EVALUATION OF ASPHALT RUBBER AND RECLAIMED TIRE RUBBER IN CHIP SEAL APPLICATIONS

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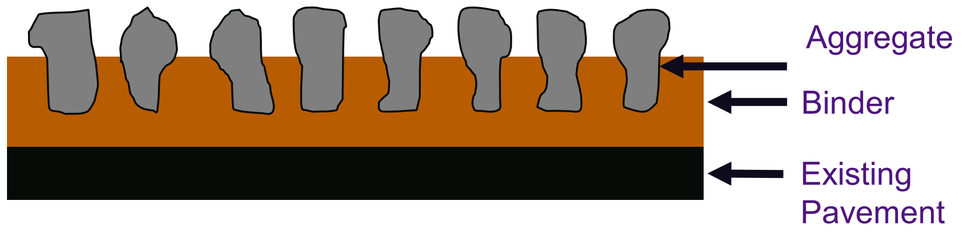
Chip Seal

- Spraying of asphalt emulsion or hot binder on the existing roadway surface followed by the application of a layer of aggregate
- Benefits (Gransberg and James 2005):
  - Enhanced durability and skid resistance
  - Eliminate raveling
  - Resistance to water intrusion in the underlying pavement
  - Rejuvenates an existing oxidized surface

Chip Seal Composition

- **Binder**
  - Asphalt emulsion
  - Asphalt cement
  - Asphalt rubber binder
  - Polymer modified binder



Single Chip Seal

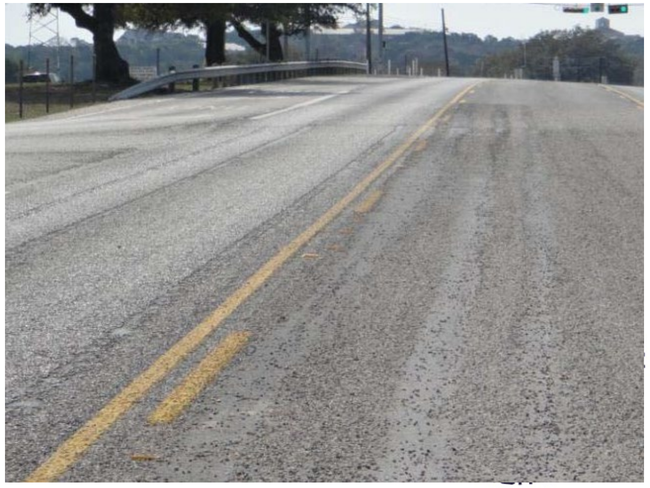
- **Aggregate**
  - Natural aggregate (Gravel, Crushed Stone etc.)
  - Synthetic light-weight aggregate (artificially produced, e.g., expanded shale and clay)

Economics of Chip Seal

- Extends pavement service life from 4 to 7 years (Zaniewski and Mamlouk 1996).
- Low initial costs and convenient construction process (California DOT 2008).
- Half to one-fifth the cost of a regular thin overlay (Chen et al. 2003).
- Fills minor cracks (<¼ in.) (Testa and Hossain 2014).

Limitations of Chip Seal

- Does not increase pavement structural capacity
- Should not be applied to roads that exhibit severe cracking and potholes
- Is ineffective when rut depth >3/4 in.
- Observed distresses associated with chip seal treatment:
  - Bleeding
  - Loss of aggregate
  - Streaking
- Functional limitations:
  - High surface roughness
  - Increased traffic noise



Asphalt Rubber (AR) Chip Seal

- Has been used by many state agencies (e.g., Arizona, Florida, Texas, and California)
- Has demonstrated unique advantages such as:
  - Improved durability
  - Cracking resistance
  - Resistance to reflective cracking

Limitations of Asphalt Rubber Chip Seal

- High viscosity
- Poor workability
- Storage instability
- Strong distinctive odors
- High equipment mobilization cost
- Cost is 2-3 times higher than conventional chip seal
- Hot application of asphalt rubber at an elevated temperature of 190-218°C (375-425°F) is a safety concern for many states

Research Objectives

- Improve the durability and extend the life of chip seal applications in Louisiana using rubberized asphalt emulsion and reclaimed rubber tires in the aggregate layer
- Evaluate the short-term field performance of chip seal sections constructed with rubberized modified asphalt emulsion

Chip Seal Laboratory Performance

Test Materials - Asphalt

Sample ID	Description
CRS-2	Conventional emulsified binder with no polymer.
CRS-2P	Polymer-modified emulsified binder
CRS-2TR	Tire rubber modified emulsified binder
AC20-5TR	Crumb-rubber modified asphalt binder
CHFRS-2P	High float polymer modified emulsion

Aggregate

- Coarse aggregate included light-weight aggregate (LWA), granite aggregate (GA), and rubber aggregate (RA)

- Size 3 aggregate gradation was selected for LWA and 90-10 and 80-20 blends of LWA-RA were prepared

Type of Aggregate	Bulk specific gravity in SSD condition	Absorption capacity (%)	Unit weight (Kg/m^3)
Light weight aggregate (LWA)	1.51	15.63	595
Granite aggregate (GA)	2.61	1.36	1561.8
Rubber aggregate (RA)	1.15	2.55	460

Experimental Factorial

<table>
<tr><th>Case</th><th>Primary Factors</th><th>Levels</th><th>Corresponding Factors</th><th>Levels</th><th>Corresponding Factors</th><th>Levels</th></tr>
<tr><td>1</td><td rowspan="8">Application rates</td><td rowspan="2">LaDOTD</td><td rowspan="8">Types of emulsion</td><td rowspan="4">CRS-2P</td><td rowspan="8">Aggregate blends</td><td rowspan="8">LWA
GA</td></tr>
<tr><td>2</td></tr>
<tr><td>3</td><td rowspan="2">TxDOT</td></tr>
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<tr><td>5</td><td rowspan="2">ASTM D 7000</td><td rowspan="4">CRS-2TR</td></tr>
<tr><td>6</td></tr>
<tr><td>7</td><td rowspan="2">NCHRP 680</td></tr>
<tr><td>8</td></tr>
<tr><td>9</td><td rowspan="4">Types of emulsion</td><td>CRS-2P</td><td rowspan="4">Application rates</td><td rowspan="4">LaDOTD</td><td rowspan="4">Aggregate blends</td><td rowspan="4">LWA
GA</td></tr>
<tr><td>10</td><td>CRS-2TR</td></tr>
<tr><td>11</td><td>CRS-2</td></tr>
<tr><td>12</td><td>AC20-TR or CHFRS-2P</td></tr>
<tr><td>13</td><td rowspan="4">Aggregate blends</td><td rowspan="2">LWA</td><td rowspan="4">Application rates</td><td rowspan="4">LaDOTD</td><td rowspan="4">Types of emulsion</td><td rowspan="2">CRS-2P</td></tr>
<tr><td>14</td></tr>
<tr><td>15</td><td rowspan="2">90-10 and 80-20 blend of LWA and RA – GA and RA</td><td rowspan="2">CRS-2TR</td></tr>
<tr><td>16</td></tr>
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Chip Seal Performance Test

Sample Preparation

Application of preheated emulsion

Application of pre-weighed aggregates

Roller compaction

Final specimen

Chip Seal Performance Test

- Loss of aggregate in chip seals was evaluated using the Sweep Test and the Pennsylvania Aggregate Retention Test (PART)

- The Bitumen Bond Strength (BBS) test was conducted to measure the adhesion bond between the emulsion and the aggregate

Chip Seal Performance Test

Sweep Test

- Conducted according to ASTM D 7000
- An A120 Hobart Mixer equipped with a modified brush holder was used
- The test specimens were abraded for 60 sec at 0.83 gyrations per second
- Loss of aggregate:

$$\%\ Aggregate\ Loss = \left(\frac{A-B}{A-C}\right) * 100$$

A = Initial specimen weight;
B = Final specimen weight; and
C = Asphalt disk weight.

