WIRTGEN REMIXER SURFACE RECYCLING

U.S. 90 JENNINGS, LA.

CONSTRUCTION REPORT

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EXPERIMENTAL PROJECT NO. 9
SURFACE REHABILITATION TECHNIQUES

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ABSTRACT

This report documents the surface recycling of 7.4 miles of route U.S. 90 from the junction of La 99 to Jennings, Louisiana. The specialized recycling equipment was provided and operated by Remixer Contracting Co., Inc. of Austin, Texas. Roadway production included heating the existing pavement, milling to a 1.5 inch depth, adding rejuvenator and new mix and placing 2.0 inches of recycled, Type 3 wearing course. The daily roadway production proceeded with very few problems and averaged 0.9 lane-miles per day. The surface recycling project realized a savings over the conventional design. The economic benefit of such savings will be determined after performance evaluations are completed.

SI UNIT CONVERSION FACTORS*

To Convert from	To	Multiply by
Length		
foot	meter (m)	0.3048
inch	meter (m)	0.0254
yard	meter (m)	0.9144
mile (statute)	kilometer (km)	1.609
Area		
square foot	square meter (m^2)	0.0929
square inch	square meter (m^2)	0.000645
square yard	square meter (m^2)	0.8361
Volume (Capacity)		
cubic foot	cubic meter (m^3)	0.02832
gallon (U.S. liquid)**	cubic meter ($m^{3)}$	0.003785
gallon (Can. liquid)**	cubic meter ($m^{3)}$	0.004546
ounce (U.S. liquid)	cubic meter (m^3)	0.03382
Mass		
ounce-mass (avdp)	kilogram (kg)	0.02835
pound-mass (avdp)	kilogram (kg)	0.4536
ton (metric)	kilogram (kg)	1000
ton (short, 2000 lbs)	kilogram (kg)	907.2
Mass per Volume		
pound-mass/cubic foot	kilogram/cubic meter (kg/m^3)	16.02
pound-mass/cubic yard	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		
deg Celsius (C)	Kelvin (K)	$t_k=(t_c+273.15)$
deg Fahrenheit (F)	Kelvin (K)	$t_k=(t_F+459.67)/1.8$
deg Fahrenheit (F)	Kelvin (K)	$t_c=((t_F-32)/1.8)$

*The reference source for information on SI units and more exact conversion factors is "Metric Practice Guide" ASTM E 380.

**One U.S. gallon equals 0.8327 Canadian gallon.

TABLE OF CONTENTS

ABSTRACT -- iii
SI UNIT CONVERSION FACTORS ------------------------------ iv
LIST OF TABLES -- vi
LIST OF FIGURES --- vii
INTRODUCTION -- 1
EXPERIMENTAL FIELD PROJECT ------------------------------ 4
    Location and Section Design ------------------------- 4
    Recycle Mix Design ---------------------------------- 7
    Plant Production ------------------------------------ 11
    Roadway Construction -------------------------------- 13
    Quality Control ------------------------------------- 17
ECONOMIC ANALYSIS --------------------------------------- 27
CONCLUSIONS --- 29
APPENDIX - Special Provisions --------------------------- 31

LIST OF TABLES

Table No.		Page No.
1	Asphalt Content & Physical Properties of Reclaimed Materials ------------------------	7
2	Project Job Mix Formulas -------------------	12
3	Plant Production ---------------------------	13
4	Rejuvenator Addition Rates & Screed Temperatures --------------------------------	17
5	Marshall Properties ------------------------	18
6	Extracted Recycled Mix Gradation & Asphalt Cement Content ----------------------------	20
7	Plant Extracted Virgin Mix Gradation & Asphalt Cement Content ---------------------	21
8	LTRC Extracted Virgin Mix Gradation and Asphalt Cement Content ---------------------	22
9	Roadway Compaction ------------------------	23
10	Physical Properties of Recovered Asphalt Cement -------------------------------------	26

LIST OF FIGURES

Figure No.		Page No.
1	Project location ------------------------------	5
2	Experimental design section ------------------	6
3	Sample site locations ------------------------	8
4	Theoretical blended viscosities --------------	10
5	Wirtgen Remixer train ------------------------	15
6	Leveling auger and screed --------------------	15
7	Heaters --------------------------------------	16

INTRODUCTION

Surface recycling for the purpose of this report is defined as the in-place recycling of an existing asphaltic concrete wearing surface by heating, milling, applying a rejuvenating agent, thoroughly combining the reclaimed material with virgin asphaltic concrete mix in a pugmill and leveling and screeding the total mix in a single pass of the specialized recycling equipment. Surface recycling has been recommended as an alternative whenever rutting or other surface deterioration is less than one inch in depth and there are no structural deficiencies. The surface recycling process examined herein was proposed by Remixer, Inc. as an alternative section design to cold milling and thin overlay through which an economic savings could be realized.

In general, hot, in-place surface recycling can be characterized by one of the following three processes:

(1) heating existing pavement, scarifying, adding rejuvenator and compacting in-place;
(2) heating existing pavement, scarifying, adding rejuvenator, redistributing material, adding new material on top of the recycled material and compacting in-place; and,
(3) heating existing pavement, scarifying or milling, remixing of recycled materials with rejuvenator and new asphaltic concrete, redistribution of materials and compacting in-place.

During the last 22 years, the Louisiana Department of Transportation and Development has examined methods (1) and (2) on four occasions. Method (1) which simply heats, scarifies and recompacts the existing materials proved ineffective and construction was halted on two projects which used this method due to oxidation of the asphalt cement and/or the lack of fine aggregate in the recycled pavement surface causing excessive ravelling. Two additional surface recycling projects were constructed using method (2), one in 1980 and the other in 1986. This process was proclaimed to be superior to method (1) in that the new hot mix was placed immediately on top of the recycled in-place materials providing a monolithic mixture. On both of these projects the recycling machine was found to further oxidize the existing asphalt cement. Therefore, the effect of method (2) was to cover up a layer of recycled material that contained oxidized asphalt.

