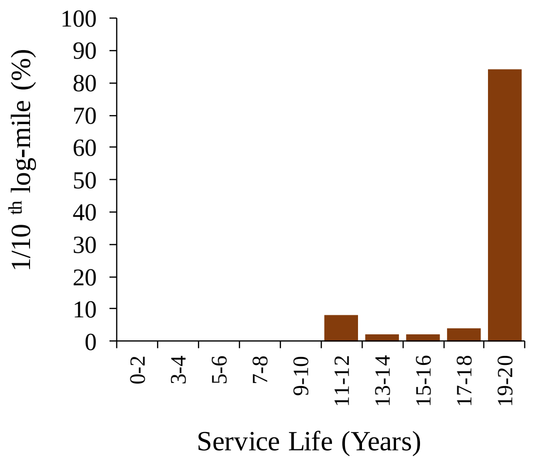
Figure 167: LC comparison, CTD vs CSD base (Cat. x16 vs x8)

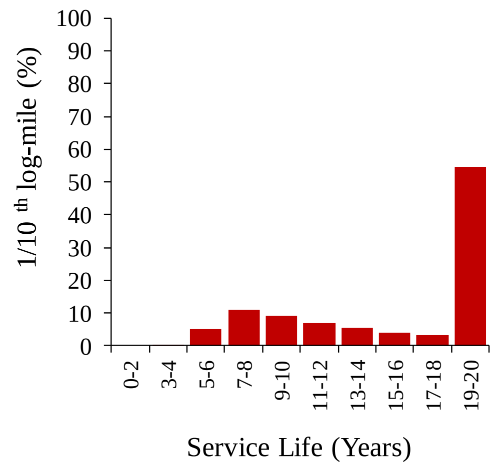
Stone Interlayer Evaluation. Figure 168 and Figure 169 evaluate stone interlayer for CTD and CSD bases, respectively. For both cases, stone interlayer provides positive GainSL and GainNBA values for longitudinal cracking. From the histogram comparison, it is evident that stone interlayer sections had reduced longitudinal cracking with respect to no interlayer sections. However, due to higher cost associated with stone interlayer installation, it became slightly less cost-effective for longitudinal cracking.

LONGITUDINAL CRACKING COMPARISON, CTD Bases, Stone vs No Interlayer

ESAL Category	0	150000	ESAL		**Data Category**	3	Data points
Thickness Category	0	5	inches		**Base Category**	CTD	Soil Cement

STONE INTERLAYER, CTD						NO INTERLAYER, CTD					
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
2	50	18.9	2.7	18.4	3.2	55	1783	15.7	5.3	14.9	5.6





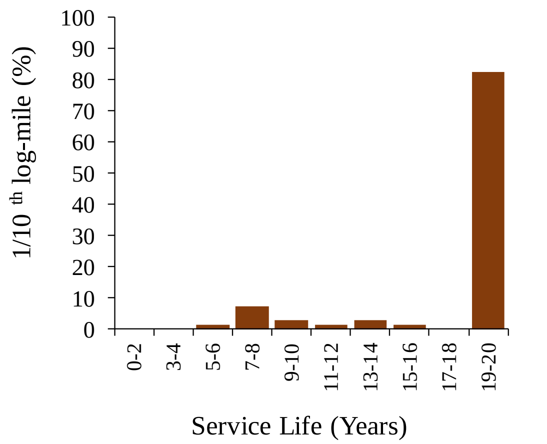
B/C (SL) =	111.5	Yrs / Dollar		B/C (SL) =	114.9	Yrs / Dollar
B/C (NBA) =	108.7	Ft-yr/ft/Dollar		B/C (NBA) =	109.3	Ft-yr/ft/Dollar
Category:	Gain SL by Stone Interlayer		=	3.2	Yrs	Category:
x17	Gain NBA by Stone Interlayer		=	3.5	Ft-yr/ft	x19

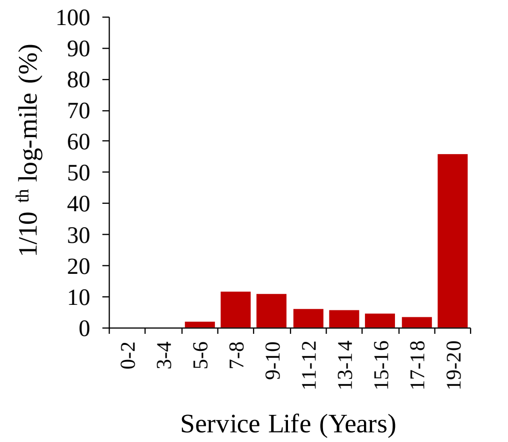
Figure 168: LC comparison for stone vs no interlayer, CTD base (Cat. x17 vs x19)

LONGITUDINAL CRACKING COMPARISON, CSD Bases, Stone vs No Interlayer

ESAL Category	0	30000	ESAL		**Data Category**	3	Data points
Thickness Category	0	5	inches		**Base Category**	CSD	Soil Cement

STONE INTERLAYER, CSD							**NO INTERLAYER, CSD**					
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev		N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
3	68	18.2	4.2	17.3	4.3		45	1718	16.0	5.0	15.2	5.4





B/C (SL) =	90.0	Yrs / Dollar		B/C (SL) =	106.2	Yrs / Dollar
B/C (NBA) =	86.0	Ft-yr/ft/Dollar		B/C (NBA) =	101.0	Ft-yr/ft/Dollar
Category:	Gain SL by Stone Interlayer		=	2.2 Yrs		Category:
x18	Gain NBA by Stone Interlayer		=	2.1 Ft-yr/ft		x20

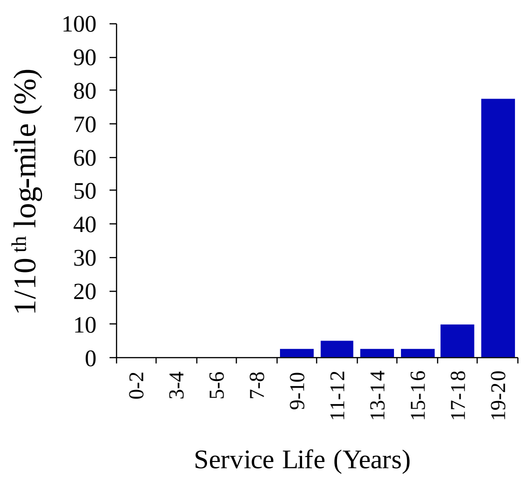
Figure 169: LC comparison for stone vs no interlayer, CSD base (Cat. x18 vs x20)

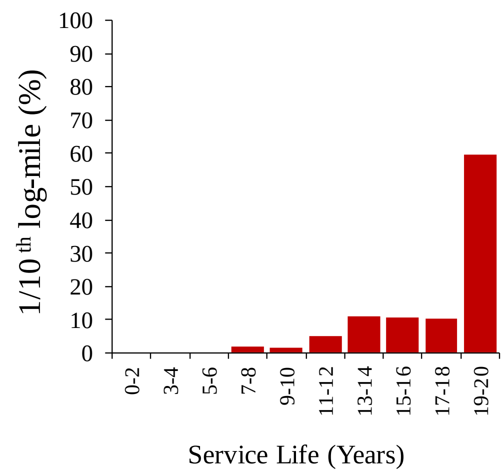
Longitudinal Cracking Comparison (6 data points)

AST Interlayer Evaluation (Over CSD). Figure 170 and Figure 171 illustrate the longitudinal cracking comparison for Category x1' vs x5' and Category x4' vs x8' for 6 data points, respectively. For the lower ESAL and less thickness Category x1' vs x5' (as shown in Figure 170), AST interlayer over CSD has positive GainSL and GainNBA values of 1.1 years and 1.7 Ft-yr/ft. There are only 3 available projects for AST interlayer over CSD for this comparison, hence this result is not conclusive.

LONGITUDINAL CRACKING COMPARISON, CSD Bases, AST vs NO Interlayer							
ESAL Category	0	30000	ESAL		**Data Category**	6	Data points
Thickness Category	0	4	inches		**Base Category**	CSD	Soil Cement

AST INTERLAYER							NO INTERLAYER					
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev		N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
3	40	18.8	2.7	18.1	3.2		45	1745	17.7	3.2	16.4	3.7



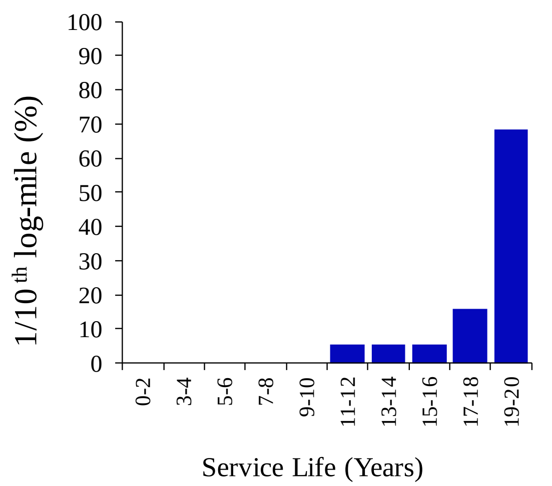


B/C (SL) =	131.4	Yrs / Dollar		B/C (SL) =	136.5	Yrs / Dollar
B/C (NBA) =	126.6	Ft-yr/ft/Dollar		B/C (NBA) =	126.7	Ft-yr/ft/Dollar
Category:	Gain SL by AST Interlayer		=	1.1 Yrs	Category:	
x1'	Gain NBA by AST Interlayer		=	1.7 Ft-yr/ft	x5'	

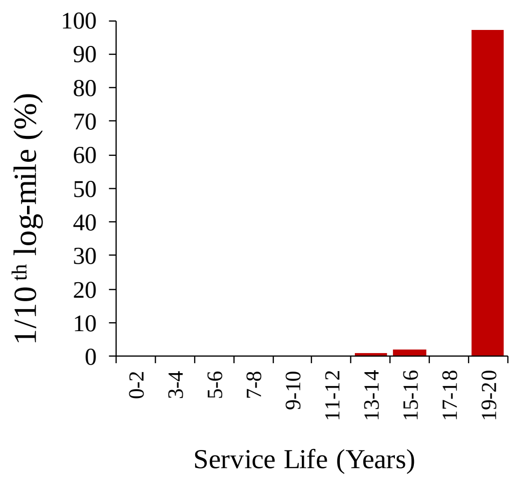
Figure 170: LC comparison for AST vs no interlayer, CSD base (Cat. x1' vs x5')

LONGITUDINAL CRACKING COMPARISON, CSD Bases, AST vs NO Interlayer							
ESAL Category	30001	2E6	ESAL		**Data Category**	6	Data points
Thickness Category	4.1	10	inches		**Base Category**	CSD	Soil Cement

AST INTERLAYER					
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
2	19	18.6	2.5	17.7	3.2



NO INTERLAYER					
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
2	107	19.8	0.9	19.5	1.3



B/C (SL) =	130.2	Yrs / Dollar		B/C (SL) =		170.3	Yrs / Dollar
B/C (NBA) =	123.8	Ft-yr/ft/Dollar		B/C (NBA) =		167.8	Ft-yr/ft/Dollar
Category:	Gain SL by AST Interlayer		=	-1.2	Yrs	Category:	
x4'	Gain NBA by AST Interlayer		=	-1.8	Ft-yr/ft	x8'	

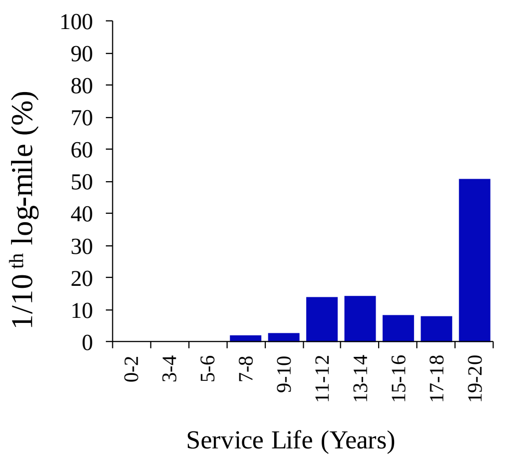
Figure 171: LC comparison for AST vs no interlayer, CSD base (Cat. x4' vs x8')

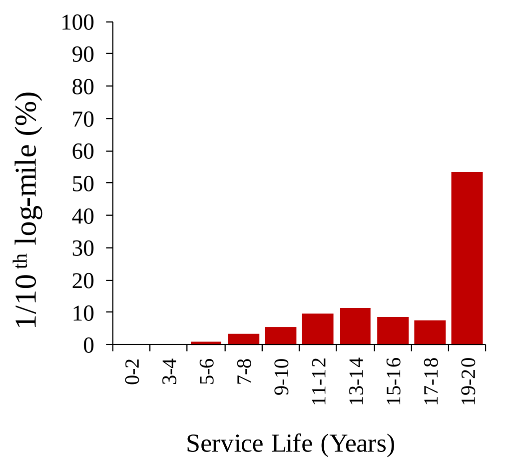
AST Interlayer Evaluation (Over CTD). Figure 172 compares AST interlayer over CTD with no interlayer over CTD sections for longitudinal cracking. Here, both cases had similar AvgSL and AvgNBA, hence the GainSL and GainNBA becomes zero in this case. It is interesting to see that this result exactly matches with the same category of transverse cracking comparison (Figure 157).

LONGITUDINAL CRACKING COMPARISON, CTD Bases, AST vs NO Interlayer

ESAL Category	0	30000	ESAL		**Data Category**	6	Data points
Thickness Category	0	4	inches		**Base Category**	CTD	Soil Cement

AST INTERLAYER						NO INTERLAYER					
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
6	344	16.8	3.7	15.7	4.2	46	1477	16.8	4.0	15.7	4.4





B/C (SL) =	119.6	Yrs / Dollar		B/C (SL) =	139.4	Yrs / Dollar
B/C (NBA) =	111.6	Ft-yr/ft/Dollar		B/C (NBA) =	130.1	Ft-yr/ft/Dollar
Category:	Gain SL by AST Interlayer		=	0.0 Yrs	Category:	
x9'	Gain NBA by AST Interlayer		=	0.0 Ft-yr/ft	x13'	

Figure 172: LC comparison for AST vs no interlayer, CTD base (Cat. x9' vs x13')

CTD Bases Evaluation. For 6 data points analyses of longitudinal cracking, the three comparison categories are shown from Figure 173 to Figure 175. As explained before, Figure 173 has sufficient data and Figure 174 has acceptable data at both sides for any conclusion. From these two figures, it is evident that CTD base behaves similar to CSD bases for both ESAL category and for longitudinal cracking. As CTD is inexpensive, at the end it remains similarly cost-effective to CSD bases.

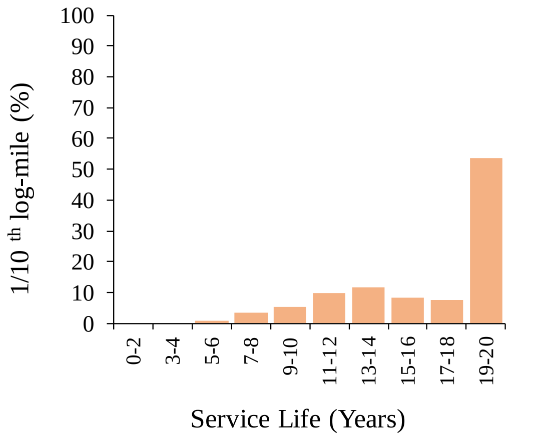
Comparison Category x16' vs x8' is shown in Figure 175, but this comparison does not provide conclusive results as sufficient data points are not present on both sides.

LONGITUDINAL CRACKING COMPARISON, No Int CTD vs No Int CSD Bases

ESAL Category	0	30000	ESAL		**Data Category**	6	Data points
Thickness Category	0	4	inches		**Base Category**		Soil Cement

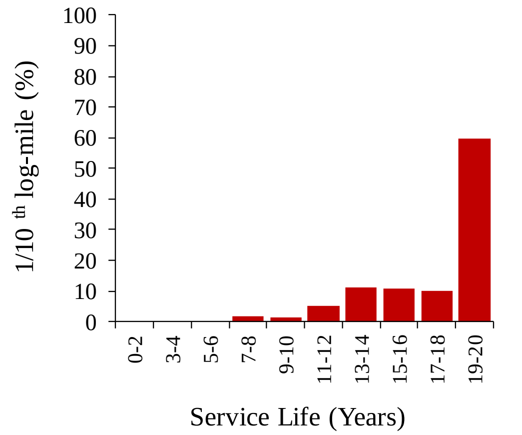
NO INTERLAYER, CTD

N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
46	1477	16.8	4.0	15.7	4.4



NO INTERLAYER, CSD

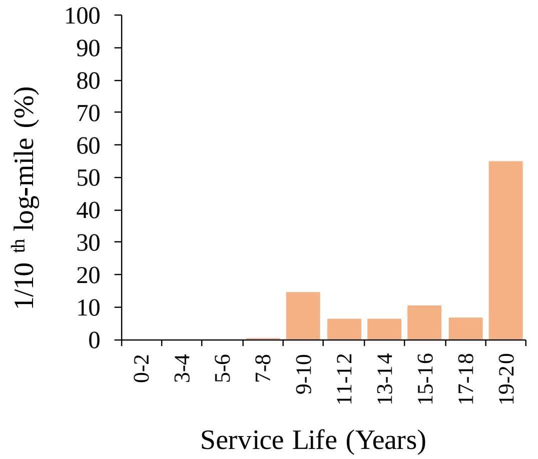
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
45	1745	17.7	3.2	16.4	3.7

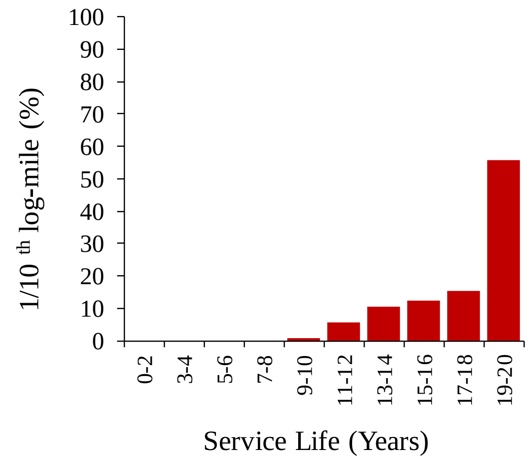


B/C (SL) =	139.4	Yrs / Dollar		B/C (SL) =	136.5	Yrs / Dollar
B/C (NBA) =	130.1	Ft-yr/ft/Dollar		B/C (NBA) =	126.7	Ft-yr/ft/Dollar
Category:	Gain SL by AST Interlayer		=	-0.9 Yrs	Category:	
x13'	Gain NBA by AST Interlayer		=	-0.8 Ft-yr/ft	x5'	

Figure 173: LC comparison, CTD vs CSD base (Cat. x13' vs x5')

LONGITUDINAL CRACKING COMPARISON, No Int CTD vs No Int CSD Bases												
ESAL Category	30001	2E6	ESAL			**Data Category**	6	Data points				
Thickness Category	0	4	inches			**Base Category**		Soil Cement				
NO INTERLAYER, CTD							**NO INTERLAYER, CSD**					
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev		N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
6	207	16.8	4.0	15.7	4.4		17	772	17.8	2.8	16.5	3.4



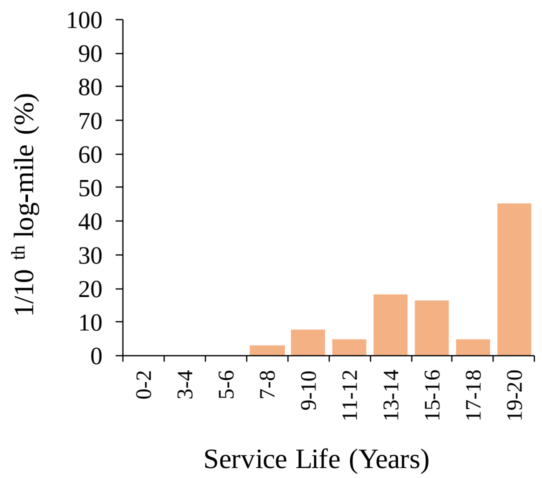


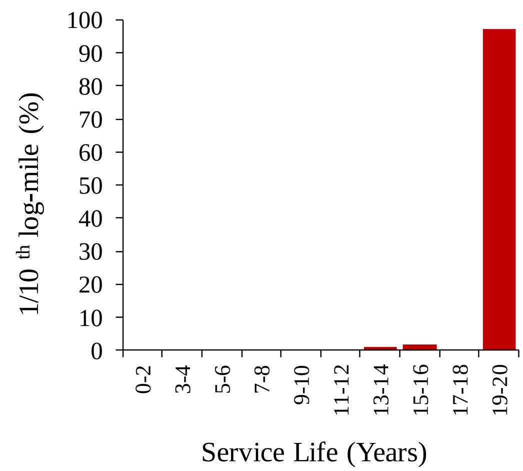
B/C (SL) =	140.2	Yrs / Dollar		B/C (SL) =	139.6	Yrs / Dollar
B/C (NBA) =	130.4	Ft-yr/ft/Dollar		B/C (NBA) =	128.9	Ft-yr/ft/Dollar
Category:	Gain SL by AST Interlayer		=	-1.0 Yrs	Category:	
x14'	Gain NBA by AST Interlayer		=	-0.8 Ft-yr/ft	x6'	

Figure 174: LC comparison, CTD vs CSD base (Cat. x14' vs x6')

LONGITUDINAL CRACKING COMPARISON, No Int CTD vs No Int CSD Bases							
ESAL Category	30001	2E6	ESAL		**Data Category**	6	Data points
Thickness Category	4.1	10	inches		**Base Category**		Soil Cement

NO INTERLAYER, CTD							NO INTERLAYER, CSD					
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev		N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
3	104	16.4	3.8	15.2	4.2		2	107	19.8	0.9	19.5	1.3





B/C (SL) =	134.8	Yrs / Dollar		B/C (SL) =	170.3	Yrs / Dollar
B/C (NBA) =	125.1	Ft-yr/ft/Dollar		B/C (NBA) =	167.8	Ft-yr/ft/Dollar
Category:	Gain SL by AST Interlayer		=	-3.4 Yrs	Category:	
x16'	Gain NBA by AST Interlayer		=	-4.3 Ft-yr/ft	x8'	

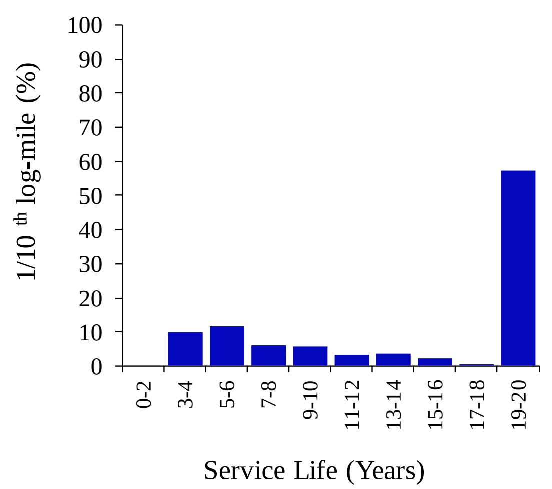
Figure 175: LC comparison, CTD vs CSD base (Cat. x16' vs x8')

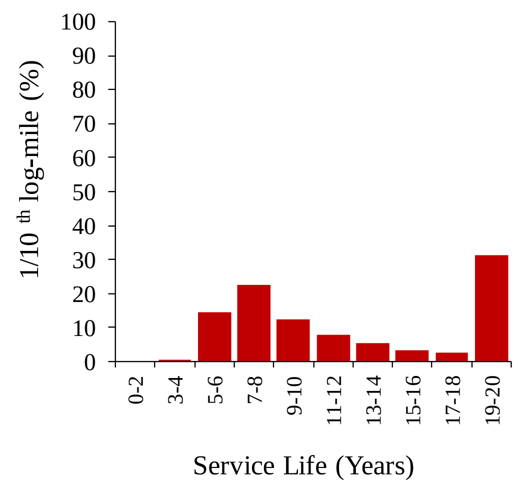
Alligator Cracking Comparison (3 data points)

AST Interlayer Evaluation (Over CSD*).* Figure 176 to Figure 178 illustrate the alligator cracking comparison for AST interlayer over CSD bases for the three categories mentioned above. Figure 176 shows the comparison Category x1 vs x5 for alligator cracking. AST interlayer sections behave better than no interlayer sections in this case. As AST interlayer had positive GainSL and GainNBA (2.2 years and 2.1 Ft-yr/ft, respectively), it became slightly cost-effective in this case, as confirmed by the B/C ratios. The results of alligator cracking are similar to transverse cracking for this category. Figure 177 shows the same trend whereas Figure 178 had negative GainSL and GainNBA, but these results are not conclusive due to lack of data.

