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214

DEMONSTRATION PROJECT NO. 39

RECYCLING ASPHALT PAVEMENTS

Palm Beach County, Florida

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INITIAL REPORT

RECYCLING OF ASPHALT CONCRETE PAVEMENTS

Project No. 93610-3601

State Road 802, Palm Beach County

by

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Demonstration Projects Division
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January, 1980

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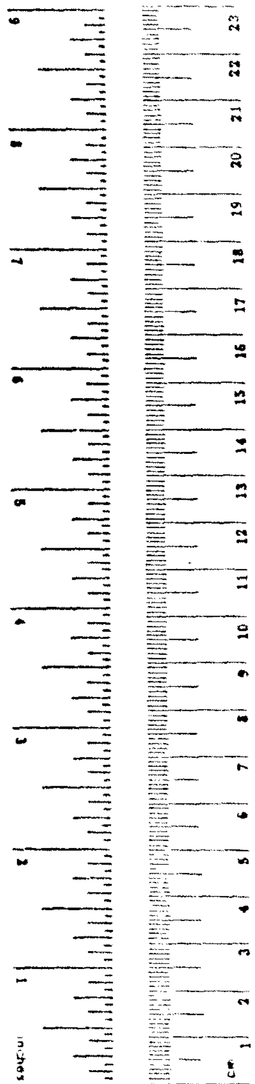
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

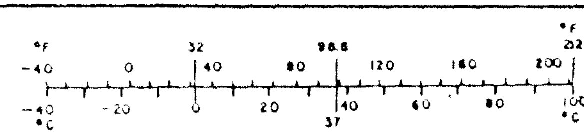
Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
	AREA			
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
	MASS (weight)			
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
	VOLUME			
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in ≡ 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
	AREA			
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
	MASS (weight)			
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
	VOLUME			
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
	TEMPERATURE (exact)			
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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ABSTRACT

This report covers the design and testing of a hot mix recycling project. The project involved the crushing and sizing of old pavement removed from an airport runway and the inclusion of this salvaged material in the production of a hot mixed asphalt concrete base course mixture. The mix was produced by a heat transfer method through a modified batch plant.

The field testing included condition surveys and post construction analyses of the paving mixture and pavement structure.

The initial results indicate an acceptable asphalt concrete mixture can be produced utilising the heat transfer method of production. Further field evaluations will be necessary in order to draw definite conclusions with regard to long-term pavement performance.

RECYCLING OF ASPHALT CONCRETE PAVEMENTS
Project No. 93610-3602
State Road 802, Palm Beach County

INTRODUCTION

Historically, rehabilitation of aged flexible pavements in the state of Florida has involved the placement of a leveling course and some form of asphalt overlay. In many cases, these improvements have also included removal of all or a portion of the existing pavement in order to preserve existing drainage facilities and height clearances.

More recently, the overlay program has included the removal of severely cracked pavement in order to eliminate structurally unsound asphalt concrete layers which result in the rapid appearance of reflective cracking. This removal of pavement results in the accumulation of rather significant quantities of salvaged asphalt concrete materials.

The advancements that have been made in recent years relative to improvements in equipment have made possible substantial advancements in the removal and reprocessing of these materials in order to make high-quality hot asphalt concrete mixtures. This study reports on the findings of Florida's first involvement in hot mix recycling.

In 1977, a proposal was made by Rubin Construction Company to the Department relative to the use of asphalt concrete materials that they had salvaged from a previous project. Their proposal involved the use of approximately 25 percent of this material in an asphalt concrete base course that they were constructing in Palm Beach County, Florida. The salvaged material had been previously removed from an old runway at Palm Beach International Airport. The salvaged material was to be processed and sized through a crusher at the contractor's plant site and then added from a separate cold bin which would by-pass the asphalt plant's dryer.

PURPOSE AND SCOPE

The primary purpose of this study was to evaluate the material characteristics, mix design, structural equivalency, and performance of the recycled pavement. Data was also collected regarding the cost effectiveness of this approach and the conservation of materials and energy as compared to an equivalent conventional method of construction.

PROJECT DESCRIPTION

The project selected for this study is located on Lake Worth Road (SR 802) in Palm Beach County, Florida (Figure 1) and consists of a four-lane curb and gutter section, 1.590 miles in length.

Work on the project included placement of a 7-inch recycled asphalt base course totaling approximately 28,000 tons, followed by a standard Department of Transportation Type S-1 surface course, 2-inches thick, totaling 8,240 tons, and a 5/8-inch open-graded friction course totaling 85,868 square yards.

CONSTRUCTION PROCEDURE

Processing of Salvaged Material

The old pavement material used in the asphalt base course was salvaged from an old runway at the Palm Beach International Airport. The old pavement was torn out by the contractor and stockpiled in large pieces near the asphalt plant (Figure 2). The material was then processed through a crusher, reducing the large pieces to approximately 1/4-inch to 1/2-inch particle size before recycling (Figure 3).

A five-ton capacity CMI batch plant was used to process the recycled material. The salvaged material could not be processed through the dryer because of pollution problems that would have been created; therefore, a separate cold bin and conveyor was set up to feed the old material directly to the hot elevator (Figures 4 and 5).

