EXPERIMENTAL USE OF AN

ASPHALT RUBBER SURFACE TREATMENT

INITIAL REPORT 79-6

DECEMBER 1979

Reporting On

Category III Work Plan 79-R-6

SPRINGFIELD-WEATHERSFIELD IR-F 91-1(4)

STATE OF VERMONT
AGENCY OF TRANSPORTATION
MATERIALS & RESEARCH DIVISION

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16. Abstract

This report discusses the application of an asphalt rubber surface treatment and a section of asphalt rubber membrane interlayer on 9.5 miles of 14 year old interstate roadway. Three hundred forty tons of the material available under the trade name OVER-FLEX was spray applied at a temperature of 350°F± and at a rate of 0.624 gallons per square yard. Three-eighths or 1/2 inch cover stone was immediately placed over the material and compacted with pneumatic rollers.

The embedment of cover stone in the asphalt rubber was considered satisfactory, however, exposure to traffic has resulted in the continued loss of aggregate. The riding quality of the surface treatment was measured at 29.8 inches of roughness per mile, a level considered acceptable even though it was nearly double the value obtained on the control pavement.

The cost of the experimental treatment totaled $2.86/sy or 25 percent less than the control treatment. The cost of the asphalt rubber was equal to the cost of a 1 3/8 inch course of bituminous pavement.

Energy requirements for the experimental treatment totaled 29,382 BTU/sy or 57 percent less than the control treatment. Asphalt and aggregate requirements were also 80 and 83 percent less than the control treatment.

The report also includes information on an asphalt rubber application completed in September 1979 on Interstate 89 in Richmond, Vermont.

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Asphalt Rubber Surface Treatment Asphalt Rubber Membrane Interlayer OVER-FLEX Control Treatment	No Restrictions

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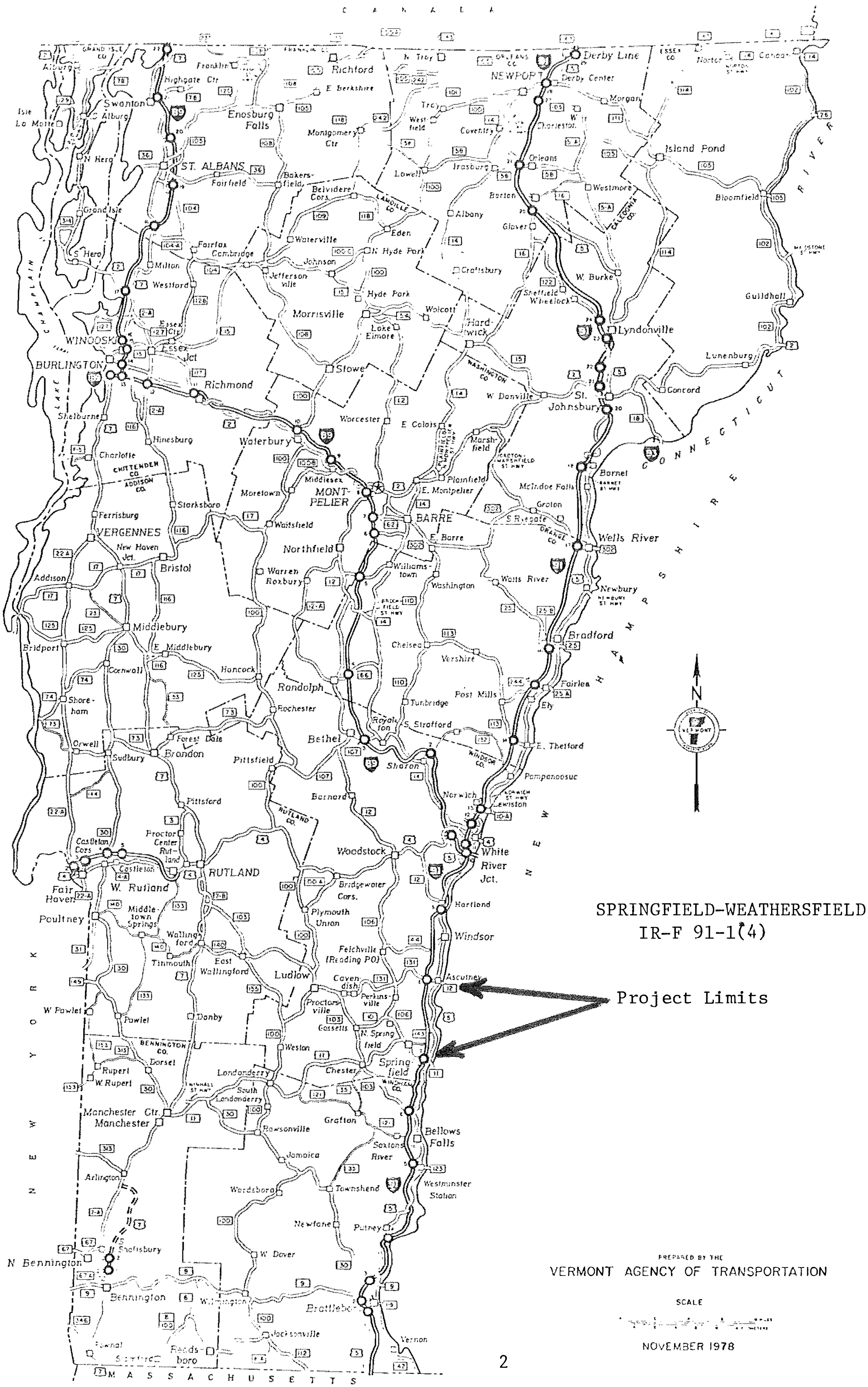
INTRODUCTION

Recent oil shortages and increases in crude oil prices have brought about a forced conservation of energy which in turn has resulted in a leveling off of gas tax revenues available to State governments to finance highway construction and maintenance. The shortage of funds combined with a rapid escalation in the cost of bituminous materials has prompted increased interest in seeking alternate methods or materials for the rehabilitation of distressed bituminous pavements.

In an attempt to stretch the amount of funds available for pavement maintenance, the Vermont Agency of Transportation chose to place an asphalt rubber surface treatment on a section of interstate roadway in lieu of the standard rehabilitation procedure of crack filling, leveling and overlaying with 1-1/2 to 2 inches of new bituminous concrete pavement. In addition to financial considerations, it was hoped that the application would result in a reduction in the amount of energy, asphalt, and aggregates consumed while providing a cost effective service life. Furthermore, it is hoped that the asphalt rubber treatment will be capable of resisting the upward propagation of cracks which were present in the existing pavement.

This report covers the construction phase of Vermont's first Category III experimental project completed in August, 1979 under Demonstration Project No. 37 Discarded Tires in Highway Construction.


CANADA
MASSACHUSETTS
NEW YORK
NEW HAMPSHIRE
CONNECTICUT RIVER
LAKE CHAMPLAIN
Derby Line
NEWPORT
Richford
Enosburg Falls
Swanton
ST. ALBANS
Island Pond
Lyndonville
St. Johnsbury
WINOOSKI
BURLINGTON
Essex Jct
Richmond
Morrisville
Stowe
Hardwick
Waterbury
MONTPELIER
BARRE
Northfield
VERGENNES
Bristol
Middlebury
Randolph
Bethel
Wells River
Bradford
Brandon
RUTLAND
Woodstock
White River Jct.
Ludlow
Windsor
Springfield
Bellows Falls
Manchester Ctr.
Manchester
Bennington
Brattleboro
SPRINGFIELD-WEATHERSFIELD
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Project Limits
PREPARED BY THE
VERMONT AGENCY OF TRANSPORTATION
SCALE
NOVEMBER 1978

PROJECT DESCRIPTION AND ROADWAY CONDITION

The roadway selected for the application of the asphalt rubber surface treatment consisted of 9.49 miles of the southbound lane of Interstate 91 between the Ascutney and Springfield, Vermont interchanges (MM 41/75-51/40). The project area is located in Windsor County in southeastern Vermont, adjacent to the Connecticut River and the New Hampshire border.

Climatological data for the project area discloses a freezing index of 1119, an average of 108 freeze-thaw cycles and 111 inches of snowfall. Frost penetration within the roadway cross section would be expected to reach a depth of 60 inches.

When first opened in 1965, traffic counts averaged 1425 vehicles per day with 9 percent truck traffic. Prior to initiating reconstruction, the ADT had increased 141 percent to 3435 vehicles with 11 percent consisting of truck traffic.

The section of interstate and the accompanying northbound lane which serves as the control treatment were constructed in 1965 and had been open to traffic for 14 years without receiving any maintenance treatment. The roadway featured a 38 foot roadbed with 24 inches of crushed rock, two 2 1/2 inch lifts of plant mixed base course, a 1 3/4 inch binder course of Type II pavement, and a 1 1/4 inch lift of Type III bituminous pavement. All of the mixes utilized an 85-100 penetration asphalt with crushed rock used in the base courses and both crushed rock and crushed gravel used for aggregate in the surface courses.

Numerous evaluations were made of the pavement condition including core recoveries, rutting measurements, crack surveys and surface ride tolerances. Testing on 10 inch diameter cores taken from the surface course on the southbound lane disclosed an average asphalt content of 6.3 percent and a unit weight of 150.6 pounds per cubic foot. Abson recoveries revealed absolute viscosities averaging 39,067 poises and penetration values of 25.3 as compared to the initial asphalt penetration grade of 85-100. Test results on cores taken from the northbound lane disclosed an average asphalt content of 6.5 percent, absolute viscosities of 41,580 poises and penetration values averaging 30.5.

Pavement condition surveys made at five locations on the southbound lane revealed an average of 176 lineal feet of cracks per 100 lineal feet of 24 foot wide roadway. The type of cracks consisted of 49 percent longitudinal, 46 percent transverse, and 5 percent miscellaneous. However, it should be noted that miscellaneous cracks less than 18 inches in length were not included in the survey. The longitudinal cracks were generally located in the left wheel path of the travel lane varying from 1/8 to 1/2 inch in width with most in the 1/4 inch range. The transverse cracks were most severe averaging 5/8 inch in the passing lane by up to 2 measurable inches in depth and 1/4 inch wide in the travel lane.

