Demonstration Projects Program
Technology Transfer
FHWA-DP-39-31
February 1981

DEMONSTRATION PROJECT NO. 39

RECYCLING ASPHALT PAVEMENTS

Beaver, Utah

epared for
and
stributed by

.S. DEPARTMENT OF TRANSPORTATION
EDERAL HIGHWAY ADMINISTRATION
EGION 15
EMONSTRATION PROJECTS DIVISION
00 NORTH GLEBE ROAD
RLINGTON, VIRGINIA 22201

Hot Recycling of Asphaltic Concrete Pavement
IR-15-3(8)121, Wildcat to Pine Creek

Report for FHWA
Demonstration Projects Division

Author and Principal Investigator

Wade B. Betenson, P.E.
Pavement Design Engineer

Development Unit Coordinator

Victor K. Sorbe
Materials Engineer

Utah Department of Transportation
Materials and Research Section
Pavement Design and Bituminous Mix Design Unit
Salt Lake City, Utah

October 1980

ACKNOWLEDGEMENT

The author gratefully acknowledges partial financial support from the Demonstration Projects Division of the Federal Highway Administration through a project designed to make effective use of our resources and conserve the energy value of our fossil fuels. Special acknowledgements are extended to Henry Plancher of Laramie Energy Technology Center who assisted in the preparation and testing of various samples; to Jack B. Parson Construction Company for their cooperation during construction of the project; and Steven E. Niederhauser and Elliott Carlsen of the Materials and Test staff personnel who performed the central laboratory testing and field testing.

Gratitude is extended to the District Construction staff and Project Engineer Darwin Hunt and his staff who administered the contract and furnished assistance during the project.

We thank the Utah Department of Environmental Air Quality for their assistance and cooperation concerning the stack emissions produced by the process.

Gratitude is expressed to Nancy Tracy who typed the many drafts of this report.

TABLE OF CONTENTS

ABSTRACT

The technology to recycle asphalt pavement materials has been developed to a state of commercial application and offers the public official broad energy and economic savings without having to sacrifice quality.[1] There are various methods of pavement material recycling. This report is devoted to hot-mix plant recycling considerations and procedures. The several phases of the hot-mix recycling process are discussed separately, including removal and size reduction of existing asphaltic concrete pavement material, analyzing pavement composition, determining the amount of recycling agent required, mixing the ingredients with new aggregate and asphalt, the hot-mix plant process, spreading and compaction, quality control, the economics of hot-mix recycling, and other pertinent information.

The ability to recycle has enormous implications not only for conservation of valuable resources, but also for energy requirements in the manufacturing process and economic benefits to be realized in both.[2] The primary reason to recycle is economics. The economics consist of a comparison between the relative cost of reclaimed pavement materials as compared to the cost of new aggregate and asphalt cement. The final end product must meet the same design standards and performance criteria regardless of the source of material. The use of reclaimed materials without sacrificing quality offers public officials and the public the ability to do more physical miles of work with the limited available dollars.

INTRODUCTION

The Utah Department of Transportation is faced with an on-going maintenance problem on their interstate, primary, and secondary roadways. In the past there were three solutions that could be used to solve the maintenance problems: 1 - Patching and seal coating, 2 - An overlay to improve the riding surface and the structural adequacy, or 3 - In critical cases, total reconstruction. Now, due to the technology developed during the last decade, the Transportation Department has one other solution to this problem. That is partial or full depth recycling of the existing asphaltic concrete pavement.

Seal coating does little more than cover the pavement surface and increase the skid resistance. An overlay can cause problems with width, slope, guardrail, and bridge structures. Total new construction is expensive and is fast depleting two of our natural resources - the asphalt and aggregates needed to reconstruct the pavement. Recycling uses the existing pavement materials and, even though a small amount of new asphalt and aggregate is needed, still conserves our natural resources.

One large maintenance problem faced the Utah Department of Transportation. On I-15 near Beaver, Utah, "Wildcat to Pine Creek Hill, the existing flexible pavement had extensive thermal cracking, and Dynaflect data indicated that the pavement system was weak and reconstruction was suggested. An overlay on this project would cause the problems mentioned above with width, slope, guardrail, and bridge structures, and would not eliminate the real problem - the cracking. Total new construction was considered, but due to high cost factors was discarded.

