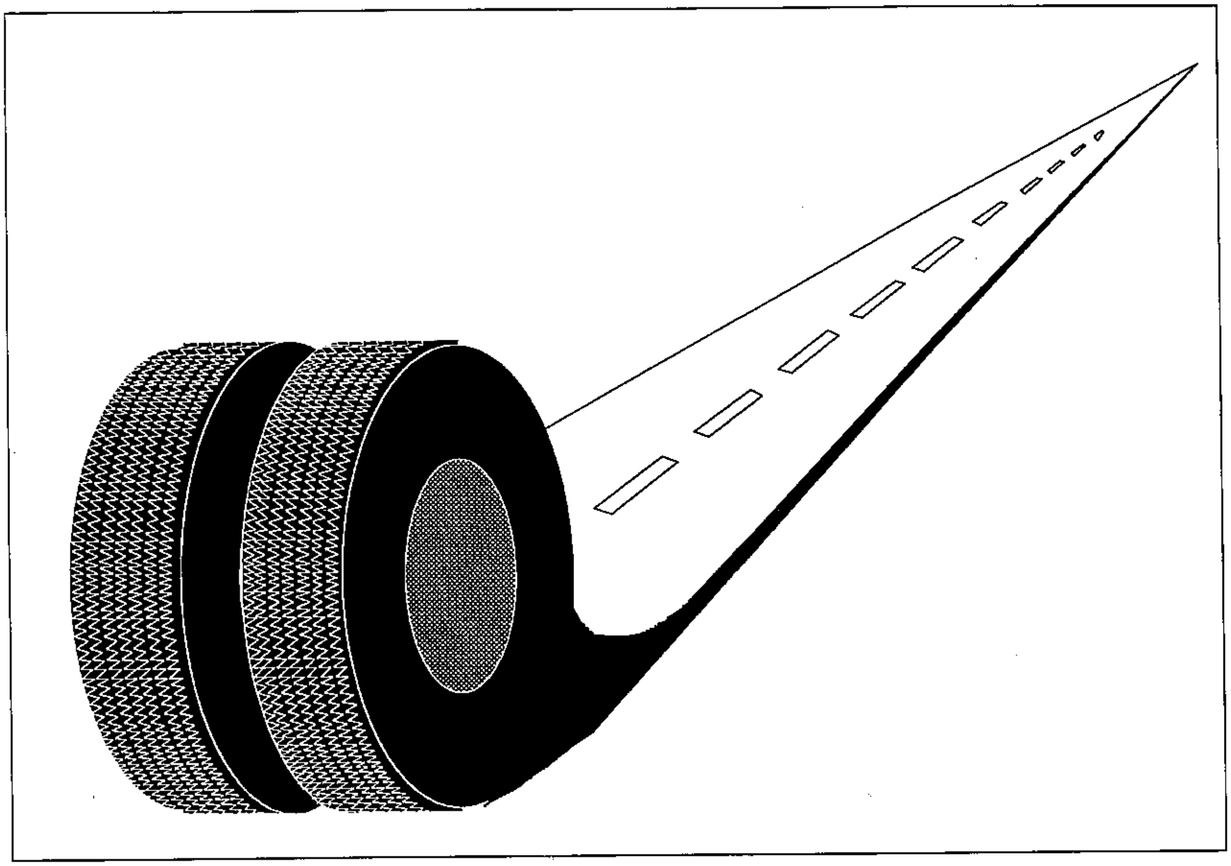
Evaluation of Reclaimed Rubber in Bituminous Pavements



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16. Abstract

Section 1038 of the 1991 Intermodel Surface Transportation Efficiency Act (ISTEA) mandated use of crumb rubber from scrap tires in asphalt pavement starting in FY 94. To gain some experience, the Illinois Department of Transportation (IDOT) constructed five demonstration projects in 1993 and one in 1994. All used the "dry process" to introduce crumb rubber into the mix. With the dry process, crumb rubber is added to the heated aggregate prior to addition of asphalt cement (AC).

Three projects used very low addition rates. Each was divided into five equal segments. One segment, the control, used no crumb rubber. The other segments used ½, 1, 1½ and 2 pounds of crumb rubber per ton of hot mix. The other three projects each used 20 pounds of crumb rubber per ton of hot mix. Both batch plants and drier-drum plants were used, and the crumb rubber was supplied in pre-measured batch-size packets, 50-pound paper bags and 2000-pound super sacks.

Addition rates of two pounds or less: There was little effect on mix appearance and test values. Nuclear gages were accurate for both AC content and density.
Addition rates of 20 pounds: A special mix design was required and the mix was stickier. Density measurements were accurate with the nuclear gauge, but AC content measurements were not.
All addition rates: The mix was placed and compacted using normal equipment and procedures. Drier-drum plants were easily modified to use the vane feeder to introduce the crumb rubber into the mix. Regardless of addition rate, crumb rubber increased costs by about 20 percent.

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FINAL REPORT

EVALUATION
OF
RECLAIMED RUBBER IN BITUMINOUS PAVEMENTS

BY
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June, 1995

Illinois Department of Transportation
Bureau of Materials and Physical Research
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NOTICE

The contents of this report reflect the views of the author who is responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policy of the Federal Highway Administration or the Illinois Department of Transportation. This report does not constitute a standard, specification, or regulation.

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I. INTRODUCTION

Section 1038 of the 1991 Intermodal Surface Transportation Efficiency Act (ISTEA) requires that each state use crumb rubber from scrap tires in asphalt pavement. This mandated crumb rubber usage for Illinois amounts to an estimated 3,000,000 lbs. in 1994 and increases by 3,000,000 lbs. each following year to a maximum of 12,000,000 lbs. in 1997.

There are currently two general methods of incorporating crumb rubber into Hot-Mix Asphalt (HMA). They are referred to as the "wet process" and the "dry process".

The wet process involves incorporating the crumb rubber into liquid Asphalt Cement (AC) prior to mixing the AC with the aggregate. The AC and crumb rubber mixture is then held at a high temperature (350° - 400° F.) in a reactor for approximately one hour. This allows the crumb rubber to expand and absorb aromatic oils from the AC.

The dry process involves mixing the crumb rubber with the hot aggregate prior to the addition of AC. In contrast to the wet process, the dry process does not require specialized equipment.

This report focuses on six demonstration projects constructed in 1993 and 1994 using the **dry process**.

II. PROJECTS

A. Variable Rate Projects

During the initial years of the mandate IDOT intends to satisfy the required quantities by placing small amounts of crumb rubber in every ton of state funded HMA. This approach will be utilized until more viable methods can be demonstrated. In order to gain some early experience using **small amounts** of crumb rubber in each ton of HMA, IDOT constructed three projects in 1993.

Each of the three projects were divided into five test sections. The test sections contained the following amounts of crumb rubber:

Test Section	Crumb Rubber Content (lbs./ton)
1	0
2	1/2
3	1
4	1 1/2
5	2

These projects will be referred to throughout this report as the "Variable Rate" or "V-Rate" projects.

District # 7 - V-Rate Project - May 1993:

Location: IL 33 between Shumway and Beecher City. (See Appendix A-1).

Tonnage: 5,000 tons of Class I, Type 2*, C dense graded surface mix.

Road Bed: The surface mix was placed 1 1/2" thick over an intermittent leveling binder which had been placed the previous year over a milled surface.

ADT: Average Daily Traffic (ADT) of approximately 2,700 (i.e. 1,350/lane).

District # 4 - V-Rate Project - July 1993:

Location: IL 116 ten miles west of Farmington. (See Appendix A-2).

Tonnage: 10,000 tons of Class I, Type 2, D dense graded surface mix.

Road Bed: The surface mix was placed 1 1/2" thick over a 3/4" lift of leveling binder which had been placed the previous fall over the existing asphalt surface.

ADT: Approximately 1,600 (i.e. 800/lane).

* Type 2 mixture is typically used on State primary routes.

District # 6 - V-Rate Project - September 1993:

Location: IL 107 between Perry and Mt. Sterling. (See Appendix A-3).

Tonnage: 5,000 tons of Class I, Type 2, C dense graded surface mix.

Road Bed: The surface mix was placed 1 1/2" thick over an intermittent leveling binder.

ADT: Approximately 1,000 (i.e. 500/lane).

B. Fixed Rate Projects

As part of the search for a beneficial method of utilizing crumb rubber, IDOT also constructed two additional demonstration projects in 1993, using the "Generic Dry Process". A third project planned for construction in 1993 was not constructed until 1994. These three projects specified a much higher crumb rubber content (20 lbs. per ton) than the variable rate projects and therefore required a special mix design to accommodate the additional crumb rubber. These projects will be referred to as the "Fixed Rate" or "F-Rate" projects.

District # 6 - F-Rate Project - October 1993:

Location: US-67 between Bethel and the US-67/IL 100 Junction.
(See Appendix A-4).

Tonnage: 2,400 tons of Class I, Type 2, C dense graded surface mix.

Road Bed: The surface mix was placed 1 1/2" thick over a 3/4" thick lift of leveling binder. The level binder was placed over a milled asphalt surface.

ADT: Approximately 3,000 (i.e. 1500/lane).

District # 7 - F-Rate Project - October 1993:

Location: IL 242 between McLeansboro and the I-64 Junction.
(See Appendix A-5).

Tonnage: 5,000 tons of Class I, Type 2, C dense graded surface mix.

Road Bed: The surface mix was placed 1 1/2" thick over a milled asphalt surface.

ADT: Approximately 1,300 (i.e. 650/lane).

District # 4 - F-Rate Project - July 1994:

Location: IL 91 between US 150 and Alta road. (See Appendix A-6).

Tonnage: 3,100 tons of Class I, Type 2, D dense graded surface mix.

Road Bed: The surface mix was placed over a milled asphalt surface which was completely covered with area crack control.

ADT: Approximately 2,850 (i.e. 1,425/lane).

III. MIX DESIGN

A. Variable Rate Projects

Due to the low dosage rates for the V-Rate projects, the crumb rubber was not accounted for in the mix design. It was determined by laboratory experiments that conventional mix properties are not affected by adding 2 lbs./ton or less of crumb rubber.

