REPORT FHWA/NY/SR-92/107

Performance of Two Rubber-Modified Asphalt-Concrete Overlays: A Three-Year Progress Report

THOMAS F. VANBRAMER

SPECIAL REPORT 107

ENGINEERING RESEARCH AND DEVELOPMENT BUREAU
NEW YORK STATE DEPARTMENT OF TRANSPORTATION
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PERFORMANCE OF TWO RUBBER-MODIFIED ASPHALT-CONCRETE OVERLAYS: A THREE-YEAR PROGRESS REPORT

Thomas F. Van Bramer, Civil Engineer I

Interim Report on Research Project 214-1
Conducted in Cooperation With
The U.S. Department of Transportation
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16. Abstract

In 1987 the New York State Legislature asked the Department of Transportation to undertake a pilot project demonstrating the use of waste tire rubber in construction or improvement of state highways. This resulted in constructing two test roads in the summer of 1989 using various percentages of rubber as an aggregate incorporated in asphalt cement concrete pavement, by what is commonly called the "dry process." Each site consists of five 2000-ft test sections, containing 1-, 2-, or 3-percent rubber by total weight of the mix, a proprietary rubber additive of coarser gradation at 3 percent by total weight, and a conventional mix used as a control.

This report covers an extension of that study addressing the issues of performance and service life of rubber-modified asphalt concrete (RUMAC) pavements. Performance is recorded semi-annually and types and locations of distress are documented. Falling-weight deflectometer tests and laboratory analyses are also conducted. Lab and field testing and performance are reported up to date. Early results indicate that RUMAC pavements are not performing as well as conventional mixes.

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METRIC (SI*) CONVERSION FACTORS

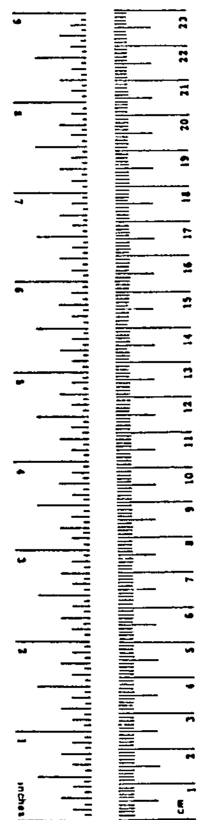
APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
	LENGTH			
in	inches	2.54	millimetres	mm
ft	feet	0.3048	metres	m
yd	yards	0.914	metres	m
mi	miles	1.61	kilometres	km
	AREA			
in^2	square inches	645.2	millimetres squared	mm^2
ft^2	square feet	0.0929	metres squared	m^2
yd^2	square yards	0.836	metres squared	m^2
mi^2	square miles	2.59	kilometres squared	km^2
ac	acres	0.395	hectares	ha
	MASS (weight)			
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
	VOLUME			
fl oz	fluid ounces	29.57	millilitres	mL
gal	gallons	3.785	litres	L
ft^3	cubic feet	0.0328	metres cubed	m^3
yd^3	cubic yards	0.0765	metres cubed	m^3

NOTE: Volumes greater than 1000 L shall be shown in m^3.

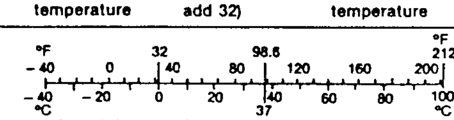
Symbol	When You Know	Multiply By	To Find	Symbol
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

* SI is the symbol for the International System of Measurements



APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
	LENGTH			
mm	millimetres	0.039	inches	in
m	metres	3.28	feet	ft
m	metres	1.09	yards	yd
km	kilometres	0.621	miles	mi
	AREA			
mm^2	millimetres squared	0.0016	square inches	in^2
m^2	metres squared	10.764	square feet	ft^2
km^2	kilometres squared	0.39	square miles	mi^2
ha	hectores (10 000 m^2)	2.53	acres	ac
	MASS (weight)			
g	grams	0.0353	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams (1 000 kg)	1.103	short tons	T
	VOLUME			
mL	millilitres	0.034	fluid ounces	fl oz
L	litres	0.264	gallons	gal
m^3	metres cubed	35.315	cubic feet	ft^3
m^3	metres cubed	1.308	cubic yards	yd^3
	TEMPERATURE (exact)			
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



These factors conform to the requirement of FHWA Order 5190.1A.

CONTENTS

I. INTRODUCTION

A. Background

Each year 12 million tires are discarded in New York State. Because of stricter environmental regulations, disposing of used tires in landfills is becoming increasingly difficult and expensive. Thus, in 1987 the State Legislature requested that the State Department of Transportation investigate the feasibility of using waste tires in asphalt pavements (1). In response to this request, the Department contracted to have two resurfacing projects paved with rubber-modified asphalt concrete (RUMAC) during the summer of 1989 (2,3). Each contained five 2000-ft test sections:

1. Three separate sections containing 1-, 2-, or 3-percent crumb rubber from New York State waste tires;

2. A fourth section containing 3-percent "Plus-Ride" (PR), a proprietary crumb-rubber aggregate substitute of coarser gradation, and

3. A fifth section of conventional (C) asphalt-concrete mix used as an experimental control.

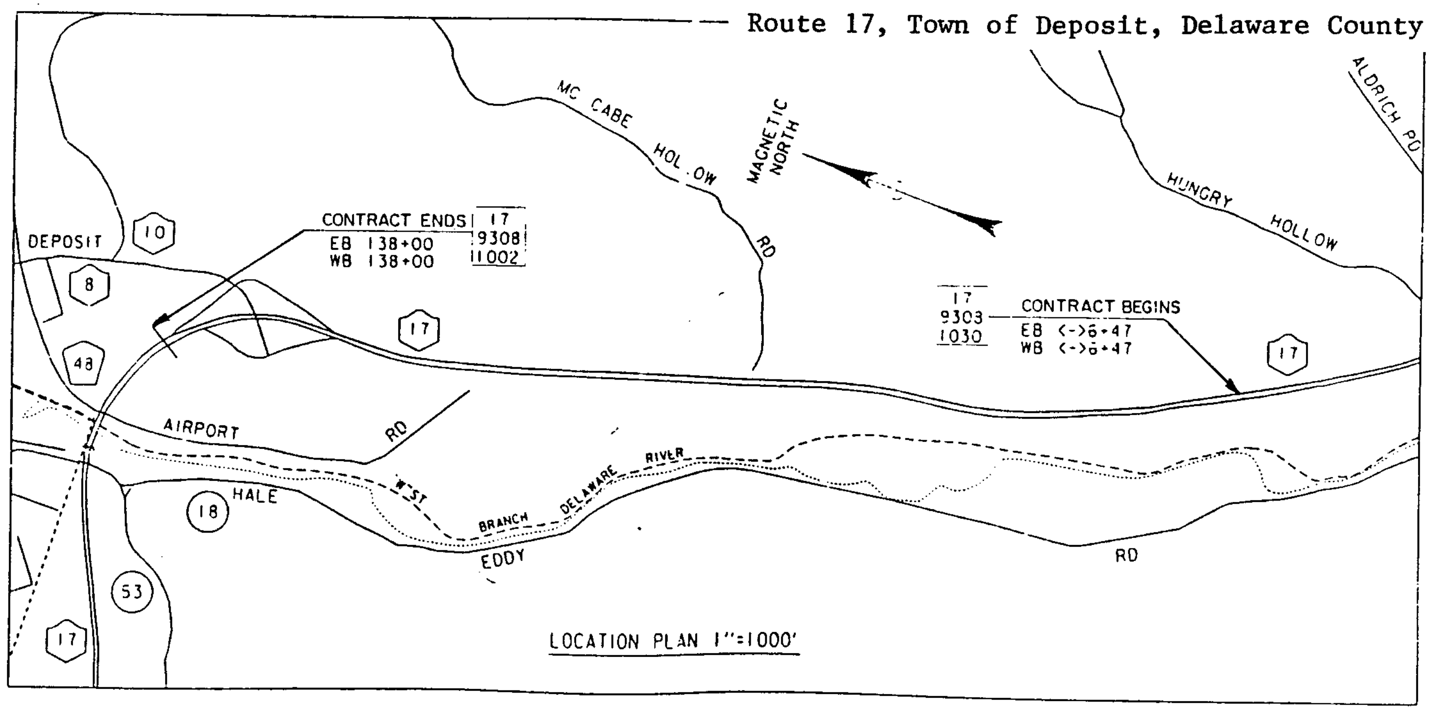
The uniqueness of this project is use of waste-tire crumb rubber, generic in nature, as an aggregate in a dense asphalt-rubber mix (the dry process). Several states are monitoring results of their own inclusion of rubber in asphalt pavements, but most are using a rubber-asphalt preblending process (the wet process) or a proprietary dry product. At the time of placement New York was the only state replacing aggregate with crumb rubber in a dense surface course. In the meantime various other states have followed suit, and have either developed their own mix designs or are now in the process of doing so. FHWA and numerous other agencies have contacted New York to learn of the performance of these two roadways. Information from New York's experience as well as from others may be used to determine the cost-effectiveness and durability of RUMAC. Thus, it has been important to monitor long-term performance of these two RUMAC projects.