ALLIGATOR CRACKING COMPARISON, CSD Bases, AST vs NO Interlayer							
ESAL Category	0	30000	ESAL		**Data Category**	3	Data points
Thickness Category	0	4	inches		**Base Category**	CSD	Soil Cement

AST INTERLAYER							NO INTERLAYER					
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev		N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
27	736	14.7	6.6	13.8	6.5		46	1786	12.5	5.7	11.7	5.9





B/C (SL) =	66.2	Yrs / Dollar		B/C (SL) =	65.1	Yrs / Dollar
B/C (NBA) =	62.0	Ft-yr/ft/Dollar		B/C (NBA) =	60.9	Ft-yr/ft/Dollar
Category:	Gain SL by AST Interlayer		=	2.2 Yrs	Category:	
x1	Gain NBA by AST Interlayer		=	2.1 Ft-yr/ft	x5	

Figure 176: AC comparison for AST vs no interlayer, CSD base (Cat. x1 vs x5)

ALLIGATOR CRACKING COMPARISON, CSD Bases, AST vs NO Interlayer

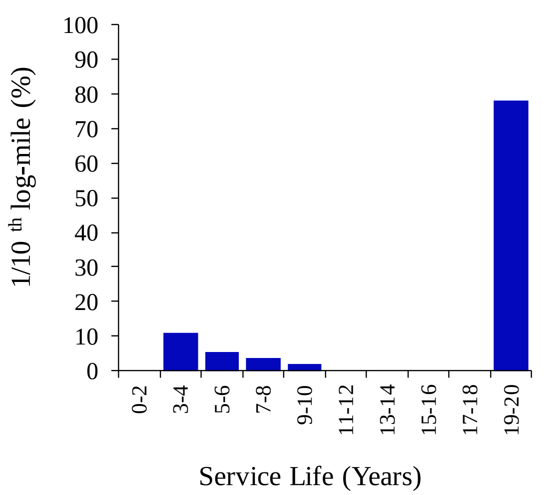
ESAL Category	30001	2E6	ESAL		**Data Category**	3	Data points
Thickness Category	0	4	inches		**Base Category**	CSD	Soil Cement

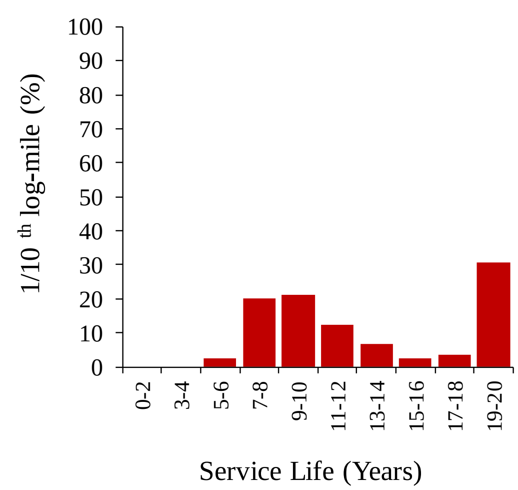
AST INTERLAYER

N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
2	55	16.8	6.2	15.8	6.1

NO INTERLAYER

N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
17	757	13.1	5.1	12.2	5.4



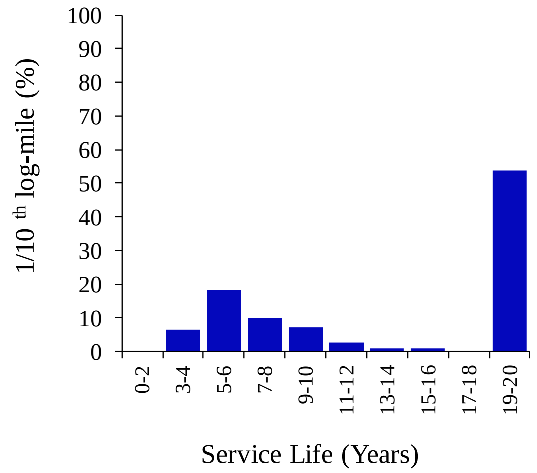


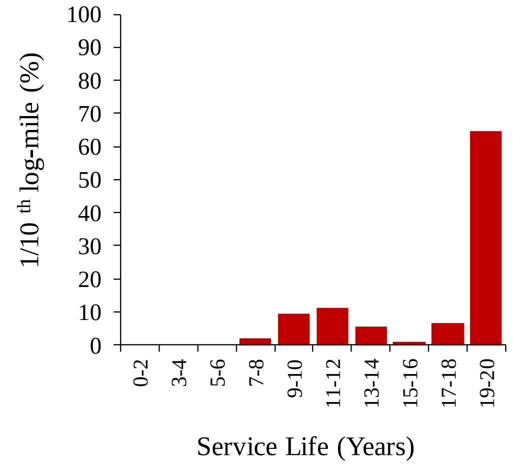
B/C (SL) =	84.3	Yrs / Dollar		B/C (SL) =	74.3	Yrs / Dollar
B/C (NBA) =	79.5	Ft-yr/ft/Dollar		B/C (NBA) =	69.0	Ft-yr/ft/Dollar
Category:	Gain SL by AST Interlayer		=	3.6	Yrs	Category:
x2	Gain NBA by AST Interlayer		=	3.6	Ft-yr/ft	x6

Figure 177: AC comparison AST vs no interlayer, CSD base (Cat. x2 vs x6)

ALLIGATOR CRACKING COMPARISON, CSD Bases, AST vs NO Interlayer							
ESAL Category	30001	2E6	ESAL		**Data Category**	3	Data points
Thickness Category	4.1	10	inches		**Base Category**	CSD	Soil Cement

AST INTERLAYER						NO INTERLAYER					
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
8	110	14.0	6.7	13.1	6.6	2	107	17.2	4.1	16.4	4.4





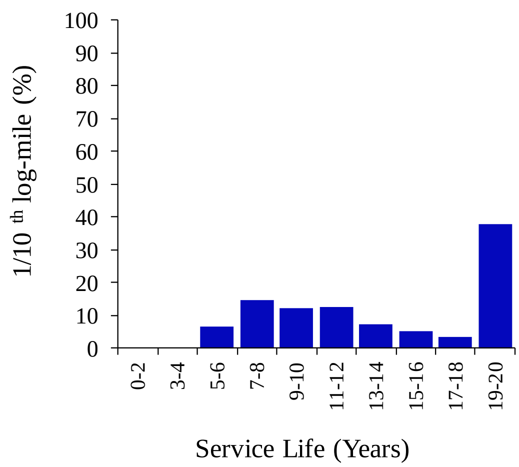
B/C (SL) =	61.4	Yrs / Dollar		B/C (SL) =	127.3	Yrs / Dollar
B/C (NBA) =	57.3	Ft-yr/ft/Dollar		B/C (NBA) =	120.7	Ft-yr/ft/Dollar
Category:	Gain SL by AST Interlayer		=	-3.2 Yrs	Category:	
x4	Gain NBA by AST Interlayer		=	-3.3 Ft-yr/ft	x8	

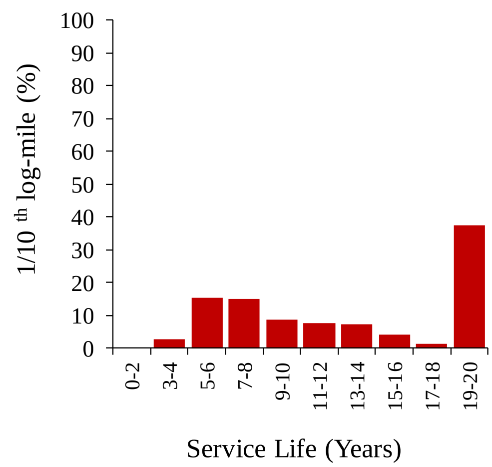
Figure 178: AC comparison for AST vs no interlayer, CSD base (Cat. x4 vs x8)

AST Interlayer Evaluation (Over CTD). Figure 179 shows the comparison category for AST interlayer over CTD base performance: Category x9 vs x13. Here, from Figure 179, it is obvious that AST interlayer over CTD shows an analogous trend of no interlayer over CTD bases. Both histograms are similar in nature, and GainSL and GainNBA values are slightly positive.

ALLIGATOR CRACKING COMPARISON, CTD Bases, AST vs NO Interlayer							
ESAL Category	0	30000	ESAL		**Data Category**	3	Data points
Thickness Category	0	4	inches		**Base Category**	CTD	Soil Cement

AST INTERLAYER						NO INTERLAYER					
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev	N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
6	346	14.0	5.3	13.1	5.6	46	1458	13.2	6.0	12.4	6.2





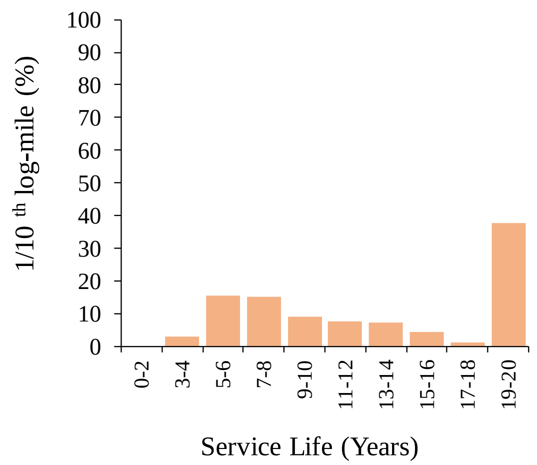
B/C (SL) =	80.0	Yrs / Dollar		B/C (SL) =	78.5	Yrs / Dollar
B/C (NBA) =	75.0	Ft-yr/ft/Dollar		B/C (NBA) =	73.9	Ft-yr/ft/Dollar
Category:	Gain SL by AST Interlayer		=	0.9 Yrs	Category:	
x9	Gain NBA by AST Interlayer		=	0.7 Ft-yr/ft	x13	

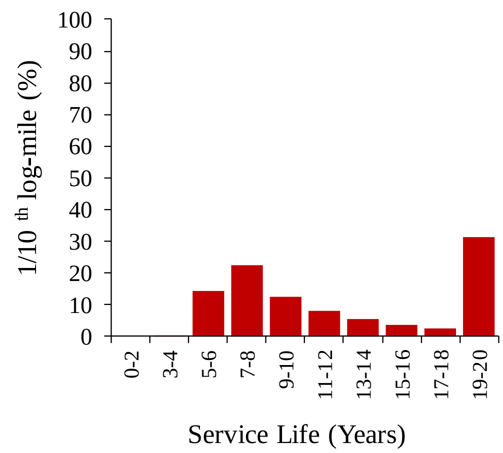
Figure 179: AC comparison for AST vs no interlayer, CTD base (Cat. x9 vs x13)

CTD Bases Evaluation. For alligator cracking, the three comparison categories for CTD base evaluation are shown from Figure 180 to Figure 182. From Figure 180 and Figure 181, it is clear that CTD base and CSD base have similar behavior. As CTD base has the lesser installation cost, it becomes the more cost-effective option. Comparison Category x16 vs x8 is shown in Figure 182, but this comparison is not supported by sufficient data.

ALLIGATOR CRACKING COMPARISON, No Int CTD vs No Int CSD Bases							
ESAL Category	0	30000	ESAL		**Data Category**	3	Data points
Thickness Category	0	4	inches		**Base Category**		Soil Cement

NO INTERLAYER, CTD							NO INTERLAYER, CSD					
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev		N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
46	1458	13.2	6.0	12.4	6.2		46	1786	12.5	5.7	11.7	5.9





B/C (SL) =	78.5	Yrs / Dollar		B/C (SL) =	65.1	Yrs / Dollar
B/C (NBA) =	73.9	Ft-yr/ft/Dollar		B/C (NBA) =	60.9	Ft-yr/ft/Dollar
Category:	Gain SL by CTD Base		=	0.6	Yrs	Category:
x13	Gain NBA by CTD Base		=	0.7	Ft-yr/ft	x5

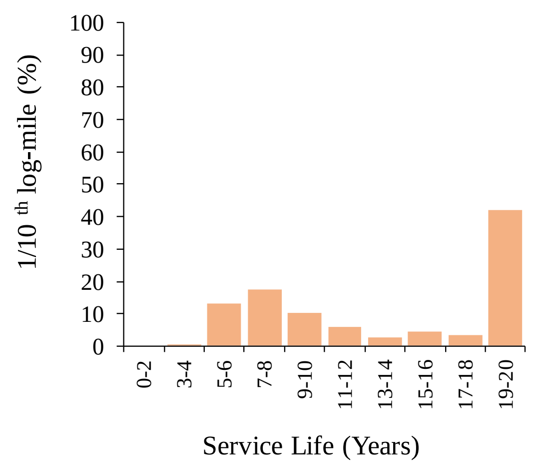
Figure 180: AC comparison, CTD vs CSD base (Cat. x13 vs x5)

ALLIGATOR CRACKING COMPARISON, No Int CTD vs No Int CSD Bases

ESAL Category	30001	2E6	ESAL		**Data Category**	3	Data points
Thickness Category	0	4	inches		**Base Category**		Soil Cement

NO INTERLAYER, CTD

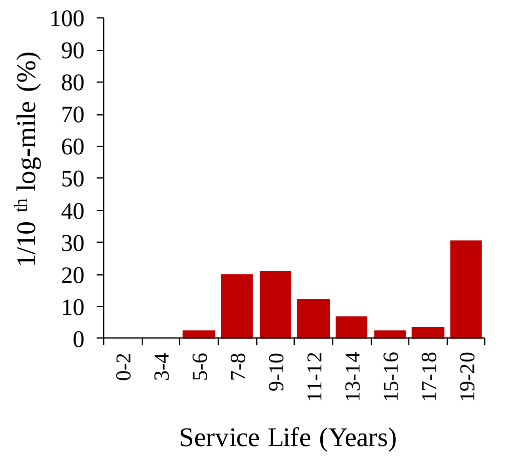
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
5	154	13.7	6.0	13.0	6.3



B/C (SL) =	85.8	Yrs / Dollar
B/C (NBA) =	81.0	Ft-yr/ft/Dollar

NO INTERLAYER, CSD

N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
17	757	13.1	5.1	12.2	5.4



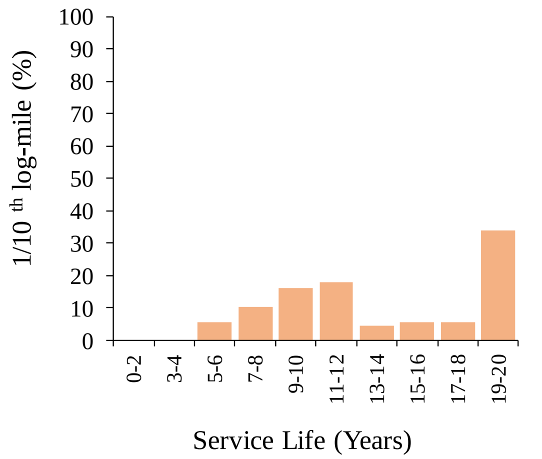
B/C (SL) =	74.3	Yrs / Dollar
B/C (NBA) =	69.0	Ft-yr/ft/Dollar

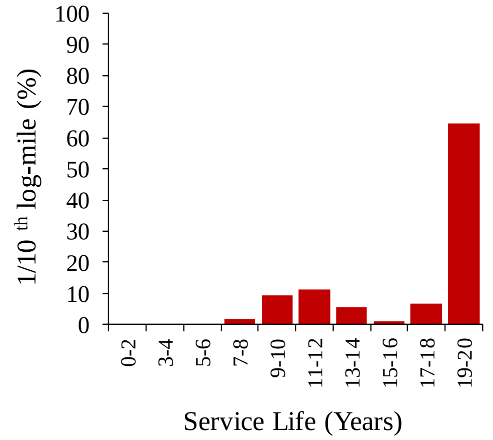
Category:	Gain SL by CTD Base	=	0.6	Yrs	Category:
x14	Gain NBA by CTD Base	=	0.8	Ft-yr/ft	x6

Figure 181: AC comparison, CTD vs CSD base (Cat. x14 vs x6)

ALLIGATOR CRACKING COMPARISON, No Int CTD vs No Int CSD Bases						
ESAL Category	30001	2E6	ESAL		**Data Category**	3	Data points
Thickness Category	4.1	10	inches		**Base Category**		Soil Cement

NO INTERLAYER, CTD							NO INTERLAYER, CSD					
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev		N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
3	106	14.0	5.1	13.0	5.3		2	107	17.2	4.1	16.4	4.4





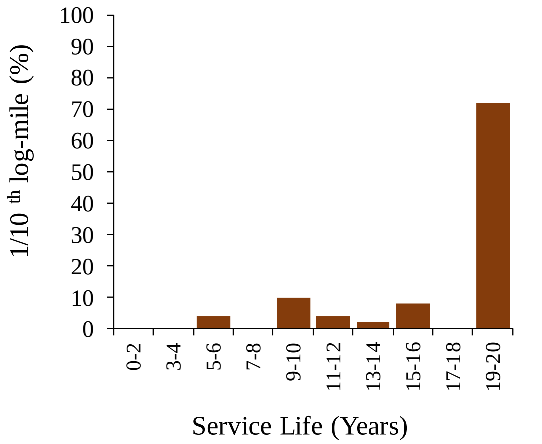
B/C (SL) =	95.4	Yrs / Dollar		B/C (SL) =	127.3	Yrs / Dollar
B/C (NBA) =	89.0	Ft-yr/ft/Dollar		B/C (NBA) =	120.7	Ft-yr/ft/Dollar
Category:	Gain SL by CTD Base		=	-3.3 Yrs		Category:
x16	Gain NBA by CTD Base		=	-3.3 Ft-yr/ft		x8

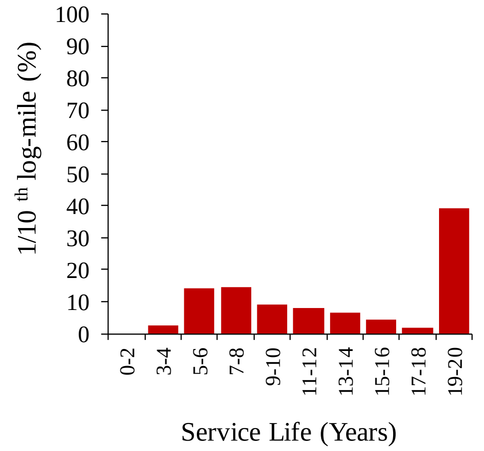
Figure 182: AC comparison, CTD vs CSD base (Cat. x16 vs x8)

Stone Interlayer Evaluation. Figure 183 and Figure 184 evaluate the stone interlayer for CTD and CSD bases, respectively, for alligator cracking. In both cases, stone interlayer provides significant positive GainSL and GainNBA values. For CTD and CSD bases, the GainSL is 4.2 years and 6.4 years. Also, from the histogram comparison, it is evident that stone interlayer sections had reduced alligator cracking significantly with respect to no interlayer sections. Even though there are higher costs associated with stone interlayer installation, it became more cost-effective for both cases. Stone interlayer provides better results for all crackings.

ALLIGATOR CRACKING COMPARISON, CTD Bases, Stone vs No Interlayer							
ESAL Category	0	150000	ESAL		**Data Category**	3	Data points
Thickness Category	0	5	inches		**Base Category**	CTD	Soil Cement

STONE INTERLAYER, CTD							NO INTERLAYER, CTD					
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev		N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
2	50	17.6	4.3	17.0	4.8		54	1726	13.4	6.0	12.7	6.2



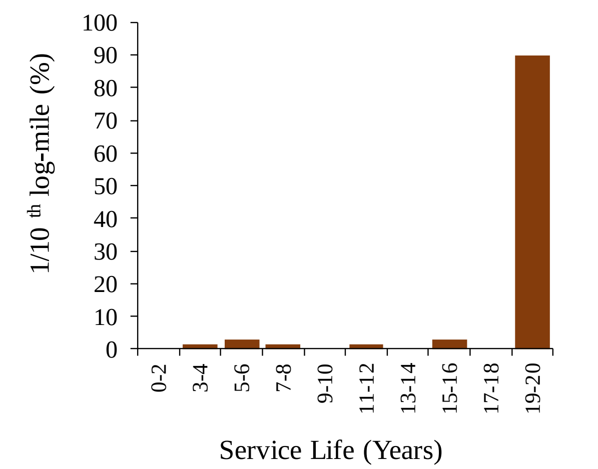


B/C (SL) =	93.1	Yrs / Dollar		B/C (SL) =		81.7	Yrs / Dollar
B/C (NBA) =	90.2	Ft-yr/ft/Dollar		B/C (NBA) =		77.0	Ft-yr/ft/Dollar
Category:	Gain SL by Stone Interlayer		=	4.2	Yrs	Category:	
x17	Gain NBA by Stone Interlayer		=	4.4	Ft-yr/ft	x19	

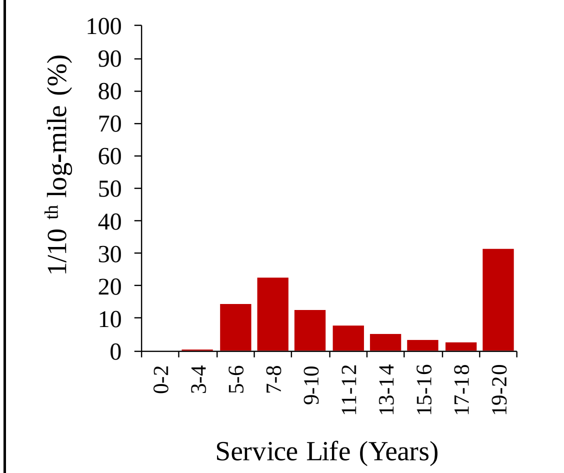
Figure 183: AC comparison for stone vs no interlayer, CTD base (Cat. x17 vs x19)

ALLIGATOR CRACKING COMPARISON, CSD Bases, Stone vs No Interlayer							
ESAL Category	0	30000	ESAL		**Data Category**	3	Data points
Thickness Category	0	5	inches		**Base Category**	CSD	Soil Cement

STONE INTERLAYER, CSD					
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
3	68	18.9	3.5	18.2	3.6



NO INTERLAYER, CSD					
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
46	1786	12.5	5.7	11.7	5.9



B/C (SL) =	97.2	Yrs / Dollar		B/C (SL) =	65.1	Yrs / Dollar
B/C (NBA) =	93.4	Ft-yr/ft/Dollar		B/C (NBA) =	60.9	Ft-yr/ft/Dollar
Category:	Gain SL by Stone Interlayer		=	6.4	Yrs	Category:
x18	Gain NBA by Stone Interlayer		=	6.4	Ft-yr/ft	x20

Figure 184: AC comparison for stone vs no interlayer, CSD base (Cat. x18 vs x20)

Alligator Cracking Comparison (6 data points)

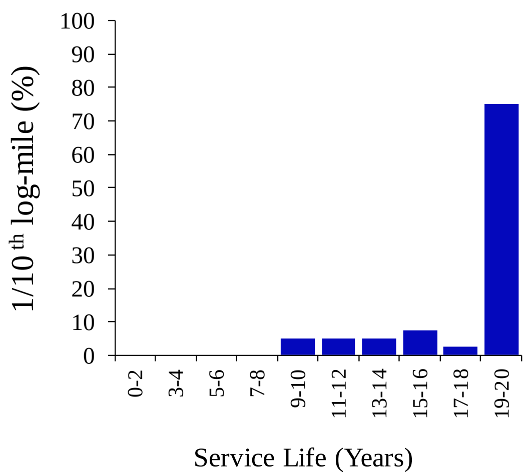
AST Interlayer Evaluation (Over CSD). Figure 185 and Figure 186 illustrates the alligator cracking comparison for Category x1' vs x5' and Category x4' vs x8' for 6 data points, respectively. For the lower ESAL and less thickness Category x1' vs x5' (as shown in Figure 185), AST interlayer over CSD has positive GainSL and GainNBA values of 4.6 years and 5.6 Ft-yr/ft. There were only three available projects for AST interlayer over CSD for this comparison, hence this result is not conclusive.