B. Fixed Rate Projects

A higher crumb rubber content of 20 lbs./ton HMA was used for the F-Rate projects. In order to maintain the desired level of air voids and stone-on-stone contact, special mix designs were performed to accommodate the additional crumb rubber. This was accomplished by reducing the volume of natural sand by 1.25% and replacing it with 1.00% crumb rubber. The remaining 0.25% allows room for expansion of the crumb rubber. Based on the experience of neighboring states, crumb rubber tends to expand by 0.25% when introduced in this manner.

Design Marshall stabilities ranged from 1200 - 1500 lbs. During production, the Marshall stabilities averaged 200 lbs. higher.

IV. CRUMB RUBBER

The current IDOT crumb rubber specifications (included in Appendix C) require that the crumb rubber be produced from processing whole automobile and/or truck tires by ambient temperature grinding methods. The specifications also require the crumb rubber be ground to meet the following gradation:

SIEVE SIZE	PERCENT PASSING
2.36 mm (#8)	100
1.18 mm (#16)	65 ± 10
600 um (#30)	30 ± 10
300 mm (#50)	10 ± 5

A. Variable Rate Projects

District # 7 - V-Rate Project:

Manufacturer: Tire Technology of Rockton, Illinois.

Packaging: Custom packaged in meltaway plastic bags at the following prescribed weights (weights were based on the asphalt plant batch sizes).

RUBBER CONTENT (lbs./ton)	PACKAGE WEIGHT (lbs.)
1/2	2.1
1	4.2
1 1/2	6.3
2	8.4

District # 4 - V-Rate Project:

Manufacturer: Baker Rubber Inc. of South Bend, Indiana.

Packaging: Custom packaged in meltaway plastic bags at the following prescribed weights (weights were based on the asphalt plant batch sizes).

RUBBER CONTENT (lbs./ton)	PACKAGE WEIGHT (lbs.)
1/2	1.8
1	3.5
1 1/2	5.2
2	7.0

District # 6 - V-Rate Project:

Manufacturer: Tire Technology of Rockton, Illinois.

Packaging: 50 lb. paper bags.

B. Fixed Rate Projects

District # 6 - F-Rate Project:

Manufacturer: Baker Rubber Inc. of South Bend, Indiana.

Packaging: 50 lb. paper bags.

District # 7 - F-Rate Project:

Manufacturer: D & L Rubber of Pinckneyville, Illinois.

Packaging: 20 lb. meltaway plastic bags.

District # 4 - F-Rate Project:

Manufacturer: Baker Rubber Inc. of South Bend, Indiana.

Packaging: Shipped bulk in 2,000 lb. Super Sacks.

V. PRODUCTION

Production techniques used in these demonstration projects will provide important information for future crumb rubber projects. A vital part of this information is the various innovative methods used by the Contractors to introduce the crumb rubber into the plant and asphalt mixture.

A. Variable Rate Projects

District # 7 - V-Rate Project:

Contractor: Howell Asphalt Inc.

Equipment: Barber-Greene, BE-120 Batch Plant.

Batch Size: HMA was produced in 8,400 lb. batches.

Mixing Method: The crumb rubber was added by having a laborer manually throw the preweighed bags of crumb rubber directly into the pugmill mixer, immediately after the pugmill was charged with aggregate. The dry mixing time was increased by 15 seconds to ensure proper dispersion of the crumb rubber.

Problems: None.

District # 4 - V-Rate Project:

Contractor: Pschirrer Asphalt Company.

Equipment: Barber-Greene, BE-67 Batch Plant.

Batch Size: HMA produced in 7,000 lb. batches.

Mixing Method: The crumb rubber for this project was also manually introduced into the pugmill mixer.

Problems: None.

District # 6 - V-Rate Project:

Contractor: Freesen Incorporated.

Equipment: Barber-Greene, DM-66 Drier-Drum Plant.

Mixing Method: The crumb rubber was incorporated via the Mineral Filler (MF) feed system. Modification of the MF vane feeder was necessary in order to provide a uniform flow of crumb rubber at the low dosage rates required (i.e. 1/2 to 2 lbs./ton). This method was less labor intensive than the first two projects.

Problems: In order to allow the plant to run continuously while recharging the weigh pod with crumb rubber, the Contractor found it necessary to leave the weigh pod door open. Since the pod could no longer be pressurized with the door open, the flow of rubber became sporadic. A simple modification to the plumbing, directly below the vane feeder, created the necessary vacuum to provide a constant flow of crumb rubber.

B. Fixed Rate Projects

District # 6 - F-Rate Project:

Contractor: K. E. Vas.

Equipment: Heatherington and Berner Drier-Drum Plant.

Mixing Method: The MF feed system was utilized to incorporate the crumb rubber. The only plant modification made was the extension of the MF discharge pipe, which was required by specification.

Problems: The extension of the MF discharge pipe allowed the crumb rubber to mix with the aggregate a minimum of one drum revolution before coming in contact with the liquid AC. Subsequent to completion of the project it was determined that the baghouse was contaminated with crumb rubber. It is believed that the contamination was caused by allowing the crumb rubber to mix with the aggregate prior to the addition of the AC. Since the crumb rubber is a very light material, allowing it to tumble dry in the drum enables the particles to be carried out by the dust collection system. As a result, IDOT changed the crumb rubber specifications to allow the crumb rubber to make immediate contact with the AC upon being released into the drum. This will cause the rubber particles to be immediately trapped into the mix and therefore be kept out of the airstream and baghouse.

District # 7 - F-Rate Project:

Contractor: E. T. Simonds.

Equipment: Barber-Greene KA-70 batch plant.

Batch Size: HMA produced in 6,000 lb. batches.

Mixing Method: The crumb rubber was added manually in the same manner as the District # 7, V-Rate Project.. The dry mixing time was increased by 15 seconds to ensure proper dispersion of the crumb rubber.

Problems: The mixture was produced at approximately 375° F. to ensure that it would arrive at the jobsite (60 miles away) at the proper laydown temperature. This mixing temperature is 25° F. higher than the specification allows. This pavement will be monitored for premature oxidation and cracking.

It was visually apparent the crumb rubber received after the preliminary test strip/start-up was different from the material used during the start-up. Sieve analyses revealed that 25% of the crumb rubber was retained on the # 8 sieve, while the specification requires 0% retained on the # 8 sieve. The out-of-spec material was used in the project without redesigning the mix. The pavement will also be monitored for premature distress related to the use of out-of-spec material.

District # 4 - F-Rate Project:

Contractor: Seneca Petroleum.

Equipment: CMI 1200 drier-drum plant.

Mixing Method: The crumb rubber was incorporated using a Krendl Model 500 fiber injection system. The injection system released the crumb rubber inside the drum at the same point as the liquid AC.

Problems: At the start of production, the fiber injection system clogged repeatedly. The problem was alleviated by moving the injection system closer to the drier-drum, thus allowing a shorter feed line to be used.

VI. CONSTRUCTION

During construction, each project was monitored to determine the following:

- Constructability
- Problems
- Unusual Construction Practices

A. Variable Rate Projects

The V-Rate projects were intended to verify that adding small amounts of crumb rubber (i.e. 1/2 - 2 lbs./ton) would neither affect the mix properties nor normal laydown practices.

District # 7 - V-Rate Project:

Contractor: Howell Asphalt Inc.

Equipment/Technique: The HMA was placed using normal laydown techniques and equipment.

Observations: Visually there was no apparent difference between the mixture containing crumb rubber and the mixture that did not. According to District personnel there were no construction problems experienced.

District # 4 - V-Rate Project:

Contractor: Pschirrer Asphalt Company.

Equipment/Technique: The HMA was placed using normal laydown techniques and equipment.

Observations: Visual inspection of the material revealed no apparent difference between the mix containing crumb rubber and the mix that did not. Discussion with District personnel indicated no apparent construction problems were experienced other than some slight sticking with the pneumatic roller. There were some areas which did exhibit some longitudinal tearing of the mat. This tearing was observed by Bureau of Materials & Physical Research personnel and thought to be caused by one or both of the following reasons:

1) A considerable amount of blotter sand (required for the area crack control) had accumulated in a row, 1/4 in. thick in some areas, along the edge of the pavement (approximately 1 ft. in from the edge).

2) An inexperienced person was operating the finish roller in the areas where the tear occurred.

District # 6 - V-Rate Project:

Contractor: Freesen Incorporated.

Equipment/Technique: The HMA was placed using normal laydown techniques and equipment.

Observations: There were no apparent differences between the test section containing rubber and the control section. The pneumatic roller picked up a considerable amount of material throughout the entire job. According to the Resident Engineer the pickup was no worse on the sections containing rubber than it was on the control section.

B. Fixed Rate Projects

District # 6 - F-Rate Project:

Contractor: K. E. Vas.

Equipment/Technique: The HMA was placed using normal laydown techniques and equipment, with the exception of the pneumatic roller. The F-Rate specification does not allow the use of a pneumatic roller.

Observations: The material was on the sticky side although it did not appear to be sticking to the truck beds. This was probably because diesel fuel was being used as a truck bed release agent.

There was a 30 ft. long section of the mat which experienced minor rutting resulting from traffic being allowed on the freshly laid mat before it had a chance to cool sufficiently.

District # 7 - F-Rate Project:

Contractor: E. T. Simonds.

Equipment/Technique: The HMA was placed using normal laydown techniques and equipment, with the exception of the pneumatic roller. The F-Rate specification does not allow the use of a pneumatic roller.

Observations: There were a considerable amount of fumes emanating from the mix as it traveled through the paver. Extremely high mix temperature was believed to be the cause of the fumes.

District # 4 - F-Rate Project:

Contractor: Seneca Petroleum.

Equipment/Technique: The HMA was placed using normal laydown techniques and equipment, with the exception of the pneumatic roller. The F-Rate specification does not allow the use of a pneumatic roller.

Observations: Stickiness of the F-Rate HMA did not cause any major problems, although it was noted that diesel fuel was being used as a release agent for some trucks.

VII. TESTING

The asphalt mixtures for both types of projects were tested to verify conformance to the mix design and also to evaluate the effectiveness of the nuclear density and AC content gauges for testing mixtures containing crumb rubber. In addition, for the V-Rate projects, test results from the sections containing the various quantities of crumb rubber were compared to the test results from the control section. This was done to determine what effects, if any, adding the various amounts of crumb rubber had on the tested mix parameters.