B. Project Locations

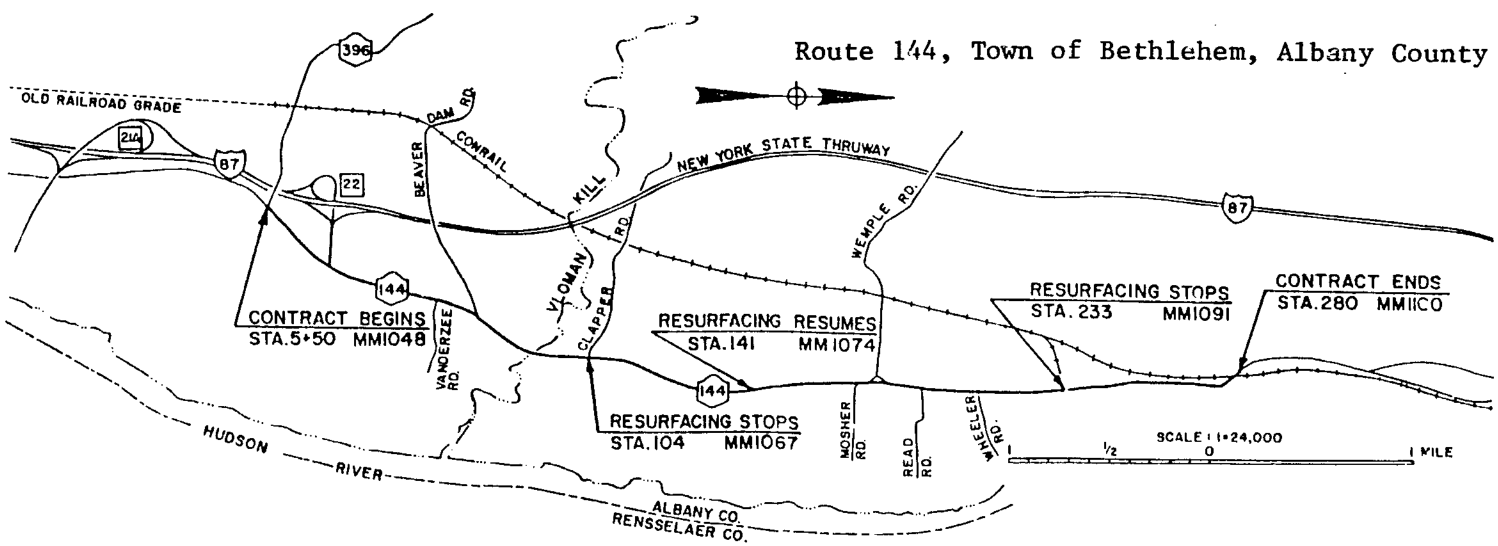
Of 101 paving contracts scheduled for letting in the 1989 construction season, 38 were identified as possible candidate sites. One site parameter considered necessary was a high incidence of truck traffic, which narrowed the possibilities to the two 10,000-ft sites that were eventually selected:

Figure 1. Locations of RUMAC pavements.

Route 17, Town of Deposit, Delaware County



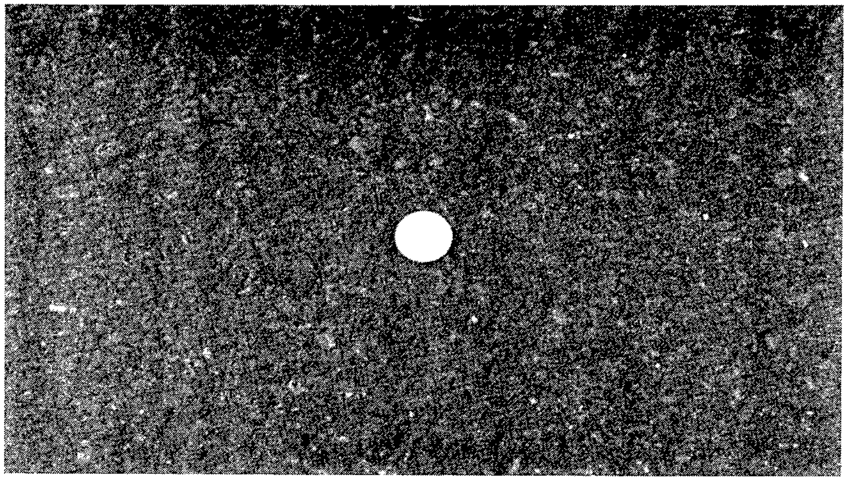
Route 144, Town of Bethlehem, Albany County

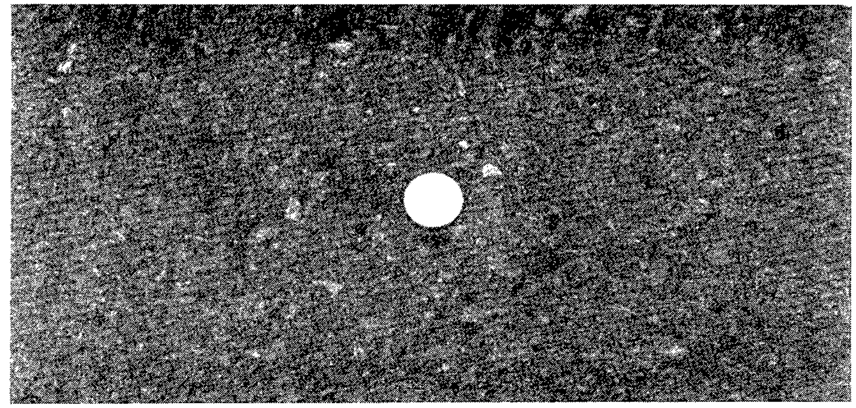


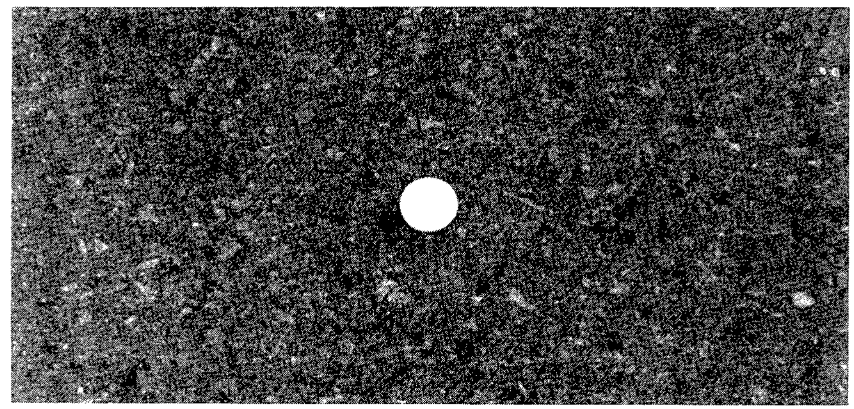
1. The Rte 17 site is in the Town of Deposit, Delaware County (Fig. 1), with an AADT of 5200 and 15-percent trucks. This was a "crack-and-seat" project on an existing concrete pavement, consisting of 5½ in. of new asphalt concrete pavement as an overlay. The first 2½ in. course was for truing-and-leveling, the next 1½ in. was a binder course, and the final 1½ in. was either a mix incorporating rubber as a percentage of total weight of the mix, or a conventional top-course. Each of the mix segments was about 2000 ft long and the paving sequence progressed as follows: 1-percent, 3-percent, Plus-Ride (also 3-percent), 2-percent, and conventional.

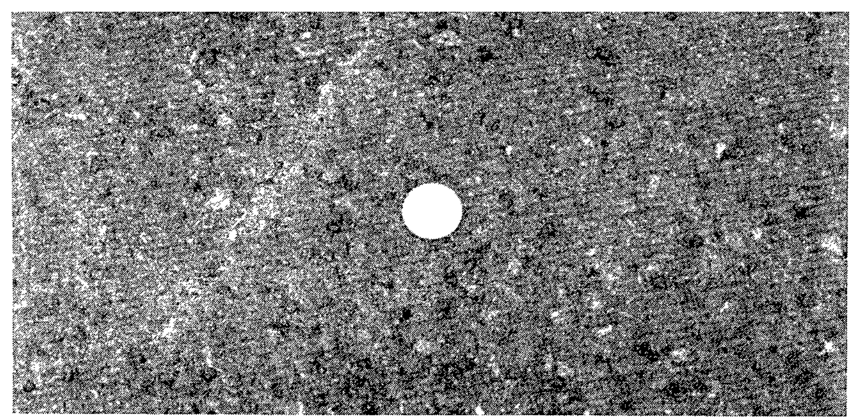
2. The Rte 144 site is in the Town of Bethlehem, Albany County (Fig. 1), and is similar in traffic pattern. It also has an AADT of 5200 with a slightly higher truck count of 16 percent. The contract was an asphalt concrete resurfacing project consisting of a 1½-in. overlay, again incorporating a percentage of rubber or a conventional top course mix, over an existing 1½ in. asphalt cement concrete overlay, which in turn was over an original 9-in. concrete pavement. Because of contract limitations, paving took place in two sections 1.75-miles apart. The mix segments are about 1000 ft long in each section. Section 1 was paved in this order: 1-percent, 2-percent, 3-percent, Plus-Ride, and conventional, with Section 2 in random order -- conventional, 2-percent, Plus-Ride, 1-percent, and 3-percent. Typical closeups of each mix are shown in Figure 2.

About 1760 tons of RUMAC were placed at each test site, with about 7900 waste tires (40 tons of rubber) being consumed.









