ASPHALT RUBBER HOT MIX
US ROUTE 2 BOLTON-WATERBURY

INITIAL REPORT 95-6
FEBRUARY 1996

REPORTING ON WORK PLAN 92-R-21

STATE OF VERMONT
AGENCY OF TRANSPORTATION
MATERIALS AND RESEARCH DIVISION

GLEN GERSHANECK, SECRETARY OF TRANSPORTATION
GORDON MACARTHUR, P.E., DIRECTOR OF CONSTRUCTION AND MAINTENANCE
ROBERT F. CAULEY, P.E., MATERIALS AND RESEARCH ENGINEER

Prepared By:

Ronald I Frascoia, R&D Supervisor
Robert E. Brunelle, Transportation Tech IV
Research and Development Subdivision

Reviewed By: Robert F Cauley

R.F.Cauley,
Materials and Research Engineer

Date: 8 Feb 96

TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
95-6		

4. Title and Subtitle	5. Report Date
ASPHALT RUBBER HOT MIX US ROUTE 2, BOLTON-WATERBURY RS 0284(13)	FEBRUARY, 1996
	6. Performing Organization Code
7. Author(s) R.I. FRASCOIA & R.E.BRUNELLE	8. Performing Organization Report No. 95-6
9. Performing Organization Name and Address Vt. Agency of Transportation Materials and Research Division 133 State Street Montpelier, Vt. 05633	10. Work Unit No. 11. Contract or Grant No.
12. Sponsoring Agency Name and Address Federal Highway Administration Division Office Federal Building Montpelier, Vt. 05602	13. Type of Report and Period Covered Initial 14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

In the interest of gaining experience in a relatively new and promising field, the Vermont Agency of Transportation initiated the use of Wet Blend Asphalt Rubber Hot Mix (ARHM) during the 1993 construction season. Several variations of the ARHM treatment were utilized for comparison with similar applications of standard mix.

Mix production, laydown and compaction were comparatively trouble free. Some minor problems with quality assurance occurred, but these were related to the properties of the product, rather than failure to meet specifications.

Although it is much too early to form definitive conclusions, early performance surveys have been disappointing, with some test sections showing premature cracking.

17. Key Words	18. Distribution Statement
PAVEMENTASPHALT OVERLAYS RUBBER ASPHALT	

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No.of Pages	22. Price
NONE	NONE	21	

Form DOT F 1700.7 (8-69)

EXECUTIVE SUMMARY

The Vermont Agency of Transportation initiated the use of wet process asphalt rubber hot mix (ARHM) on a 6.92 km (4.3 mi) section of US Route 2 during the 1993 construction season. Approximately 9070 t (10,000 tn) of ARHM were produced and placed for a variety of design typicals which were compared with 2204 t (2430 tn) of standard hot mix placed in similar applications.

Mix designs and preliminary testing were completed by Western Technologies of Phoenix, AZ and the asphalt rubber binder was produced by Asphalt Rubber Systems of Riverside, RI under subcontract with FW Whitcomb of Walpole, NH. The ARHM was bid at a cost of $51.00/ton or 82% more than the standard mix.

The ARHM binder was composed of 77% AC-10, 6% extender oil, 15 % ground tire rubber and 2% natural rubber. The gradation of the tire rubber included a range of 100% passing the #16 sieve through 50% passing the #30 sieve.

Independent testing at the VAOT Materials and Research Laboratory established that the rubber modified AC-10 asphalt used in the ARHM was equivalent to a Performance Grade (PG) 70-40 and the AC 20 used in the standard mix was equivalent to a PG 64-16.

Approximately 17,800 waste tires were used to produce the experimental mix. Mix production, laydown and compaction were relatively trouble free. Some minor problems with quality assurance occurred, but these were related to the properties of the product rather than failure to meet specifications.

With the exception of the first half day of paving, there were no health related problems or complaints associated with the production or placement of the rubber modified mix.

Field surveys through two winters of exposure indicate some disappointing early trends with regard to cracking, but it is far too early to draw any definitive conclusions relative to the performance of the ARHM.

ASPHALT RUBBER HOT MIX
US ROUTE 2 BOLTON-WATERBURY

INTRODUCTION:

In recent years the likelihood of future shortages of non-renewable resources, as well as the spiraling costs for waste disposal operations, have motivated a growing interest in the use of recycled materials in roadway construction and rehabilitation. One such material which has been the focus of expanding interest is used-tire rubber. According to estimates, there are some six billion waste tires already strewn across America, and this number is growing by approximately 300 million tires per year. The waste tire problem is especially worthy of attention because of the difficulty of disposing of the material which is non-biodegradable and produces noxious fumes when burned.