A. Variable Rate Projects

For each V-Rate project, hot-mix samples were obtained from each test section (with the exception of the District # 7 control section) for Marshall testing, nuclear AC contents, and split tensile strengths. Review of the test results (included in Appendix B) reveal no apparent difference between the control section and the sections containing crumb rubber.

For the District # 7 V-Rate project, nuclear gauge densities were correlated with core densities. Correlations were performed on both the control section and the test section containing 2 lbs./ton of crumb rubber. The resulting correlation coefficients were 0.985 for the control section and 0.986 for the 2 lbs./ton test section.

On the District # 6 V-Rate project, nuclear/core correlations were performed for the control section, the 1/2 lb./ton section, and the 2 lbs./ton section. The correlation coefficients were 0.984, 0.812 and 0.945 respectively.

Since the minimum acceptable correlation coefficient established by the Department is 0.715, these correlations are all well within the acceptable range. This suggests that crumb rubber, when added at a rate of 2 lbs./ton or less, has little or no effect on the accuracy of the nuclear density gauge.

B. Fixed Rate Projects

District # 6 - F-Rate Project - October of 1993:

Two mix designs were performed for this project. The first mix design was performed by the Bureau of Materials and Physical Research (BM&PR) and will be referred to as Job Mix Formula (JMF) # 1. The Marshall stability value resulting from JMF # 1 was 1,200 lbs.

In an attempt to achieve a higher stability, District # 6 performed a second mix design which will be referred to as JMF # 2. JMF # 2 resulted in a Marshall stability of 1,500 lbs. and an AC content 0.4% lower.

During the preliminary test strip/start-up, mixture was produced using both JMF # 1 and JMF # 2. The test results (included in Appendix B) contain data from both mix designs used during the preliminary test strip/start-up and also data from the normal production, which utilized JMF # 2. The test results for the preliminary test strip/start-up show a low AC content for material produced using JMF # 1, which resulted in high Marshall voids. However, the material produced using JMF # 2 had the design asphalt content but still resulted in high Marshall voids. During normal production, the test results (including Marshall voids) compared closely with JMF # 2. The stabilities for all of the material tested were, on the average, at least 500 lbs. higher than either of the two mix designs.

Comparisons were run between the nuclear AC gauge and extraction AC contents, to determine whether the nuclear AC gauge is a valid method for determining AC content in mixtures containing crumb rubber. The AC content determined by nuclear gauge was consistently lower than the AC content determined by extraction. This difference may be the result of an erroneous calibration. Since the aggregates used in the calibration were sent at a later date, the gravities may have been different, thus causing the gauge to read the same AC content differently between calibration and production.

A nuclear/core density correlation was performed at the start of laydown with a correlation coefficient value of 0.9322. The minimum acceptable correlation coefficient established by the Department is 0.715, which indicates crumb rubber, when used at a rate of 20 lbs./ton of HMA, has little or no effect on the accuracy of the nuclear density gauge.

District # 7 - F-Rate Project:

The District # 7 F-Rate project test results (included in Appendix B) reveal an adjustment to the JMF made by District # 7 prior to the preliminary test strip/start-up. This adjustment required 0.3% less AC than the mix design and resulted in high air voids and low stability. Prior to the start of normal production the Adjusted Job Mix Formula (AJMF) was changed back to the original JMF. This change resulted in air voids and stability in the desired range.

AC contents determined by extractions and nuclear gauge were again compared to determine the effectiveness of the nuclear AC gauge on mixtures containing 20 lbs. crumb rubber per ton of HMA. The nuclear gauge AC contents compared closely to the AC contents determined by reflux extractions, provided the nuclear gauge is calibrated with mixture containing the correct amount of crumb rubber. When the same samples were tested by the nuclear gauge using a calibration which was done without crumb rubber, the resulting AC contents were typically 0.7% higher. The addition of 1.0% crumb rubber results in approximately 0.7% higher AC content (i.e. the nuclear AC gauge reads crumb rubber as AC but not on a one to one basis).

A nuclear/core density correlation was performed at the start of laydown. The correlation coefficient was 0.957 which is well within the acceptable range.

District # 4 - F-Rate Project:

The extraction test results for the District #4 F-Rate project (included in Appendix B) reveal significant variations in the AC content and minus #200 material which resulted in air voids ranging from 2.6% to 9.2%.

Comparative testing was performed for AC contents using a nuclear gauge calibrated with rubber in the mix, a nuclear gauge calibrated without rubber in the mix, and extractions. All three tests were run on the same sample. The AC contents determined using the calibrated nuclear gauge were consistently higher (approximately 0.3%) than the AC contents by extractions. The AC contents from the gauge calibrated without rubber in the mix were also consistently higher (approximately 0.85%) than the AC contents by extractions.

The high AC contents from the nuclear gauge calibrated without rubber in the mix can be attributed to the fact that the nuclear gauge reads rubber as AC but not on a one to one basis. Based on previous testing it was determined the nuclear AC gauge will read 1.0% rubber as approximately 0.7% AC.

The reason for the high AC contents from the calibrated nuclear gauge is that the gauge was calibrated for 0.942% rubber By Total Weight of Mix (BTWM) (which was the design rubber content), while during production the average rubber content was 1.13%; 0.2% more than target. Therefore, the additional rubber added during production was read as AC. The nuclear gauge cannot detect which material is fluctuating (AC or rubber) and, therefore, does not appear to be an effective method for determining AC content of mixtures containing 20 lbs. or more crumb rubber per ton.

A nuclear/core density correlation was performed at the start of laydown. The correlation coefficients were 0.790 & 0.866 for the two state-owned gauges and 0.913 for the Contractor-owned gauge. All three correlations are within the acceptable range.

VIII. PERFORMANCE

Although the intent of this study was to gain knowledge and experience in the design, production, and placement of bituminous mixtures containing crumb rubber to meet the mandates set forth in Section 1038 of ISTEA, early pavement performance was monitored.

Pavement friction properties were tested and the results indicate the mixtures are comparable to conventional mixtures utilizing similar aggregate types.

The projects were all visually inspected in 1994 to determine if differences between mixtures containing crumb rubber and conventional mixtures were evident. Due to the early age, less than one year in most cases, no differences could be seen.

The projects will continue to be monitored to determine what impacts, if any, the different quantities of crumb rubber have on performance.

IX. COST

The cost per ton of HMA containing crumb rubber, as listed below, includes asphalt, placement, and compaction.

A. Variable Rate Projects

Listed below is the cost information for each of the V-Rate projects:

Project	Cost/Ton Conventional HMA	Cost/Ton HMA Containing Crumb Rubber	% Increase In Cost
Dist. #4	$30.00	$36.63	22.1%
Dist. #6	$27.39	$31.36	14.5%
Dist. #7	$33.20	$39.76	19.8%

B. Fixed Rate Projects

Listed below is the cost information for each of the F-Rate projects:

Project	Cost/Ton Conventional HMA	Cost/Ton HMA Containing Crumb Rubber	% Increase In Cost
Dist. #6	$32.66	$38.36	17.5%
Dist. #7	$32.30	$39.90	23.5%
Dist. #4	$36.00	$51.60	43.3%

X. CONCLUSIONS

A. Variable Rate Projects

The V-Rate projects demonstrated that crumb rubber, when used at low dosage rates ranging between 1/2 to 2 lbs. per ton of HMA:

- does not require a special mix design,
- does not affect Marshall voids, stability, flow density or split tensile strengths,
- can be introduced uniformly without complex plant modification,
- can be placed using normal laydown procedures and equipment,
- costs approximately 20% more than conventional mix, on the average
- can be tested effectively using the nuclear AC content and density gauges.
- with some modification, can be introduced uniformly into a drier-drum plant using a vane feeder.

B. Fixed Rate Projects

The F-Rate projects have demonstrated that crumb rubber, when used a rate of 20 lbs. per ton of HMA:

- requires a special mix design,
- can be introduced uniformly into a drier-drum plant using a vane feeder,
- must make immediate contact with the liquid AC upon being released into the drum of a drier-drum plant,
- costs approximately 28% more than conventional mix, on the average
- can be tested effectively using the nuclear density gauge,
- cannot be tested effectively using a nuclear Asphalt Content gauge.