The transverse cracks also exhibited a surface depression of up to 3/8 inch in depth by 1 1/2 inches in width at each edge of the wider cracks. Such depressions made the existence of the cracks apparent to the traveling public. It should also be noted that all crack width measurements were recorded in June during periods of relatively high ambient temperatures, therefore, such widths would increase significantly during colder weather.

Wheel path rutting values averaged 5/8 inch in the left wheel path and 1/2 inch in the right wheel path of the travel lane while rutting was limited to 3/8 inch ± on the passing lane. The overall condition of the pavement did not indicate evidence of significant base support problems.

Pavement condition surveys made at five locations on the northbound or control lane revealed greater pavement deterioration than that noted on the southbound lane. Cracking averaged 244 lineal feet per 100 lineal feet of roadway with 48 percent longitudinal, 38 percent transverse, and 14 percent miscellaneous. Here again the transverse cracks were the most severe particularly in the passing lane where some were open to a depth of four inches.

The longitudinal cracks averaged 1/2 inch in width and were generally located in either the left or both wheel paths of the travel lane. Such cracks together with numerous short adjacent longitudinal cracks (which were not included in the crack count) and occasional raveling gave the impression that a portion of the pavement failure was the result of inadequate base or subgrade support. Wheel path rutting averaged 5/8 inch in the travel lane and 3/8 inch in the passing lane.

The riding quality of the pavement was measured in inches of roughness per mile with a Mays Ride Meter in 1978. Values obtained on the southbound lane averaged 139.6 inches per mile while the northbound pavement was 38 percent rougher with readings averaging 193.4 inches per mile.

Pavement distress on SB experimental area. Note how traffic has sealed and depressed the pavement surface over the crack in the travel lane.

Severe pavement distress on crack filled NB control area.

MATERIALS AND TREATMENT SPECIFIED

The treatment specified for rehabilitation of the southbound lane included crack filling, placement of a nominal 1/2 inch leveling course and the application of the asphalt rubber surface treatment. In addition, one mile of the asphalt rubber was designated to receive an overlay of bituminous pavement to determine if the material could reduce reflective cracking when used as a membrane interlayer.

Over-Flex was specified as the acceptable asphalt rubber system. The material is a patented product manufactured and applied by the Sahuaro Petroleum and Asphalt Company, 731 North 19th Avenue, P.O. Box 6536, Phoenix, Arizona 85005, Phone No. 602-252-2061.

The product consists of 75±2 percent asphalt cement and 25± 2 percent by weight vulcanized ground tire rubber. The latter material which is sized between the No. 8 and No. 40 sieve was derived from buffings from tire recappers, further reduced in size and supplied in 50 pound bags by Eastern Products Corporation of Andover, Massachusetts.

An AC 10 viscosity grade asphalt cement was specified to be used in the asphalt rubber mixture. The asphalt, supplied by New England Bituminous, included 0.5 percent antistripping additive and one ounce of silicone per 5000 gallons. As soon as the contract was awarded and the source of asphalt was known, samples were shipped to Sahuaro's laboratory to test for compatibility between the asphalt and rubber, to determine the percentage of rubber and solvent required, and to establish the length of time required for the asphalt rubber reaction to occur. The latter is dependent upon the fractionization of the asphalt which effects the amount and rate of swelling of the rubber particles.

Overflex MS was specified as the pavement crack filler since it met the contract requirement that the material be the same as the asphalt rubber used for the roadway surface material. The product is manufactured by Crafco, Inc. of Phoenix, Arizona under a patent agreement with Sahuaro.

The treatment specified for the northbound lane included crack filling by State Maintenance Forces, placement of a 24 foot wide 1/2 inch leveling course, a 26 foot wide one inch thick binder course and a 34 foot wide one inch thick wearing course. The latter included the four foot median shoulder and six feet of the remaining ten foot breakdown shoulder.

INITIAL CONSTRUCTION OPERATION

The construction contract was awarded on the 19th of June, 1979 to the F.W. Whitcomb Construction Corporation of Bellows Falls, Vermont with a completion date requirement of September 14, 1979.

Southbound traffic was rerouted onto parallel U.S. Route 5 on June 20, 1979 as the rehabilitation process began with a crack filling operation carried out by a subcontractor, New England Sealcoating. The procedure carried out by a six man crew included routing, burning and filling all cracks over 3/8 inch in width. Due to the high viscosity of the Crafco crack filler, the subcontractor found it necessary to switch his operation from pour pots to a pressure hose application. Excess material was leveled by dragging a U shaped hoe over the treated areas. The application procedure resulted in an acceptable end product with a total of 36,180 pounds of Overflex MS asphalt rubber placed.

The application of a 1/2 inch leveling course closely followed the crack filling operation. Placement of the Type V bituminous concrete mix (85-100% passing No. 4 sieve) extended six inches either side of the travel lanes for a 25 foot total width. The thin pavement application was believed necessary to insure a smooth riding surface prior to the placement of the surface treatment.

ASPHALT RUBBER APPLICATION

The asphalt rubber application began on July 12th and was completed nine working days later on July 21, 1979. The weather was good during the period with the exception of a threat of rain on July 17th and scattered showers during the afternoon of July 18th. Daily temperatures averaged 60° F early in the morning and from 75° F to 95° F by mid afternoon. Pavement surface temperatures ranged from a low of 77° F to a high of 151° F with readings averaging 120° F during the application.

The mobilization for the experimental treatment by the Sahuaro Petroleum and Asphalt Company included supplying two distributors and two trailer loads of ground rubber, a crew of 7 men and scheduling of the asphalt cement shipments. The crew included a superintendent, field technician, two operators, a boot man and two laborers.

It should be noted that the Bear Cat distributor trucks used by Sahuaro include a special equipment package required to mix and spray the viscous asphalt rubber material. The equipment includes a 5 cylinder 125 HP diesel engine used to power a mixing auger and heavy duty pump rather than the normal means of using a power take off from the truck engine. The special equipment by Bear Cat Manufacturing is a patented package made exclusively for Sahuaro.

The prime contractor F. W. Whitcomb Construction Corporation, was responsible for supplying, placing and rolling the cover aggregate. Their crew of 19 included a superintendent, stone box operator and crew of three, power broom driver and operator, seven truck drivers, three roller operators and two sweeper operators.

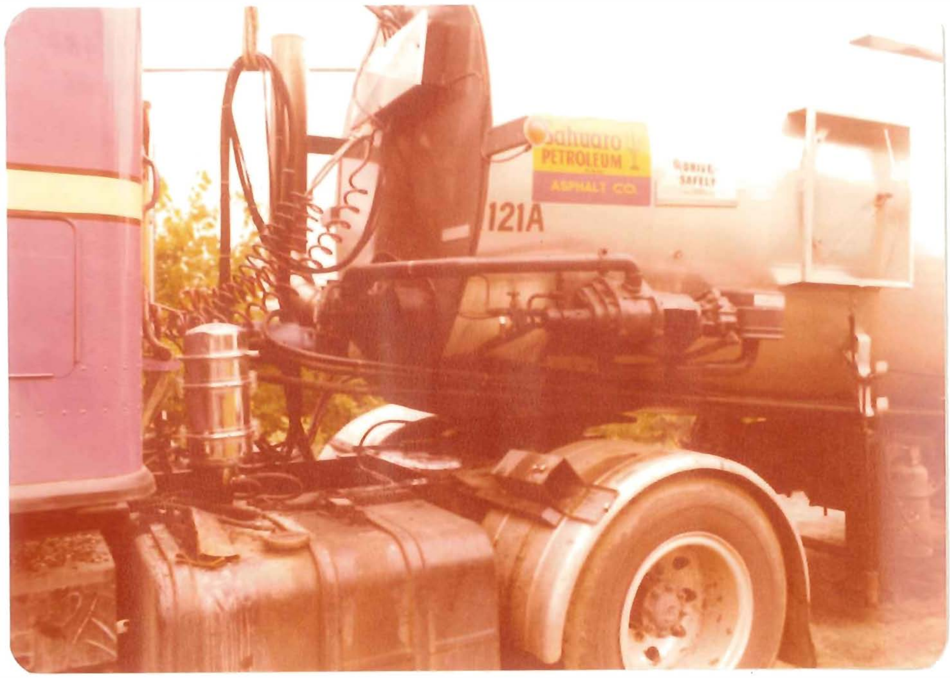
The same general procedure was followed each day. It began at approximately 4:00 A.M. with the transfer of 2500 to 2700 gallons of AC 10 asphalt from the tanker to the Sahuaro distributor. As the asphalt was taken on, the distributor's on board diesel heator was fired to bring the 260°- 280° F asphalt up to the desired 385° F temperature. At the same time the pump was activated to circulate the material and prevent spot overheating. When the proper temperature was achieved, the burner was turned off and the vulcanized crumb rubber was manually added to each truck by means of a hopper and conveyor belt system. The amount of rubber added per load varied from 36 to 38 percent by weight of asphalt or an average of 26 percent of the total blend.

As the rubber particles were being added, a chemical and physical reaction began between the asphalt and rubber causing the latter material to begin swelling to approximately twice its original volume. The rubber particles are also reported to become much softer and more elastic following the reaction with the asphalt. The testing carried out at Sahuaro's Laboratories indicated the asphalt rubber reaction would be complete approximately 100 minutes after one half of the rubber had been added to the distributor load. After sufficient time had elapsed, a sample of the asphalt rubber blend was drawn from the distributor and tested with a portable viscosimeter to insure that the material had reached a viscosity of 12,000 to 14,000 centipoises which would indicate the reaction was complete. After the reaction had been confirmed, the viscosity of the asphalt rubber mixture was reduced for spraying and for better wetting of the cover material by the addition of a diluent (AMSCO 140 solvent) at an average rate of 4.6 percent by volume of the hot asphalt rubber mixture. After additional recirculation, the mixture was resampled and checked to determine if the viscosity had been reduced to the desired 8,000 to 10,000 centipoise range. If satisfactory, the distributor was moved onto the project and the application begun. In most cases the mixing process ran smoothly on the 26 loads required to complete the project. The exception was an occasional load which required additional mixing time or rubber to reach the desired viscosity range or additional solvent to reduce the viscosity of the mixture.