The salvaged material was combined with the hot virgin aggregates in the hot elevator. The virgin aggregates were heated to above normal temperatures in the dryer to provide adequate heat for transfer to the salvaged material during processing through the plant. A major portion of the heat transfer took place in the hot bins; however, the dry mixing time in the pugmill was extended for approximately 30 seconds to assure a uniform temperature prior to adding the new asphalt cement (AC-20). Wet mixing was then continued until the mixture was thoroughly coated.

Because of the heat transfer required for proper mixing, the amount of salvaged material that could be used in the recycled mix was somewhat limited. It was found that good results could be achieved at a normal production rate using a maximum of 25 percent of the old material.

Mix Design

Design of the recycled mixture consisted of blending new and old materials to provide the desired mixture and asphalt properties.

First, the aggregate gradation and asphalt content of the old crushed material was determined. Gradations were then established on coarse and fine aggregates available to the contractor for use in the mix.

It was determined that a blend of 15 percent crushed stone, 60 percent local shell, and 25 percent salvaged material would provide a gradation within the design gradation ranges specified for a standard Department of Transportation Type ABC-3 mixture.

Extraction tests indicated the asphalt content in the old material to be 6.0 percent; therefore, 1.5 percent of the total asphalt required in the recycled mix would be provided with the use of 25 percent old material. Based on previous experiences with materials of this type and gradation, it was assumed that the optimum asphalt content in the recycled mixture (including old and new asphalt) would range from 6.5 to 7.5 percent.

For the purpose of determining the optimum asphalt content, a limited amount of mix was processed through the plant with the addition of 5.0, 5.5, and 6.0 percent new asphalt. Plant operations were then ceased until Marshall properties were established from specimens compacted at each of the various asphalt contents. This was considered to be the most convenient and accurate method of design since complete Marshall design facilities were available at the plant site.

The design blend and Marshall mix properties of the recycled asphalt base course mixture are presented in Table 1.

The Abson method of recovery (FM 1-T 170)* was used to recover the asphalt cement from the old pavement material. The viscosity of the recovered asphalt was then determined to be 6,214 poises at 140°F.

Based on the low viscosity value obtained in the old material, it was believed that the addition of a standard viscosity grade AC-20 would provide adequate physical properties in the recycled mixture without the addition of a softening agent.

The design blend and Marshall design data for the Type S-1 asphalt concrete surface course is presented in Table 2. The mixture consists of 30 percent Florida Grade No. 15 crushed stone, 25 percent Florida Grade No. 16 crushed stone, 25 percent crushed stone screenings, and

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*Florida Department of Transportation test method designation.

20 percent local sand. The asphalt cement (AC-20) content was 6.5 percent by weight of the total mixture.

The design blend for the open-graded friction course (FC-2) is given in Table 3. The mixture consisted of 93 percent crushed stone (Miami oolite) and 7 percent local sand. The asphalt cement (AC-20) content was 6.5 percent by weight of the total mixture.

Plant Operations

After the design for the recycled mixture was established from the trial batches, plant operations were resumed. The average production rate when producing the recycled mix was approximately 140 tons per hour.

The relatively low production encountered on numerous days during processing of the recycled mix was attributed to blinding of the screens by the asphalt in the old material. It was recommended that the screens be removed and to rely completely on the cold gate setting for gradation control. The contractor elected to accept the low production rather than remove the screens because the plant was used at night to produce asphalt concrete for non-state projects. The mixture produced at night was stored in hot storage bins and transported to these jobs throughout the following day.

Another problem that slowed production somewhat was moisture in the aggregates. Moisture contents determined from the aggregate stockpiles showed an average of 4.7 percent in the crushed stone, 11.7 percent in the shell, and 6.3 percent in the salvaged material.

The temperature of the recycled mix was measured at the plant on the first five loads each day and an average of once every five loads thereafter. The temperature of the mixture when discharged from the pugmill ranged from 262°F to 296°F with the average temperature being 283°F.

Gradation control at the plant was based on results of hot bin gradations which were determined at the beginning of each day's production. Results of the composite hot bin gradations were found to be somewhat coarser than the gradation of aggregates extracted from the final mix. Therefore, a correlation between the two was determined at the time the design mix was established. The difference between the two gradation results was due to bonding of the aggregate particles in the salvaged material as measured in the hot bin gradations. A summary of the hot bin gradation results are shown in Table 4.

A minimum of one extraction test was performed on the recycled mix each day in accordance with Florida Test Method FM 1-T 164. Results of the extraction analyses are included in Table 5.

Samples of the hot recycled mix were compacted and tested at the plant each day for Marshall stability, flow, and density determinations. Results of these tests representing each day's production are included in Table 6.

Indirect tension tests were also performed on specimens compacted at the plant to determine the tensile strength of the recycled mixture. Results of the indirect tension tests as determined at different intervals of production are shown in Table 7.

Samples of the recycled mix representing each day's production were also taken for recovery of the asphalt cement by the Abson process (FM 1-T 170). The physical characteristics of the recovered asphalt including the penetration and rheological properties are summarized in Table 8.

The Type S-1 and FC-2 mixtures used on this project were produced using conventional methods in accordance with the 1973 Edition of the Standard Specifications for Road and Bridge Construction. The quality control and acceptance test results were all within allowable tolerances.