XI. RECOMMENDATIONS

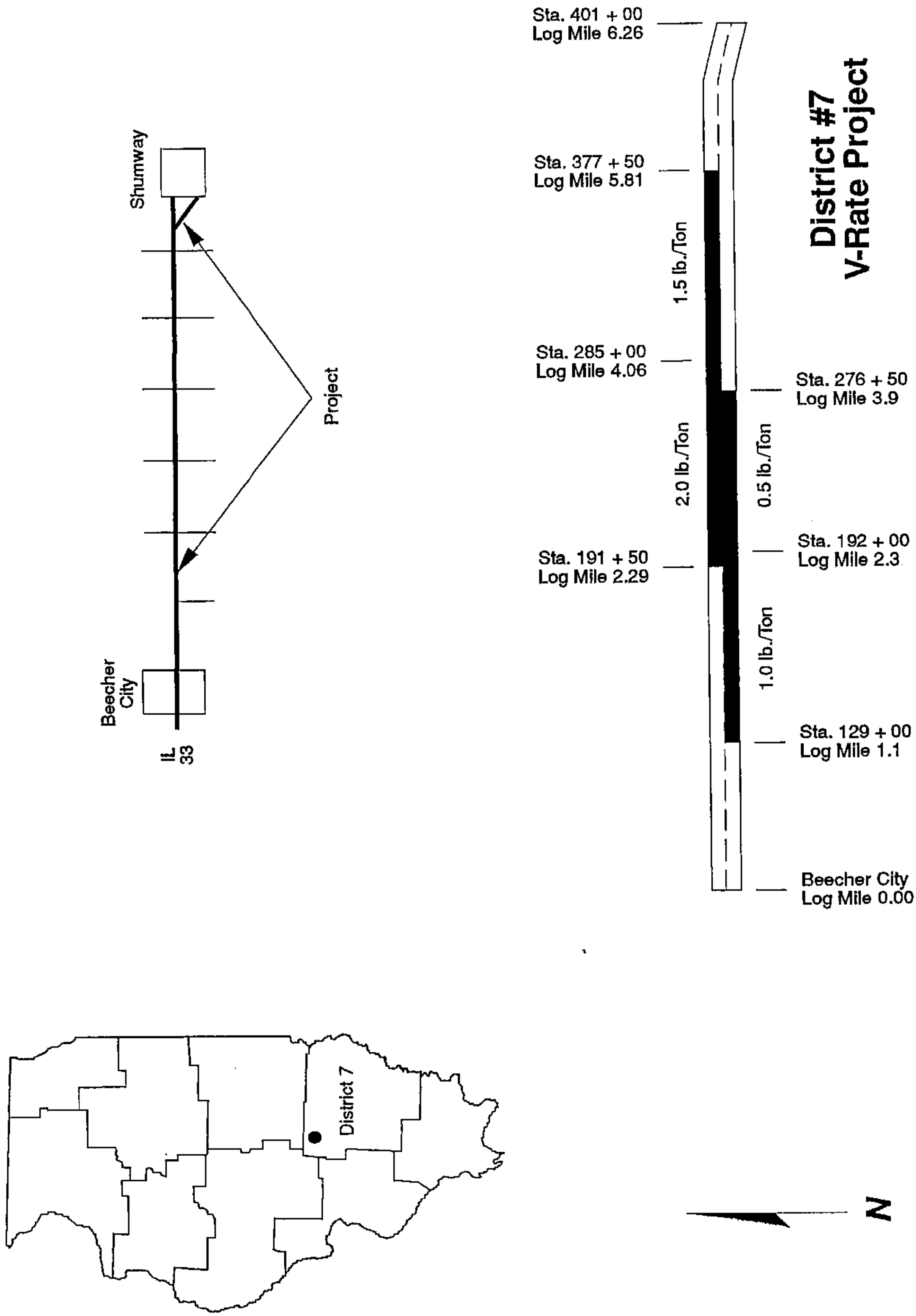
1. Require small amounts of crumb rubber modifier in all HMA produced, to comply with the ISTEA mandate. This strategy will cause less concern among Contractors and State inspectors, and should add little cost once more experience is gained.

2. Continue to monitor performance of the test sections to determine any performance differences attributable to the use of crumb rubber in HMA.

3. Construct additional test pavements using 4.0 - 6.0 pounds of crumb rubber per ton of HMA without redesign of mixture. Reduction of HMA tonnages impacted by recommendation # 1 will be dependent on the success of these projects.

   Also, construct additional test pavements using 20 pounds of crumb rubber per ton of HMA with the necessary mix design modifications, to continue gaining experience with this technology.

   Both project types should include the crumb rubber in the binder course and full depth shoulders, in addition to the surface course, to expand our research.


District #7
V-Rate Project
Sta. 401 + 00
Log Mile 6.26
Sta. 377 + 50
Log Mile 5.81
1.5 lb./Ton
Sta. 285 + 00
Log Mile 4.06
Sta. 276 + 50
Log Mile 3.9
2.0 lb./Ton
0.5 lb./Ton
Sta. 191 + 50
Log Mile 2.29
Sta. 192 + 00
Log Mile 2.3
1.0 lb./Ton
Sta. 129 + 00
Log Mile 1.1
Beecher City
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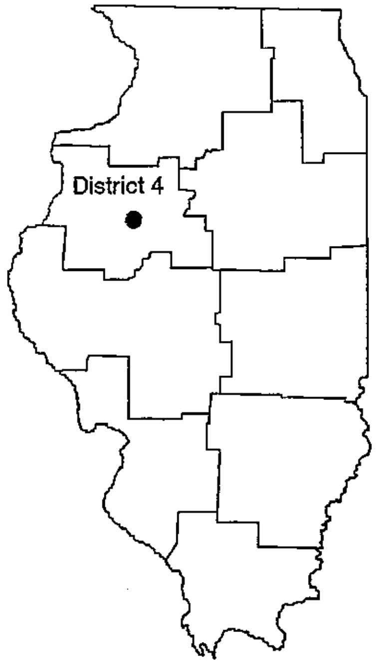
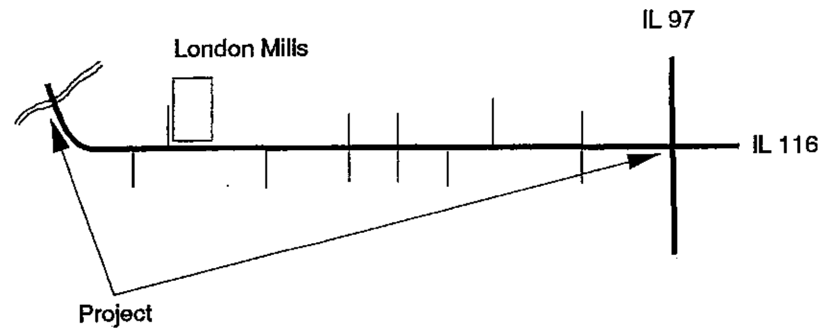
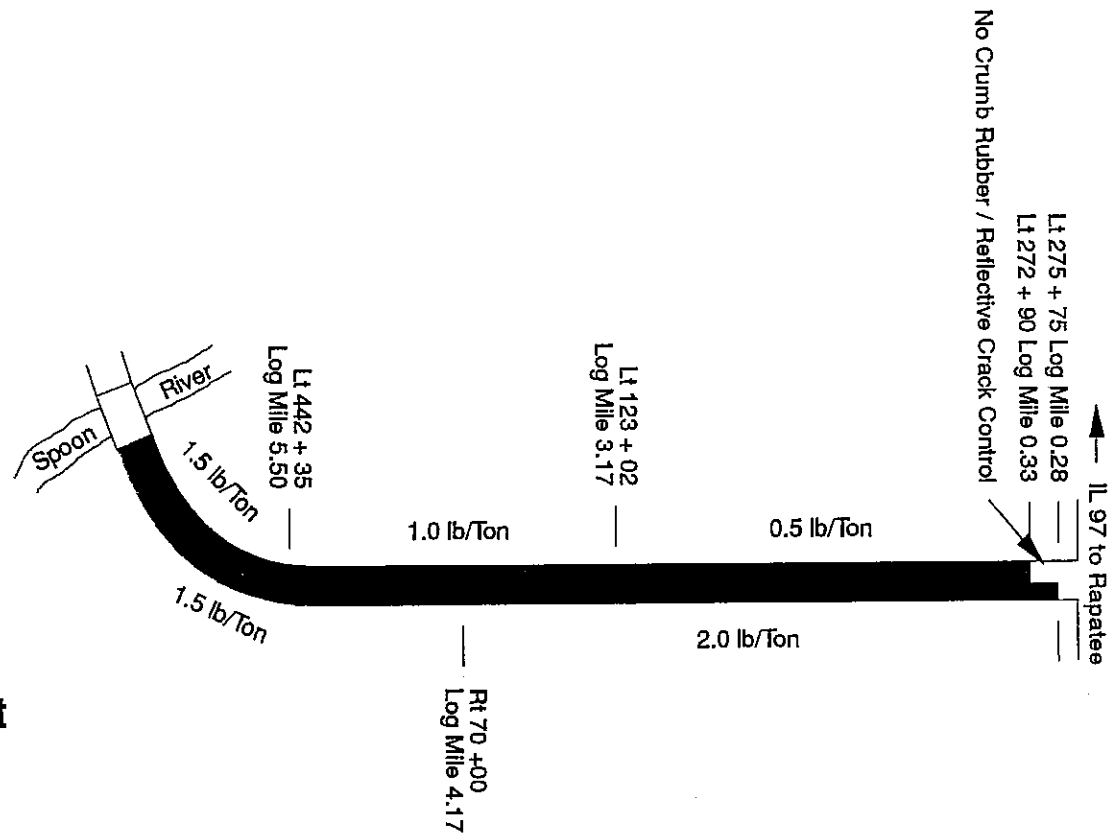
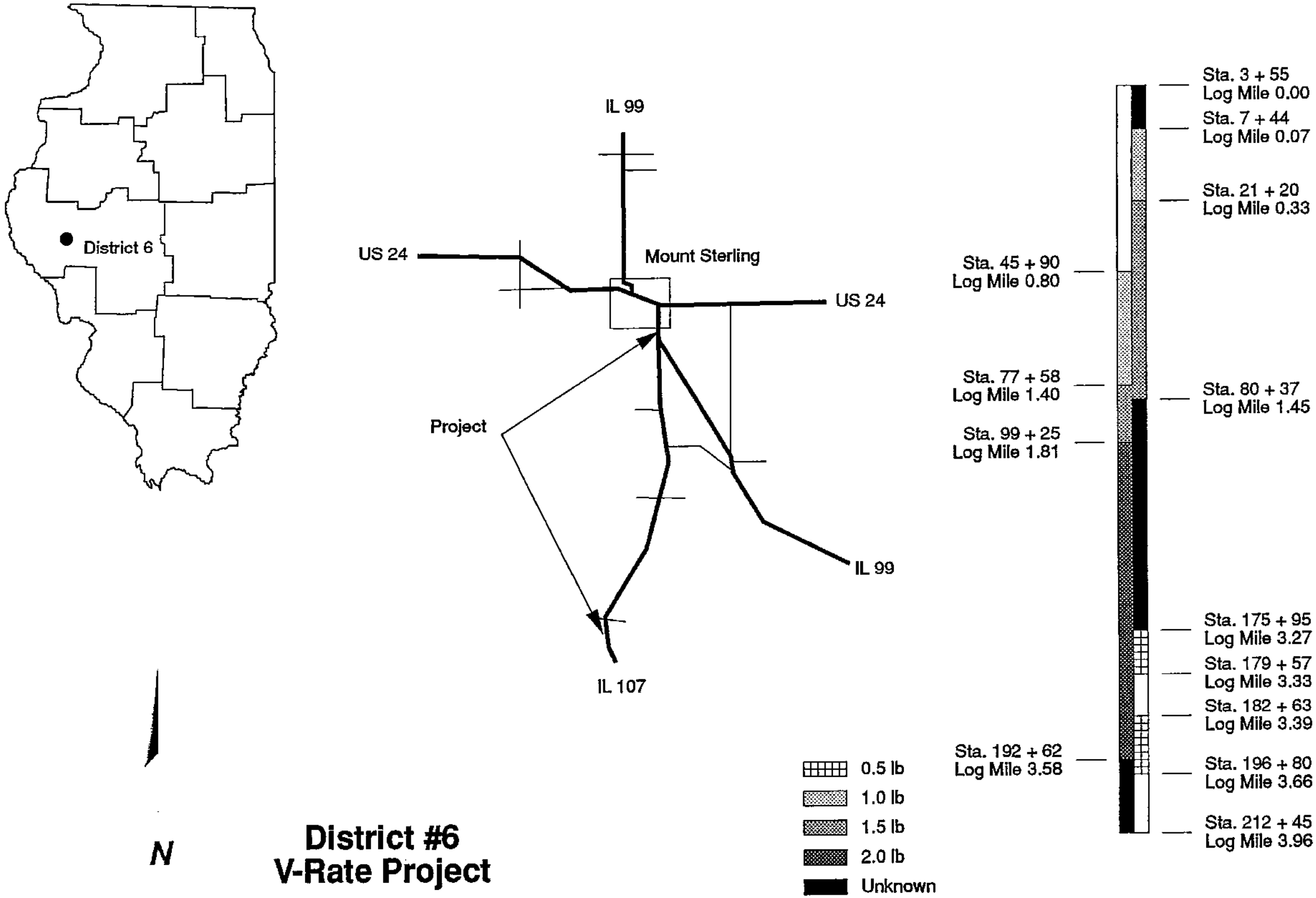