Crumb rubber
particle size

Introducing crumb
rubber by means
of a conveyor
system

Mixing and heating units on Bear Cat Distributors.



Measuring asphalt rubber viscosity following reaction period.

The tack coat of emulsified asphalt normally specified was not applied due to the presence of the clean, new bituminous leveling course. The asphalt rubber application was made in three passes over a 26 foot width resulting in one foot of coverage on each shoulder lane. The first 10 foot wide pass, centered two feet from centerline, was continued from 3000 to 8000 feet before setting back to complete the adjoining 10 and 6 foot wide passes. However, the continuous spray application of asphalt rubber rarely exceeded 800 feet in length due to the necessity of stopping the distributor to allow the slower moving chip spreader and rollers to catch up. Some of the short delays occurred when it became necessary to switch the trucks supplying the spreader. When the equipment spreader and rollers caught up, the distributor would line up on the end of the area just treated and continue the application. Occasionally this would result in a slight overlap of asphalt rubber which in turn would result in a bump when such areas retained a greater thickness of stone.

When a delay in the application was expected to last for more than a few minutes, the entire area would be covered with stone and then the spreader would be moved out of the working area so that the rollers could compact the entire area. Following such situations, the start up would begin on a sheet of roofing paper to reduce the possibility of applying a double application of both asphalt rubber and cover stone.

Application
train underway

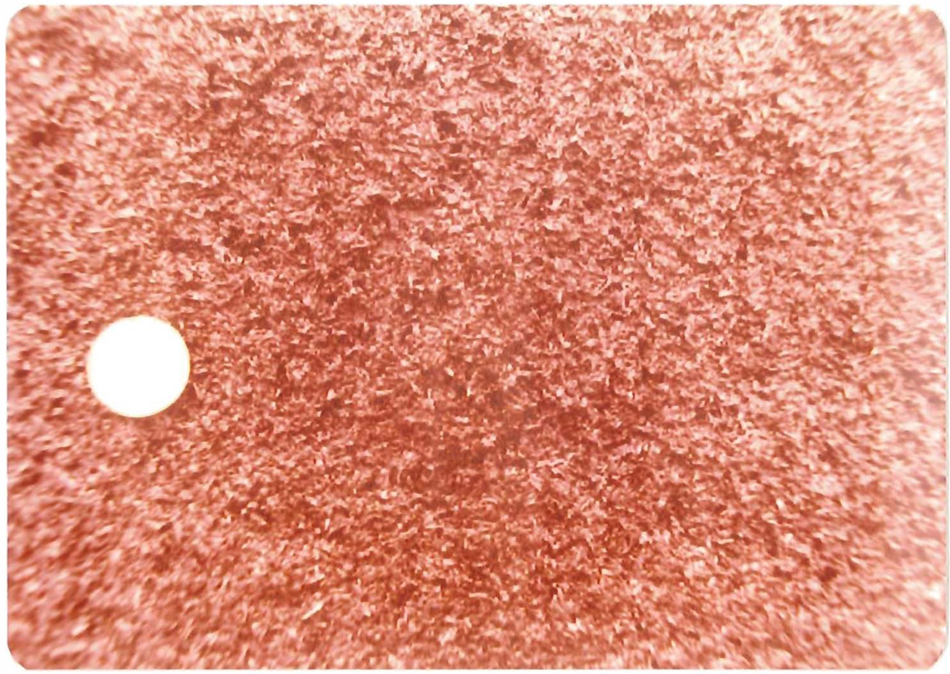
Spraybar
application

Using roofing
paper at cold
transverse
construction
joints

The distributor truck operator was responsible for obtaining the desired 0.60 gallon per square yard application rate on the road surface. On board monitoring equipment used to control the application rate included a gallon per minute meter which indicated the quantity of material being pumped off or circulated through the lines and a bitumeter or foot per minute gauge. Between shots while waiting for cover stone or when otherwise delayed, the operator could check the application rate obtained using onboard scales which constantly meter the reduction in load weight or by noting the location of the vernier float gauge on the side of the tank. With experience, the operator could also estimate the rate of application quite closely by noting the visual appearance of the asphalt rubber material fan beneath the spray bar jets.

The quality of the application was at least partially dependent upon the boot man stationed on the rear of the distributor. His duties included signaling the driver when to start and stop plus freeing any plugged jets which would otherwise result in skips in the coverage.

Overlap on Longitudinal Joints



Texture of asphalt rubber in place

Cover stone application and roller operation

The application of cover stone was made with a self propelled Flarrity spreader box which closely followed the asphalt rubber application. The stone consisted of a crushed gravel which was preheated to a temperature of 180 °F - 240° F and coated with an average of 0.4 percent asphalt at Whitcomb's Cold River, New Hampshire hot mix plant. A 3/8 inch maximum size stone was used on 8.4 miles of the treatment and 1/2 inch maximum size was used on the remaining one mile segment. The application rate varied until the operator and crew became familiar with the equipment and the amount of chips required. Occasional checks made on consecutive truck loads disclosed an average of 42 pounds of stone applied per square yard. Of that total, approximately 18 pounds or 43 percent was excess material which was removed during the vacuum brooming process. Although the application often appeared to be heavier than required, any significant reductions in the stone application rate always resulted in a bleed through and pick up of both asphalt rubber and stone by the tires on the equipment.

The stone was applied over the full width of the asphalt rubber application and then the loose stone was power broomed off the edge of each strip prior to applying adjoining longitudinal passes of material. Coverage with the next pass of asphalt rubber included a lap of 3-6 inches onto the preceeding strip. Although necessary to insure complete coverage, the procedure often resulted in the formation of a longitudinal ridge or bump where the double application of asphalt rubber tended to retain a greater thickness of cover stone.

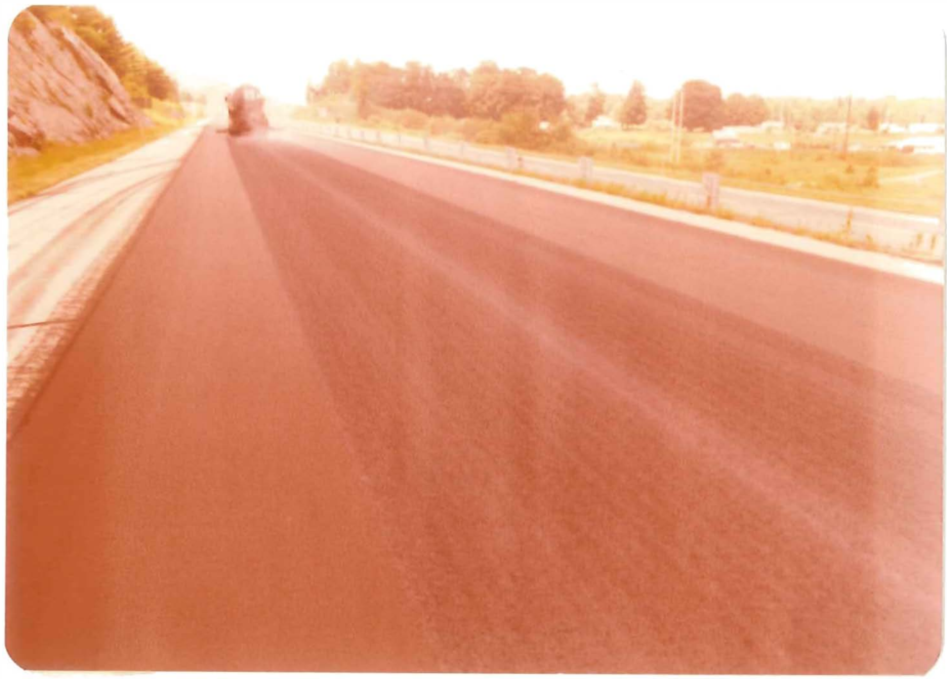
Rolling of the cover stone was achieved shortly after placement using three pneumatic rollers loaded to approximately 15 tons each. As a rule the rollers were within 200 feet of the spreader and were rarely more than 500 feet back except when making succeeding passes. A minimum of three passes were made over all areas. In addition, the area from MM 42/75 - 43/75 was rolled with a triple axle steel roller in order to determine if such a procedure would prove beneficial. The procedure appeared to densify or consolidate the surface without crushing a significant number of the stone particles. The exception was at locations where ridges were present due to butt joints or longitudinal laps. Stone was crushed at such locations without the benefit of leveling off the high points.

As work progressed, a number of partial and full length transverse cracks were noted in the 1/2 inch leveling course over the filled cracks in the old pavement. The tenderness of the thin overlay caused the Sahuaro representatives to express some concern over the stability of the leveling course, preferring in some ways that their material could have been applied over an older stable pavement as it is normally used.

As a general rule, the application was maintained close to the 0.60 gallon per square yard rate specified. Daily totals disclosed a low of 0.561 and a high of 0.673 with an overall application rate for the complete project averaging 0.624 gallons per square yard. Occasional variations in the application rate occurred for a variety of reasons. Applications in excess of the 0.60 gallon rate were never of significant magnitude to result in bleeding or other visually apparent conditions due in part to the excess of cover stone placed. Light applications were occasionally recognized due to the existence of holidays in the application. It is assumed that they were caused by insufficient pump pressure or improper speed.

Imperfections in the asphalt rubber treatment included a streaked appearance on about five percent of the area treated. The lines or ridges in the asphalt rubber material were believed due to higher than normal viscosities which resulted in less flow or leveling of the material as it was sprayed on the pavement surface. The higher viscosities may have been caused by several factors including lower temperature or insufficient solvent resulting from evaporation following delays in the application. It is also possible that the condition was simply the result of too light an application rate. Few of the ridges remained visible following the application of the cover stone. Other imperfections included occasional voids caused by plugged jets and ridges along some of the longitudinal and butt joints.