Chip Seal Performance Test

Pennsylvania Aggregate Retention Test (PART)

- Developed by Kandhal et al. in 1991
- A Mary Ann laboratory sieve shaker was used
- Test specimens were placed up-side down on a modified sieve with three screws drilled from the sides to the inward direction
- Four 12.5 mm standard sieves were placed to build height
- Loss of aggregate:

$$\% \, Knock - off \; Loss = \left(\frac{C}{A - B}\right) * 100$$

A = Weight of total aggregate applied to the specimen;

B = Weight of initial loss of aggregates by hand sweep; and

C = Weight of knock-off aggregates.

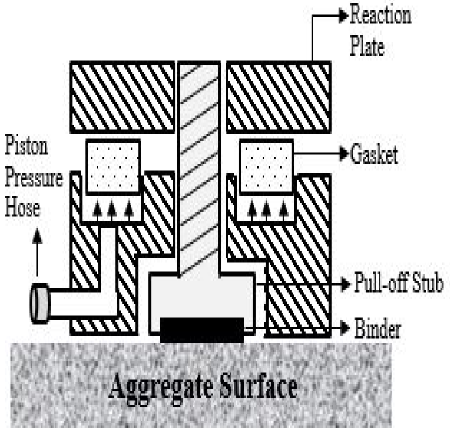
Chip Seal Performance Test

BBS Test

- Conducted according to ASTM D 4541
- A Type IV self-aligning portable adhesion tester was used
- A stub-aggregate system was prepared and cured at 25°C
- Pull-off tensile strength:

$$POTS = \frac{(BP - Ag) - C}{Aps}$$

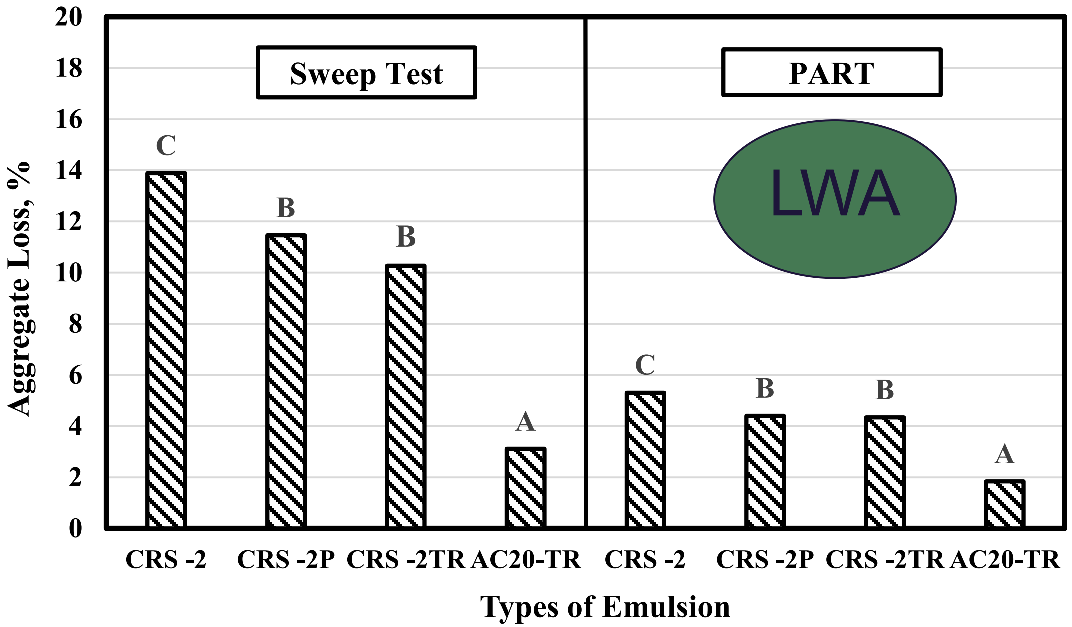
POTS = Pull-off tensile strength in psi;
BP = Burst pressure in psi;
Ag = Contact area between gasket and piston plate = 2.009 in^2;
C = Piston Constant = 0.1775 lbs ± 1.5% for F-2 piston; and
Aps = Area of pull stub = 0.1963 in^2 for ½-in diameter pull-stub.

