Research Project # 2003-053
Evaluation of Post – Consumer Shingles in HMA

Final Report
November 2009

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Evaluations and Research Section
Engineering Technology and Information Division
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16. Abstract

This research project was to evaluate pulverized post-consumer roofing shingles, as a replacement for a percentage of virgin asphalt cement in hot mixed asphalt. This study was to determine if post-consumer shingles has a beneficial use in hot mixed asphalt (HMA). The Superpave mixture contained 5 % by weight post consumer shingles, which replaced 1.3% of the PG 64-22 virgin asphalt used in this mix design. The results of the preliminary laboratory testing by Materials Testing Division (MTD) revealed that the asphalt binder recovered from the shingles was extremely stiff, and demonstrated an elevated "melting" point. This raised the concern that the binder would not effectively coat aggregate during HMA production, and may not blend significantly with the virgin binder. Based on the results, MTD recommended the use of the performance graded asphalt cement PG 64-22 as the virgin binder.

The performance of the HMA with post-consumer shingles as an additive was unsatisfactory based on the results of the pavement that started to deteriorate within a year and a half after placement. The wearing surface was losing fines, which provides additional proof that the shingle material did not completely coat the aggregate in the bituminous mix.

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Post-Consumer Shingles, Hot Mixed Asphalt, Recycle, Roofing Shingles

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DISCLAIMER

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METRIC CONVERSION FACTORS		
Convert From	**To**	**Multiply By**
Length		
Foot	Meter (M)	0.3048
Inch	Millimeter (mm)	25.4
Yard	Meter (M)	0.9144
Mile (Statute)	Kilometer(KM)	1.609
Area		
Square Foot	Square Meter (M^2)	0.0929
Square Inch	Square Centimeter (CM^2)	6.451
Square Yard	Square Meter(M^2)	0.8361
Volume		
Cubic Foot	Cubic Meter (M^3)	0.02832
Gallon (U.S. Liquid)	Cubic Meter (M^3)	0.003785
Gallon (CAN. Liquid)	Cubic Meter (M^3)	0.004646
Ounce (U.S. Liquid)	Cubic Centimeter (CM^3)	29.57
Mass		
Ounce-Mass (AVDP)	Gram(G)	28.35
Pound-Mass (ADVP)	Kilogram (KG)	0.4536
Ton (Metric)	Kilogram (KG)	1,000
Ton (Short, 2,000 LBM)	Kilogram (KG)	907.2
Density		
Pound-Mass/Cubic Foot	Kilogram/Cubic Meter (KG/M^3)	16.02
Mass/Cubic Foot	Kilogram/Cubic Meter (KG/M^3)	0.5933
Pound-Mass/Gallon (U.S.)	Kilogram/Cubic Meter (KG/M^3)	119.8
Pound-Mass/Gallon (CAN)	Kilogram/Cubic Meter (KG/M^3)	99.78
Temperature		
Degree Celsius (C)	Kelvin (K)	$T_K = (T_C + 273.15)$
Degree Fahrenheit (F)	Kelvin (K)	$T_K = (T_F + 459.67)/1.8$
Degree Fahrenheit (F)	Degree Celsius (C)	$T_C = (T_F - 32)/1.8$
Illumination		
Foot-Candles	Lux (LX)	10.76
Foot-Lamberts	Candela/Meter sq. (CD/M^2)	3.426
Force and Pressure or Stress		
Pound-Force	Newton (N)	4.45
Pound-Force/sq. in.	Kilopascals (KPA)	6.89

EXECUTIVE SUMMARY

This research project was to evaluate pulverized post-consumer roofing shingles, a building construction waste product from Delaware Valley Recycling as a replacement for a percentage of virgin asphalt cement in hot mixed asphalt. This study was to determine if post-consumer shingles has a beneficial use in hot mixed asphalt (HMA). The Superpave mixture contained 5% by weight post-consumer shingles, which replaced 1.3% of the PG 64-22 virgin asphalt used in this mix design.

The project was divided into two areas. The first area was paved with a Superpave, HMA Wearing Course, PG 64-22, 0.3 to <3 M ESALS, 9.5mm Mix, SRL-H (Control Mix A). The second area of the project was paved with Superpave HMA Wearing Course, PG 64-22, 0.3 to <3 M ESALS, 9.5mm Mix, SRL-H (Experimental Mix B) with 5% pulverized post-consumer bituminous mix.