The 1980 project is performing well to date. The 1986 project has not performed as well. Proper densification was not achieved throughout this project. This lack of compaction was attributed to the further oxidation of the existing asphalt cement by the heaters and/or the temperature loss of the new hot mix as it passed from the haul trucks to the final screed. An evaluation after two years found ruts up to 0.5 inch in the wheel paths and also a loss of structural integrity in the recycled layer; cores taken in the recycled section disintegrated in the recycled layer.

Method (3), represented by the Wirtgen Remixer machine, provides a significant change in the surface recycling process from the other methods examined so far in Louisiana. This process purports that new material (up to 90 lb/yd^2) can be blended and mixed with the existing recycled material in a pugmill type mixer, similar to a hot mix plant, thereby producing a uniform recycled hot mix. The capability of adding new material which can be mixed with the existing materials provides the opportunity to correct deficiencies in the existing pavement materials such as the addition of fines or the use of nonpolishing, high friction aggregate. In this manner the surface can be rehabilitated to an original state. In addition, the limited use of new materials and the ability to maintain existing grade makes this process an attractive alternative to milling and thin overlay.

Department personnel have observed the Wirtgen machine in the field and were particularly impressed by its ability to blend the existing and newly added hot mix. Also, another significant advantage of the Wirtgen machine was its use of infrared heating as opposed to the open flames experienced with the surface recycling machines observed previously in Louisiana. It is reported by the manufacturer that the infrared heat does not overly oxidize the existing asphalt cement. It was believed that this would increase the chance of success of the surface recycling process as Louisiana's past experience would indicate that excessive oxidation of the asphalt was a prime reason for the failure of the experimental sections.

FIELD EXPERIMENTAL PROJECT

Location and Section Design

The surface recycling experimental section encompassed 7.353 miles on US 90 from the Junction of LA 99 to Jennings, Louisiana. J. B. Talley & Co., Inc. was the successful bidder for this contract. Remixer Contracting Co., Inc., Austin, Texas was the sub-contractor for the surface recycling portion. The Special Provisions governing the surface recycling work can be found in Appendix A. The general location, approximately 20 miles east of Lake Charles in southwest Louisiana, is provided in Figure 1.

The roadway was scheduled for cold planing (2 inch average, developing 0.025 ft/ft cross slope), followed by a 2.0 inch, Type 3 wearing course (1500 pound stability). This typical section was constructed as a control section at the west end of the project in both lanes. Approximately 14.7 lane miles of the east and west bound lanes were surface recycled. The typical design section shown in Figure 2 for the experimental section included heating and scarifying to a 1.5 inch depth, addition of rejuvenator and concurrent placement of a 2.0 inch, Type 3 wearing course. The existing section was composed of portland cement concrete that had been overlayed with asphaltic concrete, adding approximately 5 to 8.5 inches to the cross section. The ride of this existing composite pavement was poor because of spalling of the reflection cracks at transverse joint locations.

Figure 1. Project location.

Figure 2. Experimental design section.

Recycle Mix Design

Before the contract was let, the existing roadway was sampled to determine the quantity and quality of the asphalt cement. Six-inch diameter cores were taken at eight locations on the project as indicated in Figure 3. The top 1.5 inches of each core was saw cut to provide material for extraction and recovery of the asphalt cement which would be representative of the material to be actually recycled. The asphalt cement was extracted and recovered by the Abson process. The binder content was determined and absolute viscosity (140^{0}F), penetration (77°F) and ductility (77°F) were tested. The results are presented in Table 1. Generally, the asphalt cement was found to have viscosities greater than 200,000 poises. The one exception (sample ID No.4) was taken in a patched area. The mean asphalt content of the top 1.5 inches of the original roadway was 5.44 percent.

TABLE 1

ASPHALT CONTENT AND PHYSICAL PROPERTIES OF RECLAIMED MATERIALS

Sample ID	Asphalt Content (%)	Viscosity (Poise)	Penetration (0.10 mm)	Ductility (cm)
1	5.8	200,000+	13	4.0
2	5.2	200,000+	11	3.5
3	5.9	200,000+	16	4.0
4	5.7	19,230	42	45.0
5	5.3	200,000+	11	4.0
6	5.5	200,000+	15	4.0
7	4.8	200,000+	9	2.5
8	5.3	200,000+	12	3.5