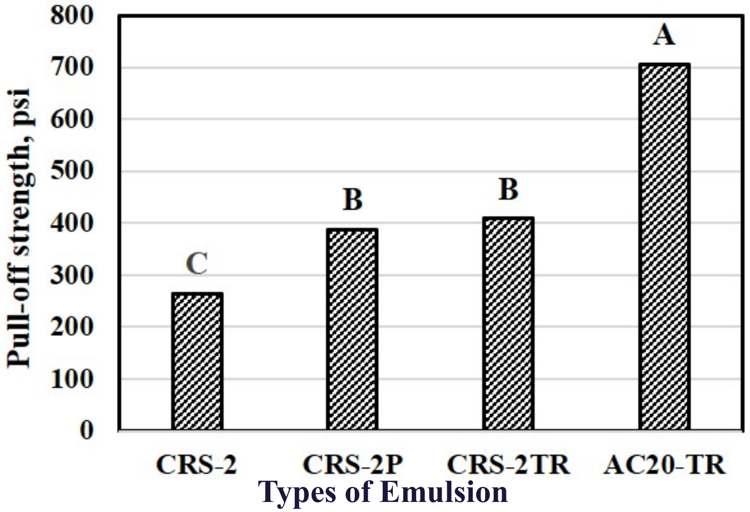


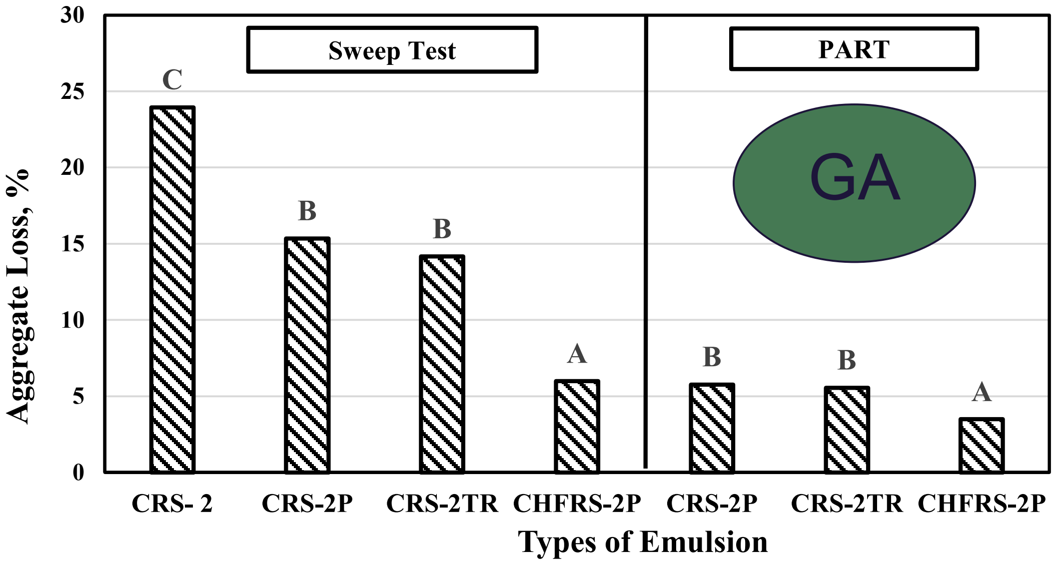
CHIP SEAL LABORATORY PERFORMANCE - RESULTS

Effect of Types of Emulsion

- %Aggregate Loss for the emulsions can be ordered as:
  - LWA: CRS-2 > CRS-2P > CRS-2TR > AC20-TR
  - GA: CRS-2 > CRS-2P > CRS-2TR > CHFRS-2P
- CRS-2P and CRS-2TR had similar performance
- Aggregate loss was higher for granite aggregate than for LWA

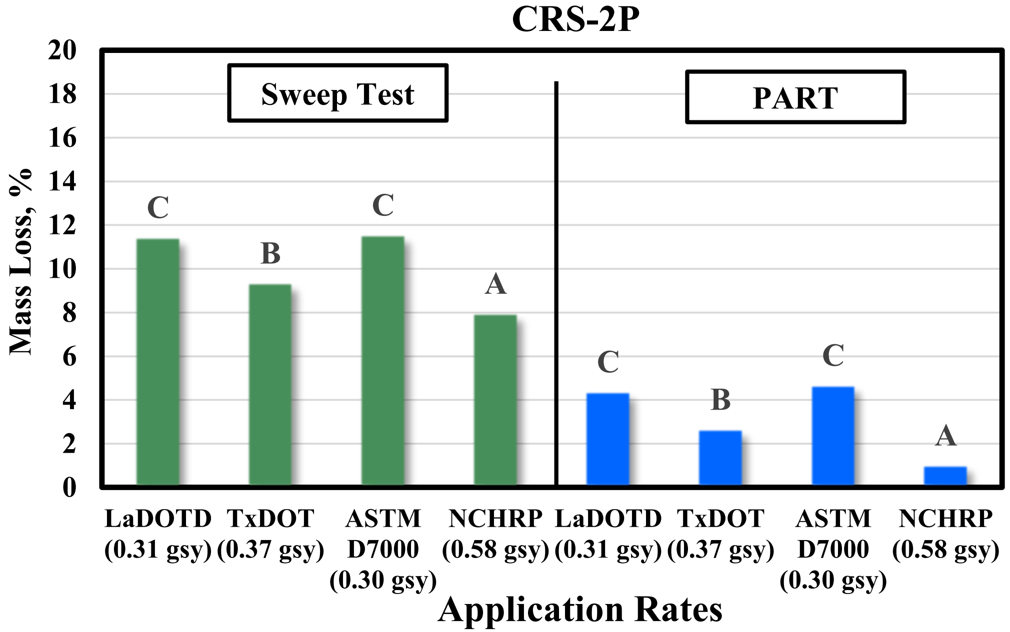


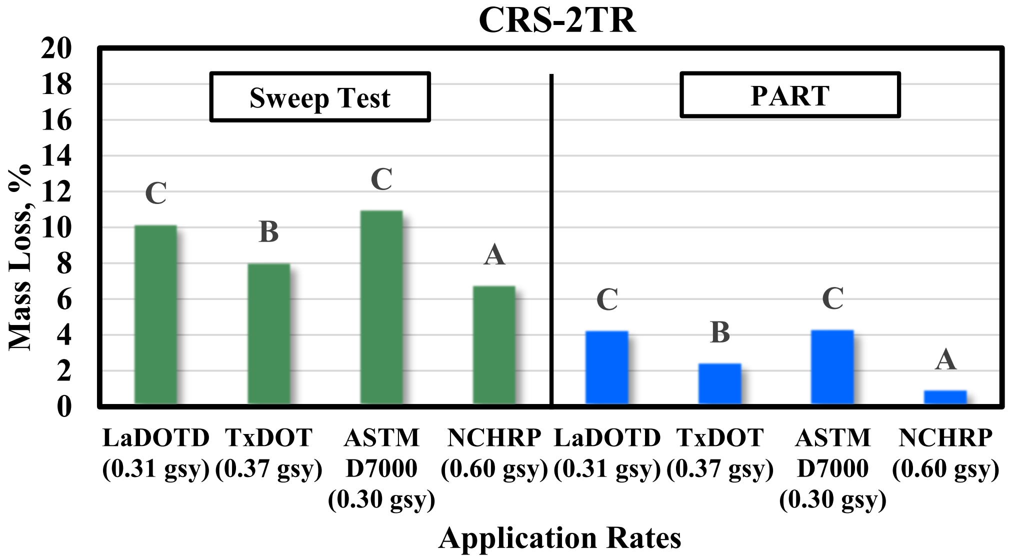




Effect of Application Rates

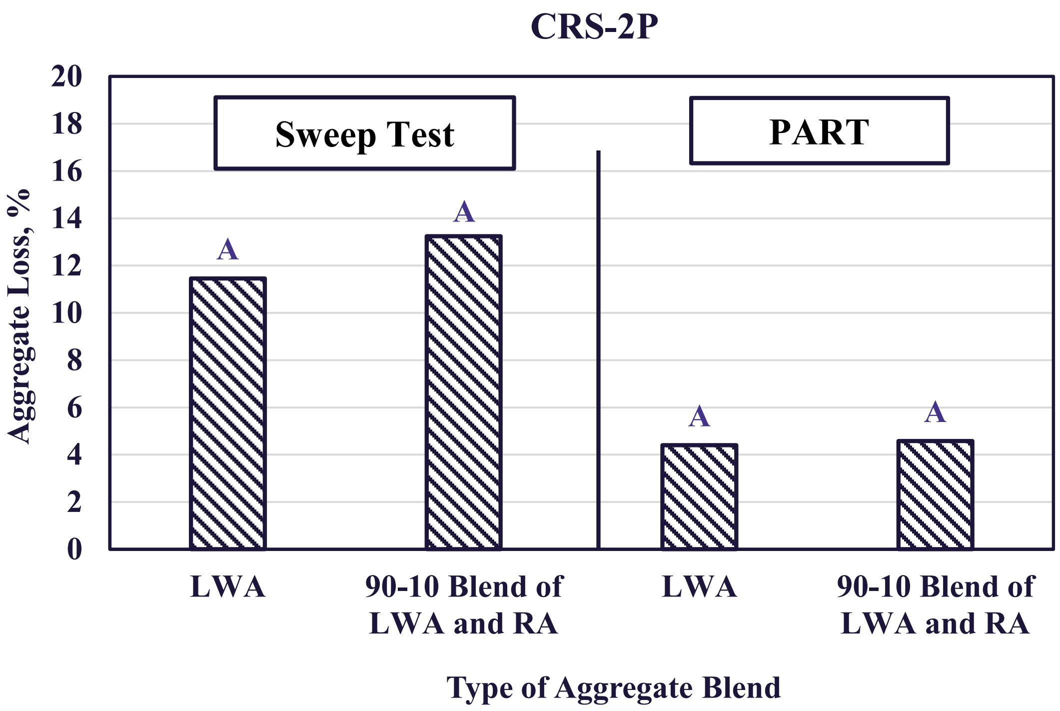
- With respect to %Aggregate Loss, the application rates can be ordered as LaDOTD > ASTM D 7000 > TxDOT > NCHRP
- NCHRP application rate was the best performer
- LaDOTD and ASTM D 7000 had similar performance