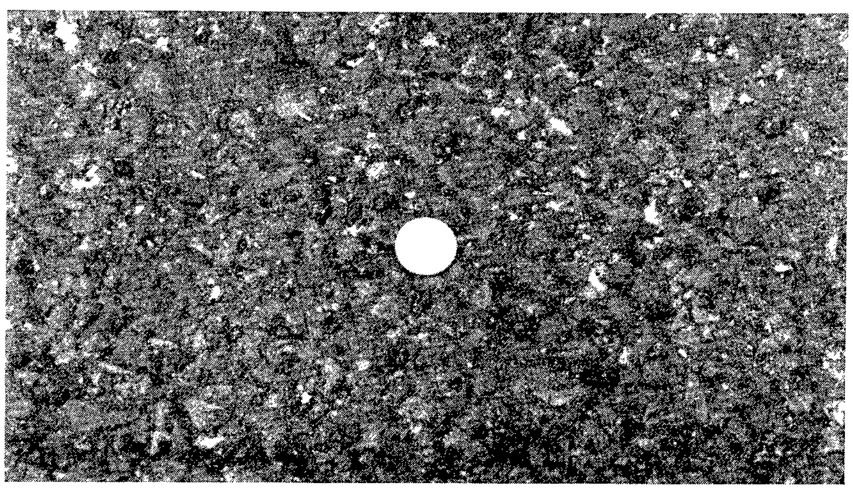


Figure 2. Surface texture (clockwise from upper left) of conventional asphalt concrete in control section, rubber-modified asphalt with 1-, 2, and 3-percent rubber, and "Plus-Ride." Dark specks are rubber particles.

II. PAVEMENT PERFORMANCE

Each site has been visually examined and tested for surface irregularities twice a year in the spring and fall.

A. Condition Surveys

Distress surveys have been conducted semi-annually, or more often as need warranted. These surveys documented such problems as cracks, ravels, rut depths, (Table 1) and any other pavement deformities. Documentation included identifying the distress, length or area encompassed, and location.

1. Rut Depth

A steel straight-edge was placed transversely from the pavement shoulder to the lane centerline to delineate the outside wheelpath (OWP) and from the centerline to the inner edge of the pavement for the inside wheelpath (IWP). The maximum reveal recorded from a ruler with 1/10th-in. incremental

Table 1. Progress of pavement distress.

	Route 17 Surveys					Route 144 Surveys				
Pavement	5/90	9/90	5/91	9/91	5/92	5/90	9/90	5/91	9/91	5/92
	Maximum Rut Depth, in.									
1%	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.07	0.11	0.13
2%	0.00	0.00	0.00	0.06	0.08	0.00	0.09	0.10	0.10	0.12
3%	0.00	0.00	0.00	0.02	0.03	0.00	0.04	0.07	0.10	0.12
PR	0.00	0.00	0.02	0.05	0.05	0.00	0.09	0.09	0.09[a]	0.11
C	0.00	0.00	0.00	0.03	0.08	0.00	0.04	0.06	0.11	0.12
	Total Cracks									
1%	0	0	0	0	0	25	29	40	40	54
2%	0	0	2	2	4	22	25	35	35	48
3%	0	0	1	1	2	24	28	34	35	41
PR	0	0	0	0	0	15	17	24	25[a]	29
C	0	0	0	0	1	10	12	21	21	36
	Raveled Area, ft^2									
1%	0	0	0	2	3	0	0	0	0	0
2%	0	0	0	0	0	<1	<1	<1	86[b]	154
3%	0	0	40	220	1213	<1	2	2	576[b]	1409
PR	0	<1	<1	<1	<1	21	61	509	777[a]	781
C	0	0	0	0	0	0	0	<1	<1	<1

[a]Section 2 Plus-Ride removed shortly after survey because of severe raveling.
[b]Distressed areas removed and cut back to sound pavement, then repaved with conventional mix.

markings, placed behind the straight-edge, is the rut depth for each wheelpath. Reported rut depths are the average of 12 observations for Rte 17 and 16 readings for Rte 144. Table 1 shows that no pavement is a clear performance leader in terms of rutting resistance. Although the 1-percent mix is lowest on Rte 17, it is highest on Rte 144.

2. Cracks

The number of visible cracks within each section was recorded in each survey (Table 1). Almost all reported are transverse reflective cracks, either full-width (across both lanes) or at least one lane wide. The difference in performance between Rtes 17 and 144 is attributable to the different construction methods used. Recall that Rte 17 was a "crack-and- seat" project where existing concrete pavement was cracked, rolled, and 5½-in. of asphalt concrete was placed, and Rte 144 was an overlay on an overlay. The conventional pavement sections have the lowest crack frequency on Rte 17 and are second lowest on Rte 144, but it could be that they are the overall performance leaders on both projects since one Plus-Ride section was removed on Rte 144.

3. Raveling

The area of surface course debonding (raveling) from the underlying pavements is documented in Table 1. Raveling is facilitated by water intrusion through cracks and other surface distress areas. Water is prevented from draining in these RUMAC sections because the shoulder mixes are denser. Water ponds at the pavement edges (usually the lowest point on the pavement) and ravels thus appear mostly in the outer wheelpath. Raveling initially occurs as alligator or slippage (shear) cracks (Fig. 3). Occurrence of shear failures in the RUMAC pavement sections is inexplicable, because historically they take place in transition (stop/go/turn) traffic areas. In the case of these sections, they appear randomly. As the percentage of rubber increases, severity of this particular distress also increases.

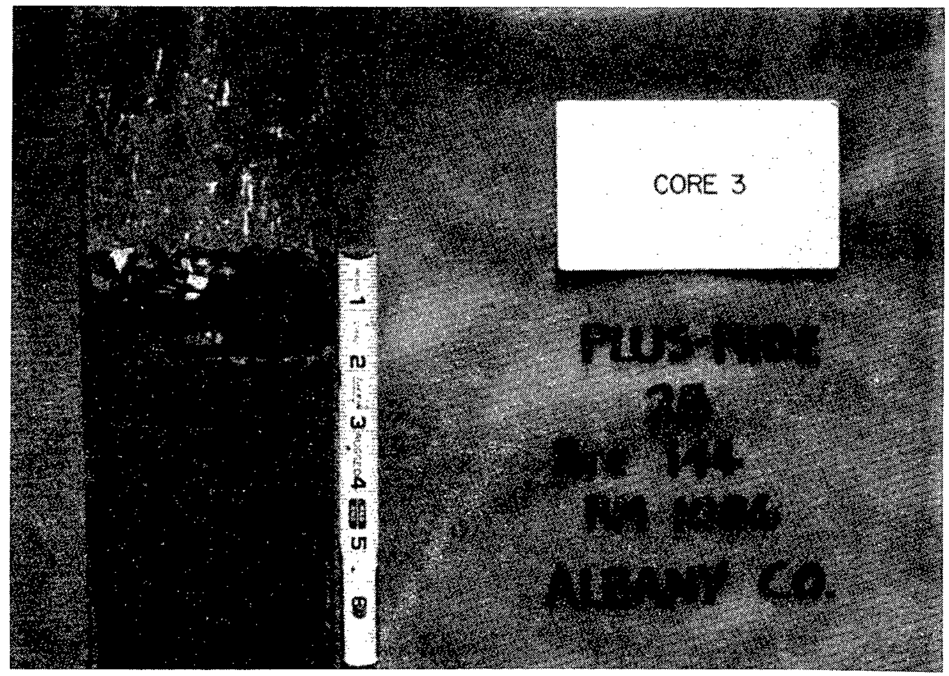
An observation during one condition survey was that after a rain shower the conventional pavement dried much faster than any RUMAC pavements. Surface moisture remained about an hour longer on those pavements.

4. Aggregate Popouts

This distress was not documented on a regular basis because of frequency of occurence, but was noted as a potential problem in each survey. Lack of affinity between asphalt and the rubber aggregate is a cause for concern in the RUMAC sections. The particle rubber specified for these projects was granular, connoting a cubical shape with straight shear faces for the asphalt cement to adhere to. A more appropriate specification might have called for ground rubber, which would have increased the surface area, with more exposure to asphalt cement. All the RUMAC mixes show varying stages and degrees of aggregate popouts. As noted for raveling, the higher the

Figure 3. Typical raveled areas resulting from shear failure on Route 17.

Figure 4. Typical raveling repair by patching on Route 144 before removal of Plus-Ride section (left), and appearance of core from raveled area (below).



percent of rubber in the mix the greater is the frequency (size and number) of popouts.

In consultation with the Regional Materials Engineer, it was determined from pavement cores extracted in Fall 1990 from Plus-Ride Section 2 on Rte 144 that this mix was more permeable than the underlying pavement, leading to premature deterioration. In October 1991, after numerous complaints from the motoring public and inability of maintenance forces responsible for this section of highway to keep up with steady eroding of pavement due to raveling (Fig. 4), the Plus-Ride course in Section 2 on Rte 144 was removed and replaced with a conventional mix. During its removal, because of the presence of standing water after a relatively dry period, it was apparent that the failure was caused by the Plus-Ride mix's permeability in contrast to the shoulder or underlying mixes.

In July 1992 notification was sent to both Regional Materials Engineers to eliminate the 3-percent area in Section 1 on Rte 144 and the 3-percent area on Rte 17 due to uncontrollable raveling. Removal and replacement of these two distressed sections by whatever means convenient was suggested to them. It should be noted that in 1991 each site's problem areas were properly cut back to sound pavement and patched with conventional mix to no avail.

B. Marshall Properties

These were determined by the Department's Materials Bureau. Stability and flow have not been determined because that would mean destroying the cores, which may still prove of value for other testing. A final decision to test for these and other Marshall properties will be made in the future.