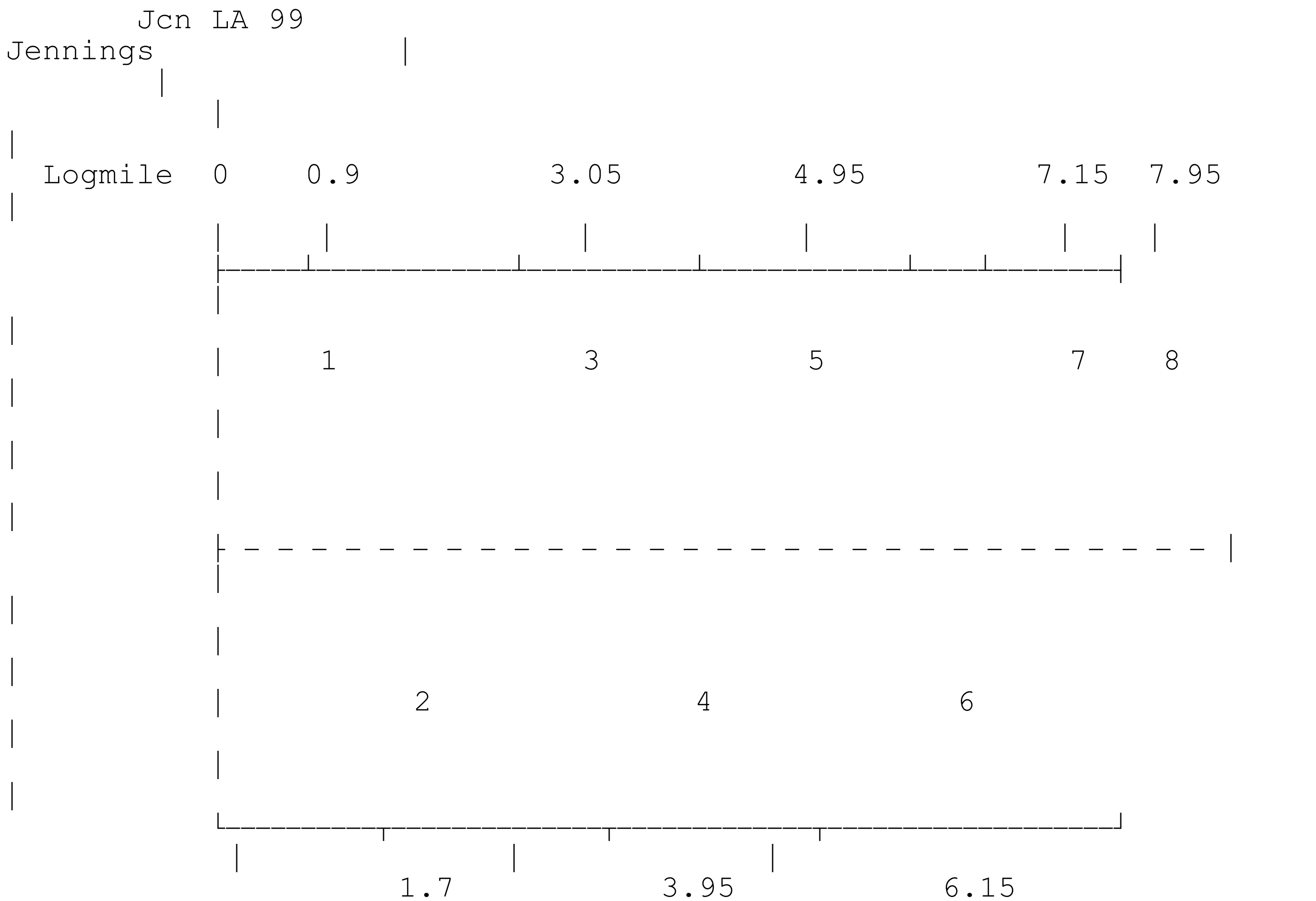

Figure 3. Sample site locations.

A records search indicated that the original job mix for this project called for a binder content range of 5.0 - 5.8 percent. From past experience with recycled mixes (<u>Effects of Asphalt Cement Rejuvenating Agents</u>, Carey, D.E. and Paul, H.R., Louisiana Department of Transportation & Development, Research Report No. 146, 1980), the blended viscosity of an aged asphalt with a rejuvenator can be theoretically established by the relationship:

$$\text{Log Log } V = a + bp$$

where: V = viscosity of the blend (centipoises at 140^{0}F)
p = percent of rejuvenator (by volume)
a,b = constants (determined for each asphalt / rejuvenator blend)

This relationship is presented graphically in Figure 4. The existing asphalt cement (20,000,000 cp) and the proposed rejuvenator (80 cp) are plotted as end points in a straight line relationship as indicated. A 15 percent residual rejuvenator proportion should provide a blended viscosity of 9,300 poises. Such a viscosity would fall within the department's specification for new asphaltic concrete which calls for plant-produced mixtures having a binder viscosity of 12,000 poises or less.

In addition to the blended viscosity of the reclaimed material and rejuvenator, consideration must be given to the total binder content of the recycled mixture. The use of the rejuvenator at a 15 percent residual rate would increase the binder content of the existing materials to 6.3 percent, which is considerably higher than the original job mix formula. In order to compensate for the excess binder from the rejuvenator, the virgin asphaltic concrete binder content was adjusted to 3.0 percent such that the total mixture (i.e., existing material, rejuvenator and virgin asphaltic concrete) would have an overall binder content of 5.4 percent. Thus, a residual rejuvenator rate of 15 percent (approximately 0.33 gallons of rejuvenator emulsion per square yard) and 55 lb/yd^2 of virgin mix with a binder content of 3.0 percent were specified.

```
    10^8 ┬──────────────────────────────────────────┐
         │                                                   │
     2.0 │
    10^7 ┼─      Existing AC                               ─┼─
         │                                                  │
         │                                                  │
    10^6 ┼─                                                ─┼─
     9.3 │                                                  │
         │                                                  │
         │                                                  │
A        │                                                  │
B   10^5 ┼─                                                ─┼─
S        │                                                  │
O        │                                                  │
L        │                                                  │
U        │                                                  │
T        │                                                  │
E   10^4 ┼─                                                ─┼─
         │                                                  │
V        │                                                  │
I        │                                                  │
S        │                                                  │
C        │                                                  │
O        │                                                  │
S   10^3 ┼─                                                ─┼─
I        │                                                  │
T        │                                                  │
Y        │                                                  │
|        │                                                  │
(cp)     │                                                  │
         │                                                  │
         │                                                  │
    10^2 ┼─                                                ─┼─
     8.0 │                                                  │ARA1
         │                                                  │
         │                                                  │
         │                                                  │
         │                                                  │
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```
|                                                  |
|                                                  |
|                                                  |
|                                                  |
+----+----+----+----+----+----+----+----+----+----+
0    10   20   30   40   50   60   70   80   90   100

              Rejuvenator (%)
```

Figure 4. Theoretical blended viscosities.

Plant Production

J. B. Talley & Co., Inc. utilized its dryer drum plant in Duson, Louisiana for mix production on this job. The plant was located approximately 25 miles from the construction site. There were no modifications to normal plant operations for the production of the Type 3 wearing course placed with the recycled mix.

Job mix formula 09 (JMF) was used for the wearing course for the control section. This JMF was modified for the recycled section by reducing the asphalt content to 3.0 percent. Table 2 provides the pertinent mix design data. The source of coarse aggregate was a crushed gravel from Louisiana Industries while the source for the coarse and fine sands were Talley Sand Pit and Roger Miller Aggregate Co., respectively. Sunshine Oil supplied the AC-30 grade asphalt cement and ELF Asphalt provided the ARA-1 rejuvenating agent.

Recycling operations began on May 14, 1990. Because the surface recycling equipment was only using 55 lb/yd^2 of new asphaltic concrete, typical plant production rates could not be attained. As a result of the limited amount of hot mix produced, the entire project quantity was considered as one lot. Table 3 provides production rates for the virgin mix. Other than verification of JMF 09 for the control mix, no Marshall properties testing was conducted on the virgin asphaltic concrete at the reduced binder content. However, the virgin mix was tested daily for binder content and gradation.