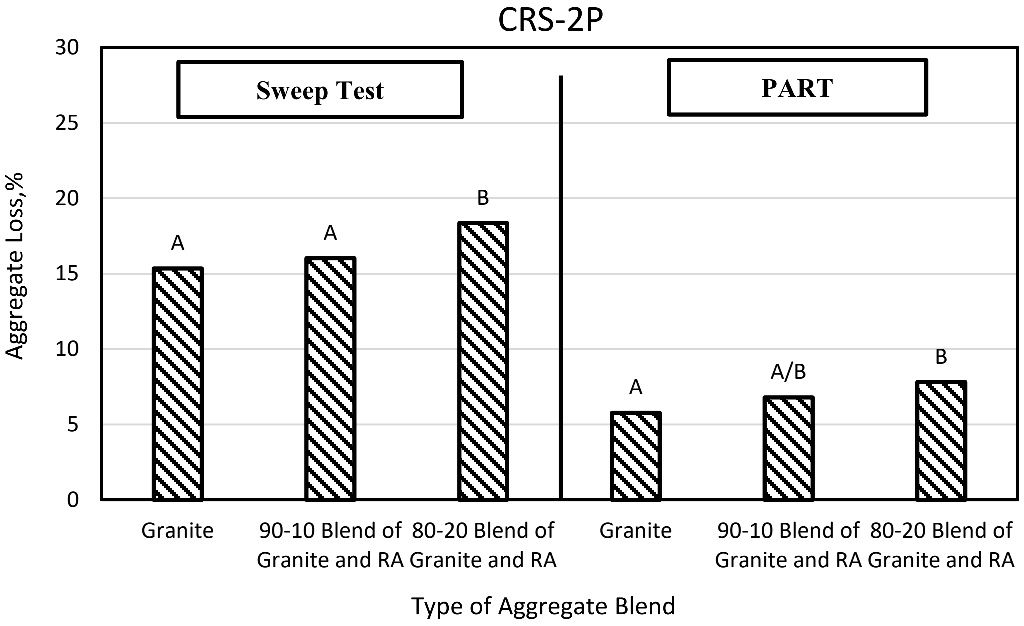




Effect of Aggregate Blends

- The percentage of aggregate loss increased when crumb rubber aggregate was used
- For the 90-10 blends, aggregate loss did not increase significantly as they were statistically in the same group
- A small percentage of crumb rubber may be used in chip seal without significantly affecting its performance





Findings of Experiment

- The laboratory performance of rubberized asphalt emulsion was statistically comparable to that of the conventional polymer modified emulsion
- In terms of aggregate loss, the emulsions investigated in this study can be ordered as CRS-2 > CRS-2P > CRS-2TR > AC20-5TR for LWA and CRS-2 > CRS-2P> CRS-2TR > CHFRS-2P for granite aggregate
- The investigation of the different application rates showed that the loss of aggregate in chip seal is reduced at high application rates.
  - A high application rate may not be practically feasible due to an aggregate embedment depth of 100%, causing a frictionless surface for the traveling vehicles.
- ANOVA test results indicated that emulsion type, emulsion application rates, and aggregate blends are all significant factors influencing aggregate loss performance of chip seal.

Findings of Experiment

- Incorporation of rubber as aggregate in the LWA gradation increased the loss of aggregate in chip seal specimens
- A small percentage of crumb rubber (10% or less) may be used in chip seal without significantly affecting its performance
  - Further investigation is necessary to understand the emulsion-aggregate compatibility with crumb rubber aggregate.
- The loss of aggregate determined from both the sweep test and PART had similar trends indicating the high correlation between these two tests

Short-Term Field Performance of Chip Seal Sections

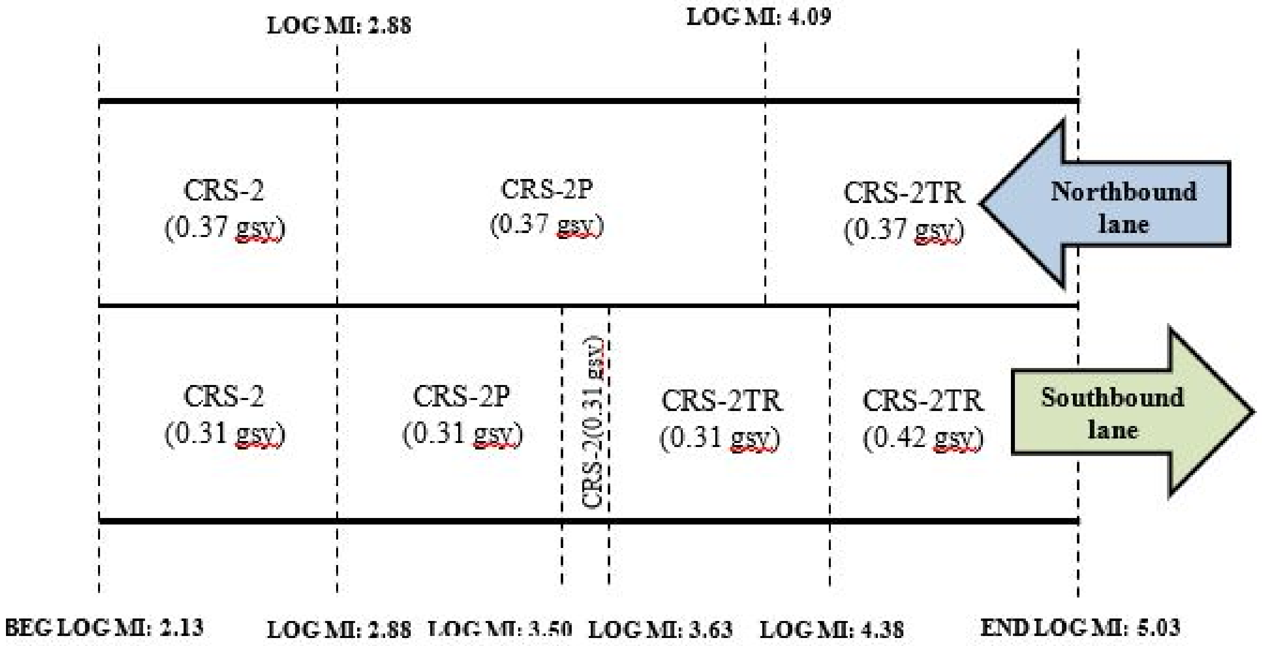
Test Project

- Chip seal sections were constructed in the LA 128 project in Tensas Parish.
- Control section (036-05) is 2.9 miles long.
- Traffic volume is 470 vehicle/lane/day.