The results of the preliminary laboratory testing by MTD revealed that the asphalt binder recovered from the shingles was extremely stiff and demonstrated an elevated "melting" point. Specifically, the binder had to be heated to 180 - 190°C (355-375°F) in order to properly mold the test specimens. This raised the concern that the binder would not effectively coat aggregate during HMA production, and may not blend significantly with the virgin binder. Based on these results, the MTD of the Bureau of Construction and Materials recommended the use of the performance graded asphalt cement PG 64-22 as the virgin binder. The post-consumer shingles were to act more like asphalt coated sand than an actual asphalt cement binder in the HMA.

Due to the extremely high melting point [180 – 190°C (355 – 375°F)] of the asphalt cement binder from the post-consumer shingles (see Table 1), it was doubtful that the pulverized shingles material would actually coat the aggregate in the bituminous mix. Therefore, the amount of binder contributed by the asphalt shingles was lower than expected. This reduction in the asphalt cement film coating the stone would allow this mix to deteriorate faster, thus resulting in poor pavement performance over time. This means the design life of the pavement was compromised due to the post consumer shingles additive.

Based on this research, post-consumer shingles are not recommended for approval as a HMA recycled additive. The performance of the HMA with post- consumer shingles as an additive was unsatisfactory because the pavement started to deteriorate within a year and a half after placement. The wearing surface was losing fines, which provides additional proof that the shingle material did not completely coat the aggregate in the bituminous mix. There were also contaminants found in the HMA mix during construction and at the annual field reviews.

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INTRODUCTION

Manufacturer's shingle tabs have proven to be a recyclable product useful in hot mix asphalt (HMA) as the Department determined in a study performed in 1991. Approximately 10 million metric tons of asphalt roofing shingle scrap are generated annually in the United States. Post-consumer shingles make up 90-95% of this amount (FHWA, 1998). These shingles vary in composition as the specified life and application of the shingle varies. Components of asphalt shingles are presented in Table 1 (Newcomb et al., 1993).

Table 1, Components of Asphalt Shingles (Newcomb et al., 1993)

Component	Amount by Weight (%)	Notes
Asphalt Cement	25 – 35	Saturant or coating
Granular Material	60 – 70	Ceramic and headlap granules Backsurfacer sand Asphalt stabilizer
Backing	5 – 15	Cellulose or glass felt

Post-consumer shingles are shingles that have been used on a roof and vary in composition due to degradation. Because of their varying composition and the presence of undesirable materials (nails, etc), it is not recommended or beneficial to re-use post-consumer shingles. For this reason, post-consumer shingles have always been avoided because of the fear of contamination of nails/ debris/asbestos and uncontrolled asphalt contents of the shingle themselves. Most use of asbestos was stopped in the early 1970's for manufactured commercial shingles. EPA testing of recycled shingles has shown acceptable levels of asbestos are present. Post-consumer shingles have been used in parking lots and driveways because of the cost savings incurred by the addition of AC and fibers.

Generally, the land fill of post-consumer shingles could be considered a large waste of a valuable source of a HMA recycled additive. Unfortunately, the pulverized post-consumer shingle material has inconsistent asphalt content depending on the type of shingle, a 15, 20, 25, or 30 year asphalt shingle. Each of these shingle types have aged or oxidized differently due to service life in varying environmental conditions. The mix design needs to be adjusted for the variability of asphalt content in the recycled shingles along with other contaminants.

From the report **"Influence of Roofing Shingles on Asphalt Concrete Mixture Properties", Newcomb, et al., 1993**, it provides documentation on the maximum allowable amount of post-consumer shingles by weight in an HMA mixture design. The report finds for minimum impact on the properties of the asphalt concrete mixture that up to 5% by weight of mixture is manufacturing waste roofing shingles. A noticeable softening of the mixture occurs with 7.5% by weight of mixture. Post-consumer shingles used on projects resulted in the embrittlement of the mixture which may be undesirable for low temperature cracking of pavements. The manufactured shingle waste seems to work well in stone mastic asphalt (SMA) mixtures."

This research study was the first time PENNDOT has evaluated post-consumer shingles in hot mix asphalt. A previous study **RP 91-77 Reclaimed Manufacturer Asphalt Roofing Shingles in Asphalt Mixtures, Final Report, April 1999, by Andrew B. Reed, P.E.** resulted in the approval of shredded manufactured shingles (pre-consumer shingles) as an additive for the Department's mixture designs. These shingles were new and recycled because they did not meet the manufacturer's specification for color or they were shingle tabs.

The economics and approval of using post-consumer shingles in HMA must be based on performance and beneficial use. The addition of post-consumer shingles to HMA must meet or exceed current or existing performance standards. Production costs of shredded reclaimed roofing materials are estimated at approximately $8.82 to $21.00 per metric ton. Extra costs can be offset by savings in virgin asphalt cement. In addition, extra costs may be offset by increased asphalt pavement performance, which equates to lower maintenance costs and increased life cycle of the asphalt pavement.