Paving Operations

The 7-inch recycled asphalt base course was placed with a paving machine in three approximately equal lifts (Figure 6). Compaction of the mixture was accomplished by conventional means. Seal rolling was done in a single pass by a 12-ton vibratory roller. Five passes were then applied with a 6-ton self-propelled pneumatic tired roller, followed by a final pass with the 12-ton vibratory roller (Figure 7).

During the 8-mile haul from the plant to the roadway, the temperature of the mix decreased from approximately 280°F to approximately 255°F. The temperature at time of laying was approximately 240°F. To prevent shoving of the mix during rolling, it was found that the seal rolling had to be delayed until the mat temperature decreased to about 190°F. This was attributed to the fineness of the mix and thickness of the mat (2 to 3 inches).

In an effort to establish optimum rolling conditions, a temperature sensing device was placed in the mat for continuous monitoring of temperature during rolling.

The mat temperatures and time lapse between rollers considered to give optimum results are recorded in Table 9, along with the density results obtained (nuclear direct transmission method).

Density of the compacted mat for job control was determined from core samples in accordance with FM 1-T 166 (Method B). The lot size represented by the density sample was one for each day's run or 500 tons, whichever was less. The average density obtained in the recycled base course was determined to be 96.8 percent of laboratory density, which was well above the 95 percent minimum requirement.

Placement and compaction of the Type S-1 surface course and the Type FC-2 friction course was accomplished by conventional means, meeting all specification requirements.

POST-CONSTRUCTION PERFORMANCE

A pavement performance evaluation was conducted on the completed recycling project on February 20, 1979, after the open-graded mix had been placed. All testing was done in the traffic lane in both the eastbound and westbound directions.

Friction Numbers

Friction measurements were made at 40 mph in accordance with ASTM E 274-77. An average friction number at 40 mph (FN_{40}) of 40.2 was obtained for the eastbound roadway and 40.6 for the westbound roadway (Table 10).

Present Serviceability Index Values

Present Serviceability Index values based on slope variance only ($PSI_{\overline{SV}}$) were determined using the Mays Ride Meter. Results of these tests indicate a rating of 4.44 in the eastbound roadway and 4.47 in the westbound roadway (Table 10). All tests were performed in accordance with Florida Method of Test Designation FM 5-509.

Benkelman Beam Deflections

Benkelman beam deflection measurements were made at 200-foot intervals throughout the project. The measurements were obtained from both the inside and outside wheelpaths of the eastbound and westbound traffic lanes. The deflection measurements varied from 0.007 inch to 0.020 inch in the outside wheelpath of the eastbound traffic lane, with an average of 0.009 inch, and from 0.001 inch to 0.018 inch in the inside wheelpath with an average of 0.006 inch.

Measurements in the outside wheelpath of the westbound traffic lane ranged from 0.008 inch to 0.017 inch, with an average of 0.008 inch, and from 0.005 inch to 0.016 inch in the inside wheelpath, with the average being 0.008 inch. The average deflection measurements are summarized in Table 10.

Benkelman beam deflection measurements were also determined on the recycled base course prior to placement of the surface course to determine the strength of the base alone. The average deflection measurements obtained were as follows:

	Outside Wheelpath	Inside Wheelpath
Eastbound Traffic Lane	0.013	0.012
Westbound Traffic Lane	0.012	0.011

ENVIRONMENTAL CONSIDERATIONS

The asphalt batch plant was tested for particulate emissions after extensive modifications were made in the wet scrubber and outlet stack approximately two weeks prior to processing the recycled mixture. The tests were performed in accordance with the Department of Environmental Regulation procedures, while producing a standard Type II mixture at the rate of 207 tons per hour. A summary of the test data is as follows:

Run Number	Flow Rate (cfm)	Emission Rate (lbs./hr.)	Allowable Rate (lbs./hr.)
1	49,229	7.60	40.63
2	42,156	17.70	40.63
3	52,326	5.61	40.63
Average	51,237	10.30	40.63

Since the salvaged material by-passed the dryer while processing the recycled mixture, it was anticipated that the particulate emissions would not exceed that of a conventional mixture. The primary concern was to keep the temperature of the salvaged material below the smoke point while processing through the plant. The smoke point of the asphalt recovered from the old material was determined to be 340°F.

Visual observations during production of the recycled mixture indicated the emissions to be well within compliance limitations.

COST ANALYSIS

Conservation of Natural Resources

Listed below are the percentages of aggregates and virgin asphalt that would have been required on this project under a conventional equivalent method of construction (standard Type ABC-3), as compared to the reycling method used:

Description of Material	Standard Type ABC-3	Recycled Type ABC-3
Crushed Stone (S-1A)	25*	15*
Local Shell	75*	60*
Old Pavement	0*	25*
Asphalt Cement (AC-20)	7.0**	5.5**

*By weight of total aggregate.

**By weight of total mix.

Based on these figures it was determined that 10 percent crushed stone, 15 percent local shell, and 1.5 percent asphalt were replaced by the old pavement material used in the recycled mixture.

