STATE STUDY NO. 67-102

FINAL REPORT

EVALUATION OF HOT IN-PLACE RECYCLING

Prepared by

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16. Abstract

This report documents the surface recycling of 7.688 miles (12.37 km) of Interstate 55 in Pike County from about 10 miles (16.1 km) south of McComb to the Louisiana state line. The recycling equipment was by Remixer Contracting Co., Inc. of Austin, Texas. The existing pavement was first heated, milled to 1.25 in. (31.75 mm) depth, rejuvenator and virgin mix was added, and then the 1.5 in. (38.10 mm) of recycled mix was re-laid and compacted. The daily productions proceeded with few problems on the four field inspection days and averaged 0.69 lane-miles (1.11 lane-km) per day.

The reuse of the existing asphaltic concrete pavement is desirable because of the decreasing supply and increasing costs of raw materials. The remixing leaves the final grade almost the same, which allows the user the option of rehabilitation only one lane of a multi-lane highway and is a good safety factor.

Structural integrity was measured with the Dynaflect and Falling Weight Deflectometer. The South Dakota profiler was used to obtain before and after International Roughness Index values.

Materials from the test roadway were sampled and compared with other roadways for viscosity, penetration, and ductility, percent voids, density, specific gravity, percent asphalt, gradations, and resilient modulus.

After six years of service life, the recycled pavement proved its competency to perform comparably to conventional hot-mix. This study found that pavements using reclaimed asphalt concrete material in the wearing course mixes perform as well as pavements with normal mixes. The cost of each type of pavement was found to be almost the same dollar/SY amount.

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Additional acknowledgment is made to involved personnel in the TESTING LAB and involved personnel in the Fifth and Seventh Districts of MDOT for their help with traffic control while running the Dynaflect and when samples were taken.

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CHAPTER 1: INTRODUCTION

The process of hot in-place recycling, as used for this project, involves heating the old asphalt pavement, milling, remixing the milled material with rejuvenator and new asphaltic concrete, redistributing the materials, and compacting in-place. The reuse of the existing asphaltic concrete pavement is desirable because of the decreasing supply and increasing costs of raw materials. The remixing leaves the final grade almost the same, which allows the user the option of rehabilitating only one lane of a multi-lane highway.

Background

Hot in-place recycling is usually performed by one of three methods:

1. heating the existing pavement, scarifying, adding rejuvenator, and compacting in-place;
2. heating the existing pavement, scarifying, adding rejuvenator, redistributing material, adding new material on top of the recycled material, and compacting in-place;
3. heating the existing pavement, scarifying or milling, remixing of recycled materials with rejuvenator and new asphaltic concrete, re-spreading the mixture , and compacting in-place.[2]

Objectives

This study was originally designed to monitor and evaluate the performance of the mix and surface over five years. Properties of the recycled layer in the monitored sections were determined and compared with another hot in-place recycling project and an overlay project. The evaluation of performance was to also be based on ride quality as measured with a South Dakota Profiler (SDP) and the overlay thickness computed from Dynamic Deflection Determination System (Dynaflect) and Falling Weight Deflectometer (FWD) deflection data.

Scope

This research study was part of State Maintenance Project No. (54-0055-067-10) in Pike county on I-55 from the Louisiana and Mississippi border and continuing north about 8.95 miles (14.4 km) (figure 1). The typical design section is shown in figure 2. The existing pavement consisted of:

- 4.5 in. (114 mm) or 10 in. (254 mm) variable thickness topping soil,
- 8 in. (203 mm) of roadbed topping for 8 in. (203 mm) of 4.5 percent cement treated base or 6 in. (152 mm) of roadbed topping for 8 in. (203 mm) of 5.5 percent cement treated base, and

- 5.5 in. (140 mm) of dense graded not plant mix.

The project was built in 1965 and was overlaid in 1984 with a single bituminous surface treatment and 1 in. (25-mm) leveling course and 1.5 in. (38-mm) surface course.

The construction contractor specified for surface recycling 1.5 in. (38 mm) of 263,415 SY (220 241 m^2) of in-place pavement. The contractor recommended adding about 40 lb/SY (21.7 kg/m^2) of new hot bituminous mix and about 0.15 to 0.20 gal/SY (0.68 to 0.91 L/m^2) of asphalt rejuvenating agent (e.g. ARA-1). A polymerized emulsion for the rejuvenator was used some in the northbound lane (AES-300 RP).

The research plan included:

1. Two 2,500 ft. (762-m) monitoring sections of roadway for evaluation.
2. Existing properties of the hot in-place mix were determined such as; AC content, aggregate gradation, and binder properties of viscosity, penetration and ductility.
3. Construction activities were documented in the monitoring sections such as, surface temperatures and mix temperatures. Data pertaining to the cutting, mixing, compaction, and finishing operations were obtained.
4. After construction, properties of the mix were obtained.
5. After construction condition of the reconstructed surface were taken, such as surface transverse and longitudinal profile, and Dynaflect deflection characteristics.
6. Part 5 was repeated for five years. The existing pavement was tested to determine the asphalt content at seven locations.

CHAPTER 2:DESIGN AND CONSTRUCTION

Description of Equipment

The remixing machine used on the project was the Wirtgen recycler (figure 3), which is made in Germany. It was first used in the USA in 1983 and has been used in eleven states.[1] It has completed over 7 million SY (5.6 million m^2) and recycles from depths of 1½ in. to 3 in. (38.10 mm to 76.20 mm). The remixing is used on roads with asphalt, which has a minimum penetration value of 15-20, rutting is less than 1 in. (25.4 mm) in depth, and there are no structural deficiencies.

Two self-propelled infrared asphalt heaters operated from 100 to 300 yards (91 to 274 m) ahead of the main recycling machine. The first pre-heater heats the surface to 190°F (88°C) and the second one heats the surface to about 240°F (116°C). The use of infrared heating, which the manufacturer claims, does not overly oxidize the existing asphalt cement.[2] They keep the mix temperatures between 240°F and 275°F (116°C and 135°C) after the screed (figure 4).

The rejuvenating machines ran at about (three m/minute), milled 1¼ in. (31.75 mm) of pavement, and added ¼ in. (6.35 mm) of new asphalt for 1½ in. (38.10-mm) total rejuvenated thickness. Up to 90 lb/SY (48.83 kg/m^2) of new material can be mixed with the existing material in the machine, which produces a uniform recycled hot mix

New material was placed in the hopper in the front of the machine. A conveyor belt then moved it the length of the machine above the recycling process to a pugmill-type mixing chamber. Behind the hopper were six banks of infrared heaters (figures 5). The softened pavement was milled, formed into a windrow, and moved to the mixing chamber, where it was mixed with the rejuvenator (figure 6) and new asphaltic concrete. The mixture was then spread by reversing augers, leveled by a vibratory screed, and compacted with a roller.

Construction

The hot in-place recycling section consisted of 7.688 miles (12.37 km) of Interstate 55 in Pike County from about 10 miles (16.1 km) south of McComb to the Louisiana State line. REMIXER CONTRACTING CO., INC. recommended adding approximately 40 lb/SY (21.7 kg/m^2) of new asphalt and 0.15 to 0.20 gal/SY (0.68 to 0.91 L/m^2) of rejuvenating emulsion (e.g. ARA-1). The contractor used polymer-modified emulsion instead of the normal rejuvenator north of station 300+00 (9 + 144.018) in both of the northbound lanes. Work began on 8 Oct 91 and stopped for cold weather on 12 Dec 91. Work resumed on 9 Mar 92 and finished on 22 Apr 92.

Economics

The total cost of the project was $1,939,934.60 for the 263,415 SY (220 241 m^2) of surface recycling. The cost per square yard is calculated in Table 1.

Table 1. Recycling costs.

ITEM NO	DESCRIPTION	UNIT	QUANTITY	UNIT PRICE	AMOUNT	$/SY
402-A	SURFACE RECYCLING OF EXIST BIT PAVE	SY	263,415	1.7	$447,805.60	$ 1.70
402-B	REJUVENATING AGENT	G	52,683	1.5	$ 79,024.50	$ 0.30
402-C	VIRGIN HOT BIT MIX	t	6,585	35	$230,475.00	$ 0.87
						$ 2.87

For hot bituminous surface course costing $35/ton ($38.58/metric ton), a 1½ in. (38 mm) overlay would cost about $2.89/SY ($3.56/m^2).

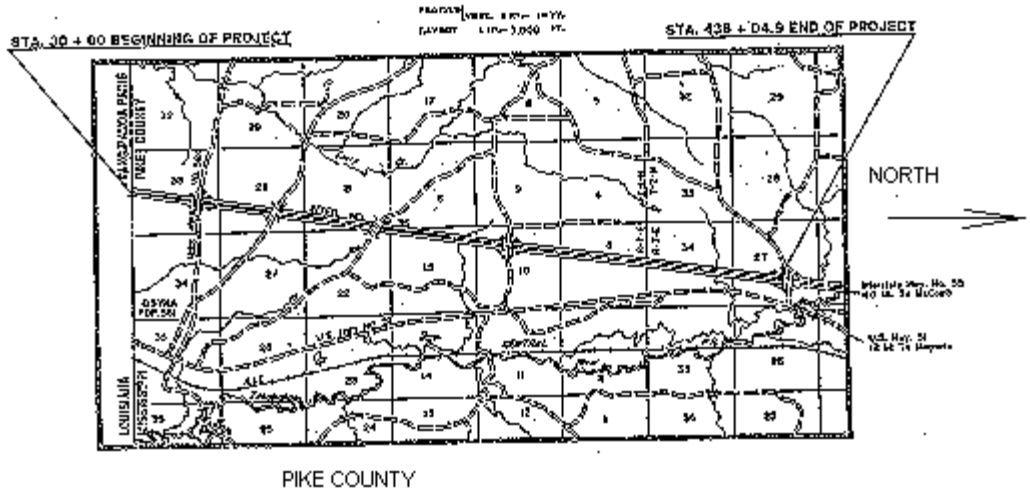

Figure 1. Project location.

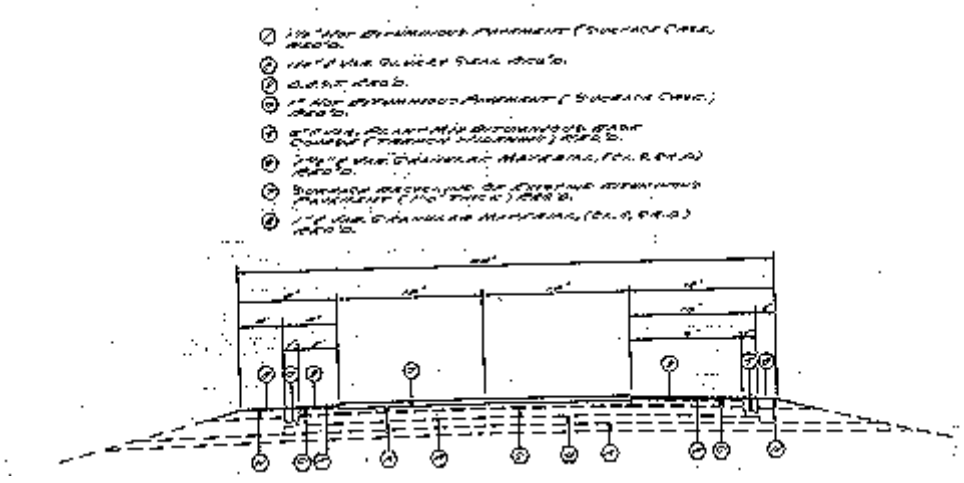

Figure 2. Design Section.

Figure 3. Wirtgen Remixer train.

Figure 4. Leveling auger and screed.

Figure 5. Heaters.

Figure 6. Adding rejuvenator.

Figure 7. Control panel.

Figure 8. Before and after.

CHAPTER 3: TEST RESULTS AND DISCUSSION

Dynaflect and Falling Weight Deflectometer Testing

The Dynaflect measures pavement deflection induced by an applied load. It is an electro-mechanical system consisting of a dynamic force generator and a motion measuring system, which is mounted on a towed trailer. The five motion sensing geophones are suspended from the towing arm of the trailer. The first geophone is between the steel wheels and the other four geophones are at 12 in. (305-mm) intervals in front of the first geophone. The generator produces a vertical force, which varies at the rate of eight cycles/second. This is applied to the pavement though a pair of rigid steel wheels, which are 20 in. (508 mm) apart. The total force applied to the pavement consists of the static load of the instrument trailer, which is 1,600 pounds (7.1 kN), plus the dynamic force which consecutively add to and subtracts from this load. The peak to peak excursion of the dynamic force is 1,000 pounds (4.4 kN).

A Falling Weight Deflectometer (FWD) replaced the Dynaflect in 1995. The FWD simulates the pulse load applied by a 18,000-pound (80-kN) axle load moving at about 48 mph (77 km/hr). A 440-pound (200-kg) weight is raised up a mast and dropped a spring-loaded plate which is about 12 in. (305 mm) in diameter. This produces a 9,000-pound (40-kN) impact dynamic force with a loading time of 25-30 milliseconds. The pulse wave is detected by transducers located at the center of the plate and at various distances away from the plate.

The entire project was tested with the Dynaflect on 10 Apr 91. In the northbound lane, 41 Dynaflect readings were taken at 1,000 ft. (304.8-m) intervals. In the southbound lane, 43 readings were taken at 1,000 ft. (304.8-m) intervals. Two 1,000 ft. (304.8-m) test sections with readings taken at 100 ft. (30.48-m) intervals were used for later testing.

Table 2. Required overlay thickness before recycling.

DATE	NOTES	NORTHBOUND overlay thickness	NOTES	SOUTHBOUND overlay thickness
10-Apr-91	41 readings on entire project	0.00" (0.0 mm)	43 readings on entire project	0.58" (14.7 mm)
10-Apr-91	Test section	0.33" (8.4 mm)	Test section	1.11" (28.2 mm)
25-Sep-91	Test section	0.28" (7.1 mm)	Test section	0.85" (21.6 mm)

The same two 1,000 ft. (304.8-m) test sections with readings taken at 100 ft. (30.48-m) intervals were used for testing after the hot in-place recycling.

Table 3. Required overlay thickness after recycling.

DATE	NOTES	NORTHBOUND overlay thickness	NOTES	SOUTHBOUND overlay thickness
9-Jul-92	Test section	0.00" (0.0 mm)	Test section	0.05" (4.3 mm)
12-Aug-93	Test section	0.00" (0.0 mm)	Test section	0.00" (0.0 mm)
25-Aug-94	Test section	0.00" (0.0 mm)	Test section	0.56" (14.2 mm)
21-Sep-95	Test section (FWD)	0.00" (0.0 mm)	Test section (FWD)	0.00" (0.0 mm)
6-Oct-96	Test section (FWD)	0.00" (0.0 mm)	Test section (FWD)	0.00" (0.0 mm)

Roughness Testing

The roughness statistic International Roughness Index (IRI) was determined from the roadway profile. The IRI is the ratio of the accumulated suspension motion of a vehicle, divided by the distance traveled during the test at 50 mph (80 km/hr) and the units are meters per kilometer of roughness. A perfectly smooth pavement has an IRI of zero and the roughest pavements in the United States may have an IRI greater than five.

The entire project was surveyed for measurements of roughness with the SDP quarterly for the evaluation period. The roughness tests were made at about 50 mph (80 km/hr). Four trips were made on each test date. The runs on June 20, 1991, October 10, 1991, and October 21, 1991 were before the pavement was recycled.

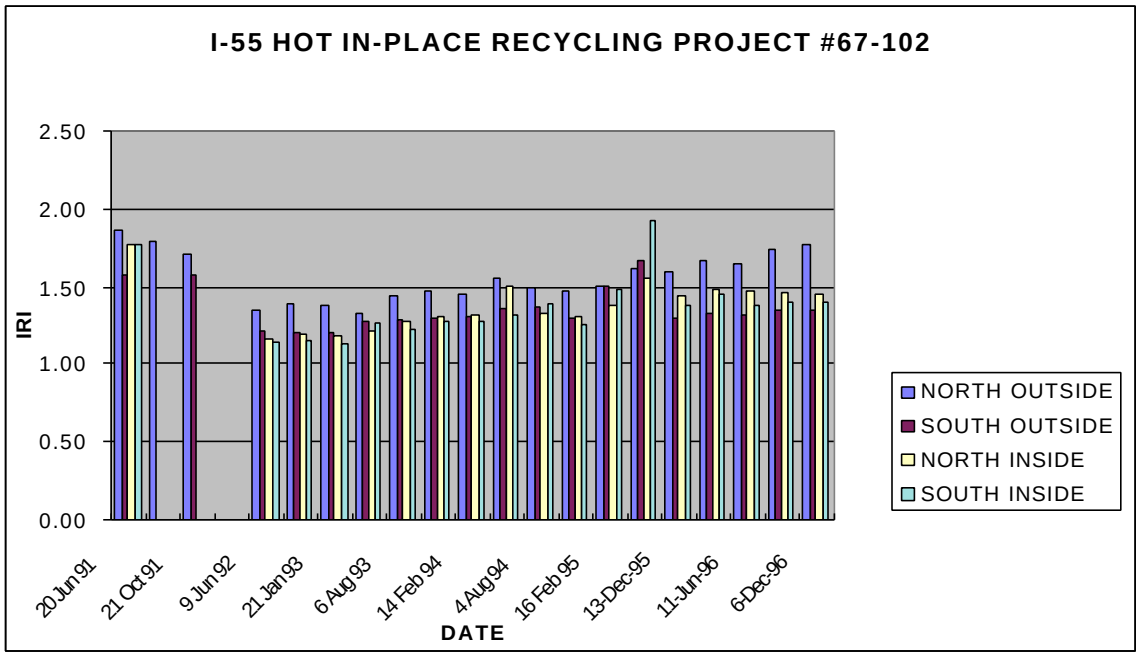

Figure 9. IRIs on the project.