PROJECT SUMMARY

The prime contractor on this bituminous paving project was Blooming Glen, an affiliate of Haines and Kibblehouse (H&K), Inc. H&K Inc. initiated this study by requesting that pulverized post-consumer shingles be allowed as an additive or asphalt substitute on a demonstration project. The post-consumer shingles supplied for this study were provided by Delaware Valley Recycling that was capable of processing the shingles to ensure they were ground to a uniform size and were of good quality. The asphalt plant increased the mixing time slightly to allow the pulverized shingles to disperse well into the batched bituminous paving mixture. This action was justified by the initial lab results presented in **RP 2003-053 Post-Consumer Shingles in HMA, Construction Report, October 2005, by John J. Hughs, P.E. & Matthew Sypolt** under Appendix A.

Engineering District 6-0 was willing to place this recycled product in a PG 64-22, 9.5 mm Superpave mix. The test section was located in Bucks County on SR 4033, Upper Ridge Road (Figure 1) between segment 0060 offset 4241 to segment 120 offset 2248. On SR 4033 the ADT is 2,241 with 9% truck traffic and a speed limit of 40 mph. The distribution of the 3,300 tons of HMA was addressed below in the plan of study (Table 2).

The project began in early August 2003 and ran through November 2003 as an HMA base repair and a bituminous wearing overlay with 1.5-inch depth.

The Research Project Location

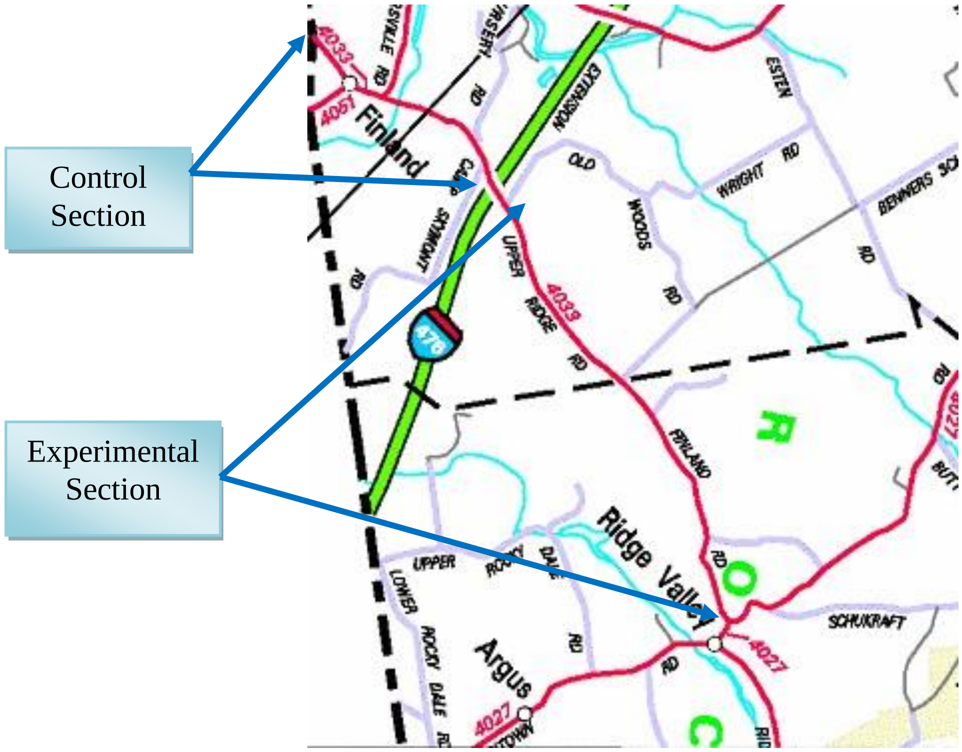

Figure 1, Research Project Location
District 6-0 – Bucks County SR 4033

Table 2, Plan Material Quantities for the Surface Treatment Project

Mix Numbers	Mixes	Units
512 / 513	25.0 mm .3-3 PG 64-22 Base 5"	1,200 Tons
216 / 217	**Control Mix A and Experimental Mix B**	**3,300 Tons**
226 / 227	9.5mm .3 – 3 SRL-H Leveling PG 64-22	500 Tons
	Milling – Variable depth	40,000 S.Y.

A Superpave 9.5 mm with a PG 64-22 was specified for this project. The approval to use the post-consumer shingles binder additive to this mix was based on the additive meeting the criteria that properties must meet or exceed the PG 64-22 binder grading. Two mixes were placed: A Control Mix A with virgin AC (~1300 Tons), and a Experimental Mix B using 5% post-consumer shredded recycled shingles (~2000 Tons). The Materials Testing Division verified the mix designs through lab testing.