The actual quantity of natural resources conserved by using the recycled asphalt base course is computed as follows:

10.0% Crushed Stone x 26,040 Tons	=	2,604 Tons
15.0% Local Shell x 26,040 Tons	=	3,906 Tons
1.5% Asphalt x 28,000 Tons	=	420 Tons, or 98,844 Gallons

Economic Analysis

The estimated cost of the aggregates and asphalt that were replaced the the old pavement material is computed as follows:

2,604 Tons of Crushed Stone @ $5.30/Ton	=	$13,801.00
3,906 Tons of Local Shell @ $4.00/Ton	=	$15,624.00
98,844 Gallons of Asphalt @ $0.35/Gallon	=	$34,595.00
		$64,020.00

The old pavement material was considered to be a waste product having no value prior to crushing. The cost of crushing and hauling was approximately as follows:

6,600 Tons @ $0.67/Ton = $4,422.00

Based on these figures, the recycled asphalt base course was constructed for $59,598 less than estimated for a conventional equivalent method.

Considering that the total cost of materials required for a conventional Type ABC-3 mixture was estimated to be $274,035, there was a reduction in the cost of the recycled base course of approximately 23 percent.

ENERGY REQUIREMENTS

The amount of energy required to produce and haul the aggregates and asphalt that was replaced by the old pavement material and the energy required to crush and haul the old pavement material is computed in Table 11. Based on these computations, a total savings of 1,490,830,200 BTU's was provided by using the recycling method.

Considering that the energy required to produce and haul the aggregates and asphalt for a conventional Type ABC-3 mixture was estimated to be 7,468,522,600 BTU's, use of the recycling method provided an energy reduction in the recycled base course of approximately 20 percent.

SUMMARY

The Marshall test results obtained from the laboratory design and those obtained on the processed mixture utilizing the salvaged material were in the same range as would be anticipated from a similar mix utilizing 100 percent virgin material. There would appear to be no reason to modify the physical design parameters utilized for flexible pavement systems simply as a result of using recycled asphalt concrete mixtures.

Results from this study indicate the conventional asphalt concrete production plant can be used in the production of recycled asphalt concrete mixtures. It is obvious that the production rate and overall plant efficiency would be improved if the salvaged material were conveyed directly to the weigh hopper, by-passing the screen deck and hot bins. The virgin aggregate could then be super-heated to permit heat transfer during the dry mixing operation. This would result in a more uniform product and would not restrict the contractor's ability to produce mixes other than the recycled mixture. Producing the recycled asphalt concrete mixture by the heat transfer method would also permit better control of the temperature of the mix when delivered to the roadway site. This would eliminate the necessity for varying the rolling pattern on the roadway to accommodate the temperature fluctuation.

Another problem that occurred on this project was related to the high moisture content in the local shell material used in the mix. By increasing the temperature in the dryer, this problem would have been eliminated. It is believed that the moisture content contributed to the variability of the final mix temperature.

Evaluation of this project will continue, but performance to date has been very favorable.