Testing of Asphalt Cement

Core and bucket samples were taken before and after the hot in-place recycling. Samples were also taken off the trucks with the new material. Roadway cores were tested for viscosity, penetration, ductility, percent asphalt content, and aggregate gradation.

Table 4. Before REMIX samples.

DATE	SAMPLE LOCATION & DESCRIPTION
5-Feb-91	Eight core samples in the northbound lanes were taken in the center of the lanes at one-mile intervals half way between the mile markers.
7-Feb-91	Eight core samples in the south bound were taken in the center of the lanes at one-mile (1.61-km) intervals half way between the mile markers.
25-Sep-91	At station 305+95 (9 + 357.378) in the northbound outside lane, 25 4" (101.6-mm) diameter core samples were taken with the electric core borer down to 3" (76.2 mm). 12 cores in the outer wheel path at 2' (0.61-m intervals) and 13 cores in the middle of the lane at 2' (0.61-m) intervals were taken.
25-Sep-91	At station 189+00 (5 + 760.731) in the southbound outside lane, 25 4" (101.6-mm) diameter core samples down to 3" (76.2 mm) were taken. 12 cores in the outer wheel path at 2' (0.61-m) intervals and 13 cores in the middle of the lane at 2' (0.61-m) intervals were taken.
17-Mar-92	The REMIX machines got to station 189+00 (5 + 760.731) in the southbound outside lane, where the earlier cores were taken. Four buckets of samples were collected. The second was from the heated pavement.
17-Mar-92	The REMIX machines got to station 189+00 (5 + 760.731) in the southbound outside lane, where the earlier cores were taken. Four buckets of samples were collected. The fourth was deeper in the heated pavement.
16-Apr-92	The REMIX machines got to station 307+00 (9 + 357.378) in the northbound out-side lane, where the earlier cores were taken. Three buckets of samples were collected. The second was from the heated pavement.

Table 5. New asphalt samples off truck.

DATE	SAMPLE LOCATION & DESCRIPTION
17-Mar-92	The REMIX machines got to station 189+00 (5 + 760.731) in the southbound outside lane, where the earlier cores were taken. Four buckets of samples were collected. The first was new asphalt from the truck.
16-Apr-92	The REMIX machines got to station 307+00 (9 + 357.378) in the northbound out-side lane, where the earlier cores were taken. Three buckets of samples were collected. The first was new asphalt from the truck.

Table 6. After REMIX samples.

DATE	SAMPLE LOCATION & DESCRIPTION
17-Mar-92	The REMIX machines got to station 189+00 (5 + 760.731) in the southbound outside lane, where the earlier cores were taken. Four buckets of samples were collected. The third was the recycled mix with the rejuvenator added.
16-Apr-92	The REMIX machines got to station 306+00 (9 + 357.378) in the northbound out-side lane, where the earlier cores were taken. Three buckets of samples were collected. The third was the recycled mix with the polymer rejuvenator added.
8-Jul-92	At station 189+00 (5 + 760.731), in the southbound outside lane, 15 4" (101.6 mm) diameter core samples were taken down to 3" (76.2 mm). Seven cores were taken in the outer wheel path at 2' (0.61-m) intervals and eight cores were taken in the middle of the lane at 2' (0.61-m) intervals.
8-Jul-92	At station 306+00 (9 + 357.378) in the northbound outside lane, 15 4" (101.6-mm) diameter core samples were taken. Seven cores were taken in the outer wheel path at 2' (0.61-m) intervals and eight cores were taken in the middle of the lane at 2' (0.61-m) intervals.
20-Sep-94	In the southbound outside lane, at station 189+00 (5 + 786.335) 15 4" (101.6-mm) diameter core samples down to 3" (76.2 mm) were taken. Seven cores were taken in the outer wheel path at 2' (0.61-m) intervals and eight cores were taken in the middle of the lane at 2' (0.61-m) intervals.
20-Sep-94	In the northbound outside lane, at station 306+00 (9 + 362.256), 15 4" (101.6-mm) diameter core samples down to 3" (76.2 mm) were taken. Seven cores were taken in the outer wheel path at 0.61-m intervals and eight cores were taken in the middle of the lane at 2' (0.61-m) intervals.

Figure 10 displays the comparison of the average viscosities, figure 11 displays the comparison of the average penetration, figure 12 displays the comparison of the average ductlities, and figure 13 displays the comparison of the average percent asphalt concrete.

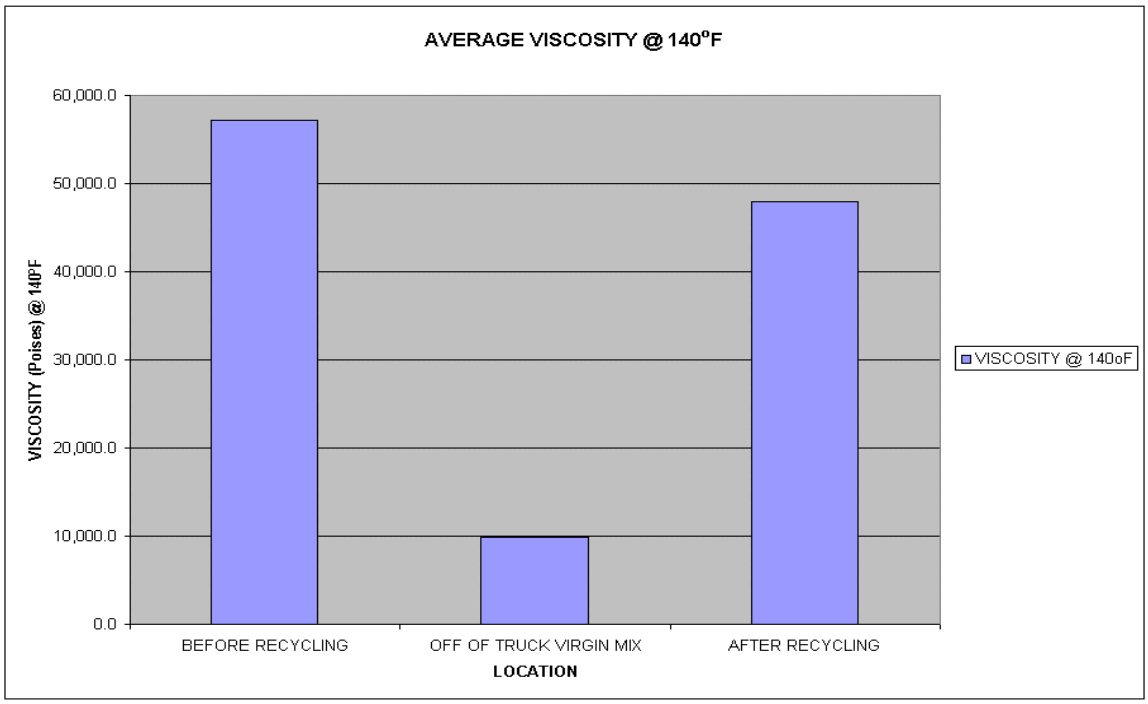

Figure 10. Average viscosity of samples.

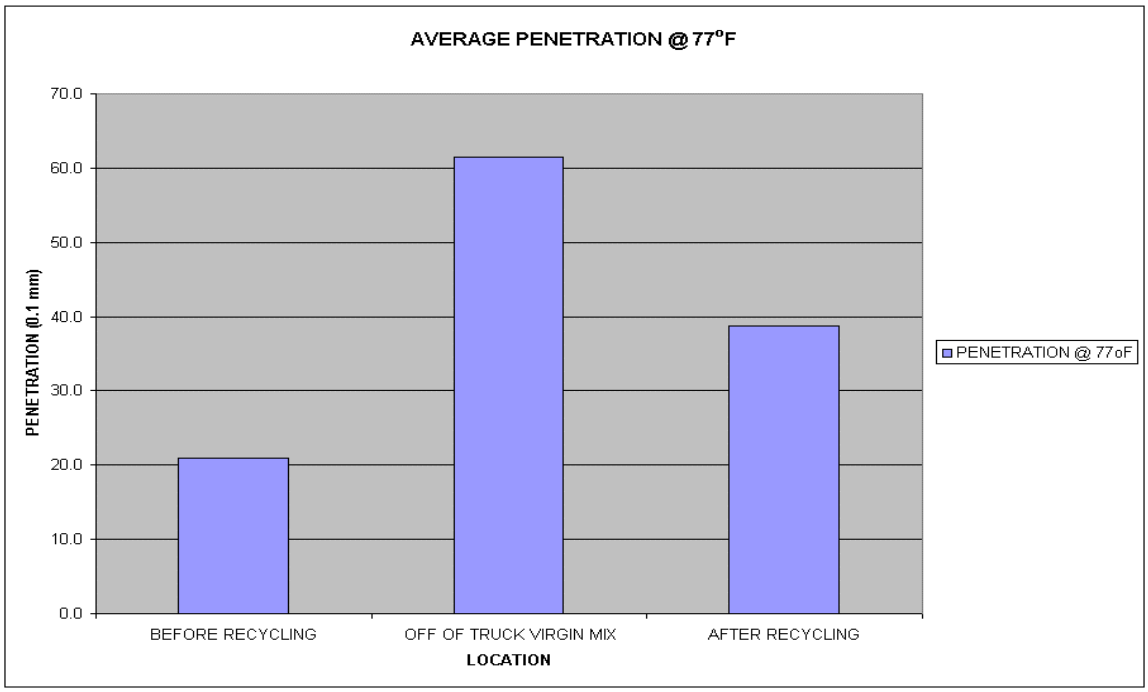

Figure 11. Average penetration of samples.

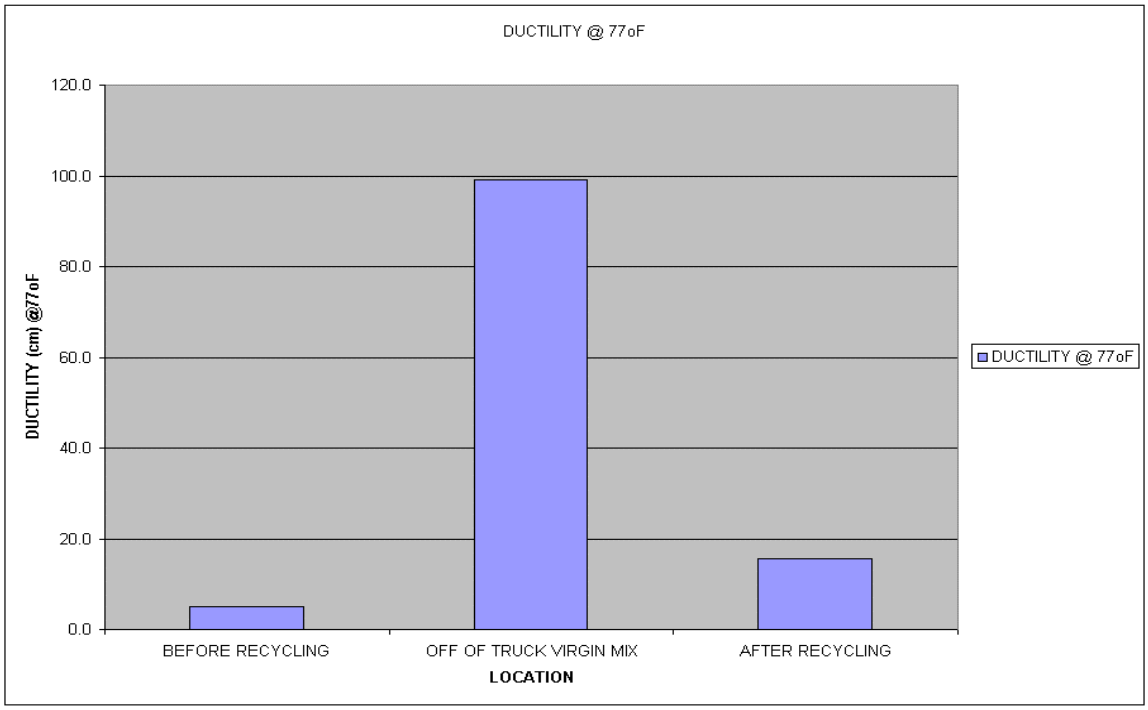

Figure 12. Average ductility of samples.

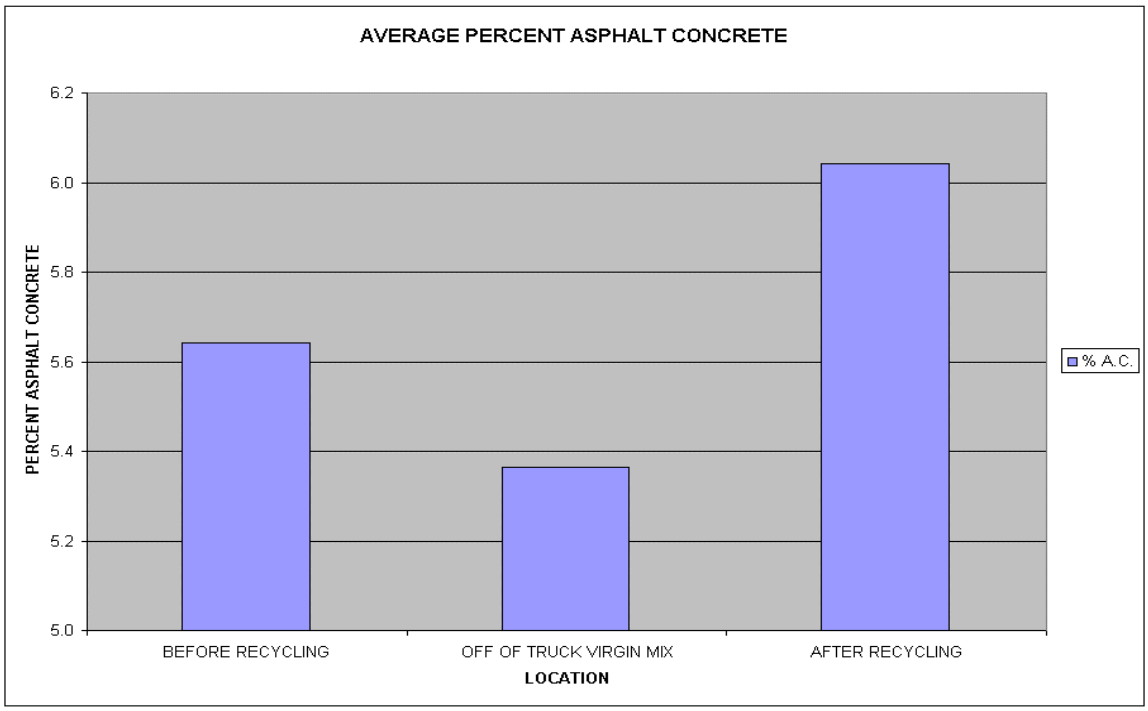

Figure 13. Average percent asphalt concrete.

Table 7 presents the differences of four properties of asphalt samples taken more than two years apart. Figure 14 and Table 8 present the differences in gradation of the asphalt samples.

Table 7. Differences in properties of asphalt cement after more than 2 years.