TABLE 2

PROJECT JOB MIX FORMULAS

Sequence No.	09	
Mix Use	Wearing	

Recommended Formula
(% Passing)

U.S. Sieve Size	Control	Recycle
1"	100	100
3/4"	100	100
1/2"	96	96
3/8"	88	88
No. 4	60	60
No. 10	43	43
No. 40	24	24
No. 80	14	14
No. 200	6	6
% A.C.	5.4	3.0
% Crushed	94	94
Mix Temp.	315	315

Marshall Properties

Specific Gravity	2.34	---
Theoretical Gravity	2.43	---
% Theoretical	96.3	---
% Air Voids	3.7	---
% V.F.A.	79.0	---
Marshall Stability	1902	---
Flow	10	---

TABLE 3

PLANT PRODUCTION

DATE	LOT No.	TONNAGE
5/14/90	91	32.82
5/15/90	91	102.87
5/18/90	91	181.83
5/19/90	91	139.01
5/21/90	91	210.98
5/22/90	91	236.41
5/23/90	91	251.88
5/24/90	91	166.25
5/25/90	91	132.97
5/30/90	91	162.20
5/31/90	91	240.68
6/01/90	91	204.37
6/02/90	91	90.17
6/04/90	91	191.28
6/05/90	91	191.44
6/06/90	91	196.61
6/07/90	91	169.20
6/08/90	91	89.61

Roadway Construction

The heart of the surface recycling operation is the specialized recycling equipment, in this case, the Wirtgen Remixer shown in Figure 5. A hopper on the front of the machine accepts the new hot-mix which will be blended with the rejuvenator and milled material. This new mix is lifted and carried the length of the machine above the recycling process on a chain-driven conveyor system from which it is deposited into a pugmill-type mixing chamber. Following the hopper are six banks of infrared heaters which soften the pavement for the milling head. After milling, the reclaimed mix is collected in a windrow and deposited into the mixing chamber where the rejuvenating agent and new asphaltic concrete are added. An auger then redistributes and transversely levels the resultant mix before screeding (Figure 6).

In an effort to mill to the required depth and to maintain mix temperatures between 225 and 300°F after the screed, the subcontractor used two self-propelled infrared heaters that operated approximately 100-300 yards ahead of the main recycling machine. Each of these machines heated the existing material in order to retain as much heat as possible for the remixer. In so doing, the desired depth of milling could be achieved. The heaters are shown ahead of the repaver (distant right in Figure 7).

In general, the recycling operation progressed according to the special provisions. The daily roadway production averaged 0.9 lane-miles per day. Because the recycling operation used an average of 150 tons of virgin mix per day (as compared with 1000 to 2000 tons per day with conventional operations), plant production rates were limited, inducing occasional coordination problems with mix production during the first half of the project.

The original recycled mix design prescribed a rejuvenator rate of 0.33 gal/yd^2. This rejuvenator rate, however, raised concerns by Wirtgen Remixer personnel because the construction crew had no experience with rates higher than 0.2 gal/yd^2. Consequently, trial sections were placed on the first day of construction and adjustments were made to the rejuvenator rate (ranging from 0.2 to 0.33 gal/yd^2) and to the virgin mix asphalt cement content (ranging from 3.0 to 4.0%) in order to provide an acceptable final mix. These decisions were based on visual inspections of the screeded mix consistencies, the extracted binder content and the quality of the recovered binder via viscosity and penetration data. After the second day of production, a rejuvenator rate of 0.2 gal/yd^2 and a virgin mix binder content of 4.0 percent were established for the remainder of the project.

Figure 5. Wirtgen Remixer train.

Figure 6. Leveling auger and screed.

Figure 7. Heaters.

The rejuvenating agent was applied to the roadway exclusively by the main machine. The actual measured rates along with final mix temperatures are provided in Table 4. Overall, the 20,112 gallons of ARA-1 rejuvenator used was slightly lower than the revised design quantity of 22,678 gallons. Screed temperatures generally remained above the established minimum of 225°F. Scarification depths were measured randomly throughout the project and were found to meet the minimum 1.5 inch depth required by the special provisions. A polymer rejuvenator (400 gallons of AES 300RP, Elf Asphalt) was placed in the east-bound lane for 1550 feet (approximately 3100 feet west of the east end of the project). This area will be evaluated separately during the performance evaluation.

TABLE 4

REJUVENATOR ADDITION RATES AND SCREED TEMPERATURES

	RATE (Gals/Yd^2)	MIX TEMPERATURES (F°) 1	2	3	4
5/14/90	0.21	225	220	---	---
5/15/90	0.20	210	210	220	---
5/18/90	0.20	220	245	245	240
5/19/90	0.20	240	230	225	240
5/21/90	0.20	255	225	225	230
5/22/90	0.20	220	225	250	255
5/23/90	0.22	270	230	270	255
5/24/90	0.21	240	235	245	265
5/25/90	0.17	290	230	250	255
5/30/90	0.18	250	240	240	260
5/31/90	0.19	225	245	250	240
6/01/90	0.19	245	240	240	235
6/02/90	0.21	---	---	---	---
6/04/90	0.19	235	250	255	250
6/05/90	0.20	235	250	255	250
6/06/90	0.19	240	230	245	260
6/07/90	0.19	240	265	225	245
6/08/90	0.20	200	245	---	---

Quality Control

Although Marshall properties acceptance testing was waived at the plant, an attempt was made to determine the feasibility of conducting Marshall testing at the project site. If successful, the Marshall properties could be used for quality control of the recycling process. As required by specifications, a field laboratory was set up on the project site. Transport of samples to the field laboratory averaged ten minutes. Upon arrival, samples experienced notable temperature reductions inducing large variations in stabilities, percent voids filled with asphalt and percent air voids. Attempts were made to account for the loss of temperature by immediately placing the samples in the field laboratory oven. However, the length of time necessary to increase temperature (3 - 4 hours) quickly backlogged the following samples. Table 5 presents the daily averages of the Marshall data for this project. A regression analysis with 5 percent confidence limits revealed a poor correlation and that the air void levels accounted for approximately 50 percent of the standard error associated with stability variation. It is believed that sample temperature and time in the oven encompassed a major portion of the remaining stability variation. As this information was not acquired during construction, no further work could be accomplished with field Marshall quality control.