ALLIGATOR CRACKING COMPARISON, CSD Bases, AST vs NO Interlayer

ESAL Category	0	30000	ESAL		**Data Category**	6	Data points
Thickness Category	0	4	inches		**Base Category**	CSD	Soil Cement

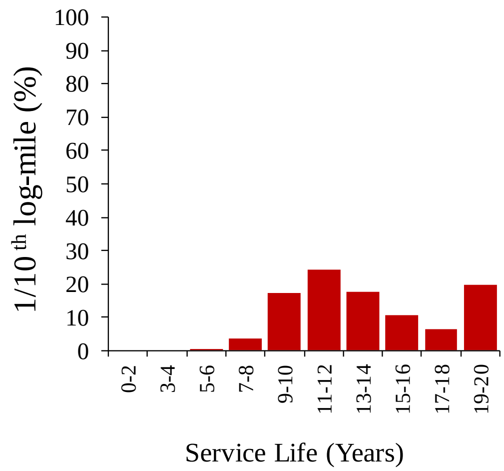
AST INTERLAYER

N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
3	40	18.4	3.0	18.0	3.6



NO INTERLAYER

N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
46	1789	13.8	3.8	12.4	4.0

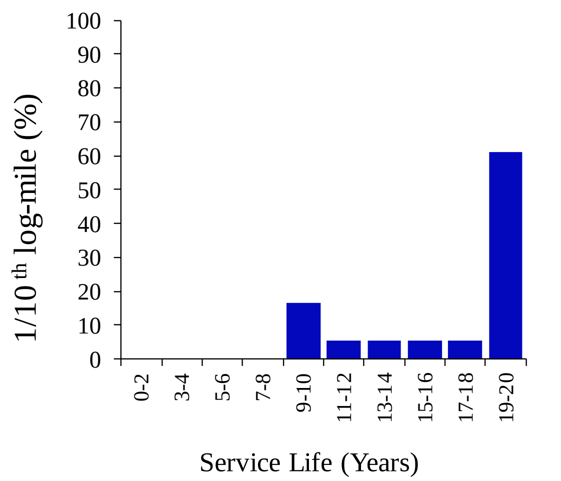


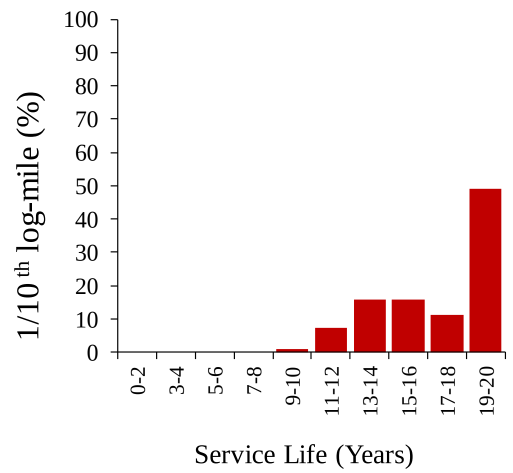
B/C (SL) =	126.3	Yrs / Dollar		B/C (SL) =		86.5	Yrs / Dollar
B/C (NBA) =	123.3	Ft-yr/ft/Dollar		B/C (NBA) =		77.3	Ft-yr/ft/Dollar
Category:	Gain SL by AST Interlayer		=	4.6	Yrs	Category:	
x1'	Gain NBA by AST Interlayer		=	5.6	Ft-yr/ft	x5'	

Figure 185: AC comparison for AST vs no interlayer, CSD base (Cat. x1' vs x5')

ALLIGATOR CRACKING COMPARISON, CSD Bases, AST vs NO Interlayer							
ESAL Category	30001	2E6	ESAL		**Data Category**	6	Data points
Thickness Category	4.1	10	inches		**Base Category**	CSD	Soil Cement

AST INTERLAYER							NO INTERLAYER					
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev		N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
2	18	16.9	4.3	16.0	4.6		2	108	17.2	3.1	15.9	3.4





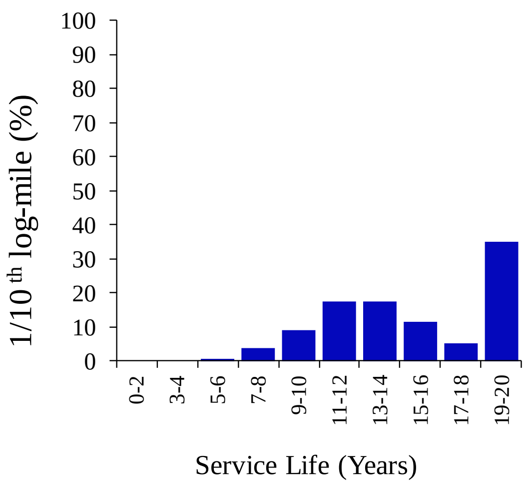
B/C (SL) =	105.6	Yrs / Dollar		B/C (SL) =	130.3	Yrs / Dollar
B/C (NBA) =	99.6	Ft-yr/ft/Dollar		B/C (NBA) =	120.3	Ft-yr/ft/Dollar
Category:	Gain SL by AST Interlayer		=	-0.2	Yrs	Category:
x4'	Gain NBA by AST Interlayer		=	0.1	Ft-yr/ft	x8'

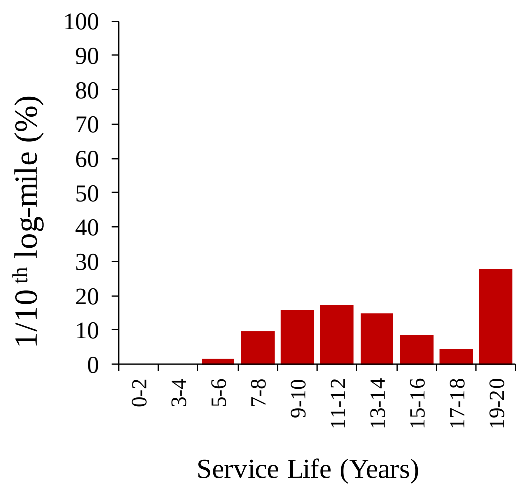
Figure 186: AC comparison for AST vs no interlayer, CSD base (Cat. x4' vs x8')

AST Interlayer Evaluation (Over CTD). Figure 187 compares AST interlayer over CTD with no interlayer over CTD sections for alligator cracking. Here, AST interlayer sections here 1.3 years of GainSL and 1.4 Ft-yr/ft of GainNBA compared to no interlayer sections for CTD bases.

ALLIGATOR CRACKING COMPARISON, CTD Bases, AST vs NO Interlayer							
ESAL Category	0	30000	ESAL		**Data Category**	6	Data points
Thickness Category	0	4	inches		**Base Category**	CTD	Soil Cement

AST INTERLAYER							NO INTERLAYER					
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev		N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
6	346	15.2	4.1	14.0	4.5		46	1478	13.9	4.4	12.7	4.7





B/C (SL) =	98.7	Yrs / Dollar		B/C (SL) =	98.3	Yrs / Dollar
B/C (NBA) =	91.1	Ft-yr/ft/Dollar		B/C (NBA) =	89.2	Ft-yr/ft/Dollar
Category:	Gain SL by AST Interlayer		=	1.3 Yrs		Category:
x9'	Gain NBA by AST Interlayer		=	1.4 Ft-yr/ft		x13'

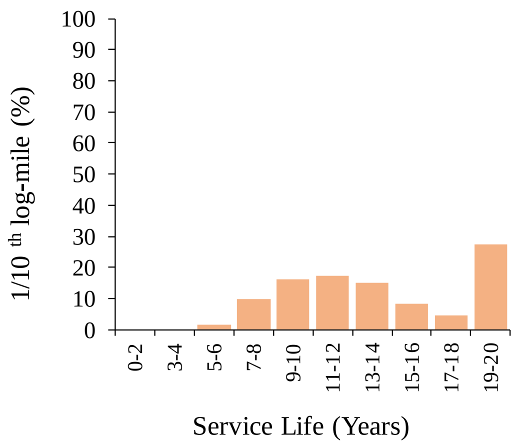
Figure 187: AC comparison for AST vs no interlayer, CTD base (Cat. x9' vs x13')

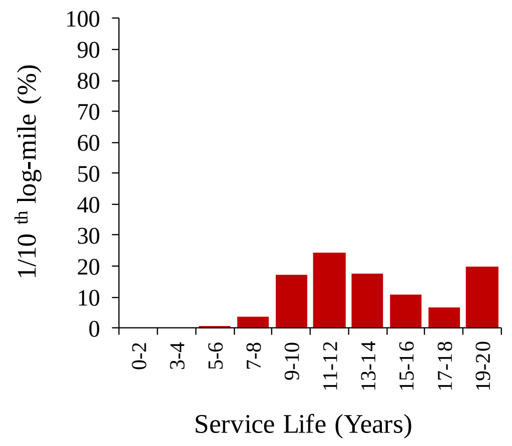
CTD Bases Evaluation. The three comparison categories for CTD bases are shown from Figure 188 to Figure 190. From the first two figures, it is evident that CTD bases behave very similar to CSD bases for both ESAL categories. As CTD is inexpensive, at the end it becomes a more cost-effective option then CSD bases.

ALLIGATOR CRACKING COMPARISON, No Int CTD vs No Int CSD Bases

ESAL Category	0	30000	ESAL		**Data Category**	6	Data points
Thickness Category	0	4	inches		**Base Category**		Soil Cement

NO INTERLAYER, CTD							NO INTERLAYER, CSD					
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev		N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
46	1478	13.9	4.4	12.7	4.7		46	1789	13.8	3.8	12.4	4.0





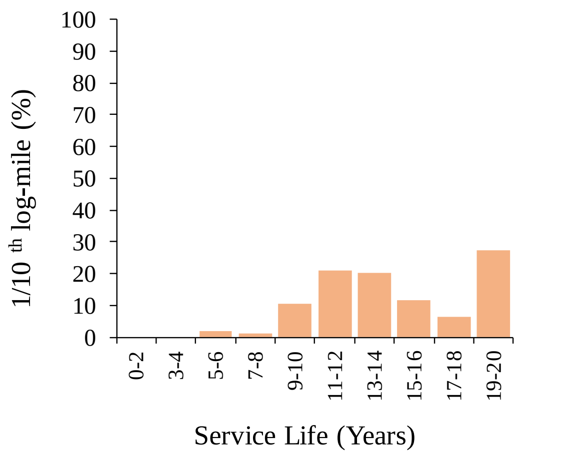
B/C (SL) =	98.3	Yrs / Dollar		B/C (SL) =	86.5	Yrs / Dollar
B/C (NBA) =	89.2	Ft-yr/ft/Dollar		B/C (NBA) =	77.3	Ft-yr/ft/Dollar
Category:	Gain SL by AST Interlayer		=	0.1 Yrs	Category:	
x13'	Gain NBA by AST Interlayer		=	0.3 Ft-yr/ft	x5'	

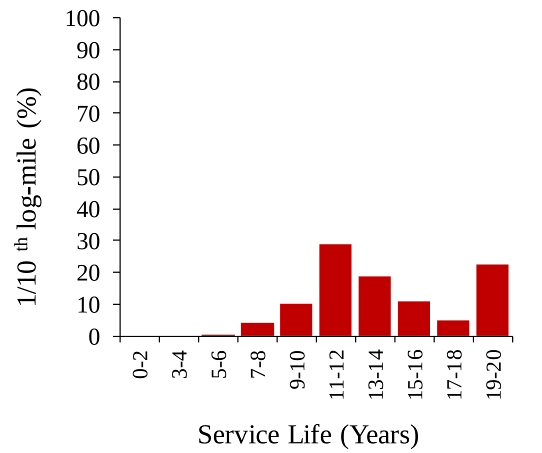
Figure 188: AC comparison, CTD vs CSD base (Cat. x13' vs x5')

ALLIGATOR CRACKING COMPARISON, No Int CTD vs No Int CSD Bases						
ESAL Category	30001	2E6	ESAL	**Data Category**	6	Data points
Thickness Category	0	4	inches	**Base Category**		Soil Cement

NO INTERLAYER, CTD					
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
5	154	14.7	3.9	13.3	4.2

NO INTERLAYER, CSD					
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
17	769	14.0	3.8	12.6	4.0



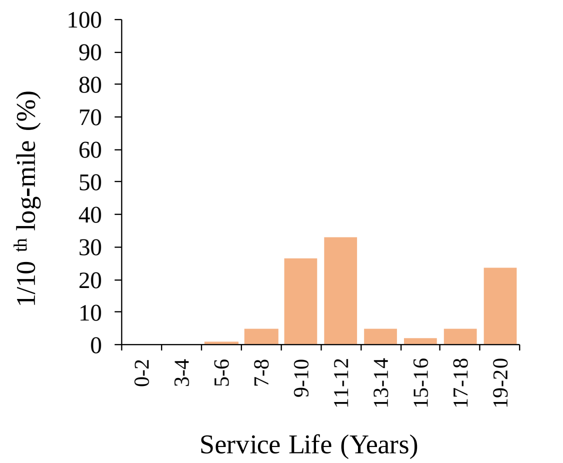


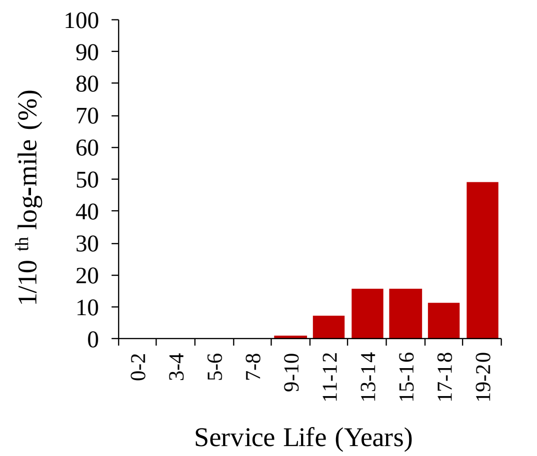
B/C (SL) =	110.4	Yrs / Dollar		B/C (SL) =	89.4	Yrs / Dollar
B/C (NBA) =	99.9	Ft-yr/ft/Dollar		B/C (NBA) =	80.2	Ft-yr/ft/Dollar
Category:	Gain SL by AST Interlayer		=	0.7 Yrs		Category:
x14'	Gain NBA by AST Interlayer		=	0.7 Ft-yr/ft		x6'

Figure 189: AC comparison, CTD vs CSD base (Cat. x14' vs x6')

ALLIGATOR CRACKING COMPARISON, No Int CTD vs No Int CSD Bases							
ESAL Category	30001	2E6	ESAL		**Data Category**	6	Data points
Thickness Category	4.1	10	inches		**Base Category**		Soil Cement

NO INTERLAYER, CTD							NO INTERLAYER, CSD					
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev		N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
3	106	13.2	4.3	12.1	4.6		2	108	17.2	3.1	15.9	3.4





B/C (SL) =	89.9	Yrs / Dollar		B/C (SL) =	130.3	Yrs / Dollar
B/C (NBA) =	82.7	Ft-yr/ft/Dollar		B/C (NBA) =	120.3	Ft-yr/ft/Dollar
Category:	Gain SL by AST Interlayer		=	-4.0	Yrs	Category:
x16'	Gain NBA by AST Interlayer		=	-3.7	Ft-yr/ft	x8'

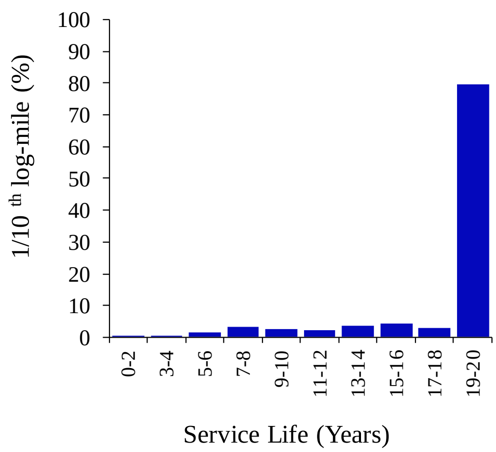
Figure 190: AC comparison, CTD vs CSD base (Cat. x16' vs x8')

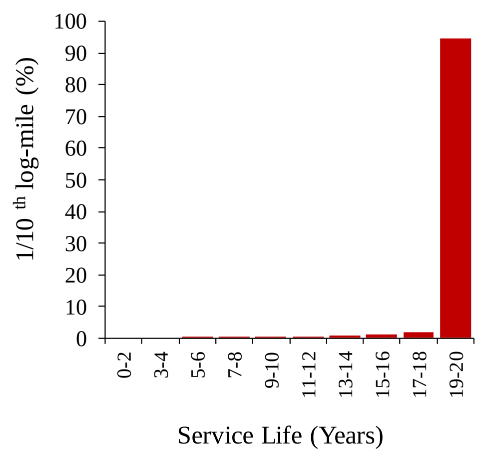
IRI Comparison (3 data points)

AST Interlayer Evaluation (Over CSD). Figure 191 to Figure 193 illustrates IRI comparison for AST interlayer over CSD bases. Figure 191 shows the major comparison Category x1 vs x5 where AST interlayer sections behave very similarly to the no interlayer sections. As AST interlayer has slightly negative GainSL and GainNBA, it becomes less cost-effective in this case which is confirmed by the B/C ratios. Figure 192 and Figure 193 also present different results but those are not conclusive. AST interlayer does not have significant impact on roughness unlike the cracking.

IRI COMPARISON, CSD Bases, AST vs NO Interlayer							
ESAL Category	0	30000	ESAL		**Data Category**	3	Data points
Thickness Category	0	4	inches		**Base Category**	CSD	Soil Cement

AST INTERLAYER							NO INTERLAYER					
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev		N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
19	570	18.3	3.7	11.0	3.5		46	1584	19.7	1.5	12.1	2.3





B/C (SL) =	118.7	Yrs / Dollar		B/C (SL) =	167.2	Yrs / Dollar
B/C (NBA) =	71.4	Ft-yr/ft/Dollar		B/C (NBA) =	103.1	Ft-yr/ft/Dollar
Category:	Gain SL by AST Interlayer		=	-1.3 Yrs	Category:	
x1	Gain NBA by AST Interlayer		=	-1.1 Ft-yr/ft	x5	

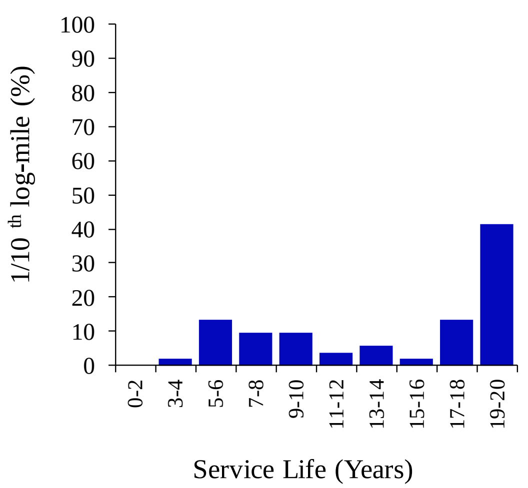
Figure 191: IRI comparison for AST vs no interlayer, CSD base (Cat. x1 vs x5)

IRI COMPARISON, CSD Bases, AST vs NO Interlayer

ESAL Category	30001	2E6	ESAL		**Data Category**	3	Data points
Thickness Category	0	4	inches		**Base Category**	CSD	Soil Cement

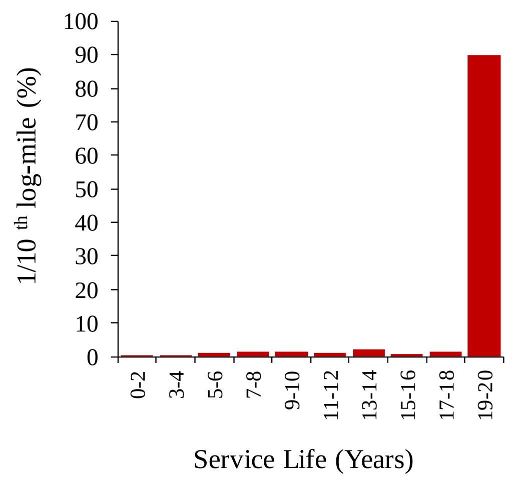
AST INTERLAYER

N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
2	53	14.2	6.2	6.2	3.9



NO INTERLAYER

N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
17	702	19.0	3.2	11.7	3.1



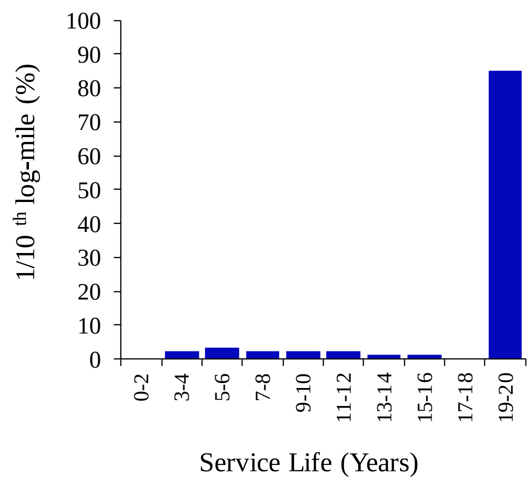
B/C (SL) =	81.0	Yrs / Dollar		B/C (SL) =	150.9	Yrs / Dollar
B/C (NBA) =	35.5	Ft-yr/ft/Dollar		B/C (NBA) =	92.9	Ft-yr/ft/Dollar
Category:	Gain SL by AST Interlayer		=	-4.9	Yrs	Category:
x2	Gain NBA by AST Interlayer		=	-5.5	Ft-yr/ft	x6