Experimental Factorial

Section No.	I	II	III	IV	V	VI	VII
Type of emulsion	CRS-2	CRS-2P	CRS-2TR	CRS-2	CRS-2P	CRS-2TR	CRS-2TR
Application rate	TxDOT	TxDOT	TxDOT	LaDOTD	LaDOTD	LaDOTD	NCHRP[1]
Length, mile	0.75	1.21	0.94	0.75	0.62	0.75	0.65

[1] The application rate was reduced to 0.42 gsy for constructability reasons.



Construction of Chip Seal Sections

Mean Texture Depth

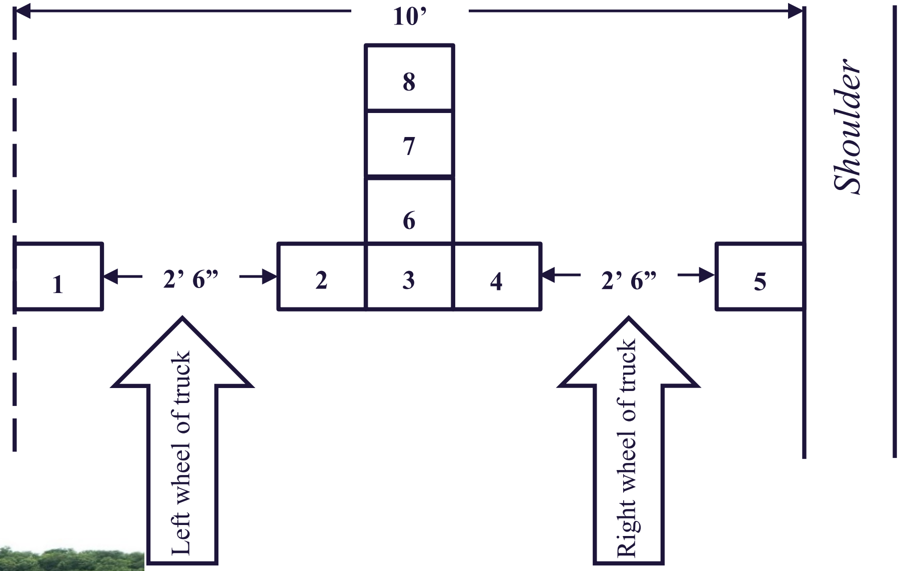
- Conducted according to ASTM E 965.
- 25 mL Ottawa sand was used to create a circular flat surface of sand on the pavement surface.
- Four diameter measurements were taken.
- Mean texture depth:

$$MTD = \left(\frac{4V}{\pi D^2}\right)$$

V = Volume of sand; and
D = Average diameter of the circle.

Application Rate Measurements During Construction

- Conducted according to ASTM D 2995
- Width of the test sections was 10-11'.
- Eight pre-weighed geotextile pads (12 in. x 12 in.) were placed along the length and width
- The pads were retrieved and weighed immediately after emulsion application



Pad layout for distributor truck

Geotextile pads placement on the test sections

Geotextile pads after application of emulsion

Distress Survey

- Manual distress survey was conducted:
  - After 3, 6, 12, & 18 months of construction
- Distresses monitored:
  - Bleeding
  - Rutting
  - Cracking
  - Potholes
- All sections were inspected for bleeding along wheel path

Rutting

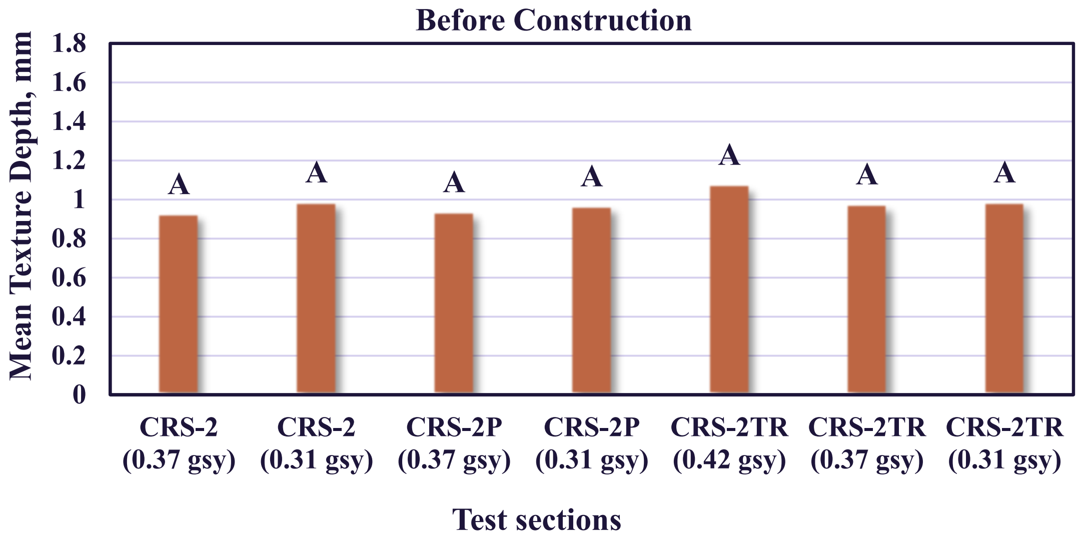
- Measurement conducted every 400 ft.
- A triangular rut scale was used.
- Two measurements were taken along wheel paths.