Streaks or ridges in the asphalt rubber application

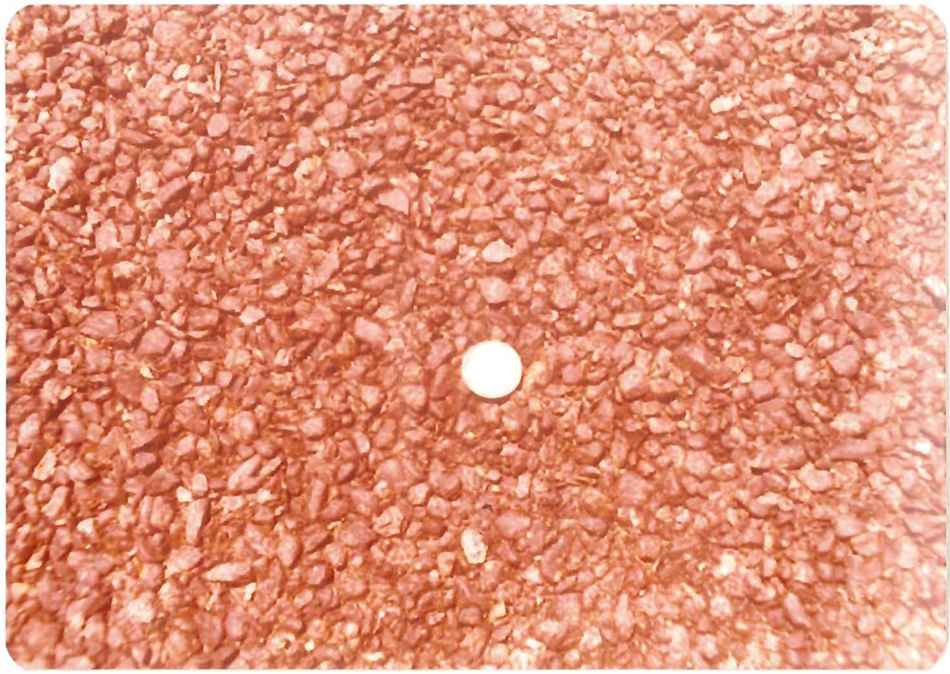


Streaks or ridges in the cover stone

The development of adhesion between the asphalt rubber and cover aggregate was closely monitored during the construction operation. Very little adhesion was noted for up to three days following the application. During that period, the removal of a portion of the chips was easily accomplished by brushing the surface with the finger tips. However, the level of adhesion did improve significantly with an additional two to four days of cure time, presumably due to further evaporation of the solvent.

The initial and long term retention of the cover stone is greatly effected by the depth of embedment in the asphalt rubber. The ideal condition would result in 50 percent embedment of the individual chips. Close inspection revealed a wide variation in the level of embedment depending on whether the asphalt rubber retained a single layer of stone or a combination of small and large stone. When the latter condition was noted, it often appeared that the smaller chips would be absorbed in the liquid, but in turn would prevent adequate embedment of the larger overlying stone. There were no significant visual differences in embedment between the areas treated with the 3/8 inch and 1/2 inch sized aggregate. Due to the absence of any flushing, the normal four to six pound per square yard application of blotting sand was not used.

Typical surface with 3/8 inch cover stone .



Abutting areas of 3/8 and 1/2 inch cover stone.

The one inch overlay of Type III Bituminous Pavement was placed without difficulty over nearly one mile of the asphalt rubber on the southerly end of the project (MM 41/73 - 42/70) on July 20, 1979, eight days after the asphalt rubber had been applied over the area. There were no problems noted during the paving process.

Following the removal of excess cover stone with power vacuum brooms and the application of centerline and shoulder traffic paint, the roadway was opened to traffic on July 25, 1979. The exposure to traffic resulted in the continued displacement of cover stone particles which had not been embedded securely in the asphalt rubber. The amount of chips displaced was sufficient to require one additional brooming by the contractor to remove loose material from the edge of the travel lane and shoulders.

The completion of the 145,292 square yard application took nine working days or nearly double the estimated completion time. Production rates varied widely depending on the amount of down time caused by a number of reoccurring delays. The greatest amount of down time occurred while waiting for the asphalt to be heated from 275° F$\pm$ to 385° F and for the 100 minute wait for the asphalt rubber reaction to occur. Generally short but numerous delays also occurred due to the lack of a sufficient number of trucks hauling aggregate. A third distributor truck would have greatly increased the production potential, however, actual production would not have increased without the commitment of additional trucks by the general contractor.

Daily production rates varied from 10,255 to 25,392 square yards with two to four loads applied daily. Each load covered an average of 5588 square yards or 0.366 miles of 26 foot wide roadway. Average hourly production rates for individual days ranged from a low of 1139 sy/hr to a high of 3119 sy/hr. Individual loads of asphalt rubber were applied in as few as 50 minutes for application rates of up to 6800 square yards per hour. However, the overall hourly rate for the nine working days averaged 1940 square yards per hour.

CONTROL TREATMENT

The crack filling operation on the northbound lane or control section was carried out by State Maintenance forces. The procedure differed somewhat from that used on the southbound lane in that a TAFA burner was used in place of routing and hot poured joint sealer meeting the requirement of Federal Specification SS-S-001401 was used as the crack filler. The application was made with pour pots and appeared satisfactory on normal sections. However, the self-leveling characteristics of the material resulted in flow problems in the larger cracks on the steeper grades or on banked sections. Random inspections revealed that fewer than 20 percent of the cracks were completely filled at some locations with the conditions occurring primarily over cracks in the passing lane. A total of 41,250 pounds of material was placed on the northbound roadway and shoulders, 14 percent more than the amount placed on the southbound area.

On July 25, 1979, traffic was detoured off the northbound lane and paving began with the application of a 1/2 inch leveling course of Type IV bituminous concrete mix. Placement of a 26 foot wide one inch thick binder course followed during the period July 30 - August 2. The one inch wearing course of Type III bituminous concrete mix which included the four foot median shoulder and six of the 10 foot shoulder was placed full width. Paving was completed on August 13 and the roadway was reopened to traffic on August 17, following the completion of the shoulder treatment and traffic markings.

POST CONSTRUCTION OBSERVATIONS

Inspections of the experimental treatment through early November revealed a continued loss of cover stone from the travelled areas. The loss of stone had resulted in numerous verbal reports of damage to windshields, headlights and vehicle finishes. However, only three written claims for damage were received by the State during the first three months of exposure to traffic. In general, the loss of stone is estimated at less than one percent although losses of 20 percent or more were noted within small localized areas. The accumulation of displaced stone along the edge of roadway and on shoulder areas necessitated a sweeping operation by Maintenance forces in early November. Any further loss of stone during the winter months will be displaced by snow plowing operations.

Approximately 10 weeks after the roadway was opened to traffic, friction tests were taken on the asphalt rubber surface treatment by Federal Highway Administration and State personnel using a locked wheel friction trailer. The measurements, taken at a speed of 40 mph revealed average values of 45.8 on the 3/8 inch stone and 46.0 on the 1/2 inch stone surfaces. This compares to readings of 44 to 48 obtained on one year old bituminous surface courses constructed with Vermont's Type III mix.

The riding quality of the experimental and control treatments were checked with a Mays Ride Meter during the week of November 5, 1979. The readings on the asphalt rubber surface treatment averaged 29.8 inches per mile, a decrease of 109.8 inches or a 78.6 percent improvement over the readings obtained in 1978. Values obtained on the 3/8 inch and 1/2 inch cover stone were essentially the same. Readings on the northbound control pavement averaged 15.6 inches per mile, a decrease of 177.8 inches or a 92 percent improvement over the old riding surface.

ENERGY AND COST ANALYSIS

The amount of energy required to complete each construction operation was computed using information gathered on the project and from the Asphalt Institute publication, "Energy Requirements for Roadway Pavements", Misc. - 75-3, April 1975.

The experimental treatment on 8.54 miles of the southbound lane which included crack filling, asphalt tack coat, 1/2 inch leveling course and the asphalt rubber surface treatment required a total of 3.8301×10^9 BTU of energy or 29,382 BTU/sy. The treatment on the remaining mile of the southbound lane which also included a one inch surface course of pavement required 7.9339×10^8 BTU of energy or 53,636 BTU/sy.

The standard rehabilitation procedure carried out on the 9.73 mile northbound lane, which included crack filling, asphalt tack coat, 1/2 inch leveling course and two - one inch courses of bituminous pavement required a total of 10.3588×10^9 BTU of energy. This amounted to 68,369 BTU/sy, or 133 percent more than the area rehabilitated with the asphalt rubber surface treatment and 27 percent more than the area treated with the asphalt rubber and bituminous overlay.

Energy consumption data can be seen in Tables 2 and 3 on pages 32 - 41 with a summary in Table 4 on page 42.

The cost of the experimental treatment totaled $2.86 per square yard while the area treated with the asphalt rubber and bituminous overlay cost $4.39 per square yard. In comparison, the cost of the standard pavement rehabilitation procedure on the northbound was $3.82 per square yard or 34 percent more than the asphalt rubber surface treatment but 13 percent less than the membrane interlayer procedure. A comparison between the cost of the asphalt rubber at $1.91 per square yard and the bituminous pavement at $24.45 per ton or $1.38 per square yard inch reveals that the cost of the experimental treatment was equal to the cost of a 1 3/8 inch course of pavement. A cost summary can be seen in Table 5, page 43.

CONSERVATION OF NATURAL RESOURCES

The standard rehabilitation treatment utilizing two - one inch lifts of bituminous pavement on the northbound lane required 132 tons of asphalt and 1896 tons of aggregate per mile of roadway. In comparison, the asphalt rubber surface treatment utilized 27 tons of asphalt and 320 tons of aggregate per mile or 80 percent less asphalt and 83 percent less aggregate per mile of roadway. The section treated with the asphalt rubber and one inch bituminous overlay required 85 tons of asphalt and 1150 tons of aggregate per mile or 36 percent less asphalt and 39 percent less aggregate than the standard rehabilitation treatment.

The experimental treatment used nearly 90 tons of ground crumb rubber or an amount roughly equivalent to 10,800 automobile tires.