TABLE 5

MARSHALL PROPERTIES
Type 3 Wearing Course

Date	Stability* (lbs)	Specific* Gravity	VFA* (%)	Air Voids* (%)
5/14/90	1461.20	2.271	65.76	5.54
5/15/90	1630.50	2.294	72.33	4.30
5/18/90	1495.25	2.263	68.40	5.21
5/19/90	1151.50	2.233	61.31	6.70
5/21/90	1255.25	2.288	70.87	4.44
5/22/90	1547.50	2.278	72.83	4.41
5/23/90	1290.25	2.305	75.55	3.58
5/24/90	1458.75	2.265	70.35	5.00
5/25/90	1271.50	2.225	62.84	6.73
5/30/90	1304.75	2.241	71.06	5.94
5/31/90	1102.50	2.272	69.49	5.09
6/01/90	1059.00	2.250	65.47	6.08
6/02/90	.	.	.	.
6/04/90	1256.50	2.294	76.53	3.76
6/05/90	1605.75	2.273	71.74	4.68
6/06/90	1097.00	2.276	72.73	4.49
6/07/90	1413.25	2.289	74.59	3.93
6/08/90	.	.	.	.

* Daily average

Gradation and binder content testing were also used for field quality control. Both the subcontractor's field technician and LTRC technicians sampled recycled material from the auger, just before screeding. When possible, these samples were taken at the same time but constituted two distinct samples. All LTRC samples were returned to Baton Rouge for testing. The samples were extracted using a centrifuge; asphalt contents were corrected for ash. The contractor's technician determined ash corrected binder content only (denoted as %AC - Field in Table 6). Table 6 provides the results of the gradation and binder content testing. The means and standard deviations are based on individual results. In addition, samples of the virgin asphaltic concrete were taken by LTRC personnel from the Remixer hopper and by the plant technicians. For this testing at LTRC, reflux extraction was used. Gradations and binder contents are presented in Tables 7 and 8.

Generally, LTRC and plant results of the virgin mix were similar. Both LTRC and plant results provided higher than historical variation on the No. 4 and No. 10 sieves and on binder content. These higher than normal variations were probably because of the low production and start and stop plant processing. This variation of the virgin mix did not affect the variation of the recycled mix as illustrated in Table 6. These gradation variations are consistent with hot plant recycled mixes. The variation in virgin mix asphalt content has affected the recycled mix, however. The final binder content was lower than the estimated design of 5.4 percent and the variation in the LTRC corrected binder content sample was significantly higher than hot plant recycled mixtures.

Roadway density is used as an acceptance criteria in Louisiana with the contractor required to achieve 96 percent of the plant briquette density for 100 percent payment. Because of the uncertainties associated with field Marshall briquettes, it was decided that the state's current requirement of five roadway cores for each day's run was appropriate but that the roadway compactive effort should not be based on field briquettes. Also, since the recycled mix might demonstrate more variation in gradation and binder content than normal plant produced mix, it was decided to use maximum theoretical specific gravity (Rice method) rather than the department's customary calculated theoretical specific gravity. A specification of 93 percent of maximum theoretical gravity was set as a minimum requirement. The roadway compactive effort is provided in Table 9.

TABLE 6

EXTRACTED RECYCLED MIX GRADATION AND ASPHALT CEMENT CONTENT
(Daily Averages -- 2-4 Samples/Day)

Date	1/2"	3/8"	No 4	No 10	No 40	No 80	No200	%AC (LTRC)	%AC (FIELD)
5/14/90	98	90	69	49	28	18	8	5.0	4.8
5/15/90	98	89	64	47	26	16	8	5.2	5.1
5/18/90	97	88	63	44	25	15	7	4.9	5.2
5/19/90	97	90	64	46	26	17	8	4.9	5.0
5/21/90	95	85	60	44	25	15	7	5.0	5.0
5/22/90	96	87	63	46	26	16	8	5.2	5.4
5/23/90	96	86	59	44	25	16	8	5.2	5.0
5/24/90	98	91	65	46	25	16	8	5.8	5.4
5/25/90	98	91	65	45	25	16	8	5.1	5.3
5/30/90	96	89	62	43	23	15	8	4.9	5.3
5/31/90	97	89	61	43	23	15	8	5.3	5.3
6/01/90	98	93	66	45	24	15	8	5.3	5.3
6/02/90	97	89	63	47	27	17	8	5.6	5.1
6/04/90	97	88	61	43	24	16	8	5.4	5.5
6/05/90	97	89	62	45	25	16	8	5.1	5.4
6/06/90	96	85	61	45	25	16	8	4.9	5.4
6/07/90*	96	87	62	46	26	16	8	5.0	5.2
6/08/90	----	Half day's run -- no samples received						----	----
MEAN	97	88	62	45	25	16	8	5.1	5.2
STD	1.37	2.89	3.22	2.39	1.59	1.10	0.61	0.45	0.20

* Polymer rejuvenator

TABLE 7

PLANT EXTRACTED VIRGIN MIX GRADATION AND ASPHALT CEMENT CONTENT
(Daily Averages -- 2 Samples/Day)

Date	1/2"	3/8"	No 4	No 10	No 40	No 80	No 200	%AC
5/14/90	95	82	54	36	20	12	5	3.0
5/15/90	89	70	42	30	19	11	4	3.0
5/18/90	92	81	51	39	24	15	7	3.6
5/19/90	95	87	59	42	26	15	6	3.9
5/21/90	95	84	54	38	22	13	6	3.6
5/22/90	94	78	50	35	22	14	7	3.3
5/23/90	93	86	57	40	25	15	6	4.4
5/24/90	95	82	54	42	23	15	7	4.0
5/25/90	95	81	56	41	24	14	6	3.5
5/30/90	93	84	56	41	24	14	6	4.1
5/31/90	96	85	61	44	25	15	7	4.0
6/01/90	95	85	58	41	25	14	6	3.9
6/02/90	96	91	67	51	30	17	7	4.6
6/04/90	95	85	60	44	24	14	6	4.0
6/05/90	95	87	61	44	25	14	6	4.4
6/06/90	96	89	60	44	25	14	6	3.9
6/07/90	94	84	56	41	24	14	6	3.9
6/08/90	93	77	51	38	23	14	6	3.8
MEAN	94	83	56	41	24	14	6	3.8
STD	1.73	4.82	5.48	4.47	2.28	1.28	0.76	0.44

