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Installation and Early Performance of a Field Test Section of Asphalt Rubber Concrete

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Supplementary Notes

Abstract

Asphalt rubber, which is produced by reacting asphalt cement and crumb rubber, is claimed to increase fatigue life and reduce rutting of asphalt concrete; however, the service life must be increased significantly to offset the additional coast of adding the rubber. In order to assess the performance of asphalt rubber mixtures and how effectively they can be used in construction, text sections of asphalt concrete surface courses using either asphalt rubber binder or the conventional binder were installed on a heavily traveled highway in Northern Virginia. Special equipment was required to blend the asphalt cement and crumb rubber; however, the production of the mixture and construction of the test sections were accomplished with minimal problems. Various laboratory tests including Marshall, gyratory shear, creep, resilient modulus, indirect tensile strength, and stripping were used to evaluate the mixtures in the laboratory. The results indicated that the asphalt rubber mixtures were more susceptible to permanent deformation than the same mixtures without rubber; however, the conventional temperature at which the mixtures were compacted and tested with the gyratory shear machine may not have presented a true estimate of performance because pavement deformation occurs at lower temperatures.

Friction numbers of one section of asphalt rubber mixture were significantly lower at a 95 percent confidence level than friction numbers of the other asphalt rubber section, possibly the result of the pavement surface being filled by soil from a nearby construction project. However, there was no difference at a 95 percent confidence level between the average friction values of the control and asphalt rubber sections.

Surveys of pavement performance, measurements of rut depth, and friction tests will be conducted periodically, and a final report will be published June 30, 1994.

INTERIM REPORT

INSTALLATION AND EARLY PERFORMANCE OF A FIELD TEST SECTION OF ASPHALT RUBBER CONCRETE

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Virginia Transportation Research Council
(A Cooperative Organization Sponsored Jointly by the
Virginia Department of Transportation and
the University of Virginia)

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INTERIM REPORT

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INTRODUCTION

Rubber has been used in asphalt pavement construction in various applications during the last several decades. In fact, attempts to use rubber date back to the 1920s.[1] Logically, the attempt to impart elastic properties to asphalt through the use of rubber is a good idea, and there have been claims that rubber can decrease permanent deformation and reduce reflective cracking.[2] Although there have been encouraging reports, some users have not found enough improvement in pavement performance to justify the extra cost of adding the rubber.[3]

There are two processes used to make asphalt concrete containing ground tire rubber: (1) the dry process and (2) the wet process using asphalt rubber. The dry process involves adding 3 to 5 percent of rubber (by weight of aggregate) to the aggregate before the asphalt is introduced. The wet process, which is more popular, requires reacting 15 to 25 percent of rubber (by weight of asphalt cement) with asphalt at an elevated temperature for 1 to 2 hours. It was recommended in a study done for the Florida DOT that the wet process be used rather than the dry process because the technology is well developed and a great deal of field performance data are available.[4]

The asphalt rubber process has been improved, resulting in a better product, but there is still a need to experiment further with asphalt rubber on a local level to determine how it performs under various conditions. It should be tested under adverse traffic conditions where other types of asphalt have not been effective. Urban highways, which are subjected to a high volume of slowly moving traffic, making them susceptible to rutting and other types of permanent deformation, are prime locations. If rubber could be used as an economically feasible alternative to polymers and other stiffening additives to alleviate this problem in Virginia, then waste tires that are now disposed of could be used.

After Virginia Senate Bill No. 287, which encouraged demonstration projects using ground rubber from used tires in road surfacing, was passed, an experimental field section of asphalt rubber concrete was installed on an urban highway in Fairfax County.

The purpose of this study is to evaluate asphalt rubber as a binder for asphalt concrete by installing and evaluating a highway test section. Laboratory tests were conducted to predict the performance of the experimental mixture and a control mixture, which is being used for comparison. Rutting tests will be performed periodically, and the performance will be evaluated visually. This interim report describes the installation of the test sections and gives results of laboratory tests on the mixtures, which were sampled during construction, and results of skid tests, which were performed shortly after construction.

DESCRIPTION OF TEST SECTIONS

Two test sections are located approximately 5 miles apart on Route 1 near Fort Belvoir U.S. Military Reservation in Fairfax County (see Figures 1 and 2). At each location, a control section paved with the conventional SM-2C mixture containing AC-30 binder and a section containing the experimental mixture with asphalt rubber binder were installed. The sites were chosen after a thorough search throughout the state for a location with pavement conditions and traffic loading that would provide a satisfactory test environment. The existing pavement had considerable reflection cracking and was subjected to slow-moving traffic. The pavement on which the test mixtures were placed consisted of portland cement concrete with several asphalt overlays. The 1989 traffic volume for the two locations is listed in Table 1.[5] The traffic lane, which will be evaluated, typically carries approximately 40 percent of the total traffic in each direction.

Table 1

TOTAL TRAFFIC VOLUMES FOR HIGHWAY CONTAINING TEST SECTIONS

Test Section	Cars	Single-Unit Trucks	Tractor Trailers
Southern	27,800	1,545	290
Northern	37,000	2,370	430

MATERIALS

Asphalt and Rubber

The asphalt rubber binder consisted of AC-30 asphalt cement (blended with 6 percent extender oil), which was mixed with 17 percent crumb rubber (by weight of asphalt cement). The crumb rubber was 14 percent tire rubber and 3 percent tennis ball rubber because the asphalt rubber supplier felt that the small percentage of tennis ball rubber added desirable properties to the mixture. The specified gradation of the rubber is listed in Table 2, and the specified properties of the asphalt rubber binder are listed in Table 3.