SUMMARY AND CONCLUSIONS

In general the following observations and conclusions can be drawn from the project:

Material and Application

The material produced for the project consisted of 74 percent AC 10 asphalt and 26 percent vulcanized ground tire rubber. The spray bar application was made at a temperature of 350° F$\pm$ in three passes over a 26 foot width of roadway. A total of 340 tons of asphalt rubber was applied on 145,292 square yards of roadway for an average application rate of 0.624 gallons per square yard. Three-eighths and 1/2 inch cover stone which had been preheated to a temperature of 180° F to 240° F and coated with an average of 0.4 percent asphalt was immediately placed over the asphalt rubber at an average rate of 42 pounds per square yard. The cover stone was rolled a minimum of three passes shortly after placement using pneumatic rollers loaded to approximately 15 tons each.

Production Rates

Production rates attained with the asphalt rubber application varied from 10,255 to 25,392 square yards per day with two to four distributor loads applied daily. Individual loads of asphalt rubber were applied in as few as 50 minutes for application rates of up to 6800 square yards per hour while the average hourly rate for the project was 1940 square yards per hour.

Cover Stone

The retention of the cover stone is greatly effected by the depth of embedment in the asphalt rubber. A wide variation in the level of embedment was noted depending on whether the asphalt rubber retained a single layer of stone or a combination of small and large stones. When the latter condition was noted, it often appeared that the smaller chips would be absorbed in the liquid, but in turn would prevent adequate embedment of the larger overlying stone.

In general, the embedment of the cover stone was considered satisfactory; however, exposure to traffic has resulted in the continued loss of cover stone particles with some damage to highway user's vehicles resulting. It is possible that the loss of stone or at least a portion of it could have been prevented with a 0.08 to 0.10 gallon per square yard application of asphalt emulsion over the surface treatment prior to it's exposure to traffic.

Riding Quality

Imperfections in the asphalt rubber treatment included minor ridges or bumps where adjoining longitudinal passes resulted in three to six inches of overlapping asphalt rubber which tended to retain a greater thickness of cover stone. Transverse bumps also occurred at some locations where the distributor stopped to allow the slower moving chip spreader and rollers to catch up. Streaks or ridges remained visually apparent in about five percent of the area treated. Mays Ride Meter readings taken on the asphalt rubber surface treatment averaged 29.8 inches per mile while the control pavement averaged 15.6 inches per mile for respective improvements of 79 percent and 92 percent over the old riding surfaces.

Friction Numbers

Friction tests taken on the asphalt rubber surface treatment disclosed readings averaging 46. Such results compare closely with readings of 44 to 48 obtained on one year old surface courses constructed with a Type III bituminous concrete mix similar to that used on the northbound control section.

Cost of Treatment

The cost of the experimental treatment totaled $2.86/sy while the area treated with the asphalt rubber and bituminous overlay cost $4.39/sy. The cost of the standard rehabilitation procedure was $3.82/sy or 34 percent more than the asphalt rubber surface treatment, but 13 percent less than the membrane interlayer procedure. The cost of the asphalt rubber surface treatment was equal to the cost of a 1 3/8 inch course of bituminous pavement.

Energy Requirements

Energy requirements for the experimental treatment totaled 29,382 BTU/sy or 57 percent less than the amount required for the standard rehabilitation procedure. The area treated with the asphalt rubber and bituminous overlay required 53,636 BTU/sy or 21 percent less than the control treatment.

Conservation of Resources

The asphalt rubber surface treatment utilized 27 tons of asphalt and 320 tons of aggregate per mile or 80 percent less asphalt and 83 percent less aggregate than that required for the standard rehabilitation procedure. The asphalt rubber and bituminous overlay required 85 tons of asphalt and 1150 tons of aggregate per mile or 36 percent less asphalt and 39 percent less aggregate than the standard rehabilitation treatment. The asphalt rubber system's reduced use of asphalt, aggregate and energy consumption are factors which will become increasingly important in the near future.

Summary

From the standpoint of production and application, the experimental use of OVER-FLEX as an asphalt rubber surface treatment and as an asphalt rubber membrane interlayer was considered successful; continuing loss of cover stone could jeopardize success as a surface treatment.

Recommendations

(1) Consider a light spray application of asphalt emulsion as a means of preventing further loss of cover stone as soon as weather permits.

(2) Withhold further use of the material until the performance of the experimental treatments can be monitored and compared with that of the standard rehabilitation procedure used on the control section.

(3) If the long term performance of the asphalt rubber surface treatment is favorable, consideration should be given to use on Force Account pavement maintenance contracts where the application could be carried out by the manufacturer working directly with State Maintenacne Forces.

TABLE 1
APPLICATION RATE SUMMARY

Date	Hours Worked On Roadway	No. Of Loads	S.Y. Treated	S.Y./Hr.	Gal. Applied	Gal./S.Y.
7/12/79	11:30-4:30 5	2	10673	2135	7026	0.669
7/13/79	8:00-6:45 10.75	4	23908	2224	14949	0.625
7/14/79	9:15-4:45 7.5	3	19489	2598	10932	0.561
7/16/79	7:55-7:05 11.17	4	25392	2273	15440	0.608
7/17/79	11:25-2:55 3.5	2	11616	3319	6874	0.592
7/18/79	8:00-5:00 9.0	2	10255	1139	6105	0.595
7/19/79	7:45-3:30 7.75	1	7685	992	5083	0.660
7/20/79	7:50-8:25 12.58	4	22165	1762	14614	0.660
7/21/79	9:00-8:15 11.25	3	14109	1254	9837	0.673

TABLE 2

ENERGY CONSUMED WITH THE

EXPERIMENTAL TREATMENT

PAVEMENT CRACK FILLING

Materials		
Manufacture Asphalt Cement =	587,500	BTU/Ton
Manufacture Rubber Component		
0.0408 KWH/LB x 2000x3415 BTU/KWH =	278,664	BTU/Ton
Mix Composition and Blending		
Asphalt (75%) @ 587,500 BTU/Ton	440,625	BTU/Ton
Rubber (25%) @ 278,664 BTU/Ton	69,666	BTU/Ton
Manufacture Blend (heat to combine asphalt & rubber) 175 degrees F to 375 degrees F =200 degrees F @ 470 BTU/^{o}F/Ton =	94,000	BTU/Ton
Total =	510,291	BTU/Ton
Transportation		
Loaded haul 2552 miles x 3270 BTU/Ton Mi.	8,345,040	BTU
Preparing Cracks, Heating and Applying Material		
Routing cracks, 10 hrs./day @ 0.3 gal/hr. x 125,000 BTU/gal, x 5½ days =	2,062,500	BTU
L.P. gas used for compressor, torch and kettle @		
69 gal/day x 91,000 BTU/gal x 7½ days =	47,092,500	BTU
Vehicle, 8 hrs/day @$1.25 gal/hr. x 125,000 BTU/gal x 7.5 days =	9,375,000	BTU
Total BTU For 1 Ton Crack Filler		
(Asphalt) 440,625 + (rubber) 69,666 + (blending) 94,000 + (haul) 8,345,040 =	8,949,331	BTU/Ton

Total BTU For Preparation And Application

(Routing) 2,062,500 + (L.P. Gas) 47,092,500
+ (vehicle) 9,375,000 = 5.8530×10^7 BTU

Total Energy Used

Crack filler 18.09 Tons x 8,949,331 BTU/TON =	1.6189×10^8 BTU
Preparation + Application =	5.8530×10^7 BTU
Total =	2.2042×10^8 BTU

Total Energy Per S.Y. For Pavement Crack Filling

9.51 mi. x 5280' x 38' x 1/9 = 212,010 s.y.
$2.2042 \times 10^8 \div 212{,}010$ = 1040 BTU/S.Y.

ASPHALT TACK COAT

Materials

Manufacture Asphalt Emulsion

1950 BTU/gal. x 241 gal/ton =	469,950	BTU/Ton
Haul 82 mi. x 2 x 3270 BTU/Ton Mi. =	536,280	BTU/Ton
Total =	1,006,230	BTU/Ton

Asphalt Distributor Operation

Application (assume no heating required)
44 BTU/gal x 241 gal/ton = 10,604 BTU/Ton

Total BTU For 1 Ton Asphalt Emulsion in Place
(Manuf.) 469,950 + (haul) 536,280 + (appl.)
10,604 = 1,016,834 BTU/Ton

Total Asphalt Emulsion Applied
Weight slips = 21.39 tons

Total Energy Used

21.39 tons x 1,016,834 BTU/Ton = 2.1750×10^7 BTU

Total Energy Per S.Y. For Asphalt Tack Coat

9.5/mi. x 5280' x 25' x 1/9 = 139,480 s.y.
2.1750×10^7 BTU $\div$ 139,480 s.y. = 156 BTU/S.Y.

Table 2 (con't.)

1/2 INCH LEVELING COURSE

Materials

Manufacture asphalt cement =	587,500 BTU/ Ton
Haul 125 mi. x 2 x 3,270 BTU/TON Mi. =	817,500 BTU/ Ton
Total for asphalt =	1,405,000 BTU/ Ton
Crushed gravel @ 40,000 BTU/TON (18%) =	7,200
Sand @ 15,000 BTU/TON (82%) =	12,300 BTU/ Ton
Total for aggregate =	19,500 BTU/ Ton

Mix Composition

Asphalt (7.4%) @ 1,405,000 BTU/TON =	103,970 BTU/ Ton
Aggregate (92.6%) @ 19,500 BTU/TON =	18,057 BTU/ Ton
Total for mix =	122,027 BTU/ Ton

Plant Operations

Dry aggregate, 5% @ 28,000 BTU/% 0.926 Ton =	129,640 BTU/Ton
Heat 230 degrees F @ 470 BTU/ degrees F / Ton, 0.926 Ton =	100,100 BTU/Ton
Other Plant operations =	19,820 BTU/Ton
Total plant operations =	249,560 BTU/Ton

Haul And Place

Haul mix 17 mi. x 2 @ 3,800 BTU/TON Mi.=	129,200 BTU/Ton
Spread and compact =	16,700 BTU/Ton
Total for haul and place =	145,900 BTU/Ton

Total Energy For 1 TON Type III Mix In Place

(Mix) 122,027 + (plant operation) 249,560 + (haul & place) 145,900 = 517,487 BTU/Ton

Total Energy Used

517,487 BTU/TON x 4016 tons placed = 2.0782×10^9 BTU

Total Energy Per S.Y. For 1/2" Leveling Course Type V Mix

Area = 9.51 mi. x 5280 x 25' x 1/9 = 139,480 s.y.