DATE SAMPLED	AVERAGE VISCOSITY (Poises) @ 140°F	AVERAGE PENETRATION @ 77°F 0.1 mm	AVERAGE DUCTILITY @ 77°F, cm	AVERAGE PERCENT ASPHALT CONCRETE
08-Jul-92	49,574.5	36.5	11.8	6.0
20-Sep-94	59,491.0	39.5	17.5	6.1
PERCENT CHANGE	20.0%	8.2%	48.9%	2.7%

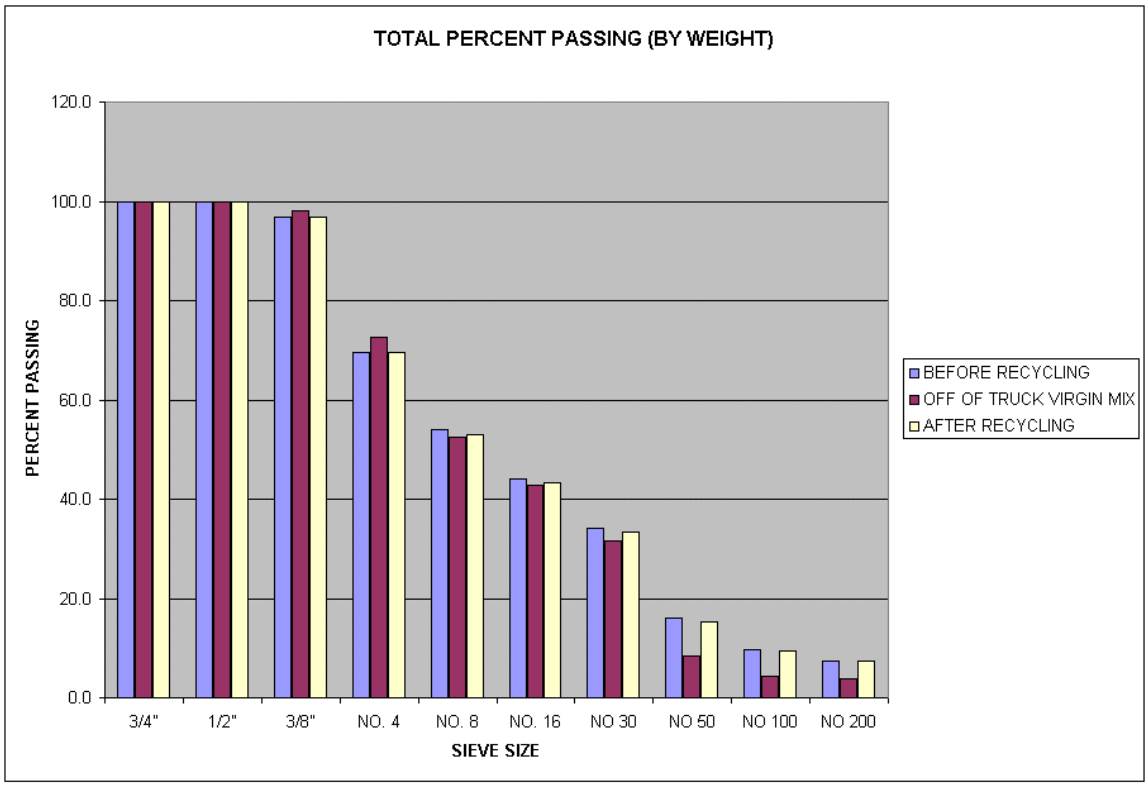

Figure 14. Sample gradations before and after recycling.

Table 8. Differences in gradations after more than 2 years.

DATE SAMPLED	3/4"	1/2"	3/8"	NO. 4	NO. 8	NO. 16	NO 30	NO 50	NO 100	NO 200
08-Jul-92	100.0	100.0	96.9	69.3	52.7	43.3	33.5	15.0	9.2	7.3
20-Sep-94	100.0	99.6	96.5	69.4	53.3	43.5	33.6	16.3	10.0	7.9
PERCENT CHANGE	0.0	-0.4%	-0.4%	0.1%	1.1%	0.3%	0.3%	8.5%	8.7%	8.2%

Comparison of hot in-place cores with overlay cores

Core samples were taken to the testing laboratory where specific gravities were determined. Asphalt cement was extracted from the cores to determine the asphalt cement content and gradation testing was performed. The asphalt cement was recovered from the extracted cores by the Abson process and tested for viscosity, penetration, and ductility. Cores were tested for viscosity, penetration, ductility, voids, density, specific gravity, percent asphalt content, and aggregate gradation.

Core samples were taken from:

1. the hot in-place recycling project south of McComb (Table 9),
2. the hot in-place recycling projects south of Meridian on I-59 and east of Meridian on I-20 (Table 9),
3. from an overlay project (Table 10) east and west of Forest on I-20.

Table 9. Description of location of cores that have been hot in-place recycled.

DATE	SAMPLE LOCATION & DESCRIPTION
20-Sep-94	South of McComb on I-55. In the southbound outside lane, at station 189+84 (5 + 786.335), fifteen 4" (101.6-mm) diameter core samples down to 3" (76.2 mm) were taken. Seven cores were taken in the outer wheel path at 2' (0.61-m) intervals and eight cores were taken in the middle of the lane at 2' (0.61-m intervals).
20-Sep-94	South of McComb on I-55. In the northbound outside lane, at station 307+16 (9 + 362.256), fifteen 4" (101.6-mm) diameter core samples down to 3" (76.2 mm) were taken. Seven cores were taken in the outer wheel path at 2' (0.61-m) intervals and eight cores were taken in the middle of the lane at 2' (0.61-m) intervals.
11-Oct-94	South of Meridian in the southbound outside lane of I-59 at the end of the Dynaflect test section at about mile marker 145, fifteen 4" (101.6-mm) diameter core samples down to 3" (76.2 mm) were taken. Seven cores were taken in the outer wheel path at 2' (0.61-m) intervals and eight cores were taken in the middle of the lane at 2' (0.61-m) intervals.
11-Oct-94	West of Meridian in the westbound outside lane of I-20 and I-59 near the first bridge past the Alabama State line at about mile marker 172, fifteen 4" (101.6-mm) diameter core samples down to 3" (76.2 mm) were taken. Seven cores were taken in the outer wheel path at 2' (0.61-m) intervals and eight cores were taken in the middle of the lane at 2' (0.61-m) intervals.

Table 10. Description of location of cores from overlay on I-20.

DATE	SAMPLE LOCATION & DESCRIPTION
15-Nov-94	I-20 west of Forest in the eastbound outside lane at mile marker 83. Fifteen 4" (101.6-mm) diameter core samples down to 3" (76.2 mm) were taken. Seven cores were taken in the outer wheel path at 2' (0.61-m) intervals and eight cores were taken in the middle of the lane at 2' (0.61-m) intervals.
15-Nov-94	I-20 west of Forest in the westbound outside lane at mile marker 95. Fifteen 4" (101.6-mm) diameter core samples down to 3" (76.2) mm were taken. Seven cores were taken in the outer wheel path at 2' (0.61-m) intervals and eight cores were taken in the middle of the lane at 2' (0.61-m) intervals down to 1.5" (38 mm) because they all broke off there.

Table 11. Comparison of average properties of cores, data for figures 15, 16, 17, 18, 19, 20, and 21.

LOCATION	AVERAGE VISCOSITY (@ 140°F Poises)	AVERAGE PENETRATION (@ 77°F 0.1 mm)	AVERAGE DUCTILITY (@ 77°F, cm)	AVERAGE PERCENT VOIDS	AVERAGE DENSITY (pounds/ft^3)	AVERAGE MAXIMUM SPECIFIC GRAVITY	AVERAGE PERCENT ASPHALT CONCRETE
#1 I-55 SOUTH OF McCOMB AVERAGE (RECYCLED)	59,491.0	39.5	17.5	4.7	139.8	2.3	6.1
#2 I-59-20 NEAR MERIDIAN AVERAGE (RECYCLED)	9,864.0	43.5	72.8	2.3	150.8	2.5	5.4
#3 I-20 NEAR FOREST AVERAGE (CONTROL)	8,878.8	32.8	150.0	4.6	142.6	2.4	5.6
PERCENT CHANGE FROM #1 TO #2	-83.4%	10.1%	315.7%	-50.7%	7.8%	5.4%	-11.4%
PERCENT CHANGE FROM #1 TO #3	-85.1%	-17.1%	757.1%	-0.8%	2.0%	2.2%	-9.1%
PERCENT CHANGE FROM #2 TO #3	-10.0%	-24.7%	106.2%	101.3%	-5.4%	-3.1%	2.6%

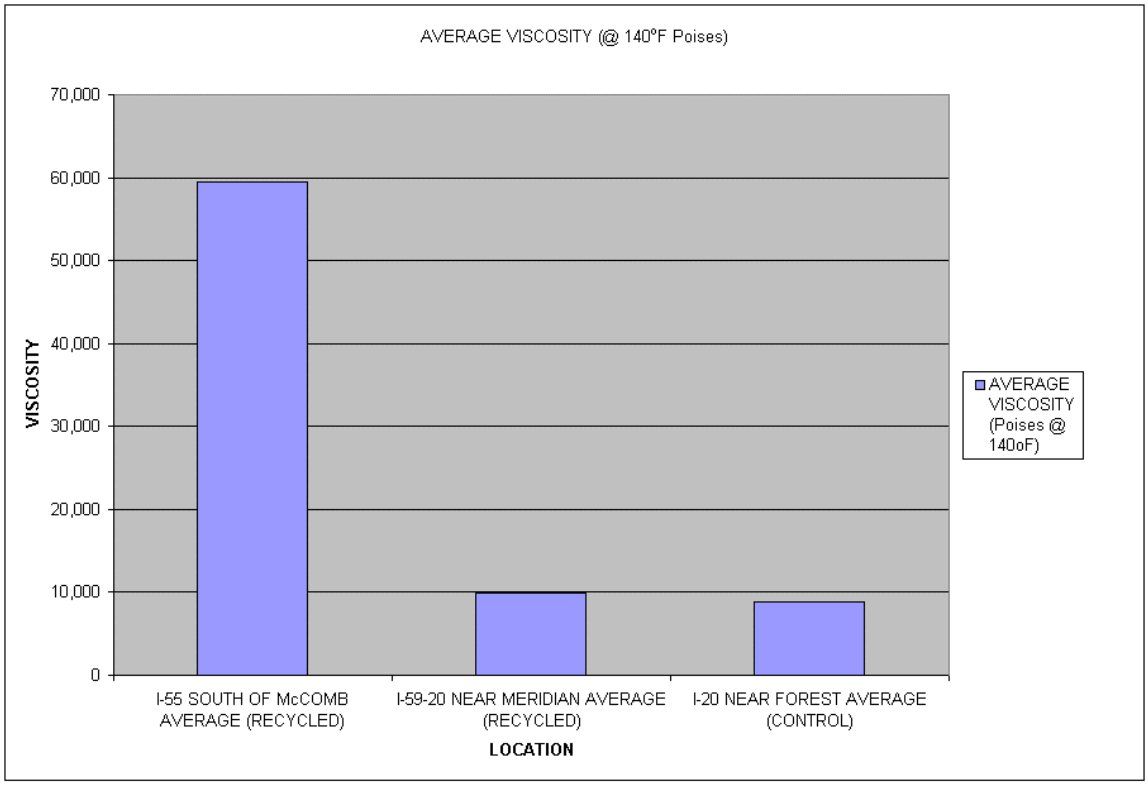

Figure 15. Average viscosities of samples.

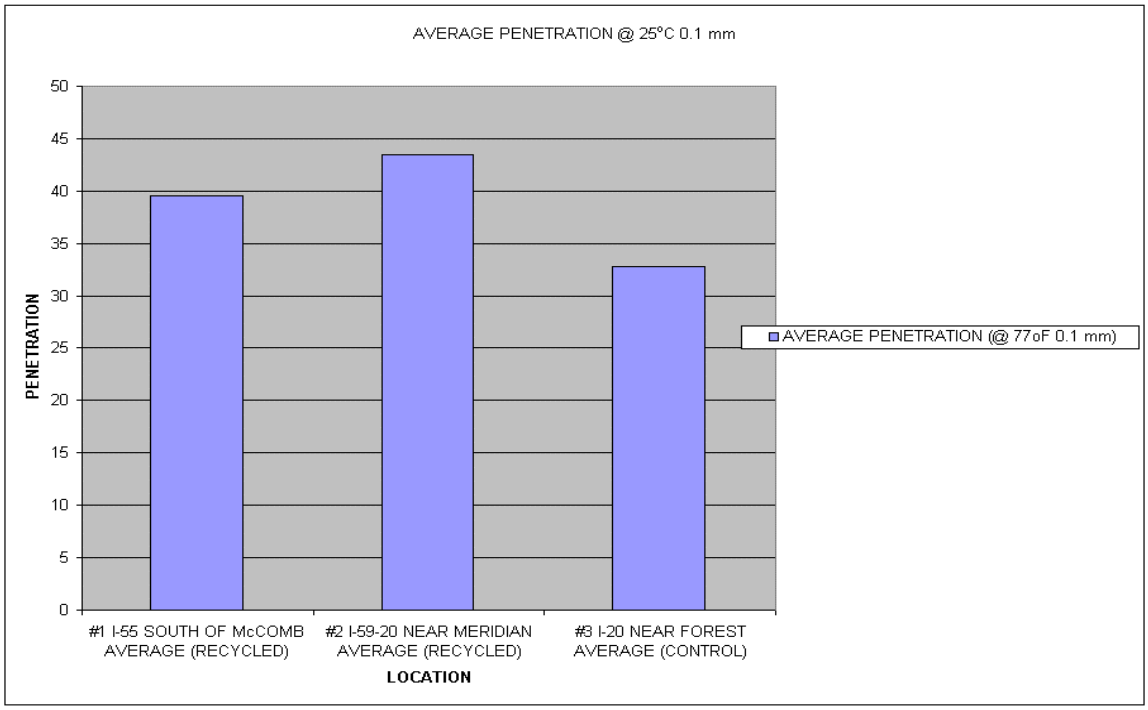

Figure 16. Average penetration of samples.

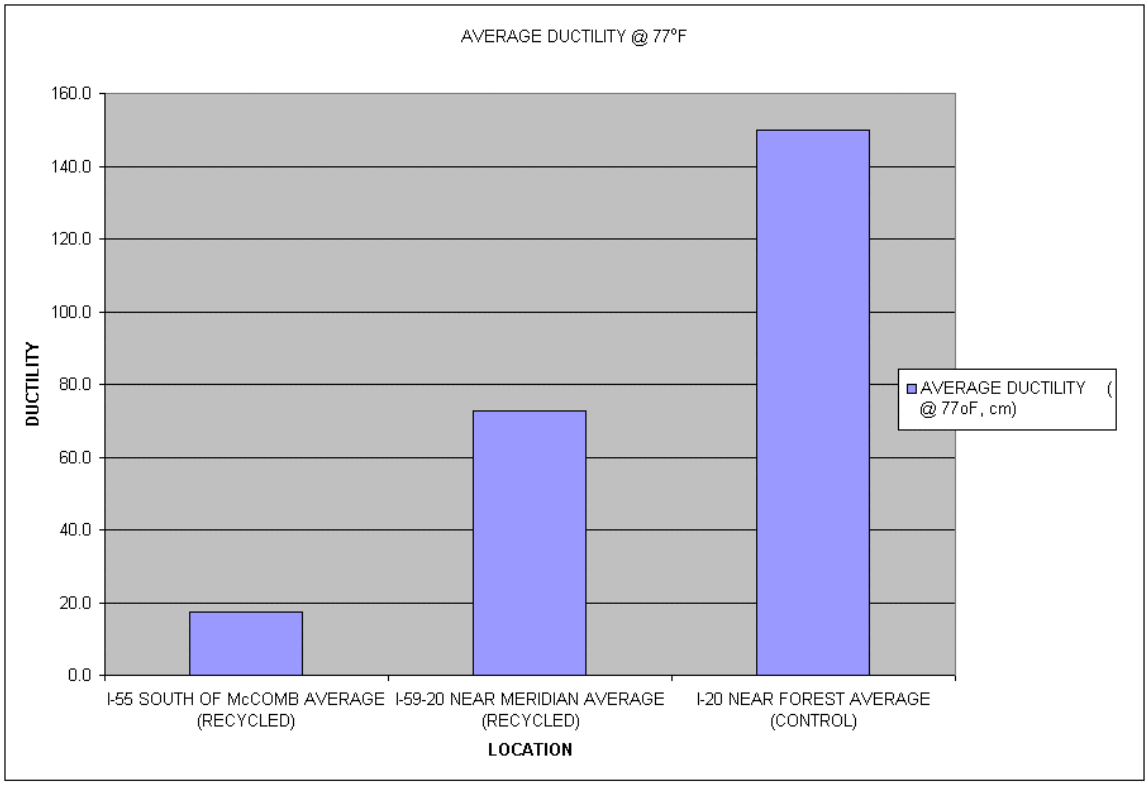

Figure 17. Average ductilities of samples.

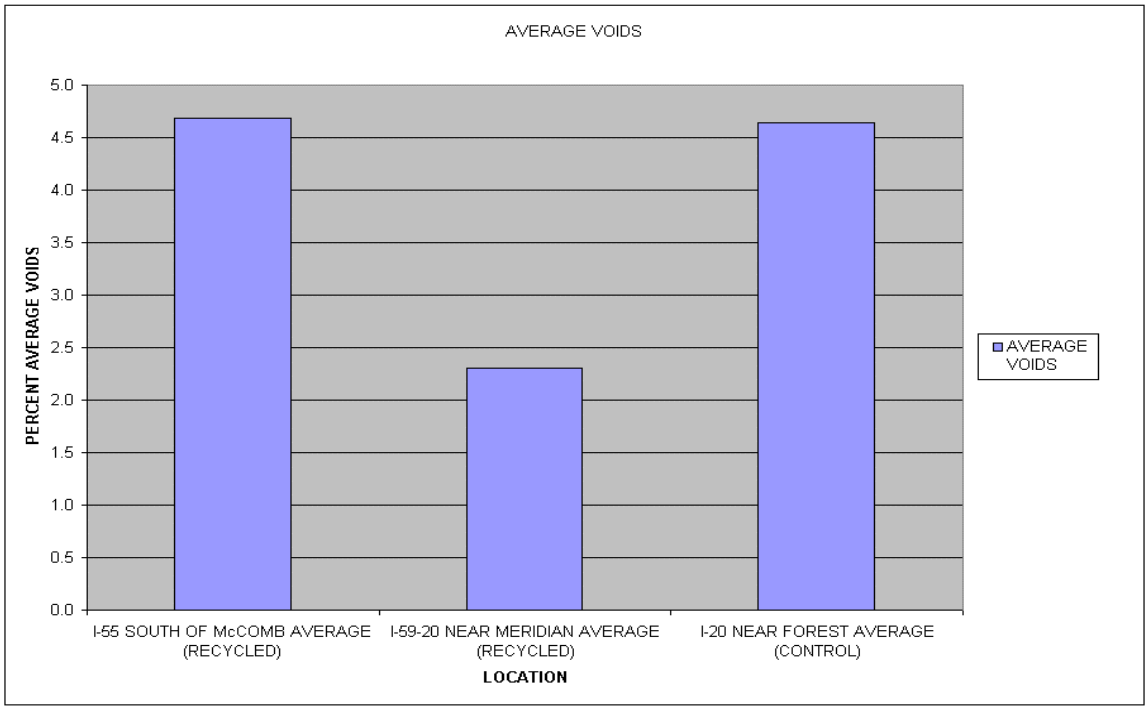

Figure 18. Average percent voids of samples.