Over the past 10 years, a number of state transportation agencies and local governments have evaluated bituminous concrete pavements containing ground rubber derived from waste tires. In general the performance of the experimental applications has been superior to that of the standard control mixes, but the cost of the rubberized mixes is almost double that of conventional asphaltic concrete. Interest in developing this technology has become more acute recently due to a provision of the Intermodal Surface Transportation Efficiency Act (ISTEA) which calls for incrementally increasing use of waste tires in pavement construction. Beginning in fiscal year 1994, 5% of all asphalt pavement tonnage used in each state's federal participating paving operations was to contain rubber from waste tires. The specified tonnage increases by 5% each year through fiscal year 1997 to an upper limit of 20%. ISTEA also stipulates a minimum utilization of 10 kilograms per ton of recycled rubber per metric ton of hot mix (20 pounds per ton), or 150 kg/t (330 lb/tn) of spray applied binder.

The ISTEA stipulation has not yet been enforced, but the Vermont Agency of Transportation deemed it prudent to initiate a demonstration project to gain experience with the use of ground waste tire rubber in asphalt rubber hot mix (ARHM) pavements during the 1993 construction season. The specific project was Bolton-Waterbury RS 0284(13) on US Route 2.

EXISTING US ROUTE 2 - PROJECT DESCRIPTION:

Bolton-Waterbury Project RS0284(13) began at a point on existing US Route 2 in the town of Bolton, 4.355 km (2.706 mi) east of the Waterbury/Bolton town line and extending easterly for 6.994 km (4.346 mi).

The existing roadbed was originally constructed in 1961 with a 6.7 m (22 ft) pavement width and 1.83 m (6 ft) shoulders. The constructed subbase was 457 mm (18 in) of crushed rock, topped with 76 mm (3 in) of crushed stone base and 63.5 mm (2.5 in) of bituminous concrete pavement. The entire length of Project RS 0284(13) received a 19 mm (0.75 in) overlay in 1982 and in 1984 a 1.77 km (1.1 mi) segment from km 5.63 to km 7.40 (MM 3.5 to MM 4.6) was treated with a styrene-butadiene latex (STYRELIEF) chip seal application. The latter treatment was not considered successful initially, but it was observed that the chip seal slowed the deterioration of the pavement enough so that the designers chose not to reclaim (pulverize) the pavement within the STYRELIEF treated section. Current ADT through the project area is in the 3000 range and the truck traffic component is 12%.

PURPOSE OF THE EVALUATION:

Although the prospect of a required number of projects utilizing ARHM each year is not imminent, the Agency continues to be interested in the cost effectiveness of projects of this type. The Bolton-Waterbury project evaluation was designed to answer many of the cost and performance related questions which will be major considerations if the ISTEA requirements are ever enforced. Another goal of the experiment was to determine the feasibility of choosing ARHM as a valid rehabilitation material, regardless of legal mandates.

The project included several variations in the pavement design. Pavement designs were modified for the evaluation so as to compare the cost effectiveness of the ARHM against standard mix in several design configurations.

The project treatment variations are summarized in the table below.

WATERBURY-BOLTON RS 0204(13) CONSTRUCTION SUMMARY							
Town	Test Section(s)	Begin km (MM)	End km (MM)	Length km (mi)	Pvt.Dpth* mm (in)	Pvt.* Type	Treatment*
Bolt		4.354 (2.706)	4.546 (2.825)	0.192 (0.119)	38 (1.5)	AC	OVL
Bolt		4.546 (2.825)	4.659 (2.895)	0.113 (0.070)	38 (1.5)	AC	38 mm (1.5" CP)
Bolt		4.659 (2.895)	4.701 (2.921)	0.042 (0.026)	32 (1.25)	AC	Untreated (Bridge)
Bolt		4.701 (2.921)	4.723 (2.935)	0.023 (0.014)	89 (2.0)	AC	51 mm (2" CP)
Bolt	2.96, 2.99, 3.18	4.723 (2.935)	5.150 (3.200)	0.426 (0.265)	89 (3.5)	AC	102 mm (4" RB)
Bolt	3.40	5.150 (3.200)	5.633 (3.500)	0.483 (0.300)	89 (3.5)	ARHM	102 mm (4" RB)
Bolt	3.60, 3.65	5.633 (3.500)	5.954 (3.700)	0.322 (0.200)	38 (1.5)	AC	OVL
Bolt	3.80 ,4.20, 4.40	5.954 (3.700)	7.443 (4.625)	1.489 (0.925)	38 (1.5)	ARHM	OVL
Bolt	4.80, 5.00, 5.40	7.443 (4.625)	9.197 (5.715)	1.754 (1.090)	57 (2.25)	ARHM	102 mm (4" RB)

WATERBURY-BOLTON RS 0204(13) CONSTRUCTION SUMMARY (Cont'd.)							
Town	Test Section(s)	Begin km (MM)	End km (MM)	Length km (mi)	Pvt.Dpth* mm (in)	Pvt.* Type	Treatment*
Wtby	0.00, 0.20, 0.39, 0.60, 1.01, 1.16	0.000 (0.000)	1.744 (1.084)	1.744 (1.084)	89 (3.5)	ARHM	102 mm (4" RB)
Wtby		1.744 (1.084)	1.908 (1.186)	0.164 (0.102)	89 (3.5)	ARHM	51 mm (2" CP)
Wtby		1.909 (1.186)	2.152 (1.337)	0.243 (0.151)	38 (1.5)	AC	OVL

***RB = Reclaimed Base CP = Cold Plane OVL = Overlay Only**
AC = Asphaltic Concrete (Standard) ARHM = Asphalt Rubber Hot Mix

*The reclaimed base construction (RB) was performed to a 102 mm (4 in) depth, so as to reconstitute the 64 mm (2.5 in) of existing pavement with 38 mm (1.5 in) of the crushed stone base and not reach to the depth of the much coarser subbase of crushed rock.