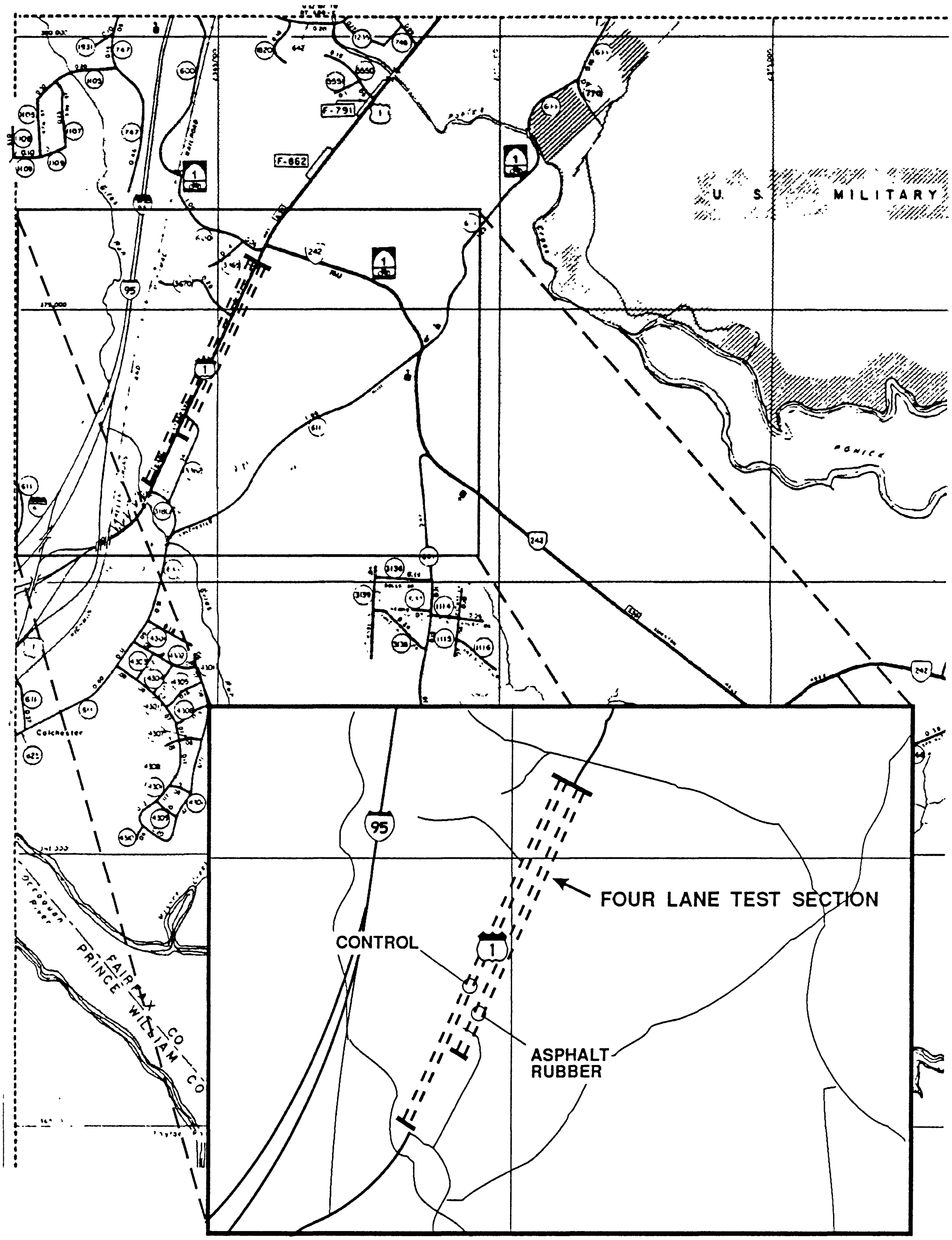

Figure 1. Southern location of test sections.

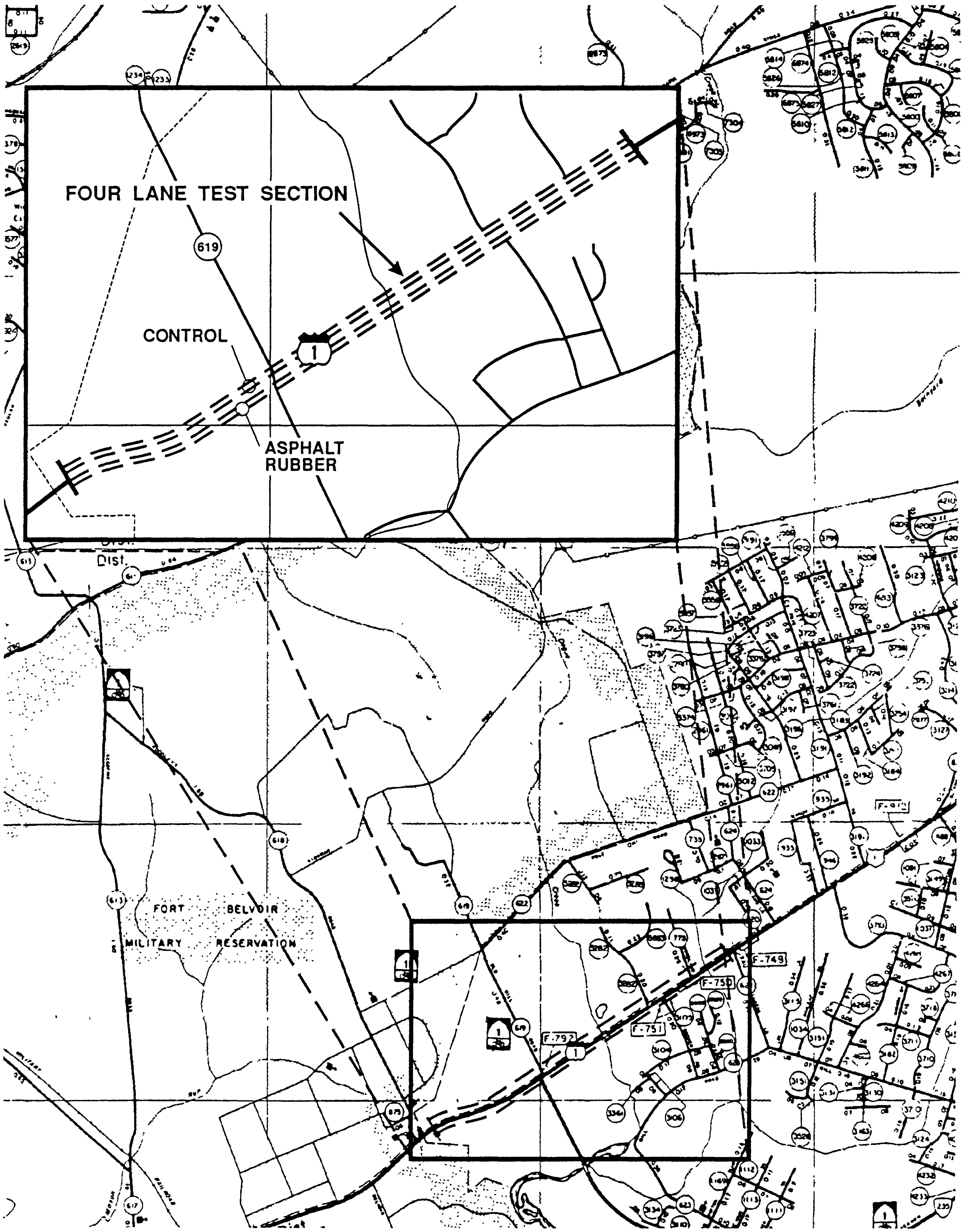

Figure 2. Northern location of test sections.