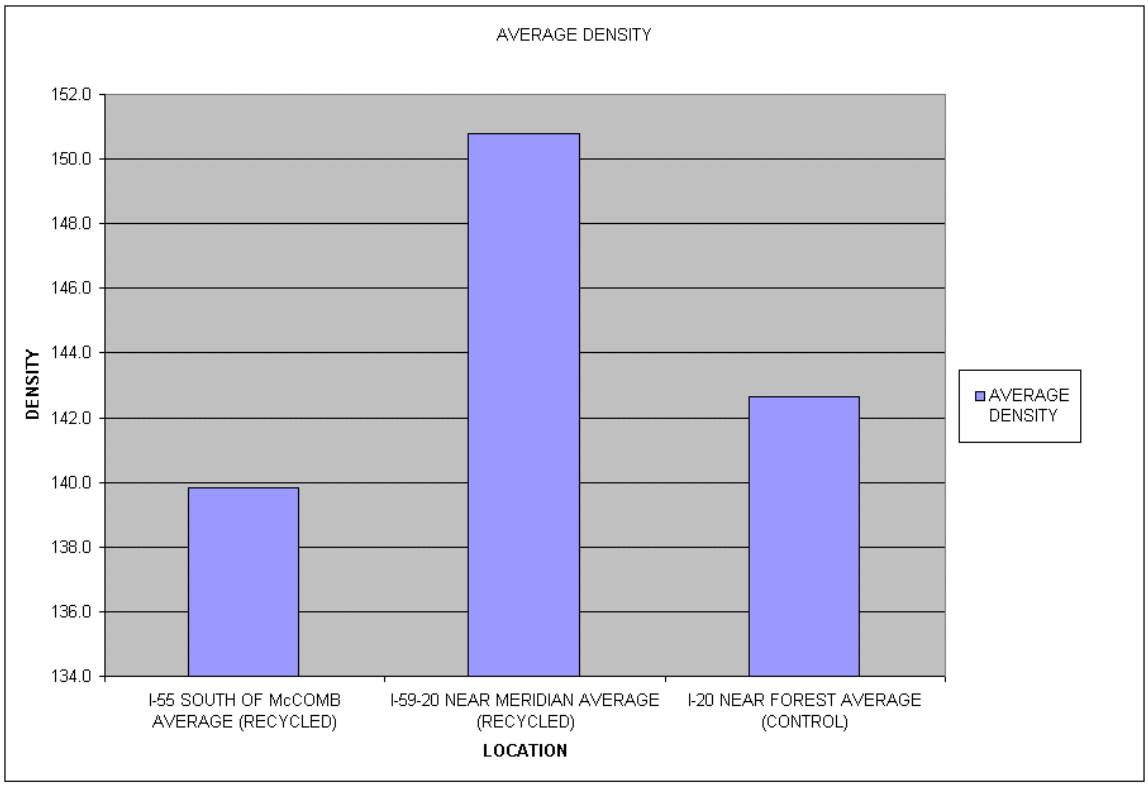

Figure 19. Average densities of samples.

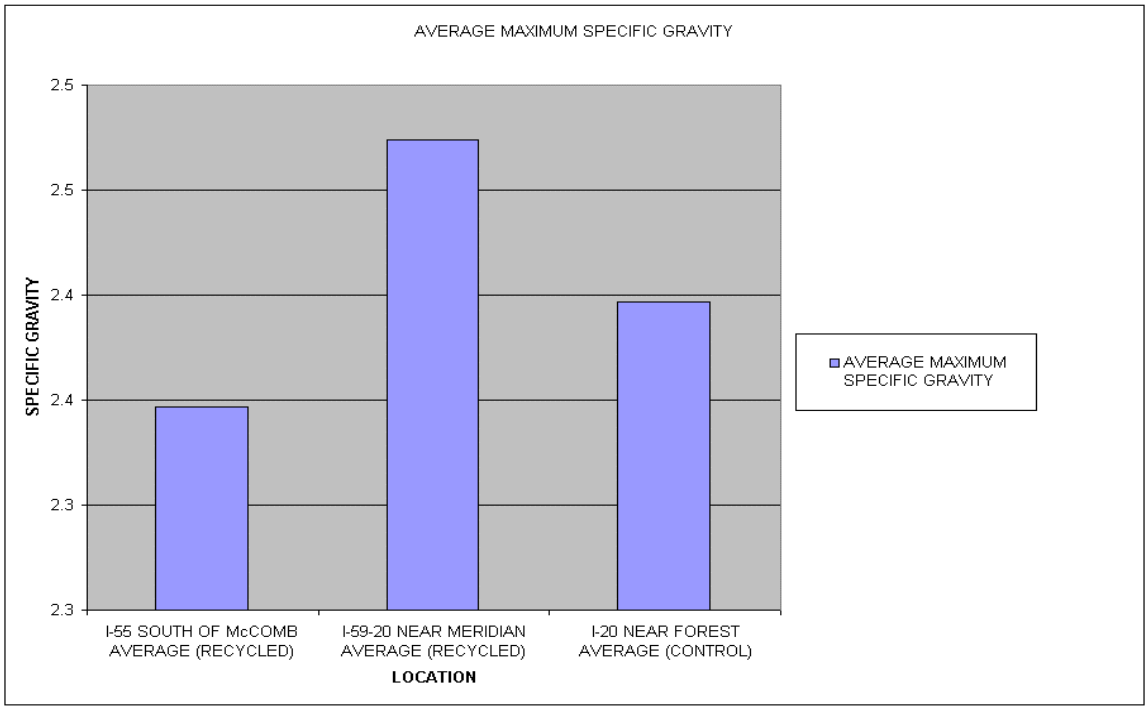

Figure 20. Average maximum specific gravities of samples.

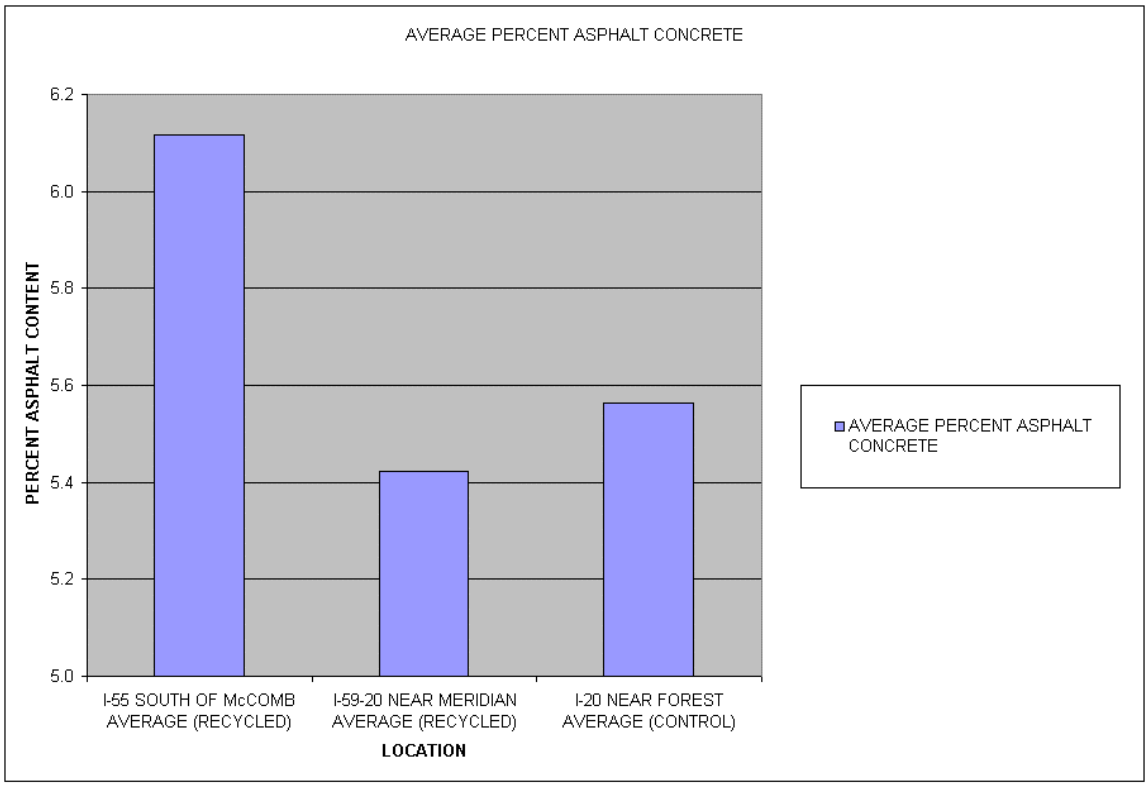

Figure 21. Average percent asphalt concrete in samples.

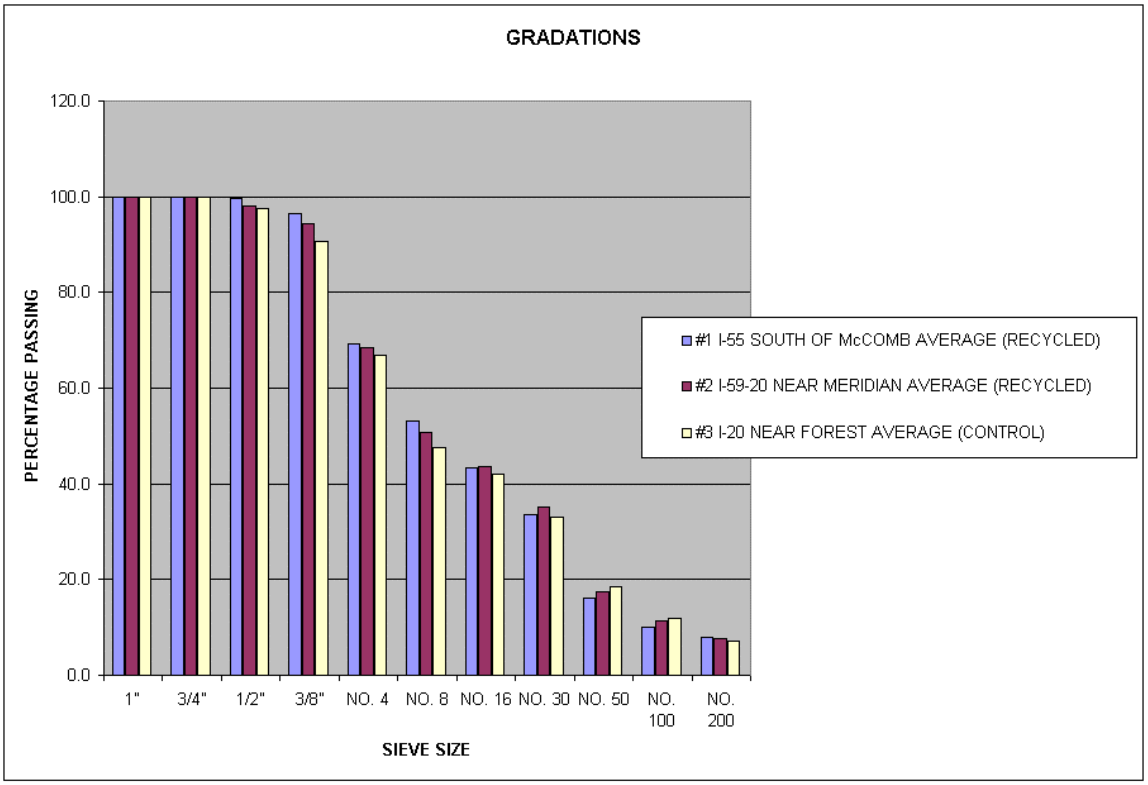

Figure 22. Average gradations of core samples.

Resilient Modulus Results

The resilient modulus values are used to evaluate the relative quality of materials and generate input for pavement evaluation and analysis.

Two cores from I 59, one core on I 20 at Forest, two cores on I 20 west of Meridian, one core on I 55 southbound, and one core on I 55 northbound were tested at the University of Mississippi. Figure 23 shows that the recycled asphalt had a lower average modulus than the control pavement.

The resilient modulus values are used to appraise the quality of materials and help in pavement evaluation and analysis. After the test sample is placed into the testing machine, ten consecutive readings of load and deformation are taken. Then the sample is rotated 90^o and ten more consecutive readings of load and deformation are taken and the values are averaged. The entire testing procedure should be redone if the difference in average M_R values is lmore than 10%.

The Resilient modulus is computed using the following formula:

$M_R = (P * (\mu + 0.2734))/(t * (?))$ where P= load in pounds

μ = Poisson's ratio (usually 0.35)

t = thickness of specimen in inches

? = deformation in inches

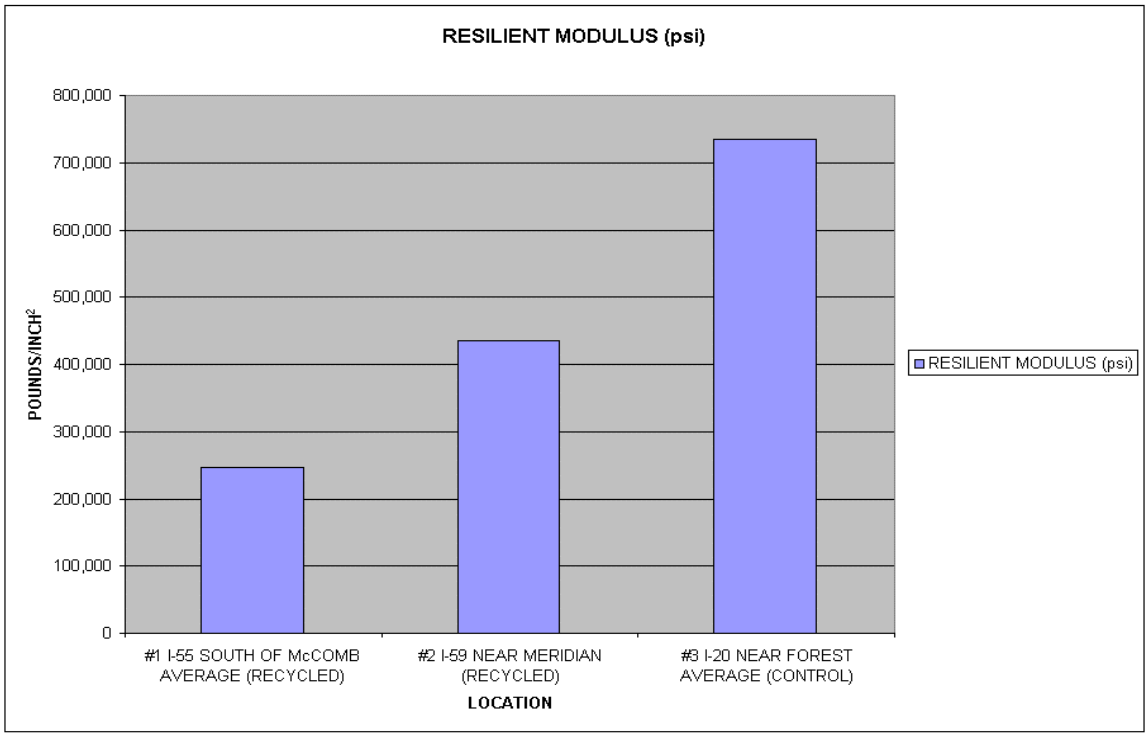

Figure 23. Resilient modulus of samples.

Discussion of Results

Structural

The required overlay thicknesses are provided in tables 2 and 3. The hot in-place recycling solved the required overlay thickness requirement calculated from the Dynaflect and FWD.

The average IRIs on the project are presented in table 4 and figure 9. They show that the hot in-place recycling reduced the average IRI on the project by 30.4 percent for the first testing on 9 Jun 92. The last testing on 6 Dec 96 was 14.5 percent less than the 20 Jun 91.

Materials and mix analysis

The penetration tests performed by the contractor on the field studies were greater or equal to the minimum value of 50 in 13 of 143 tests. The penetration tests performed by the Mississippi testing laboratory on the core samples were greater or equal to the minimum value of 50 in only one of 10 penetration tests.

It was conclude in another study that: " Limestone coarse aggregate is apparently a prime contributor to longer pavement life as compared to chert gravel coarse aggregate,…"[5]

The I-55 test section used chert gravel coarse aggregate, while the other sections had limestone coarse aggregate.

The asphalt cement properties were consistant with most findings; the higher viscosity corresponded to lower penetrations and ductilities.

The average of the viscosities of the test samples in the I-55 test section was much higher than the other samples.

The average penetration of the test samples in the I-55 test section was between the other samples.