Energy used = 2.0782×10^9 BTU ÷ 139,480 s.y. = 14,900 BTU/S.Y.

Table 2 (con't.)

ASPHALT RUBBER SURFACE TREATMENT

Materials

Manufacture asphalt cement =	587,500	BTU/Ton
Haul 125 mi. x 2 x 3270 BTU/Ton Mi. =	817,500	BTU/Ton
Total for asphalt =	1,405,000	BTU/Ton
Manufacture crumb rubber 0.408 KWH/lb		
.0408 x 2000 x 3415 BTU/KWH =	278,664	BTU/Ton
Haul 110 mi. x 2 x 5040 BTU/Ton Mi. =	1,108,800	BTU/Ton
Total for rubber =	1,387,464	BTU/Ton
Manufacture diluent		
62% of asphalt energy requirement =	364,250	BTU/Ton
Haul 125 mi. x 2 x 3270 BTU/Ton Mi. =	817,500	BTU/Ton
Total for diluent =	1,181,750	BTU/Ton
Produce crushed gravel 40,000 BTU/Ton =	40,000	BTU/Ton

Mixing Operation

Asphalt 74% @ 1,405.000 BTU/Ton =	1,039,700	BTU/Ton
Rubber 26% @ 1,387,464 BTU/Ton =	360,740	BTU/Ton
Diluent 4.6% by volume of total mix (12.2 gal/ton) 1,181,750 x 6.69 lbs/gal. ÷ 2000 x 12.2 gal	48,226	BTU/Ton
Heat AC10 from 270 degrees F to 385 degrees F, 12 gal/hr #2 diesel @ 139,000 BTU/gal x 2 hr ÷ 13.1 tons/load =	254,656	BTU/Ton
Conveyor to add rubber 1 hr/load 1/2 gal. gasoline/m @ 125,000 BTU/gal. ÷ 13.1 tons/load =	4,770	BTU/Ton
Maintain temperature 12 gal/hr #2 diesel @ 139,000 BTU/gal assume 1/2 hr retort load 12 ÷ 2 x 139,000 ÷ 13.1 tons/load =	63,664	BTU/Ton

Plant Operations

Dry aggregate, 3% @ 28,000 BTU/%, 0.996 ton =	83,664	BTU/Ton
Heat aggregate to 220 degrees, 160 degrees x 470 BTU/degrees F/ton =	75,200	BTU/Ton
0.004% asphalt/ton of agg., 1,405,000 x 0.004 =	5,620	BTU/Ton
Other plant operations =	13,420	BTU/Ton
Total plant operations =	177,904	BTU/Ton

Haul And Place Materials

Distributor application, 4 hrs. turn around/ load @ 5 gal/hr. each for deutz engine & truck @ 13.1 tons/load =	424,427	BTU/Ton
Haul aggregate, 17 mi. x 2 @ 3,800 BTU/Ton Mi. =	129,200	BTU/Ton
Place cover aggregate (10 BTU/sy)	10	BTU/sy
Roll cover aggregate, 4 passes @ 30 BTU/sy each	120	BTU/sy

Sweep And Remove Excess Cover Aggregate

Sweep and power vacuum operation 2 pieces equipment with field consumption of 355 gals. gas and 120 gals. diesel 6.1055 x 107 ÷ 145,292 sy =	420 BTU/sy
Remove excess aggregate 18#/sy x 145,292 sy ÷ 2000 = 1308 tons removed Haul agg., 9 mi. x 1 @ 3800 = 34,200 BTU/Ton Mi. 34,200 x 1308 ÷ 145,292 =	308 BTU/sy

Total BTU For 1 Ton Asphalt Rubber

(Asphalt) 1,039,700 + (rubber) 360,740 + (diluent) 48,226 + (heat) 254,656 + (load rubber) 4,770 + (maintain temp.) 63,664 + (apply) 424,427 =	2,196,183 BTU/Ton

Total BTU For 1 Ton Cover Aggregate

(Produce Agg.) 40,000 + (plant operation) 177,904 + (haul) 129,200 =	347,104 BTU/Ton

Total Asphalt Rubber Applied

0.624 gal/sy x 145,292 sy x 7.5 #/gal ÷ 2000 =	340 Tons

Total Cover Aggregate Placed

42 #/sy x 145,292 sy ÷ 2000 =	3,051 Tons

Total Energy Used

Asphalt rubber 340 Tons x 2,196,183 BTU/Ton =	7.4670×10^8	BTU
Cover aggregate 3051 Tons x 347,104 BTU/Ton =	10.5900×10^8	BTU
Place and roll cover agg. 130 BTU/sy x 145,292 sy =	1.8888×10^7	BTU
Sweep and remove excess agg. 728 BTU/sy x 145,292 sy =	1.0577×10^8	BTU
Total =	19.30358×10^8	BTU

Total Energy Per SY For Asphalt Rubber Surface Treatment

$19.30358 \times 10^8 \div 145.292$ sy =	13,286 BTU/SY

Table 2 (con't.)

1 INCH SURFACE COURSE

Materials

Manufacture asphalt cement =	587,500 BTU/ Ton
Haul 125 mi. x 2 x 3,270 BTU/ Ton Mi. =	817,500 BTU/ Ton
Total for asphalt =	1,405,000 BTU/ Ton

Crushed gravel @ 40,000 BTU/TON (54%) =	21,600 BTU/Ton
Sand @ 15,000 BTU/TON (46%) =	6,900 BTU/Ton
Total for aggregate =	28,500 BTU/Ton

Mix Composition

Asphalt (6.5%) @ 1,405,000 BTU/TON =	91,325 BTU/Ton
Aggregate (93.5%) @ 28,500 BTU/TON =	26,648 BTU/Ton
Total for Mix =	117,973 BTU/Ton

Plant Operations

Dry aggregate, 3% @ 28,000 BTU/%, 0.935 Ton =	78,540 BTU/Ton
Heat 230 degrees F @ 470 BTU/degrees F/Ton, 0.935 Ton =	101,074 BTU/Ton
Other plant operations =	19,820 BTU/Ton
Total plant operations =	199,434 BTU/Ton

Haul And Place

Haul mix 13 mi. x 2 @ 3,800 BTU/ Ton Mi. =	98,800 BTU/Ton
Place and compact =	16,700 BTU/Ton
Total for haul and place =	115,500 BTU/Ton

Total Energy For 1 Ton Type III Mix In Place

(Mix) 117,973 + (plant operation) 199,434 + (haul and place) 115,500 =	432,907 BTU/Ton

Total Energy Used

432,907 BTU/TON x 860.9 Tons placed =	3.7269×10^{8} BTU

Total Energy Per SY For 1" Surface Course Type III Mix

Area = 27' x 5122' ÷ 9 = 15,366 sy	
Energy used = 3.7269 x 108 ÷ 15,366 sy =	24,254 BTU/SY

TABLE 3

ENERGY CONSUMED WITH THE STANDARD MAINTENANCE TREATMENT

PAVEMENT CRACK FILLING

Materials

Manufacture asphalt cement =	587,500 BTU/Ton
Manufacture rubber component 0.0408 KWH/LB x 2000 x 3415 BTU/KWH =	278,664 BTU/Ton

Mix Composition And Blending

Asphalt (75%) @ 587,500 BTU/ Ton =	440,625 BTU/Ton
Rubber (25%) @ 278,664 BTU/ Ton =	69,666 BTU/Ton
Manufacture blend (heat to combine asp and rubber) 175 degrees F to 375 degrees F = 200 degrees F @ 470 BTU/^{o}F/Ton =	94,000 BTU/Ton
Total =	510,291 BTU/Ton

Transportation

Haul 188 mi. x 1 x 3270 BTU/ Ton Mi. =	614,760 BTU/Ton

Preparing Cracks, Heating and Applying Material

L.P. gas used for torch, kettle and pour pots 20 gal/day @ 91,000 BTU/gal x 21 days =	38,220,000 BTU
Vehicle, 8 hrs/day @ 1.25 gal/hr x 125,000 BTU/gal x 21 days =	26,250,000 BTU
Compressor @ 15 gal/day @ 125,000 BTU/gal x 21 days =	39,375,000 BTU

Total BTU For 1 Ton Crack Filler

(Asphalt) 440,625 + (rubber) 69,666 + (blending) 94,000 + (haul) 614,760 =	1,219,051 BTU/ Ton

Total BTU For Preparation And Application

(L.P. gas) 38,220,000 + (vehicle) 26,250,000 + (compressor) 39,375,000 =	1.0385×10^{8} BTU

Total Energy Used

Crack filler 20.625 Tons x 1,219,051 BTU/Ton =	2.5143×10^{7} BTU
Preparation + application =	1.0385×10^{8} BTU
Total =	1.2899×10^{8} BTU

Total Energy Per SY For Pavement Crack Filling

9.73 mi. x 5280' x 38' x 1/9 = 216,912 sy	
1.2899 x 108 ÷ 216,912 =	595 BTU/SY

ASPHALT TACK COAT

Materials

Manufacture Asphalt Emulsion		
1950 BTU/gal. x 241 gal./ton =	469,950	BTU/Ton
Haul 82 mi. x 2 x 3270 BTU/Ton Mi. =	536,280	BTU/Ton
Total =	1,006,230	BTU/Ton

Asphalt Distributor Operation

Application (assume no heating required)		
44 BTU/gal. x 241 gal./ton =	10,604	BTU/Ton