The Marshall cores were fabricated in the laboratory from sample mix taken directly from the spreaders on the projects. Pavement cores were taken initially within a month of paving and after 1 year of service. More cores will be taken in the Fall of 1992 and 1994. Results of this analysis are given in Table 2.

In the pavement cores, air void content has generally decreased and density increased for all the mixes, except Plus-Ride on Rte 144 (where that material shows opposite trends) and on Rte 17 (where the rate of densification is very slight). A closer look will be taken at this after more data is collected because it may have far-reaching ramifications as to why one section of Plus-Ride failed after only 2 years. The normal maximum theoretical density requirements of New York State standard asphalt concrete mixes of 95-98 percent was waived for the RUMAC sections because this specification was thought to be unobtainable on a regular basis, based on laboratory results even on 75-blow Marshall mix designs and previously reported field experience by others. It is apparent from Table 2 that the two mixes performing most effectively against raveling (the conventional and the 1-percent) have the highest densities.

Design asphalt percentages are also given in Table 2. Asphalt cement content from pavement cores has not been determined and will not be until more is known about reliably extracting and separating the rubber and asphalt. Penetrations and viscosities given in Table 2 were determined from asphalt samples taken

Table 2. Mix and binder properties.

Property*	Route 17					Route 144				
	1%	2%	3%	PR	C	1%	2%	3%	PR	C
Maximum Theoretical Specific Gravity	2.393	2.345	2.313	2.295	2.420	2.433	2.388	2.344	2.360	2.457
Bulk Specific Gravity										
Marshall	2.307	2.228	2.204	2.235	2.323	2.225	2.188	2.228	2.214	2.354
After 1 Month	2.265	2.147	2.125	2.230	2.277	2.249	2.195	2.101	2.243	2.238
After 1 Year	2.295	2.180	2.178	2.233	2.324	2.314	2.221	2.184	2.234	2.269
Air Voids, %										
Marshall	3.59	4.99	4.71	2.61	4.01	8.55	8.38	4.95	6.19	4.19
After 1 Month	5.36	8.44	8.13	2.83	5.91	7.56	8.08	10.37	4.96	8.91
After 1 Year	4.11	7.06	5.84	2.71	3.97	4.90	7.01	6.84	5.35	8.32
Bulk Density, pcf										
Marshall	144.0	139.0	137.5	139.5	145.0	138.8	136.5	139.0	138.2	146.9
After 1 Month	141.3	134.0	132.6	139.2	142.1	140.3	137.0	131.1	140.0	139.7
After 1 Year	143.2	136.0	135.9	139.4	145.0	144.4	138.6	136.3	139.4	141.6
Design Asphalt Content, %	6.2	6.8	7.4	7.4	6.2	6.4	6.8	7.2	7.2	6.0
Penetration, 0.1 mm at 77 F			69					76		
Viscosity										
140 F, poises			2107					1847		
275 F, centistokes			433					402		

*Marshall cores taken from original mix at spreader, others taken within 1 month and 1 year after paving.

Table 3. Mean resilient modulus values.

Section	Modulus, psi x 10^5*		
	Marshall	After 1 Month	After 1 Year
Route 17			
1%	3.72	3.77	5.27
2%	2.82	2.42	4.05
3%	2.71	2.78	4.10
PR	2.62	2.71	2.74
C	3.62	2.49	3.39
Route 144			
1%	3.37	3.96	2.64
2%	2.98	2.72	4.31
3%	2.51	3.02	3.69
PR	2.64	3.13	3.63
C	3.09	3.58	3.68

*Marshall cores taken from original mix at spreader, others taken within 1 month and 1 year after paving.

Table 4. Mean skid numbers

	At 40 mph			At 55 mph		
Pavement	Initial	1 Year	2 Years	Initial	1 Year	2 Years
Route 17						
1%	48.8	51.9	50.2	39.3	44.1	42.5
2%	51.3	51.7	50.6	41.9	44.0	42.4
3%	48.2	50.4	49.9	36.7	42.4	43.1
PR	31.5	44.4	43.2	26.2	37.2	36.1
C	53.6	52.9	52.4	43.4	45.6	42.9
Route 144						
1%	54.6	53.9	48.9	46.2	44.7	41.6
2%	54.2	52.3	46.9	45.3	44.1	39.4
3%	55.2	52.4	47.7	46.3	43.8	41.7
PR	49.3	47.3	41.7	41.3	40.4	36.4
C	54.8	55.7	47.2	47.4	48.0	42.3

directly from the holding tanks at the asphalt plants. Asphalt grade on both projects was AC 20.

C. Resilient Modulus

This test was performed in accordance with ASTM D 4123-82 and procedures described in an earlier report (4). Three test specimens from each mix were tested at 77 F. The modulus of each specimen was taken as the mean of one determination on each of two mutually perpendicular random diametrical axes. A Poisson ratio of 0.35 was assumed for all mixes. Each independent value was measured after at least 50 repetitions of a diametric compressive load applied for 0.10 sec at 3-sec intervals, and horizontal deformation was recorded on a digital readout meter (Table 3). The results are consistent with previous findings for New York State mixes (4). No conclusions are yet apparent except that resilient modulus values increased as a whole from initial pavement cores to after 1 year in service, with the exception of the Rte 144 1-percent pavement. This anomaly is unexplained. Further analysis will occur when more cores are obtained and tested in subsequent years.

D. Surface Friction

Pavement friction was measured at 40 and 55 mph with a locked-wheel trailer in accord with procedures in ASTM E 274, with the results given in Table 4. It is interesting that conventional pavement overall outperformed all the rubber sections in 9 of the 12 reported test runs, regardless of speed. After 2 years it appears that the conventional and rubber sections (with the exception of Plus-Ride) are reaching parity in terms of performance.

E. Survey of Snowplow Operators

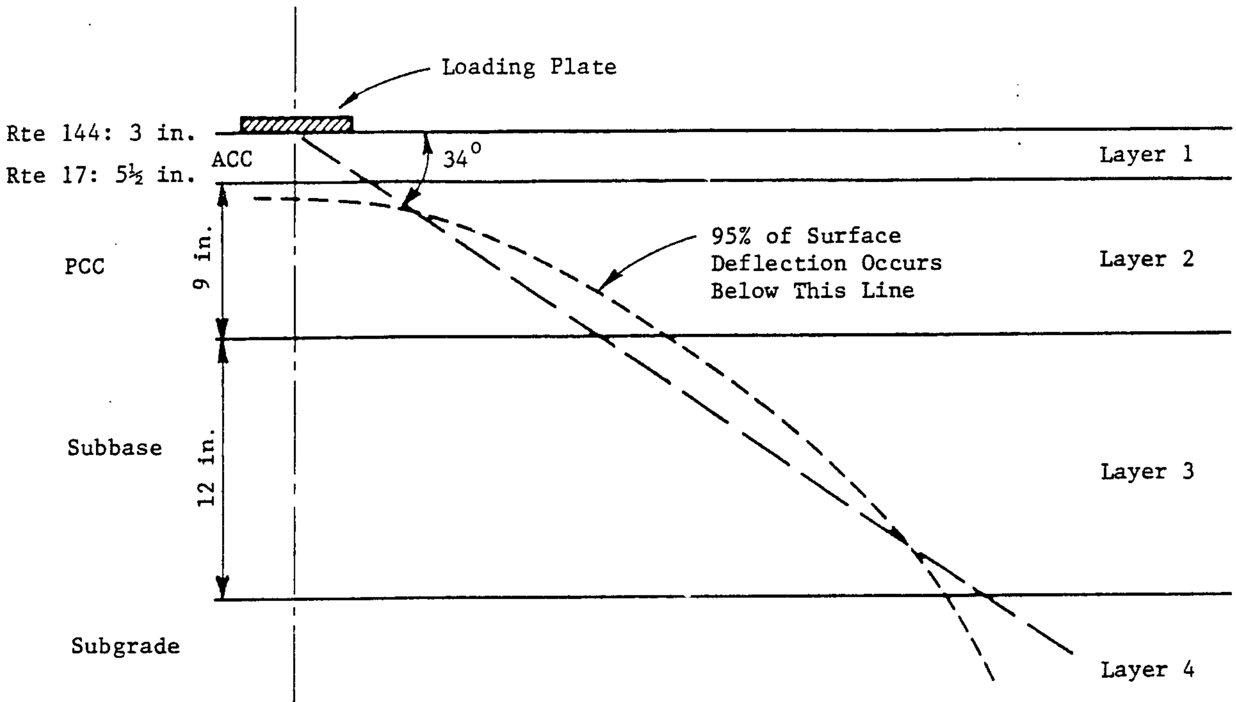
Maintenance personnel responsible for plowing, salting, and sanding the RUMAC pavements were asked their opinions regarding ease of performing standard operations during snowstorms. A standard form (Appendix A) was drafted to record

Figure 5. Appearance of Route 144 pavement after snowfall is shown in upper view with Plus-Ride in foreground and conventional mix in background, and lower view with conventional mix in foreground and 2-percent crumb rubber in background.

this information. Of 23 observations by five different operators, typical responses were that there were no noticeable differences on any of the test sections. Two operators (one from each region) independently stated that RUMAC pavements were actually harder to clear of ice and snow than conventional sections.

None of the 23 operator reports noted any shedding or prevention of icing on the RUMAC pavements. Similarly, ice-shedding capabilities were not observed by researchers during winter field inspections on Rte 144. In one field observation during inclement weather (air and windchill temperatures of about 10 and -10 F, respectively) consisting of light granular snow quickly turning to ice upon contact with pavement and the action of traffic, with a hazardous driving condition warning issued by the U.S. Weather Bureau, there was no apparent difference in performance (ice/pavement debonding) between RUMAC and conventional pavements (Fig. 5).