The average of the ductilities of the test samples in the I-55 test section was the lowest of all the test samples.

The average of the voids in the northbound test sample was the largest of the test samples, while having the lowest density.

The average of the maximum specific gravities of the samples in the I-55 test section was the lowest, while the average percent of asphalt concrete was the highest.

The average of the resilient modulus values of the samples in the I-55 test section was lower than the other samples. This is probably due to the different types of gravel used in the asphalt mix.

CHAPTER 4: CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The construction of this project followed the hot in-place recycling of I-59 south of Meridian which lasted from November 1989 to May 1990. This project was was originally scheduled to be a Research Division study. Although some core data from I-59 was used from this study, Dynaflect and SDP data would have been useful to compare with this study.

The reuse of the existing asphaltic concrete pavement can often be very desirable, because of the decrease in new asphalt needed and as a safety factor because the finished grade is essentially the same elevation as the existing pavement. The hot in-place recycling project also produced a savings over the conventional design.

There were no major differences in the hot in-place recycling projects and the overlay project in properties, which included viscosity, penetration, ductility, percent voids, specific gravity, aggregate gradations, and resilient modulus.

Recommendations

This study found that pavements using reclaimed asphalt concrete material in the wearing course mixes perform as well as pavements with normal mixes. However, the cost of each type of pavement was found to be almost the same dollar/SY amount.

APPENDIX A

ASPHALT TESTS

Table 12. IRIs on the projects, data for figure 9.

	I-55 HOT IN-PLACE RECYCLING PROJECT #67-102						PERCENT
	DATE	NORTH	SOUTH	NORTH	SOUTH	AVERAGE	LESS THAN
		OUTSIDE	OUTSIDE	INSIDE	INSIDE	IRI	20-Jun-91 AVERAGE
BEFORE #1	20-Jun-91	1.86	1.58	1.77	1.77	1.75	
REMIX #2	10-Oct-91	1.79				1.79	
#3	21-Oct-91	1.70	1.58			1.64	
AFTER #1	9-Jun-92	1.35	1.21	1.16	1.14	1.22	30.4%
REMIX #2	1-Oct-92	1.39	1.20	1.19	1.15	1.23	29.4%
#3	21-Jan-93	1.38	1.20	1.18	1.13	1.22	29.9%
#4	19-Apr-93	1.33	1.28	1.21	1.27	1.27	27.1%
#5	6-Aug-93	1.44	1.29	1.28	1.22	1.31	25.1%
#6	11-Nov-93	1.47	1.30	1.31	1.28	1.34	23.2%
#7	14-Feb-94	1.45	1.31	1.32	1.28	1.34	23.2%
#8	19-May-94	1.56	1.36	1.51	1.32	1.44	17.6%
#9	4-Aug-94	1.50	1.37	1.33	1.39	1.40	19.9%
#10	7-Nov-94	1.48	1.30	1.31	1.26	1.34	23.4%
#11	16-Feb-95	1.51	1.51	1.38	1.49	1.47	15.6%
#12	9-May-95	1.61	1.66	1.56	1.92	1.69	3.3%
#13	13-Dec-95	1.60	1.30	1.44	1.38	1.43	18.1%
#14	20-Mar-96	1.66	1.33	1.49	1.45	1.48	15.0%
#15	11-Jun-96	1.64	1.32	1.47	1.38	1.45	16.8%
#16	6-Sep-96	1.74	1.35	1.46	1.40	1.49	14.8%
#17	6-Dec-96	1.77	1.35	1.45	1.40	1.49	14.5%

Table 13. Data for figures 10, 11, 12, and 13. Average asphalt cement properties before and after recycling.

	AVERAGE VISCOSITY @ 140°F	AVERAGE PENETRATION @ 77°F 0.1 mm	AVERAGE DUCTILITY @ 77°F, cm	AVERAGE PERCENT ASPHALT CONCRETE
BEFORE RECYCLING	57,134.0	21.0	5.1	5.6
OFF OF TRUCK VIRGIN MIX	9,877.0	61.5	99.0	5.4
AFTER RECYCLING	47,901.2	38.8	15.6	6.0
PERCENT CHANGE	-16.2%	84.8%	203.3%	7.1%

Table 14. Data for figure 14. Average gradations before and after recycling.

	3/4"	1/2"	3/8"	NO. 4	NO. 8	NO. 16	NO 30	NO 50	NO 100	NO 200
BEFORE RECYCLING	100.0	100.0	96.9	69.4	54.1	44.0	34.2	16.0	9.6	7.4
OFF OF TRUCK VIRGIN MIX	100.0	100.0	98.2	72.6	52.6	42.9	31.6	8.5	4.5	3.9
AFTER RECYCLING	100.0	99.8	96.8	69.5	53.0	43.4	33.5	15.4	9.4	7.5
PERCENT CHANGE	0.0%	-0.2%	0.0%	0.2%	-2.0%	-1.4%	-1.9%	-3.6%	-2.0%	0.6%

Table 15. Average percentages of core gradations, data for figure 22.

LOCATION	1"	3/4"	1/2"	3/8"	NO. 4	NO. 8	NO. 16	NO. 30	NO. 50	NO. 100	NO. 200
#1 I-55 SOUTH OF McCOMB AVERAGE (RECYCLED)	100.0	100.0	99.6	96.5	69.4	53.3	43.5	33.6	16.3	10.0	7.9
#2 I-59-20 NEAR MERIDIAN AVERAGE (RECYCLED)	100.0	99.8	98.0	94.5	68.4	50.7	43.7	35.1	17.4	11.3	7.6
#3 I-20 NEAR FOREST AVERAGE (CONTROL)	100.0	99.8	97.5	90.6	66.8	47.6	41.9	33.1	18.4	12.0	7.3
PERCENT CHANGE FROM #1 TO #2	0.0%	-0.2%	-1.6%	-2.1%	-1.4%	-4.8%	0.5%	4.5%	6.8%	12.7%	-4.4%
PERCENT CHANGE FROM #1 TO #3	0.0%	-0.2%	-2.1%	-6.1%	-3.7%	-10.7%	-3.6%	-1.4%	13.2%	19.7%	-8.5%
PERCENT CHANGE FROM #2 TO #3	0.0%	0.0%	-0.5%	-4.1%	-2.4%	-6.2%	-4.0%	-5.7%	6.1%	6.2%	-4.3%

Table 16. Resilient modulus of samples, data for figure 23.

SUMMARY	RESILIENT MODULUS (psi)	RESILIENT MODULUS (MPa)
#1 I-55 SOUTH OF McCOMB AVERAGE	246,703	1 701
#2 I-59 NEAR MERIDIAN (RECYCLED)	434,450	2 995
#3 I-20 NEAR FOREST AVERAGE (CONTROL)	734,083	5 061
PERCENT CHANGE FROM #1 TO #2	76.1%	76.1%
PERCENT CHANGE FROM #1 TO #3	197.6%	197.6%
PERCENT CHANGE FROM #2 TO #3	69.0%	69.0%

APPENDIX B

CONSTRUCTION DATA

Table 17. Test strip information.

TABLE 17 a.
TEST STRIP OR ROADWAY DENSITY 10-8-91

SUBLOT NO.		1	2	3	4	5	
STATION		66+93	69+99	71+23	73+12	75+10	
LOCATION FROM BASELINE		10.4 LT CL	6.9 LT CL	7.7 LT CL	8.0 LT CL	5.1 LT CL	
CORE	THICKNESS						
DENSITY	AIR WEIGHT	1 057.7	643.6	648.0	647.2	644.7	
	WATER WEIGHT	600.4	362.7	365.0	369.7	377.0	
	SSD WEIGHT	1 075.3	649.5	662.3	658.6	667.4	
	VOLUME	474.9	286.8	297.3	288.9	290.4	AVERAGE
	SP. GRAVITY	2.227	2.244	2.180	2.240	2.220	DENSITY
	MAX. SP. GRAV.	2.359	2.359	2.359	2.359	2.359	
	% DENSITY	94.4	95.1	92.4	95.0	94.1	94.2

TABLE 17 b.
TEST STRIP OR ROADWAY DENSITY 10-9-91

SUBLOT NO.		1	2	3	4	5	
STATION		57+53	59+98	60+98	62+90	64+77	
LOCATION FROM BASELINE							
CORE	THICKNESS						
DENSITY	AIR WEIGHT	530.0	672.0	861.8	700.8	608.2	
	WATER WEIGHT	293.7	366.3	479.8	381.9	333.8	
	SSD WEIGHT	531.1	673.4	863.9	702.8	609.7	
	VOLUME	237.4	307.1	384.1	320.9	275.9	AVERAGE
	SP. GRAVITY	2.233	2.188	2.244	2.184	2.204	DENSITY
	MAX. SP. GRAV.	2.398	2.398	2.398	2.398	2.398	
	% DENSITY	93.1	91.2	93.6	91.1	91.9	92.2

TABLE 17 c.
TEST STRIP OR ROADWAY DENSITY 10-9-91

SUBLOT NO.		1	2	3	4	5	
STATION		16+91	18+93	20+09	21+06	23+05	
LOCATION FROM BASELINE							
CORE	THICKNESS						
DENSITY	AIR WEIGHT	955.7	662.0	990.6	967.0	721.5	
	WATER WEIGHT	534.7	368.5	552.4	539.4	406.5	
	SSD WEIGHT	956.4	663.1	992.4	968.5	722.3	
	VOLUME	421.7	294.6	440.0	429.1	315.8	AVERAGE
	SP. GRAVITY	2.266	2.247	2.251	2.254	2.285	DENSITY
	MAX. SP. GRAV.	2.393	2.393	2.393	2.393	2.393	
	% DENSITY	94.7	93.9	94.1	94.2	95.5	94.5

TABLE 17 d.
TEST STRIP OR ROADWAY DENSITY 10-10-91

SUBLOT NO.		1	2	3	4	5	
STATION		403+00	414+07	416+41	425+40	430+39	
LOCATION FROM BASELINE		8.0 RT CL	8.0 RT CL	11.0 RT CL	10.5 RT CL	11.0 RT CL	
CORE	THICKNESS						
DENSITY	AIR WEIGHT	852.1	896.6	1 286.4	1 228.4	935.3	
	WATER WEIGHT	464.6	496.2	705.2	690.7	515.0	
	SSD WEIGHT	860.9	901.2	1 293.2	1 233.7	942.5	
	VOLUME	396.3	405.0	588.0	543.0	427.5	AVERAGE
	SP. GRAVITY	2.150	2.214	2.188	2.262	2.188	DENSITY
	MAX. SP. GRAV.	2.366	2.366	2.366	2.366	2.366	
	% DENSITY	90.9	93.6	92.5	95.6	92.5	93.0

Table 18. Laboratory data set 1.

COUNTY: PIKE
PROJECT NO.: 54-0055-01-067-10
CONTRACTOR REMIXER CONST. CO.

PROJECT ENGINEER: ALAN CROSS
PRODUCER OF VIRGIN MIX: DICKERSON & BOWEN, INC.

LOT	DATE	EXTRACTIONS	STATION	3/4"	1/2"	3/8"	No 4	No 8	No 30	No 50	No 200	Agg Bulk	JOB MIX	LOCATION	PENETROMETER
NO.		(MT-31)	NO.									Sp. Grav.	A.C.%		READINGS
				TOTAL EXTRACTED JOB MIX WEIGHT											
				100.0	100.0	97.0	68.0	50.0	30.0	13.7	6.4				
1	08-Oct-91	1		100.0	100.0	96.1	70.2	52.1	28.7	12.2	6.8	2.568	5.35	EXIT #4 SOUTH	38
2A	09-Oct-91	1		100.0	100.0	95.7	69.7	52.2	32.1	15.5	7.9	2.568	5.35	EXIT #4 NORTH	28
2B	09-Oct-91	1		100.0	100.0	97.9	72.3	54.5	34.2	15.3	6.6	2.568	5.35	EXIT #8 SOUTH	34
3A	10-Oct-91	1		100.0	100.0	96.7	69.8	50.9	28.3	12.4	6.4	2.568	5.35	STA. 13 + 258.826	26
3B	10-Oct-91	1		100.0	100.0	97.7	72.6	53.0	32.9	17.6	8.8	2.568	5.35	Inside S LANE	45
4A	11-Oct-91	1	401+00	100.0	98.1	95.2	64.4	47.1	28.0	14.2	7.2	2.568	5.35	Inside S LANE	45
4B	11-Oct-91	1	390+00	100.0	98.0	94.5	68.7	50.2	30.0	15.6	7.8	2.568	5.35		58
5A	14-Oct-91	1	374+75	100.0	100.0	97.0	65.6	47.9	28.9	14.5	6.8	2.568	5.35	sta 11 + 422.402	43
5B	14-Oct-91	2	363+50	100.0	100.0	96.8	66.9	47.8	26.7	12.5	6.6	2.568	5.35	sta 11 + 079.501	42
6A	15-Oct-91	1	335+50	100.0	99.4	95.1	68.0	49.6	29.1	13.7	6.4	2.568	5.35	Inside S LANE	32
6B	15-Oct-91	2	323+00	100.0	100.0	96.2	66.5	48.5	27.8	12.0	4.1	2.568	5.35		30
7A	16-Oct-91	1	295+90	100.0	100.0	96.8	66.8	49.1	30.3	16.0	8.6	2.568	5.35	N BD LT SIDE	30
7B	16-Oct-91	2	277+85	100.0	99.5	96.1	67.0	49.0	29.8	13.9	7.3	2.568	5.35	NW RAMP	35
8A	17-Oct-91	1	250+00	100.0	100.0	99.2	64.5	46.4	26.5	13.4	6.4	2.568	5.35	RT LN LT SIDE	35
8B	17-Oct-91	2	237+40	100.0	100.0	94.7	66.4	50.0	26.9	12.3	6.2	2.568	5.35	LT LN RT SIDE	35
9A	18-Oct-91	1	215+60	100.0	100.0	95.4	66.6	49.7	29.9	15.0	6.9	2.568	5.35	RT LN LT SIDE	34
9B	18-Oct-91	2	207+35	100.0	100.0	95.8	66.7	49.6	29.6	14.1	6.6	2.568	5.35	LT LN RT SIDE	35
10	21-Oct-91	1	184+60	100.0	98.8	93.0	63.8	46.5	26.5	11.3	5.4	2.568	5.35	RT LN LT SIDE	33 & 32
11A	22-Oct-91	1	137+50	100.0	100.0	95.0	70.2	51.6	29.2	13.2	5.8	2.568	5.35	LT LN RT SIDE	30
11B	22-Oct-91	2	123+00	100.0	100.0	95.4	70.6	50.6	29.0	13.0	6.1	2.568	5.35	RT LN LT SIDE	30
12	24-Oct-91	1	91+00	100.0	100.0	95.0	70.0	51.2	28.5	12.3	6.6	2.568	5.35	LT LN RT SIDE	30
13A	25-Oct-91	1	71+85	100.0	100.0	97.1	70.9	53.5	31.6	14.6	6.9	2.568	5.35	RT LN LT SIDE	32
13b	25-Oct-91	2	58+25	100.0	100.0	96.5	71.0	51.0	29.7	13.0	6.1	2.568	5.35	RT LN RT SIDE	40
14	26-Oct-91	1	34+00	100.0	100.0	97.8	70.5	52.5	31.3	13.9	6.6	2.568	5.35	RTLNLT&LTLNRT	30
15	28-Oct-91	1	RAMP	100.0	100.0	97.3	70.7	51.0	30.9	14.9	7.0	2.568	5.35	RT LN RT SIDE	30
16	06-Nov-91	1	31+50	100.0	100.0	97.3	73.0	53.6	33.6	15.3	7.3	2.568	5.35		32
17	07-Nov-91	1	45+15	100.0	100.0	96.4	68.9	51.6	32.7	15.7	7.9	2.568	5.35		32
18	12-Nov-91	1	65+00	100.0	100.0	97.9	70.3	52.4	31.7	15.1	7.1	2.568	5.35	LT LN LT SIDE	33 & 38
19	13-Nov-91	1	95+00	100.0	100.0	95.8	68.6	51.7	32.3	14.2	7.6	2.568	5.35	LT LN LT SIDE	38 & 36
20	14-Nov-91	1	121+35	100.0	100.0	96.0	71.1	52.5	32.1	14.6	6.9	2.568	5.35	LT LN LT SIDE	35 & 39
21	15-Nov-91	1	397+75	100.0	100.0	96.9	73.0	51.7	29.4	12.8	6.4	2.568	5.35	LT LN LT SIDE	50 & 33
22	16-Nov-91	1	366+55	100.0	100.0	97.7	73.0	53.0	30.5	12.2	5.8	2.568	5.35	LT LN LT SIDE	50
23	18-Nov-91	1	178+00	100.0	100.0	97.9	72.8	54.9	32.5	12.9	6.9	2.568	5.35		44 & 44
24	19-Nov-91	1	351+00	100.0	100.0	95.2	68.2	52.1	31.3	12.2	6.6	2.568	5.35	RT LN RT SIDE	48 & 42
25	22-Nov-91	1	324+10	100.0	100.0	96.9	69.3	49.2	27.9	11.5	5.7	2.568	5.35	RT LN RT SIDE	48 & 42
26	23-Nov-91	1	289+25	100.0	100.0	95.9	69.1	48.8	28.2	11.8	5.9	2.568	5.65	RT LN RT SIDE	40 & 43
27	06-Dec-91	1	512+00	100.0	100.0	97.2	72.6	53.1	34.0	14.7	6.8	2.568	5.65	RT LN RT SIDE	34
28	07-Dec-91	1	EXIT #1	100.0	100.0	97.3	72.1	52.8	33.8	11.3	5.1	2.568	5.65	RT LN RT SIDE	NONE
29	09-Dec-91	1	EXIT #1	100.0	100.0	97.6	76.5	59.6	37.8	12.8	5.4	2.568	5.65	RT LN RT SIDE	NONE
30	10-Dec-91	1	95+20	100.0	100.0	96.2	72.6	53.4	33.5	11.5	5.2	2.568	5.65	RT LN RT SIDE	30
31	11-Dec-91	1	10+00	100.0	100.0	95.7	72.9	54.0	33.7	11.7	5.0	2.568	5.65	RT LN RT SIDE	30
32	12-Dec-91	1	103+30	100.0	100.0	94.5	63.9	47.6	29.0	11.9	5.3	2.568	5.65	RT LN RT SIDE	30
33	09-Mar-92	1	111+25	100.0	100.0	95.3	68.9	49.6	29.0	14.2	5.8	2.568	5.65	LT LN RT SIDE	31
34	10-Mar-92	1	266+50	100.0	100.0	96.3	66.0	49.9	29.6	10.9	5.3	2.568	5.65	LT LN RT SIDE	34
35	12-Mar-92	1	268+50	100.0	100.0	94.2	68.3	52.2	30.6	11.7	5.3	2.568	5.65	LT LN RT SIDE	33
36	13-Mar-92	1	248+50	100.0	100.0	97.1	72.5	54.5	31.9	13.2	5.7	2.568	5.65	RT LN RT SIDE	42 & 39
37	14-Mar-92	1	216+75	100.0	100.0	96.1	67.9	50.1	30.4	15.4	7.3	2.568	5.65	LT LN RT SIDE	38
38	16-Mar-92	1	210+35	100.0	100.0	95.0	66.9	47.3	27.7	13.2	6.0	2.568	5.65	LT LN RT SIDE	30 & 34
39	17-Mar-92	1	212+10	100.0	99.1	94.3	70.3	52.8	28.3	12.4	6.3	2.568	5.65	LT LN RT SIDE	49 & 43
40	19-Mar-92	1	178+50	100.0	100.0	94.8	69.8	51.7	26.8	11.4	5.6	2.568	5.65	LT LN RT SIDE	46 & 31
41	20-Mar-92	1	134+00	100.0	100.0	94.2	70.1	52.4	26.2	11.2	5.4	2.568	5.65	LT LN RT SIDE	44
42	21-Mar-92	1	122+50	100.0	100.0	95.8	66.8	47.5	27.9	13.0	5.9	2.568	5.65	LT LN LT SIDE	44
43	24-Mar-92	1	109+50	100.0	100.0	97.2	70.5	53.3	31.0	12.2	4.7	2.568	5.65	LT LN LT SIDE	39
44	25-Mar-92	1	74+00	100.0	100.0	98.6	71.0	52.1	30.9	12.8	5.4	2.568	5.65	LT LN LT SIDE	39
45	26-Mar-92	1	68+00	100.0	100.0	96.5	69.2	50.1	29.2	11.8	5.0	2.568	5.65	LT LN LT SIDE	41 & 39
46	27-Mar-92	1	33+00	100.0	100.0	98.8	66.7	51.2	28.9	11.8	5.1	2.568	5.65	LT LN LT SIDE	35
47	28-Mar-92	1	77+00	100.0	100.0	98.1	67.9	50.7	27.8	11.7	5.1	2.568	5.65	LT LN LT SIDE	38
48	30-Mar-92	1	94+00	100.0	100.0	96.4	67.2	49.4	29.6	12.4	5.9	2.568	5.65	RT LN LT SIDE	39 & 37
49	31-Mar-92	1	128+00	100.0	100.0	97.3	71.1	51.3	28.9	11.1	5.0	2.568	5.65	RT LN LT SIDE	38 & 44
50	01-Apr-92	1	258+00	100.0	100.0	97.9	69.8	51.3	30.1	11.7	5.2	2.568	5.65		41 & 44
51	02-Apr-92	1	293+00	100.0	100.0	97.9	70.4	51.7	30.9	11.4	5.6	2.568	5.65		27 & 44
52	03-Apr-92	1	323+50	100.0	100.0	98.6	69.9	51.8	31.2	12.0	5.5	2.568	5.65		42 & 36
53	07-Apr-92	1	358+00	100.0	100.0	98.1	71.8	53.2	32.4	14.5	6.5	2.568	5.65		34, 31, & 33
54	08-Apr-92	1	399+00	100.0	100.0	95.7	71.2	52.3	32.6	15.3	6.3	2.568	5.65		40, 34, & 53
55	09-Apr-92	1	WELCOME	100.0	93.5	89.4	62.7	46.6	28.4	12.6	6.0	2.568	5.65		NONE
56	10-Apr-92	1	WC APR RMP	100.0	99.3	96.5	69.5	52.5	31.3	13.3	5.3	2.568	5.65		33
57	11-Apr-92	1	162+10	100.0	100.0	98.9	72.0	52.3	31.9	11.9	5.0	2.568	5.65		44
58	13-Apr-92	1	191+00	100.0	100.0	96.0	65.8	49.1	30.3	11.6	4.5	2.568	5.65		30 & 34
59	15-Apr-92	1	221+00	100.0	100.0	98.4	71.6	52.6	32.9	11.9	5.1	2.568	5.65		55 & 38
60	16-Apr-92	1	272+00	100.0	100.0	97.9	70.6	54.6	33.8	13.6	6.0	2.568	5.65		48 & 57
61	17-Apr-92	1	327+50	100.0	100.0	98.4	72.1	53.4	33.5	12.3	5.5	2.568	5.65		53
62	21-Apr-92	1	377+00	100.0	100.0	94.9	70.9	53.9	33.7	16.3	7.7	2.568	5.65		59 & 55
63	22-Apr-92	1	RAMP #8+F25	100.0	100.0	96.6	71.2	53.9	33.7	15.0	6.9	2.568	5.65		61