The variations in treatment as described above, will provide the following comparisons of performance:

38 mm (1.5 in) standard (no rubber) AC versus 38 mm (1.5 in) ARHM.

89 mm (3.5 in) standard AC w/102 mm (4 in) RB versus 89 mm (3.5 in) ARHM w/102 mm (4 in) RB.

89 mm (3.5 in) standard AC w/102 mm (4 in) RB versus 57 mm (2.25 in) ARHM w/102 mm (4 in) RB.

TESTING AND CONTROLS:

Fifteen test sections were established through the length of the project, placed so as to enable the evaluation and comparison of the following treatments:

Test Section 2.96 in Bolton - This segment received a 89 mm (3.5 in)overlay of standard asphaltic concrete over a 102 mm (4.0 in) reclaimed base.

Test Section 2.99 in Bolton - Same as Test Section 2.96.

Test section 3.18 in Bolton - Same as Test Section 2.96.

Test Section 3.40 in Bolton - This segment received an 89 mm (3.5 in) overlay of ARHM over a 102 mm (4.0 in) reclaimed base.

Test Section 3.60 - This segment received a 38 mm (1.5 in) overlay.

Test Section 3.65 - Same as Test Section 3.60.

Test Section 3.80 in Bolton - This segment received a 38 mm (1.5 in) overlay of ARHM.

Test Section 4.20 in Bolton- Same as Test Section 3.80.

Test Section 4.40 in Bolton - Same as Test Section 3.80.

Test Section 4.80 in Bolton - This segment received a 57 mm (2.25 in) overlay of ARHM over a 102 mm (4 in) reclaimed base.

Test Section 5.00 in Bolton - Same as Test Section 4.80.

Test Section 5.40 in Bolton - Same as Test Section 4.80.

Test Section 0.00 in Waterbury - This segment received a 89 mm (3.5 in) overlay of ARHM over a 102 mm (4 in) reclaimed base.

Test Section 0.20 in Waterbury - Same as Test Section 0.00.

Test Section 0.39 in Waterbury - Same as Test Section 0.00.

Test Section 0.60 in Waterbury - Same as Test Section 0.00.

Test Section 1.01 in Waterbury - Same as Test Section 0.00.

Test Section 1.16 in Waterbury - This segment was cold planed to a depth of 51 mm (2 in) and received an 89 mm (3.5 in) overlay of ARHM.

A pre-construction pavement survey of cracking and rutting was taken within each of the test sections on 22 Jun 92. The results are shown in the table below.

PRE-CONSTRUCTION PAVEMENT SURVEY 22 JUN 92				
Town	**TS #**	**Cracking m/100m (ft/100ft)**	**Avg Wheel Path Ruts mm (1/16 in)**	**Roughness (Mays) mm/km (in/mi)**
Bolton	2.96	445 (445)	6 (4)	3551 (225)
Bolton	2.99	Data not available	Data not available	3551 (225)
Bolton	3.18	Data not available	Data not available	3551 (225)
Bolton	3.40	432 (432)	5 (3)	3551 (225)
Bolton	3.60	Data not available	Data not available	3172 (201)
Bolton	3.65	Data not available	Data not available	3172 (201)
Bolton	3.80	342 (342)	Data not available	2320 (147)
Bolton	4.20	323 (323)	Data not available	2730 (173)

PRE-CONSTRUCTION PAVEMENT SURVEY 22 JUN 92 (Cont'd)				
Town	**TS #**	**Cracking m/100m (ft/100ft)**	**Avg Wheel Path Ruts mm (1/16 in)**	**Roughness (Mays) mm/km (in/mi)**
Bolton	4.40	390 (390)	Data not available	2730 (173)
Bolton	4.80	550 (550)	6 (4)	2825 (179)
Bolton	5.00	3427 (3427)	6 (4)	2715 (172)
Bolton	5.40	2191 (2191)	7 (5)	3030 (192)
Waterbury	0.00	1128 (1128)	9 (6)	2888 (183)
Waterbury	0.20	1704 (1704)	14 (9)	2888 (183)
Waterbury	0.39	750 (750)	6 (4)	3236 (205)
Waterbury	0.60	616 (616)	12 (8)	3488 (221)
Waterbury	1.01	462 (462)	7 (4)	3425 (217)
Waterbury	1.16	628 (628)	10 (6)	4056 (257)

ARHM WET BLEND PROCESS:

The rubber utilized in the ARHM asphalt in the Bolton-Waterbury project was not necessarily from Vermont tires. The reason for this was the lack of a facility in the state with the capability to process the raw material (waste tires) to obtain the required gradation (100% passing #16 seive thru 50% passing #30). To insure that Vermont tires were recycled, a volume of Vermont waste tires equivalent to the rubber to be used on the project was prepared at Palmer Shredding in North Ferrisburg and shipped to Baker Rubber, located at Chambersburg, PA., where facilities to process the tires were available that allow gradation requirements to be met.