Engineering District 6-0 and the Engineering Technology and Information Division monitored construction and construction samples were sent back to the Materials Testing Division for recovery testing. The areas of different mix designs were delineated by placards by Engineering District 6-0 to show beginning and endings of pavement sections. The duration of the study was 5 years. A visual distress study was made annually.

The general condition of the existing bituminous road on SR 4033 indicated that it was in need of extensive base repair and drainage upgrades. The road in the south bound direction was in much worse shape with more extensive base failure than the north bound direction.

CONSTRUCTION SUMMARY

Prior to placing the Superpave wearing course, all areas of the existing pavement that were showing signs of alligator cracking or base failure were repaired by milling the existing asphalt from the road and filling the hole with new asphalt. This method of base repair was performed by milling designated areas as directed down to a 2-inch depth and the milled material is replaced with a 9.5mm bituminous mix and compacted. This operation was performed over the entire length of the project.

Apparently some of the base repair areas that were repaired in this mill and fill manner had failed prior to the start of paving operations. These failed areas were replaced with full depth base repair of either BCBC or 25mm bituminous mix and compacted. The geometry of Upper Ridge Road was as curvy as it was hilly. This resulted in some of the existing pavement areas exhibiting edge break off or deterioration on curves. These areas were also repaired prior to starting the wearing course operation. These repair operations were noted to clarify the fact that every precaution was taken to ensure that the underlying road base would not be responsible for any future potential failures in the wearing course during the five year study of the Experimental Mix B.

The initial laboratory testing performed to develop a proper mixture design revealed that the asphalt recovered from the pulverized shingles sample was extremely stiff, and demonstrated an elevated melting point. Specifically, the binder had to be heated to 180 – 190°C (355 – 375°F) in order to properly mold test specimens. This data raises the concern that the binder may not effectively coat aggregate during HMA production, and may not blend significantly with the virgin binder. Based on these tests results, the lab recommends the use of the PG 64-22 virgin asphalt. Therefore the 5% post consumer shingles admixture could be considered as aggregate filler to the HMA. The asphalt in the shingles was rated as a PG 88(+) +3 and will replace 1.3% of the PG 64-22 asphalt in the Superpave mixture.

Photo 1, The pulverized shingles were stockpiled at the H&K, Bechelsville Plant under roof. The material resembled coarse black sand.

The stockpiled pulverized shingle material looked like coarse black sand (Photo 1). The consultant construction inspection staff from Site Engineers was briefed on what to expect that was different with this experimental asphalt shingles mix:

- It may be a hotter mix due to increased mixing time
- Ensure drums on rollers are wet prior to rolling the shingles mix because it may pick up.
- Mix may be stiffer to work with than conventional bituminous mixes

The paving operation for the project began around noon on **Friday, October 31, 2003**. The Experimental Mix B was to be placed in the afternoon. However due to a break down at the asphalt plant in Bechelsville only 200 tons of the shingles mix was produced. Due to the insufficient quantity of bituminous shingles material produced none of the shingles mix was placed. Instead the contractor placed 451 ton of 1.5-inch depth of the Control Mix A (Temperature: 320ºF at the plant). This Virgin Mix material was placed between Station 99+48 and Station 124+52.

On **Monday, November 3, 2003** the paving operation resumed and the contractor started placement of 272.43 tons of 1.5-inch depth of the Experimental Mix B. This material was placed in Lot 1 between Stations 84+48 to 97+86. The odor of the shingles mix was different than the conventional asphalt mix. The contractor also placed 507.73 tons of 1.5-inch depth of the Control Mix A in Lot 2, between Station 99+48 to Station 124+52.

On **Tuesday, November 4, 2003** the paving operation continued but there was a problem at the plant when Experimental Mix B was tested. The asphalt plant laboratory testing indicated that the voids in the batched asphalt mixture were low. This problem was indicative of either too much asphalt or too many fines. The plant operators took unauthorized corrective action and made adjustments to the mixture, during batching operations. The amount of asphalt in the mixture was reduced. Further testing by MTD of the cores indicated that the fines passing #200 sieve was high. After this asphalt adjustment was made, 685.55 tons of the Experimental Mix B was placed in Lot 2, between Station 46+60 and Station 84+48. Then it was determined from the cores taken that day that the asphalt content was low. This resulted in the contractor being penalized for the asphalt being out of compliance with the approved mixture design. As a result of the penalty the contractor only received 75% pay for this day’s production. Paving operations were also shut down until corrective action was taken by the asphalt plant to ensure that the air voids and deficient asphalt content problems were properly addressed.