Table 2

GRADATION OF CRUMB RUBBER

Sieve	% Passing
No. 10	100
No. 16	95–100
No. 30	70–100
No. 80	0–20
No. 200	0– 5

Table 3

PHYSICAL PROPERTIES OF ASPHALT RUBBER BINDER

Minimum viscosity, 350°F	1500 cp
Minimum cone penetration, 77°F (ASTM D1191)*	20
Minimum softening point (ASTM D36)*	125°F
Minimum resilience, 77°F (ASTM D3407)*	15%

*See ASTM.[6]

Mixture

The specified gradation of the mixture and sources of materials are listed in Tables 4 and 5, respectively. The same gradation was used for both the control and asphalt rubber mixtures.

Table 4

GRADATION OF MIXTURE

Sieve	% Passing
3/4 inch	100
1/2 inch	93–100
3/8 inch	88–96
No. 4	52–60
No. 30	18–24
No. 200	4–6

Table 5

SOURCE OF MATERIALS

10% 1/2-inch RAP	APAC Virginia, Occoquan, Virginia
47% No. 8's	Vulcan Materials, Inc., Occoquan, Virginia
23% No.10's	Vulcan Materials, Inc., Occoquan, Virginia
20% Sand	Solite Sand, Fredericksburg, Virginia
AC-30	ARMCO, Dumfries, Virginia
0.7% Adhere HP-Plus (by weight of asphalt concrete)	ARMAZ Products, Washington, North Carolina

CONSTRUCTION

The asphalt rubber supplier provided a truck containing tanks and mixing apparatus to heat and mix the asphalt–extender oil liquid with the crumb rubber (see Figure 3 for the production process). A tanker truck containing the extender oil, two trucks to transport the asphalt rubber to the hot mix plant, and a pump to pump the high-viscosity asphalt rubber binder into the plant were also provided.

The southern control section in the southbound lanes of Route 1 near Route 242 was paved on the night of August 13, 1990, and the asphalt rubber mixture in

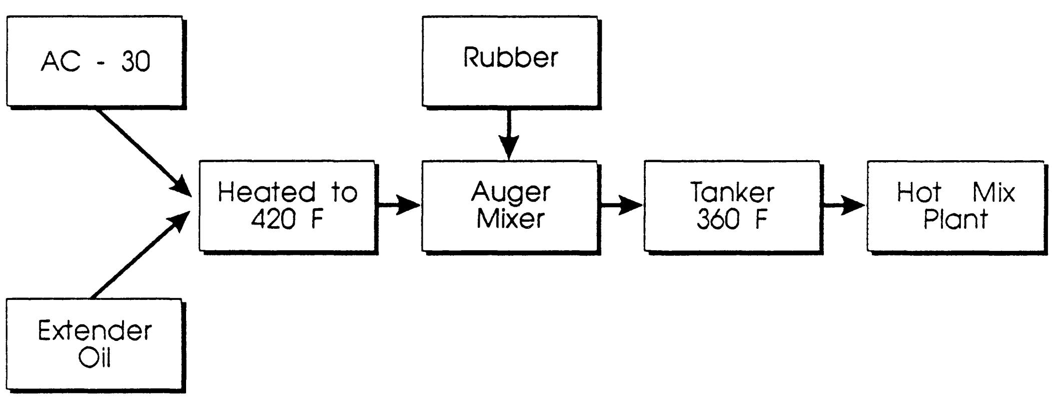

Figure 3. Manufacturing process for asphalt rubber binder.

the adjacent northbound lanes was placed on the night of August 16, 1990. The asphalt rubber mixture was placed in the northbound lanes at the northern location near Route 235 on the night of August 17, and the control mixture was placed in the adjacent southbound lanes on the night of August 20. The weather was excellent for the entire job, with temperatures in the 70s. Approximately 1 1/2 in was milled from most of the pavement in the northern location prior to placement of the overlay in order to provide a uniform surface and remove badly deteriorated pavement; however, several hundred feet of the northern control section near the intersection with Route 5282 was not milled or repaved. Only the edge of the pavement adjacent to a right-turn lane on the control section at the southern location was milled.

There were minor problems during paving, but the overall quality of the product appeared to be satisfactory. The biggest problem was pickup of the asphalt rubber mixture on the leading roller drum of the breakdown roller. This was kept to a minimum by the application of an ample supply of water to the drum. The pickup did not seem to affect the final appearance of the pavement, especially after it had been subjected to some traffic. Also, small accumulations of asphalt rubber binder and fines gathered on the back of the paver screed and dropped onto the new surface; however, the deposits were barely noticeable.

Since the viscosity of the asphalt rubber binder was higher than the viscosity of the normal AC-30 binder, the mixture had to be mixed at a high temperature in order to coat the aggregate. The temperature of the asphalt rubber mixture was approximately 325°F when it was delivered to the paver. An attempt was made to lower the temperature 15 to 20 degrees to deter roller pickup; however, at this temperature, the aggregate did not coat well and the temperature was returned to its original level.

TESTING

Laboratory Tests

Extraction and Gradation

Reflux extraction and gradations tests in accordance with, ASTM D2172[6] and AASHTO T30-84,[7] respectively, were performed by the Culpeper District Materials laboratory on samples of plant mixture (See Table 6).

Even though the design gradations of the control and asphalt rubber mixtures were identical, the design asphalt content of the asphalt rubber mixture was much higher. The higher asphalt content resulted from increased binder viscosity and thicker binder films for the asphalt rubber mixture than for the control mixture. However, all results were within the specified tolerances, indicating that satisfactory quality control was maintained. The extracted asphalt content of the asphalt rubber mixtures was slightly lower than the target value. Since part of the

Table 6

GRADATION OF PLANT MIXTURE SAMPLES

		% Passing			
		Southern		Northern	
Sieve	Design	Rubber	Control	Rubber	Control
3/4 inch	100.0	100.0	100.0	100.0	100.0
1/2 inch	93–100	99.3	99.3	99.2	99.8
3/8 inch	88–96	89.2	89.7	91.6	93.1
No. 4	52–60	53.8	53.3	54.4	58.0
No. 8		40.1	39.2	39.4	40.5
No. 30	18–24	21.2	21.5	21.6	21.3
No. 50		12.4	12.8	13.0	12.1
No. 200	4–6	5.2	5.8	4.9	5.4
Asphalt (%)	4.5–5.1 Control 6.4–7.05 Rubber	6.5	5.0	6.4	5.4

asphalt rubber binder is not soluble, the extracted asphalt content of asphalt rubber mixtures can be expected to be lower than the binder input value.