The Palmer processing included chipping to a 76 mm (3 in) size, removal of tire wire and steel, and rechipping to a 25 mm (1 in) size. The product shipped to Baker Rubber was estimated to be 60% to 70% free of steel. The trucker transporting the tire chips returned to Vermont loaded with the ground tire and natural rubber processed at the Baker Rubber plant and packaged in 22.7 kg (50 lb) bags. The gradation of the tire rubber used included 100% passing the #16 sieve and approximately 50% passing the #30 sieve.

Type II and Type III mix designs for the pavements with rubber added to the binder were developed by Western Technologies, Inc., of Phoenix, Arizona, and were comprised of the following:

- F.W. Whitcomb's 13 mm (½ in) and 10 mm (3/8 in) aggregate plus washed and dry screenings (Colchester, VT).

- Parco AC 10 asphalt (Athens, NY).

- Sundex 790 extender oil (Marcus Hook, PA).

- Baker WRF-30 ground tire rubber (Chambersburg, PA).

- Baker TBS-20 ground natural rubber (Chambersburg, PA).

The Parco AC 10 was tested in the Materials and Research Laboratory and analysis indicated that it was a PG 70-40 binder. Tests of the Bitumar AC 20 used in the standard mix indicated it was a PG 64-16. The Type III AC 20 mix from Cibro, used during the first day of leveling, did not include any rubber and was not tested for the PG classification.

The mix designs submitted by Western Technologies were devised to yield the properties shown in the following table:

VALUE	TYPE II W/ASPH. CONTENT OF 5.5%	TYPE III W/ASPH. CONTENT OF 6.3%	SPECIFICATION REQUIREMENT
Stability, lbs.	3100	2750	1800 min.
% Air Voids Total Mix	4.2	3.9	3-5
Unit Wt., pcf	148.0	146.5	
Max Theor. Unit Wt., pcf	154.5	152.4	
Flow, 1/100 in.	13	11	8-16
% VMA	15.4	16.9	14 min. Type II 15 min. Type III
% Voids Filled	73.0	77.5	

The selected ARHM binder was 77% AC 10, 6% extender oil, 15% ground tire rubber and 2% ground natural rubber (tennis balls).

The production of asphalt rubber hot mix (ARHM) can be accomplished by several methods. ARHM used on the Bolton-Waterbury project was produced via the "wet blend" process. This method is distinct from the so called "dry blend" process in that the rubber is incorporated into the asphalt cement before it is combined with the aggregate. The blending was accomplished in the quarry, adjacent to the hot mix plant and the blended asphalt was shuttled to the batch plant as needed. The contractor, F.W. Whitcomb of Walpole, N.H. used a sub-contractor to produce the wet blend product, Asphalt Rubber Systems of Riverside, Rhode Island.

MOBILIZATION, TRIAL DROPS AND ACCEPTANCE TESTING:

Asphalt Rubber Systems began moving their equipment into Whitcomb's Colchester batch plant on Monday, 16 Aug 93 and commenced production the following Thursday. Due to time constraints, only one trial drop of the Type III rubber mix was made on the first day. It failed due to high air voids (5.5%) and low fines (1.9%). Four trial drops of the Type II mix were made, but all failed due to high air voids and low fines. The following Monday morning, additional drops were tested and failed. Once again the failures were due to high air voids and low fines. After the second series of failures, the asphalt content of the Type II mix was increased gradually from 5.5% to 6.2%. The increase brought the air voids within an acceptable (3%-5%) range but low fines remained a problem. The consensus was that the xylol solvent used to extract the asphalt from the mixture had reacted with the rubber particles, causing them to agglomerate, and in the process, some of the fines adhered to the rubber, and to the coarser sands and aggregates. Wet sieving of the sample after the normal dry sieve analysis generally yielded enough minus #200 material to meet the minimum job aim. A decision was made on 24 Aug 93 to waive the fines requirement so long as the percent voids filled with asphalt was ≥70%. This allowed production to begin.

Further acceptance testing continued to reveal occasional problems with high air voids, low voids filled with asphalt and low stabilities. The final day of production of the Type II mix produced the best test results with stabilities averaging nearly 2200 lbs, 450 lbs. higher than the previous two days. It should be noted that in general, however, all acceptance testing yielded results that were significantly less than theoretical values predicted in the mix design and only marginally acceptable in light of the original specification which was based on a binder content of 5.5%.

MIX DESIGN AND PRODUCTION:

The AC 20 binder for the standard mix was supplied by two manufacturers, Cibro of Albany, NY and Bitumar of Montreal, Canada. As previously mentioned, the AC 10 asphalt used to produce the ARHM was supplied by Parco of Athens, NY. The fine and coarse aggregates were from F.W. Whitcomb's Colchester quarry.