Paving operations on Upper Ridge Road did not resume again until **Monday, November 17, 2003**. Paving began at 10:00AM several truck loads of asphalt were rejected due to high temperatures.

On the first day of paving, the project inspection staff was advised to ensure that the drums on rollers were wet prior to getting on the shingles mix because it may pick up. During placement of the 4th load of the Experimental Mix B the break down roller began picking up the asphalt (Photo 2) due to a dry spot on the drum (Photo 3). This was the first time that this incident was observed. The contractor took immediate action to correct the problem. The drum was scraped clean and ample water distribution to the drum was restored.

Photo 2, The dry areas on the roller drum picked up the 9.5mm Superpave mix with 5% pulverized shingles material.

Photo 3, The marred surface of the pavement mat.

The mat of the placed Experimental Mix B appeared to look like a dry mixture, as exhibited by Photo 4 and Photo 5, note the open texture.

Photo 4, Before compaction pavement mat.

Photo 5, After compaction pavement mat.

About 12:30PM the contractor returned to the starting point of the day's paving operation to begin placing HMA material on the opposite side of the road. By the end of the day's paving operation 528.07

tons of 1.5-inch depth of the Experimental Mix B was placed in Lot 3, between Station 46+60 and Station 84+48.

As noted earlier, the Experimental Mix B has a much stronger smell than the conventional Control Mix A. For this reason it was proposed by one of the suppliers that an asphalt deodorizer be used. However no asphalt deodorizer was used on this project.

The workability of the Experimental Mix B was affected because the shingles mix was much stiffer to work with and not as easy to shape with a lute as the Control Mix A. This was evident when the contractor's laborers adjusted driveways with the shingle mix to meet the edge of the new pavement. The stronger odor and the more difficult workability of the shingles asphalt mix may have an effect on commercial sales of this material.

The asphalt content of the Control Mix A was 6.4%. The asphalt content of Experimental Mix B was 6.1%; the asphalt from the pulverized post consumer shingles added to the mixture was supposed to augment the Asphalt Cement (AC) in this job mix formula (JMF).

The consultant field inspectors discovered scraps of rubber roofing membrane (Photo 6) in the mat after the asphalt was placed. Additional pieces of this rubber roofing membrane material were observed in the loaded bed of the dump truck carrying the shingles mix. These scraps of shredded rubber did not meet H&K's own specification for the shingles material regarding both size (gradation) and material composition. The scraps of rubber roofing membrane were a contaminant to the bituminous mix.

Photo 6, Pieces of shredded roofing membrane contaminant is removed during the paving operation.

The final day of paving was **Tuesday, November 18, 2003**; 341.36 tons of the Experimental Mix B was placed.

Table 3 contains information pertaining to the date the material was placed, area, tonnage, locations and mixture type. Table 4 provided the bituminous paving summary in tons per day.

Table 3, Pavement Area Designations, Dimensions and Calculations (SY)

AREA	REMARKS	LENGTH (ft.)	WIDTH (ft.)	Square Yards
A	11-18-03 341.36 Tons Exp. Mix B	**65.00**	**½(57.00+26.00)**	**299.72**
B		**1,640.00**	**23.00**	**4191.11**
C		**295.00**	**22.00**	**721.11**
D	11-17-03 528.07 Tons Exp. Mix B	**1,500.00**	**21.00**	**3,500.00**
E		**1,000.00**	**19.00**	**2,111.11**
F		**1,000.00**	**20.00**	**2,222.22**
G	11-04-03 685.55 Tons Exp. Mix B	**3,000.00**	**19.00**	**6,333.33**
H	11-03-03 272.43 Tons Exp. Mix B	**500.00**	**20.00**	**1,111.11**
I		**786.00**	**22.0**	**1,921.33**
J		**N0 PAVING**		
K	11-03-03 507.73 Tons Control Mix A	**52.00**	**28.00**	**161.78**
L		**2,000.00**	**20.00**	**4,444.44**
M		**452.00**	**22.00**	**1,104.89**
N		**N0 PAVING**		
O	10-31-03 444.31 Tons Control Mix A	**429.00**	**24.00**	**1,144.00**
P		**1,000.00**	**21.00**	**2,333.33**
Q		**717.00**	**19.00**	**1,513.67**
R		**70.00**	**24.00**	**186.67**
1.	11-03-03 Exp. Mix B	**99.00**	**4.00**	**44.0**
2.	10-31-03 Control Mix A	**62.00**	**4.0**	**27.56**
3.		**115.00**	**6.00**	**76.67**
				TOTAL = 33,448.05 S.Y.