TABLE 8

LTRC EXTRACTED VIRGIN MIX GRADATION AND ASPHALT CEMENT CONTENT

Date	1/2"	3/8"	No 4	No 10	No 40	No 80	No 20	%AC
5/14/90	.	.	.	.	.	.	.	.
5/15/90	.	.	.	.	.	.	.	.
5/18/90	97	89	68	52	32	20	9	4.4
5/19/90	95	84	57	41	24	15	7	3.8
5/21/90	96	89	62	42	24	15	7	3.9
5/22/90	96	90	69	51	29	17	8	4.1
5/22/90	96	87	62	44	25	15	7	3.9
5/23/90	93	83	56	40	22	14	7	3.5
5/24/90	94	83	60	45	25	16	8	3.8
5/25/90	96	80	49	35	21	13	7	3.5
5/30/90	95	85	56	38	21	13	7	3.4
5/31/90	93	81	53	38	22	14	7	3.6
6/01/90	.	.	.	.	.	.	.	3.3
6/02/90	.	.	.	.	.	.	.	4.4
6/02/90	97	87	58	43	26	24	8	4.0
6/04/90	.	.	.	.	.	.	.	4.1
6/05/90	.	.	.	.	.	.	.	3.7
6/06/90	.	.	.	.	.	.	.	3.9
6/07/90	92	79	53	40	24	15	7	4.0
*6/07/90	98	92	65	48	26	16	8	.
*6/07/90	97	92	66	48	26	15	8	5.6
MEAN	95	85	59	42	25	16	7	3.8
STD	1.65	3.70	5.98	5.07	3.26	3.18	0.67	0.29

*Polymer rejuvenator

TABLE 9

ROADWAY COMPACTION

DATE	SPECIFIC GRAVITY 1	2	3	4	5	MEAN	% CMPCTN
5/14/90	2.312	2.292	-----	-----	-----	2.302	96.0
5/15/90	2.183	2.211	2.275	-----	-----	2.223	92.7*
5/18/90	2.327	2.317	2.239	2.257	2.228	2.274	94.0
5/19/90	2.253	2.233	2.264	2.203	2.250	2.241	92.8*
5/21/90	2.258	2.236	2.245	2.262	2.239	2.248	92.9*
5/22/90	2.225	2.301	2.261	2.312	2.297	2.279	94.9
5/23/90	2.321	2.345	2.354	2.325	2.307	2.330	97.3
5/24/90	2.271	2.295	2.220	2.275	2.218	2.256	94.7
5/25/90	2.270	2.308	2.299	2.297	2.266	2.288	95.8
5/30/90	2.260	2.274	2.286	2.277	2.229	2.265	94.5
5/31/90	2.196	2.274	2.270	2.255	2.280	2.255	93.8
6/01/90	2.222	2.245	2.254	2.209	2.204	2.227	93.0
6/02/90	2.236	2.281	-----	-----	-----	2.259	94.5
6/04/90	2.279	2.293	2.281	2.289	2.222	2.273	95.0
6/05/90	2.281	2.311	2.250	2.268	2.228	2.268	94.4
6/06/90	2.186	2.243	2.286	2.354	2.254	2.265	93.7
6/07/90	2.263	2.285	2.253	2.244	2.252	2.259	94.0
6/08/90	2.242	2.287	-----	-----	-----	2.265	93.7
MEAN							95.1
STD							1.30

*Below acceptance limits

The contractor used a three-roller operation with a vibratory roller, a rubber tire pneumatic roller and a three-wheel steel finish roller. During the first several days of construction, compaction was generally marginal which was attributed to the difficulties encountered by the rolling operators with the slower than normal progress of the paving process. Subsequently, roadway compaction was within the acceptable range. Concerns were raised early in construction when pneumatic roller tracks seemingly flushed the asphalt in the wheel paths. Further examination indicated that because of a split screed, additional fine material was directed to the wheel path zone by the augers. The fine material gave a closed-up and flushed appearance in the mat in the area of the wheel path. After several days of traffic, the flushed appearance was diminished. Future evaluations will determine the effect on performance.

Another concern about the surface recycling process which had been evident in all previous projects of this type was the additional oxidation of the existing asphalt cement by the heaters, followed by rejuvenation in the recycling process. The 1980 and the 1986 projects described earlier demonstrated that the radiant preheaters and the main equipment heaters successively further oxidized the existing asphalt cement. Although the rejuvenator returned the oxidized asphalt to various viscosity levels, the consistencies were varied longitudinally along the pavement.

On this project, generally two samples of loose mix were obtained by LTRC personnel each day to examine the quality of the recycled binder. Also, the subcontractor's technician sampled loose mix once per day. While the LTRC and subcontractor sample were not necessarily obtained at the same time, the mix was always taken from the distribution auger just before the screed. Because of the construction of the equipment, it was impractical to sample at other locations. The loose mix was extracted and the asphalt was recovered by the Abson process. Both absolute viscosity (140°F) and penetration (77°F) were tested at LTRC. The field lab tested penetration only. The results are provided in Table 10.

The LTRC and field penetrations were found to be similar. The mean viscosity of 21,566 poises was very close to the 24,000 poises predicted by the theoretical relationship provided in Figure 4 (10 percent residual rejuvenator rate = 0.20 gal rejuvenator / yd^2). The overall variation is higher than desirable but is generally low within daily production. Although the viscosities of the existing pavement were all 200,000 + poises, it is possible that some areas were considerably harder than others (i.e. 800,000 versus 200,000) which could account for the between-day differences. A more likely explanation for the variation observed may be because of the manual adjustment of the rejuvenator feed. Because of changes in the forward speed of the machine, both within a day or between days, the variation in viscosity can readily be explained. Future special provisions should require automatic control of the rejuvenator feed.