Finally, it was decided the most economical procedure would be to recycle the existing asphaltic concrete pavement.

With recycling, the existing thermal cracking would be eliminated, and the experts believe that by recycling, the absorption and shrinkage phenomenon which takes place in pavements would already have taken place and the new recycled pavement would not be greatly subject to new thermal cracking. Another benefit with recycling would be that the oxidation from the catalytic action of the aggregates would not be as severe with the recycled mix as with new conventional mix.

Using salvaged asphaltic concrete pavement and recycling it as a temporary 400 feet connection on I-70 near Cove Fort in 1975 not only stirred Utah DOT's interest in recycling but showed that the recycled material was better than when used originally.(3) At the time, we did not check air quality nor uniform size of material placed in the drum mix plant. After 60 months of extensive testing the reheologic properties of the recycled bitumens appear better than those of asphalt from the new hot mix section.(4)

There were actually four preliminary design alternates considered for the restoration of the roadway. A concrete overlay was considered but we did not have good quality aggregate in the area. Next was a bituminous overlay but with the amount of existing cracking we did not feel that was the answer. We felt the cracks would reflect through the overlay in a few years and the cracking phenomenon would cycle itself to the same magnitude it is now. We did consider a fabric membrane with the overlay but there is not a lot of long term success with this type membrane system. The most economic design alternate was recycling which would allow us to scarify and reconstruct the existing cement treated base. The equivalent annual cost for a 40 year life of 2 lane mile for each design alternate is:

1.	Recycling	$7500
2.	Bituminous Overlay	$8500
3.	Bituminous Overlay with FMAI	$8600
4.	Concrete Overlay	$9200

The benefits inherent with recycling are expected to be the cost savings to the Department through the preservation of our natural resources.

MATERIALS TESTING

The interstate project on I-15, Wildcat to Pine Creek, was 4.6 miles in length with approximately 100,000 tons of reclaimed material to be recycled. The project was a four-lane interstate, 38 feet wide with 7 1/2 inches of old bituminous pavement in place. The pavement was approximately 18 years old and had a lot of maintenance expenditures. The base material consisted of cement treated base which we felt had contributed to much of the cracking problem. The CTB would have to be scarified, two inches of untreated base course added for leveling, reshaped, and recompacted to the grade line.

The existing roadway was cored every half mile, with six 6-inch cores taken at each location. These specimens were measured for height and density. The cores were then crushed to minus one inch, the material mixed, and twenty four representative samples taken for asphalt content, gradation, and asphalt recoveries. From the gradation samples, it was determined that 20% +4 rock was needed to correct the gradation. Marshall Designs and Immersion-Compressions were based on repetition on nine samples after the percentage of asphalt and softening agent had been determined.

Marshall mix designs were made from 80/20 ratio to 50/50 with 20 percent plus four virgin rock used as a constant in all mixes. The laboratory data on the Marshall design parameters were as follows:

Core Gradation		Design Gradation	Marshall Parameters	
3/4	100	100	Air Voids	3
1/2	90	81	Stability	2800
3/8	82	69	Flow	20
4	58	50	V.M.A.	85
8	43	35		
16	33	27		
50	18	15		
200	11.2	8.2		

Not knowing the ratio of reclaimed to virgin material the contractor would use to meet the air quality requirements, the decision was made to use a mix proportion chart. This would allow the contractor the freedom for his operation and still provide the quality control required by the Department.

Historical data indicated that the old pavement was in need of a fortifier, some method to better bond the asphalt to the rock. Immersion-compression tests were made on all the Marshall designs. The ratio of 100 to 80 percent reclaimed material indicated that we had good unconfined strength. The unconfined strengths on the 70 to 50 percent ratio were borderline and not that conclusive. We knew that the Laramie Energy Technology Center at Laramie, Wyoming was developing new tests to predict susceptibility of asphalt aggregate mixtures to moisture damage.[5] We shipped a sample of the reclaimed and virgin material with the data for a 70/30 combination calling for a known percent of reclaimed material, new material, asphalt and recycling agent. Three samples were made by the L.E.T. Center containing zero additive, one-percent anti-stripping agent and a set with one-percent hydrated lime. The results of the testing on cycles to failure were 1 cycle, 2 cycles and greater than 15 cycles, respectively. The latter test was discontinued after 15 freeze-thaw cycles when the briquets showed no evidence of failure. These results parallel previous studies which showed that the addition of hydrated lime to bituminous mixtures increased their resistance to moisture damage and reduced the age hardening process.(6, 7)