Marshall Tests

Marshall tests were performed on samples of plant mixture in accordance with ASTM D1559[6] using the 75-blow compactive effort. Properties that were evaluated were voids in the total mixture (VTM), voids filled with asphalt (VFA), voids in the mineral aggregate (VMA), and stability.

Marshall design criteria and test results are listed in Table 7 and Table 8, respectively. The VTM was lower than desirable and the VFA was higher than desirable for the southern asphalt rubber mixture. The extraction result did not indicate any reason for these undesirable properties, such as poor gradation or high asphalt content. However, since the asphalt is difficult to extract from an asphalt rubber mixture, the mixture could have contained more asphalt than indicated by the extraction test, which would have resulted in properties consistent with those obtained by the Marshall tests.

Table 7

DESIGN CRITERIA

Property	SM-2C Control	Asphalt Rubber*
VTM (%)	4–6	3–4
VFA (%)	60–75	
VMA (%)	15	15

* Criteria suggested by Chehovitz.[8]

Table 8

75-BLOW MARSHALL TEST RESULTS

	Southern		Northern	
Property	Rubber	Control	Rubber	Control
VTM (%)	2.4	6.1	3.8	6.0
VFA (%)	87	65	80	67
VMA (%)	17.7	17.5	18.9	18.3
Stability (lb)	2,580	2,960	2,660	3,120

Gyratory Testing Machine

The mixtures were tested with the gyratory testing machine (GTM) in accordance with ASTM D3387.[6] Strength properties and strain information were obtained using the oil-filled mode of operation with initial gyratory angles of 1 and 0.75 degrees with a vertical pressure of 120 psi. The specimens were compacted until the rate of compaction decreased to 1 lb/ft^3 per 100 revolutions, which simulates the level of compaction after traffic. These compactive efforts are believed to simulate the range of compaction that may exist after several years of traffic, which is being studied in a separate investigation.[9] The 1 degree–120 psi compactive effort simulates heavier traffic than the 0.75 degree–120 psi effort. Properties used to characterize the mixtures were final voids, shear strength, and gyratory stability index (GSI). The final air void content, which should be greater than 3 percent, predicts the anticipated ultimate void level of pavement after it is subjected to traffic. Shear strength, which should be greater than 38 psi, is an important property because rutting failures are thought to be caused primarily by low shear strength.[10] GSI usually indicates whether a mixture contains too much binder, with high values (greater than 1.1) being undesirable.

Figures 4 through 6 show the predicted final air void content after traffic, shear strength, and GSI, respectively. Both rubber mixtures failed the criteria that were suggested by the manufacturer of the GTM. In fact, the shear strength at 1 degree and 120 psi for the asphalt rubber mixture at the southern location was too low to measure. Since asphalt rubber mixtures require more binder than mixtures with standard asphalt cement binder, they are more unstable at high compaction temperatures; however, the rubber provides additional reinforcement at summer pavement temperatures. The rubber is claimed to resist deformation and provide additional strength at summer temperatures. The test on asphalt rubber needs to be conducted in a manner that will indicate the performance of asphalt mixtures at critical summer temperatures. A preferable method may be to compact the specimen at the normal field compaction temperature (250°F–275°F) to the density expected before traffic and then cool the specimen to typical summer pavement temperatures (140°F) before the simulated compaction by traffic is resumed. The southern control section had low shear strengths, a high GSI for the specimens

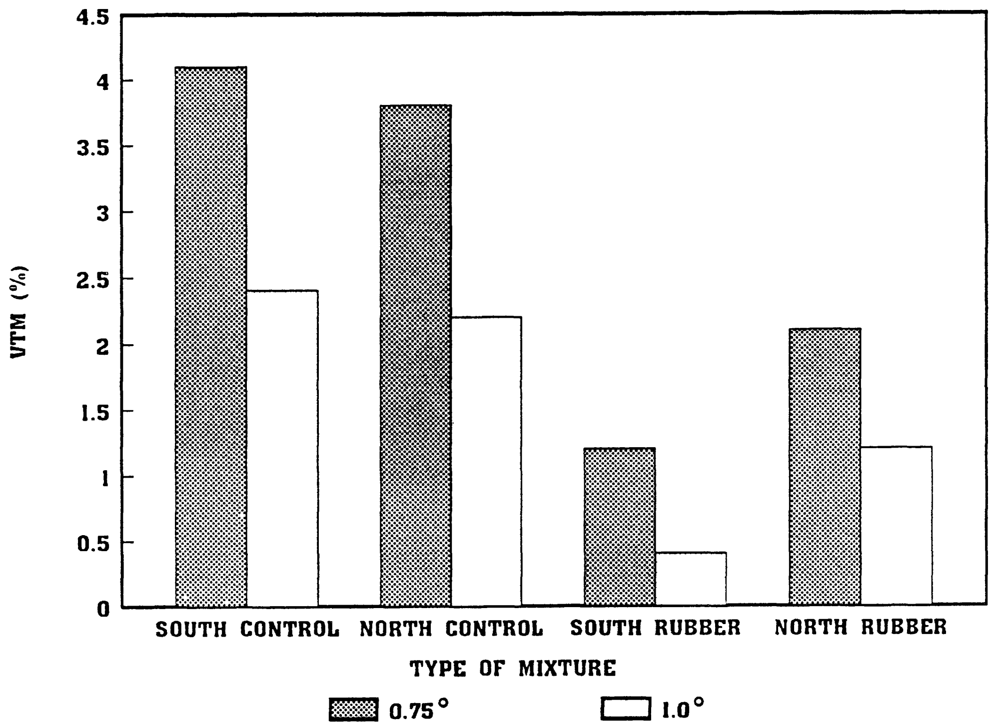

Figure 4. Predicted void content by use of the gyratory testing machine.