The first course (leveling course) with Type III standard mix was placed on 3 Jun 93. Subsequently, paving operations were suspended until 24 Aug 93, when the first of two phases of paving with the ARHM began. During the first phase of paving, 5385 t (5937 tn) of ARHM and 562 t (620 tn) of standard mix were produced from 24 Aug 93 thru 27 Aug 93. During the second paving period, from 26 Oct 93 thru 30 Oct 93, 3693 t (4072 tn) of ARHM and 1254 t (1382 tn) of standard mix were produced. The two month delay (from late August to late October) separating the two paving periods was due to the need for installation of new and reset guardrail prior to the placement of the final pavement course. Total production for the two phases was 9078 t (10,009 tn) of ARHM and 1816 t (2002 tn) of standard mix. The average daily production, based on total tonnage of both mixes during the combined ten day production period was 1201 tons.

PRODUCTION QUANTITIES OF BITUMINOUS CONCRETE MIXES					
MANUFACTURER	**Std. Type II** t (tn)	**Std. Type III** t (tn)	**ARHM TypeII** t (tn)	**ARHM Type III** t (tn)	**Totals** t (tn)
Parco (AC 10)			5385 (5937)	3693 (4072)	9078 (10,009)
Bitumar (AC 20)	562 (620)	1254 (1382)			1816 (2002)
Cibro (AC 20)		388 (428)			328 (428)
Totals	562 (620)	1642 (1810)	5385 (5937)	3693 (4072)	11,282 (12,439)

Pavement cores were taken during the first four days of the ARHM paving operations to determine if the pavement met the 92% to 96% compaction specification requirement. The compaction on the first day's placement was satisfactory, averaging 93.6%. The mix placed on the second day failed to meet the specification, averaging 91.4%. The cause of the failure was believed to be a delay in the breakdown rolling. Cores taken on the two other days yielded acceptable results, with compaction averaging 93.0% and 94.0%, respectively.

During the second paving period, in late October, air temperatures were much cooler than summer temperatures, occasionally dropping below 4^0 C (40^0 F). As a result, the paving crew and the roller operators found the rubber modified mix much easier to work with, more stable and less offensive with regard to the odor of the rubber than what they had experienced during the hot weather in August. The 12 ton vibratory breakdown roller was able to stay much closer to the paver and the final rolling with a twelve ton, two axle, steel wheel roller did not have to be delayed to accomodate the higher heat retention of the rubber modified mix. The fall paving seemed to produce more small concentrations of rubber and asphalt on the compacted surface, but fewer fine cracks were noted in the finished pavement surface. Although increased stickiness had been observed in the rubber modified mix during the earlier paving operations, none was noted during the later, fall paving. Cores taken during the final paving phase yielded acceptable results with compaction averaging 92.8% to 94.8%.

HEALTH CONCERNS:

The asphalt rubber hot mix placed on the first morning brought complaints of strong odors from the paving crew. Several workers reported the fumes from the continuous blend product made them nauseous; however, there weren't any further complaints later that day or through the remainder of the paving period. Humidity, air movement, mix temperature and other factors might have had an effect on the fumes from the rubber modified mix. There were no health related problems attributable to mix production or testing at the batch site where the blended asphalt rubber was combined with aggregate to produce the ARHM.

TIRES UTILIZED:

A primary advantage of ARHM is the use of recycled waste tires. In the case of the Bolton-Waterbury project the number of waste tires used for production of ARHM was estimated as follows:

1. The Type II ARHM contained 6.2% binder by weight.

   a) The tire rubber content of the binder was 15% or 9.3 kg/t (18.6 lb/tn) of bituminous concrete.
   b) Production of the Type II ARHM totaled 5385 t (5937 tn).
   c) The average passenger car tire weighs 10 kg (22 lb) and of that weight, approximately 50% or 5 kg (11 lb) is recyclable rubber.

Therefore, the number of waste tires used to produce the Type II ARHM was approximately 10,000.

2. The 3693 t (4072 tn) Type III ARHM contained 7.0% binder by weight or 10.5 kg/t (21.0 lb/tn). All other variables were equal to those of the Type II mix and the number of waste tires used to produce the Type III ARHM was about 7800. The number of recycled waste tires used for both types of ARHM was approximately 17,800.

COSTS:

Based on the contract prices for Item 406.25, Bituminous Concrete Pavement ($30.98/t ($28.10/tn)), for Item 406.25 (mod.), ARHM ($56.23/t ($51.00/tn)), and for Item 310.15, Reclaimed Base Stabilization ($1.20/m^2 ($1.00/SY)), the costs of the various treatments evaluated are shown in the table on the following page.