TABLE 10

PHYSICAL PROPERTIES OF RECOVERED ASPHALT CEMENT

DATE	REJUVENATOR (GAL/YD^2)	AVERAGE* VIRGIN AC	LTRC VISC (Poises)	PEN LTRC	PEN FIELD
5/14/90	0.20	3.6	37557	32	33
	0.33	2.7	3443	75	.
	0.20	3.6	33435	32	.
5/15/90	0.20	3.0	30782	31	35
	.	.	11079	41	.
5/18/90	0.20	4.0	80852	23	28
	.	.	29204	29	.
	.	.	31020	29	.
	.	.	35798	26	.
5/19/90	0.20	3.9	15917	36	38
	.	.	6625	48	.
5/21/90	0.20	3.8	6294	52	.
	.	.	14746	33	35
5/22/90	0.20	3.7	47149	34	37
	.	.	3821	44	.
5/23/90	0.22	4.0	11392	37	44
	.	.	9882	44	.
	.	.	5110	60	.
5/24/90	0.21	3.9	16816	84	32
	.	.	31708	31	.
5/25/90	0.17	3.5	34919	26	28
	.	.	71860	24	.
5/30/90	0.18	3.8	32239	30	62
	.	.	10156	44	.
5/31/90	0.19	3.8	24290	32	62
	.	.	4151	60	.
6/01/90	0.19	3.9	7671	43	35
	.	.	4254	63	.
6/02/90	0.21	4.6	3220	64	52
	.	.	2037	84	.
6/04/90	0.19	4.0	7393	46	52
	.	.	10101	42	.
6/05/90	0.20	4.4	16876	36	62
	.	.	17837	35	.
6/06/90	0.19	3.9	4414	65	38
	.	.	6191	50	.
6/07/90	0.19	3.9	17045	35	44
	.	.	13292	39	.
6/08/90	0.20	3.8	51424	26	.
	.	.	60634	26	.
MEAN			21566	42	42
STD			19483	16.0	11.7

*Note: Average of daily LTRC and Plant values.

ECONOMIC ANALYSIS

The unit cost of the bid items for the recycled and control sections are reproduced as follows:

Item	Description	Unit	Cost
501(1)	Asphaltic Concrete	TON	29.50
736(01)	Cold Planing Asphaltic Pavement	SYD	0.75
S-001	Surface Recycling Asphaltic Pavement	SYD	2.65
S-002	Rejuvenating Agent	GAL	1.95
S-003	Asphaltic Concrete for Recycling	TON	29.25

The total cost of the surface recycled section was $3.84 per square yard which includes the surface recycling, rejuvenating agent at 0.20 gallons/square yard and 55 lb/yd^2 of asphaltic concrete wearing course. The corresponding cost for the conventional section used as a control was $4.00 per square yard based on cold planing (2 inch average cut) and 2.0 inch wearing course, so that an approximate 4 percent savings was realized for this project assuming equivalent section performance. The surface recycling subcontractor indicated that this savings could be increased if the surface recycling had been bid as a prime contractor.

CONCLUSIONS

1. The Wirtgen Remixer met specifications on all but three days of production where the required pavement densities were not achieved; these substandard densities occurred during the first four days of full production and may be attributed to the unfamiliarization of the roller operators with the characteristics of the recycled mix. No problems were encountered for the remainder of the project.

2. Because of the rapid loss of sample temperature, efforts to use Marshall properties as a mix quality control tool were unsuccessful. Reheating of the material to a temperature sufficient to achieve proper air void levels took so long that test results could not be obtained in a timely manner. Whether the variation in Marshall properties was attributable to mix variation or the reheating could not be determined.

3. The mean viscosity of the recovered binder from the recycled mixture was very close to that predicted by the theoretical relationship and the project variation was not as great as experienced with previous surface recycling equipment. However, the variation was greater than anticipated. The variation was believed to have occurred because the rejuvenator feed rate was not automatically controlled by the machine's forward speed. Future special provisions should stipulate such positive control.

4. The surface recycling project realized a savings over the conventional design. The economic benefit of such savings can be determined after performance evaluations are completed.

APPENDIX
SPECIAL PROVISIONS

STATE PROJECT NO.
SPECIAL PROVISIONS

Item S-1, Surface Recycling Asphalt Concrete:
This item consists of in-place recycling of asphaltic concrete surfacing in a simultaneous, multi-step process of heating, milling, applying a rejuvenating agent, adding additional asphaltic concrete, pugmill mixing and levelling and screeding the mixed material in a single pass of the equipment in accordance with plan details and the following requirements. Construction methods, equipment and required materials shall be approved by the department prior to beginning work under this item.

(a) Surface Preparation: Any required patching, levelling or joint repair shall be completed prior to commencement of recycling operations. The pavement surface shall be cleaned of surface water, dirt and debris immediately prior to recycling operations.

(b) Equipment: The equipment shall consist of a self contained, self-propelled, automated unit capable of heating, milling, applying a rejuvenating agent, adding additional asphaltic concrete, pugmill mixing and levelling and screeding the mixed material in a single pass of the equipment. Equipment shall be capable of accurately and automatically establishing a profile grade along each edge of the machine by referencing from the existing pavement by means of all of the following: a 30 foot minimum travelling stringline, a matching shoe or an independent grade control. Additional pre-heaters shall be permitted.

Preheaters: The preheaters shall be separate self-propelled units consisting of multiple rows of infrared burners utilizing liquid propane gas for heating fuel. Direct or indirect open flames shall not be permitted. They shall be of sufficient number to heat to the desired penetration of depth without overheating, coking or sooting of the existing asphaltic concrete and to comply with air pollution laws. The preheaters shall contain the heat to prevent damage to trees and shrubs and to traffic passing by the unit.

Recycling Machine: The recycling machine shall be equipped with additional heaters conforming to the same requirements as the preheaters. The resulting heated, existing asphaltic concrete shall be between 225°F and 300°F prior to milling.