Figure 6. Pavement system, showing line of 95-percent deflection.



$d/x = \tan(34^\circ)$ $\qquad$ $x = d/\tan(34^\circ)$

d = depth

x = horizontal distance from point of load application

R = actual distance from sensor to load point

	<u>Route 144</u>		<u>Route 17</u>	
<u>AC & PCC Overlay</u>:	$d = 0$	<u>R = 0</u>	$d = 0$	<u>R = 0</u>
<u>Subbase</u>:	$d = 12$ in. $x = \frac{12 \text{ in.}}{\tan(34^\circ)} \approx 17.8$ in.	<u>r = 20 in.</u>	$d = 14$ in. $x = \frac{14 \text{ in.}}{\tan(34^\circ)} \approx 20.8$ in.	<u>R =20 in.</u>
<u>Subgrade</u>:	$d = 24$ in. $x = \frac{24 \text{ in.}}{\tan(34^\circ)} \approx 35.6$ in.	<u>R = 32 in.</u>	$d = 26$ in. $x = \frac{26 \text{ in.}}{\tan(34^\circ)} \approx 38.5$ in.	<u>R = 50 in.</u>

III. TRAFFIC AND PAVEMENT STRUCTURAL CONDITION

A. Vehicle Weight Classification

Traffic volumes and vehicle classifications provided by the Department's Data Services Bureau are given in Appendix B, showing average distribution of traffic by vehicle class for each lane, and representing a typical day's traffic pattern.

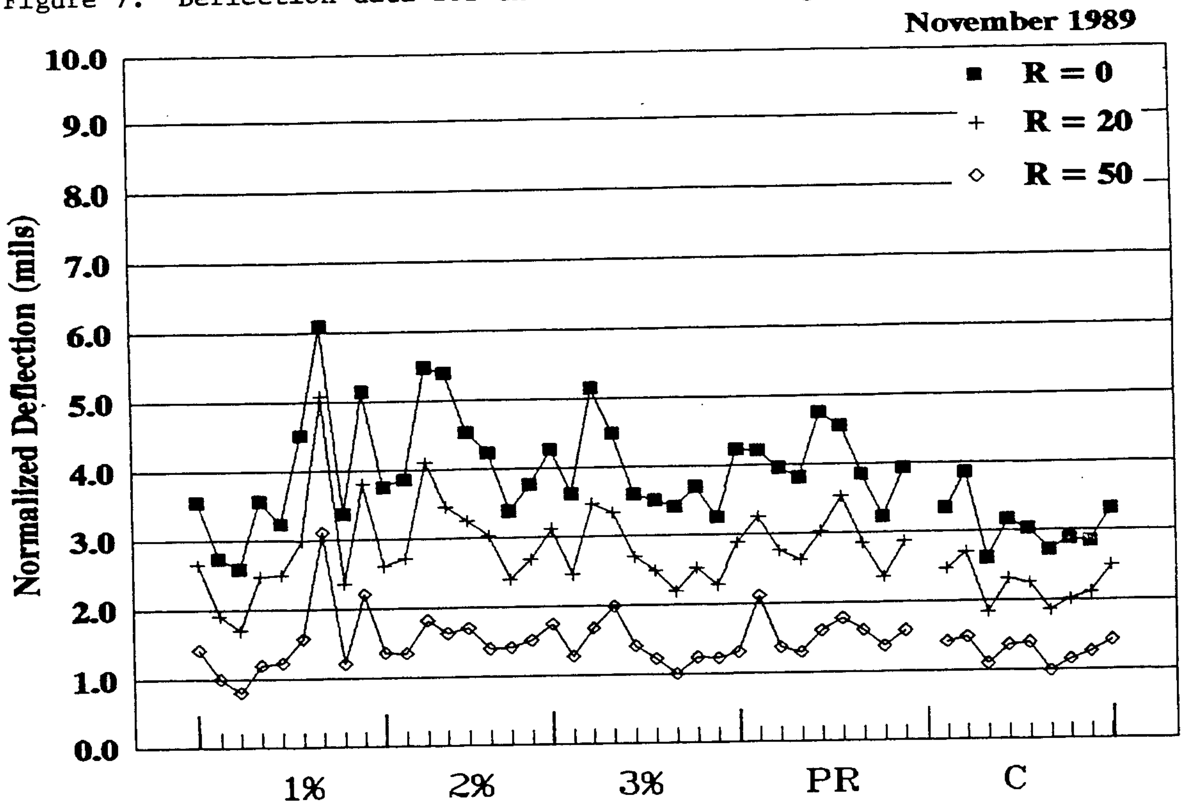
B. Pavement Structural Condition

Structural characteristics were evaluated by the falling-weight deflectometer (FWD). For this project, four loads were applied and seven sensors, positioned at 0, 8, 13, 20, 32, 50, and 60 in. from the center of the loading plate, recorded surface deflection. To examine pavement condition, surface deflections were plotted against station number. Data were normalized before plotting because most pavement design procedures use the 18-kip Equivalent-Single-Axle-Load (ESAL) concept (i.e., 9000 lb per wheel load). Among the four load levels, the one nearest 9000 lb thus was chosen for plotting.

By computing deflections in the pavement system, a typical 95 percent-of-surface deflection curve can be drawn (Fig. 6). It should be noted that the depth beneath which 95 percent of the surface deflection occurs gradually moves downward with increasing radial distance from the loading plate. The actual shape and position of this curve is a function of the moduli and thickness of the pavement layers. The outer sensors are used to characterize deeper layers and the center ones to represent composite effects of the pavement system. To estimate sensor spacing for the layers, a 34-deg line is used. It has been determined that this line gives a good estimation of the 95-percent surface deflection curve (5).

Three sensors were used to represent response of three subsystems -- entire pavement layers, the subbase and subgrade combined, and the subgrade. As just discussed, a 34-deg line was used to estimate spacing for layers. Center deflection (R = 0) was used for all the layers. The other two sensors were determined using R = depth to the top of the layer ÷ tan (34 deg). For Rte 17, sensor spacings of 0, 20, and 50 in. were used. For Rte 144, sensor spacing was determined to be 0, 20, and 32 in. Deflection data are plotted for Rtes 17 and 144 in Figures 7 and 8. By examining magnitude of deflection in mils, relative weakness and changes with time at each individual test station can be identified, and the layer(s) responsible for any weaknesses can be determined.

Figure 7. Deflection data for the Route 17 driving lane.