VARIOUS ALTERNATIVE TREATMENTS WATERBURY-BOLTON RS 0284(13) Cost/m² (Cost/SY)					
Mix Type **AC = Std.** **ARHM = Rubber**	**Pavement Thickness** 38 mm (1.5 in)	**Pavement Thickness** 57 mm (2.25 in)	**Pavement Thickness** 89 mm (3.5 in)	**RB Thickness** 102 mm (4.0 in)	**Total Cost** Cost/m² (Cost/SY)
AC	$2.80 ($2.34)				$2.80 ($2.34)
ARHM			$6.53 ($5.46)	$1.20 ($1.00)	$7.73 ($6.46)
ARHM	$5.08 ($4.25)				$5.08 ($4.25)
ARHM		$7.63 ($6.38)		$1.20 ($1.00)	$8.83 ($7.38)
ARHM			$11.86 ($9.92)	$1.20 ($1.00)	$13.06 ($10.92)

The 82% increase in cost/ton for the ARHM material was questioned early in the development of the project, since there was only one supplier of wet blend binder located within a reasonable distance for this project. The subcontractor's (Asphalt Rubber Systems) explanation for the high cost of the ARHM was based on the following:

a) **Recapture of large capital outlays** - These costs were required to prepare for the wet process production of ARHM. Costs of approximately $1.3 million which had been invested in new equipment were cited.

b) **Increased materials costs** - Requirement for extender oil, which is used to control viscosity during the ARHM process, increased the unit cost by approximately $2.54/t ($2.30/tn). The rubber in the Type III mix added another $4.26/t ($3.86/tn) to the cost, while the rubber in the Type II mix added another $3.78/t ($3.43/tn) for that mix type.

c) **Costs for labor and expenses** - High production costs were also attributed to a process that required 9 trained men, working approximately 14 hrs/day.

d) **Mobilization and transportation** - Since the process requires movement of multiple units of heavy equipment, mobilization costs were very high. Additional costs included chipping and shipping Vermont waste tires to Pennsylvania and returning the properly graded rubber to the project.

e) **Other miscellaneous expenses** - Marketing expenses for a relatively untried process, laboratory expenses and patent royalties were also mentioned.

POST-CONSTRUCTION PERFORMANCE EVALUATION:

Post-construction performance was monitored at the conclusion of paving operations and each year thereafter. The results of the inspections and testing are shown in the table below, based upon a 3 year effort thus far.

POST-CONSTRUCTION ANNUAL PAVEMENT PERFORMANCE SURVEYS					
TOWN Treatment	**TS# & Surv. Yr.**		**Cracking m/100m (ft/100 ft)**	**Avg Wheelpath Ruts mm (1/16 in)**	**Roughness mm/km (in/mi)**
Bolton	TS 2.96	1993	0	0	1531 (97)
3.5" AC		1994	0	0	1910 (121)
w/4" RB		1995	0	0	1626 (103)
Bolton	TS 2.99	1993	Data Not Avail.	Data Not Avail.	1531 (97)
3.5" AC		1994	Data Not Avail.	Data Not Avail.	1562 (99)
w/4" RB		1995	0	1	1562 (99)
Bolton	TS 3.18	1993	Data Not Avail.	Data Not Avail.	1720 (109)
3.5" AC		1994	Data Not Avail.	Data not Avail.	2051 (130)
w/4" RB		1995	2	1	1830 (116)
Bolton	TS 3.4	1993	0	0	1736 (110)
3.5" ARHM		1994	0	0	1989 (126)
w/3.5" RB		1995	7 (7)	0	1815 (113)
Bolton	TS 3.6	1993	0	0	1720 (109)
1.5" AC		1994	2 (2)	0	2020 (128)
OVL		1995	17 (17)	0	1705 (108)
Bolton	TS 3.65	1993	0	0	1720 (109)
1.5" AC		1994	13 (13)	0	2020 (128)
OVL		1995	33 (33)	0	1594 (101)
Bolton	TS 3.80	1993	0	0	1515 (96)
1.5" ARHM		1994	62 (62)	0	1784 (113)
OVL		1995	106 (106)	0	1705 (108)
Bolton	TS 4.2	1993	0	0	1547 (98)
1.5" ARHM		1994	71 (71)	0	1815 (115)
OVL		1995	156 (156)	0	1563 (99)
Bolton	TS 4.4	1993	0	0	1420 (90)
1.5" ARHM		1994	0	0	1641 (104)
OVL		1995	35 (35)	0	1641 (104)