Table 19. Laboratory data set 2.

CHARACTERISTICS OF LABORATORY COMPACTED SPECIMENS (MT-34 & MT-35)

LOT NO.	DATE	SAMPLE NUMBER	STATION NUMBER	TEMPERATURE	AIR WEIGHT	WATER WEIGHT	SSD WEIGHT	VOLUME	SPECIFIC GRAVITY	VOIDS	VMA	DIAL	STABILITY	FLOW
1a	08-Oct-91	1		210	1 179.8	662.8	1 180.7	517.9	2.278	3.4	16.8	205	3 025	12
1b	08-Oct-91	2		280	1 177.4	666.4	1 178.2	511.8	2.301	2.5	15.9	239	3 500	12
2a	09-Oct-91	1		200	1 177.0	645.3	1 180.9	535.6	2.198	8.3	19.3	195	2 883	12
2b	09-Oct-91	2		200	1 183.5	649.2	1 187.8	538.6	2.197	8.4	19.4	158	2 317	12
2c	09-Oct-91	3		270	1 179.4	659.0	1 183.0	524.0	2.251	6.1	17.4	250	3 657	12
2d	09-Oct-91	4		270	1 181.2	656.8	1 187.0	530.5	2.227	7.1	18.3	247	3 614	12
2apm	09-Oct-91	1		250	1 179.6	651.1	1 186.3	535.2	2.204	7.9	19.1	158	2 317	11
2bpm	09-Oct-91	2		300	1 137.6	662.1	1 167.8	505.7	2.309	3.5	15.3	243	3 557	12
2cpm	09-Oct-91	3		300	1 171.9	662.2	1 173.0	510.8	2.294	4.1	15.8	249	3 643	12
3aam	10-Oct-91	1		230	1 168.9	631.9	1 195.1	563.2	2.075	12.4	23.8	82	1 047	10
3bam	10-Oct-91	2		250	1 167.1	643.8	1 175.1	541.3	2.156	9.0	20.8	162	2 216	11
3cam	10-Oct-91	3		300	1 169.1	645.3	1 179.6	534.3	2.188	7.6	19.6	209	2 952	12
3dam	10-Oct-91	4		300	1 171.1	647.5	1 198.0	550.5	2.127	10.2	21.9	138	1 814	11
3apm	10-Oct-91	1		300	1 172.6	664.5	1 173.5	509.0	2.304	2.5	15.6	310	4 575	12
3bpm	10-Oct-91	2		300	1 174.9	664.4	1 175.7	511.3	2.298	2.8	15.8	298	4 383	12
4aam	11-Oct-91	1	401+00	300	1 169.0	663.0	1 169.4	506.4	2.308	2.1	15.3	272	4 326	12
4bam	11-Oct-91	2	390+00	300	1 181.4	669.5	1 182.2	512.7	2.300	2.2	15.4	279	4 100	12
4cam	11-Oct-91	3		300	1 179.3	670.8	1 179.7	508.9	2.317	2.3	15.1	234	3 696	12
4dam	11-Oct-91	4		300	1 174.4	667.9	1 175.0	507.1	2.316	2.3	15.1	211	3 224	12
5a	14-Oct-91	1	374+75	300	1 180.7	671.5	1 181.4	509.9	2.316	1.6	15.3	277	4 071	12
5b	14-Oct-91	2	363+50	300	1 179.7	669.8	1 180.6	510.8	2.310	1.8	15.5	273	4 014	12
5c	14-Oct-91	3		300	1 185.0	670.8	1 186.2	515.4	2.299	3.3	15.6	248	3 629	12
5d	14-Oct-91	4		300	1 182.5	671.5	1 183.4	511.9	2.310	2.9	15.2	251	3 671	12
6a	15-Oct-91	1	335+50	300	1 176.3	666.0	1 177.4	511.4	2.300	2.5	15.8	254	3 717	12
6b	15-Oct-91	2	323+00	300	1 182.2	668.5	1 183.5	515.0	2.296	2.6	15.9	250	3 657	12
6c	15-Oct-91	3		300	1 184.1	666.8	1 185.0	518.2	2.285	3.2	16.4	270	3 567	12
6d	15-Oct-91	4		300	1 184.4	663.5	1 185.5	522.0	2.269	3.9	17.0	256	3 750	12
7a	16-Oct-91	1	295+90	300	1 185.5	661.6	1 187.4	525.8	2.255	4.3	17.2	251	3 671	12
7b	16-Oct-91	2	277+85	300	1 184.2	665.1	1 185.3	520.2	2.276	3.8	16.3	296	4 350	12
8a	17-Oct-91	1	250+00	300	1 184.7	661.7	1 186.8	525.1	2.256	4.5	17.0	340	5 050	12
8b	17-Oct-91	2	237+40	300	1 177.9	661.8	1 180.4	518.6	2.271	5.0	16.4	291	4 271	12
9a	18-Oct-91	1	215+60	300	1 189.5	663.7	1 190.5	526.8	2.258	4.4	17.1	302	4 438	12
9b	18-Oct-91	2	207+35	300	1 182.5	665.0	1 184.0	519.0	2.278	3.5	16.4	286	4 200	12
10a	21-Oct-91	1	184+60	300	1 185.1	666.9	1 185.6	518.7	2.285	3.5	16.6	303	4 450	12
10b	21-Oct-91	2	164+00	300	1 181.9	658.3	1 183.1	524.8	2.252	4.6	17.3	289	4 243	12
11a	22-Oct-91	1	137+50	300	1 185.1	666.6	1 185.9	519.3	2.283	3.5	16.2	298	4 383	12
11b	22-Oct-91	2	123+00	300	1 181.8	656.2	1 183.0	526.8	2.243	5.6	17.7	286	4 200	12
11c	22-Oct-91	3	VERIFY	300	1 184.9	664.3	1 185.6	521.3	2.273	4.4	16.6	301	4 425	12
12	24-Oct-91	1	91+00	300	1 187.8	671.9	1 188.2	516.3	2.301	3.2	15.5	326	4 817	12
13a	25-Oct-91	1	71+85	300	1 184.9	668.5	1 185.5	517.0	2.292	3.5	15.9	315	4 650	12
13b	25-Oct-91	2	58+25	300	1 182.0	664.6	1 183.0	518.4	2.280	3.3	16.3	297	4 367	-
14	26-Oct-91	1	34+00	300	1 185.6	665.0	1 186.9	521.9	2.272	4.5	16.5	300	4 412	12
15	28-Oct-91	1	RAMP	300	1 187.2	670.2	1 188.4	518.2	2.291	4.5	15.4	420	6 383	12
16	06-Nov-91	1	31+50	300	1 185.7	668.7	1 186.9	518.2	2.288	3.5	16.0	370	5 550	12
17	07-Nov-91	1	45+15	300	1 185.3	667.5	1 186.4	518.9	2.284	3.9	16.2	330	4 883	12
18a	12-Nov-91	1	65+00	300	1 186.4	668.2	1 187.6	519.4	2.284	4.0	16.0	305	4 475	12
18b	12-Nov-91	2	77+20	300	1 181.6	668.3	1 182.7	514.4	2.297	3.6	15.4	312	4 612	12
19a	13-Nov-91	1	95+00	300	1 184.4	668.1	1 185.3	517.2	2.290	3.9	15.7	328	4 850	12
19b	13-Nov-91	2	420+00	300	1 182.7	666.1	1 183.6	517.5	2.285	3.3	15.8	310	4 575	12
19c	13-Nov-91	3	110+90	300	1 185.6	668.7	1 186.7	518.0	2.289	3.4	15.7	356	5 317	12
20a	14-Nov-91	1	121+35	300	1 185.6	667.1	1 186.3	519.2	2.284	3.7	16.1	255	3 733	12
20b	14-Nov-91	2	131+50	300	1 186.5	667.8	1 187.2	519.4	2.284	4.3	16.1	301	4 425	12
20c	14-Nov-91	3	135+85	300	1 185.3	670.1	1 186.2	516.1	2.297	3.2	15.6	321	4 733	12
21a	15-Nov-91	1	397+75	300	1 180.5	658.6	1 183.2	524.6	2.250	4.9	16.8	225	3 288	12
21b	15-Nov-91	2	159+60	300	1 185.5	660.6	1 186.4	525.8	2.255	4.6	17.2	248	3 629	12
21c	15-Nov-91	3	371+50	300	1 185.8	663.4	1 186.7	523.3	2.266	4.3	16.6	305	4 475	12
22	16-Nov-91	1	366+55	300	1 185.1	668.1	1 186.3	518.2	2.287	3.6	16.0	320	4 717	12
23a	18-Nov-91	1	178+00	300	1 186.2	670.6	1 186.8	516.2	2.298	3.0	15.6	220	3 225	12
23b	18-Nov-91	2	195+00	300	1 184.7	669.5	1 185.4	515.9	2.296	3.3	15.7	224	3 275	12
24a	19-Nov-91	1	351+00	300	1 191.1	668.0	1 192.4	524.4	2.271	3.1	16.6	216	3 044	12
24b	19-Nov-91	2	333+80	300	1 187.6	667.2	1 188.1	520.9	2.280	3.2	16.2	212	3 114	12
25a	22-Nov-91	1	324+10	300	1 192.2	669.4	1 193.0	523.6	2.277	3.1	16.6	270	3 808	12
25b	22-Nov-91	2	226+00	300	1 190.2	668.7	1 191.6	522.9	2.276	3.5	16.6	281	3 964	12
26a	23-Nov-91	1	289+25	300	1 187.6	667.7	1 188.2	520.5	2.282	3.5	16.1	295	4 333	12
26b	23-Nov-91	2		300	1 188.4	668.8	1 189.2	520.4	2.284	3.3	16.1	303	4 450	12
27	06-Dec-91	1	512+00	300	1 178.9	660.5	1 179.4	518.9	2.272	4.6	16.3	296	4 350	12

Table 19. Laboratory data set 2 (continued).