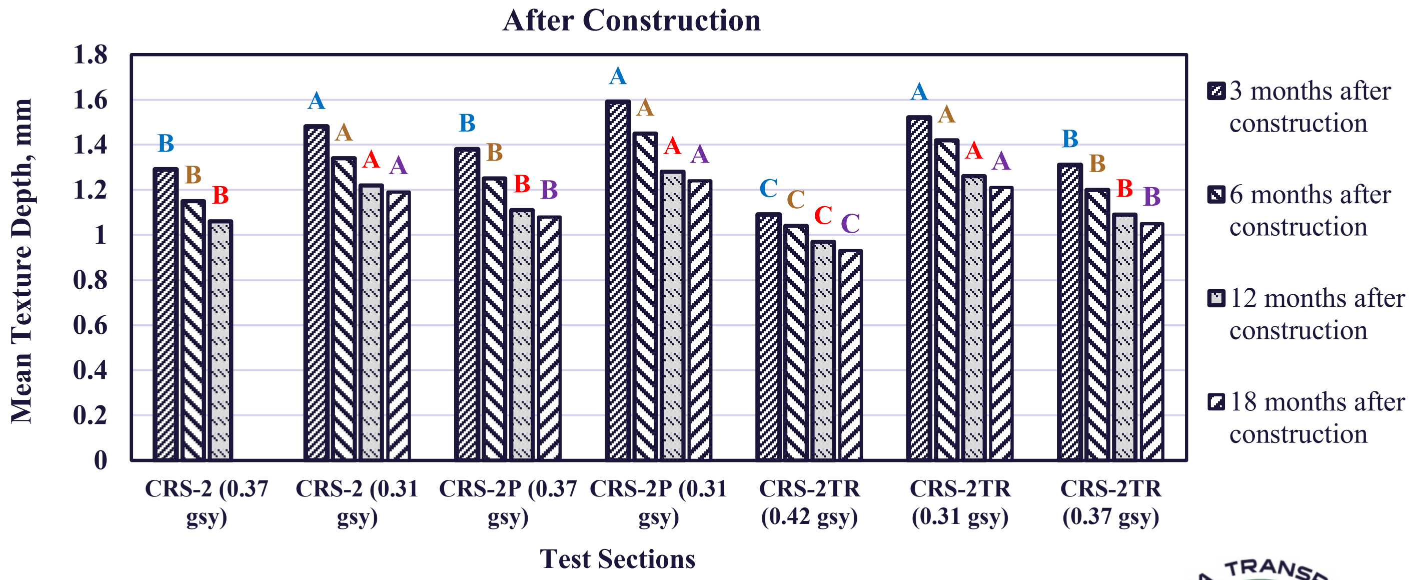
Cracks and Potholes

- Test sections were inspected before and after construction
- Type of cracks inspected:
  - Longitudinal cracks
  - Transverse cracks
  - Fatigue cracks
  - Edge cracks
- Crack length, width, and location were recorded

SHORT-TERM FIELD PERFORMANCE RESULTS

Mean Texture Depth





- MTD increased after construction.
- MTD decreased over time.
- The use of higher application rates for the emulsion leads to a decrease in MTD after construction

Percent Embedment Depth

- Percent embedment depth of the aggregate increased in the short-term; therefore, decreasing the MTD in the chip seal sections.
- The chip seal sections constructed at higher application rates had higher aggregate percent embedment depths indicating more susceptibility to bleeding.

Chip seal section	Percent embedment depth			
	After 3 months of construction	After 6 months of construction	After 12 months of construction	After 18 months of construction
CRS-2 (0.37 gsy)	53.41	60.86	66.52	N/A
CRS-2 (0.31 gsy)	48.00	54.05	56.63	N/A
CRS-2P (0.37 gsy)	49.06	58.00	63.67	N/A
CRS-2P (0.31 gsy)	42.35	48.58	51.53	N/A
CRS-2TR (0.42 gsy)	69.72	76.88	79.72	N/A
CRS-2TR (0.31 gsy)	45.71	50.28	53.82	N/A
CRS-2TR (0.37 gsy)	51.22	57.16	60.72	N/A

Measurement of Application Rates

Types of emulsion	LaDOTD application rate, gsy			TxDOT application rate, gsy			Field adjusted application rate, gsy		
	Target	Measured		Target	Measured		Target	Measured	
CRS-2	0.31	AVG	0.29	0.37	AVG	0.34	N/A	N/A	N/A
		STD	0.02		STD	0.04			
		COV (%)	7.11		COV (%)	11.25			
CRS-2P	0.31	AVG	0.25	0.37	AVG	N/A			
		STD	0.01		STD				
		COV (%)	4.16		COV (%)				
CRS-2TR	0.31	AVG	0.27	0.37	AVG	0.38	0.42	AVG	0.41
		STD	0.02		STD	0.01		STD	0.04
		COV (%)	8.70		COV (%)	3.57		COV (%)	9.57

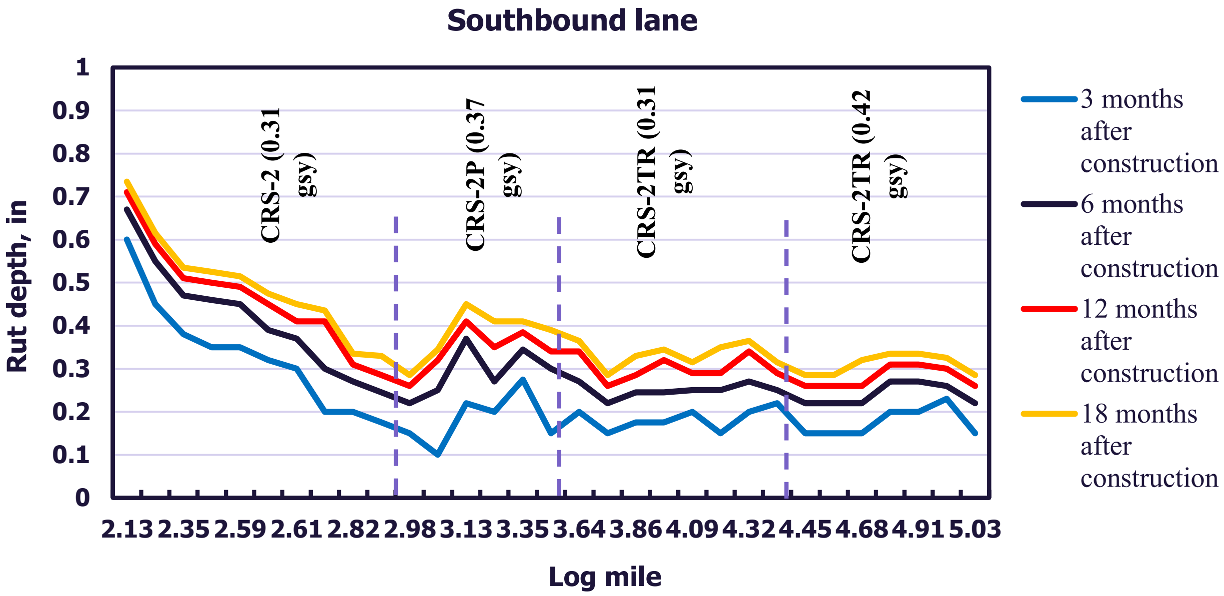
- The measured application rates of the distributor trucks were very close to the target application rate