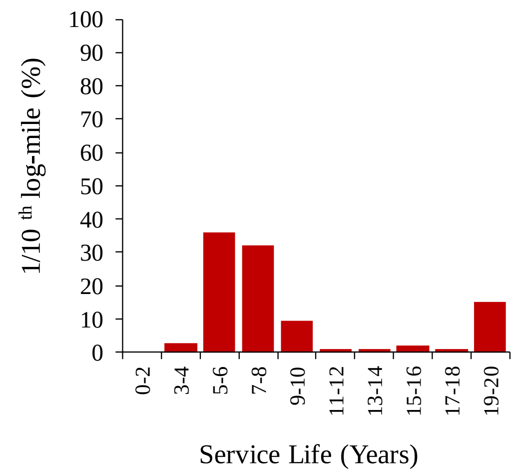
Figure 192: IRI comparison for AST vs no interlayer, CSD base (Cat. x2 vs x6)

IRI COMPARISON, CSD Bases, AST vs NO Interlayer

ESAL Category	30001	2E6	ESAL		**Data Category**	3	Data points
Thickness Category	4.1	10	inches		**Base Category**	CSD	Soil Cement

AST INTERLAYER							**NO INTERLAYER**					
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev		N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
8	87	18.3	4.3	10.9	3.7		2	106	9.1	5.1	4.4	2.8





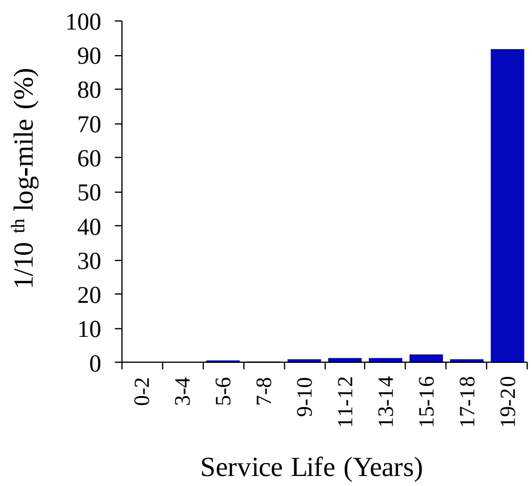
B/C (SL) =	114.1	Yrs / Dollar		B/C (SL) =	36.3	Yrs / Dollar
B/C (NBA) =	68.3	Ft-yr/ft/Dollar		B/C (NBA) =	17.5	Ft-yr/ft/Dollar
Category:	Gain SL by AST Interlayer		=	9.2 Yrs		Category:
x4	Gain NBA by AST Interlayer		=	6.6 Ft-yr/ft		x8

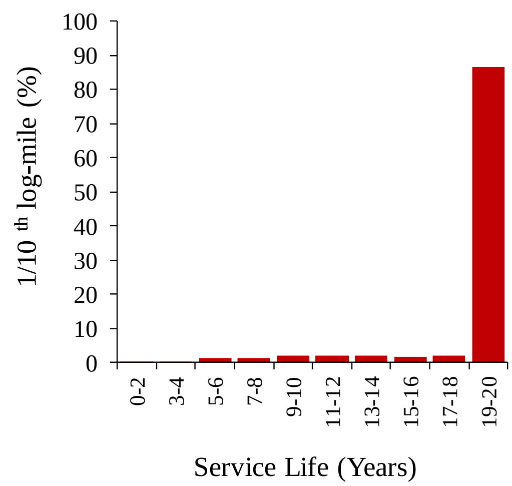
Figure 193: IRI comparison for AST vs no interlayer, CSD base (Cat. x4 vs x8)

AST Interlayer Evaluation (Over CTD)*.* Figure 194 shows the only comparison category for AST interlayer over CTD base performance: Category x9 vs x13. It is obvious that AST interlayer over CTD shows an analogous trend of no interlayer over CTD bases. Both histograms are similar in nature and GainSL value is slightly positive. Due to the higher cost of the AST interlayer, the B/C ratio for no interlayer has higher value in this case.

IRI COMPARISON, CTD Bases, AST vs NO Interlayer							
ESAL Category	0	30000	ESAL		**Data Category**	3	Data points
Thickness Category	0	4	inches		**Base Category**	CTD	Soil Cement

AST INTERLAYER							**NO INTERLAYER**					
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev		N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
6	314	19.4	2.2	11.5	2.7		44	1178	18.8	3.8	11.5	3.2





B/C (SL) =	156.5	Yrs / Dollar		B/C (SL) =	167.4	Yrs / Dollar
B/C (NBA) =	92.3	Ft-yr/ft/Dollar		B/C (NBA) =	102.4	Ft-yr/ft/Dollar
Category:	Gain SL by AST Interlayer		=	0.6	Yrs	Category:
x9	Gain NBA by AST Interlayer		=	-0.1	Ft-yr/ft	x13

Figure 194: IRI comparison for AST vs no interlayer, CTD base (Cat. x9 vs x13)

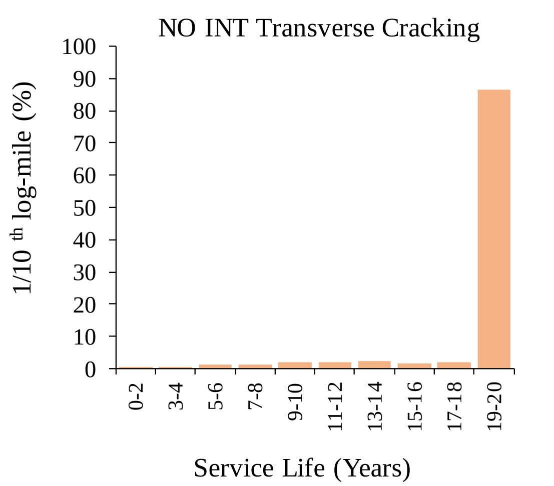
CTD Bases Evaluation. The three comparison categories for CTD base evaluation for IRI are shown from Figure 195 to Figure 197. From Figure 195 and Figure 196, it is obvious that CTD base and CSD base have similar behavior for IRI.

IRI COMPARISON, No Int CTD vs No Int CSD Bases

ESAL Category	0	30000	ESAL		**Data Category**	3	Data points
Thickness Category	0	4	inches		**Base Category**		Soil Cement

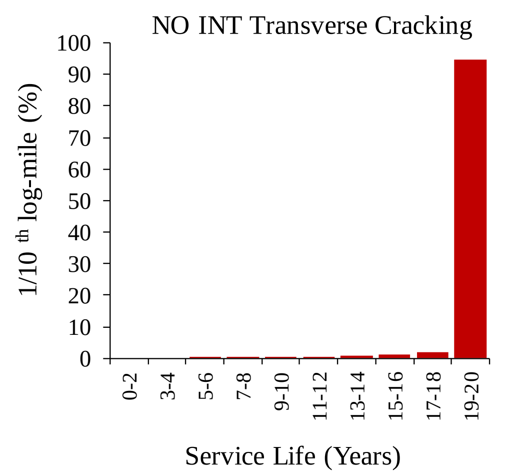
NO INTERLAYER, CTD

N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
44	1178	18.8	3.8	11.5	3.2



NO INTERLAYER, CSD

N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
46	1584	19.7	1.5	12.1	2.3



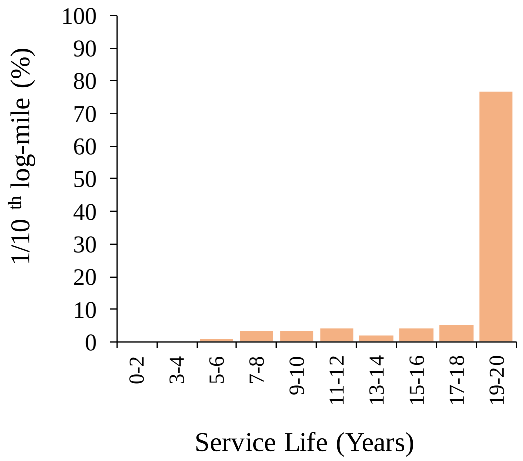
B/C (SL) =	167.4	Yrs / Dollar		B/C (SL) =	167.2	Yrs / Dollar
B/C (NBA) =	102.4	Ft-yr/ft/Dollar		B/C (NBA) =	103.1	Ft-yr/ft/Dollar

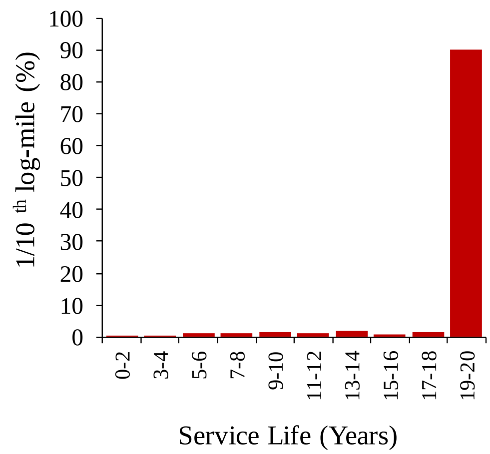
Category:	Gain SL by CTD Base	=	-0.9 Yrs	Category:
x13	Gain NBA by CTD Base	=	-0.6 Ft-yr/ft	x5

Figure 195: IRI comparison, CTD vs CSD base (Cat. x13 vs x5)

IRI COMPARISON, No Int CTD vs No Int CSD Bases							
ESAL Category	30001	2E6	ESAL		**Data Category**	3	Data points
Thickness Category	0	4	inches		**Base Category**		Soil Cement

NO INTERLAYER, CTD							NO INTERLAYER, CSD					
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev		N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
6	197	18.2	3.7	10.4	3.3		17	702	19.0	3.2	11.7	3.1

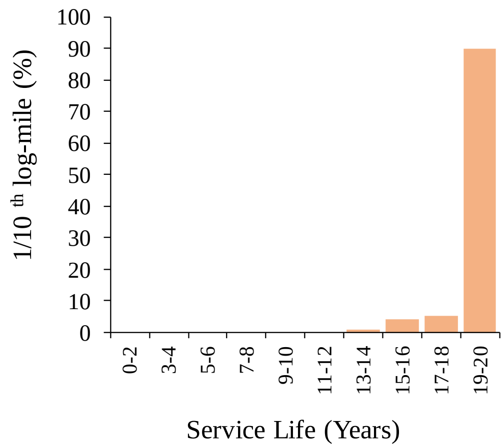


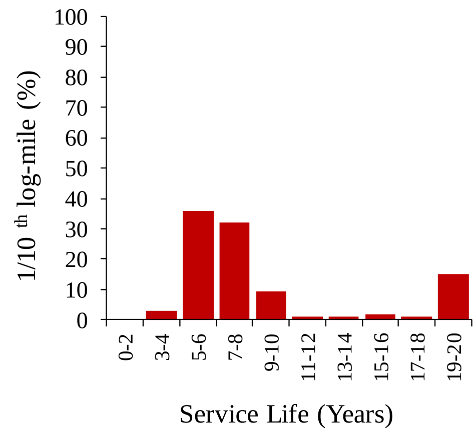


B/C (SL) =	161.3	Yrs / Dollar		B/C (SL) =		150.9	Yrs / Dollar
B/C (NBA) =	92.4	Ft-yr/ft/Dollar		B/C (NBA) =		92.9	Ft-yr/ft/Dollar
Category:	Gain SL by CTD Base		=	-0.8	Yrs	Category:	
x14	Gain NBA by CTD Base		=	-1.3	Ft-yr/ft	x6	

Figure 196: IRI comparison, CTD vs CSD base (Cat. x14 vs x6)

IRI COMPARISON, No Int CTD vs No Int CSD Bases												
ESAL Category		30001	2E6	ESAL			**Data Category**	3	Data points			
Thickness Category		4.1	10	inches			**Base Category**		Soil Cement			
NO INTERLAYER, CTD							NO INTERLAYER, CSD					
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev		N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
3	98	19.6	1.3	9.6	2.8		2	106	9.1	5.1	4.4	2.8





B/C (SL) =	190.9	Yrs / Dollar		B/C (SL) =	36.3	Yrs / Dollar
B/C (NBA) =	93.8	Ft-yr/ft/Dollar		B/C (NBA) =	17.5	Ft-yr/ft/Dollar
Category:	Gain SL by CTD Base		=	10.5 Yrs	Category:	
x16	Gain NBA by CTD Base		=	5.2 Ft-yr/ft	x8	

Figure 197: IRI comparison, CTD vs CSD base (Cat. x16 vs x8)

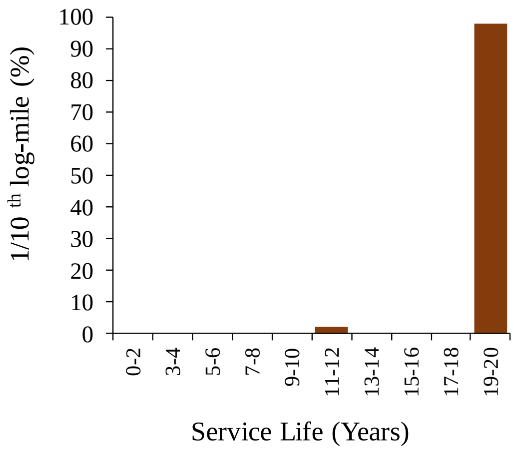
Stone Interlayer Evaluation. For IRI, Figure 198 and Figure 199 evaluate stone interlayer for CTD and CSD bases, respectively. For both cases, stone interlayer has analogous behavior to no interlayer. Also, from the histogram comparison, it is evident that stone interlayer sections did not create any additional roughness.

IRI COMPARISON, CTD Bases, Stone vs No Interlayer

ESAL Category	0	150000	ESAL		**Data Category**	3	Data points
Thickness Category	0	5	inches		**Base Category**	CTD	Soil Cement

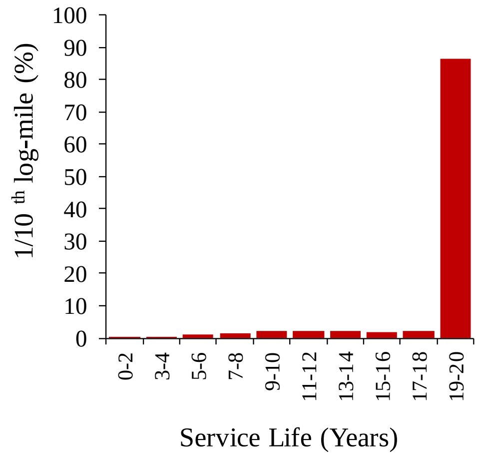
STONE INTERLAYER, CTD

N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
2	49	19.8	1.1	12.3	1.6



NO INTERLAYER, CTD

N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
53	1480	18.8	3.7	11.4	3.1

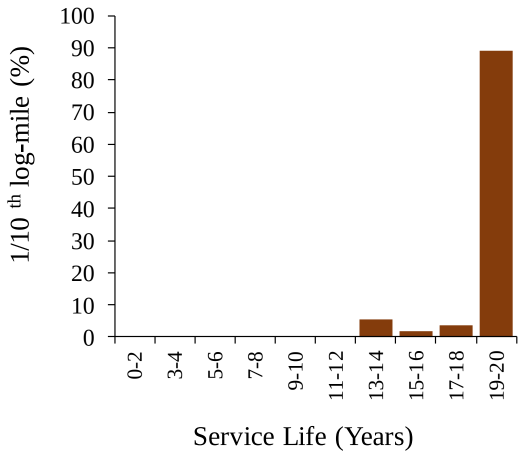


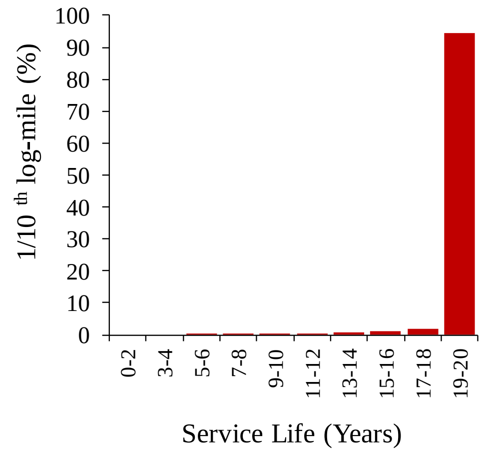
B/C (SL) =	123.3	Yrs / Dollar		B/C (SL) =	168.6	Yrs / Dollar
B/C (NBA) =	76.7	Ft-yr/ft/Dollar		B/C (NBA) =	101.7	Ft-yr/ft/Dollar
Category:	Gain SL by Stone Interlayer		=	1.0	Yrs	Category:
x17	Gain NBA by Stone Interlayer		=	1.0	Ft-yr/ft	x19

Figure 198: IRI comparison for stone interlayer, CTD base (Cat. x17 vs x19)

IRI COMPARISON, CSD Bases, Stone vs No Interlayer							
ESAL Category	0	30000	ESAL		**Data Category**	3	Data points
Thickness Category	0	5	inches		**Base Category**	CSD	Soil Cement

STONE INTERLAYER, CSD							NO INTERLAYER, CSD					
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev		N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
3	55	19.4	1.7	11.6	2.5		46	1584	19.7	1.5	12.1	2.3





B/C (SL) =	108.4	Yrs / Dollar		B/C (SL) =	167.2	Yrs / Dollar
B/C (NBA) =	65.0	Ft-yr/ft/Dollar		B/C (NBA) =	103.1	Ft-yr/ft/Dollar
Category:	Gain SL by Stone Interlayer		=	-0.3 Yrs	Category:	
x18	Gain NBA by Stone Interlayer		=	-0.5 Ft-yr/ft	x20	

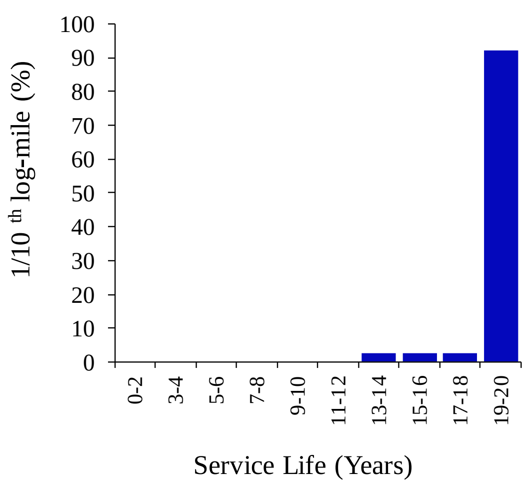
Figure 199: IRI comparison for stone interlayer, CSD base (Cat. x18 vs x20)

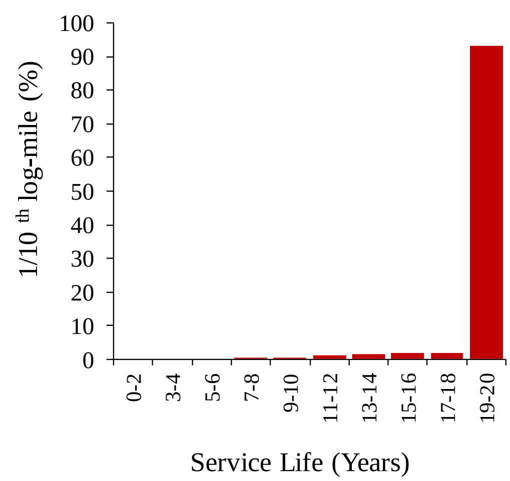
IRI Comparison (6 data points)

AST Interlayer Evaluation (Over CSD). Figure 200 and Figure 201 illustrate the IRI comparison for Category x1' vs x5' and Category x4' vs x8' for 6 data points, respectively. For the lower ESAL and less thickness Category x1' vs x5' (as shown in Figure 200), AST interlayer over CSD sections behave similar to no interlayer sections. It should be noted here that there were only three available projects for AST interlayer over CSD for this comparison, hence this result is not conclusive.

IRI COMPARISON, CSD Bases, AST vs NO Interlayer							
ESAL Category	0	30000	ESAL		**Data Category**	6	Data points
Thickness Category	0	4	inches		**Base Category**	CSD	Soil Cement

AST INTERLAYER							**NO INTERLAYER**					
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev		N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
3	38	19.6	1.3	12.3	2.3		46	1710	19.6	1.9	12.0	2.4



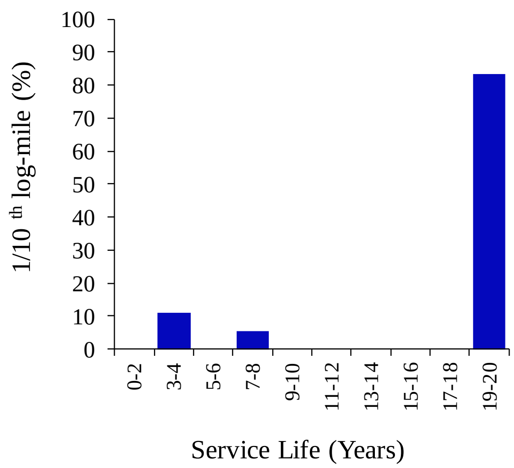


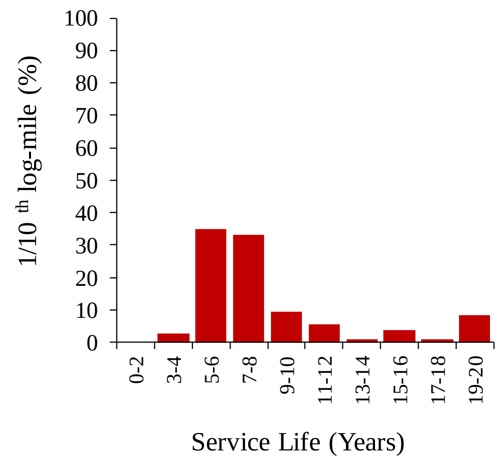
B/C (SL) =	143.8	Yrs / Dollar		B/C (SL) =	166.5	Yrs / Dollar
B/C (NBA) =	89.8	Ft-yr/ft/Dollar		B/C (NBA) =	101.7	Ft-yr/ft/Dollar
Category:	Gain SL by AST Interlayer		=	0.0	Yrs	Category:
x1'	Gain NBA by AST Interlayer		=	0.3	Ft-yr/ft	x5'

Figure 200: IRI comparison for AST vs no interlayer, CSD base (Cat. x1' vs x5')

IRI COMPARISON, CSD Bases, AST vs NO Interlayer							
ESAL Category	30001	2E6	ESAL		**Data Category**	6	Data points
Thickness Category	4.1	10	inches		**Base Category**	CSD	Soil Cement

AST INTERLAYER							NO INTERLAYER					
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev		N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
2	18	17.5	5.9	9.1	4.0		2	106	8.6	4.3	4.0	2.2





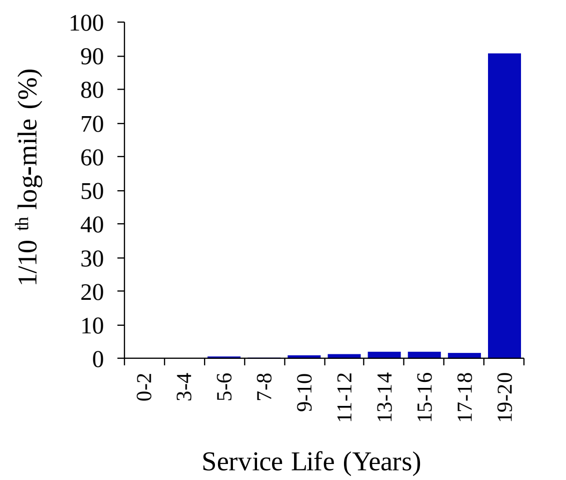
B/C (SL) =	91.6	Yrs / Dollar		B/C (SL) =	34.0	Yrs / Dollar
B/C (NBA) =	47.6	Ft-yr/ft/Dollar		B/C (NBA) =	15.9	Ft-yr/ft/Dollar
Category:	Gain SL by AST Interlayer		=	8.8 Yrs		Category:
x4'	Gain NBA by AST Interlayer		=	5.0 Ft-yr/ft		x8'

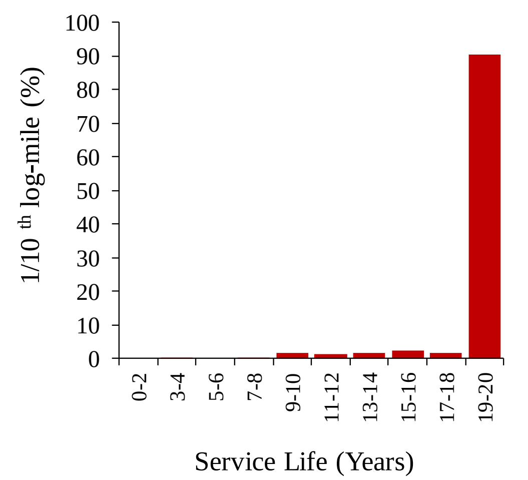
Figure 201: IRI comparison for AST vs no interlayer, CSD base (Cat. x4' vs x8')

AST Interlayer Evaluation (Over CTD). Figure 202 compares AST interlayer over CTD with no interlayer over CTD sections for IRI. Here, the AST interlayer sections had very similar behavior compared to no interlayer sections for CTD bases.