There has been a lot of speculation by some technologists that the Abson recovery of the extracted asphalt is not a measure of how good the homogeneity of the recycled material really is.(8) To limit future speculation, we took the reclaimed conglomerate material that had been screened over a number four screen, heated it to 260°F and then mixed the reclaimed material in a Hobart mixer for 90 seconds and screened off all the minus four fractions. We then ran an Abson recovery on the asphalt extracted from plus No. four material. The results were as follows:

No. 4 Reclaimed Material (after heating and rescreening)	Penetration @77°F(.1mm)	Viscosity @140°F(Poise)	Viscosity @275°F(Cs)	Ductility @39.2°F(Cm)
	27	25,075	706	0.25

Then a mix ratio of 50/50 conforming to the Recycled Asphalt Concrete Pavement-Mix Proportion Chart (See Appendix A) was prepared for recovery using 2.5 percent AC-10 and 0.6 percent recycling agent. The only deviation made on the virgin material was instead of using 33 percent plus four aggregate and 17 percent fine aggregate, 50 percent fine aggregate was used. The sample procedure as above was followed, preheating to 260°F, mixing 90 seconds, screening off all minus four material and running an Abson recovery on the plus No. four material. The results were as follows:

No. 4 Reclaimed Material (after heating, mixing with virgin material and rescreening)	Penetration @77°F(.1mm)	Viscosity @140°F(poise)	Viscosity @275°F(Cs)	Ductility @39.2°F(Cm)
	96	1283	275	60

SPECIAL PROVISIONS

Special provisions were added to the project plans pertaining to the pre-bid conference, energy consumption, stack tests, air quality requirements for stationary sources, experimental test sections to be constructed, removing, crushing and stockpiling existing bituminous pavement, scarifying and reconstructing existing base course, and recycled asphalt concrete pavement. These special provisions are in Appendix A.

There was a minimum air quality variance granted. The contractor would be allowed to exceed the requirements as necessary for plant calibration and adjustment at the start of production, and for construction of test sections No. 5 and 6 as detailed in these special provisions. This variance in air quality standard was limited to production of the initial 5300 cubic yards of paving mix produced on the project.

A pre-bid conference was held with the bidders to discuss the special provisions and job requirements that are somewhat unique with the project.

PROJECT CONSTRUCTION

The department opened the bids in the fall of 1978. Jack B. Parson Construction Company of Ogden, Utah was low bidder. The contract amount was $2,071,180 for the 4.6 miles of roadway. Due to the contractor's scheduling problems, the project did not start until July 1979.

The removal, crushing, and stockpiling of the existing bituminous pavement was outlined in the special provision. The contractor could use any method or methods deemed necessary to remove the pavement as long as the material was not contaminated or degradated and the maximum size of the material was 1½ inches with no more than a 5 percent override.

Parsons elected to subcontract the removal to Vernon Paving Co., of California. They used the Barber-Greene RX-75 Dynaplane with a 12 foot cutter assembly. There were 236,000 square yards to remove, crush, and stockpile. The bid price was $1.47/square yard based on 7½ inches in depth and mean width of 41 feet. The subcontractor had no problems in the removal or with gradation control. He removed half the depth of the center section then came back and removed the total depth on the two outside shoulders, then removed the remaining center section. Typical production was 400 ton per hour, and 5 ton per tooth life. A set of teeth lasted approximately one day and cost between $3.00 to $4.00 a tooth. The cutting assembly has 230 teeth.

After removal of the existing bituminous pavement, the upper three inches of the existing portland cement treated base course was scarified and processed to reduce the size of the component particles to 1½ inches or less. Two inches of base gravel was added and uniformly mixed with the scarified portland cement treated base, refinished to a relatively smooth surface, and recompacted. The base price for scarifying and reconstructing the PCTB three inches deep and 44.5 feet wide was 0.38¢ per square yard plus $4.05 per ton for the base gravel.