Table 4, Bituminous Paving Summary

SR 4033, UPPER RIDGE ROAD, BUCK COUNTY PAVING SUMMARY WEARING COURSE			
DATE	**BITUMINOUS MIXTURE TYPE**	**TONS**	**REMARKS**
10-31-03	Control Mix A	**444.31**	**LOT#1**
11-03-03	Control Mix A	**507.73**	**LOT#2**
11-03-03	Experimental Mix B	**272.43**	**LOT#1**
11-04-03	Experimental Mix B	**685.55**	**LOT#2 75% PAY "Corrective Action is Necessary"**
11-17-03	Experimental Mix B	**528.07**	**LOT#3**
11-18-03	Experimental Mix B	**341.36**	**LOT#4**
TOTAL TONS = 2,779.45 Tons			
Control Mix A= **952.04 Tons**			
Experimental Mix B = **1,827.41 Tons**			
Note: Entire roadway was binder leveled with 19mm 0.3 to 3 "E" (Average Yield 200 lbs/SY). A second lift of 19mm was used on Left Side from Station 19+00 to 60+00 for edge build-up.			

The research project diagram (Figure 2 and Figure 3 - continued) gives dimensions, dates, area designations, stations and mixture locations of material placed on the entire project.

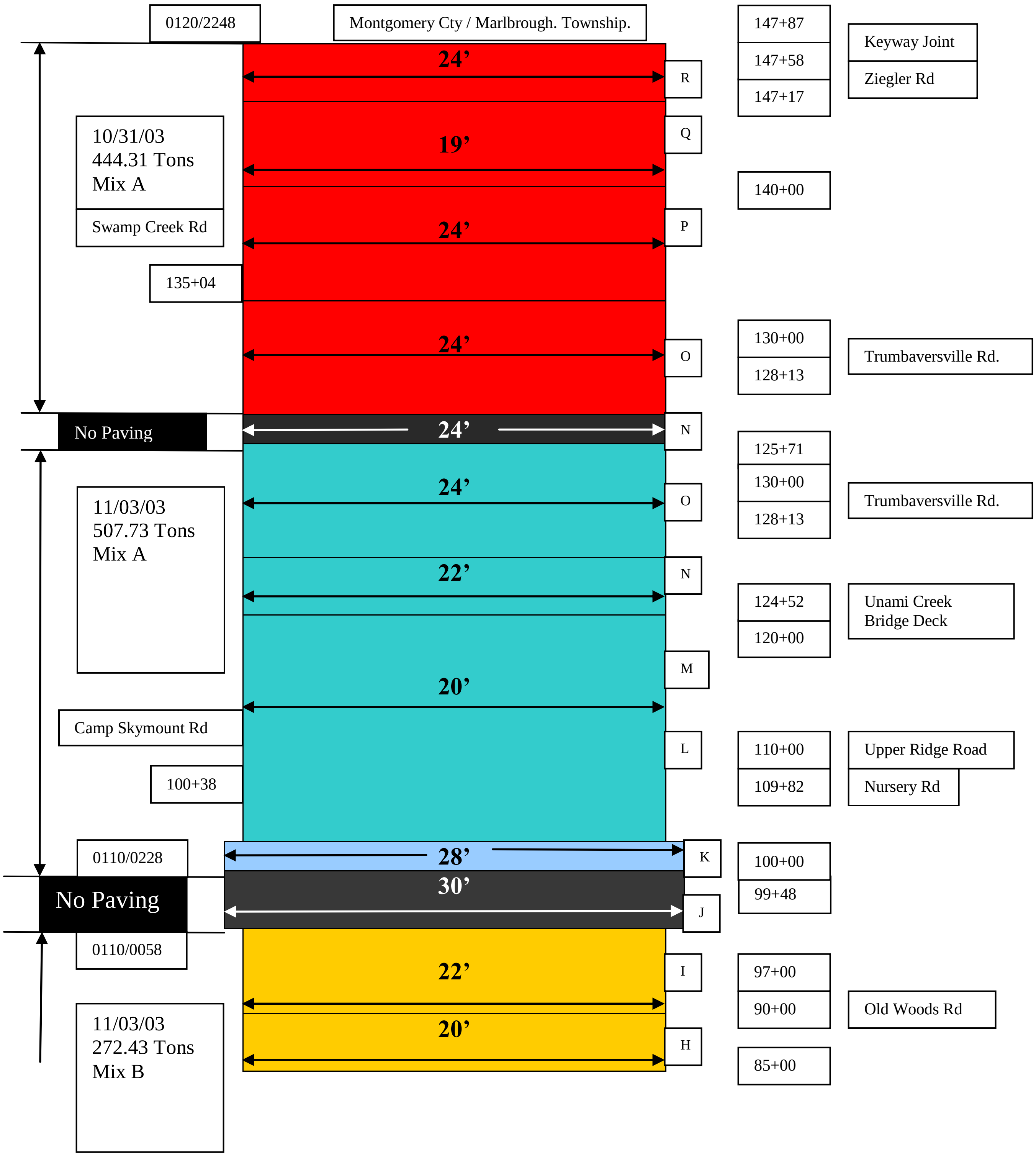

Figure 2, Research Project Diagram

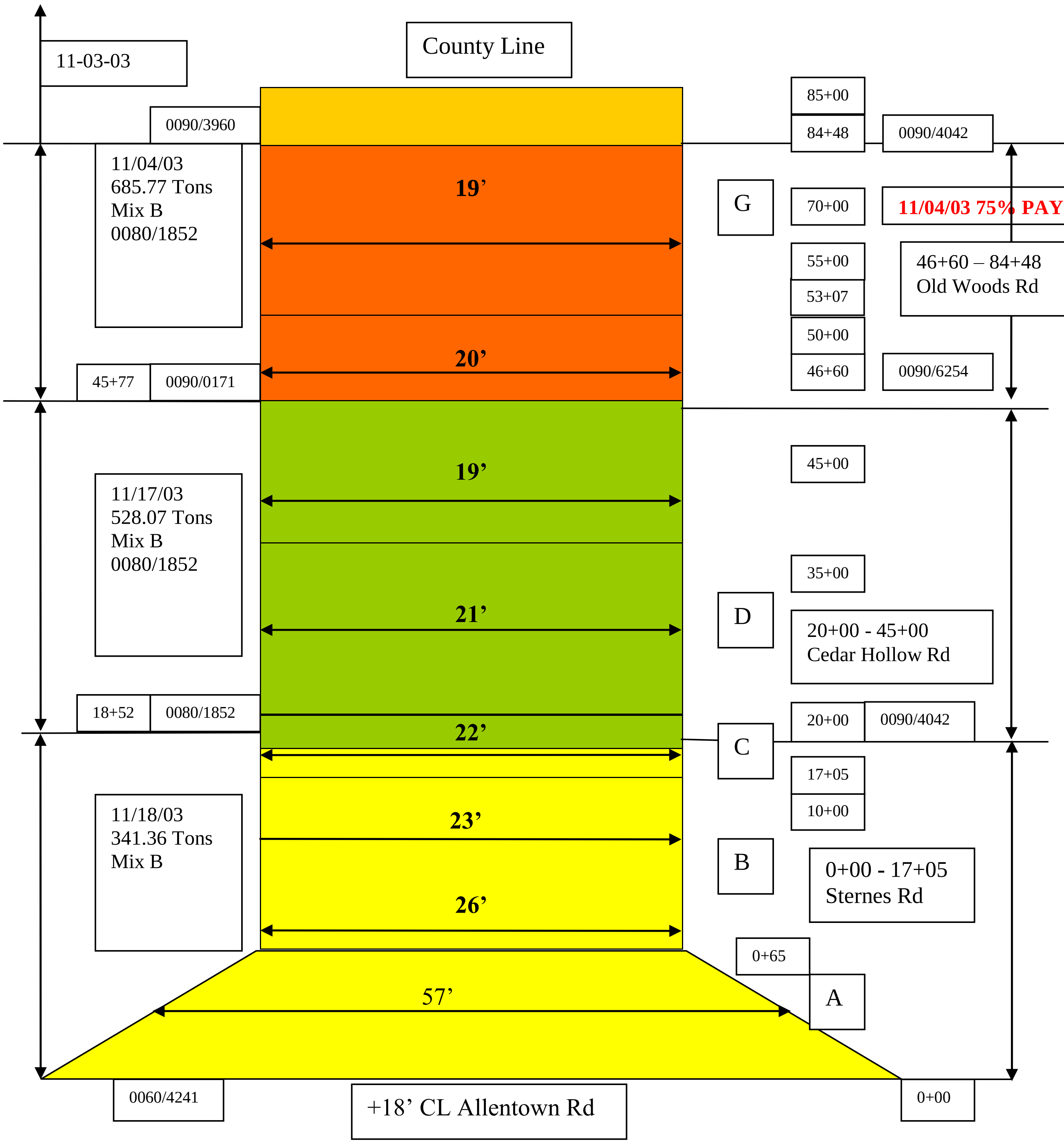

Figure 3, Research Project Diagram (continued)

FIELD PERFORMANCE

April 2004

The photographs shown were taken (April 29, 2004) 5 months after placement of the asphalt pavement with the 5% post-consumer shingles. A concern of using post-consumer shingles was contaminates in the shingles that would jeopardize the quality of the pavement. A sample of shredded roofing membrane (Photo 7) was protruding from the finished pavement on the research section of the project.