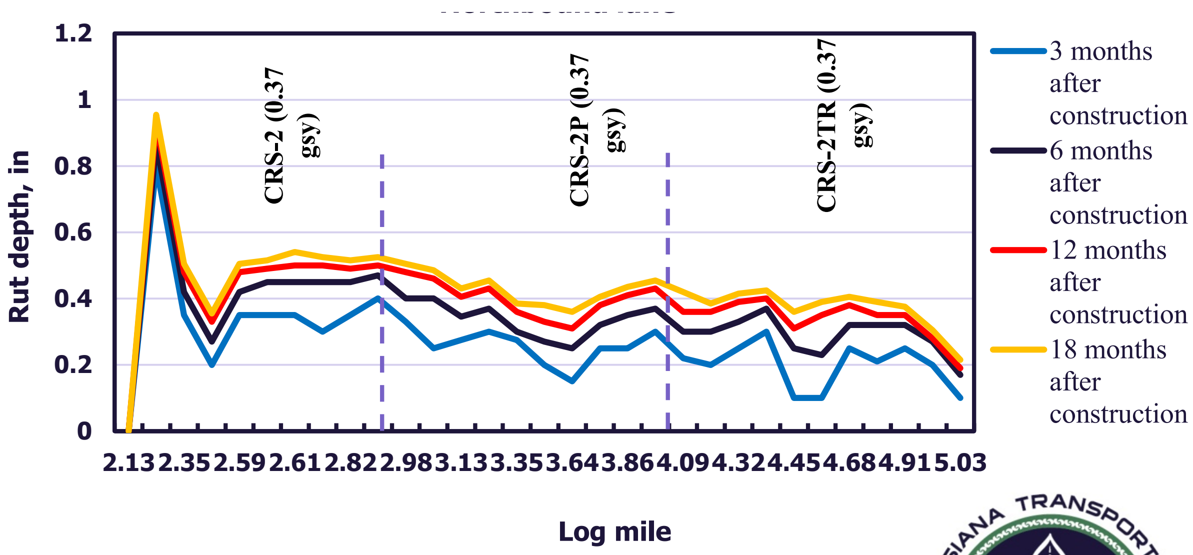
Rutting

- Relatively lower rut depths were observed in the CRS-2TR test sections.
- Measured rut depths may be related to pavement conditions prior to the construction.

Northbound Lane			Southbound Lane		
Log Mile	Section	Avg. Rut Depth (in.)	Log Mile	Section	Avg. Rut Depth (in.)
2.13 – 2.88	CRS-2 (0.37 gsy)	0.22	2.13 – 2.88	CRS-2 (0.31 gsy)	0.18
2.88 – 4.09	CRS-2P (0.37 gsy)	0.21	2.88 – 3.50	CRS-2P (0.31 gsy)	0.14
4.09 – 5.03	CRS-2TR (0.37 gsy)	0.31	3.63 – 4.38	CRS-2TR (0.31 gsy)	0.20
N/A			4.38 – 5.03	CRS-2TR (0.42 gsy)	0.22

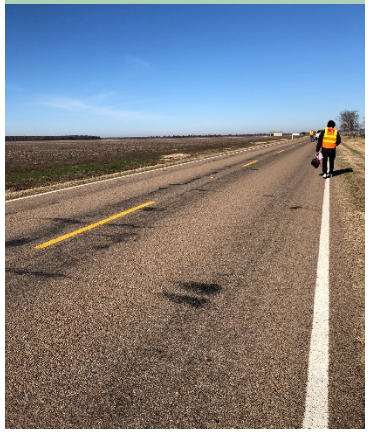
Average rut depth of the test sections prior to chip seal construction





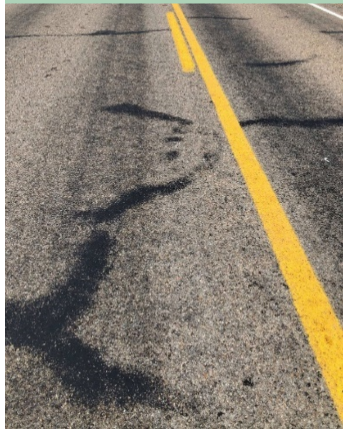
Bleeding

CRS-2 (0.37 gsy)



CRS-2P (0.37 gsy)

CRS-2TR (0.37 gsy)

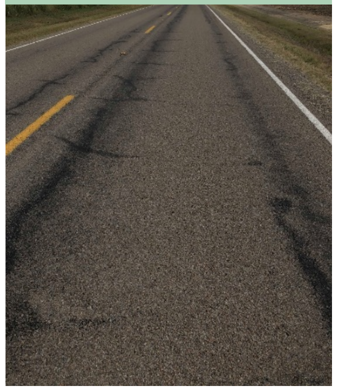


CRS-2 (0.31 gsy)

CRS-2P (0.31 gsy)

CRS-2TR (0.31 gsy)

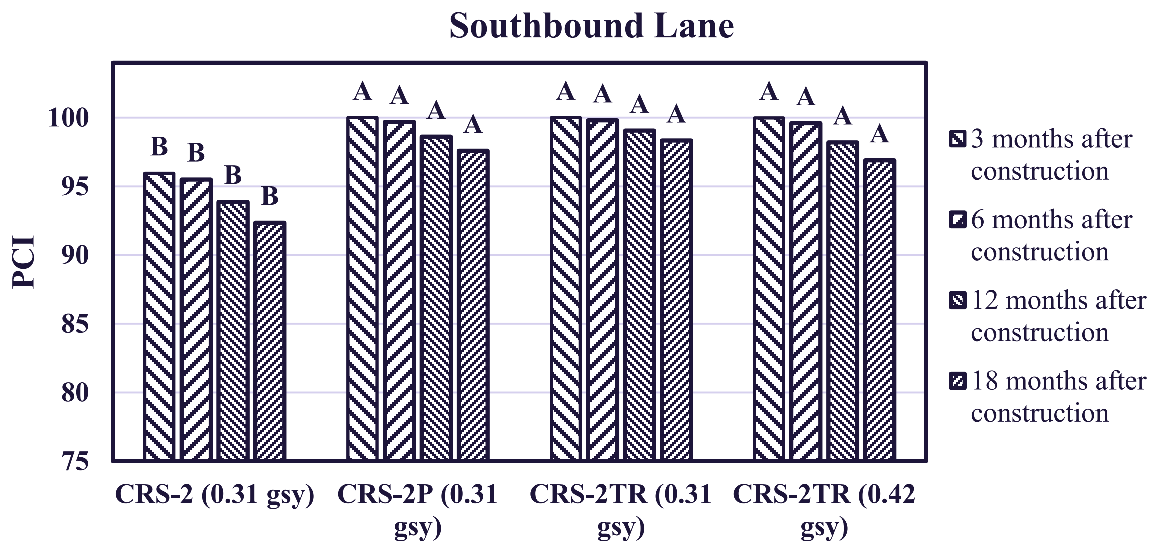
CRS-2TR (0.42 gsy)