POST-CONSTRUCTION ANNUAL PAVEMENT PERFORMANCE SURVEYS (Cont'd.)					
TOWN Treatment	TS# & Surv. Yr.		Cracking m/100m (ft/100 ft)	Avg Wheelpath Ruts mm (1/16 in)	Roughness mm/km (in/mi)
Bolton 2.5" ARHM w/4" RB	TS 4.8	1993 1994 1995	0 0 7 (7)	0 0 0	1657 (105) 2289 (145) 1926 (122)
Bolton 2.5" ARHM w/4" RB	TS 5.0	1993 1994 1995	0 0 27 (27)	0 0 0	1894 (120) 2083 (132) 2131 (135)
Bolton 2.5" ARHM w/4" RB	TS 5.4	1993 1994 1995	0 0 0	0 0 0	1878 (119) 2273 (144) 1784 (133)
Waterbury 3.5" ARHM w/4" RB	TS 0.0	1993 1994 1995	0 3 (3) 19 (19)	0 0 0	1705 (108) 2099 (133) 2004 (127)
Waterbury 3.5" ARHM w/4" RB	TS 0.2	1993 1994 1995	0 0 0	0 0 0	1689 (107) 2083 (132) 1909 (121)
Waterbury 3.5" RB w/4" RB	TS 0.39	1993 1994 1995	0 0 0	0 0 0	1452 (92) 1815 (115) 1373 (87)
Waterbury 3.5" ARHM w/4" RB	TS 0.60	1993 1994 1995	0 0 0	0 0 0	1641 (104) 1784 (113) 1578 (100)
Waterbury 3.5" ARHM w/4" RB	TS 1.01	1993 1994 1995	0 0 5 (5)	0 0 0	1752 (111) 1894 (120) 1484 (94)
Waterbury 3.5" ARHM 2" CP	TS 1.16	1993 1994 1995	0 0 7 (7)	0 0 0	2099 (133) 2320 (147) 1705 (108)

The data shown above record performance information for only the first two years and are adequate to establish preliminary trends at best. One troubling observation is related to the Mays data which show a clear increase in roughness for the first two years and a seemingly anamolous improvement in the ride index in 1995.

Another troubling and somewhat disappointing observation is related to premature cracking, observed after two years in some of the test sections. The most extensive cracking has occurred in ARHM 38 mm (1.5 in) overlay Test Sections 3.8 and 4.2 in Bolton. Comparison of these test sections with the similar test section overlaid with standard asphaltic concrete mix (TS 3.65) is unfavorable with regard to cracking. Some test sections which included substantial overlays of ARHM over a reclaimed base have also shown early evidence of cracking (TS 5.0 in Bolton and 0.0 in Waterbury). Although not substantial, the cracking is more than would normally be anticipated after such an extensive rehabilitation treatment and is significantly greater than that occurring in comparable test sections comprised of standard mix.

SUMMARY AND CONCLUSIONS:

The Bolton - Waterbury project included a wide variety of treatments which will allow a thorough comparison of the wet process ARHM product with standard bituminous concrete mix.

There were few problems with the production of rubber modified mix, but some difficulties were experienced in achieving the mix design requirements. At least some of these problems were attributable to standard test procedures which may require modification when working with wet process ARHM.

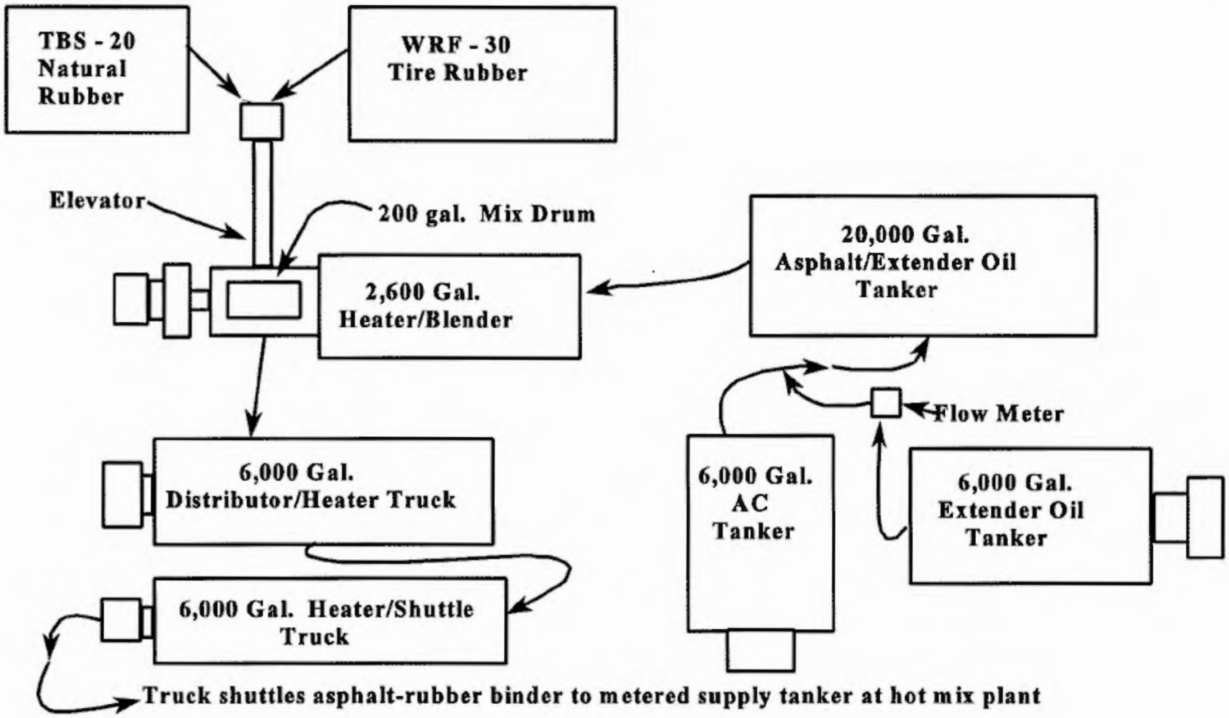
Although it is too early to draw any definitive conclusions, some early evidence relative to the ARHM experiment is disappointing. When compared with their standard mix counterparts, some of the ARHM sections have shown significantly more cracking.