To continue the development of hot-mix recycling technology the contractor, as part of this contract, was required to construct six test sections. Each test section was 1600 feet in length, 8½ inches deep and 38 feet wide.

A mix proportion chart included in the special provision titled "Recycled Asphaltic Concrete Pavement" was used to determine and control the proportions of reclaimed material, recycling agent, coarse aggregate, fine aggregate and asphalt cement used in the test sections. The six test sections were constructed in accordance with the proportions shown on the chart corresponding to the following percentages of reclaimed material:

TEST SECTION NO.	% RECLAIMED MATERIAL
1	0
2	50
3	60
4	70
5	80
6	100

Test section 5, corresponding to 80 percent reclaimed materials, was constructed during the initial 10,000 tons calibration period when a variance from air quality standards was allowed.

We did not construct test section 6 corresponding to 100 percent reclaimed material, because the split feed system requires that some virgin aggregate be added at the burner end of the drum. In place of 100 percent reclaimed material, a 40/60 ratio was used.

South Bound Lanes 1979 Construction

During construction of test sections 5, 4, 3, 2, and 1, the hot plant did not meet air quality requirements of 20 percent opacity. The drum was then equipped with a new Genco burner that had never been fired. The manufacturer was unable to obtain complete combustion with the new burner. Even with 100% virgin aggregate the opacity was 35 to 65 percent. The Genco people ended up bringing in five burners, with the fourth burner tried finally working and the fifth burner used as a spare. After the combustion problem was finally solved, CMI felt they could improve the air quality by changing the flighting inside the drum and adding water to the reclaimed material.

With the changes in the burner, flighting, and after adding water, the opacity of a 70/30 combination was reduced to 35 percent. We were unable to meet the 20 percent opacity on any of the following combinations: 70/30, 60/40, and 50/50. The various combinations of mixes produced were very good from a quality standpoint. The proportion chart worked excellently with no last minute changes and all the mixes met a recovered asphalt specification of an AC-10. The bid price for the recycled asphaltic concrete pavement was $19.65/cubic yard in place. This is cheaper by 39 percent when compared with regular virgin mix.

Handling of the recycled bituminous mix beyond the mixer was the same as for a conventional mix. The dryer-drum mixer used on the project was a CMI-1900 UDM and production rates averaged 300 tons/hour at 240°F. Basically, for the south bound lanes excluding the test sections, a

70/30 recycled mix was used consisting of 2.0 percent AC-10 and 0.8 percent recycling agent for the mix design.

The 50,000 tons of recycled mix produced for the 1979 season on the southbound lanes was a disappointment as far as air quality was concerned. Violations of the air quality led the Division of Environmental Health to issue an order on Sept. 14, 1979 to immediately cease and desist plant operation. The Department was concerned with potential safety and structural problems if the second lift was not completed. As a result, a stipulation was arranged allowing Parson Construction to operate the plant for a limited time to complete the lift. The stipulation included the provision that any violation of the air quality requirements on any day of operation would result in a fine of $1,000 for that day. The second lift and the final lift were both completed under this stipulation, and the company subsequently paid a fine of $11,000. During the winter of 1979, CMI took the drum back to Oklahoma for new flighting, a larger draft system and a hauck burner, and placed a hydrocarbon incinerator on the stack.

North Bound Lanes 1980 Construction

On March 26, 1980, the Bureau of Air Quality Section of the Division of Environmental Health met with Parson Construction Company, representatives from CMI, and staff from the Materials Section to discuss the CMI Model UDM 1900 Asphalt Plant and HPD 936 venturi scrubber with an after burner for hot-mix recycling. Plans and specifications covering the new changes in the plant and scrubber from last year were found to be acceptable by the Bureau of Air Quality. But before the contractor could proceed this year, another 30 day published notice of intent to issue a new permit approval order by the Bureau of Air Quality had to be available for review and comment. The conditions upon which the approval was given were:

1. Stack gas outlet grain loading shall not exceed 0.04 gr/dscf for any reclaimed/virgin mix used.
2. Visible emissions shall not exceed 20% opacity for any mix used.
3. The after burner is considered part of the air quality control facilities.
4. A compliance stack test will be conducted per EPA methods 1-5 and will be performed with all control facilities in operation. The test will be run with the plant at maximum proposed production rate and at the highest proposed recycle/virgin material ratio. Limitations on maximum allowable production rate (TPH) and maximum recycle/virgin material mix, which shall be applicable throughout the State, shall be based on results of the stack test. These limits shall be added to the air quality order as an addendum. Each future temporary relocation shall be per regulations, Section 3.1.9.
5. A maximum of six (6) working days or 10,000 tons of production will be allowed for equipment tune-up before the stack test shall be conducted.
6. For the purposes of the stack testing and future operations, instrumentation shall show: a) water flow to venturi, b) pressure drop across scrubber unit and c) water supply line pressure to venturi.

7. The back half condensibles of the stack test data shall also be submitted to the Bureau of Air Quality (BAQ), but as a separate item.

8. Test results on grain loadings shall be submitted to the BAQ no later than two working days after completion of the test. Operations will be permitted during this time subject to visible emissions regulations (maximum of 20% opacity).

9. If additional stack test results demonstrate that the plant can meet the required emission limitations stated in conditions 1 and 2 without the afterburner in operation, use of the afterburner may be suspended at the option of the Executive Secretary.

On July 8, 1980, Parson Construction began paving the north bound lanes with a 50/50 ratio of reclaimed and virgin material. The plant opacity was approximately 35%. The next day and the remaining five days, the mix ratio was 50/50 with some 40/60 and 30/70 ratios being produced. The following changes were made in the field in addition to the changes made in Oklahoma: (1) Replaced the lifters with a saw tooth lifter, (2) Cut out kicker flights near the end of the drum and (3) put a ring in front of the reclaimed material to hold the virgin material longer before mixing with the reclaimed material.

American Chemical and Research Laboratories conducted three particulate matter compliance tests on July 15, 1980. All tests were conducted with a production ratio of 40 percent reclaimed material and 60 percent virgin. The three particulate rates wre 0.0414, 0.0162 and 0.0271 gr/SDCF and visible emission averaged 13 percent opacity (See Appendix D).

The remainder of the project was finished with a 40/60 ratio. The recovered bitumens met an AC-10 specification. The contractor had no more problems with the air quality, the 40/60 ratio produced a range of opacity between 7 and 14 percent.

Basically for the NB lanes, the ratio of recycled mix was 40/60, with 3.7 percent AC-10 asphalt and 0.6 percent recycling agent.

As had been expected, the recycling process paralleled the laboratory preliminary design investigation. The test results all met the asphalt requirements for an AC-10 (ASTM 3381). (See Appendix B).

The recycling operation produced a high quality mix and pavement with no major changes needed in the preliminary mix designs. The Recycled Asphalt Concrete Pavement-Mix Proportion Chart was unchanged throughout the project other than to extend the mix proportion chart to include a 40/60 ratio.

COST ANALYSIS

Four preliminary design alternates were developed using bid prices from other projects. At that time, we reviewed three large overlay projects for cost comparison. The following shows the original cost comparison of the five alternates. The savings between new pavement costs and recycling costs are approximately $322,278.00. When the contractor's actual bid prices for alternate design one was compared to alternate design two, there is a savings of $110,416.00.

Cost Comparison	Construction Cost Per Two-Lane Mile	Annual Cost Per Two-Lane Mile
Design		
1. Recycling	$178,632.00	$ 8,912.00
2. Bituminous Overlay	$187,466.00	$ 9,133.00
3. Bituminous Overlay/SAMI	$189,132.00	$ 9,174.00
4. Rigid Pavement	$318,893.00	$ 9,772.00
5. Rigid Pavement (FHWA)	$352,930.00	$10,623.00

New Pavement Cost

Removal of Existing Surface

$1.47/sq. yd.

236,000 sq. yds. removed

$1.47 x 236,000 = $346,920.00

Scarifying and Reconstructing Existing Base Course

0.38/sq. yd.

243,600 sq. yds.

$.38 x 243,600 = $ 92,568.00

Untreated Base Course

$4.05/ton

27,800 Tons

$4.05 x 27,800	=	$ 112,590.00

New Plant Mix Pavement

$25.92/cu. yd.