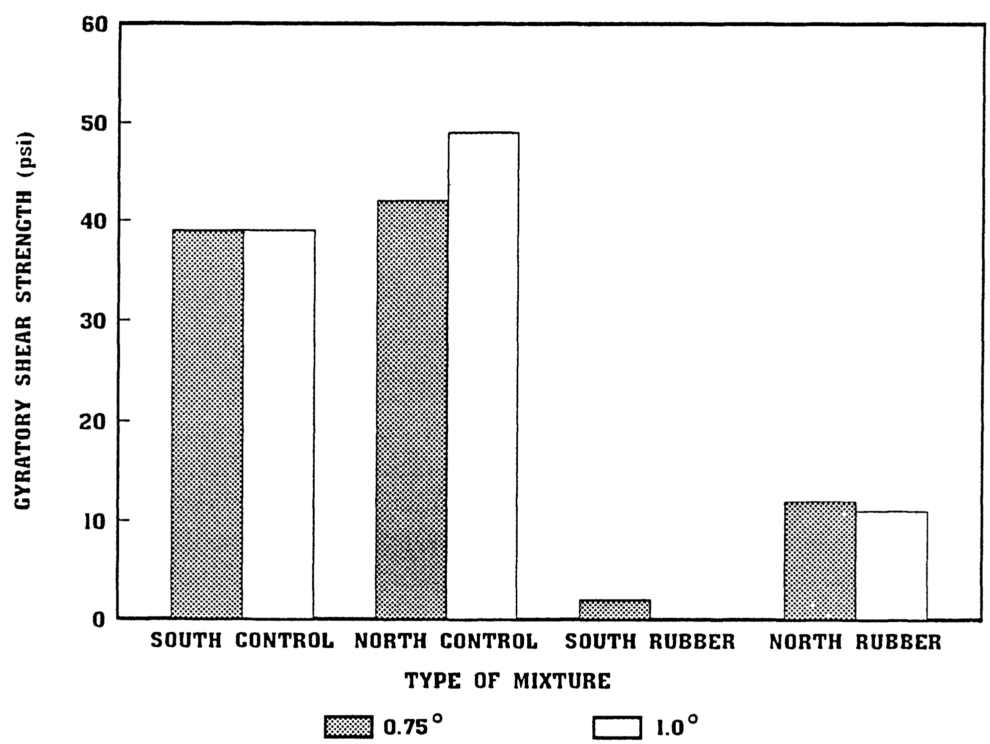

Figure 5. Gyratory shear strength.

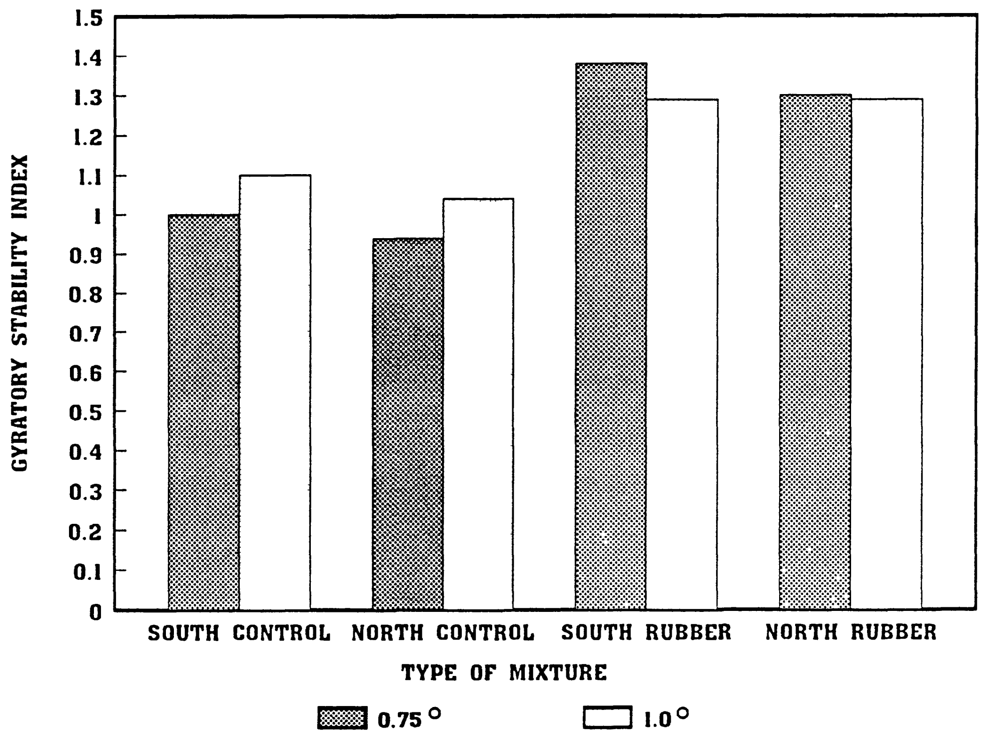

Figure 6. Gyratory stability index.

compacted at 1 degree and 120 psi, and borderline predicted voids for the specimens compacted at 1 degree and 120 psi. These tests performed by current procedures predict that the asphalt rubber mixtures and possibly the southern control mixture may be prone to permanent deformation if the traffic is severe.

Creep Tests

Compression creep tests were performed at 104°F on specimens 2 $^1/_2$ by 4 in, which were constructed on the GTM to the predicted void content of the pavement after being subjected to traffic. The specimens were preloaded for 2 min at 30 psi, unloaded and allowed to rest for 5 min, and reloaded for 60 min at 30 psi. Axial deformation was recorded at set intervals after the load was being applied and again for 60 min after the load had been released. The stiffness modulus at 60 min of loading and the unrecovered strain after the load had been removed for 60 min were the primary properties of interest. The stiffness modulus measures the resistance to deformation under load, and the unrecovered strain measures the permanent deformation characteristics of the mixtures.