Unless the unit cost of ARHM decreases substantially, and the preliminary performance trends already established improve, the use of waste tire rubber in bituminous mixtures will not be cost effective.

A schematic diagram depicting the ARHM production process used for the Bolton-Waterbury project is appended to this report.

FOLLOW-UP:

Performance monitoring will continue on the Bolton - Waterbury project until clear-cut conclusions can be drawn as to the cost effectiveness of the ARHM product. Emphasis will be placed on the performance differences between the ARHM and standard bituminous concrete.



SCHEMATIC OF THE ASPHALT/RUBBER PRODUCTION AT THE F.W. WHITCOMB COLCHESTER, VT. PLANT

ASPHALT RUBBER HOT MIX PRODUCTION PROCESS - BOLTON WATERBURY RS 0284 (13)

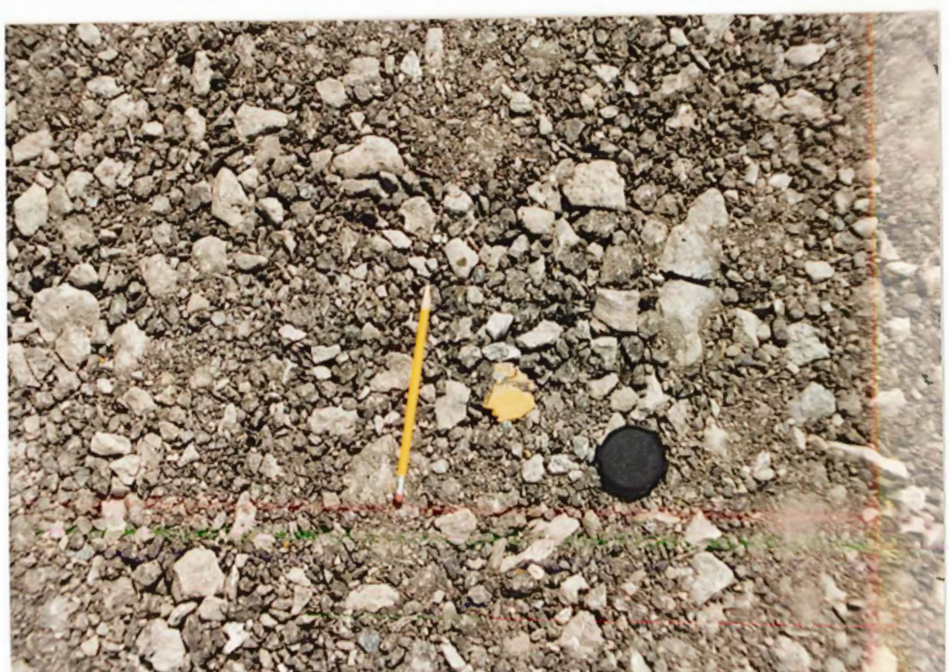
1) Parco AC 10 asphalt received from Athens, NY.
2) 0.3% Wetfix antistrip added to tanker.
3) AC pumped into heatec heater, extender oil added at same time via flow meter,
4) Heater raises AC and oil from 240° F average to 400°-425° F.
5) Materials pumped into heater/blender where ground tire rubber and natural rubber are added to the mix drum via an auger elevator.
6) Rubber and AC are mixed with twin augers for 10 -25 seconds in the 200 gallon mix drum prior to pumping asphalt rubber into the distributor truck.
7) Material pumped from the distributor truck to the shuttle truck.
8) Binder viscosity checked after 45 minutes of mixing to insure reaction has occurred.
9) Truck shuttles material to supply tanker at mix plant.
10) Asphalt rubber binder is metered into asphalt weight bucket as required.

Bolton-Waterbury
RS0284(13)
RTE 2 Asphalt
Rubber Hot Mix

Reclaiming Pavement at Test Section 1.01 Waterbury.

Note typical crack pattern.

Pavement and subbase reclaimed to 8" depth.



Recompacted base.

Bolton-Waterbury
RS0284(13) RTE 2
Asphalt Rubber
Hot Mix

Charging 20,000 gallon tank with AC 10 and extender oil.

Pumping 400 deg. F. AC and extender oil into heater/blender.

Ground tire and natural rubber supplied in 50 pound bags.

Bolton-Waterbury
RS0284(13) RTE 2
Asphalt Rubber
Hot Mix

Charging mix drum with ground rubber via auger elevator.

Overview of binder production process.

Metered supply tanker at hot mix plant.

Bolton-Waterbury
RS0284(13)
RTE 2 Asphalt
Rubber Hot Mix

Asphalt rubber is metered into asphalt weight bucket as required.

Trial drops and acceptance tests often failed with high % voids, low % voids filled with asphalt and low stabilities.

Placement and compaction were similar to standard mix.