IRI COMPARISON, CTD Bases, AST vs NO Interlayer							
ESAL Category	0	30000	ESAL		**Data Category**	6	Data points
Thickness Category	0	4	inches		**Base Category**	CTD	Soil Cement

AST INTERLAYER							NO INTERLAYER					
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev		N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
6	320	19.4	2.2	11.4	2.9		44	1288	19.3	3.2	11.8	2.7





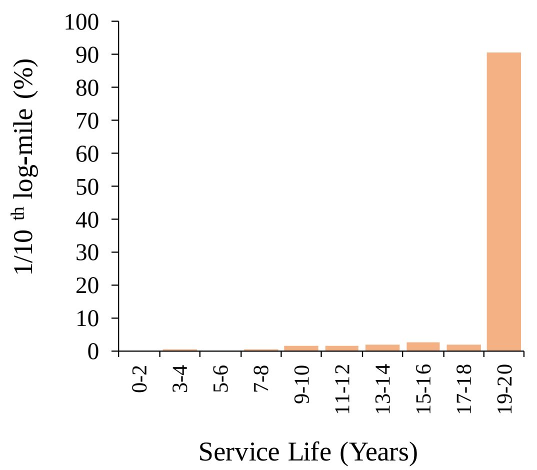
B/C (SL) =	155.6	Yrs / Dollar		B/C (SL) =	185.4	Yrs / Dollar
B/C (NBA) =	91.9	Ft-yr/ft/Dollar		B/C (NBA) =	113.1	Ft-yr/ft/Dollar
Category:	Gain SL by AST Interlayer		=	0.0 Yrs	Category:	
x9'	Gain NBA by AST Interlayer		=	-0.3 Ft-yr/ft	x13'	

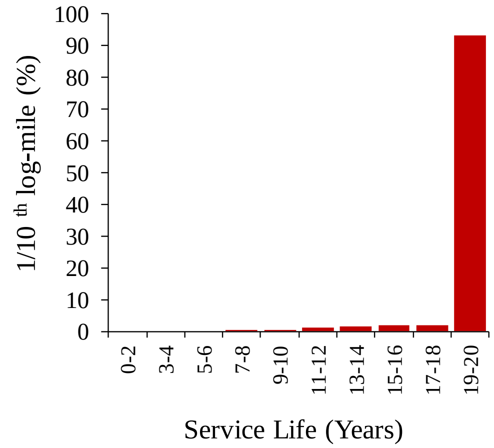
Figure 202: IRI comparison for AST vs no interlayer, CTD base (Cat. x9' vs x13')

CTD Bases Evaluation. The three comparison categories for CTD bases are shown from Figure 203 to Figure 205 for IRI. From the first two figures, it is obvious that CTD bases behave similarly to CSD bases for both ESAL categories. As CTD is inexpensive, at the end it becomes more cost-effective option than CSD bases.

IRI COMPARISON, No Int CTD vs No Int CSD Bases							
ESAL Category	0	30000	ESAL		**Data Category**	6	Data points
Thickness Category	0	4	inches		**Base Category**		Soil Cement

NO INTERLAYER, CTD							NO INTERLAYER, CSD					
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev		N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
44	1288	19.3	3.2	11.8	2.7		46	1710	19.6	1.9	12.0	2.4



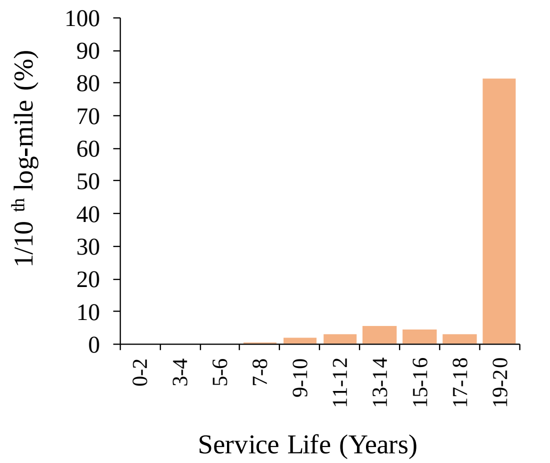


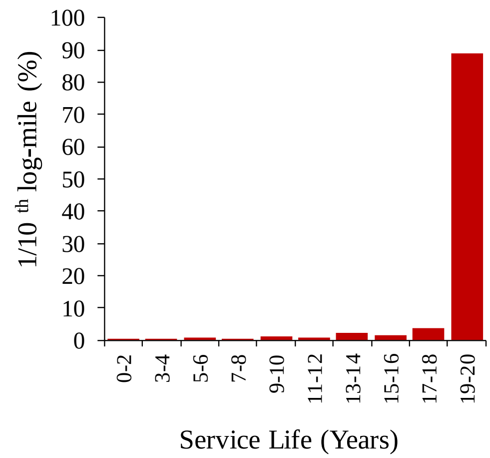
B/C (SL) =	185.4	Yrs / Dollar		B/C (SL) =	166.5	Yrs / Dollar
B/C (NBA) =	113.1	Ft-yr/ft/Dollar		B/C (NBA) =	101.7	Ft-yr/ft/Dollar
Category:	Gain SL by CTD Base		=	-0.3	Yrs	Category:
x13'	Gain NBA by CTD Base		=	-0.2	Ft-yr/ft	x5'

Figure 203: IRI comparison, CTD vs CSD base (Cat. x13' vs x5')

IRI COMPARISON, No Int CTD vs No Int CSD Bases							
ESAL Category	30001	2E6	ESAL		**Data Category**	6	Data points
Thickness Category	0	4	inches		**Base Category**		Soil Cement

NO INTERLAYER, CTD							NO INTERLAYER, CSD					
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev		N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
6	197	18.8	2.7	11.1	3.1		17	758	19.2	2.8	11.4	3.0

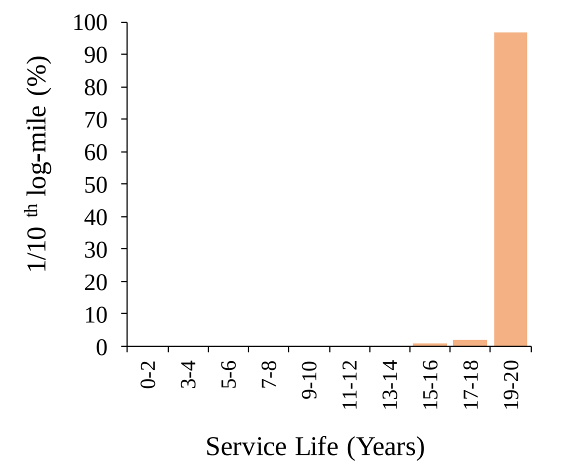


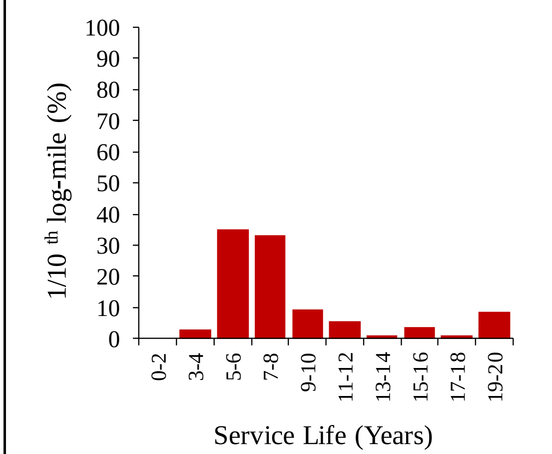


B/C (SL) =	174.9	Yrs / Dollar		B/C (SL) =	158.6	Yrs / Dollar
B/C (NBA) =	103.3	Ft-yr/ft/Dollar		B/C (NBA) =	94.3	Ft-yr/ft/Dollar
Category:	Gain SL by CTD Base		=	-0.4	Yrs	Category:
x14'	Gain NBA by CTD Base		=	-0.3	Ft-yr/ft	x6'

Figure 204: IRI comparison, CTD vs CSD base (Cat. x14' vs x6')

IRI COMPARISON, No Int CTD vs No Int CSD Bases												
ESAL Category		30001	2E6	ESAL			**Data Category**	6	Data points			
Thickness Category		4.1	10	inches			**Base Category**		Soil Cement			
NO INTERLAYER, CTD							**NO INTERLAYER, CSD**					
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev		N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
3	99	19.9	0.6	10.1	2.4		2	106	8.6	4.3	4.0	2.2





B/C (SL) =	196.7	Yrs / Dollar		B/C (SL) =	34.0	Yrs / Dollar
B/C (NBA) =	99.4	Ft-yr/ft/Dollar		B/C (NBA) =	15.9	Ft-yr/ft/Dollar
Category:	Gain SL by CTD Base		=	11.3 Yrs	Category:	
x16'	Gain NBA by CTD Base		=	6.0 Ft-yr/ft	x8'	

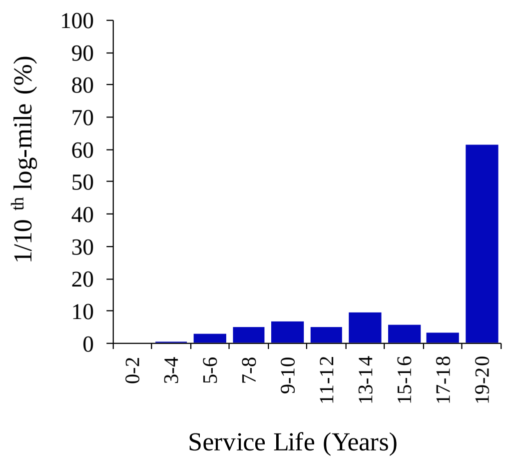
Figure 205: IRI comparison, CTD vs CSD base (Cat. x16' vs x8')

Rut Depth Comparison (3 data points)

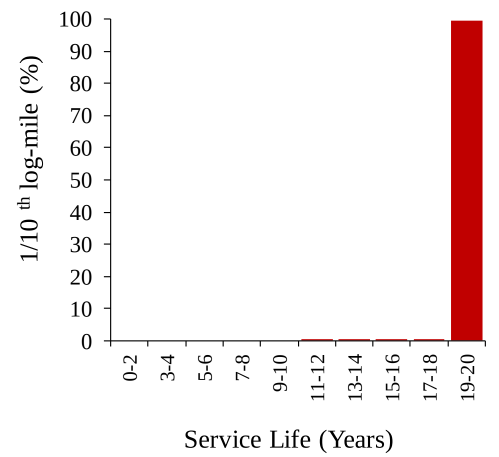
AST Interlayer Evaluation (Over CSD). Figure 206 to Figure 208 illustrate the comparison of rut depth for AST interlayer over CSD bases for the three above-mentioned categories. Figure 206 shows the comparison Category x1 vs x5 for rut depth. It is obvious from the histograms that AST interlayer creates unnecessary rutting for CSD bases. For the CSD bases without any interlayer, about 99% sections had 20 years of service life, indicating no rutting problem for the control, whereas about 38% AST interlayer sections had failed for rutting before 20 years of service lives. GainSL and GainNBA values are -3.2 years and -4.6 Ft-yr/ft for AST interlayer for this comparison category. B/C ratios are considerably higher for no interlayer over CSD bases group. Figure 207 and 208 also had a similar trend. As the Category x1 vs x5 has N(P)≥ 24 for both sides (shown in Figure 206), this result is very conclusive.

Rut Depth COMPARISON, CSD Bases, AST vs NO Interlayer							
ESAL Category	0	30000	ESAL		**Data Category**	3	Data points
Thickness Category	0	4	inches		**Base Category**	CSD	Soil Cement

AST INTERLAYER					
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
24	724	16.8	4.6	9.5	3.9



NO INTERLAYER					
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
46	1789	20.0	0.4	14.1	1.6



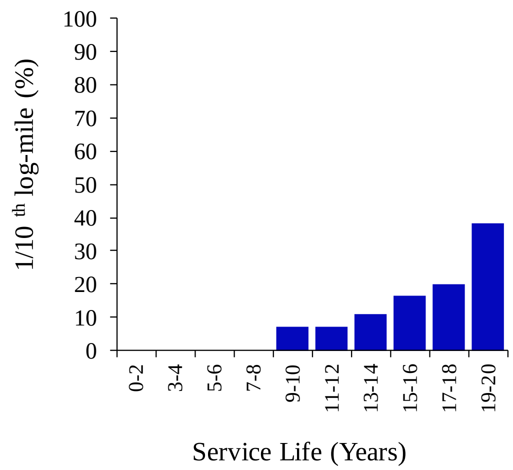
B/C (SL) =	100.6	Yrs / Dollar		B/C (SL) =	172.6	Yrs / Dollar
B/C (NBA) =	57.0	Ft-yr/ft/Dollar		B/C (NBA) =	121.5	Ft-yr/ft/Dollar
Category:	Gain SL by AST Interlayer		=	-3.2 Yrs		Category:
x1	Gain NBA by AST Interlayer		=	-4.6 Ft-yr/ft		x5

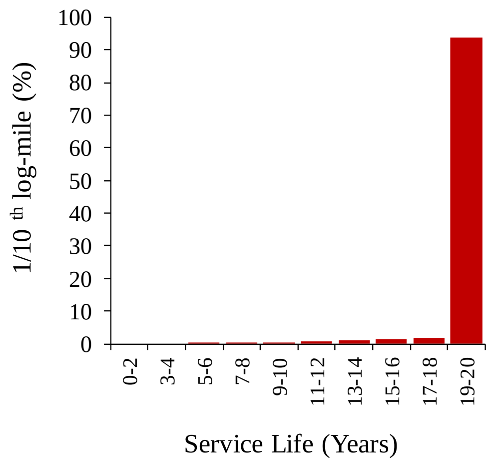
Figure 206: Rut depth comparison for AST vs no interlayer, CSD base (Cat. x1 vs x5)

Rut Depth COMPARISON, CSD Bases, AST vs NO Interlayer

ESAL Category	30001	2E6	ESAL		**Data Category**	3	Data points
Thickness Category	0	4	inches		**Base Category**	CSD	Soil Cement

AST INTERLAYER							NO INTERLAYER					
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev		N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
2	55	16.7	3.5	7.8	2.2		17	774	19.6	1.7	13.3	2.8

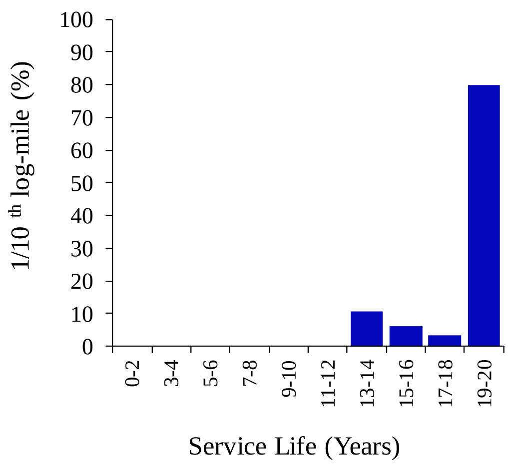




B/C (SL) =	105.2	Yrs / Dollar		B/C (SL) =		165.8	Yrs / Dollar
B/C (NBA) =	49.2	Ft-yr/ft/Dollar		B/C (NBA) =		112.6	Ft-yr/ft/Dollar
Category:	Gain SL by AST Interlayer		=	-3.0	Yrs	Category:	
x2	Gain NBA by AST Interlayer		=	-5.5	Ft-yr/ft	x6	

Figure 207: Rut depth comparison for AST vs no interlayer, CSD base (Cat. x2 vs x6)

Rut Depth COMPARISON, CSD Bases, AST vs NO Interlayer												
ESAL Category	30001	2E6	ESAL			**Data Category**	3	Data points				
Thickness Category	4.1	10	inches			**Base Category**	CSD	Soil Cement				
AST INTERLAYER							**NO INTERLAYER**					
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev		N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
8	114	19.0	2.1	11.0	3.0		2	108	20.0	0.0	12.4	2.1
B/C (SL) =		135.0	Yrs / Dollar				B/C (SL) =		173.0	Yrs / Dollar		
B/C (NBA) =		78.1	Ft-yr/ft/Dollar				B/C (NBA) =		107.1	Ft-yr/ft/Dollar		
Category:		Gain SL by AST Interlayer			=		-1.0	Yrs	Category:			
x4		Gain NBA by AST Interlayer			=		-1.4	Ft-yr/ft	x8			



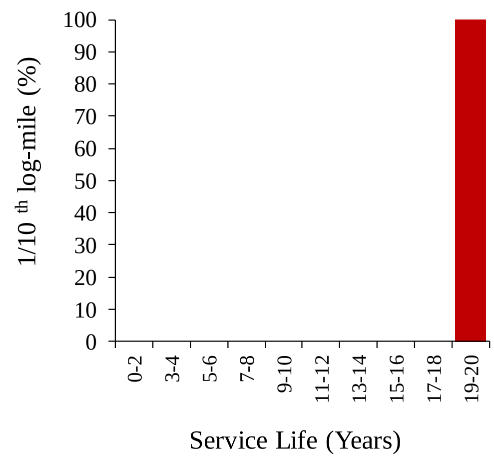
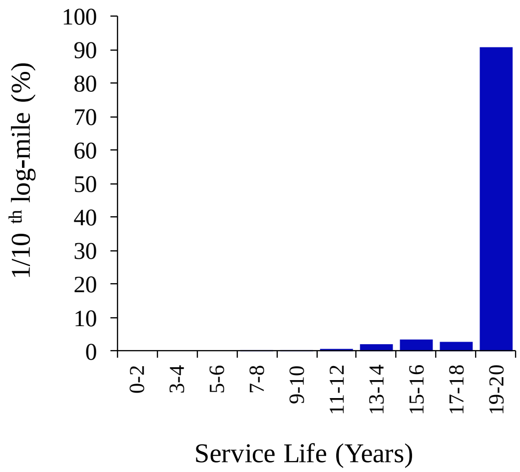


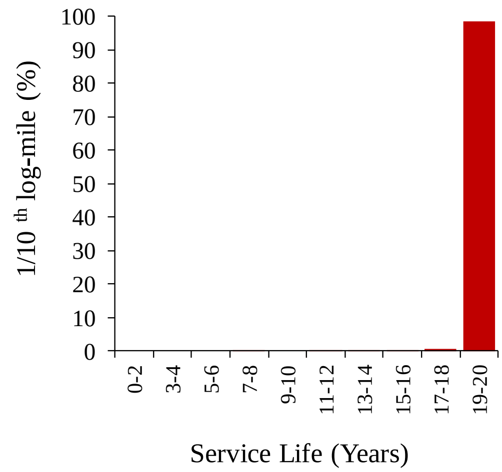
Figure 208: Rut depth comparison for AST vs no interlayer, CSD base (Cat. x4 vs x8)

AST Interlayer Evaluation (Over CTD). Figure 209 shows the comparison category for AST interlayer over CTD base performance: Category x9 vs x13. It is obvious that AST interlayer over CTD did not create significant rutting like CSD bases. It should be noted that N(P) = 6 for interlayer projects, so these results may not be that decisive.

Rut Depth COMPARISON, CTD Bases, AST vs NO Interlayer											
ESAL Category	0	30000	ESAL		**Data Category**	3	Data points				
Thickness Category	0	4	inches		**Base Category**	CTD	Soil Cement				

AST INTERLAYER							NO INTERLAYER					
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev		N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
6	347	19.5	1.6	13.7	2.9		46	1484	19.9	0.6	14.3	2.3





B/C (SL) =	159.8	Yrs / Dollar		B/C (SL) =	197.2	Yrs / Dollar
B/C (NBA) =	112.1	Ft-yr/ft/Dollar		B/C (NBA) =	141.3	Ft-yr/ft/Dollar
Category:	Gain SL by AST Interlayer		=	-0.4	Yrs	Category:
x9	Gain NBA by AST Interlayer		=	-0.6	Ft-yr/ft	x13

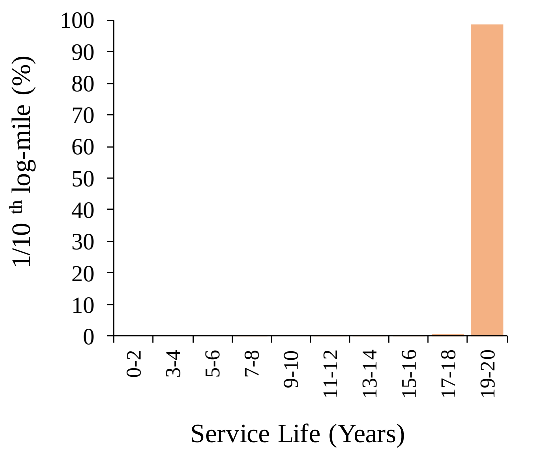
Figure 209: Rut depth comparison for AST vs no interlayer, CTD base (Cat. x9 vs x13)

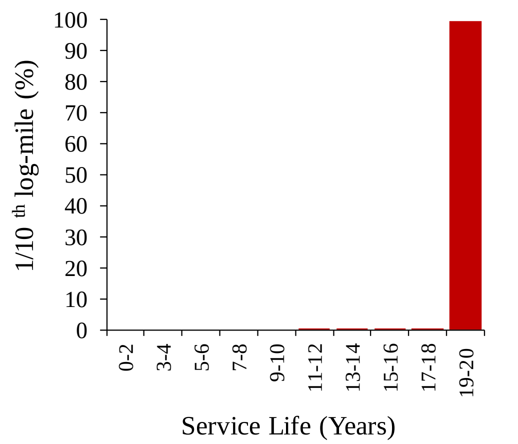
CTD Bases Evaluation. The three comparison categories for CTD base evaluation are shown from Figure 210 to Figure 212 for rut depth. From these three figures, it is shown that CTD base and CSD base have similar rut behavior. As CTD base has less installation cost, it becomes the better cost-effective option for all comparison categories. All these results indicate that CTD bases do not create any additional rutting to the pavements unlike AST interlayer.