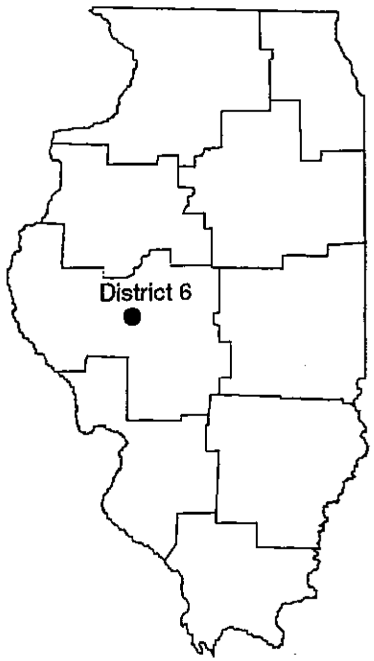


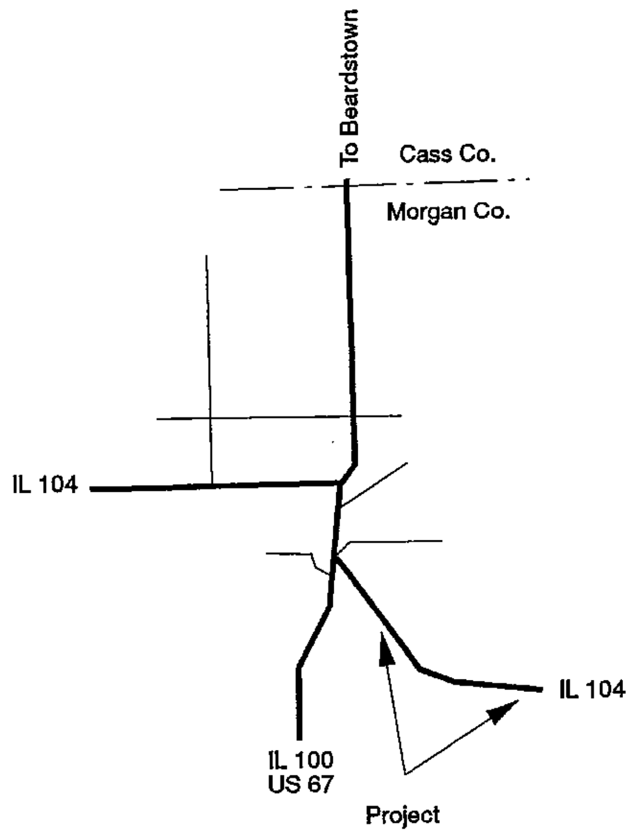


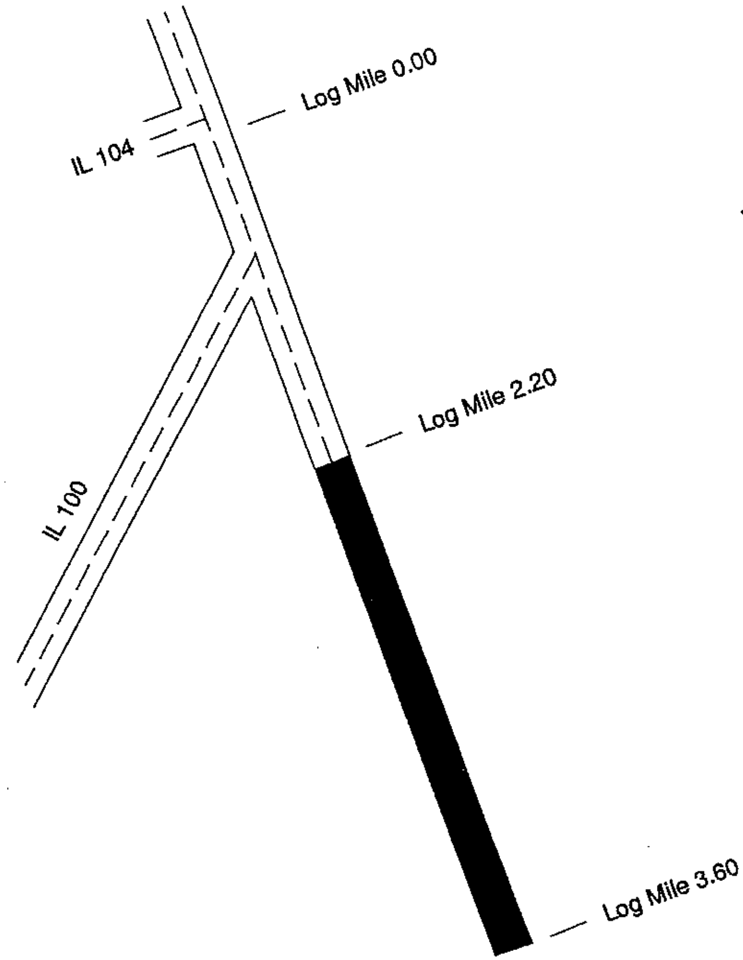
N

District #4
V-Rate Project


District 6
IL 99
US 24
Mount Sterling
US 24
Project
IL 99
IL 107
N
District #6
V-Rate Project
0.5 lb
1.0 lb
1.5 lb
2.0 lb
Unknown
Sta. 3 + 55
Log Mile 0.00
Sta. 7 + 44
Log Mile 0.07
Sta. 21 + 20
Log Mile 0.33
Sta. 45 + 90
Log Mile 0.80
Sta. 77 + 58
Log Mile 1.40
Sta. 80 + 37
Log Mile 1.45
Sta. 99 + 25
Log Mile 1.81
Sta. 175 + 95
Log Mile 3.27
Sta. 179 + 57
Log Mile 3.33
Sta. 182 + 63
Log Mile 3.39
Sta. 192 + 62
Log Mile 3.58
Sta. 196 + 80
Log Mile 3.66
Sta. 212 + 45
Log Mile 3.96