51,400 cu. yds.

$25.92 x 51,400	=	$1,332,228.00
TOTAL	=	$1,884,366.00

Recycling Cost

Removal of Existing Surface

$1.47/sq. yd.

236,000 sq. yds. removed

$1.47 x 236,000	=	$ 346,920.00

Scarifying and Reconstructing Existing Base Course

0.38/sq. yd.

243,600 sq. yds.

$0.38 x 243,600	=	$ 92,568.00

Untreated Base Course

$4.05/ton

27,800 tons

$4.05 x 27,800	=	$ 112,590.00

Recycled Asphaltic Concrete

$19.65/cu. yds.

51,400 cu. yds.

$19.65 x 51,400	=	$1,010,010.00
TOTAL	=	$1,562,088.00
Savings over New Pavement	=	$ 322,278.00

ENERGY ANALYSIS

The energy usage of the various operations was either taken from actual fuel consumption on the project or derived from estimates of equipment performance and fuel consumption made by the contractor. Energy consumption for the recycled mix is based on two ratios, 70/30 and 40/60, respectively.

The energy consumed by recycling showed a 12,284,085,760 BTU savings in energy as compared to the energy needed to produce new plant mix pavement. This energy savings is equivalent to heat 110 homes in Utah for one energy year.

ENERGY CONSUMPTION OF OPERATIONS

Diesel Fuel	139,000 BTU/gal
Gasoline	125,000 BTU/gal
Fuel Oil, No. 6	154,500 BTU/gal

<u>Crushing of Virgin Aggregate</u>

This particular pit when crushed to 3/4 inch maximum size has the following distribution:

40 Percent Waste

35 Percent Rock

25 Percent Sand

<u>Haul</u>

A truck gets 4 miles/gal, or 2 miles a haul gal.

A truck hauls approximately 25 tons

25 x 2 = 50 ton-miles/gal

$$\frac{139{,}000 \text{ BTU/gal}}{50 \text{ Ton-miles/gal}} = 2780 \text{ BTU/ton-mile}$$

Energy Used to Produce Asphalt

Producer estimated 600,000 BTU/ton

Energy Used to Produce Lime

Producer estimated 4,500,000 BTU/ton

New Pavement Energy

Crushing of Aggregate

79,876 BTU/ton of aggregate

99,088 Tons aggregate needed

79,876 BTU/ton x 99,088 ton	=	7,914,753,088 BTU

Haul of Aggregate

99,088 tons of aggregate

23 miles deadhaul

2780 BTU/ton-mile of haul

99,088 tons x 23 miles x 2780 BTU/ton-mile	=	6,335,686,720 BTU

Production of New Asphalt

6481 tons of asphalt

380 miles deadhaul

2780 BTU/ton-mile

6481 tons x 380 miles x 2780 BTU/ton-mile	=	6,846,528,400 BTU
6481 tons x 600,000 BTU/ton	=	3,888,600,000 BTU

PRODUCTION OF NEW PAVEMENT

It is estimated that the energy consumption would be the same as that for producing the recycled mix

Burner Fuel	=	10,119,200,000 BTU
Plant Equipment	=	2,036,628,000 BTU

Removal of Old Pavement

7840 gals x 139,000 BTU/gal	=	1,089,760,000 BTU
103,056 tons x 9.28 mile x 2780 BTU/ton	=	2,658,679,910 BTU
Hydrated Lime Production and Haul	=	8,503,265,600 BTU
TOTAL	=	40,285,821,720 BTU

ENERGY FOR RECYCLING

Crushing of Virgin Aggregate and Base Gravel

37,476 gallons of diesel used in crushing

139,000 BTU/gal x 37,476 gallons	=	5,209,164,000 BTU

Haul of Virgin Aggregate

40,927 tons @ 23.0 miles deadhaul	=	941,321 ton-mile
941,321 ton-mile x 2780 BTU/ton-mile	=	2,616,872,380 BTU