Rut Depth COMPARISON, No Int CTD vs No Int CSD Bases

ESAL Category	0	30000	ESAL		**Data Category**	3	Data points
Thickness Category	0	4	inches		**Base Category**		Soil Cement

NO INTERLAYER, CTD							NO INTERLAYER, CSD					
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev		N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
46	1484	19.9	0.6	14.3	2.3		46	1789	20.0	0.4	14.1	1.6



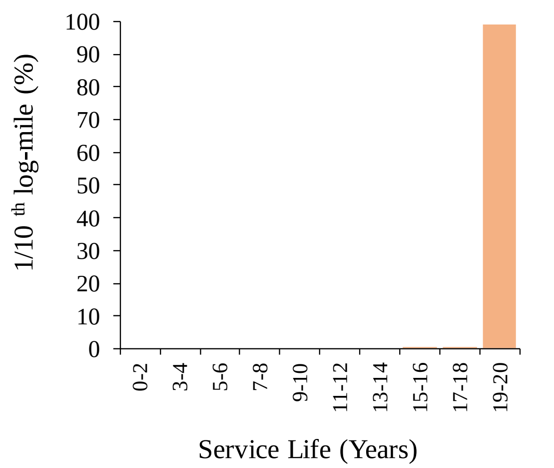


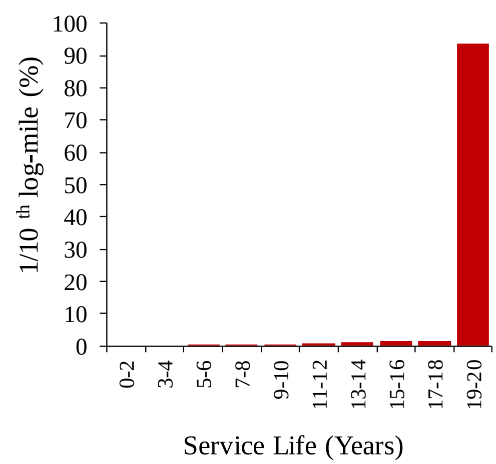
B/C (SL) =	197.2	Yrs / Dollar		B/C (SL) =	172.6	Yrs / Dollar
B/C (NBA) =	141.3	Ft-yr/ft/Dollar		B/C (NBA) =	121.5	Ft-yr/ft/Dollar
Category:	Gain SL by CTD Base		=	0.0 Yrs	Category:	
x13	Gain NBA by CTD Base		=	0.2 Ft-yr/ft	x5	

Figure 210: Rut depth comparison, CTD vs CSD base (Cat. x13 vs x5)

Rut Depth COMPARISON, No Int CTD vs No Int CSD Bases								
ESAL Category	30001	2E6	ESAL		**Data Category**	3	Data points	
Thickness Category	0	4	inches		**Base Category**		Soil Cement	

NO INTERLAYER, CTD							NO INTERLAYER, CSD					
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev		N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
6	209	20.0	0.3	14.2	1.6		17	774	19.6	1.7	13.3	2.8



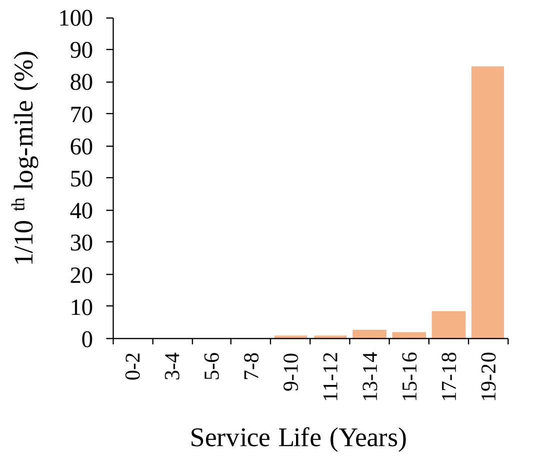


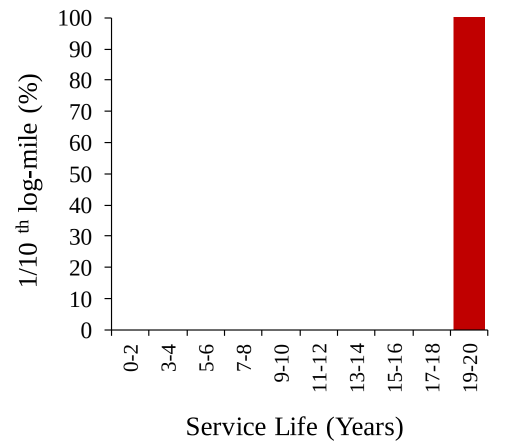
B/C (SL) =	198.0	Yrs / Dollar		B/C (SL) =	165.8	Yrs / Dollar
B/C (NBA) =	140.9	Ft-yr/ft/Dollar		B/C (NBA) =	112.6	Ft-yr/ft/Dollar
Category:	Gain SL by CTD Base		=	0.4	Yrs	Category:
x14	Gain NBA by CTD Base		=	0.9	Ft-yr/ft	x6

Figure 211: Rut depth comparison, CTD vs CSD base (Cat. x14 vs x6)

Rut Depth COMPARISON, No Int CTD vs No Int CSD Bases							
ESAL Category	30001	2E6	ESAL		**Data Category**	3	Data points
Thickness Category	4.1	10	inches		**Base Category**		Soil Cement

NO INTERLAYER, CTD							**NO INTERLAYER, CSD**					
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev		N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
3	106	19.3	1.8	12.9	3.3		2	108	20.0	0.0	12.4	2.1





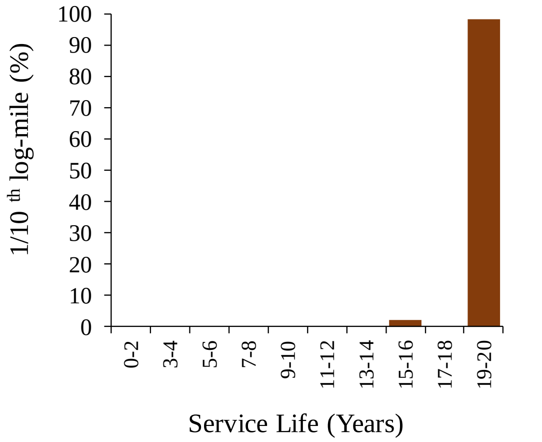
B/C (SL) =	185.5	Yrs / Dollar		B/C (SL) =	173.0	Yrs / Dollar
B/C (NBA) =	124.1	Ft-yr/ft/Dollar		B/C (NBA) =	107.1	Ft-yr/ft/Dollar
Category:	Gain SL by CTD Base		=	-0.7 Yrs	Category:	
x16	Gain NBA by CTD Base		=	0.5 Ft-yr/ft	x8	

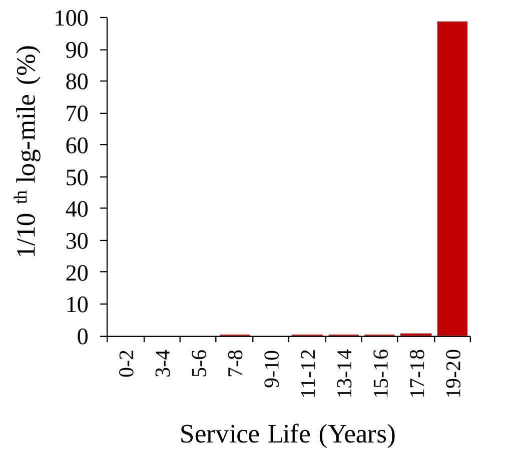
Figure 212: Rut depth comparison, CTD vs CSD base (Cat. x16 vs x8)

Stone Interlayer Evaluation. For IRI, Figure 213 and Figure 214 evaluate stone interlayer for CTD and CSD bases, respectively. For both cases, stone interlayer has analogous behavior to no interlayer. Also, from the histogram comparison, it is evident that the stone interlayer sections did not create any additional rutting.

Rut Depth COMPARISON, CTD Bases, Stone vs No Interlayer							
ESAL Category	0	150000	ESAL		**Data Category**	3	Data points
Thickness Category	0	5	inches		**Base Category**	CTD	Soil Cement

STONE INTERLAYER, CTD							**NO INTERLAYER, CTD**					
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev		N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
2	50	19.9	0.5	12.0	1.9		55	1807	19.9	0.6	14.3	2.3



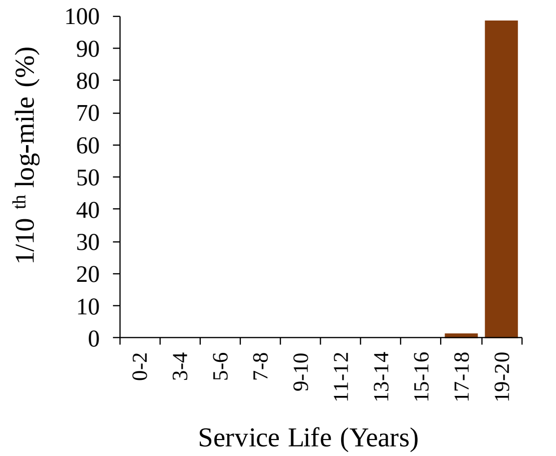


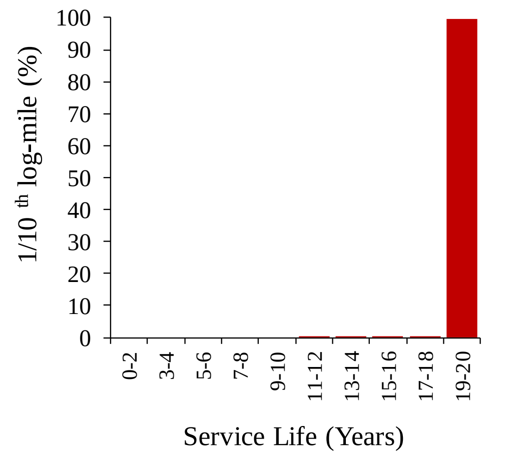
B/C (SL) =	124.5	Yrs / Dollar		B/C (SL) =	197.3	Yrs / Dollar
B/C (NBA) =	75.3	Ft-yr/ft/Dollar		B/C (NBA) =	141.9	Ft-yr/ft/Dollar
Category:	Gain SL by Stone Interlayer		=	0.0	Yrs	Category:
x17	Gain NBA by Stone Interlayer		=	-2.3	Ft-yr/ft	x19

Figure 213: Rut depth comparison for stone vs no interlayer, CTD base (Cat. x17 vs x19)

Rut Depth COMPARISON, CSD Bases, Stone vs No Interlayer							
ESAL Category	0	30000	ESAL		**Data Category**	3	Data points
Thickness Category	0	5	inches		**Base Category**	CSD	Soil Cement

STONE INTERLAYER, CSD							NO INTERLAYER, CSD					
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev		N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
3	68	20.0	0.2	13.1	1.6		46	1789	20.0	0.4	14.1	1.6





B/C (SL) =	114.3	Yrs / Dollar		B/C (SL) =	172.6	Yrs / Dollar
B/C (NBA) =	74.9	Ft-yr/ft/Dollar		B/C (NBA) =	121.5	Ft-yr/ft/Dollar
Category:	Gain SL by Stone Interlayer		=	0.0 Yrs	Category:	
x18	Gain NBA by Stone Interlayer		=	-1.0 Ft-yr/ft	x20	

Figure 214: Rut depth comparison for stone vs no interlayer, CSD base (Cat. x18 vs x20)

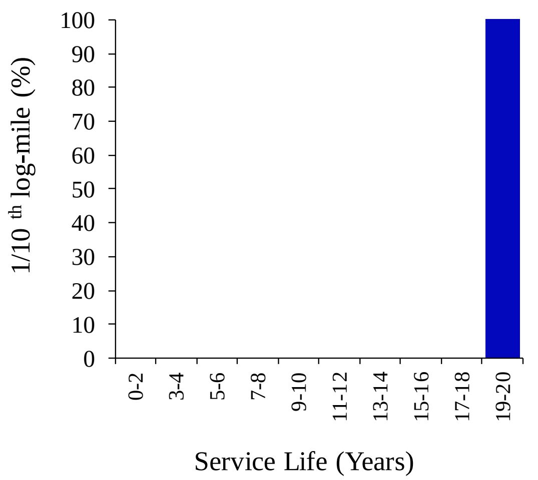
Rut Depth Comparison (6 data points)

AST Interlayer Evaluation (Over CSD). Figure 215 and Figure 216 illustrates the rut depth comparison for Category x1' vs x5' and Category x4' vs x8' for 6 data points, respectively. For both comparison categories, the AST interlayer over CSD sections behave similar to no interlayer sections. It should be notified here that there were only three available projects for AST interlayer over CSD for this comparison, hence these results are not conclusive.

Rut Depth COMPARISON, CSD Bases, AST vs NO Interlayer							
ESAL Category	0	30000	ESAL		**Data Category**	6	Data points
Thickness Category	0	4	inches		**Base Category**	CSD	Soil Cement

AST INTERLAYER

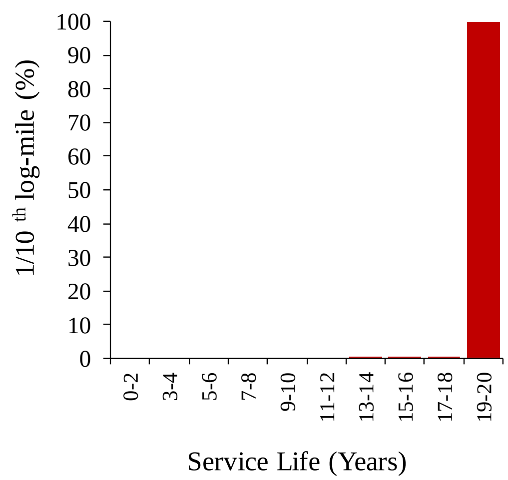
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
3	40	20.0	0.0	13.7	1.2



B/C (SL) =	148.9	Yrs / Dollar
B/C (NBA) =	101.8	Ft-yr/ft/Dollar

NO INTERLAYER

N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
46	1789	20.0	0.2	15.4	1.5



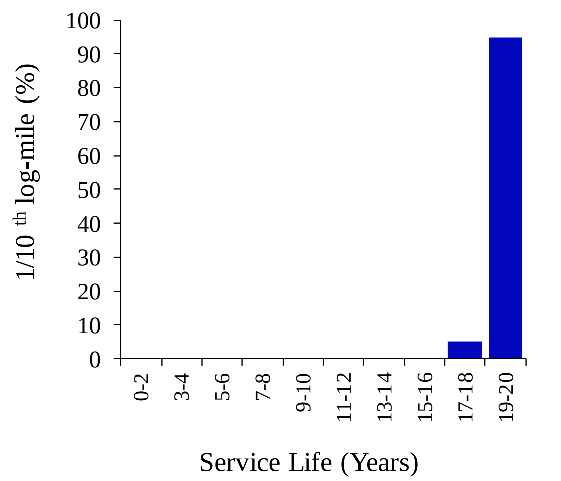
B/C (SL) =	172.9	Yrs / Dollar
B/C (NBA) =	133.3	Ft-yr/ft/Dollar

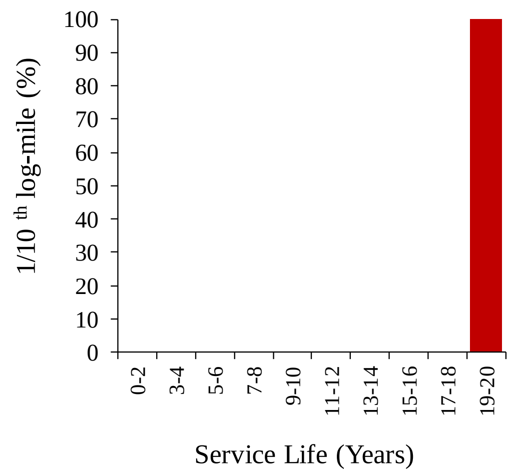
Category:	Gain SL by AST Interlayer	=	0.0	Yrs	Category:
x1'	Gain NBA by AST Interlayer	=	-1.7	Ft-yr/ft	x5'

Figure 215: Rut depth comparison for AST vs no interlayer, CSD base (Cat. X1' vs x5')

Rut Depth COMPARISON, CSD Bases, AST vs NO Interlayer							
ESAL Category	30001	2E6	ESAL		**Data Category**	6	Data points
Thickness Category	4.1	10	inches		**Base Category**	CSD	Soil Cement

AST INTERLAYER							NO INTERLAYER					
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev		N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
2	20	19.9	0.3	12.3	2.1		2	108	20.0	0.0	13.7	1.8





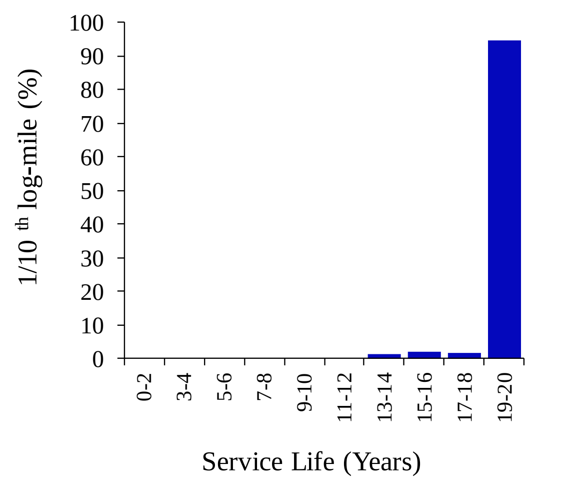
B/C (SL) =	147.9	Yrs / Dollar		B/C (SL) =	173.0	Yrs / Dollar
B/C (NBA) =	91.0	Ft-yr/ft/Dollar		B/C (NBA) =	118.2	Ft-yr/ft/Dollar
Category:	Gain SL by AST Interlayer		=	-0.1	Yrs	Category:
x4'	Gain NBA by AST Interlayer		=	-1.4	Ft-yr/ft	x8'

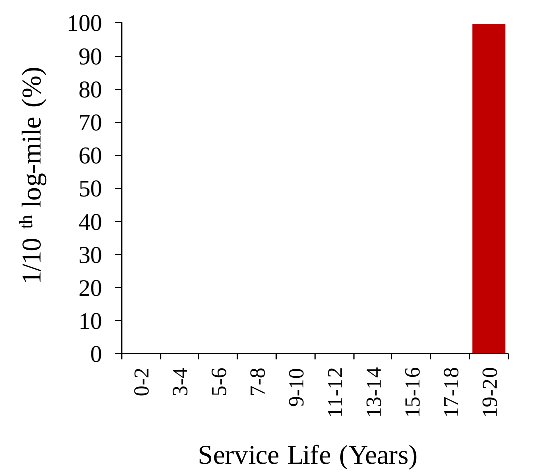
Figure 216: Rut depth comparison for AST vs no interlayer, CSD base (Cat. X4' vs x8')

AST Interlayer Evaluation (Over CTD). Figure 217 compares the AST interlayer over CTD with no interlayer over CTD sections for rut depth. Here, the AST interlayer sections has very similar behavior in comparison to no interlayer sections for CTD bases.

Rut Depth COMPARISON, CTD Bases, AST vs NO Interlayer							
ESAL Category	0	30000	ESAL		**Data Category**	6	Data points
Thickness Category	0	4	inches		**Base Category**	CTD	Soil Cement

AST INTERLAYER							NO INTERLAYER					
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev		N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
6	347	19.8	1.0	14.2	2.5		46	1485	20.0	0.4	15.0	1.7





B/C (SL) =	163.9	Yrs / Dollar		B/C (SL) =	198.1	Yrs / Dollar
B/C (NBA) =	117.5	Ft-yr/ft/Dollar		B/C (NBA) =	149.1	Ft-yr/ft/Dollar
Category:	Gain SL by AST Interlayer		=	-0.2 Yrs	Category:	
x9'	Gain NBA by AST Interlayer		=	-0.9 Ft-yr/ft	x13'	

Figure 217: Rut depth comparison for AST vs no interlayer, CTD base (Cat. x9' vs x13')

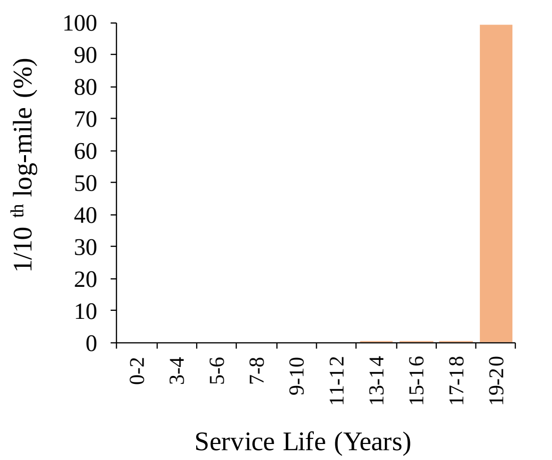
CTD Bases Evaluation. The three comparison categories for CTD bases are shown from Figure 218 to Figure 220 for rut depth. From these three figures, it is clear that CTD bases behave very similar to CSD bases for both ESAL categories. As CTD is inexpensive, at the end it becomes a more cost-effective option than CSD bases.