Total BTU For 1 Ton Asphalt Emulsion In Place

(Manuf.) 469,950 + (haul) 536,280 + (appl.) 10,604 =	1,016,834	BTU/Ton

Total Asphalt Emulsion Applied

Weight slips = 14.42 tons

Total Energy Used

14.42 tons x 1,016,834 BTU/TON = 1.4663×10^7 BTU

Total Energy Per SY For Asphalt Tack Coat

9.73 mi. x 5280' x 25' x 1/9 = 142,707 sy

1.4663 x 107 BTU ÷ 142,707 sy = 103 BTU/sy

1/2 Inch Leveling Course

Materials

Manufacture asphalt cement =	587,500 BTU/Ton
Haul 125 mi. x 2 x 3,270 BTU/TON Mi. =	817,500 BTU/Ton
Total for asphalt =	1,405,000 BTU/Ton
Crushed gravel @ 40,000 BTU/TON (51%) (Type IV)	20,400 BTU/Ton
Sand @ 15,000 BTU/TON (49%)(Type IV)	7,350 BTU/Ton
Crushed gravel @ 40,000 BTU/TON (18%) (Type V)	7,200 BTU/Ton
Sand @ 15,000 BTU/TON (82%)(Type V)	12,300 BTU/Ton
Average = 54% Type IV + 46% Type V =	23,955 BTU/Ton

Mix Composition

Asphalt 7% @ 1,405,000 BTU/TON =	98,350 BTU/Ton
Aggregate (93%) @ 23,955 BTU/TON	22,278 BTU/Ton
Total for mix =	120,628 BTU/Ton

Plant Operations

Dry aggregate, 3% @ 28,000 BTU/% 0.93 Ton =	78,120 BTU/Ton
Heat 230 degrees F @ 470 BTU/degrees F/Ton, 0.93 Ton =	100,530 BTU/Ton
Other plant operations =	19,820 BTU/Ton
Total plant operations =	198,570 BTU/Ton

Haul And Place

Haul mix 17 mi. x 2 @ 3,800 BTU/TON Mi. =	129,200 BTU/Ton
Place and compact =	16,700 BTU/Ton
Total for haul and place =	145,900 BTU/Ton

Total Energy For 1 Ton Mix In Place

(Mix) 120,628 + (plant operation) 198,570 + (haul and place) 145,900 =	465,098 BTU/Ton

Total Energy Used

465,098 BTU/TON x 2367.7 tons placed =	1.1012 x 109 BTU

Total Energy Per SY For 1/2 Leveling Course Type IV Mix

Area = 75,842 sy measured Energy used = 1.1012×10^9 BTU ÷ 75842 sy =	14,520 BTU/sy

Table 3 (con't.)

BINDER AND SURFACE COURSE

Materials

Manufacture asphalt cement =	587,500 BTU/Ton
Haul 125 mi. x 2 x 3,270 BTU/TON Mi. =	817,500 BTU/Ton
Total for asphalt =	1,405,000 BTU/Ton
Crushed gravel @ 40,000 BTU/TON (54%) =	21,600 BTU/Ton
Sand @ 15,000 BTU/TON (46%) =	6,900 BTU/Ton
Total for Aggregate =	28,500 BTU/Ton

Mix Composition

Asphalt 6.5% @ 1,405,000 BTU/TON =	91,325 BTU/Ton
Aggregate (93.5%) @ 28,500 BTU/TON =	26,648 BTU/Ton
Total for mix =	117,973 BTU/Ton

Plant Operations

Dry aggregate 3% @ 28,000 BTU/%).935 TON =	78,540 BTU/Ton
Heat 230 degrees F @ 470 BTU/degrees F/TON 0.935 TON =	101,074 BTU/Ton
Other plant operations =	19,820 BTU/Ton
Total plant operations =	199,434 BTU/Ton

Haul And Place

Haul mix 17 mi. x 2 @ 3,800 BTU/TON Mi. =	129,200 BTU/Ton
Place and Compact =	16,700 BTU/Ton
Total for haul and place =	145,900 BTU/Ton

Total Energy For 1 Ton Type III Mix In Place

(Mix) 117,973 + (plant operation) 199,434 + (haul and place) 145,900 =	463,307 BTU/Ton

Total Energy Used

(Binder) 463,307 BTU/TON x 8,177.2 tons placed =	3.7886×10^9 BTU
(Surface) 463,307 BTU/TON x 11,494.4 tons placed =	5.3254×10^9 BTU

Energy/SY For 1" Binder And 1" Surface Course Type III Mix

Area of binder course, 51,005' x 26' ÷ 9 =	147,347 SY
Energy used = $3.7886 \times 10^9 \div 147347$ =	25,712 BTU/SY
Area of surface course 51,374' x 34' ÷ 9 =	194,080 SY
Energy used = $5.3254 \times 10^9 \div 194,080$ =	27,439 BTU/SY

TABLE 4

ENERGY CONSUMPTION SUMMARY

Asphalt Rubber Surface Treatment (8.54 mi)	Area Treated	Energy Used	Energy Required BTU/SY
Pavement crack filling	190386	1.9800×10^8	1040
Asphalt tack coat	125254	1.9540×10^7	156
Leveling course (1/2")	125254	1.8663×10^9	14900
Asphalt rubber surface treatment	131441	1.7463×10^9	13286
Totals		3.8301×10^9 BTU	29382 BTU/SY
Asphalt Rubber & Bit. Overlay (0.97 mi.)			
Pavement crack filling	21624	2.2489×10^7	1040
Asphalt tack coat	14226	2.2192×10^6	156
Leveling course (1/2")	14226	2.1179×10^8	14900
Asphalt rubber surface treatment	13851	1.8402×10^8	13286
Bituminous overlay (1")	15366 sy	3.7269×10^8	24254
Totals		7.9339×10^8 BTU	53636 BTU/SY
Standard Maintenance Treatment (9.73 mi.)			
Pavement crack filling	216912	1.2899×10^8	595
Asphalt tack coat	142707	1.4663×10^7	103
Leveling course (1/2")	75842	1.1012×10^9	14520
Binder course (1")	147347	3.7886×10^9	25712
Surface course (1")	194080	5.3254×10^9	27439
Totals		10.3588×10^9	68369 BTU/SY

TABLE 5
COST SUMMARY

Asphalt Rubber Surface Treatment (8.54 mi)	Quantity	Unit Cost	Total Cost
Bituminous crack filling	32490 lbs	$1.00	32490
emulsified asphalt	384.2 CWT	12.00	4610
1/2" leveling course	3606 Ton	24.45	88176
asphalt rubber S.T.	131440 S.Y.	1.91	251050
Total cost			$376,326
Cost /S.Y.			$2.86
Asphalt Rubber & bit. overlay (0.97mi)			
Bituminous crack filling	3690 lbs.	$1.00	3690
emulsified asphalt	43.6 CWT	12.00	524
1/2" leveling course	410 Ton	24.45	10025
asphalt rubber S.T.	13852 s.y.	1.91	26457
1" bit. overlay	798.8 Ton	24.45	19530
Total cost			$60226
Cost s.y.			$4.39
Standard Maintenance Treatment (9.73 mi)			
Bituminous crack filling	41250 lbs.	State Force Account	24297
emulsified asphalt	288.4 CWT	12.00	3461
1/2" leveling course	2367.7 TON	24.45	57890
*2-1" bituminous overlays	19671.6 Ton	24.45	480970
Total cost			$566618
Cost s.y			$3.82

*Treatment includes approximately 2768 tons of mix placed on shoulders.

APPENDIX A

EXPERIMENTAL USE OF AN ASPHALT RUBBER

SURFACE TREATMENT ON INTERSTATE 89 IN

RICHMOND, VERMONT

DECEMBER, 1979

EXPERIMENTAL USE OF AN ASPHALT RUBBER SURFACE TREATMENT ON INTERSTATE 89 IN RICHMOND, VERMONT

Background

The search for a method or means of eliminating or reducing reflective cracking in new bituminous overlays has been underway for a number of years. One of the first processes tried in Vermont in 1973 and repeated in 1974 was a strain relieving interlayer (SRI). The treatment consisted of vulcanized rubber shreds and fine aggregate in an emulsion slurry placed in a 3/8 inch thickness. When initial followup evaluations indicated conclusive benefits in reducing reflective cracking, the treatment was specified for a 20.3 mile pavement overlay project on Interstate 89 from Bolton to Colchester, Vermont.

Placement of the rubber slurry began in June of 1975. As the project progressed and the first of two courses of bituminous mix was placed over the SRI, pavement distress in the form of shoving or raveling was observed at random locations exposed to traffic. During the removal of distressed pavement, observations revealed that the bituminous concrete was experiencing severe stripping problems. A number of adjustments were made in the construction procedure and materials in an attempt to combat the problem. They included increasing the first course of pavement from 1 inch to 1 1/2 inch, changing the asphalt from AC 5 to the more viscous AC 10 grade, switching from Type III bituminous concrete to the more stable Type II bituminous concrete and prohibiting traffic until both courses were in place. The changes appeared to reduce the level of pavement failure but did not totally eliminate the problem. Accordingly, a decision was made to discontinue the use of the rubber slurry on the remaining 12.8 miles of northbound highway from the area of Richmond Interchange to Colchester (MM79/05 - 91/84).

During the past four years, areas treated with the SRI have required random pavement removal and replacement which has consumed an increasing amount of maintenance funds. Through the period November 1979, repairs had been made at 538 locations totaling approximately 4060 square yards in area. In all cases the distress occurred in the form of raveling of the 1975 overlay with the major cause attributable to stripping of the asphalt from the coarse aggregate. The stripping action is initiated by a number of factors working in different combinations. The SRI is undoubtably the major factor due to its' tendency to act as a moisture barrier or dam which causes surface moisture to be retained in the overlay. This belief is supported by the increased requirement for pavement patching following extended periods of wet weather. The flexibility of the interlayer also tends to reduce the overall stability of the overlay under traffic. The belief that the SRI is a major factor leading to the stripping action is supported by the fact that the 12.8 miles of Northbound overlay placed without the SRI has not developed any areas of distress. Other contributing factors include the coarse aggregates' basic susceptibility to stripping, the asphalt in the bituminous mix, and the traffic volume on the roadway.

At the time the Sahuaro asphalt rubber treatment was being applied on 9.5 miles of Interstate 91 in Springfield - Weathersfield, a decision was made to try a test installation of the product on a section of Interstate 89 to determine if the asphalt rubber surface treatment could seal the pavement and prevent further breakups from occurring.