CHARACTERISTICS OF LABORATORY COMPACTED SPECIMENS (MT-34 & MT-35)

LOT NO.	DATE	SAMPLE NUMBER	STATION NUMBER	TEMPERATURE	AIR WEIGHT	WATER WEIGHT	SSD WEIGHT	VOLUME	SPECIFIC GRAVITY	VOIDS	VMA	DIAL	STABILITY	FLOW
28	07-Dec-91	1	EXIT #1	300	1 183.6	663.5	1 184.9	521.4	2.270	4.7	16.7	306	4 488	12
29	09-Dec-91	1	EXIT #1	300	1 176.8	662.0	1 177.7	515.7	2.282	4.2	16.0	282	4 143	12
30	10-Dec-91	1	95+20	300	1 178.3	662.7	1 179.4	516.7	2.280	4.1	16.2	290	4 257	12
31	11-Dec-91	1	10+00	300	1 179.1	660.8	1 179.9	519.1	2.271	4.7	16.7	293	4 300	12
32	12-Dec-91	1	103+30	300	1 177.2	657.0	1 179.4	522.4	2.253	4.5	16.9	293	4 128	12
33	09-Mar-92	1	111+25	310	1 175.8	660.5	1 177.3	516.8	2.275	4.0	16.6	287	4 300	12
34	10-Mar-92	1	266+50	300	1 215.8	689.5	1 216.5	527.0	2.307	3.8	15.1	225	3 264	12
35	12-Mar-92	1	268+50	300	1 182.2	661.8	1 183.2	521.4	2.267	4.9	16.8	200	3 038	12
36a	13-Mar-92	1	248+50	300	1 178.2	665.0	1 178.6	513.6	2.294	3.7	16.0	179	2 733	11
36b	13-Mar-92	2	228+40	310	1 184.2	666.8	1 185.5	518.7	2.283	4.0	16.3	173	2 633	11
37	14-Mar-92	1	216+75	300	1 183.8	667.5	1 184.4	516.9	2.290	3.2	15.8	240	3 614	11
38a	16-Mar-92	1	210+35	300	1 188.9	547.3	1 194.2	536.9	2.214	7.8	18.5	370	5 239	11
38b	16-Mar-92	2		verif.	1 193.7	657.5	1 202.4	544.9	2.191	8.7	19.4			
38c	16-Mar-92	3	138+00	300	1 185.7	665.6	1 186.9	521.3	2.275	4.7	16.5	238	3 586	11
39a	17-Mar-92	1	212+10	300	1 185.4	669.7	1 185.7	516.0	2.297	2.4	16.4	253	3 800	11
39b	17-Mar-92	2		verif.	1 182.7	667.0	1 183.4	516.2	2.291	2.7	16.6			
39c	17-Mar-92	3	197+15	300	1 187.4	670.5	1 188.4	517.9	2.293	3.1	16.5	248	3 729	11
39d	17-Mar-92	4		verif.										
40a	19-Mar-92	1	178+50	300	1 181.6	668.4	1 182.3	513.9	2.299	3.0	15.9	271	4 062	11
40b	19-Mar-92	2	157+00	300	1 183.6	668.2	1 184.1	515.9	2.294	3.3	16.0	263	3 950	11
41	20-Mar-92	1	134+00	300	1 177.3	669.0	1 178.4	509.4	2.311	4.2	14.7	222	3 350	11
42	21-Mar-92	1	122+50	300	1 186.2	668.7	1 187.0	518.3	2.289	4.3	15.9	214	3 229	11
43a	24-Mar-92	1	109+50	300	1 184.2	664.0	1 185.2	521.2	2.272	4.6	16.6	272	4 075	11
43b	24-Mar-92	2	95+40	300	1 186.3	665.9	1 187.1	521.2	2.276	4.3	16.4	260	3 900	11
44	25-Mar-92	1	74+00	300	1 183.7	665.4	1 184.8	519.4	2.279	4.4	16.5	273	4 088	11
45a	26-Mar-92	1	68+00	300	1 184.7	666.9	1 185.8	518.9	2.283	4.6	16.3	266	4 000	11
45b	26-Mar-92	2	48+00	300	1 182.7	663.9	1 183.9	520.0	2.274	4.6	16.2	272	4 075	11
46a	27-Mar-92	1	33+00	300	1 186.0	670.7	1 189.8	519.1	2.285	4.9	15.7	225	3 400	11
46b	27-Mar-92	2	40+00	300	1 184.7	664.9	1 185.4	520.5	2.276	4.8	16.3	241	3 629	11
47	28-Mar-92	1	77+00	300	1 184.6	667.1	1 185.7	518.6	2.284	4.7	15.8	249	3 743	11
48a	30-Mar-92	1	94+00	300	1 179.2	664.3	1 181.3	517.0	2.281	4.5	15.8	266	4 000	11
48b	30-Mar-92	2	107+00	300	1 182.6	664.9	1 183.7	518.8	2.280	4.4	15.9	281	4 200	11
49a	31-Mar-92	1	128+00	300	1 186.0	664.4	1 187.4	523.0	2.268	5.0	16.3	264	3 967	11
49b	31-Mar-92	2	143+10	300	1 185.4	667.8	1 186.4	518.6	2.286	1.4	15.7	279	4 171	11
50a	01-Apr-92	1	258+00	300	1 184.6	667.9	1 185.2	517.3	2.290	3.4	15.8	259	3 886	11
50b	01-Apr-92	2	268+20	300	1 182.6	664.9	1 183.3	518.4	2.282	4.5	16.0	266	4 000	11
51a	02-Apr-92	1	293+00	300	1 174.9	657.7	1 175.6	517.9	2.269	4.5	16.4	293	4 300	11
51b	02-Apr-92	2	305+10	300	1 179.7	664.9	1 180.6	515.7	2.288	4.1	16.0	259	3 886	11
52a	03-Apr-92	1	323+50	300	1 184.5	664.9	1 187.3	522.4	2.267	4.4	16.7	269	4 038	11
52b	03-Apr-92	2	336+00	300	1 186.9	667.9	1 187.8	519.9	2.283	4.2	16.3	280	4 186	11
53a	07-Apr-92	1	358+00	300	1 179.4	663.0	1 180.7	517.7	2.278	4.0	16.2	245	3 686	11
53b	07-Apr-92	2	362+70	300	1 182.7	664.1	1 183.8	519.7	2.276	4.4	16.3	260	3 900	11
53b	07-Apr-92	3	373+80	300	1 183.9	667.9	1 184.7	511.8	2.291	3.7	15.9	278	4 157	11
54a	08-Apr-92	1	399+00	300	1 179.9	662.7	1 180.8	518.1	2.277	4.5	16.3	256	3 843	11
54b	08-Apr-92	2	404+00	300	1 181.7	663.9	1 182.5	518.6	2.279	4.6	16.1	266	4 000	11
54c	08-Apr-92	3	416+00	300	1 184.6	665.7	1 185.6	519.9	2.279	4.3	16.0	260	3 900	11
55a	09-Apr-92	1	WELCOME	300	1 182.7	661.1	1 184.0	522.9	2.262	5.3	16.2	240	3 614	11
55b	09-Apr-92	2		300	1 181.6	660.9	1 182.9	522.0	2.264	5.2	16.1	229	3 457	11
56a	10-Apr-92	1	WC APR R	300	1 180.9	661.5	1 181.9	520.4	2.269	4.5	16.4	251	3 771	11
56b	10-Apr-92	2		300	1 185.0	663.6	1 186.1	522.5	2.268	4.5	16.4	270	4 050	11
57	11-Apr-92	1	162+10	300	1 182.7	664.9	1 183.7	518.9	2.280	4.2	16.1	267	4 012	11
58a	13-Apr-92	1	191+00	300	1 177.3	665.9	1 179.9	514.0	2.290	3.3	15.7	280	4 186	11
58b	13-Apr-92	2	209+00	300	1 181.6	662.1	1 182.9	520.8	2.269	4.6	16.4	264	3 967	11
59a	15-Apr-92	1	221+00	300	1 180.0	665.4	1 181.1	515.7	2.288	3.9	18.9	270	4 050	11
59b	15-Apr-92	2	236+00	300	1 183.6	664.9	1 184.6	519.7	2.278	4.6	16.0	267	4 012	11
60a	16-Apr-92	1	272+00	300	1 178.2	662.5	1 179.4	516.9	2.280	3.8	16.2	210	3 171	11
60b	16-Apr-92	2	283+25	300	1 181.7	664.5	1 182.7	518.2	2.280	4.1	16.1	249	3 743	11
60c	16-Apr-92	3	295+00	300	1 183.9	667.9	1 184.2	516.3	2.293	3.1	16.1	258	3 871	11
61a	17-Apr-92	1	327+50	300	1 176.2	661.7	1 177.3	515.6	2.281	3.5	16.4	276	4 129	11
61b	17-Apr-92	2	344+00	300	1 184.6	664.9	1 185.7	520.8	2.275	4.4	16.2	288	4 312	11
62a	21-Apr-92	1	377+00	300	1 191.5	676.5	1 193.1	516.8	2.306	2.5	15.4	260	3 900	11
62b	21-Apr-92	2		300	1 186.6	669.7	1 187.6	517.9	2.291	3.1	16.0	266	4 000	11
62c	21-Apr-92	3		300	1 183.7	666.9	1 184.5	517.6	2.287	3.3	16.1	250	3 757	11
63a	22-Apr-92	1	RAMP #8	300	1 190.9	674.8	1 192.1	517.3	2.302	3.0	15.7	280	4 186	11
63b	22-Apr-92	2		300	1 188.6	670.3	1 187.5	517.2	2.298	3.3	15.8	274	4 100	11

Table 20. Laboratory data set 3.

CHARACTERISTICS OF LABORATORY						COMPACTED SPECIMENS					(MT-34 & MT-35)			
LOT	DATE	SAMPLE	STATION	ASPHALT		MOISTURE CORRECTION					MAXIMUM SPECIFIC GRAVITY			
NO.		NUMBER	NUMBER	CONTENT		(AASHTO:T110)		CORRECTED			(AASHTO: T209)			MAXIMUM
				GUAGE	SAMPLE	WT.	% MOISTURE	ASPHALT	SAMPLE		CAL.	FINAL		SPECIFIC
				(MT-6)	WT.	WATER		CONTENT	WEIGHT		WEIGHT	WEIGHT	VOLUME	GRAVITY
1a	08-Oct-91	1		6.20	500	0.2	0.04	6.16	1 030.0		4 904.8	4 998.1	436.7	2.359
1b	08-Oct-91	2						6.16						2.359
2a	09-Oct-91	1		5.78	500	0.2	0.04	5.74	1 035.3		4 404.8	5 008.3	431.8	2.398
2b	09-Oct-91	2						5.74						2.398
2c	09-Oct-91	3						5.74						2.398
2d	09-Oct-91	4						5.74						2.398
2apm	09-Oct-91	1		5.79	500	0.2	0.04	5.75	1 045.6		4 404.8	5 013.4	437.0	2.393
2bpm	09-Oct-91	2						5.75						2.393
2cpm	09-Oct-91	3						5.75						2.393
3aam	10-Oct-91	1		5.73	500	0.2	0.04	5.69	1 040.3		4 404.8	5 006.0	439.1	2.369
3bam	10-Oct-91	2						5.69						2.369
3cam	10-Oct-91	3						5.69						2.369
3dam	10-Oct-91	4						5.69						2.369
3apm	10-Oct-91	1		5.99	500	0.2	0.04	5.95	1 089.3		4 404.8	5 033.1	461.0	2.363
3bpm	10-Oct-91	2						5.95						2.363
4aam	11-Oct-91	1	401+00	5.76	500	0.2	0.04	5.72	1 086.9		4 404.8	5 030.5	461.2	2.357
4bam	11-Oct-91	2	390+00					5.72						2.357
4cam	11-Oct-91	3		5.94	500	0.2	0.04	5.90	1 072.0		4 404.8	5 024.7	452.1	2.371
4dam	11-Oct-91	4						5.90						2.371
5a	14-Oct-91	1	374+75	6.12	500	0.2	0.04	6.08	1 064.0		4 404.8	5 016.6	452.2	2.353
5b	14-Oct-91	2	363+50					6.08						2.353
5c	14-Oct-91	3		5.80	500	0.2	0.04	5.76	1 045.2		4 404.8	5 010.4	439.6	2.378
5d	14-Oct-91	4						5.76						2.378
6a	15-Oct-91	1	335+50	6.00	500	0.2	0.04	5.96						
6b	15-Oct-91	2	323+00					5.96						
6c	15-Oct-91	3		6.07	500	0.2	0.04	6.03						
6d	15-Oct-91	4						6.03						
7a	16-Oct-91	1	295+90	5.74	500	0.2	0.04	5.70	1 046.2		4 404.8	5 007.1	443.9	2.357
7b	16-Oct-91	2	277+85	5.58	500	0.2	0.04	5.54	1 127.4		4 404.8	5 055.9	476.3	2.367
8a	17-Oct-91	1	250+00	5.51	500	0.2	0.04	5.47	1 016.2		4 404.8	4 990.7	430.3	2.362
8b	17-Oct-91	2	237+40	5.51				5.51	1 043.2		4 404.8	5 012.0	436.0	2.392
9a	18-Oct-91	1	215+60	5.70				5.70	1 092.3		4 404.8	5 034.7	462.4	2.362
9b	18-Oct-91	2	207+35	5.72				5.72	1 025.1		4 404.8	4 995.7	434.2	2.361
10a	21-Oct-91	1	184+60	6.22				6.22	1 040.9		4 405.1	5 006.6	439.4	2.369
10b	21-Oct-91	2	164+00	5.72				5.72	1 018.9		4 405.1	4 992.4	431.6	2.361
11a	22-Oct-91	1	137+50	5.76				5.76	1 039.9		4 405.1	5 005.7	439.3	2.367
11b	22-Oct-91	2	123+00	5.79				5.79	1 021.8		4 405.1	4 997.0	429.9	2.377
11c	22-Oct-91	3	VERIFY	5.79				5.79	1 021.8			4 997.0	429.9	2.377
12	24-Oct-91	1	91+00	5.73				5.73	1 048.7		4 405.1	5 012.8	441.0	2.378
13a	25-Oct-91	1	71+85	5.74				5.74	1 035.6		4 405.1	5 004.8	435.9	2.376
13b	25-Oct-91	2	58+25	5.74				5.74	1 066.4		4 405.1	5 019.1	452.4	2.357
14	26-Oct-91	1	34+00	5.58				5.58	1 012.8		4 405.1	4 992.3	425.6	2.380
15	28-Oct-91	1	RAMP	5.15				5.15	1 040.0		4 405.1	5 011.4	433.7	2.398
16	06-Nov-91	1	31+50	5.72	500	0.2	0.04	5.68	1 071.3		4 409.1	5 028.6	451.8	2.371
17	07-Nov-91	1	45+15	5.83	500	0.2	0.04	5.79	1 028.1		4 409.1	5 004.5	432.7	2.376
18a	12-Nov-91	1	65+00	5.62	500	0.2	0.04	5.58	1 031.0		4 409.8	5 007.3	433.5	2.378
18b	12-Nov-91	2	77+20	547.00	500	0.2	0.04	5.43	1 036.3		4 409.8	5 011.2	434.9	2.383
19a	13-Nov-91	1	95+00	5.46	500	0.2	0.04	5.42	1 043.0		4 409.8	5 015.3	437.5	2.384
19b	13-Nov-91	2	420+00	5.37	500	0.2	0.04	5.33	1 055.4		4 409.8	5 018.5	446.7	2.363
19c	13-Nov-91	3	110+90	5.51	500	0.2	0.04	5.47	1 040.1		4 409.8	5 010.8	439.1	2.369
20a	14-Nov-91	1	121+35	5.71	500	0.2	0.04	5.67	1 081.1		4 409.8	5 035.1	455.8	2.372
20b	14-Nov-91	2	131+50	5.68	500	0.2	0.04	5.64	1 058.5		4 409.8	5 024.8	443.5	2.387
20c	14-Nov-91	3	135+85	5.73	500	0.2	0.04	5.69	1 030.5		4 409.8	5 006.3	434.0	2.374
21a	15-Nov-91	1	397+75	5.03	500	0.2	0.04	4.99	1 058.8		4 409.8	5 020.7	447.6	2.365
21b	15-Nov-91	2	159+60	5.75	500	0.2	0.04	5.71	1 027.6		4 409.8	5 002.5	434.9	2.363
21c	15-Nov-91	3	371+50	5.58	500	0.2	0.04	5.54	1 032.8		4 409.8	5 006.5	436.1	2.368
22	16-Nov-91	1	366+55	5.68	500	0.0	0.04	5.64	1 036.5		4 409.8	5 009.6	436.7	2.373
23a	18-Nov-91	1	178+00	5.73	500	0.2	0.04	5.69	1 077.7		4 409.8	5 032.4	455.1	2.368
23b	18-Nov-91	2	195+00	5.70	500	0.2	0.04	5.66	1 049.4		4 409.8	5 017.3	441.9	2.375
24a	19-Nov-91	1	351+00	5.75	500	0.2	0.04	5.71	1 016.0		4 409.8	4 992.1	433.7	2.343
24b	19-Nov-91	2	333+80	5.69	500	0.2	0.04	5.65	1 043.7		4 409.8	5 010.5	443.0	2.356
25a	22-Nov-91	1	324+10	5.94	500	0.2	0.04	5.90	1 009.6		4 409.8	4 989.8	429.6	2.350
25b	22-Nov-91	2	226+00	5.97	500	0.2	0.04	5.93	1 036.7		4 409.8	5 006.8	439.7	2.358
26a	23-Nov-91	1	289+25	5.59	500	0.2	0.04	5.55	1 044.3		4 409.8	5 012.5	441.6	2.365
26b	23-Nov-91	2		5.67	500	0.2	0.04	5.63	1 033.6		4 409.8	5 005.6	437.8	2.361
27	06-Dec-91	1	512+00	5.48	500	0.2	0.04	5.44	1 031.6		4 409.8	5 008.2	433.2	2.381

Table 20. Laboratory data set 3 (continued).