LOCATION MAP

State Road 802

Palm Beach County

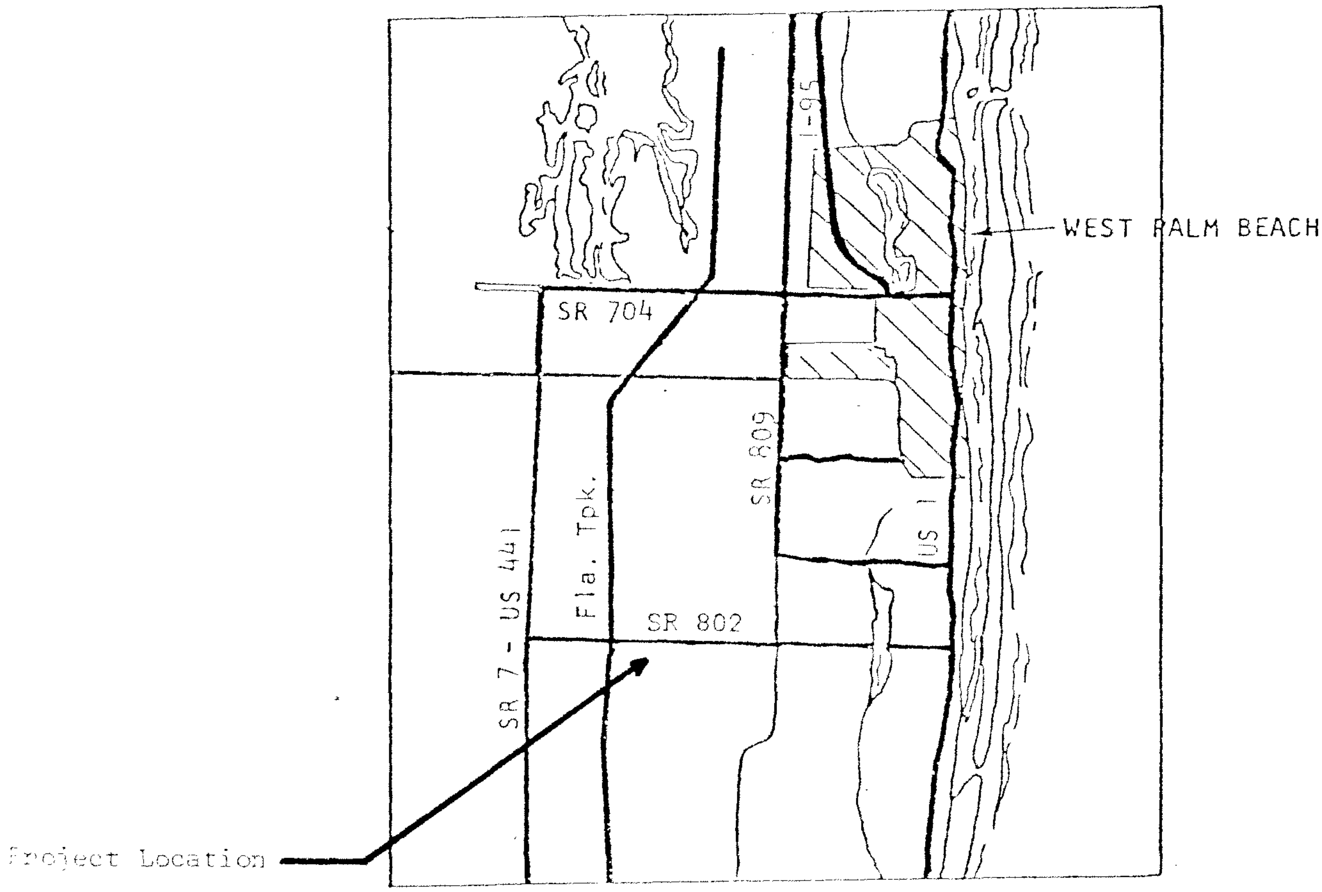

FIGURE 1

FIGURE 2

Salvaged Pavement Material Before Crushing

FIGURE 3

Salvaged Pavement Material After Crushing

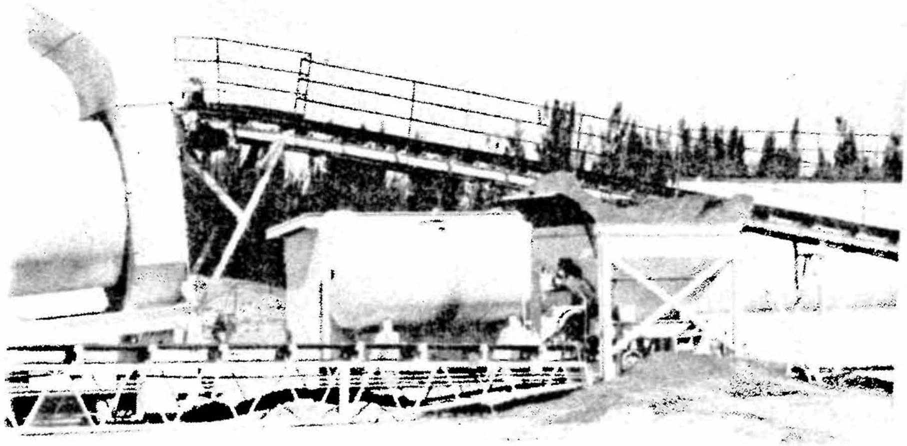

FIGURE 4

Salvaged Material Bin and Conveyor

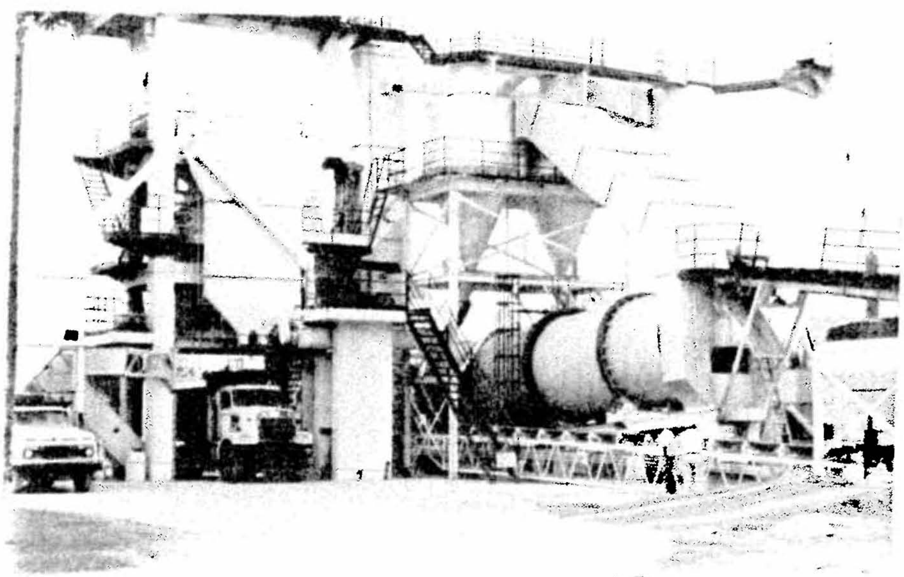

FIGURE 5

Salvaged Material Conveyed from Cold Bin to Hot Elevator

FIGURE 6

First Lift of Recycled Asphalt Base Course Being Placed Over Stabilized Subgrade

FIGURE 7

Rolling Recycled Asphalt Base Course

TABLE 1

RECYCLED ASPHALT BASE COURSE
(Design Blend and Marshall Design Data)

DESIGN BLEND

Sieve Size	Salvaged Pavement Material (25%)*	Crushed Stone (Grade S-1A) (15%)	Local Shell (Shearbrook) (60%)	Job Mix Formula**	Specification Range for ABC-3 (Percent Passing)
1-1/2"	100	100	100	100	100
3/4"	86	100	92	100	70-100
1/2"	77	98	82	98	-
3/8"	69	57	76	89	-
No. 4	46	11	67	68	30-70
No. 10	30	5	60	57	20-60
No. 40	20	4	50	45	10-40
No. 80	15	3	16	21	-
No. 200	10.0	1.6	6.0	7.3	2-10

MARSHALL DESIGN DATA

Asphalt Content (%)	Stability (lbs.)	Flow (.01 inch)	Density (pcf)
7.0***	1,825	11	139.1

*Actual gradation of crushed pavement material.