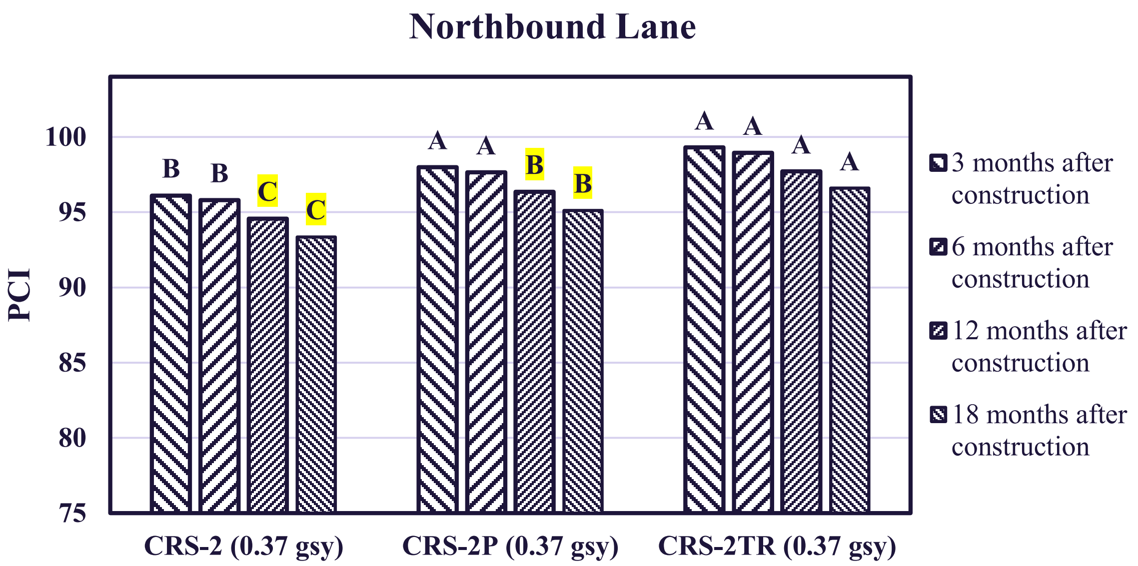


- A few bleeding spots were identified → Most locations in sections constructed with high application rates
- The presence of bleeding along the wheel path reduces pavement friction and skid resistance

Pavement Condition Index (PCI)

- The test sections constructed with CRS-2TR had the best performance
- The test sections constructed with CRS-2 had the worst performance



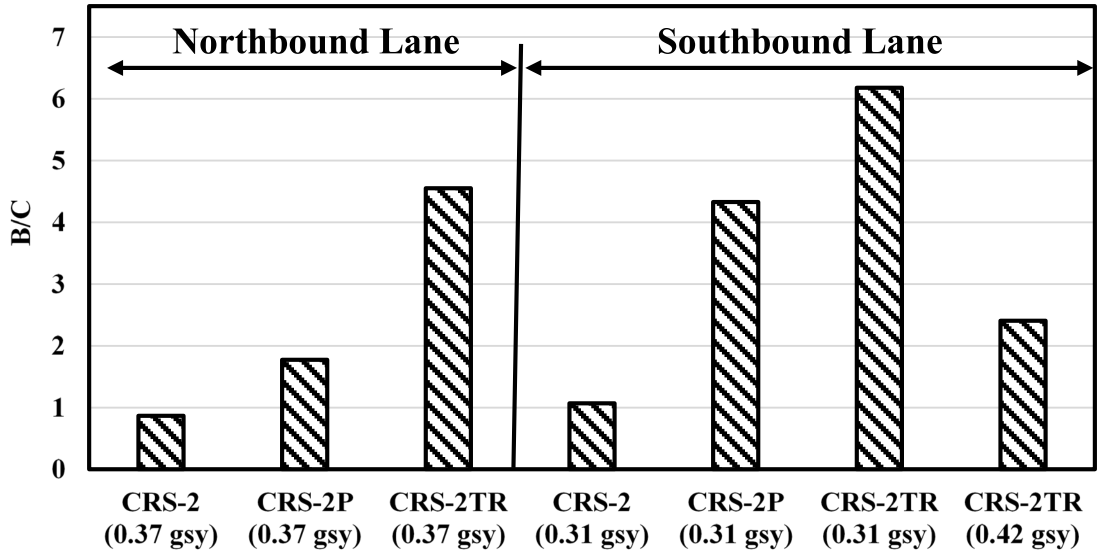


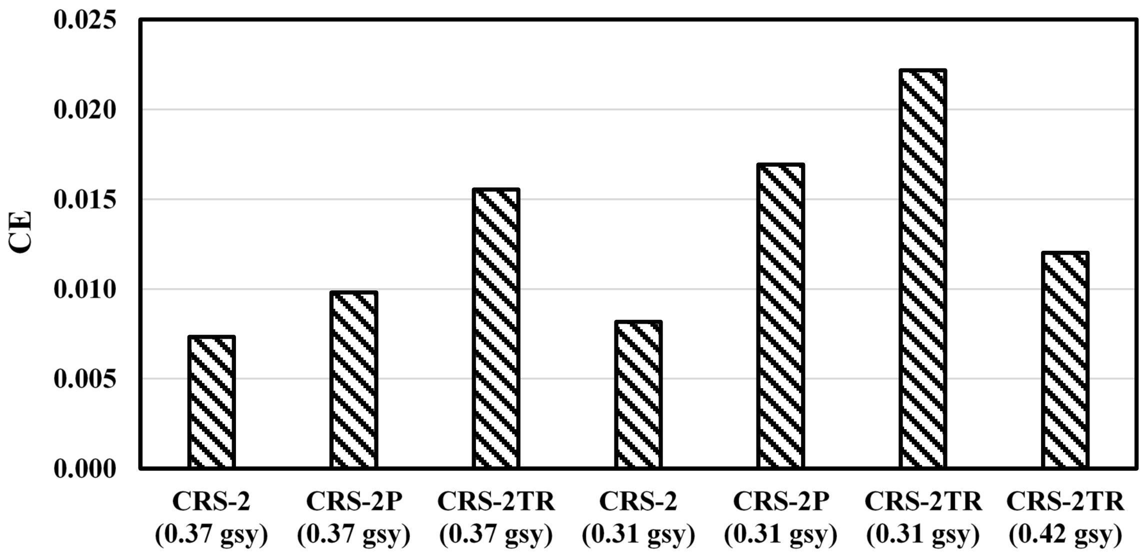
- Chip seal sections on the northbound lane can be ordered as: CRS-2TR (0.37 gsy) > CRS-2P (0.37 gsy) > CRS-2 (0.37 gsy)
- Test sections on the southbound lane can be ordered as: CRS-2TR (0.31 gsy), CRS-2TR (0.42 gsy), CRS-2P (0.31 gsy) > CRS-2 (0.31 gsy)

Benefit-Cost Analysis

- In terms of B/C, test sections can be ordered as follows:

  CRS-2TR (0.31 gsy) > CRS-2TR (0.37 gsy), CRS-2P (0.31 gsy) > CRS-2TR (0.42 gsy) > CRS-2 (0.31 gsy) > CRS-2 (0.37 gsy)





- The highest B/C was achieved for the CRS-2TR (0.31 gsy)
- Almost no net benefit was provided by the chip seal section constructed with CRS-2

Findings of Field Experiment

- Pavement macrotexture depth increased as a result of chip sealing, which indicates improved friction characteristics and skid resistance.
- In the northbound lane, the chip seal section constructed with CRS-2TR (0.37 gsy) was the best performer statistically
- In the southbound lane, the chip seal sections constructed with CRS-2TR and CRS-2P (0.31 gsy) performed similarly
- The most cost-effective chip seal section was achieved by the application of CRS-2TR emulsion at the LaDOTD recommended emulsion application rate

Implementation Recommendations

- The rubberized asphalt emulsion provided adequate results in the laboratory and in the field experiments
- Incorporation of crumb-rubber modified asphalt emulsion in the Louisiana specifications is recommended
- Current asphalt emulsion and aggregate application rates in the Louisiana specifications for chip sealing are adequate and should be maintained

Questions?