This report covers the construction phase and evaluation of the experimental treatment.

Project Description and Roadway Condition

The 5000$\pm$ foot section of I 89 selected for the experimental treatment was located in the Town of Richmond at Northbound MM 76/05-77/00. A pavement condition survey made on the test section revealed an average of 43 lineal feet of transverse cracks per 100 lineal feet of 24 foot wide roadway. The cracks averaged 1/2 inch in width in the passing lane and 1/4 inch in the travel lane. There were no other types of cracks visible in the four year old pavement. The test section also contained 31 bituminous patches encompassing an area of 794 square yards or 6 percent of the total pavement area. All of the patches were located in the travel lane with approximately 93 percent of the patched area bordering on the shoulder of the breakdown lane and the remaining 7 percent bordering on the centerline. Light to moderate pavement distress was also visible at several locations which were not patched prior to the asphalt rubber application.

Asphalt Rubber Application

The asphalt rubber was applied on the travel lane on September 11th and the passing lane on September 12, 1979. A two day operation was chosen to allow the material to cure for approximately 20 hours while a single lane of traffic was maintained on the adjacent 12 foot lane. The weather was favorable on both days with ambient temperatures ranging from 57° F to 70° F the first day and 70° F to 78° F the second day.

Pavement surface temperatures were also acceptable averaging 81° F and 87° F for the two days.

The process of heating and combining the asphalt and rubber was accomplished at the F. W. Whitcomb Construction Corporation hot mix plant in Williston, Vermont, approximately 10 miles from the project. The asphalt used in the mixture was an 85 - 100 penetration grade supplied by British Petroleum out of the Province of Quebec. The asphalt included 0.5 percent antistripping additive.

The first day began with the application of the asphalt emulsion tack coat on the travel lane at 9:30 A.M. The asphalt rubber application began at 11:00 A.M. and was completed at 12:20 P.M. A total of 3940 gallons of asphalt rubber was applied on 4963 lineal feet of 12 foot roadway for an average application rate of 0.595 gallons per square yard. The application of cover stone consisted of 3/8 inch crushed rock which was preheated to a temperature of 160° F - 260° F and coated with an average of 0.4 percent asphalt. The cover stone application rate, rolling procedure and equipment was the same as that used on the Springfield project.

The following morning, excess surface aggregate was removed from the treated surface with a power broom. The stone cover remaining appeared satisfactory with aggregate embedment sufficient to require a significant effort to dislodge individual particles. At 9:45 A.M. the traffic was switched onto the asphalt rubber surface treatment and the asphalt emulsion tack coat was applied on the passing lane from MM 77/05 - 76/82. The area from MM 76/82 - 77/05 did not receive a tack coat due to mechanical problems with the distributor.

The asphalt rubber application began at 3:35 P.M. and was completed without any noteable difficulties at 5:00 P.M. A total of 3964 gallons of asphalt rubber was applied on 5069 lineal feet of 12 foot roadway for an average application rate of 0.586 gallons per square yard.

The following morning the surface was swept with a power broom and the traffic was allowed to use both lanes of the highway.

Cost of Treatment

The treatment was completed at a cost of $2.00 per square yard which included the application of the asphalt tack coat. The traffic control was carried out by District #5 maintenance forces at a cost of $1158 for an overall cost of $27,910.

Post Construction Observations

The overall appearance of the surface treatment was similar to that obtained on the Springfield project. The longitudinal joint between the two lanes was satisfactory while the transverse joints were generally poor as evidenced by the buildup of excess asphalt rubber and cover stone. Although the treatment sealed the transverse cracks in the pavement, the location of the cracks and a few of the bituminous patches remained visible through the surface application. Exposure of the material to traffic within 17 to 21 hours of its' application resulted in the pickup of stones not securely embedded in the asphalt rubber. Most of the initial pickup was by the larger trucks and tractor-trailers with only light displacement caused by passenger cars. With additional cure time the asphalt rubber became more stable but the loss of cover stone continued. Following the receipt of numerous complaints regarding cracked windshields and head lights caused by flying stones, the District swept the test section with a power broom in mid September.

An inspection of the area on September 21, 1979, revealed a combination of stone loss and/or distress at 19 areas totaling 608 lineal feet on the travel lane. In almost all cases the effected areas were located one to three feet right of the centerline within the area treated during the first days application.

By mid October the loss of cover stone was substantial. It included a partial loss from all areas and a concentrated loss in the area immediately right of the longitudinal joint between the two passes. Additional broomings were carried out by the maintenance forces as motorist complaints were received. Failures also continued to occur in the underlying pavement, necessitating pavement removal and replacement at 19 locations totaling approximately 40 square yards in area.

An inspection on December 11 revealed a nearly complete loss of stone over an area one to two feet wide adjacent to the centerline for 90 percent of the project length. Numerous other short bare strips were noted in the travel lane and a single strip was visible in the passing lane. The short strips occurred mainly in the areas where the distributor was approaching the end of a run. With the exception of the stone loss adjacent to the centerline, there were no bare spots within the areas where the spray application first started up. Up to 40 percent of the stone had been displaced at locations other than those which appeared bare. The remaining stones appeared well embedded when force was used to remove them and the coating on such stones appeared tacky and very much alive.

There were no visible bond failures between the asphalt rubber and the underlying pavement. As far as could be detected, most of the asphalt rubber was still present even in the areas where the traffic was riding directly on the membrane due to the complete loss of cover aggregate.

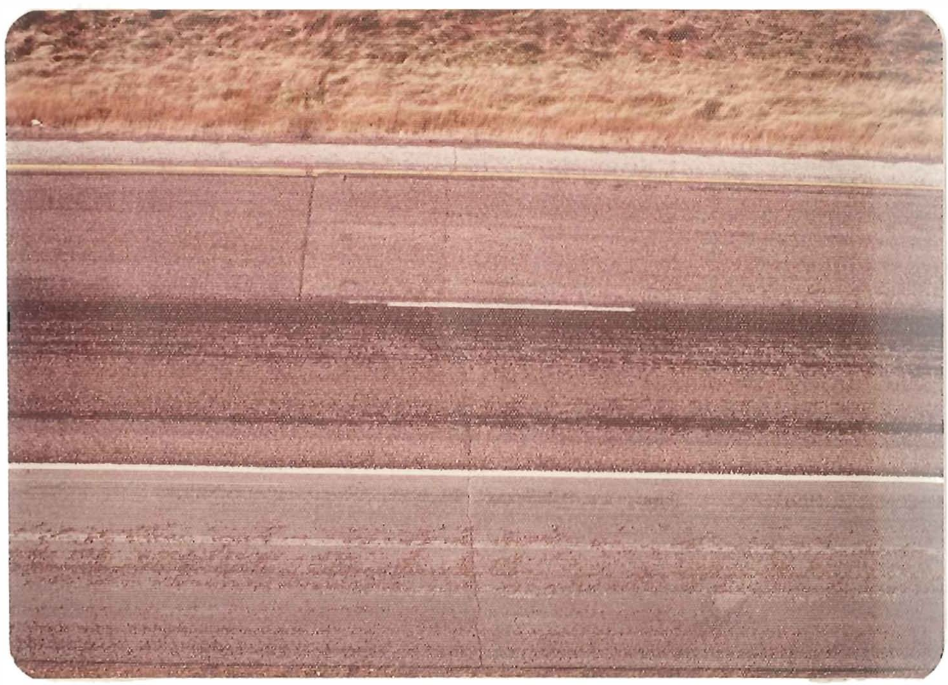
Discussion

Three months of post construction observations have disclosed that the asphalt rubber surface treatment was not capable of preventing further deterioration of the pavement within the test area. Since stripping has occurred from the bottom up in the pavement placed over the SRI, it is likely that the areas which failed were in some stage of initial deterioration prior to the asphalt rubber application. It is also assumed that further deterioration will occur at other similar locations within the test section.

The test section has also proven unsatisfactory as a surface treatment due to the continued loss of cover stone. The reasons for the loss of stone can not be clearly linked to any specific conditions or materials involved with the application. The Springfield and Richmond applications were similar with respect to personnel and equipment involved, use of an antistrip additive, gradation and temperature of stone, asphalt coating on stone, average rate of application, time lapse between asphalt rubber and stone application, time lapse between stone application and compaction, compaction effort and percent stone embedment. Conditions which varied included the viscosity of the asphalt, type of cover stone, ambient temperature, pavement surface temperature, surface width covered per pass, cure time prior to exposure to traffic and traffic volume on the roadway. The 85-100 penetration grade asphalt used in Richmond was a stiffer asphalt averaging about 350 poises higher than that used on the Springfield project. The crushed rock used in Richmond should have been better suited for the intended purpose due to more fractured faces than the crushed gravel used in Springfield. The ambient temperatures were higher in Springfield but were also acceptable in Richmond where they ranged from 67 - 70° F and 70 - 78° F. Overnight temperatures were significantly lower on the Richmond project. Pavement surface temperatures averaged over 100° F in Springfield as compared to readings between 81° F and 87° F in Richmond. The width of the application made in Richmond may be a factor in the extensive loss of aggregate from the outer edge of the pass made in the travel lane. It is possible that the distributor lacked sufficient power to apply the required amount of asphalt rubber at the outer ends of the spray bar when the application was made over a 12 foot width. The lack of cure time prior to allowing traffic on the surface treatment may have been an important factor. Although a high volume of slow moving traffic would be beneficial in embeding the cover stone, the fast moving traffic actually experienced was probably detrimental to the treatment. The quicker overall loss of cover stone in Richmond may also be attributable to 50 percent higher traffic volume over that experienced in Springfield.

Loss of cover stone photographed on Dec. 11, 1979.

Note loss of cover stone and transverse cracks visible through the surface treatment.



Conclusions

The following preliminary conclusions can be drawn from the project following three months of observation:

(1) The experimental application of the OVER-FLEX asphalt rubber surface treatment was not able to prevent further deterioration of the underlying bituminous pavement placed in 1975.

(2) The surface treatment is experiencing a loss of cover stone due to conditions or materials not clearly identified.