**Composite gradation determined from extraction of specimens used in design.

***25% Salvaged Material @ 6.0% A.C. = 1.5%
New Asphalt Cement (AC-20) Added = 5.5%

Optimum Asphalt Cement Content = 7.0%

TABLE 2

TYPE S-1 ASPHALT CONCRETE SURFACE COURSE
(Design Blend and Marshall Design Data)

DESIGN BLEND

Sieve Size	Crushed Stone (Grade S-1A) (25%)	Crushed Stone (Grade S-1B) (35%)	Asphalt Screenings (10%)	Local Sand (30%)	Job Mix Formula	Specification Range (Percent Passing)
3/4"	100	100	100	100	100	100
1/2"	96	100	100	100	99	88-100
3/8"	45	99	100	100	86	75-93
No. 4	4	50	100	100	58	47-75
No. 10	3	4	87	96	40	31-53
No. 40	0	0	56	74	28	19-35
No. 80	0	0	30	24	10	7-21
No. 200	0	0	5.0	4.0	1.7	2-7

MARSHALL DESIGN DATA

Asphalt Content (%)	Density (pcf)	Air Voids (%)	Stability (lbs.)	Flow (.01 Inch)
6.6	136.5	5.0	2,280	10

TABLE 3

TYPE FC-2 ASPHALT CONCRETE FRICTION COURSE
(Design Blend)

Sieve Size	Crushed Oolite (Grade 16A) (93%)	Local Sand (7%)	Job Mix Formula	Specification Range (Percent Passing)
1/2"	100	100	100	100
3/8"	98	99	98	85-100
No. 4	13	97	19	10-40
No. 10	4	96	10	0-10
No. 40	1	87	7	-
No. 80	1	41	4	-
No. 200	0	1.6	0.1	0-5

Asphalt Cement (AC-20) Content = 6.5%

Mixing Temperature = 250°F

TABLE 4

HOT BIN GRADATION RESULTS
(Recycled Asphalt Base Course)

Date Tested	Aggregate Gradation - Percent Passing									
	1½"	1"	3/4"	1/2"	3/8"	No. 4	No. 10	No. 40	No. 80	No. 200
10/26/77	100	100	99	94	82	63	52	31	8	0.6
10/27/77	100	100	99	96	86	66	54	29	7	0.5
10/28/77	100	100	99	92	79	63	54	29	6	0.4
10/31/77	100	100	97	91	74	58	50	29	6	0.4
12/21/77	100	100	100	95	78	56	46	30	8	0.3
12/22/77	100	100	99	96	79	59	52	37	9	0.7
12/23/77	100	99	97	93	77	60	54	33	6	0.6
1/27/78	100	99	96	91	78	62	55	29	7	0.4
1/28/78	100	100	100	96	77	62	51	32	7	0.5
2/24/78	100	100	99	95	84	69	58	29	8	0.6
2/28/79	100	99	97	93	82	63	58	34	9	0.7
3/ 1/78	100	100	96	92	82	66	59	30	7	0.5
4/10/78	100	100	99	95	81	63	59	24	5	1.0
4/11/78	100	100	100	96	89	63	58	31	8	0.8
4/12/78	100	100	100	96	86	67	59	29	8	0.3
4/13/78	100	100	99	94	80	65	54	26	7	0.4
4/14/78	100	100	99	96	85	67	58	30	7	0.3
4/17/78	100	100	100	98	92	67	59	34	9	0.5
4/18/78	100	100	100	98	94	78	63	28	7	0.5
4/19/78	100	100	100	98	94	78	63	28	7	0.5
4/21/78	100	100	100	99	98	66	54	28	7	1.0
4/25/78	100	100	100	97	89	71	58	34	10	2.2
4/26/78	100	100	100	95	87	72	60	33	10	0.8
4/27/78	100	100	100	99	93	78	68	35	10	0.7
4/28/78	100	100	100	97	84	65	57	33	19	1.0
5/ 1/78	100	100	100	100	97	72	61	30	8	0.4
5/ 2/78	100	100	100	98	89	72	61	32	9	0.6
5/ 3/78	100	100	100	100	97	74	53	31	10	1.0
5/ 4/78	100	100	100	99	93	79	68	31	12	0.8
8/23/78	100	100	100	97	84	63	36	32	18	0.5

TABLE 5

EXTRACTION ANALYSIS
(Recycled Asphalt Base Course)