The milling unit shall be a rotating milling drum capable of uniformly loosening the existing asphaltic concrete to a minimum depth of 1.5 inches and shall be equipped with automatic height adjustments in order to clear utility manholes and other obstructions in the pavement surface. All milled material shall be augured into the center of the machine prior to entry into the blending unit.

A rejuvenating agent storage unit shall be temperature controlled so that the rejuvenating agent can be applied at the desired rate. The rejuvenating agent spraying unit shall be capable of uniformly distributing an approved rate of material for a forward speed that is coincidental with the recycling operation. Spraying of the rejuvenator agent shall occur after milling and prior to entry to the blending unit.

The blending unit shall be a twin shafted pugmill capable of uniformly adding new asphaltic concrete at the approved rate. The unit shall thoroughly mix the milled asphaltic concrete, rejuvenating agent and new asphaltic concrete so as to produce a uniform mixture.

The hot recycled mixture shall be uniformly distributed to the required profile and cross slope by the use of a heated tamping and vibrating split screed which shall be an integral part of the recycling machine.

(c) Materials:

Rejuvenating Agent: The rejuvenating agent shall be ARA-1 as manufactured by ELF Asphalt, P. O. Box 1175, Mt. Pleasant, TX 75455, (214) 572-9839, or an approved equal conforming to the following specification:

PROPERTY	ASTM TEST METHOD	REQUIREMENTS	
		MIN.	MAX.
Viscosity @ 25°C, SSF	D88	15	100
Miscibility	D244	No coagulation or separation	
Sieve Test, %	D244	--	0.10
Residue*, %	D244	60	--
Particle charge	D244	Negative	
Test on Residue from Evaporation			
Asphaltenes, %	D4124	--	1.0
Saturates, %	D4124	--	30
Flash Point, COC, °F	D92	375	--
Thin-film oven test,			
Weight change, %	D1754	--	4
Viscosity @ 60°C, CST	D2170	75	250

*Determined by evaporation method in ASTM D244, except that sample shall be maintained at 300°F until foaming ceases, then cooled and weighed.

Modified Asphaltic Concrete: Asphaltic Concrete meeting the requirements of Type 3 Wearing Course according to Supplemental Specifications, Section 501, 8/87, shall be modified by reduction of asphalt content consistent with producing a recycled asphaltic concrete at an optimized binder content to be determined by the engineer. The new asphaltic concrete shall meet all requirements for a Type 3 Wearing Course prior to the reduction of asphalt content. No reclaimed asphaltic concrete materials will be permitted in the modified asphaltic concrete mixture.

(d) Recycling Operations: The surface shall be uniformly heated by infrared heating units to provide proper heat penetration without overheating, coking or sooting of the existing asphaltic concrete and to comply with air pollution laws. The milling unit shall uniformly mill the existing, heated asphaltic concrete to a minimum depth of 1.5 inches. All milled material shall be augured toward the center of the machine.

Rejuvenating agent shall be sprayed on the collected material. [NOTE: Preliminary testing indicates that 0.33 gallon/square yard of rejuvenating agent will be required to return the existing binder material to a state consistent with specification limits. The actual rate used shall be approved by the engineer.]

New asphaltic concrete (at a reduced binder content) shall be added to the rejuvenated existing materials in the pugmill unit at the rate of 55 pounds/square yard or as directed by the engineer. Preliminary testing indicates that the binder content of the new asphaltic concrete should be in the range of 2 to 3 percent. The actual binder content of the new asphaltic concrete shall be determined by field testing the final mix of rejuvenated, existing material and the new asphaltic concrete. For this purpose, the contractor shall provide a portable, on-site laboratory to determine Marshall mix design and extracted materials properties.

The combination recycled/new asphaltic concrete mixture shall be redistributed and leveled by the heated tamping and vibrating, split screed, leaving the finished surface course to the specified line and grade. The finished mat temperature shall be a minimum of 225°F. Immediate compaction shall take place according to

Subsection 501.08.

Density (determined from five cores per day) shall be 93% of the maximum specific gravity ascertained by the Rice Method, ASTM D2041-78, as established by the average value of three loose mix samples per day. Surface tolerance shall be in accordance with Section 501. Stability requirements shall be waived.

The recycling equipment shall be capable of heating and cutting back at least 2" of the standing edge of the previous adjoining passes to produce a welded longitudinal joint.

Any tonnage of mix not accepted due to a malfunction of the contractor's equipment shall be removed and replaced full depth with Type 3 Asphaltic Concrete Wearing Course at the contractor's expense.

(e) Measurement: Resurfacing existing asphaltic concrete will be measured by the square yard. The width for measurement will be that of the finished section and the length will be the centerline length. Measurement of irregular areas will be the area constructed, as determined by the engineer.

Rejuvenating agent shall be measured by the gallon of 231 cubic inches measured in its tank on the recycling equipment. Measurement shall be corrected to 60°F.

Type 3 Modified Asphaltic Concrete Wearing Course shall be measured by the ton (2000 pounds) according to Subsection 501.13.

(f) Payment:

(1) Recycling existing asphaltic concrete will be paid for the contract unit price per square yard.

(2) Pay adjustment for Pavement Density, average of 5

samples for each day's production (% of laboratory density):

Percent of Contract Unit Price/Square Yard			
100	95	80	50 or More
93 and above	92.0 - 92.9	90.0 - 91.9	Below 90.0

(3) Pay adjustment factor for Theoretical Gravity shall be waived.

(4) Payment will be made under:

Item S-1, Surface Recycling Asphaltic Concrete, per square yard.

Item S-2, Rejuvenating Agent, per gallon.

Item S-3, Type 3 Modified Asphaltic Concrete Wearing Course, per ton.

This report documents the surface recycling of 7.4 miles of route U.S. 90 from the junction of La 99 to Jennings, Louisiana. The specialized recycling equipment was provided and operated by Remixer Contracting Co., Inc. of Austin, Texas. Roadway production included heating the existing pavement, milling to a 1.5 inch depth, adding rejuvenator and new mix and placing 2.0 inches of recycled, Type 3 wearing course. The daily roadway production proceeded with very few problems and averaged 0.9 lane-miles per day. The surface recycling project realized a savings over the conventional design. The economic benefit of such savings will be determined after performance evaluations are completed.