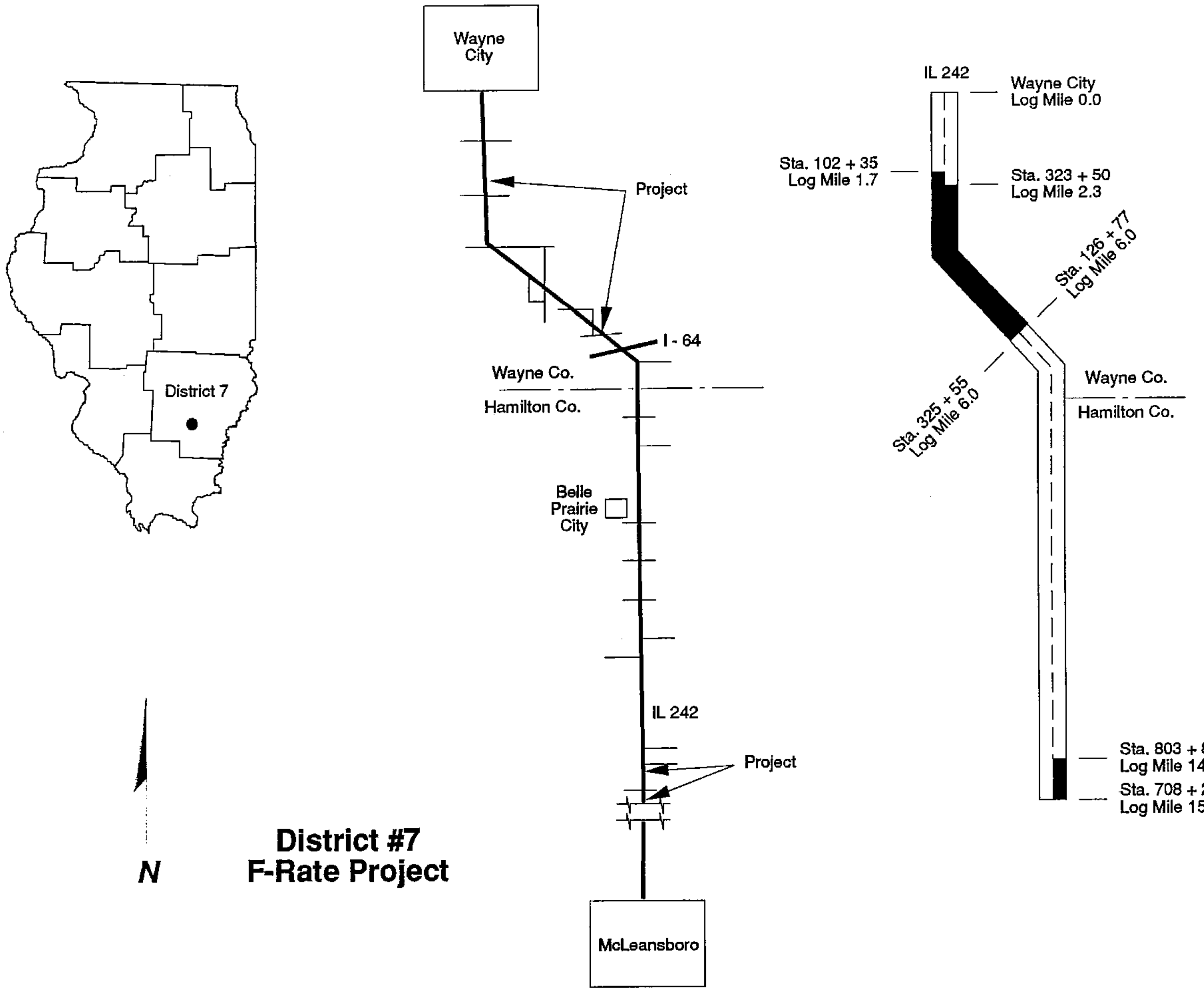




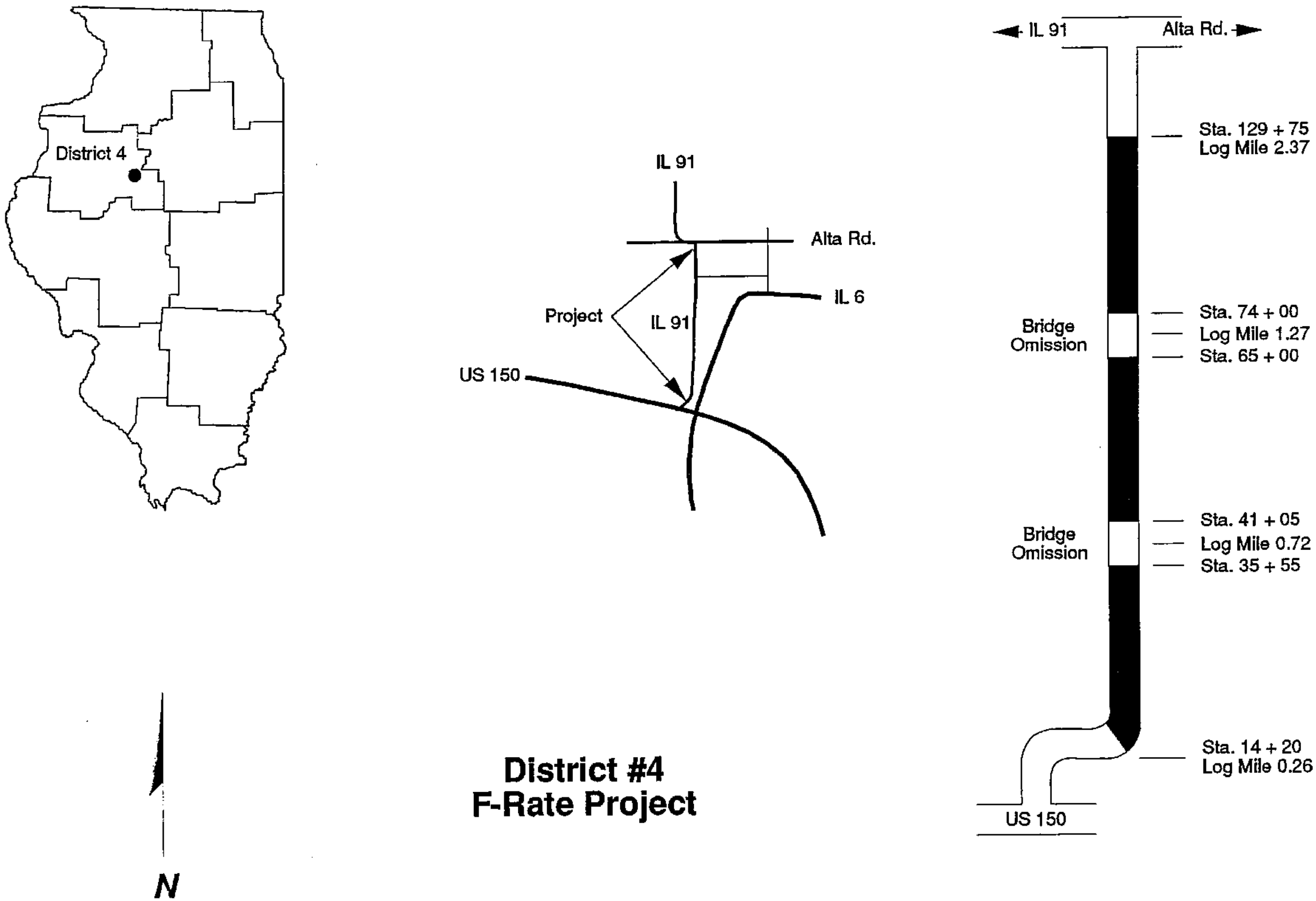


N

District #6
F-Rate Project



District #7
F-Rate Project



**District #4
F-Rate Project**

TEST RESULTS

MIXTURE PROPERTIES

DISTRICT #7 V-RATE PROJECT

PARAMETER	0#/Ton	0.5#/Ton	1#/Ton	1.5#/Ton	2#/Ton
Bulk Specific Gravity (Gmb) "d"	2.394	2.382	2.366	2.342	2.330
Maximum Specific Gravity (Gmm) "D"	2.487	2.489	2.486	2.484	2.485
Voids (%)	3.7	4.3	4.8	5.7	6.2
Stability (lbs.)	2677	2592	2241	2131	2157
Flow (1/100 in.)	8.6	8.6	7.8	8.1	8.2
Split Tensile Strength (psi.)	183.4	197.1	201.0	186.6	178.2
Tensile Strength Ratio "TSR"	0.83	0.87	0.86	0.87	0.84
AC Content (%) Extraction	5.2	5.6	5.7	5.5	5.6
AC Content (%) Nuc. Gauge	*	*	*	*	*

* Materials never received to perform calibration.

EXTRACTION RESULTS

DISTRICT #7 V-RATE PROJECT

	JMF	AJMF	0#/Ton	0#/Ton	0.5#/Ton	0.5#/Ton	1#/Ton	1#/Ton	1.5#/Ton	1.5#/Ton	2#/Ton	2#/Ton	CRUMB RUBBER SAMPLE #1	CRUMB RUBBER SAMPLE #2	CRUMB RUBBER SPEC.
1/2"	100	100	100	100	100	100	100	100	100	100	100	100	–	–	–
3/8"	99	99	98	97	100	98	99	99	100	99	99	99	–	–	–
#4	55	55	55	53	53	54	55	54	57	57	56	57	100	100	100–100
#8	35	35	35	35	36	36	36	35	36	36	34	35	72.6	73.0	55–75
#16	26	26	25	24	25	24	25	25	25	25	23	23	50.1	49.5	20–40
#30	18	18	18	18	17	17	17	17	17	17	15	16	17.4	17.3	5–15
#50	10	10	11	11	11	10	10	10	10	9	9	9	–	–	–
#100	6	6	8	7	8	8	6	6	7	6	6	7	–	–	–
#200	5.2	5.2	6.2	6.1	6.2	6.0	4.6	4.6	5.1	4.6	5.0	5.6	–	–	–
AC	5.7	5.5	5.1	5.2	5.7	5.5	5.7	5.7	5.2	5.8	5.7	5.5	–	–	–

TEST RESULTS

MIXTURE PROPERTIES

DISTRICT #4 V-RATE PROJECT

PARAMETER	0#/Ton	0.5#/Ton	1#/Ton	1.5#/Ton	2#/Ton
Bulk Specific Gravity (Gmb) "d"	2.416	2.411	2.397	2.420	2.430
Maximum Specific Gravity (Gmm) "D"	2.484	2.483	2.478	2.484	2.484
Voids (%)	2.7	2.9	3.3	2.6	2.2
Stability (lbs.)	2240	2250	1960	2130	2190
Flow (1/100 in.)	7.4	8.3	7.3	8.2	8.0
Split Tensile Strength (psi.)	136.1	137.2	132.7	134.4	135.2
Tensile Strength Ratio "TSR"	0.82	0.76	0.80	0.75	0.74
AC Content (%) Extraction	5.8	5.7	5.8	5.7	5.6
AC Content (%) Nuc. Gauge	*	*	*	*	*

* Nuclear AC contents were not run

EXTRACTION RESULTS

DISTRICT #4 V–RATE PROJECT

	JMF	0#/Ton	0#/Ton	0.5#/Ton	0.5#/Ton	1#/Ton	1#/Ton	1.5#/Ton	1.5#/Ton	2#/Ton	2#/Ton
1/2"	100	100	100	100	100	100	100	100	100	100	100
3/8"	99	98	99	98	98	99	98	98	100	98	98
#4	60	56	58	61	61	60	62	57	59	55	56
#8	40	37	38	38	38	39	40	35	36	38	38
#16	29	27	28	27	27	28	29	27	27	28	28
#30	22	21	22	21	22	22	22	21	22	21	21
#50	10	11	11	11	11	10	10	12	12	11	11
#100	6	6	6	6	6	6	6	6	7	6	6
#200	5.0	4.7	5.0	5.0	5.2	5.1	5.1	5.3	5.5	5.5	5.5
AC	5.8	5.7	5.8	5.7	5.7	5.8	5.7	5.7	5.6	5.6	5.6

TEST RESULTS

MIXTURE PROPERTIES

DISTRICT #6 V–RATE PROJECT

PARAMETER	0#/Ton	0.5#/Ton	1#/Ton	1.5#/Ton	2#/Ton
Bulk Specific Gravity (Gmb) "d"	2.399	2.391	2.400	2.400	2.389
Maximum Specific Gravity (Gmm) "D"	2.474	2.478	2.474	2.471	2.470
Voids (%)	3.0	3.5	3.0	2.9	3.3
Stability (lbs.)	2597	2709	2488	2429	2445
Flow (1/100 in.)	8.3	7.7	8.0	8.2	8.0
Split Tensile Strength (psi.)	176.3	178.3	167.7	169.6	164.1
Tensile Strength Ratio "TSR"	0.77	0.83	0.81	0.83	0.77
AC Content (%) Extraction	5.0	5.0	5.0	5.1	4.9
AC Content (%) Nuc. Gauge	7295*	7335*	7402*	7410*	7406*

* Nuclear AC counts (No mat'ls submitted for calibration).