Date Tested	Asphalt Content (%)	Gradation - Percent Passing								
		1"	3/4"	1/2"	3/8"	No. 4	No. 10	No. 40	No. 80	No. 200
10/26/77	7.1	100	100	100	86	66	57	46	20	7.5
10/27/77	7.4	100	100	100	82	63	53	43	20	8.8
10/28/77	7.0	100	100	100	85	65	55	44	20	8.2
10/31/77	6.9	100	100	97	84	66	56	43	17	6.2
12/21/77	6.8	100	100	100	86	63	56	46	16	5.4
12/22/77	6.7	100	100	100	85	65	58	48	18	5.6
12/23/77	6.1	100	100	100	81	60	53	43	14	4.6
1/27/78	6.9	100	99	97	89	70	63	50	24	6.0
1/28/78	6.9	100	100	96	87	69	61	49	24	6.0
2/23/78	6.7	100	100	94	81	60	54	44	25	6.8
2/24/78	7.2	100	100	98	89	68	58	47	27	6.7
2/28/78	7.1	100	98	93	86	67	59	48	27	6.7
3/ 1/78	6.3	100	99	94	84	62	53	43	22	6.9
4/10/78	6.8	100	100	97	88	70	58	46	22	7.5
4/11/78	7.0	100	100	99	90	69	60	48	18	7.0
4/12/78	6.1	100	100	100	91	71	62	50	18	6.1
4/13/78	6.5	100	100	100	88	70	61	50	17	5.8
4/14/78	6.9	100	100	100	88	71	63	51	18	5.6
4/17/78	5.8	100	100	100	86	68	60	49	16	6.6
4/18/78	6.6	100	100	100	92	74	64	52	19	8.2
4/19/78	6.1	100	100	100	90	75	66	53	20	7.0
4/20/78	6.4	100	100	100	85	68	60	48	18	6.6
4/21/78	6.4	100	100	100	90	72	62	50	18	6.6
4/25/78	6.9	100	100	98	93	75	65	53	20	8.0
4/26/78	6.5	100	100	97	92	82	65	49	33	5.0
4/27/78	6.9	100	99	97	91	74	63	51	20	6.8
4/28/78	6.9	100	99	97	92	72	62	51	20	7.1
5/ 1/78	6.6	100	100	97	87	65	56	43	16	5.6
5/ 2/78	6.3	100	100	97	87	66	57	44	17	4.9
5/ 3/78	6.4	100	100	97	86	57	48	47	17	5.0
5/ 4/78	6.6	100	100	97	86	65	58	48	17	5.8
7/13/78	7.6	100	100	99	92	73	63	52	20	7.2
7/14/78	7.8	100	100	100	95	79	67	53	21	7.7
7/17/78	7.8	100	100	97	92	74	63	50	21	8.0
7/18/78	7.4	100	100	98	87	62	53	42	19	7.0
8/23/78	6.7	100	100	98	89	69	58	47	20	7.1
8/24/78	7.0	100	100	98	94	65	56	46	18	8.2

TABLE 6

MARSHALL PROPERTIES OF SPECIMENS COMPACTED AT THE PLANT
(Recycled Asphalt Base Course)

Date Tested	Asphalt Content (%)	Density (pcf)	Stability (lbs.)	Flow (.01 Inch)
10/26/77	7.1	139.8	2,750	9
10/27/77	7.4	139.3	1,668	12
10/28/77	7.0	140.9	1,906	13
12/21/77	6.8	136.2	1,977	10
12/22/77	6.7	135.1	1,999	10
12/23/77	6.1	135.6	1,805	9
1/27/78	6.9	135.8	1,747	9
1/28/78	6.9	137.4	1,880	9
2/23/78	6.7	137.9	2,188	12
2/24/78	7.2	139.0	1,918	16
2/28/78	7.1	138.6	2,265	11
3/ 1/78	6.3	139.8	2,006	10
4/10/78	6.8	139.2	1,745	11
4/11/78	7.0	140.4	2,224	10
4/12/78	6.1	138.6	1,972	9
4/13/78	6.5	137.1	1,633	10
4/17/78	5.8	137.3	1,712	9
4/18/78	6.6	134.9	1,352	9
4/19/78	6.1	135.9	1,313	10
4/20/78	6.4	141.1	2,586	12
4/21/78	6.4	139.0	1,761	9
4/25/78	6.9	136.7	1,437	10
4/26/78	6.5	133.0	1,596	9
4/27/78	6.9	136.3	1,374	10
4/28/78	6.9	135.1	1,595	10
5/ 1/78	6.6	141.9	2,463	10
5/ 2/78	6.3	137.8	1,900	9
5/ 3/78	6.4	139.1	1,925	9
7/13/78	7.6	137.3	848	11
7/14/78	7.8	137.8	980	12
7/25/78	6.5	139.6	1,357	12
8/23/78	6.4	134.3	1,616	9
8/24/78	6.8	139.1	1,611	11

TABLE 7

INDIRECT TENSION TEST RESULTS ON SPECIMENS COMPACTED AT PLANT
(Recycled Asphalt Base Course)

Date Tested	Density (pcf)	Tensile Strength (psi)	Tensile Strain (in/in)	Modulus of Elasticity (psi)
10/27/77	135.3	92	.0053	37,677
	133.0	80	.0039	44,368
	135.2	91	.0058	33,885
	131.8	65	.0053	26,918
Average	133.8	82	.0051	35,712
10/31/77	136.3	115	.0042	60,488
	134.9	111	.0039	61,796
	136.0	99	.0061	35,538
	137.3	105	.0050	46,070
Average	136.1	108	.0048	50,975
1/20/78	137.9	119	.0040	64,356
	138.4	124	.0045	59,844
	135.4	97	.0045	46,997
	132.0	103	.0036	61,888
Average	135.9	111	.0042	58,271
4/13/78	138.1	104	.0057	39,726
	138.1	104	.0065	35,055
	138.7	101	.0066	33,776
Average	138.3	103	.0063	36,186