The average results and standard deviations of modulus and unrecovered strain are listed in Table 9. It was expected that the asphalt rubber would possibly improve the unrecovered strain and stiffness of the mixture; however, the modulus of the asphalt rubber mixture is less than the modulus of the control mixture. The

Table 9

CREEP TEST RESULTS

	Modulus (psi)		Unrecovered Strain (%)	
Sections	Average	Std. Dev.	Average	Std. Dev.
Control	7,900	900	0.080	0.027
Asphalt rubber	5,500	550	0.200	0.074

difference between averages was significant at a 95 percent confidence level. Similarly, the difference between the averages of the unrecovered strain of the asphalt rubber mixture and control mixture was significant at a 95 percent confidence level. The lower unrecovered strain of the control mixture indicates less chance of permanent deformation, an unexpected result. Although some research has shown asphalt rubber to increase stiffness and strength,[11,12] other research has indicated that asphalt rubber decreased the stiffness of mixtures that were already performing well with a normal binder.[13]

Resilient Modulus

The indirect tensile resilient modulus at 104°F was performed with the Schmidt device (ASTM D4123)[6] using the same specimens that were used in the creep tests. The moduli were computed by the following formula by assuming a Poisson's ratio of 0.35:

$$M_R = P(\mu + 0.273)/t\partial$$

where M_R = resilient modulus (psi)

P = applied load (lb)

μ = Poisson's ratio (assume 0.35)

t = thickness of specimen (in)

∂ = horizontal deformation (in).

The average resilient modulus of the mixture from the control sections at different locations was compared to the average resilient modulus of the mixture from the rubber sections at different locations because the populations of similar mixtures at different locations were not significantly different at a 95 percent confidence level. The comparison revealed that the resilient modulus of the mixture containing rubber was significantly less than the resilient modulus of the control mixture at a 95 percent confidence level (Figure 7).

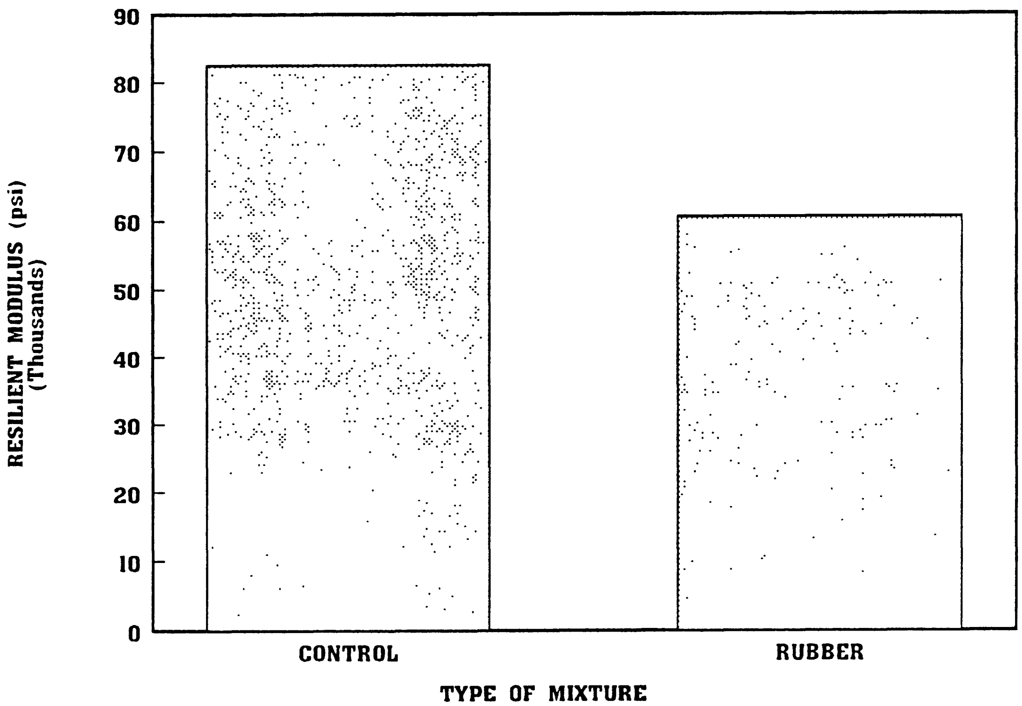

Figure 7. Resilient modulus at 104°F.

Indirect Tensile Test

The indirect tensile strengths were determined at 104°F and a vertical deformation rate of 2 in/min using the same specimens as used in the previous two tests, which were nondestructive. The strength was computed by:

$$S_T = 2P_U / td$$

where S_T = strength (psi)

P_U = ultimate applied load required to fail the specimen (lbf)

t = thickness of specimen (in)

d = diameter of specimen (in).

A statistical analysis indicates that the average strengths of mixtures from both control sections were from the same population at a 95 percent confidence level, but the average strengths of the mixtures from the two rubber sections were statistically different, indicating the likelihood that they were not from the same population (Table 10). Even though the populations were different for the rubber mixtures, the average strength of the both rubber sections was compared to the

Table 10

INDIRECT TENSILE STRENGTH

Test Section	Average	Std. Dev.
South control	102	4.9
North control	100	7.5
South and north control	101	6.2
South rubber	58	3.2
North rubber	68	4.6
South and north rubber	63	6.6

average strength of both control sections, and the differences were significant at a 95 percent confidence level. The average strengths of the control sections and asphalt rubber sections were 101 psi and 63 psi, respectively.

Stripping Tests

Stripping tests performed were the indirect tensile strength test (ASTM 4867)[6] and the Virginia boiling test for field testing (VTM 13).[14]

The tensile strength test determined susceptibility to moisture damage by the testing of two sets of specimens: one set was conditioned to simulate potential moisture damage and tested, and one set was tested in an unconditioned dry state. The tensile strength ratio (TSR), which is the ratio of the conditioned strength to the dry strength, was used to predict moisture damage.

The boiling test is performed by boiling a sample of mixture in water for 10 min. The sample is then compared with an unboiled dry sample of the same mixture. The boiled sample must be as well coated as the unboiled sample in order to pass the test.

The results of the tests are listed in Table 11. The control mixture in the southern location had a TSR that was below the minimum allowable value of 0.75. Both control mixtures had some visible stripping on the split surface of the tensile

Table 11

STRIPPING TESTS RESULTS

	Southern		Northern	
Test	Rubber	Control	Rubber	Control
TSR	0.95	0.71	0.85	0.84
Visual rating (0–5)*	0	3	0	2
Boiling	Pass	Pass	Pass	Pass

* 0 = no stripping; 5 = severe stripping.

test specimens, but the asphalt rubber mixtures did not. These results indicate that the control mixtures may be more susceptible to stripping than the asphalt rubber mixtures. The boiling test did not indicate that any of the mixtures was susceptible to stripping.

Field Tests

Pavement Plugs

Immediately after final rolling, the pavement was cooled with dry ice at several locations in each test section and plugs were removed by sawing. The plugs were transported to the laboratory where voids were determined the following day (Table 12).