Photo 7, Shredded roofing membrane protruding from the finished roadway.

The research section that was paved on the last day appears to be raveling (Photo 8) when compared to the control section of the project. This means the asphalt surface of the roadway was starting to lose aggregate.

Photo 8, The asphalt road surface of the experimental section appeared to be raveling.

Apparently a vehicle accelerating from Finland Road (Upper Ridge Road) onto Allentown Road peeled back the asphalt mat, note the tears (Photo 9).

Photo 9, Peeled back asphalt mat at the intersection of Allentown Road and Finland Road.

May 2005

The field review 1 year and 6 months (May 26, 2005) after placement of the pavement found pock marks in the road surface. The wearing surface appeared to be losing fines, which is additional evidence that the asphalt did not mix adequately with the aggregate. Some areas of the road were in distress and had to be patched. The patches were located along the outside edge of the roadway. The road surface at the leading and trailing edge of the patch continued to alligator crack and deteriorate further. During the field review, contaminants continue to be found in the surface of the roadway.

April 2006

The field review 2 years and 5 months (April 28, 2006) after placement of the pavement found continued distress of the pavement in the research section. Photo 10 shows one of the distressed pavement areas that needed to be patched.

Photo 10, Distressed pavement needed to be patched.

The quality control of the post-consumer shingles was a problem based on the amount of roofing membrane (Photo 11) and other contaminants (Photo 12) found protruding from the pavement. According to specification, the particle size of the grounded post-consumer shingles was to be less than three-eights of an inch (3/8-in.). The ground post-consumer shingles did not meet specifications, since most of the contaminants discovered were larger than three-eights of an inch.

Photo 11, Shredded roofing membrane protruding from the finished roadway.

Photo 12, Contaminant in the surface of the pavement.

December 2007

The field review 4 years (December 21, 2007) after placement of the pavement shows distress with a section of pavement with transverse cracking (Photo 13). Photo 14 shows continued deterioration with the pavement exhibiting alligator cracking and rutting.

Photo 13, The pavement is exhibiting transverse cracking.

Photo 14, The pavement has additional alligator cracking and rutting.

CONCLUSIONS

The early deterioration of the pavement and loss of aggregate is confirmation that the binder did not adequately coat the aggregate.

Using relatively small quantities of recycled asphalt shingles can be detrimental on asphalt pavement performance. In this study it was observed that 5% of asphalt shingles dramatically reduced the pavement life compared to the control sections.

Quality control of the pulverized post-consumer shingles is also a contributing factor to the early decline of the pavement. The requirements for this project were that the particle size of the grounded post-consumer shingles was to be less than three-eighths of an inch (3/8-in.) The ground post-consumer shingles did not meet specifications, since most of the contaminants discovered were larger than three-eights of an inch. An allowable amount of contaminants in the processed post consumer shingles must be determined before further research is performed.

RECOMMENDATIONS

Post-consumer shingles are not recommended for approval as a HMA recycled additive. The wearing surface appeared to be losing fines early in the review of the project, which provides proof that the shingle material did not completely coat the aggregate in the bituminous mix. The contaminants found in the HMA also contribute to the low quality of the pavement and needs to be addressed before additional research is done.

Further research will be necessary to determine if post-consumer shingles will perform more successfully as coated sand rather than as an asphalt substitute. This premise is based on the preliminary performance and what was indicated from the results of the laboratory experiment reported in the RP **2003-053 Post-Consumer Shingles in HMA, Construction Report, October 2005, by John J. Hughes, P.E. & Matthew Sypolt** on pages 49 through 53 for the project. HMA suppliers with recycled shingles mixtures should also investigate improved mixing of the virgin PG binder with the recycled shingles.

REFERENCES

"Influence of Roofing Shingles on Asphalt Concrete Mixture Properties", Newcomb, et al., 1993

RP 91-77 Reclaimed Manufacturer Asphalt Roofing Shingles in Asphalt Mixtures, Final Report, April 1999, by Andrew B. Reed, P.E.

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Evaluation 1: HMA with Post-Consumer Asphalt Shingles and
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"Roofing Shingle Scrap, User Guidelines for Waste and By-Product Materials in Pavement Construction." Publication FHWA RD-97-148, Federal Highway Administration, McLean, Virginia, 1998.