TABLE 8

CHARACTERISTICS OF ASPHALT RECOVERED FROM
RECYCLED ASPHALT BASE COURSE MIXTURE DURING PRODUCTION

Date Sampled	Penetration 77°F	Viscosity 140°F (poises)	Viscosity 77°F (megapoises)	Complex Flow 77°F
10/28/77	51	4,046	1.938	0.95
11/ 3/77	61	3,041	1.287	0.81
11/ 3/77	54	3,514	2.145	1.00
12/22/77	53	3,468	2.128	0.97
12/23/77	49	4,102	2.230	0.96
1/ 2/78	48	4,380	2.618	0.90
1/28/78	49	4,323	2.385	0.86
2/23/78	49	5,830	1.716	0.71
2/24/78	41	6,340	2.206	0.65
2/28/78	43	5,993	2.101	0.61
3/ 1/78	55	4,649	1.243	0.74
4/10/78	48	4,723	1.726	0.61
4/11/78	48	4,968	1.269	0.97
4/12/78	56	3,684	1.232	0.73
4/13/78	51	5,061	1.528	0.63
4/14/78	51	4,782	1.870	0.63
4/17/78	60	3,450	1.718	0.59
4/18/79	51	4,610	1.826	0.60
4/19/78	53	4,701	1.573	0.65
4/20/78	51	4,731	1.854	0.63
4/21/78	52	4,794	2.040	0.62
4/25/78	58	3,838	1.800	0.69
4/26/78	55	4,789	1.810	0.48
4/27/78	56	3,474	0.884	0.90
4/28/78	55	4,382	1.900	0.60
5/ 1/78	49	4,486	1.554	0.62
5/ 2/78	53	3,720	1.425	0.65
5/ 3/78	44	4,893	1.799	0.59
5/ 4/78	47	4,374	1.721	0.63
7/26/78	47	4,749	2.330	0.77
7/26/78	46	5,061	3.012	0.74
7/27/78	43	5,918	3.170	0.76
7/27/78	50	4,939	2.986	0.72

TABLE 9

COMPACTION DATA
(Recycled Asphalt Base Course)

Type Roller	Number of Passes	Time	Pavement Temperature (°F)	Density (pcf)	Percent of Laboratory Density
Paver	-	11:15 a.m.	240	-----	----
12-Ton Vibrator	1	11:30 a.m.	190	130.5	93.8
Pneumatic-Tired	1	11:50 a.m.	159		
	2		159		
	3		159		
	4		158		
	5	12:00 Noon	158	133.5	96.0
12-Ton Vibrator	1	12:20 p.m.	144	134.5	96.7

TABLE 10

SUMMARY OF POST-CONSTRUCTION PERFORMANCE EVALUATION

Friction Number at 40 mph (FN_{40})

Location	FN_{40}
Eastbound Traffic Lane	41
Westbound Traffic Lane	41

Present Serviceability Index
(Slope Variance Only)

Location	$PSI_{\overline{SV}}$
Eastbound Traffic Lane	4.44
Westbound Traffic Lane	4.47

Benkelman Beam Deflections

Location	Deflection (inch)
Eastbound Traffic Lane	
Outside Wheelpath	.009
Inside Wheelpath	.006
Westbound Traffic Lane	
Outside Wheelpath	.008
Inside Wheelpath	.008

TABLE 11

ENERGY REQUIREMENTS OF MATERIALS THAT WERE
REPLACED BY THE OLD PAVEMENT MATERIAL
IN THE RECYCLED BASE COURSE

Manufacture Asphalt Cement	=	587,500 BTU/Ton
Haul 193 Miles x 2 @ 1,960 BTU/TM	=	756,560 BTU/Ton
		1,344,060 BTU/Ton
Produce Crushed Stone	=	70,000 BTU/Ton
Haul 50 Miles x 2 @ 1,960 BTU/TM	=	196,000 BTU/Ton
		266,000 BTU/Ton
Produce Local Shell	=	41,700 BTU/Ton
Haul 10 Miles x 2 @ 5,840 BTU/TM	=	116,800 BTU/Ton
		158,500 BTU/Ton
Asphalt		
1.5% @ 1,344,060 BTU/Ton (28,000 Tons)	=	564,505,200 BTU
Crushed Stone		
10% @ 266,000 BTU/Ton (26,040 Tons)	=	692,664,000 BTU
Local Shell		
15% @ 158,500 BTU/Ton (26,040 Tons)	=	619,101,000 BTU
		1,876,270,200 BTU
Crush Old Pavement Material		
6,600 Tons @ 41,700 BTU/Ton	=	275,220,000 BTU
Haul 5 Miles x 2 @ 5,840 BTU/TM	=	385,440,000 BTU
		660,660,000 BTU
TOTAL ENERGY SAVED (1,876,270,200 BTU - 660,660,000 BTU)	=	1,490,830,200 BTU

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