EXTRACTION RESULTS

DISTRICT #6 V-RATE PROJECT

	JMF	0#/Ton	0#/Ton	0.5#/Ton	0.5#/Ton	1#/Ton	1#/Ton	1.5#/Ton	1.5#/Ton	2#/Ton	2#/Ton
1/2"	99	100	99	98	99	99	99	98	99	99	99
3/8"	85	88	87	88	88	86	87	89	90	87	86
#4	56	54	55	57	58	56	56	56	58	54	55
#8	39	37	37	37	38	38	38	37	38	35	36
#16	29	29	29	29	30	30	30	29	29	27	28
#30	20	22	22	21	21	21	21	20	21	19	19
#50	8	9	10	9	9	9	9	10	10	9	9
#100	6	6	6	6	7	6	6	7	7	6	6
#200	4.5	5.2	5.7	5.6	5.7	5.4	5.5	5.6	5.7	5.3	5.3
AC	4.9	5.0	4.9	4.9	5.0	5.1	5.0	5.1	5.1	4.9	4.9

TEST RESULTS

MIXTURE PROPERTIES

DISTRICT #6 F–RATE PROJECT

PARAMETER	JMF #1 10/01/93	JMF #2 10/01/93	10/06/93	10/07/93
Bulk Specific Gravity (Gmb) "d"	2.339	2.383	2.346	2.362
Maximum Specific Gravity (Gmm) "D"	2.470	2.449	2.444	2.452
Voids (%)	5.3	5.3	4.0	3.7
Stability (lbs.)	1958	2170	1984	1959
Flow (1/100 in.)	15.2	12.2	13.2	12.3
Split Tensile Strength (psi.)	147.4	143.5	155.6	164.2
Tensile Strength Ratio "TSR"	0.62	0.70	0.74	0.65
AC Content (%) Extraction	5.8	6.4	6.4	6.2
AC Content (%) Nuc. Gauge	5.4	6.0	6.1	5.8

EXTRACTION RESULTS

DISTRICT #6 F-RATE PROJECT

											CRUMB RUBBER	
	JMF#1	10/01/93	10/01/93	JMF#2	10/01/93	10/01/93	10/06/93	10/06/93	10/07/93	10/07/93	10/08/93 SAMPLE	SPEC.
1/2"	100	100	100	100	100	100	100	100	100	100	–	–
3/8"	98	98	98	99	98	98	98	97	98	97	–	–
#4	55	55	54	58	53	53	54	53	50	51	100	–
#8	30	31	31	33	32	32	31	30	30	30	65	100 – 100
#16	22	21	21	24	22	22	21	21	21	22	21	55 – 75
#30	16	16	16	17	17	17	16	15	16	16	6	20 – 40
#50	10	10	10	10	10	10	9	9	10	10	2	5 – 15
#100	8	8	8	7	7	7	7	7	7	7	0.3	–
#200	6.1	6.2	6.4	5.8	6.0	6.0	5.6	5.7	5.5	5.8	–	–
AC	6.8	5.8	5.8	6.4	6.5	6.5	6.4	6.3	6.1	6.2	–	–

TEST RESULTS

MIXTURE PROPERTIES

DISTRICT #7 F-RATE PROJECT

PARAMETER	Trk #8 9/14/93	Trk #9 9/14/93	10/06/93	10/07/93	10/08/93	10/13/93
Bulk Specific Gravity (Gmb) "d"	2.236	2.241	2.299	2.301	2.265	2.334
Maximum Specific Gravity (Gmm) "D"	2.414	2.408	2.408	2.408	2.410	2.410
Voids (%)	7.4	6.9	4.5	4.4	6.0	3.2
Stability (lbs.)	1171	1146	1745	2011	1407	2090
Flow (1/100 in.)	17.3	18.0	15.0	14.5	16.0	13.3
Split Tensile Strength (psi.)	*	*	129.0	134.6	113.7	158.0
Tensile Strength Ratio "TSR"	*	*	0.77	0.77	*	0.83
AC Content (%) Extraction	5.5	5.5	5.7	5.6	5.7	6.0
AC Content (%) Nuc. Gauge	*	*	5.6	5.7	5.7	5.8

* Test results not available.

NUCLEAR AC GAUGE CALIBRATIONS

AC CONTENTS (%)

	SAMPLES		
Calibration	1	2	EXTRACT.
W / Rubber	5.7	5.7	5.7
W/Out Rubber	6.3	6.3	5.7

– Samples 1 & 2 came from the same bag.
– Extraction was run on samples 1 & 2.

EXTRACTION RESULTS

DISTRICT #7 F–RATE PROJECT

	JMF	AJMF	TRK #8 09/14/93	TRK#13 09/14/93	AJMF	10/06/93 #1	10/06/93 #2	* 10/07/93	** 10/07/93	10/07/93 #1	10/07/93 #2	10/08/93 #1	10/08/93 #2	10/13/93 #1	10/13/93 #2	CRUMB RUBBER 10/08/93 SAMPLE	CRUMB RUBBER SPEC.
1/2"	98	98	99	99	98	98	99	98	99	98	98	98	97	98	98	–	–
3/8"	89	89	90	90	89	90	90	90	88	90	88	89	88	89	89	100	–
#4	47	47	46	46	47	47	49	54	44	49	47	47	48	48	48	99	–
#8	31	31	26	25	31	28	29	34	26	29	28	28	28	29	29	75	100 – 100
#16	24	24	20	19	24	22	23	27	19	23	22	22	22	22	23	65	55 – 75
#30	17	17	15	15	17	17	18	22	15	18	17	17	17	17	17	25	20 – 40
#50	10	10	8	8	10	9	10	14	8	9	9	9	9	10	10	10	5 – 15
#100	8	8	5	5	8	6	6	10	5	6	6	5	5	6	6	4	–
#200	5.0	5.0	4.0	4.0	5.0	4.8	5.2	9.9	3.4	4.8	4.8	4.0	4.0	4.4	4.7	1.1	–
AC	5.8	5.5	5.4	5.4	5.8	5.6	5.7	5.7	6.0	5.7	5.5	5.7	5.8	5.7	6.2	–	–

* Results from low density cores (rubber content = 15# / ton).
** Results from high density cores (rubber content = 20.5# / ton).

TEST RESULTS

MIXTURE PROPERTIES

DISTRICT #4 F-RATE PROJECT

PARAMETER	7/25/94 AM	7/25/94 PM	7/26/94	7/27/94 AM	7/27/94 PM
Bulk Specific Gravity (Gmb) "d"	2.360	2.335	2.341	2.248	2.348
Maximum Specific Gravity (Gmm) "D"	2.424	2.444	2.463	2.476	2.444
Voids (%)	2.6	4.5	5.0	9.2	3.9
Stability (lbs.)	2166	1953	2341	1800	2443
Flow (1/100 in.)	12.7	13.0	11.5	11.3	13.0
Split Tensile Strength (psi)	153.1	178.2	184.9	152.5	215.3
Tensile Strength Ratio "TSR"	0.67	0.56	0.80	0.77	0.74
AC Content (%) Extraction	6.38	6.40	6.12	5.50	6.46
AC Content (%) Nuc. Gauge*	6.74	6.74	6.38	5.81	6.70
AC Content (%) Nuc. Gauge**	7.26	7.28	7.00	6.39	7.21

* Calibrated With Crumb Rubber
** Calibrated Without Crumb Rubber

EXTRACTION RESULTS

DISTRICT #4 F–RATE PROJECT

	JMF	7/25/94 AM	7/25/94 AM	7/25/94 PM	7/25/94 PM	7/26/94	7/26/94	7/27/94 AM	7/27/94 AM	7/27/94 PM	7/27/94 PM	CRUMB RUBBER		
												#1	#2	SPEC.
1/2"	100	100	100	100	100	100	100	100	100	100	100	–	–	–
3/8"	99	99	99	99	99	99	99	99	99	99	100	–	–	–
#4	55	58	58	60	61	57	59	55	57	59	58	–	–	–
#8	36	36	36	35	35	33	33	30	30	35	34	100	100	100 – 100
#16	27	27	27	25	25	23	24	20	20	26	25	78	58	55 – 75
#30	19	20	20	17	17	17	17	13	13	18	18	42	22	20 – 40
#50	8	10	10	9	9	8	9	6	6	9	9	16	7	5 – 15
#100	5	7	7	6	6	6	6	4	4	6	6	4	1	–
#200	3.8	5.5	5.6	5.3	5.3	4.7	4.7	2.9	2.8	5.3	5.1	0.5	0.0	–
AC	5.8	6.35	6.42	6.39	6.42	6.05	6.19	5.47	5.54	6.44	6.47	–	–	–

* Results from low density cores (rubber content = 15# / ton).
** Results from high density cores (rubber content = 20.5# / ton).

SPECIAL PROVISION
FOR
RUBBER MODIFIED ASPHALT CONCRETE (RUMAC)
Effective March 23, 1993

Description

This special provision stipulates the requirements for materials, manufacturing and placement of rubber modified asphalt concrete (RUMAC) for Class I, Type 2 surface and binder course mixtures. The applicable portions of Section 406 of the Standard Specifications shall apply except as noted below.

Material Requirements

A. Crumb Rubber. The crumb rubber shall be produced from processing automobile and/or truck tires by ambient grinding methods. Heavy equipment tires, uncured or devulcanized rubber will not be permitted. The crumb rubber shall not exceed 0.2 mm (1/16 inch) in length and contain no free metal particles. The metal content shall be determined by thoroughly passing a magnet through a 50 gram sample. Metal embedded in rubber particles will be permitted. The crumb rubber shall be free of contaminates to the following tolerances:

Fiber content	1.0% by weight, max
Mineral content	0.3% by weight, max
Moisture content	0.75%

Fiber content shall be determined by weighing fiber balls which are formed during the gradation test procedure. Rubber particles shall be removed from the fiber balls before weighing.

The moisture content shall be determined in accordance with AASHTO T-255, using a controlled temperature oven at 60° C (140° F) and 50 gram sample.

The mineral content shall be determined by saline float separation. A 50 gram sample shall be stirred into a 1 liter glass beaker filled with saline solution (1 part table salt into 3 parts distilled water). Allow the sample to stand for 30 minutes. The mineral content is that material which does not float to the top of the beaker.