There was no significant difference at a 95 percent confidence level between the average voids of the control and asphalt rubber mixtures (12.6 versus 10.3 percent). Because the asphalt rubber mixture was designed for low voids, it was somewhat surprising that the pavement voids were as high as they were. It was possible that since the plugs were removed while the mixture was still warm that the rubber expanded, resulting in measured void levels being higher than actual pavement void levels.

Table 12

PAVEMENT VOIDS

Test Section	Average	Std. Dev.
South control	13.3	—
North control	12.2	1.64
South and north control	12.6	1.96
South rubber	9.5	2.79
North rubber	12.1	2.33
South and north rubber	10.3	3.28

Rut Depth

Rut depths were measured with a 6-ft straightedge immediately after the final pass of the finish roller in order to establish a base measurement for future rut depth measurements. Annual measurements are planned each fall.

Skid Tests

Skid tests were performed approximately 1 week and 3 months after construction with the VDOT skid trailer. The tests were performed at 40 mph with bald tires.

Figures 8 and 9 and Figures 10 and 11 show results of skid tests that were performed on the southern and northern sections, respectively. Both the asphalt rubber sections and control sections decreased 10 to 15 friction numbers during the first 2 1/2 months of service. This decrease was probably caused by smoothing of the surface by traffic, especially since the mixture was fine and had a smooth surface texture before being exposed to traffic. There was no significant difference at a 95 percent confidence level between the average values for the control and asphalt rubber sections in either of the southern or northern locations; therefore, the asphalt rubber mixtures would be considered equal to the control mixtures with respect to skid resistance. The friction numbers of the northern asphalt rubber section were significantly higher at a 95 percent confidence level than the friction numbers of the southern asphalt rubber section. It is possible that some of the low values in the southern location were caused by the pavement surface becoming filled with dirt, which was tracked onto the pavement by trucks leaving nearby construction projects.

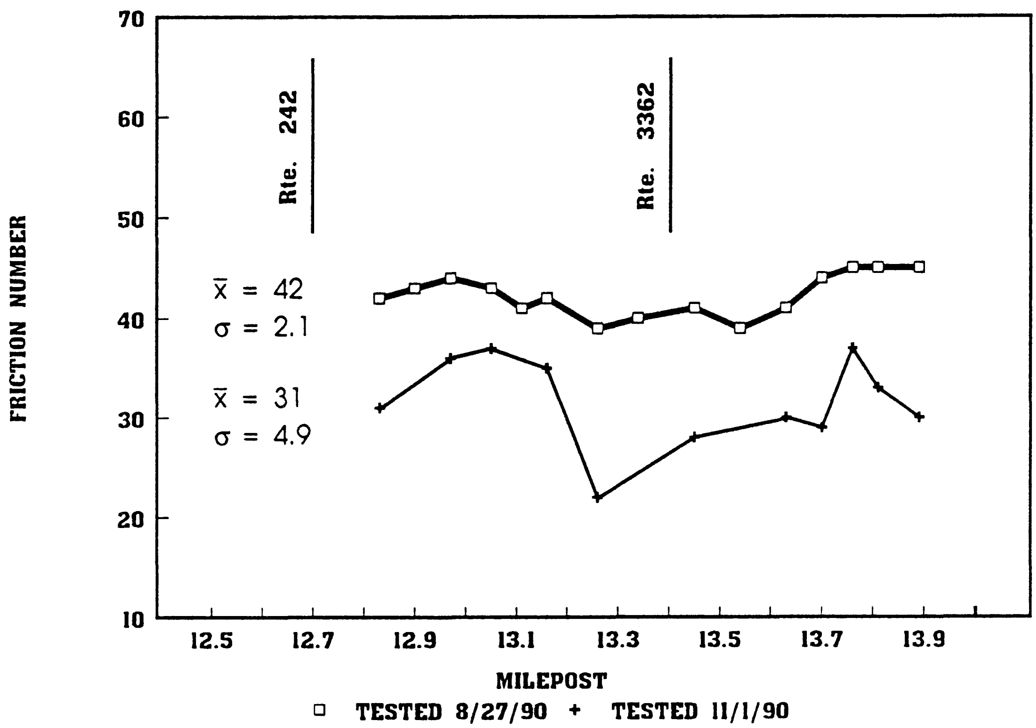

Figure 8. Skid tests for southern control mixture.

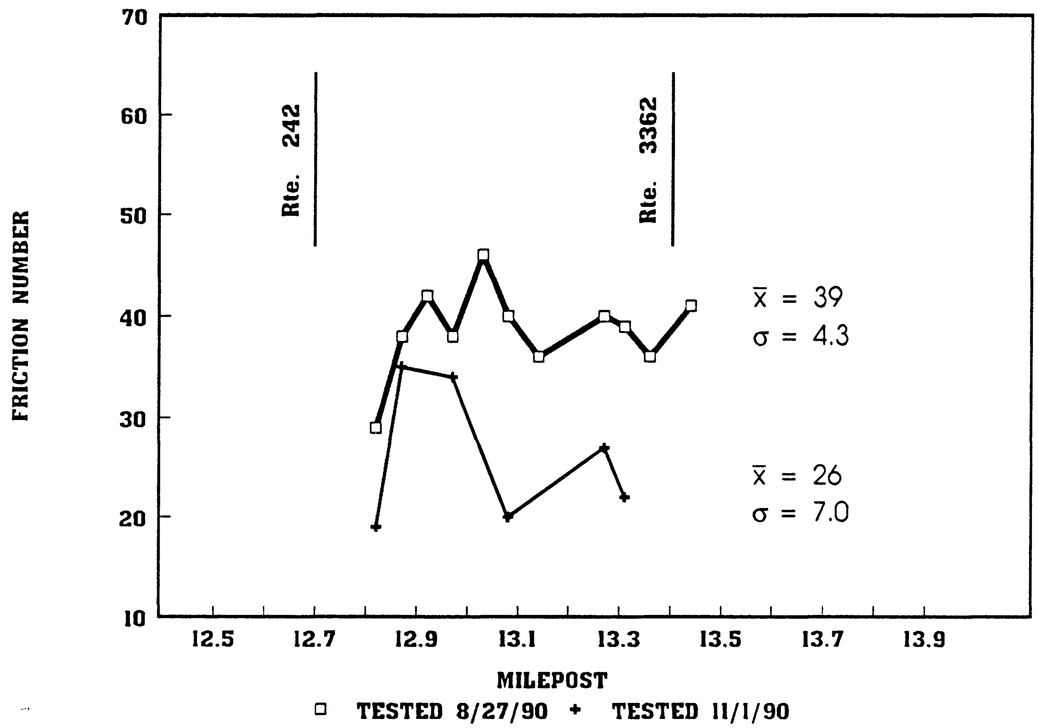

Figure 9. Skid tests for southern asphalt rubber mixture.