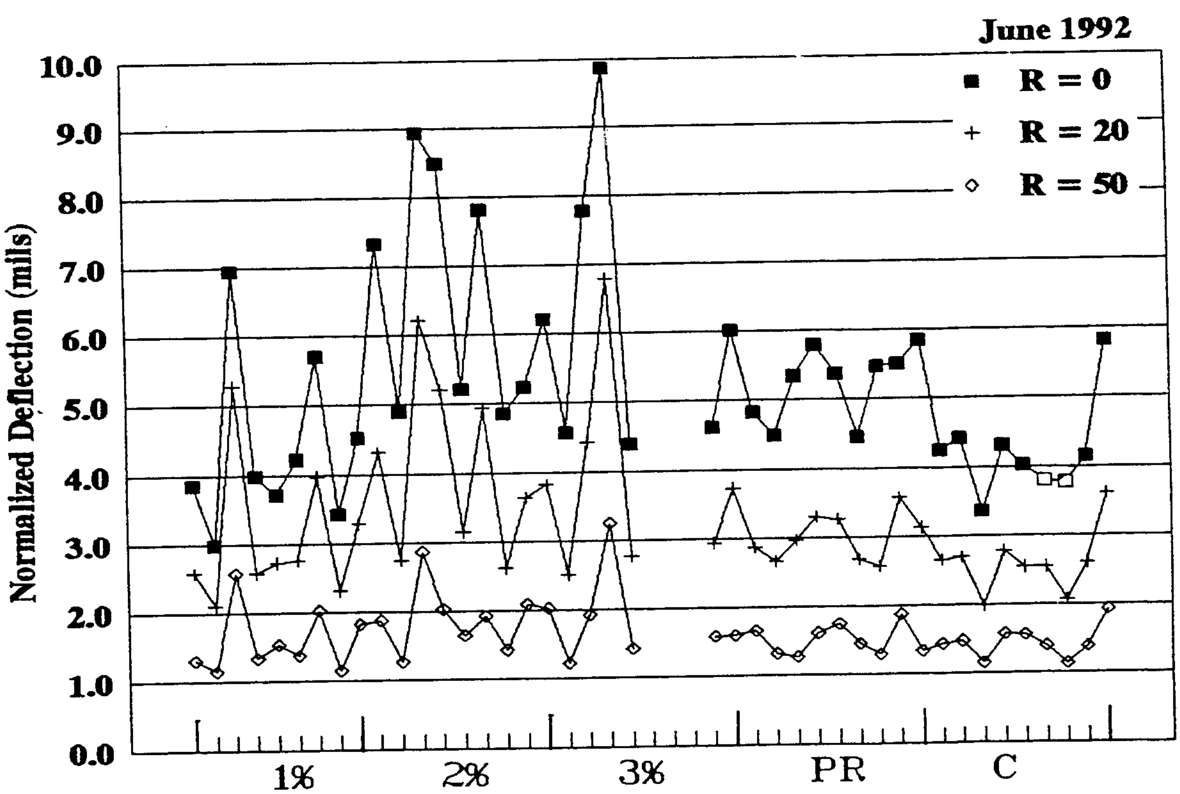
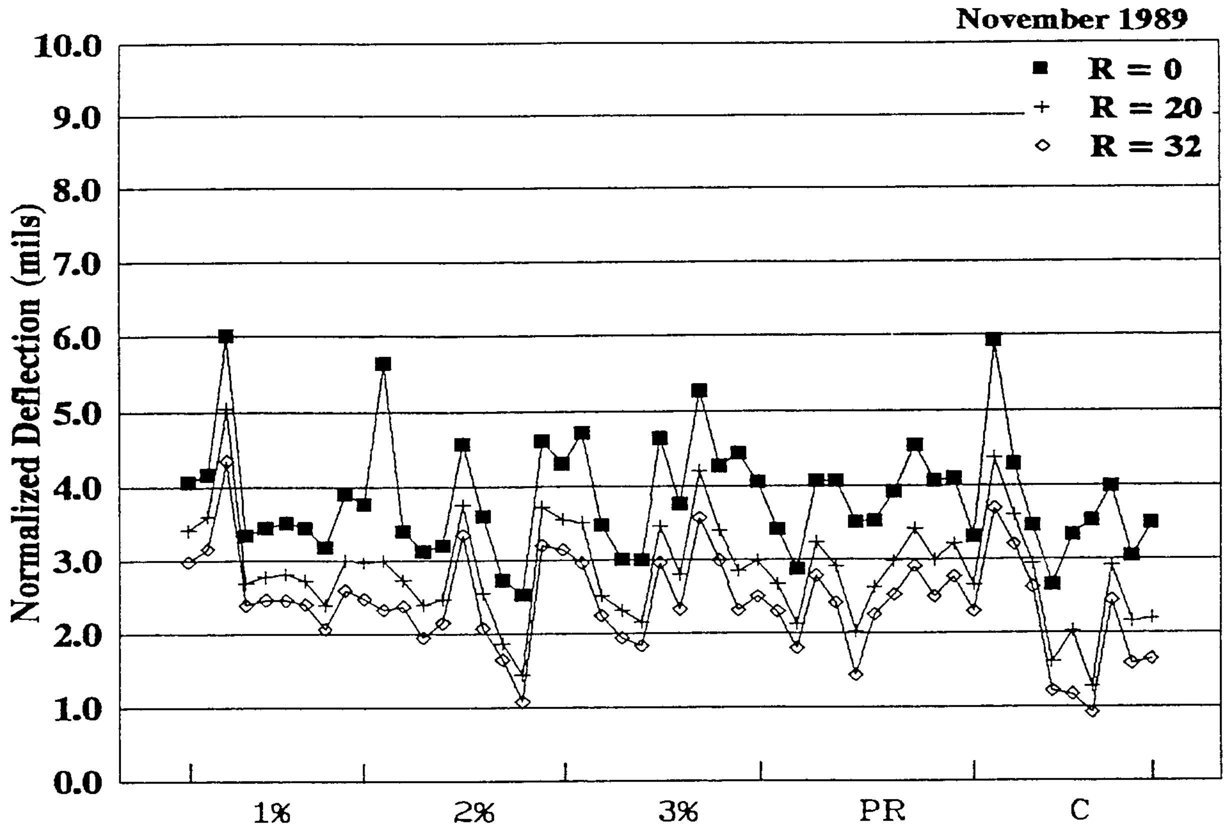
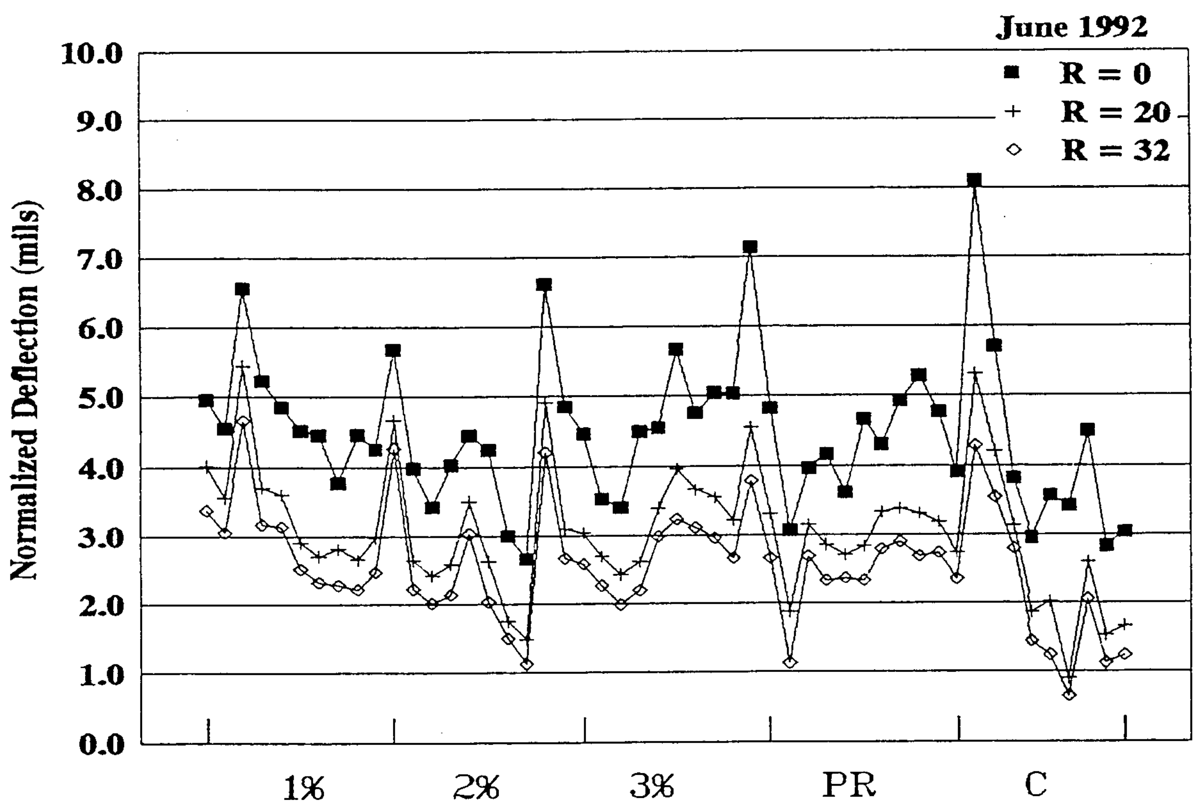


Figure 8. Deflection data for the Route 144 northbound lane.





It should be noted that FWD testing on Rte 17 was incomplete. In Figure 7 for 1989 no test was recorded for one Plus-Ride section, and for 1992 three tests were not performed on the 3-percent due to raveling. In Figure 8, the Plus-Ride data reported for 1992 are for the only remaining section.

Some general statements can be made from the FWD testing:

For Rte 17:

1. From Figure 7, it can be noted that center deflections increased between 1989 and 1992; thus on the whole all the overlays have deteriorated.

2. By comparing deflection at R = 20 in Figure 7, the subbase under Plus-Ride and conventional section remains essentially the same, since deflections were both about 3 mils. However, one point under the 1- and 3-percent sections and two points under the 2-percent section appear to be weaker in the 1992 data, with a relatively high deflection increase at R = 20, while deflections at R = 50 remain about the same.

3. It can be observed in the 1992 plot that subbase condition under Plus-Ride and the control mix is better than under the other three sections, since deflections at R = 20 are smaller and more uniform than the other three. Some of this variation in the 1-, 2-, and 3-percent sections can be attributed to the subgrade since they exhibit the same pattern.

4. Comparing 1989 and 1992 deflection readings at R = 50, the subgrade (where deflections registered around 3 mils) remained fairly constant except for one area in each of the 1-, 2- and 3-percent sections.

5. From the 1992 plot in Figure 7, the best overall condition is found in the conventional section with the smallest deflection, and the weakest in the 2- and 3- percent with the highest deflections.

For Rte 144:

1. From Figure 8, most of the conventional section's subbase and subgrade is registering the lowest deflections (R = 20 and R = 32), while the other sections are performing adequately.

2. Each section has at least one station exhibiting relatively high deflection readings at all three sensors, with the 3- percent the worst. Since all three sensors exhibit the same high reading, the weakness is most likely attributable to the subgrade.

3. With deflection readings at R = 32 increasing between 1989 and 1992, the subgrade has deteriorated in terms of strength. The subbase has essentially remained the same.

4. Examining the 1992 deflection data, overall the conventional section is performing best in all layers because it exhibits lowest deflections.

IV. CONCLUSIONS AND RECOMMENDATIONS

The work reported here concerning New York State's experience to date at test sites containing dry-process rubber-modified asphalt concrete, leads to the following preliminary conclusions:

1. After 3 years, conventional and rubber mixes tested are performing comparably with respect to rut resistance and cracking.

2. Mixes with 1-percent rubber have shown little or no raveling distress; however, those with higher rubber mix percentages have shown unacceptable amounts of raveling.

3. Conventional and rubber mixes both exhibit acceptable surface friction.

4. Rubber mixes demonstrated no ice-shedding abilities.

5. Based on the FWD results, conventional sections generally have lower deflections.

This has been a limited experimental attempt to incorporate waste tire rubber into asphalt concrete for use in highway pavements, using a single dry-process mix design. The following recommendations are based on preliminary results from this study:

1. Continue to monitor the remaining test sites.

2. New test projects, currently being planned, should incorporate a finer rubber gradation in dry-process mixes.

3. In future work, more attention should be directed to mix compaction, to ensure acceptable pavement air voids. Mixes placed on shoulders should be identical to mainline pavement mixes.