Rut Depth COMPARISON, No Int CTD vs No Int CSD Bases

ESAL Category	0	30000	ESAL		**Data Category**	6	Data points
Thickness Category	0	4	inches		**Base Category**		Soil Cement

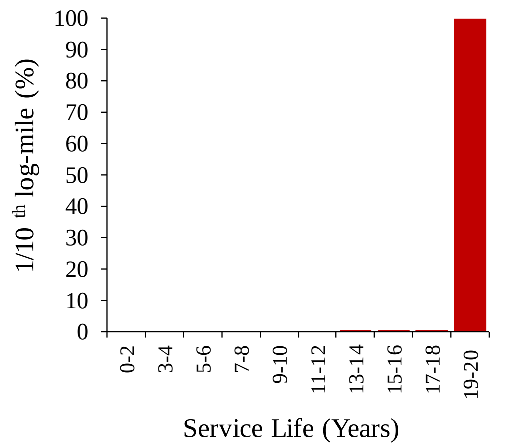
NO INTERLAYER, CTD

N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
46	1485	20.0	0.4	15.0	1.7



NO INTERLAYER, CSD

N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
46	1789	20.0	0.2	15.4	1.5



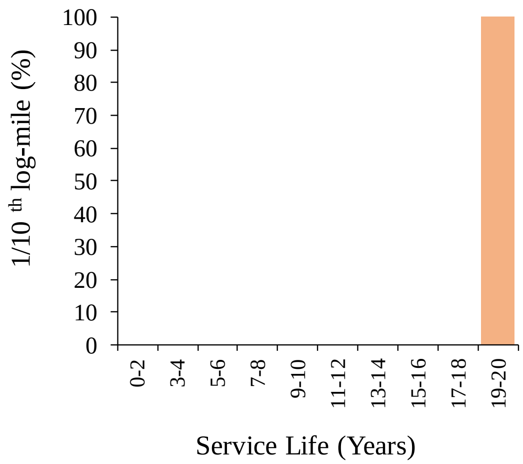
B/C (SL) =	198.1	Yrs / Dollar		B/C (SL) =	172.9	Yrs / Dollar
B/C (NBA) =	149.1	Ft-yr/ft/Dollar		B/C (NBA) =	133.3	Ft-yr/ft/Dollar
Category:	Gain SL by CTD Base		=	0.0 Yrs	Category:	
x13'	Gain NBA by CTD Base		=	-0.4 Ft-yr/ft	x5'	

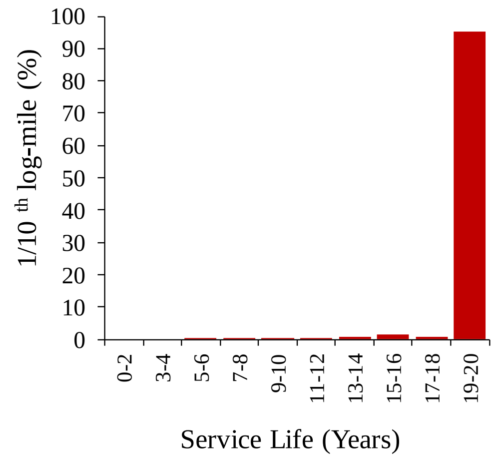
Figure 218: Rut depth comparison, CTD vs CSD base (Cat. x13' vs x5')

Rut Depth COMPARISON, No Int CTD vs No Int CSD Bases

ESAL Category	30001	2E6	ESAL		**Data Category**	6	Data points
Thickness Category	0	4	inches		**Base Category**		Soil Cement

NO INTERLAYER, CTD							NO INTERLAYER, CSD					
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev		N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
6	209	20.0	0.0	14.7	1.3		17	774	19.7	1.6	14.3	2.7

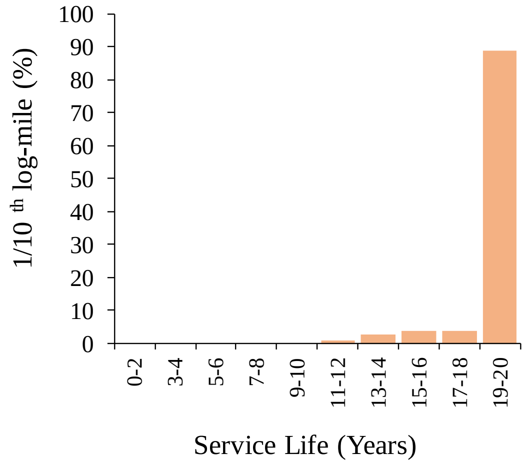


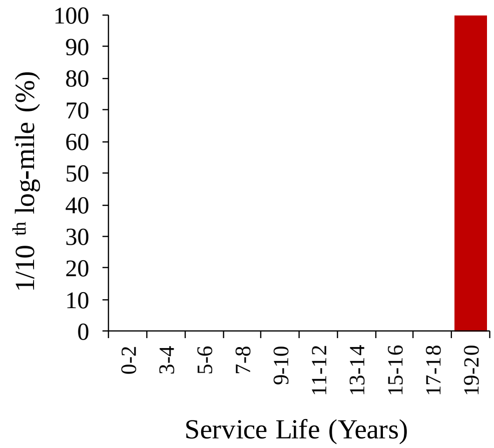


B/C (SL) =	198.5	Yrs / Dollar		B/C (SL) =	166.8	Yrs / Dollar
B/C (NBA) =	146.1	Ft-yr/ft/Dollar		B/C (NBA) =	120.8	Ft-yr/ft/Dollar
Category:	Gain SL by CTD Base		=	0.3 Yrs	Category:	
x14'	Gain NBA by CTD Base		=	0.5 Ft-yr/ft	x6'	

Figure 219: Rut depth, CTD vs CSD base (Cat. x14' vs x6')

Rut Depth COMPARISON, No Int CTD vs No Int CSD Bases												
ESAL Category		30001	2E6	ESAL			**Data Category**		6	Data points		
Thickness Category		4.1	10	inches			**Base Category**			Soil Cement		
NO INTERLAYER, CTD							**NO INTERLAYER, CSD**					
N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev		N(P)	N(S)	AvgSL	StDev	AvgNBA	StDev
3	106	19.4	1.7	12.8	3.1		2	108	20.0	0.0	13.7	1.8





B/C (SL) =	187.6	Yrs / Dollar		B/C (SL) =	173.0	Yrs / Dollar
B/C (NBA) =	124.0	Ft-yr/ft/Dollar		B/C (NBA) =	118.2	Ft-yr/ft/Dollar
Category:	Gain SL by CTD Base		=	-0.6 Yrs	Category:	
x16'	Gain NBA by CTD Base		=	-0.8 Ft-yr/ft	x8'	

Figure 220: Rut depth comparison, CTD vs CSD base (Cat. x16' vs x8')

Summary of All Comparisons

The 3 data points analyses have sufficient data for all cases, but the 6 data points analyses do not have sufficient data for these comparisons with a few exceptions. Hence, for a simple comparison, all the results are summarized in Table 27 for 3 data points analyses. From this table, it is shown that AST interlayer has positive Gain SL values for only CSD pavements for TC and AC distress. But AST interlayer creates significant rut depth for CSD pavements. IRI and LC are not much affected by AST interlayer. However, CTD pavements behave either similar to or better than CSD pavements for these distress types. CTD pavements also do not create any additional rutting or roughness problems. Moreover, CTD pavements behave better or analogous to CSD pavements for higher ESAL category. It should also be remembered that AST interlayer does not have enough projects for higher ESAL for a strong conclusion. Moreover, AST interlayer does not provide any Gain SL/NBA values for a few higher ESAL/Thickness projects that were analyzed.

Stone interlayer also provides significantly higher GainSL (4 to 6 years) and GainNBA for TC and AC, and also does not create any rutting or roughness problem. But stone interlayer has only two CTD projects and three CSD projects, hence these results are preliminary.

Table 27: Summary of AST interlayer performance evaluation over CSD/CTD bases

Distress Type	Interlayer Type	Base Type	Average Life (Years)	StDev (Years)	Number of accepted Projects	Number of accepted 1/10th log miles	GainSL (Years)
TC	AST Interlayer	CSD	14.3	6.1	26	718	***2.7***
		CTD	13.3	4.8	6	347	***-0.9***
	No Interlayer	CSD	11.6	4.6	46	1785	
		CTD	14.2	5.4	46	1476	
LC	AST Interlayer	CSD	15.3	6.2	26	695	***-0.6***
		CTD	15.3	5	6	344	***-0.3***
	No Interlayer	CSD	16	5	45	1718	
		CTD	15.5	5.4	46	1463	
AC	AST Interlayer	CSD	14.7	6.6	27	736	***2.2***
		CTD	14	5.3	6	346	***0.9***
	No Interlayer	CSD	12.5	5.7	46	1786	
		CTD	13.2	6	46	1458	
IRI	AST Interlayer	CSD	18.3	3.7	19	570	***-1.3***
		CTD	19.4	2.2	6	314	***0.6***
	No Interlayer	CSD	19.7	1.5	46	1584	
		CTD	18.8	3.8	44	1178	
RUT	AST Interlayer	CSD	16.8	4.6	24	724	***-3.2***
		CTD	19.5	1.6	6	347	***-0.4***
	No Interlayer	CSD	20.0	0.4	46	1789	
		CTD	19.9	0.6	46	1484	

To summarize, even though AST interlayer provides 2 to 3 years of service life extension (for TC and AC, for CSD sections only), it is not cost-effective at the end as it creates additional rutting in the pavement. The CTD pavement without any interlayer that becomes the most cost-effective option as it is inexpensive in nature, buts provide similar benefits to AST interlayer to reduce TC and AC, and also, does not create any rutting and roughness in the pavement.

Comparison of Benefit/Cost Ratios

Benefit ratios for all reflective crack mitigation techniques with significant data are compared in this section for all distress types. AST interlayer over CSD, AST interlayer over CTD, no interlayer over CTD—these three techniques are compared with the control group: no interlayer over CSD by bar charts. It's worth mentioning here that the comparison of B/C ratios shown here represents only 3 data points analyses, as it has sufficient data.

Figure 221 to Figure 225 illustrate the B/C ratios comparison for transverse cracking, longitudinal cracking, alligator cracking, IRI, and rut depth, respectively. For transverse and alligator cracking (shown in Figure 221 and Figure 223), the AST interlayer over CSD has slightly higher B/C ratios than control, as it provides some GainSL and GainNBA for these two distresses. But for longitudinal and IRI (shown in Figure 222 and Figure 224), AST interlayer over CSD has less B/C ratios than control, as it did not provide any significant GainSL or GainNBA. Moreover, as AST interlayer over CSD creates significant rutting, it has negative GainSL and GainNBA for rut depth analysis. Hence, AST interlayer over CSD has significantly lower B/C ratios than control for rutting (shown in Figure 225). Subsequently, the net effect of B/C ratios are not in favor of AST interlayer over CSD. Figure 226 illustrates the net B/C ratios for all reflective crack mitigation techniques, and AST interlayer over CSD become the least cost-effective option.

On the contrary, CTD base without any interlayer provides similar GainSL and GainNBA as AST interlayer for transverse and alligator cracking. At the same time, CTD base did not create any additional roughness or rutting. Moreover, CTD base installation is inexpensive with respect to CSD base. Hence, CTD base usually has more B/C ratios than control for any distress type. Subsequently, the net B/C ratio is highest for CTD base without any interlayer. Hence, CTD base without any interlayer became the most cost-effective option for reflective crack mitigation technique.

Now, AST interlayer over CTD base has similar net B/C ratios as control CSD base.

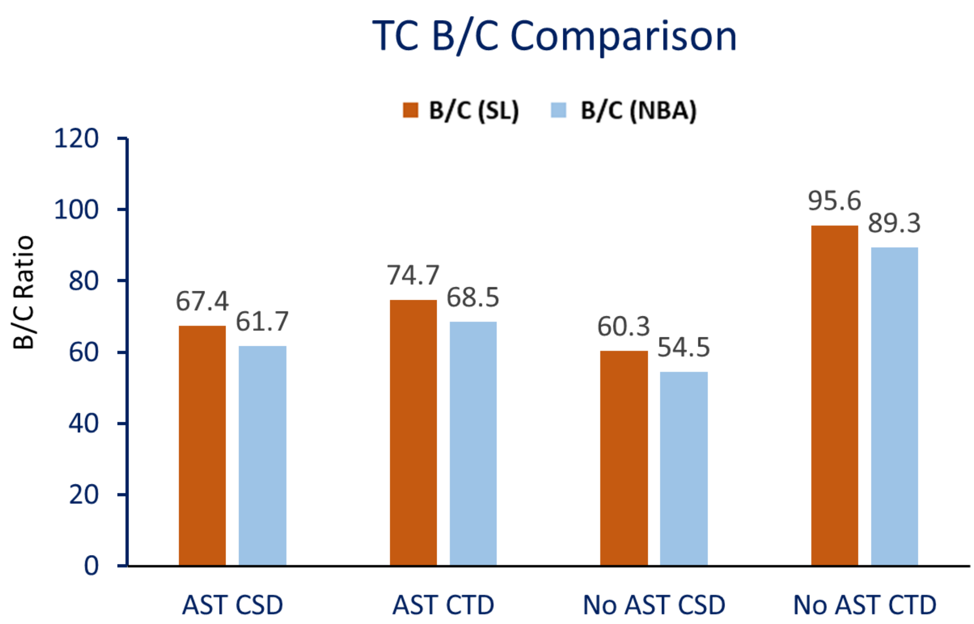


Figure 221: Transverse cracking B/C ratios comparison

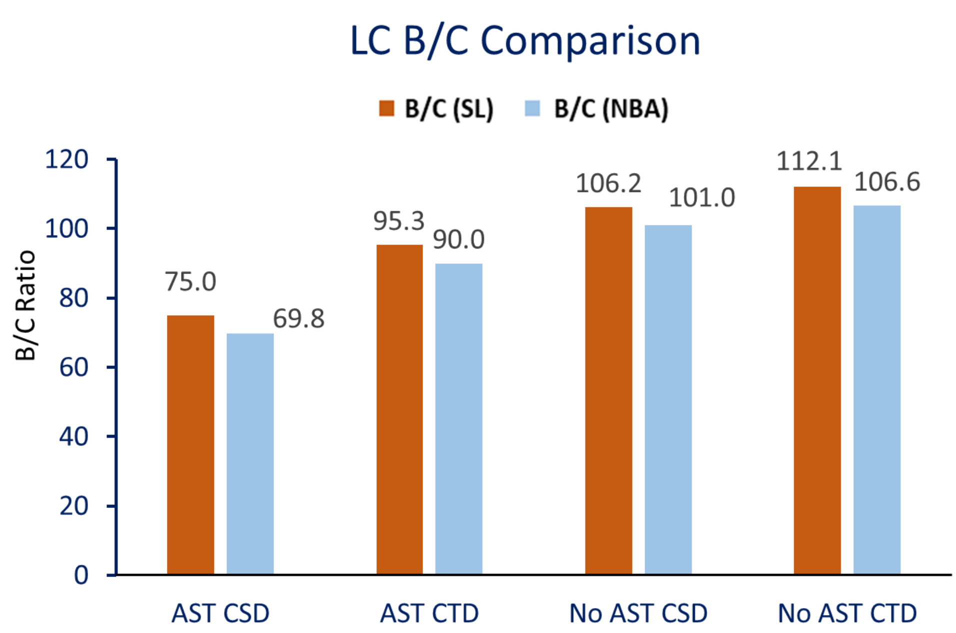


Figure 222: Longitudinal cracking B/C ratios comparison

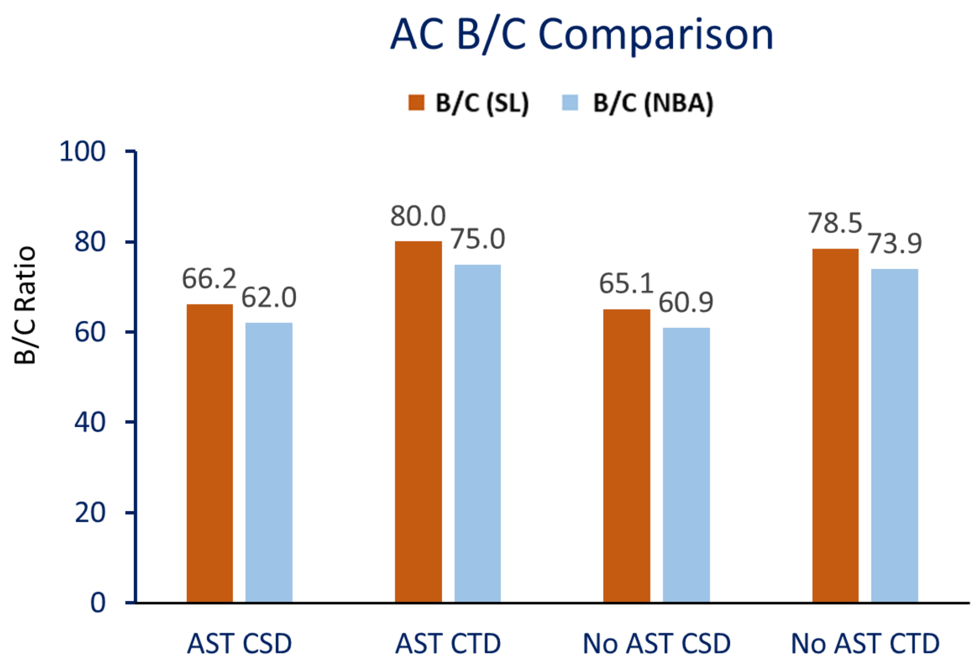


Figure 223: Alligator cracking B/C ratios comparison

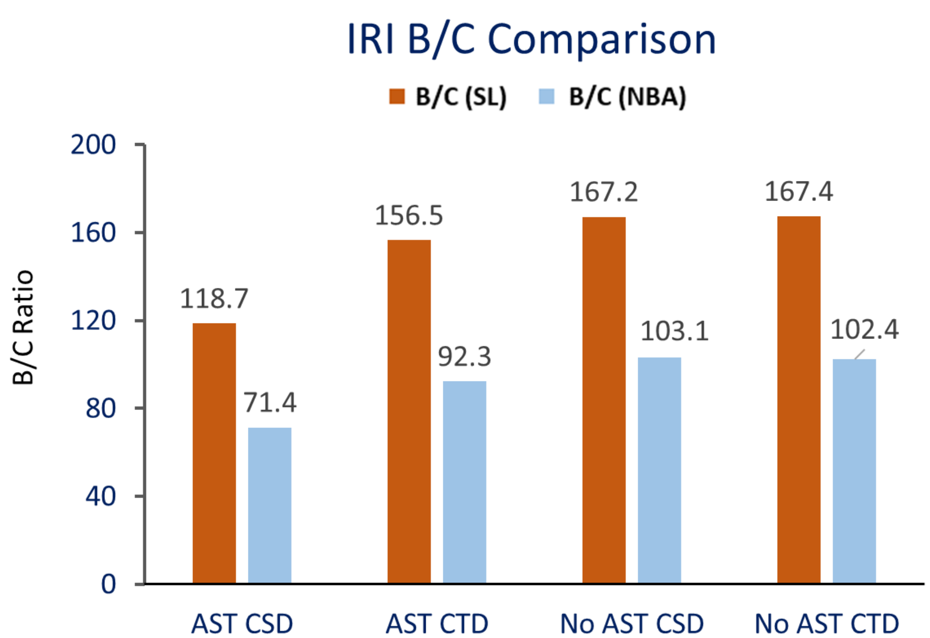


Figure 224: IRI B/C ratios comparison

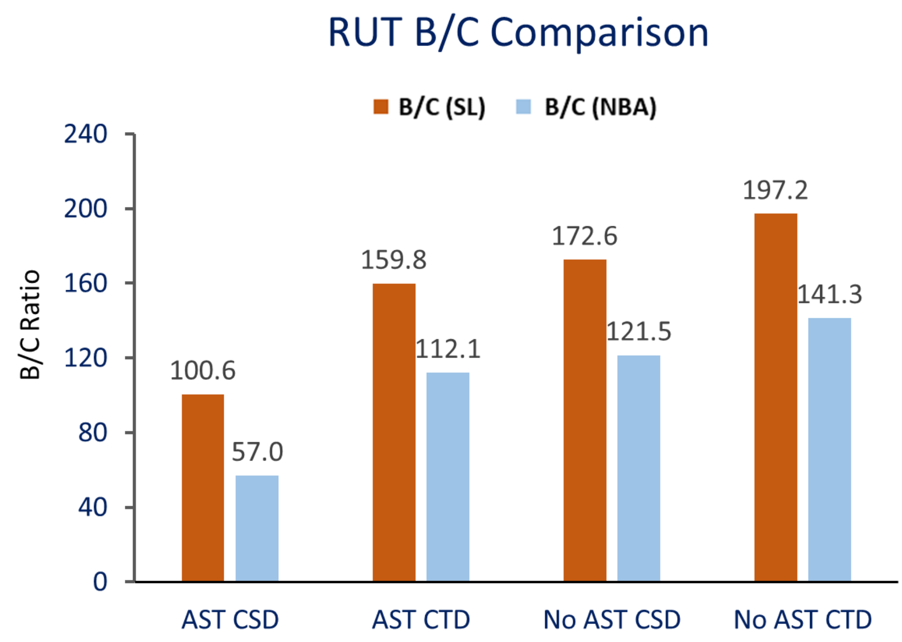


Figure 225: Rut B/C ratios comparison

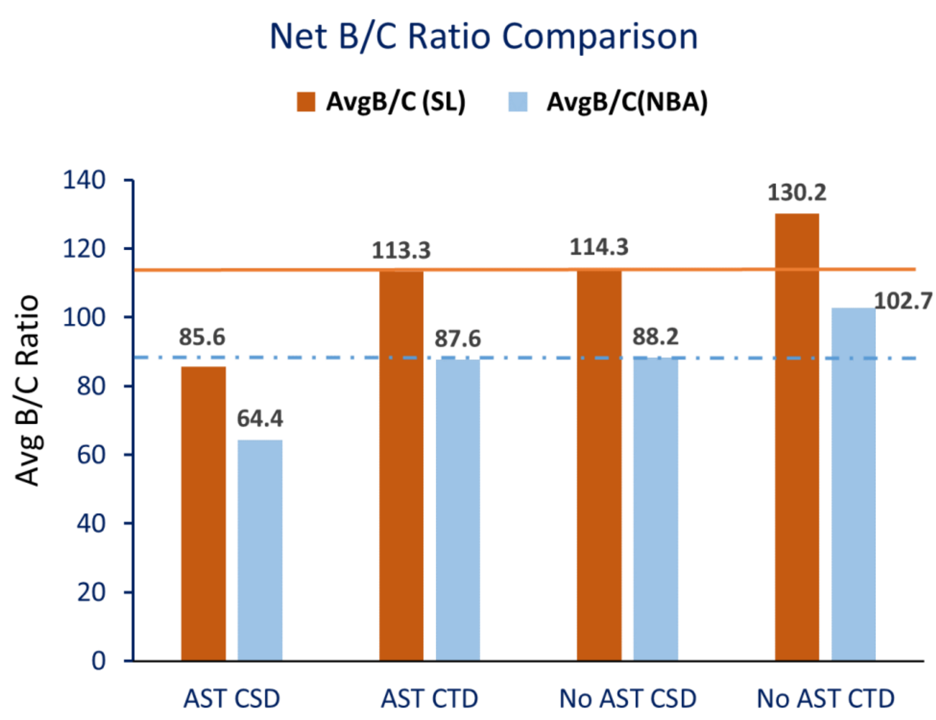


Figure 226: Net B/C ratios comparison

CONCLUSIONS

Based on the comprehensive review of state-of the-practice and analyses of the results, the summary and conclusions are presented below.

District Survey

1. The results of the district survey indicated that most of the districts use distress data and visual inspection for pavement evaluation. Some also use coring or non-destructive testing (NDT) for evaluation. Furthermore, the majority of the districts base their decisions to apply AST to improve ride quality, retard distress, reflective cracks, and distress propagation.
2. Several districts use AST interlayer on CSD soil-cement bases of flexible pavements to improve its performance. A few also reported that they use AST interlay on CTD bases. Additionally, most districts allow a curing time of 7 days before AST application while some wait for only 3 days.
3. It was found that AST interlayers did not affect the contract elapsed time between project identification and construction. The elapsed time varied from district to district, usually 6 to 36 months, as part of regular process.
4. Most districts reported that 1 to 3 contractors bid on such projects. In some districts, 4 to 6 bids/projects. The quality of contractors biding on the projects was ranked fair to good (mostly good) by the district engineers. Districts are also satisfied from their work.
5. The survey results ascertained that the service life of AST interlayer on soil-cement projects varied from 10 to 20 years. The districts reported that about 33% of the sections improved after AST interlayer was applied on soil-cement bases. Also, most agreed that the performance of AST was affected by construction procedure, quality control, and moisture damage.
6. It was found that the AST and no AST interlayer over soil-cement base were more susceptible to transverse followed by longitudinal and alligator cracking. The District 08 reported that AST interlayer showed no improvement in service life as compared to no AST interlayer bases. This was mainly due to the desiccation of soil-bases, which generated with larger crack widths. District 08 also recommended considering AST (chip seal) on top of HMA layer to extend its service life and maximize the benefit/costs of AST.