CHARACTERISTICS OF LABORATORY COMPACTED SPECIMENS (MT-34 & MT-35)													
LOT	DATE	SAMPLE	STATION	ASPHALT		MOISTURE CORRECTION				MAXIMUM SPECIFIC GRAVITY			
NO.		NUMBER	NUMBER	CONTENT		(AASHTO:T110)		CORRECTED		(AASHTO: T209)			MAXIMUM
				GUAGE	SAMPLE	WT.	% MOISTURE	ASPHALT	SAMPLE	CAL.	FINAL		SPECIFIC
				(MT-6)	WT.	WATER		CONTENT	WEIGHT	WEIGHT	WEIGHT	VOLUME	GRAVITY
28	07-Dec-91	1	EXIT #1	5.85	500	0.0	0.04	5.81	1 039.3	4 409.8	5 012.6	436.5	2.381
29	09-Dec-91	1	EXIT #1	5.53	500	0.2	0.04	5.49	1 012.6	4 147.0	4 734.7	424.9	2.383
30	10-Dec-91	1	95+20	5.67	500	0.2	0.04	5.63	1 043.2	4 147.0	4 751.5	438.7	2.378
31	11-Dec-91	1	10+00	5.82	500	0.2	0.04	5.78	1 051.4	4 147.0	4 757.2	441.2	2.383
32	12-Dec-91	1	103+30	5.31	500	0.2	0.04	5.27	1 037.5	4 147.0	4 744.5	440.0	2.358
33	09-Mar-92	1	111+25	5.87	500	0.2	0.04	5.83	1 055.8	4 144.0	4 754.4	445.4	2.370
34	10-Mar-92	1	266+50	5.50	500	0.2	0.04	5.46	1 037.1	4 144.0	4 748.5	432.6	2.397
35	12-Mar-92	1	268+50	5.83	500	0.2	0.04	5.79	1 068.9	4 144.0	4 764.6	448.3	2.384
36a	13-Mar-92	1	248+50	5.96	500	0.2	0.04	5.92	1 030.2	4 144.0	4 740.3	433.9	2.374
36b	13-Mar-92	2	228+40	5.88	500	0.2	0.04	5.84	1 011.4	4 144.0	4 730.1	425.3	2.378
37	14-Mar-92	1	216+75	5.65	500	0.1	0.02	5.63	1 015.6	4 144.0	4 730.1	429.5	2.365
38a	16-Mar-92	1	210+35	5.53	500	0.1	0.02	5.51	1 072.5	4 144.0	4 739.9	446.6	2.401
38b	16-Mar-92	2											
38c	16-Mar-92	3	138+00	5.78	500	0.1	0.02	5.76	1 040.5	4 144.0	4 748.9	435.7	2.388
39a	17-Mar-92	1	212+10	6.51	500	0.1	0.02	6.49	1 081.6	4 144.0	4 766.1	459.5	2.354
39b	17-Mar-92	2		6.55	500	0.1	0.02	6.53					
39c	17-Mar-92	3	197+15	6.52	500	0.1	0.02	6.50	1 013.5	4 144.0	4 729.4	428.1	2.367
39d	17-Mar-92	4		6.48	500	0.1	0.02	6.46					
40a	19-Mar-92	1	178+50	6.09	500	0.2	0.04	6.05	1 030.8	4 144.0	4 739.7	435.1	2.369
40b	19-Mar-92	2	157+00	6.05	500	0.2	0.04	6.01	1 016.7	4 144.0	4 732.1	428.6	2.372
41	20-Mar-92	1	134+00	5.27	500	0.1	0.02	5.25	1 003.5	4 144.0	4 731.7	415.8	2.413
42	21-Mar-92	1	122+50	5.68	500	0.1	0.02	5.66	1 026.5	4 144.0	4 741.6	428.9	2.393
43a	24-Mar-92	1	109+50	5.81	500	0.1	0.02	5.79	1 067.6	4 144.0	4 763.3	448.3	2.381
43b	24-Mar-92	2	95+40	5.67	500	0.1	0.02	5.65	1 040.7		4 747.2	437.5	2.379
44	25-Mar-92	1	74+00	5.96	500	0.1	0.02	5.94	1 061.9	4 144.0	4 760.5	445.4	2.384
45a	26-Mar-92	1	68+00	5.83	500	0.1	0.02	5.81	1 080.0	4 144.0	4 772.7	451.3	2.393
45b	26-Mar-92	2	48+00	5.36	500	0.1	0.02	5.34	1 037.6	4 144.0	4 746.2	435.4	2.283
46a	27-Mar-92	1	33+00	5.30	500	0.1	0.02	5.28	1 032.5	4 144.0	4 746.8	429.7	2.403
46b	27-Mar-92	2	40+00	5.62	500	0.1	0.02	5.60	1 019.7	4 146.8	4 740.2	426.3	2.392
47	28-Mar-92	1	77+00	5.29	500	0.1	0.02	5.27	1 022.6	4 146.8	4 742.8	426.6	2.397
48a	30-Mar-92	1	94+00	5.28	500	0.1	0.02	5.26	1 061.9	4 146.8	4 764.2	444.5	2.389
48b	30-Mar-92	2	107+00	5.31	500	0.1	0.02	5.29	1 022.7	4 146.8	4 740.9	428.6	2.386
49a	31-Mar-92	1	128+00	5.28	500	0.1	0.02	5.26	1 036.9	4 146.8	4 749.3	434.4	2.387
49b	31-Mar-92	2	143+10	5.37	500	0.1	0.02	5.35	1 060.7	4 146.8	4 764.1	443.4	2.392
50a	01-Apr-92	1	258+00	5.60	500	0.1	0.02	5.58	1 026.9	4 146.8	4 740.5	433.2	2.370
50b	01-Apr-92	2	268+20	5.50	500	0.1	0.02	5.48	1 037.9	4 146.8	4 750.3	434.4	2.389
51a	02-Apr-92	1	293+00	5.40	500	0.1	0.02	5.38	1 021.4	4 146.8	4 738.5	429.7	2.377
51b	02-Apr-92	2	305+10	5.74	500	0.1	0.02	5.72	1 007.9	4 146.8	4 732.1	422.6	2.385
52a	03-Apr-92	1	323+50	5.62	500	0.1	0.02	5.60	1 035.2	4 146.8	4 745.3	436.7	2.371
52b	03-Apr-92	2	336+00	5.87	500	0.1	0.02	5.85	1 021.7	4 146.8	4 739.6	428.9	2.382
53a	07-Apr-92	1	358+00	5.56	500	0.1	0.02	5.54	1 018.9	4 146.8	4 736.2	429.5	2.372
53b	07-Apr-92	2	362+70	5.62	500	0.1	0.02	5.60	1 030.4	4 146.8	4 744.3	432.9	2.380
53b	07-Apr-92	3	373+80	5.77	500	0.1	0.02	5.75	1 039.3	4 146.8	4 749.0	437.1	2.378
54a	08-Apr-92	1	399+00	5.59	500	0.1	0.02	5.57	1 047.5	4 146.8	4 755.1	439.2	2.385
54b	08-Apr-92	2	404+00	5.47	500	0.1	0.02	5.45	1 037.1	4 146.8	4 749.6	434.5	2.388
54c	08-Apr-92	3	416+00	5.42	500	0.1	0.02	5.40	1 027.6	4 146.8	4 742.8	431.6	2.381
55a	09-Apr-92	1	WELCOME	4.85	500	0.1	0.02	4.83	1 003.5	4 146.8	4 730.3	420.0	2.389
55b	09-Apr-92	2		4.87	500	0.1	0.02	4.85	1 003.5	4 146.8	4 730.5	419.8	2.390
56a	10-Apr-92	1	WC APR RMP	5.35	500	0.1	0.02	5.33	1 022.7	4 146.8	4 739.3	430.2	2.370
56b	10-Apr-92	2		5.39	500	0.1	0.02	5.37	1 037.1	4 146.8	4 747.0	436.9	2.374
57	11-Apr-92	1	162+10	5.47	500	0.1	0.02	5.45	1 044.1	4 146.8	4 752.0	438.9	2.379
58a	13-Apr-92	1	191+00	5.52	500	0.1	0.02	5.50	1 015.7	4 145.3	4 732.2	428.8	2.369
58b	13-Apr-92	2	209+00	5.44	500	0.1	0.02	5.42	1 037.1	4 145.3	4 746.5	435.9	2.379
59a	15-Apr-92	1	221+00	5.60	500	0.1	0.02	5.58	1 041.9	4 145.3	4 749.8	437.4	2.382
59b	15-Apr-92	2	236+00	5.29	500	0.1	0.02	5.27	1 026.4	4 145.3	4 741.7	430.0	2.387
60a	16-Apr-92	1	272+00	5.62	500	0.1	0.02	5.60	1 019.6	4 145.3	4 734.9	430.0	2.371
60b	16-Apr-92	2	283+25	5.52	500	0.1	0.02	5.50	1 036.4	4 145.3	4 745.7	436.0	2.377
60c	16-Apr-92	3	295+00	6.03	500	0.1	0.02	6.01	1 074.7	4 145.3	4 765.8	454.2	2.366
61a	17-Apr-92	1	327+50	5.95	500	0.1	0.02	5.93	1 032.5	4 145.3	4 741.0	436.8	2.364
61b	17-Apr-92	2	344+00	5.48	500	0.1	0.02	5.46	1 016.6	4 145.3	4 734.6	427.3	2.379
62a	21-Apr-92	1	377+00	5.86	500	0.1	0.02	5.84	1 028.6	4 145.3	4 738.7	435.2	2.364
62b	21-Apr-92	2		5.86				5.84					2.364
62c	21-Apr-92	3		5.85	500	0.1	0.02	5.83	1 011.5	4 145.3	4 729.1	427.7	2.365
63a	22-Apr-92	1	RAMP #8	5.94	500	0.1	0.02	5.92	1 069.5	4 145.7	4 764.0	450.8	2.372
63b	22-Apr-92	2		5.93	500	0.1	0.02	5.91	1 040.7	4 145.3	4 748.2	437.8	2.377

APPENDIX C

SPECIFICATIONS

MISSISSIPPI STATE HIGHWAY DEPARTMENT

SPECIAL PROVISION NO. 907-402-2 CODE: (SP)

DATE: 7/3/91

SUBJECT: Asphalt Pavement Surface Recycling

Section 907-402, Asphalt Pavement Recycling, is added to the 1990 Edition of the Mississippi Standard Specifications for Road and Bridge Construction as follows:

SECTION 907-402 -- ASPHALT PAVEMENT RECYCLING

907-402.01--Description. This work consists of recycling in place existing bituminous pavement in a simultaneous multi-step process of heating, milling, remixing, reshaping and compacting the asphalt surface and blending of the scarified material with an asphalt rejuvenating agent and/or virgin hot bituminous plant mix as specified herein. All work shall be in accordance with the applicable provisions of the Standard Specifications and in reasonable close conformity with the requirements contained herein or established by the Engineer.

907-402.02--Materials. Virgin materials used in the work shall meet the applicable requirements of Division 700 of the Standard Specifications.

The Department's Personnel will take and evaluate roadway samples of the existing pavement. Test results from this evaluation will be furnished to the Contractor for use in developing the job-mix formula. The Contractor may elect to obtain additional samples from the existing pavement to supplement his job-mix formula development process. Regardless of the data used, the Contractor shall be solely responsible for the accuracy of the final job-mix formula.

The Contractor shall submit a proposed mix design to the District Testing Engineer for approval at least ten days prior to commencement of the work. The mix design shall have a percentage of virgin bituminous plant mix sufficient to blend with the recycled materials and produce a bituminous plant mix meeting the total voids in compliance with 401.02.2.2 and the gradation requirements for SC-1 surface mix in compliance with 73.11.2, Table B. Aggregate for the virgin bituminous plant mix shall consist of coarse sand and/or crushed limestone.

The mix design submittal shall include as a minimum the following information:

1. Source of each virgin component.
2. The average asphalt content and average gradation of the existing pavement.
3. The target and proposed asphalt content, total voids, gradation and range of gradation of the recycled mix, percentage of anti-stripping additive, if required, and the amount of rejuvenating agent required.

The Contractor shall determine and recommend to the Engineer for approval the amount of rejuvenating agent necessary to return the recovered asphalt cement penetration to a minimum of 50 at 77^{o}F (25^{o}C) for 100 g for 5 seconds.

907-402.03--Construction Requirements.

907-402.03.1--Equipment.

907-402.03.1.1--Preheater. The preheater shall be a self-propelled unit consisting of multiple rows of infrared heaters, of a type specifically designed to heat the upper layer of asphalt pavement. Liquid propane gas shall be used for heating fuel. Direct or indirect open flames shall not be allowed.

The preheater shall be capable of containing the generated heat in a manner that does not damage trees, shrubs or other adjacent property and the traveling public.

The rows of heaters shall be spaced a maximum of 36 inches (914.4 mm) apart to effect proper heat penetration to the desired temperature while causing no injury to the pavement such as that occurring from overheating, coking or sooting of the asphalt binder and aggregate.

The heater assembly shall be design such that it may be easily raised and lowered by a single control. The heater shall be adjustable in width from 10 feet to 14 feet (3.05 m to 4.27 m).

907-402.03.1.2--Milling Unit. The milling unit shall be a rotation-milling drum and shall be adjustable in width from 10 feet to 14 feet (3.05 m to 4.27 m). The unit shall be capable of uniformly loosening the asphalt pavement to the depth specified and shall be equipped with separate automatic height adjustments in order to clear obstructions in the pavement surface. All milled material shall be augured into the center of the machine prior to entry into the blending unit.

907-402.03.1.3--Recycling Machine. The recycling machine shall be self-contained and specifically designed to reprocess existing bituminous pavement in place. The recycling machine shall be equipped with additional heaters conforming to the requirements previously outlined for preheaters, under 907-402.03.1.1, Preheater. The resulting heated bituminous pavement shall be between 225^{o} and 300^{o}F (107.2^{o} and 148.9^{o}C) prior to reprocessing.

907-402.03.1.4--Rejuvenating Agent Storage Unit. The storage unit shall be thermostatically controlled to maintain the rejuvenation agent at a constant specified temperature between 100^{o} and 325^{o}F (37.8^{o} and 162.8^{o}C).

907-402.03.1.5--Spraying Unit. The spraying unit shall be a system that will uniformly deliver the rejuvenation agent, when required, at the approved rate for a forward speed that in coincidental with the total recycling process. The spraying shall occur after the recycled material is milled and before it enters the blending unit.

907-402.03.1.6--Blending Unit. The blending unit shall be a twin-shafted pugmill capable of uniformly adding virgin bituminous plant mix when required and at an approved rate. The unit shall be capable of thoroughly mixing the scarified material with rejuvenating agent and/or virgin bituminous plant mix.

907-402.03.1.7--Screed and Initial Compaction Unit. The hot recycled material shall be uniformly distributed to the required profile and cross slope by the use of a heated oscillating screed which must be an integral attached part of the recycling machine. The screed shall be equipped with an adjustable crown control and each end of the screed shall have hand-wheel adjusting screws and an approved automatic control device for laying the mixture to the specified slope and grade.

907-402.03.1.8--Rollers. Rollers shall meet the requirements of 401.03.5.

907-402.03.2--Construction Details. The Contractor shall provide a laboratory for daily testing of the recycled materials. Test shall include asphalt content, maximum specific gravity, percent density of the cores and penetration of recovered asphalt cement. Test results shall be utilized in making adjustments to the application rates of the rejuvenating agent and plant mix material. Adjustments will be subject to the approval of the Engineer.

Approval of the Engineer shall be obtained prior to the recycling of any material.

The pavement surface to be rehabilitated shall be cleaned of all dirt and other objectionable material by blading, brooming, or other methods approved by the Engineer prior to beginning the pavement recycling operations.

Temperature and weather conditions shall conform to the requirements of 401.03.1.1.

Compaction of the recycled mix shall be in accordance with 401.03.1.4.

907-402.04--Method of Measurement. Heating, milling and mixing of the existing pavement will be measured by the square yard. Rejuvenating agents will be measured by the gallon. Virgin bituminous plant mix will be measured by the ton. An anti-stripping agent, if required, shall be an absorbed item and will not be measured for separate payment.

907-402.05--Basis of Payment. Heating, milling and mixing of the existing pavement will be paid for at the contract unit price per square yard of the measured in-place recycled surface area. This price shall include all materials (including anti-stripping agent if required), equipment, and labor incidental with processing, placing and compacting the material.

Rejuvenating agent will be paid for at the contract unit price per gallon and shall include all cost involved in use of the agent including handling, storage, temperature maintenance, and spraying into the mix.

Virgin plant mix will be paid for at the contract unit price per ton and shall include all materials, equipment and labor incidental with producing, blending, and placing the mix.

Payment will be made under:

907-402-A:	Surface Recycling of Existing Bituminous Pavement (1½ in. (38.1 mm) Thick)	- per square yard
907-402-B:	Rejuvenating Agent	- per gallon
907-402-C:	Virgin Hot Bituminous Mix	- per ton

REFERENCES

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2. Doucet, R. J. and Paul, H. R., “Wirtgen Remixer Surface Recycling,” Report No. FHWA/LA-91/235, Louisiana Transportation Research Center, Baton Rouge, Louisiana (February 1991).
3. Paul, Harold R., “Evaluation of Recycled Projects for Performance,” Report No. FHWA/LA-95-216, Louisiana Transportation Research Center, Baton Rouge, Louisiana (April 1995).
4. CONSTRUCTION OF HOT MIX ASPHALT PAVEMENTS (MS-22).
5. Lyon, J. W. Jr., “Hot Mix Performance Study,” Report No. MSHD-RD-91-092, Mississippi State Highway Department, Jackson MS (December 1991).