4. Future work should incorporate rubber mixes in surface, binder, and base courses for full-depth reconstructed pavement sections.

5. Selected experimentation with the wet-mix process should also be considered.

ACKNOWLEDGEMENTS

This study was conducted under general supervision of Dr. Robert J. Perry, Director of Engineering Research and Development, and direct supervision of Dr. Wes Yang and Michael E. Doody, Engineering Research Specialists II and I, respectively. Gratitude is also expressed to the Department's Materials Bureau for support and laboratory analyses, to the respective Regional and Main Office personnel in Construction and Design, to Resident Engineers in Regions 1 and 9, and to Peter Elkan, Engineering Research Student Intern.

REFERENCES

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2. Shook, J.F., Takallou, H.B., and Oshinski, E. Evaluation of the Use of Rubber-Modified Asphalt Mixtures for Asphalt Pavements in New York State. ARE Inc. Engineering Consultants, December 1989.

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4. Gupta, P.K., Van Bramer, T.F., Resilient and Tensile Properties of New York State Asphalt Concrete Mixes. Research Report 152, Engineering Research and Development Bureau, New York State Department of Transportation, November 1990.

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RMA EVALUATION
RESIDENT ENGINEER'S REPORT

Operator ____________ Truck Route Number ____________

Maint. Station ____________ Storm Number ____________

Date(s) ____________

A. STORM DATA

Time storm began ____________
Total snow fall ________inches
Max rate of snow fall ________ inches/hour
Duration of storm ________ hours

Precipitation Description (Circle appropriate description)
WET, DRY, BLOWING SNOW, FREEZING RAIN, SLEET, MIXED SNOW/RAIN

Temp. Beginning ________F Temp. Ending ________F
Wind Beginning ________mph Wind Ending ________mph

B. SPREAD DATA

Approx. time after storm began spreading began ________ min
Total lbs salt used ________ Total lbs sand used ________
Approx. rate of spread ________lbs/mi
Total number of applications during storm ____________
Average time between applications ____________

C. RESULTS

Overall opinion of test sections ________Good ________Poor
Spread pattern _____Good _____Poor _____Blown off road surface
Time to obtain pack free surface ____More ____Less _____ Same

D. GENERAL OPINION (Comments on positive/negative aspects)

____
____
____
____
____
____

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ROUTE: 17
COUNTY NAME: DELAWARE
REGION CODE: 9
LOCATION: BETWEEN EX 84 RTS 8 10 AND CR 56 HALE EDDY
REF-MARKER: 17 93081014
END MILEPOINT: 0810438
FUNC-CLASS: 02
HPMS NO: 00000000
STATION NO: 017

YEAR: 1992
MONTH: JULY

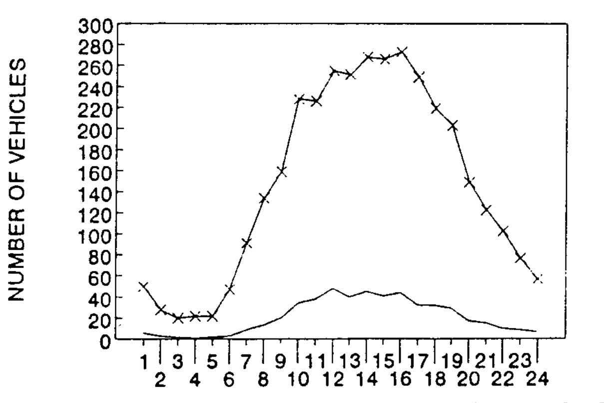
AVERAGE WEEKDAY DATA

I.D. # 93017

	TRAVEL LANE	PASSING LANE	TOTAL
DIRECTION CODE	7	7	
NUMBER OF VEHICLES	3520	500	4020
NUMBER OF AXLES	8102	1065	9166
% HEAVY VEHICLES (F4 – F13)	15.37%	5.40%	14.13%
% TRUCKS AND BUSES (F3 – F13)	33.95%	18.20%	31.99%
AXLE CORRECTION FACTOR	0.87	0.94	0.88

	VEHICLE CLASS	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	TOTAL
	NO. OF AXLES	2	2	2	2.5	2	3	4	3.5	5	6	5	6	8.75	
ENDING HOUR	1:00	0	30	10	1	1	0	0	1	7	0	0	0	0	50
	2:00	0	17	3	0	0	0	0	1	7	0	0	0	0	28
	3:00	0	11	2	1	0	0	0	0	6	0	0	0	0	20
	4:00	0	8	4	1	1	0	0	1	7	0	0	0	0	22
	5:00	0	10	1	0	1	0	0	1	9	0	0	0	0	22
	6:00	0	25	7	0	1	0	0	3	11	0	0	0	0	47
	7:00	0	53	23	1	2	2	0	1	9	0	0	0	0	91
	8:00	0	89	28	1	3	1	0	1	11	0	0	0	0	134
	9:00	0	99	35	2	6	3	0	1	13	0	0	0	0	159
	10:00	2	157	39	2	8	3	1	2	13	1	0	0	0	228
DIRECTION	11:00	2	150	40	5	9	1	2	3	13	1	0	0	0	226
7	12:00	1	176	47	5	8	1	0	2	15	0	0	0	0	255
	13:00	1	167	42	6	8	4	1	4	18	0	0	0	0	251
TRAVEL LANE	14:00	0	190	42	2	8	1	1	1	22	1	0	0	0	268
	15:00	1	177	54	3	11	1	1	5	13	0	0	0	0	266
	16:00	0	174	54	5	15	1	0	3	19	2	0	0	0	273
	17:00	1	160	60	2	5	1	1	2	17	0	0	0	0	249
	18:00	1	144	41	3	7	1	1	3	17	0	1	0	0	219
	19:00	1	136	38	1	5	1	2	3	16	0	0	0	0	203
	20:00	1	93	29	2	3	1	0	1	19	0	0	0	0	149
	21:00	1	84	20	2	1	1	0	1	13	0	0	0	0	123
	22:00	0	73	15	1	1	0	0	1	12	0	0	0	0	103
	23:00	1	52	14	0	2	1	0	1	6	0	0	0	0	77
	24:00	0	37	6	2	2	0	0	1	9	0	0	0	0	57
TOTAL VEHICLES		13	2312	654	48	108	24	10	43	302	5	1	0	0	3520
TOTAL AXLES		26	4624	1308	120	216	72	40	151	1510	30	5	0	0	8102
ENDING HOUR	1:00	0	4	1	0	0	0	0	0	1	0	0	0	0	6
	2:00	0	2	0	0	0	0	0	0	1	0	0	0	0	3
	3:00	0	1	1	0	0	0	0	0	0	0	0	0	0	2
	4:00	0	1	0	0	0	0	0	0	0	0	0	0	0	1
	5:00	0	1	0	0	0	0	0	0	1	0	0	0	0	2
	6:00	0	2	1	0	0	0	0	0	0	0	0	0	0	3
	7:00	0	8	1	0	0	0	0	0	0	0	0	0	0	9
	8:00	0	9	3	0	0	0	0	0	1	0	0	0	0	13
	9:00	0	17	2	0	0	0	0	0	1	0	0	0	0	20
	10:00	0	28	5	0	0	0	0	0	1	0	0	0	0	34
DIRECTION	11:00	0	31	5	0	1	0	0	0	1	0	0	0	0	38
7	12.00	1	37	5	1	1	1	0	0	2	0	0	0	0	48
	13:00	0	34	5	0	0	0	0	0	1	0	0	0	0	40
PASSING LANE	14:00	0	36	6	0	1	0	0	0	2	0	0	0	0	45
	15:00	0	35	4	0	0	0	0	0	2	0	0	0	0	41
	16:00	0	33	8	0	1	0	0	0	2	0	0	0	0	44
	17:00	0	27	4	0	0	0	0	0	1	0	0	0	0	32
	18:00	0	28	3	0	0	0	0	0	1	0	0	0	0	32
	19:00	1	23	4	0	0	0	0	0	1	0	0	0	0	29
	20:00	1	13	3	0	0	0	0	0	0	0	0	0	0	17
	21:00	0	13	1	0	0	0	0	0	1	0	0	0	0	15
	22:00	0	9	1	0	0	0	0	0	0	0	0	0	0	10
	23:00	0	8	1	0	0	0	0	0	0	0	0	0	0	9
	24:00	0	6	0	0	0	0	0	0	1	0	0	0	0	7
TOTAL VEHICLES		3	406	64	1	4	1	0	0	21	0	0	0	0	500
TOTAL AXLES		6	812	128	3	8	3	0	0	105	0	0	0	0	1065
GRAND TOTAL VEHICLES		16	2718	718	49	112	25	10	43	323	5	1	0	0	4020
GRAND TOTAL AXLES		32	5436	1436	123	224	75	40	151	1615	30	5	0	0	9166

TRAFFIC FLOW BY LANE



VEHICLE CLASSIFICATION CODES:

F1. MOTORCYCLES
F2. AUTOS *
F3. 2 AXLE, 4-TIRE PICKUPS, VANS, MOTORHOMES *
F4. BUSES
F5. 2 AXLE, 6-TIRE SINGLE UNIT TRUCKS
F6. 3 AXLE SINGLE UNIT TRUCKS
F7. 4 OR MORE AXLE SINGLE UNIT TRUCKS
F8. 4 OR LESS AXLE VEHICLES, ONE UNIT IS A TRUCK
F9. 5 AXLE DOUBLE UNIT VEHICLES, ONE UNIT IS A TRUCK
F10. 6 OR MORE AXLE DOUBLE UNIT VEHICLES, ONE UNIT IS A TRUCK
F11. 5 OR LESS AXLE MULTI-UNIT TRUCKS
F12. 6 AXLE MULTI-UNIT TRUCKS
F13. 7 OR MORE AXLE MULTI-UNIT TRUCKS

* INCLUDING THOSE HAULING TRAILERS

FUNCTIONAL CLASS CODES:

RURAL	URBAN	SYSTEM
01	11	PRINCIPAL ARTERIAL-INTERSTATE
02	12	PRINCIPAL ARTERIAL-EXPRESSWAY
02	14	PRINCIPAL ARTERIAL-OTHER
06	16	MINOR ARTERIAL
07	17	MAJOR COLLECTOR
08	17	MINOR COLLECTOR
09	19	LOCAL SYSTEM

DIRECTION CODES:

1. NORTH
3. EAST
5. SOUTH
7. WEST

SOURCE: NYSDOT DATA SERVICES BUREAU

APPENDIX B. ROUTE 144 TRAFFIC DATA FOR AUGUST 1992

ROUTE: 144
COUNTY NAME: ALBANY
REGION CODE: 1
LOCATION: BETWEEN ACC 871
AND RT 910A GLENMONT
REF-MARKER: 144 11011056
END MILEPOINT: 0211032
FUNC-CLASS: 16
HPMS NO: 00000000
STATION NO. 061

YEAR: 1992
MONTH: AUGUST

NO. OF LANES: 2
DDHV: 259
AADT: 4245

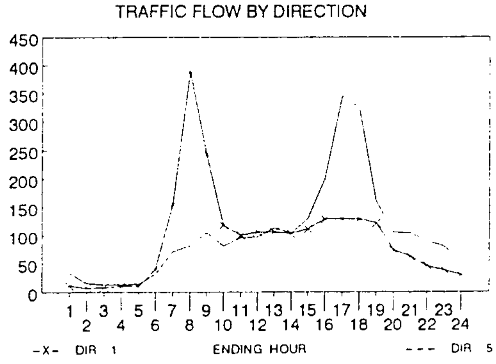
AVERAGE WEEKDAY DATA

I.D. # 11061

DIRECTION CODE	1	5	TOTAL
NUMBER OF VEHICLES	2278	2459	4737
NUMBER OF AXLES	4962	5276	10238
% HEAVY VEHICLES (F4 – F13)	7.64%	6.87%	7.24%
% TRUCKS AND BUSES (F3 – F13)	21.03%	20.46%	20.73%
AXLE CORRECTION FACTOR	0.92	0.93	0.93

	VEHICLE CLASS	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	TOTAL
	NO. OF AXLES	2	2	2	2 5	2	3	4	3 5	5	6	5	6	8 75	
ENDING HOUR	1:00	0	8	1	0	0	0	0	0	2	0	0	0	0	11
	2.00	0	3	2	0	0	0	0	0	2	0	0	0	0	7
	3:00	0	5	1	0	0	0	0	0	2	0	0	0	0	8
	4:00	0	6	2	0	0	0	0	0	2	0	0	0	0	10
	5:00	0	5	2	0	0	0	0	0	3	0	0	0	0	10
	6.00	0	33	7	0	0	0	0	0	1	0	0	0	0	41
	7:00	0	111	36	0	1	1	0	1	4	0	0	0	0	154
	8:00	2	331	44	1	0	2	0	4	5	0	0	0	0	389
	9:00	0	214	20	0	1	1	0	2	5	0	0	0	0	243
	10:00	0	93	16	1	1	2	1	0	4	0	0	0	0	118
DIRECTION	11.00	1	71	14	0	2	3	1	2	6	0	0	0	0	100
1	12.00	0	78	17	0	1	2	0.	1	6	1	0	0	0	106
	13 00	0	80	11	0	2	2	0	0	10	1	0	0	0	106
	14:00	1	77	16	0	0	1	0	1	7	0	0	0	0	103
	15 00	0	80	20	0	1	1	0	0	7	2	0	0	0	111
	16 00	1	98	17	0	2	3	0	1	7	0	0	0	0	129
	17:00	1	102	16	0	2	2	0	1	4	1	0	0	0	129
	18 00	0	100	17	0	0	4	0	0	8	0	0	0	0	129
	19.00	1	100	14	0	0	2	0	1	4	0	0	0	0	122
	20.00	2	58	10	0	0	0	0	1	3	0	0	0	0	74
	21 00	1	51	7	0	0	0	0	0	4	0	0	0	0	63
	22:00	1	35	5	0	0	0	0	0	4	1	0	0	0	46
	23 00	0	28	5	0	0	1	0	0	5	0	0	0	0	39
	24 00	1	20	5	0	0	0	0	0	4	0	0	0	0	30
TOTAL VEHICLES		12	1787	305	2	13	27	2	15	109	6	0	0	0	2278
TOTAL AXLES		24	3574	610	5	26	81	8	53	545	36	0	0	0	4962
ENDING HOUR	1:00	0	27	4	0	0	0	0	0	2	0	0	0	0	33
	2 00	0	13	1	0	0	0	0	0	2	0	0	0	0	16
	3 00	0	8	0	0	0	0	0	0	5	0	0	0	0	13
	4 00	0	4	1	1	0	0	0	0	7	0	0	0	0	13
	5.00	0	4	1	0	0	0	0	0	9	0	0	0	0	14
	6 00	0	13	8	0	0	1	0	1	8	1	0	0	0	32
	7:00	0	46	15	0	1	2	0	0	7	0	0	0	0	71
	8:00	0	60	12	0	1	2	0	0	6	0	0	0	0	81
	9 00	2	76	15	0	2	3	0	1	5	1	0	0	0	105
	10 00	0	57	13	0	1	5	0	1	3	1	0	0	0	81
DIRECTION	11.00	0	68	16	1	3	2	0	1	5	0	0	0	0	96
5	12 00	0	71	15	0	2	2	0	1	5	1	0	0	0	97
	13 00	0	87	20	0	2	1	0	0	3	0	0	0	0	113
	14 00	0	78	19	0	1	3	0	0	3	0	0	0	0	104
	15 00	1	98	22	0	2	2	0	0	4	0	0	0	0	129
	16 00	0	159	32	0	2	2	1	2	2	0	0	0	0	200
	17.00	1	299	36	0	2	1	0	3	4	0	0	0	0	346
	18:00	2	285	27	1	0	3	0	4	2	0	0	0	0	324
	19 00	0	130	26	0	1	2	0	0	1	0	0	0	0	160
	20 00	0	88	13	0	0	0	0	1	3	0	0	0	0	105
	21:00	0	93	10	0	0	0	0	0	1	0	0	0	0	104
	22:00	0	78	10	0	0	0	0	0	2	0	0	0	0	90
	23 00	1	66	10	0	0	0	0	0	3	0	0	0	0	80
	24 00	0	41	8	0	0	0	0	0	3	0	0	0	0	52
TOTAL VEHICLES		7	1949	334	3	20	31	1	15	95	4	0	0	0	2459
TOTAL AXLES		14	3898	668	8	40	93	4	53	475	24	0	0	0	5276
GRAND TOTAL VEHICLES		19	3736	639	5	33	58	3	30	204	10	0	0	0	4737
GRAND TOTAL AXLES		38	7472	1278	13	66	174	12	105	1020	60	0	0	0	10238

TRAFFIC FLOW BY DIRECTION



PEAK HOUR DATA

DIRECTION	HOUR	COUNT	2-WAY	HOUR	COUNT
1	8	389	A M	8	470
5	17	346	P.M	17	475

FG 30
DATE 05

VEHICLE CLASSIFICATION CODES:

- F1. MOTORCYCLES
- F2 AUTOS *
- F3 2 AXLE, 4-TIRE PICKUPS, VANS, MOTORHOMES *
- F4 BUSES
- F5 2 AXLE, 6-TIRE SINGLE UNIT TRUCKS
- F6. 3 AXLE SINGLE UNIT TRUCKS
- F7. 4 OR MORE AXLE SINGLE UNIT TRUCKS
- F8 4 OR LESS AXLE VEHICLES, ONE UNIT IS A TRUCK
- F9. 5 AXLE DOUBLE UNIT VEHICLES, ONE UNIT IS A TRUCK
- F10 6 OR MORE AXLE DOUBLE UNIT VEHICLES, ONE UNIT IS A TRUCK
- F11 5 OR LESS AXLE MULTI-UNIT TRUCKS
- F12 6 AXLE MULTI-UNIT TRUCKS
- F13 7 OR MORE AXLE MULTI-UNIT TRUCKS

* INCLUDING THOSE HAULING TRAILERS

FUNCTIONAL CLASS CODES:

RURAL	URBAN	SYSTEM
01	11	PRINCIPAL ARTERIAL-INTERSTATE
02	12	PRINCIPAL ARTERIAL-EXPRESSWAY
02	14	PRINCIPAL ARTERIAL-OTHER
06	16	MINOR ARTERIAL
07	17	MAJOR COLLECTOR
08	17	MINOR COLLECTOR
09	19	LOCAL SYSTEM

DIRECTION CODES

1 NORTH
3 EAST
5 SOUTH
7 WEST

SOURCE NYSDOT
DATA SERVICES BUREAU