When tested in accordance with ASTM C-136 a 50 gram sample shall conform to the following gradation requirements:

Sieve Size	Percent Passing
2.36 mm (No. 8)	100
1.18 mm (No. 16)	65±10
600 um (No. 30)	30±10
300 um (No. 50)	10±5

A mineral powder (such as calcium carbonate) meeting AASHTO M17 requirements may be added, up to a maximum of 4% by weight, to reduce sticking and caking of the crumb rubber particles.

Crumb rubber shall have a specific gravity of 1.15 $\pm$ 0.05 when tested in accordance with ASTM D-1817 and shall meet the following chemical requirements:

Property	Allowable Percentage	Test Method
Carbon Black	25 - 38	ASTM D-297
Ash Content	8.0 Max.	ASTM D-297
Acetone Extract	10 - 22	ASTM D-297
Natural Rubber	5 - 30	ASTM D-297

The crumb rubber may be provided in bulk or in whole plastic containers. Plastic containers shall be made from low density polyethylene having a melting point less than 115° C (240° F). The manufacturer shall ship along with the ground rubber, certificates of compliance which certify that all requirements of this specification are complied with for each production lot number or shipment.

B. Anti-stripping Agent. If required, an approved, heat stable anti-stripping agent shall be provided in accordance with the Department's Special Provision for "Use of Anti-Stripping for Class I, Type 1 & 2 Mixtures (Binder and Surface)" (eff. 9-1-89).

Composition of the Mixture

Four (4) test sections and a control section shall be constructed as indicated on the plans. The test sections shall contain approximately 1500 tons of mix containing respectively 0.5 lbs, 1.0 lbs, 1.5 lbs, and 2.0 lbs of crumb rubber per ton of mix. The control section shall not contain crumb rubber.

The asphalt content in the established job mix formula shall be increased up to 0.3% for the mixture containing 2.0 lbs. of crumb rubber.

Hot Mix Plant

The type of plant used for the manufacture of RUMAC mixtures may be either a batch or drier drum plant meeting the requirements of 802.01, with the following exceptions:

A. Requirements for Batch Plants. The amount of ground rubber shall accurately be determined by weighing or metering to the approval of the Engineer. The method shall feed the material uniformly.

B. Requirements for Drier Drum Plants. Ground rubber introduced into the mixer shall be drawn from storage bins by a continuous mechanical feeder which will uniformly feed the mixer within plus or minus 0.50% of the required amount. Positive interlocking control between the flow of the ground rubber and aggregates shall be provided.

The crumb rubber shall not enter the drum with the cold aggregate. It shall be introduced to the drum beyond the flame but before the asphalt cement discharge.

C. Plant Modification. Introduction of crumb rubber into RUMAC mixtures may require plant modification. The Engineer will have final approval of the plant.

Compaction of RUMAC Mixtures

During laydown, the Engineer will peridoically determine the mat density in accordance with the Department's test procedure Il 2950-92, "Standard Test Method for Determination of Density of Bituminous Concrete In-Place by Nuclear Method." Final acceptance of mat density shall be based on cores (other than those obtained for core-nuclear correlation) obtained by the contractor at locations specified by the Engineer. Core densities will be determined by the Engineer in accordance with Departmental procedures.

"FIXED RATE"

SPECIAL PROVISION
FOR
RUBBER MODIFIED ASPHALT CONCRETE (RUMAC)

Effective March 1, 1993
Revised April 15, 1993

Description

This special provision stipulates the requirements for materials, manufacturing and placement of rubber modified asphalt concrete (RUMAC) for Class I, Type 2 surface and binder course mixtures. The applicable portions of Section 406 of the Standard Specifications shall apply except as noted below.

Material Requirements

A. Crumb Rubber. The crumb rubber shall be produced form processing automobile and/or truck tires by ambient grinding methods. Heavy equipment tires, uncured or devulcanized rubber will not be permitted. The crumb rubber shall not exceed 0.2 mm (1/16 inch) in length and contain no free metal particles. The metal content shall be determined by thoroughly passing a magnet through a 50 gram sample. Metal embedded in rubber particles will be permitted. The crumb rubber shall be free of contaminates to the following tolerances:

Fiber content	0.2% by weight, max
Mineral content	0.3% by weight, max
Moisture content	0.75%

Fiber content shall be determined by weighing fiber balls which are formed during the gradation test procedure. Rubber particles shall be removed from the fiber balls before weighing.

The moisture content shall be determined in accordance with AASHTO T-255, using a controlled temperature oven at 60° C (140° F) and 50 gram sample.

The mineral content shall be determined by saline float separation. A 50 gram sample shall be stirred into a 1 liter glass beaker filled with saline solution (1 part table salt into 3 parts distilled water). Allow the sample to stand for 30 minutes. The mineral content is that material which does not float to the top of the beaker.

When tested in accordance with ASTM C-136 a 50 gram sample shall conform to the following gradation requirements:

Sieve Size	Percent Passing
2.36 mm (No. 8)	100
1.18 mm (No. 16)	65+10
600 um (No. 30)	30∓10
300 um (No. 50)	10∓5

A mineral powder (such as calcium carbonate) meeting AASHTO M17 requirements may be added, up to a maximum of 4% by weight, to reduce sticking and caking of the crumb rubber particles.

Crumb rubber shall have a specific gravity of 1.15 $\pm$ 0.05 when tested in accordance with ASTM D-1817 and shall meet the following chemical requirements:

Property	Allowable Percentage	Test Method
Carbon Black	25 - 38	ASTM D-297
Ash Content	8.0 Max.	ASTM D-297
Acetone Extract	10 - 18	ASTM D-297
Natural Rubber	15 - 30	ASTM D-297

The crumb rubber may be provided in bulk or in whole plastic containers. Plastic containers shall be made from low density polyethylene having a melting point less than 115° C (240° F). The manufacturer shall ship along with the ground rubber, certificates of compliance which certify that all requirements of this specification are complied with for each production lot number or shipment.

B. Reclaimed Asphalt Pavement (RAP). RAP will not be permitted in the mixture.

C. Anti-stripping Agent. If required, an approved, heat stable anti-stripping agent shall be provided in accordance with the Department's Special Provision for "Use of Anti-Stripping for Class I, Type 1 & 2 Mixtures (Binder and Surface)" (eff. 9-1-89).

Composition of the Mixture

After a representative quantity of aggregate has been produced and not less than thirty (30) calendar days before production of the RUMAC mix begins, the Contractor shall furnish the Department representative samples of the materials to be used in the mixture for the project as follows:

Material	Amount
Aggregate	115 Kg. (250 lbs.) of each stockpile
Crumb Rubber	30 Kg. (60 lbs.)
Mineral Filler	10 Kg. (20 lbs.)
Asphalt Cement	7.5 L. (2 gals.) in one liter (quart) containers
Liquid Anti-Strip Additive	.5 L. (1 pint)
or	
Hydrated Lime	10 Kg. (20 lbs.)

The thirty (30) calendar day period will begin when samples of all materials, complying with the specifications, have been received by the Engineer or the material laboratory as directed by the Engineer. The Department will provide one mix design for each class of mix specified, at no cost to the Contractor. The cost of the development of any additional mix designs requested by the Contractor shall be borne by the Contractor.

The crumb rubber content shall not exceed one and a half percent by weight (1.5%) of total mix. The optimum rubber content will be determined by the mix design.

Hot Mix Plant

The type of plant used for the manufacture of RUMAC mixtures may be either a batch or drier drum plant meeting the requirements of 802.01, with the following exceptions:

A. Requirements for Batch Plants. The amount of ground rubber shall be determined by weighing on approved scales or load cells. The method shall feed the material uniformly into the pugmill mixer within plus or minus 0.50% of the amount required. The aggregates and ground rubber shall be combined and mixed throughly for a minimum of 25 seconds prior to introducing the asphalt cement. The wet mixing time shall be not less than 35 seconds.

B. Requirements for Drier Drum Plants. Ground rubber introduced into the mixer shall be drawn from storage bins by a continuous mechanical feeder which will uniformly feed the mixer with plus or minus 0.50% of the required amount. Satisfactory means shall be provided to have a positive interlocking control between the flow of the ground rubber and aggregates.

   The crumb rubber shall not enter the drum with the cold aggregate. It shall be introduced to the drum beyond the flame but before the asphalt cement discharge. The crumb rubber shall be mixed with the dry hot aggregate for at least one drum revolution before the asphalt cement is introduced.

C. Plant Modification. Introduction of crumb rubber into RUMAC mixtures may require plant modification. The Engineer will have final approval of the plant.

D. Storage and Conveyance. Heated silo storage of RUMAC mixtures shall not exceed 1 hour. Conveyance of the hot mixture on rubber belts will not be permitted.

Preliminary Test Strip/Start-Up

A preliminary test strip and start-up for the RUMAC mixture shall be conducted in accordance with the Department's "Guidelines for Preliminary Test Strip and Start-Up for Stone Matrix Asphalt/Crumb Rubber Asphalt Mixtures." Note: Preliminary Test Strip is different than the normal test strip required by the Department.

Placement of RUMAC Mixtures.

The RUMAC mixtures shall be delivered at a temperature of 150° C (300°F) to 175° C (350° F).

Compaction of RUMAC Mixtures.

Pneumatic - tired rollers will not be permitted.

During laydown, the Engineer will periodically determine the mat density in accordance with the Department's test procedure Il 2950-92, "Standard Test Method for Determination of Density of Bituminous Concrete In-Place by Nuclear Method." Final acceptance of mat density shall be based on cores obtained by the contractor at locations specified by the Engineer. Core densities will be determined by the Engineer in accordance with Departmental procedures.

Opening to Traffic

Traffic shall not be permitted on the new surface until the temperature of the mat has dropped below 60° C (140° F).

Method of Measurement

RUMAC mixtures shall be measured in accordance with Article 406.22.

Basis of Payment

This work will be paid for in accordance with Article 406.23 at the contract unit price per ton for RUBBER MODIFIED ASPHALT CONCRETE, measured as specified herein, and at the contract unit price each for PRELIMINARY TEST STRIP (RUMAC). The cost of the modified start-up shall be included in the unit price per ton for RUBBER MODIFIED ASPHALT CONCRETE.