AST Performance Evaluation and Comparison

7. The results of this study showed that the transverse cracking was the controlling distress with SL of 14.3 years for AST interlayer and 11.6 years of SL for no AST interlayers on CSD bases, respectively. This provided a Gain in SL of 2.7 years. On the other hand, the AST interlayer and no interlayer have SL of 13.3 years and 14.2 years, respectively over CTD base. Thus indicating no improvement in SL if AST interlayer was used over CTD bases.
8. The B/C ratio in terms of SL and NBA using transverse cracking performance revealed that on average the AST interlayer has about 13% more benefit than the no AST interlayer for CSD bases. However, CTD bases with no AST interlayer exhibited around 61% more benefits. It happens because CTD bases with no AST interlayer are inexpensive in nature with respect to AST interlayer over CSD bases.
9. In case of longitudinal cracking there was no improvement found due to the application of AST interlayer on both CSD and CTD bases. On average the SL was 15.5 years for all the cases studied. As mentioned before due to the slightly higher cost of the AST interlayer, the B/C was lower for AST interlayer projects. Since no interlayer CTD base was inexpensive with the same or better performance, it became the most cost-effective option.
10. The alligator performance was somewhat similar to the transverse cracking. The SL based on alligator cracking was found to be 14.7 years and 12.5 for AST and no AST interlayer over CSD bases, respectively. Thus, the gain in SL is 2.2 years for CSD base. On the other hand, the AST interlayer and no interlayer have SL of 14.0 years and 13.2, respectively, over CTD base, reflecting a slight improvement in SL when AST interlayer was used.
11. The B/C ratio in terms of SL and NBA using alligator crack performance demonstrates that on average the AST interlayer showed similar benefit in comparison to no AST interlayer for CSD bases. However, for CTD bases, the no AST interlayer showed about 21% more benefit. Similar to TC cracking, the alligator cracking performance exhibited higher B/C for no AST interlayer on CTD base.
12. The evaluation of roughness indicates that there was no improvement found in IRI due to the application of AST interlayer on both CSD and CTD bases. On average the SL was 19 years for all the cases studied. Due to the slightly higher cost of the AST interlayer, the B/C was lower for AST interlayer projects. Since the no interlayer CTD base was inexpensive with the same or better performance, it is cost-effective like CSD base for IRI.
13. The rut depth performance was very dissimilar to other distress types. It was found that AST interlayer on CSD base generates unnecessary rutting in the pavement. Only about 62% of sections retained 20 years of service life for AST interlayer, whereas about 99% retained for rutting in case of no AST interlayer over CSD bases. In other words, 38% of sections reached

the threshold of rut life (or failed) before 20 years of service life for AST interlayer but for no interlayer, only 0.4% sections reached that threshold before 20 years of service life. On average, no AST interlayer on CSD base provides 20.0 years of SL. But AST interlayer on CSD base provides 16.8 years of SL, which means the gain in SL for AST interlayer was -3.2 years for rutting. The GainNBA values for AST interlayer was -4.6 Ft-yr/ft on CSD base.

14. The B/C ratio in terms of SL and NBA demonstrates that on average AST interlayer showed 47% less benefit than no AST interlayer on CSD base for rutting. However, the CTD base with no AST interlayer did not create any extra rutting, hence it provides 15% more benefit with respect to CSD base. It's worth mentioning here that AST interlayer over CTD bases did not create any extra rutting, but it is still less cost-effective due to the higher cost of AST interlayer. It should also be noted that AST interlayer over CTD base has only six projects for performance evaluation, hence there is not much confidence on its results.

15. The net B/C ratios were determined for each category: AST interlayer on CSD, no AST interlayer on CSD, AST interlayer on CTD, and no AST interlayer on CTD. Even though, AST interlayer on CSD base has slightly higher B/C for transverse and alligator cracking, it has relatively lower B/C for longitudinal cracking, IRI, and rut depth. Hence, due to the negative net effect of 3 distress types, AST interlayer on CSD base becomes the least cost-effective option. AST interlayer over CTD has similar B/C ratios as CSD base, but as it has only six projects, the results are not conclusive. On the contrary, no AST interlayer on CTD has higher B/C for all five distress types proven by sufficient projects, hence it became the most cost-effective option.

16. The performance of stone interlayer was also evaluated in this study for both CTD and CSD bases. There were only two projects available for CTD base and three projects for CSD base. Stone interlayer provides promising results for crack prevention, in general. Stone interlayer over CSD provides a gain in SL of 6.7 years, 2.2 years and 6.4 years for TC, LC, and AC, respectively. Stone interlayer over CTD provides 1.2 years, 3.4 years, and 4.2 years of GainSL for TC, LC and AC, respectively. The roughness and rutting performance remain largely unaffected by stone interlayer for both bases. But due to lack of data, these results should be considered as preliminary rather than conclusive. More research is necessary to evaluate stone interlayer performance for the future.

17. Performance prediction models were developed for all distress types that simulate the measured data well. The developed performance models were largely affected by the cumulative ESAL, time, and thicknesses of base and HMA, and base type (CTD, CSD). The models as well as all variables incorporated displayed strong statistical significance.

18. It was found that the survey results of districts, the actual field performance evaluation based on SL and NBA, and the predicted behaviors of developed models were generally analogues.

RECOMMENDATIONS

Based on the comprehensive review of state-of the-practice and analyses of the results, the following recommendations were made.

1. Based on the cost provided by DOTD, CTD with no interlayer became the most cost-effective option for all cases. Therefore, it is recommended that DOTD continue using the CTD bases for flexible pavements.
2. Since the AST interlayer of all soil-cement became the least cost-effective option, it is recommended that it should not be used as an interlayer over soil-cement to minimize the reflective cracking.
3. As a few stone interlayer projects provide significant gain in SL, it is recommended that the DOTD continue to research the performance of stone interlayer as it has the potential to be an effective interlayer in the future.
4. It is recommended the PMS office utilize the newly-developed prediction models since these provided similar performance as reported by district engineers and evaluations using the SL and NBA concepts.
5. The AST interlayer did not exhibit cost-effectiveness, hence it is recommended to search for other alternatives for reflective crack mitigation technique. Such options may include, but not be limited to, micro-cracking of base, geotextile, geosynthetics, ARMI, and so forth.

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APPENDIX A

Table 28: All analyzed AST interlayer projects

Control section	Project No.	Treatment year	BLM	ELM	Base Type	Base Thickness	HMA Thickness	Interlayer Type
019-31-1	019-31-0013	2011	0	5.8	CTD	12	4	AST(Type E)
034-30-1	H.001067.6	2013	4.9	5.5	CSD	8.5	9	AST(Type E)
055-03-1	H.009641.6	2013	0	1.1	CSD	8.5	5	AST(Type E)
093-02-1	093-02-0007	2005	0	7.2	CTD	12	2	AST(Type B)
113-01-1	H.010539.6	2014	0	5.3	CSD	12	3.5	AST(Type E)
120-01-1	H.010538.6	2014	1.8	3.2	CSD	12	5	AST(Type E)
123-03-1	H.010537.6	2014	0	6.5	CSD	12	4	AST(Type E)
135-02-1	H.010536.6	2014	0	4.4	CSD	12	3.5	AST(Type E)
139-07-1	H.010367.6	2014	0	3.7	CSD	8.5	3.5	AST(Type E)
144-02-1	H.009068.6	2011	1	2	CSD	8.5	4	AST(Type E)
207-04-1	H.010547.6	2014	0	2	CSD	8.5	4	AST(Type E)
207-04-1	H.010547.6	2014	3.1	4.3	CSD	8.5	4	AST(Type E)
213-08-1	H.002147.6	2012	0	1.6	CSD	8.5	4.5	AST(Type E)
213-08-1	H.002147.6	2012	2	4.1	CSD	8.5	4.5	AST(Type E)
217-02-1	217-02-0014	2009	2	3	CSD	8.5	4	AST(Type E)
217-02-1	H.002161.6	2012	3.1	8.3	CSD	8.5	5	AST(Type E)
218-30-1	218-30-0005	2010	0	1.7	CSD	8.5	4.5	AST(Type E)
219-02-1	219-02-0024	2011	3.3	9.7	CTD	12	4	AST(Type E)
227-04-1	227-04-0018	2012	0.5	6.4	CSD	12	4	AST(Type E)
227-04-1	227-04-0018	2012	6.5	12.3	CSD	12	4	AST(Type E)
241-02-1	H.009643.6	2012	4.8	8.6	CSD	8.5	5	AST(Type E)
316-01-1	316-01-0007	2009	0	1.6	CTD	12	2	AST(Type E)
369-02-1	H.011062.6	2014	0	0.3	CSD	12	4	AST(Type E)
369-02-1	H.011062.6	2014	2.4	3.2	CSD	12	4	AST(Type E)
370-02-1	H.011068.6	2015	0	6.9	CSD	12	4	AST(Type E)
375-02-1	H.010523.6	2014	0	1.3	CSD	8.5	4	AST(Type E)
380-01-1	H.011049.6	2014	0	1.4	CSD	8.5	4	AST(Type E)
396-02-1	H.010548.6	2014	0.1	6.1	CSD	8.5	3.5	AST(Type E)
400-02-1	H.010522.6	2014	0	0.8	CSD	10	5	AST(Type E)
408-01-1	H.011034.6	2014	0	8.4	CSD	12	5	AST(Type E)
408-02-1	408-02-0011	2011	5.8	10.7	CSD	8.5	5	AST(Type E)
418-01-1	H.002847.6	2012	0	2	CSD	12	4	AST(Type E)

Control section	Project No.	Treatment year	BLM	ELM	Base Type	Base Thickness	HMA Thickness	Interlayer Type
424-04-1	424-04-0052	2009	11.7	13.5	CSD	8.5	3.5	AST(Type E)
424-04-1	424-04-0055	2011	0.6	0.9	CSD	8.5	6	AST(Type E)
432-02-1	432-02-0004	2004	0	8.3	CTD	12	3.5	AST(Type B)
801-10-1	H.007837.6	2012	0	6.2	CSD	8.5	4	AST(Type E)
801-28-1	H.011070.6	2014	3.9	4.8	CSD	8.5	4	AST(Type E)
801-29-1	801-29-0005	2010	0	2	CSD	8.5	4	AST(Type E)
801-59-1	H.011070.6	2014	0	6.7	CSD	8.5	4	AST(Type E)
805-19-1	805-19-0008	1999	0	1.5	CTD	12	2	AST(Type D)
819-19-1	819-19-0008	2011	0	5.5	CTD	12	3.5	AST(Type E)
820-01-1	H.011032.6	2014	0	7.9	CSD	8.5	4	AST(Type E)
820-34-1	H.011048.6	2014	0	2.6	CSD	8.5	4	AST(Type E)
822-05-1	H.011061.6	2014	0	2.1	CSD	12	5	AST(Type E)
822-05-1	H.011061.6	2014	2.8	4.7	CSD	12	5	AST(Type E)
823-12-1	H.009632.6	2013	0	1	CSD	8.5	5	AST(Type E)
823-12-1	H.009632.6	2013	2	2.4	CSD	8.5	5	AST(Type E)
823-14-1	H.010521.6	2014	2.2	6.1	CSD	10	4	AST(Type E)
840-18-1	H.009516.6	2014	0	1.3	CSD	12	3.5	AST(Type E)
849-27-1	H.010526.6	2014	0	2.3	CSD	8.5	4	AST(Type E)
849-30-1	H.010227.6	2013	0	1.8	CSD	8.5	4	AST(Type E)
850-31-1	H.009631.6	2013	0	5.6	CSD	8.5	4	AST(Type E)
857-11-1	H.009995.6	2012	0	3.1	CSD	8.5	3.5	AST(Type E)
857-25-1	H.010524.6	2014	0.6	9.1	CSD	10	4	AST(Type E)
857-63-1	H.008443.6	2012	2.3	8.7	CSD	10	4	AST(Type E)
864-11-1	H.011066.6	2015	0	7.7	CSD	8.5	3.5	AST(Type E)
864-16-1	H.010537.6	2014	0	0.7	CSD	12	4	AST(Type E)

Table 29: All analyzed no interlayer projects

Control section	Project No.	Treatment year	BLM	ELM	Base Type	Base Thickness	HMA Thickness
029-06-1	029-06-0014	1998	0	9.8	CSD	10	3.5
033-03-1	033-03-0036	2003	1	2.2	CTD	12	4
041-05-1	041-05-0019	2001	6	10.6	CSD	8.5	3.5
061-07-1	061-07-0025	1997	0	1.7	CSD	12	3.5
101-02-1	101-02-0005	1997	0	4.1	CTD	12	3.5
117-03-1	117-03-0015	2011	0	4.4	CTD	12	3.5
125-01-1	125-01-0011	1997	0	8.6	CSD	10	3.5
125-03-1	125-03-0028	2000	1.2	8.2	CSD	8.5	3.5
141-03-1	141-03-0010	2010	7.3	10.7	CTD	12	3.5
155-01-1	155-01-0013	2002	2.5	7.9	CTD	12	3.5
161-05-1	161-05-0007	1999	0	1.7	CSD	10	3.5
162-01-1	162-01-0026	1999	0	5.5	CSD	12	3.5
163-02-1	163-02-0012	2003	0.1	3.3	CTD	12	2
165-01-1	165-01-0021	2006	2.4	5.9	CTD	12	3.5
165-02-1	165-02-0027	2006	0	2.7	CTD	12	3.5
172-01-1	172-01-0014	2002	4	6.9	CTD	12	3
172-01-1	172-01-0014	2002	7	8.9	CTD	12	3
176-01-1	176-01-0011	2001	0	3.2	CSD	8.5	3.5
176-03-1	176-03-0007	1998	0	1.2	CSD	8.5	3.5
178-02-1	178-02-0020	2001	6	9.4	CSD	8.5	3.5
185-01-1	185-01-0013	1999	0.7	11.4	CSD	10	3.5
187-01-1	187-01-0030	1997	0	10.8	CSD	15	3.5
197-30-1	197-30-0003	1996	0	3.2	CSD	8.5	3.5
198-01-1	198-01-0005	1998	0	1.7	CSD	8.5	3.5
198-02-1	198-02-0022	2011	0	1.3	CTD	12	4
207-04-1	207-04-0006	1996	0	4.3	CSD	8.5	3.5
211-04-1	211-04-0011	2002	0	2	CTD	12	2
213-04-1	213-04-0006	2001	0	2.9	CSD	8.5	3.5
219-04-1	219-04-0018	2010	0	3	CTD	12	3.5
219-04-1	219-04-0017	2010	3.1	4.5	CTD	12	3.5
224-01-1	224-01-0010	2008	0	2.7	CTD	12	4.5
224-01-1	224-01-0010	2008	5.2	7.1	CTD	12	4.5
224-02-1	224-02-0029	2002	3.2	6.1	CSD	8.5	3.5
236-01-1	236-01-0008	1998	0	2.1	CSD	8.5	3.5

Control section	Project No.	Treatment year	BLM	ELM	Base Type	Base Thickness	HMA Thickness
236-01-1	236-01-0008	1998	2.8	7.1	CSD	8.5	3.5
248-02-1	248-02-0037	2000	0	2.2	CSD	8.5	3.5
256-07-1	256-07-0012	1998	0	4.2	CTD	12	3.5
256-11-1	256-11-0008	1995	0	1.6	CSD	8.5	3.5
257-01-1	257-01-0016	1995	0	0.6	CSD	8.5	3.5
257-01-1	257-01-0016	1995	1.1	2.2	CSD	8.5	3.5
260-04-1	260-04-0018	1997	0	7.1	CSD	8.5	3.5
262-30-1	262-30-0006	2000	0	2	CTD	12	3.5
262-30-1	262-30-0006	2000	2.7	3.1	CTD	12	3.5
263-01-1	263-01-0012	2003	0	9.5	CTD	12	3.5
268-01-1	268-01-0014	1999	0	8	CSD	8.5	4.5
268-03-1	268-03-0003	1996	0	3.7	CSD	8.5	3.5
269-02-1	269-02-0009	1997	0	4.4	CSD	12	3.5
269-03-1	269-03-0005	1997	0	1.3	CSD	12	3.5
269-09-1	269-09-0005	1997	0	6.1	CSD	8.5	3.5
269-10-1	269-10-0008	1997	0	6.6	CSD	8.5	3.5
270-03-1	270-03-0008	2003	2.8	6.2	CTD	12	3.5
270-04-1	270-04-0004	2003	0	2	CTD	12	3.5
270-05-1	270-05-0015	2011	6	10.6	CTD	12	3.5
272-04-1	272-04-0009	2000	4.5	6.6	CTD	12	3.5
274-03-1	274-03-0008	1997	0	8.7	CSD	8.5	3.5
277-03-1	277-03-0013	2001	0.1	6.3	CTD	12	4
278-06-1	278-06-0010	2000	0	4.2	CTD	12	3.5
279-01-1	279-01-0010	1996	1	7.3	CSD	8.5	3.5
281-03-1	281-03-0019	2003	4.2	6.8	CTD	12	5
281-03-1	281-03-0018	2003	7.1	8.3	CTD	12	5
281-04-1	281-04-0027	2011	0.6	7.4	CTD	12	4.5
300-30-1	300-30-0008	2011	0	2.8	CTD	12	3.5
332-03-1	332-03-0010	2004	0	3.6	CTD	12	2
332-03-1	332-03-0009	2002	3.8	9	CTD	12	3
346-02-1	346-02-0018	2000	9.8	12.8	CSD	8.5	3.5
349-01-1	349-01-0006	1998	0	3	CTD	12	3.5
353-01-1	353-01-0004	2002	0	3.7	CTD	12	3.5
353-02-1	353-02-0018	2002	0	1.1	CTD	12	3.5
353-03-1	353-03-0020	2000	4	7.3	CSD	8.5	3.5
354-02-1	354-02-0014	2001	3.8	8.9	CSD	8.5	3.5
355-02-1	355-02-0010	2004	0	8.5	CTD	12	3.5

Control section	Project No.	Treatment year	BLM	ELM	Base Type	Base Thickness	HMA Thickness
367-01-1	367-01-0015	2002	1.9	4.6	CTD	12	3.5
380-02-1	380-02-0008	2000	0	3.8	CSD	8.5	3.5
381-01-1	381-01-0007	1995	0	3.1	CSD	8.5	3.5
385-01-1	385-01-0006	1996	0	3.3	CSD	8.5	3.5
385-02-1	385-02-0006	1996	0	6.2	CSD	8.5	3.5
385-03-1	385-03-0005	1997	0	8.2	CSD	8.5	3.5
393-05-1	393-05-0007	1997	0	2.4	CSD	8.5	3.5
393-06-1	393-06-0004	1997	0	3	CSD	8.5	3.5
394-02-1	394-02-0005	1996	0	6	CSD	8.5	3.5
398-01-1	398-01-0007	1998	0.7	7.4	CSD	8.5	4
403-01-1	403-01-0005	1998	0	1.6	CSD	12	3.5
403-02-1	403-02-0005	1998	0	4.9	CSD	12	3.5
403-03-1	403-03-0007	1997	0	6	CSD	8.5	3.5
404-01-1	404-01-0010	1997	0	2.8	CTD	12	3.5
450-03-1	450-03-0054	2001	20	20.6	CSD	8.5	4
450-08-1	450-08-0045	2000	8.4	10	CSD	8.5	4
454-04-1	454-04-0052	2000	31	31.6	CSD	8.5	3.5
801-11-1	801-11-0004	2002	0	3.9	CTD	12	2
801-47-1	801-47-0002	1996	0	0.7	CSD	8.5	3.5
803-01-1	803-01-0013	1996	0	5.4	CSD	12	3.5
803-20-1	803-20-0004	1999	0	2	CTD	12	3.5
803-21-1	803-21-0008	1999	0	3	CTD	12	3.5
803-22-1	803-22-0007	1998	0	3.7	CTD	12	3.5
803-24-1	803-24-0003	2000	0	1.7	CSD	8.5	3.5
804-16-1	804-16-0016	1998	0	1.5	CTD	12	3.5
804-23-1	804-23-0020	2000	2.9	5.7	CSD	8.5	4.5
804-42-1	804-42-0001	1998	0	0.9	CTD	12	3.5
805-25-1	805-25-0008	2000	0	6.5	CSD	8.5	3.5
810-07-1	810-07-0014	1997	0	1.5	CSD	8.5	3.5
810-07-1	810-07-0014	1997	1.6	3.1	CSD	8.5	3.5
810-28-1	810-28-0010	2001	3.2	6.4	CSD	8.5	3.5
811-09-1	811-09-0010	2004	0	3	CTD	12	3.5
815-08-1	815-08-0008	2001	0	2.3	CSD	8.5	3.5
819-02-1	819-02-0012	2001	0	12.2	CSD	8.5	3.5
819-17-1	819-17-0004	2000	0	3.7	CTD	12	3.5
820-11-1	820-11-0005	2001	0	6	CSD	8.5	3.5
827-09-1	827-09-0009	1998	0	1.5	CSD	8.5	3.5

Control section	Project No.	Treatment year	BLM	ELM	Base Type	Base Thickness	HMA Thickness
828-25-1	828-25-0008	2003	0	4.8	CTD	12	3.5
830-03-1	830-03-0006	2001	0	1.9	CTD	12	3.5
830-14-1	830-14-0005	2004	0	1.6	CTD	12	3.5
834-17-1	834-17-0007	2004	0	3.8	CTD	12	3
839-12-1	839-12-0007	2001	0	4.6	CTD	12	3.5
849-08-1	849-08-0004	1996	0	2.7	CSD	8.5	3.5
852-06-1	852-06-0008	2010	0	1.1	CTD	12	3.5
852-06-1	852-06-0008	2010	1.2	6.2	CTD	12	3.5
852-25-1	852-25-0013	2000	2.1	5.1	CTD	12	3.5
854-01-1	854-01-0011	2000	8	10	CSD	8.5	3.5
854-13-1	854-13-0014	1998	0	1.1	CSD	8.5	3.54
859-18-1	859-18-0010	2002	0.2	1.9	CTD	12	3.5
859-24-1	859-24-0005	2006	0	1.1	CTD	12	3.5
863-02-1	863-02-0029	2007	0	6.8	CTD	12	3.5

Table 30: All analyzed stone interlayer projects

Control section	Project No.	Treatment year	BLM	ELM	Base Type	Base Thickness	HMA Thickness	Stone Interlayer Thickness
177-30-1	177-30-0021	2009	0.6	1.5	CTD	12	4	8.5
198-02-1	198-02-0022	2012	4	8.1	CTD	12	4	4
203-03-1	203-03-0016	2006	7.3	8.6	CSD	10	3.5	4
237-05-1	H.009946.6	2013	17.9	22.4	CSD	8.5	4	4
814-07-1	814-07-0001	2011	0	3.9	Soil Cement CLASS II	10	5	4
823-12-1	H.009632.6	2013	1	2	CSD	8.5	5	4

APPENDIX B

Survey Questionnaire

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)*:

____
____
____
____
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THANK YOU FOR SUPPORTING THIS IMPORTANT EFFORT!

Please Respond by December 14, 2016

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