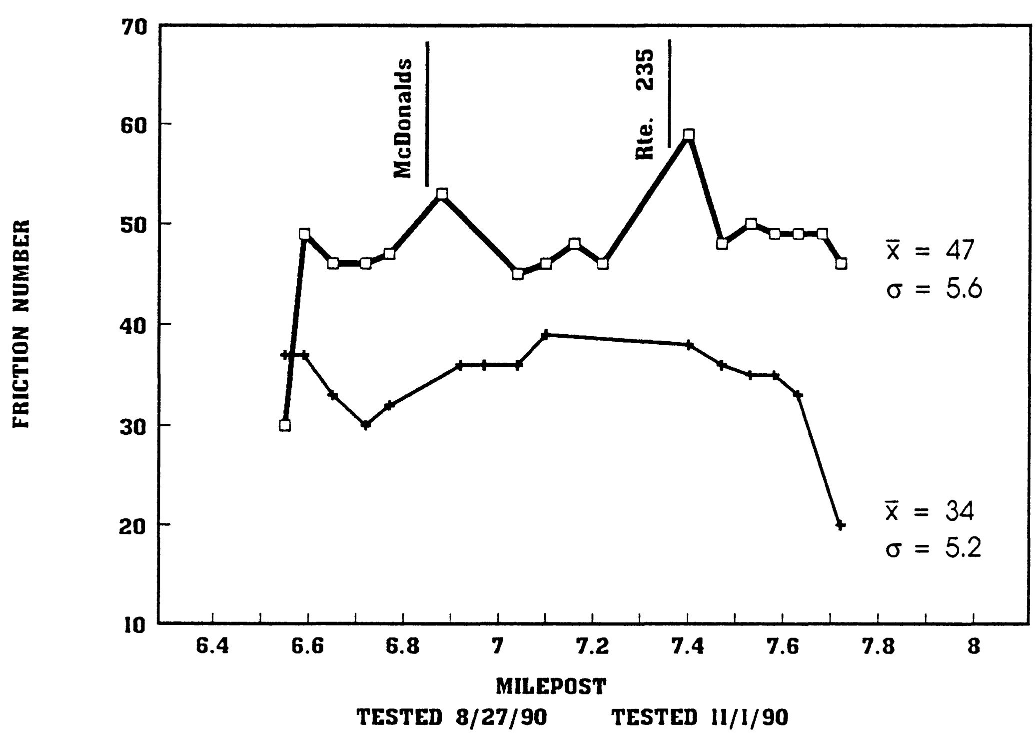

Figure 10. Skid tests for northern control mixture.

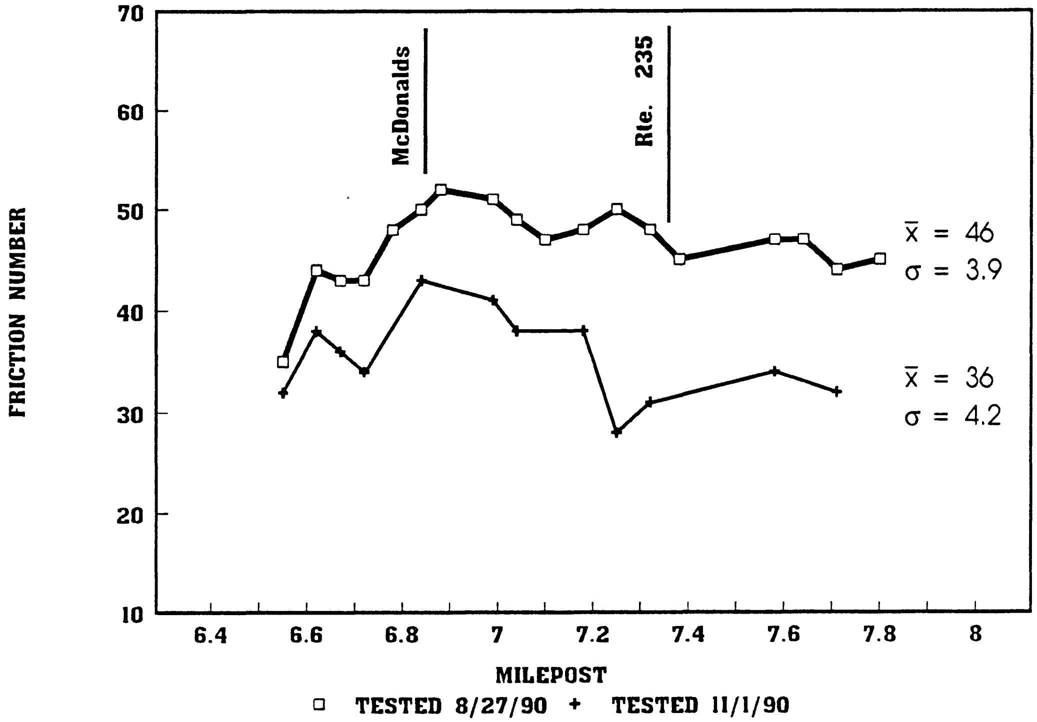

Figure 11. Skid tests for northern asphalt rubber mixture.

COST

The cost of the SM-2C control mixture and asphalt rubber mixture was $26.30/ton and $48.00/ton, respectively. This price for the asphalt rubber mixture does not necessarily reflect what the material would cost if it was produced on a large scale since the asphalt rubber supplier had to travel from Rhode Island to supply asphalt rubber for only 2,300 tons of mixture. It has been reported that asphalt rubber mixtures typically cost 1 $^3/_4$ to 2 times the cost of similar mixtures in the same locality[1]; therefore, asphalt rubber mixtures will have to last twice as long as normal mixtures to be competitive.

PRELIMINARY CONCLUSIONS

1. The asphalt rubber mixture was constructed successfully with minimal problems.
2. Laboratory tests revealed the following:
   - The asphalt rubber mixture had less strength and stiffness than the control mixture, indicating a possible weakness toward rutting.

- The asphalt rubber mixture stripped less than the control mixture.

3. Skid test results of the asphalt rubber mixture and the control mixture were comparable after 3 months.

FUTURE TESTING

Skid tests will be conducted and rut depth measured during the next year, and the pavement will be evaluated for performance by noting distresses that may develop.

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