Production of New Asphalt

2726 tons used

600,000 BTU to Produce one ton

2726 Tons x 600,000 BTU	=	1,635,600,000 BTU

Haul of New Asphalt

2726 tons asphalt

380 miles deadhaul

2,780 BTU/ton-mile

2726 tons x 380 miles x 2780 BTU/ton-mile	=	2,879,746,400 BTU

Production & Haul of Softening Agent

677 tons softening agent	384 T/SB
	293 T/NB
1488 miles deadhaul	677 tons

2780 BTU/ton mile

677 tons x 1488 miles x 2780 BTU/ton mile	=	2,800,505,280 BTU
677 tons x 600,000 BTU	=	406,200,000 BTU

PAVEMENT PROFILER

7840 gals Diesel used by profiler

103,056 tons of reclaimed material removed

4.64 miles deadhaul

7840 gals x 139,000 BTU/gal	=	1,089,760,000 BTU
103,056 tons x 4.64 mile x 2780 BTU/ton	=	1,329,339,955

Haul of Base Gravel

10,635 tons

10.68 miles deadhaul

113,561 ton-miles

113,561 ton-mile x 2,780 BTU/ton-mile	=	315,699,580 BTU

Production of Recycled Pavement

72,800 gals Diesel used by plant

92,043 tons on mix produced

14,652 gals Diesel used by Plant Equipment

87,452 gals x 139,000 BTU/gal	=	12,155,827,560 BTU

Production of Lime

4,500,000 BTU/ton production energy

920 tons of lime used

4,500,000 BTU/ton x 920 tons	=	4,140,000,000 BTU

Haul of Lime to Job Site

920 tons of lime

1706 miles deadhaul

2730 BTU/ton-mile deadhaul

920 tons x 2780 BTU/ton-mile x 1706 miles	=	4,363,265,600 BTU
TOTAL	=	28,001,735,960 BTU

POST CONSTRUCTION EVALUATION

A post-construction evaluation has been completed. Because of contractor delay in finishing the project, the SB lanes are one year older than the NB lanes. A one-year evaluation has been performed on the SB lanes and only an initial evaluation on the NB lanes.

A three year evaluation will be conducted on an annual basis and will include cores for asphalt recoveries to determine aging properties of the asphalt, mix performance tests, pavement serviceability, a dynaflect evaluation, the skid index, maintenance information and photographs.

The asphalt recoveries on the construction data were all within the parameters of an AC-10 specification. The viscosity of the asphalt recovered to determine the aging of the one-year cores has increased two to three fold. This increase is much higher than past data trends. It may be that the size of the sample taken for the one-year data to represent each 1600 foot test section is too small. Future coring will be increased to cover the full length of each test section.

The mix performance tests run on the construction mixes for creep compliance and resilient modulus were all in the range considered to be a good quality product, less than 10 on the creep and above 500,000 P.S.I. on the resilient modulus. The cores for the one-year period representing each test section look good, except for the 0/100 ratio. This section decreased slightly in resiliency but the creep has doubled.

The average pavement serviceability index (PSI) of the old existing pavement was 2.8. The PSI of the recycled pavement showed values of 3.65 and 3.67 PSI, respectively. This PSI is considered to be low for a new pavement, indicating somewhat of a marginal ride. The P.S.I. should be between 4 and 5.

The structural adequacy of the old existing pavement was determined by deflection measurements obtained with the Dynaflect. Measured deflections for the SB and NB lanes were 1.053 and 1.055 mils, respectively. The required deflection is 0.479 mils. The measured deflections after recycling were 1.009 and 0.958 mils, respectively. The structural life of the pavement has not been improved, but the distress life of the pavement has been improved considerably. Another method in evaluating structural adequacy is the spreadability method in measuring equivalent thicknesses.(9) The old pavement had a spreadability of 53 with an equivalent thickness of 5.5 inches of bituminous surface course, while the new recycled pavement had a spreadability of 60 with an equivalent thickness of 7.5 inches of BSC and actual thickness of 8.5 inches of BSC placed. Again indicating structural inadequacy.

The skid tests were performed by a MuMeter and averaged 69 for both lanes. This was a surprise because the SB lane has a chip seal and the NB lane does not. This could not be explained by the testing personnel other than the recycled pavement had good texture.

It is the Department's policy to seal all new roadways that have been through one winter. Therefore, the SB lanes have recieved a type "A" chip seal and the NB lanes will receive a seal in the summer of 1981.

CONCLUSIONS

1. The asphaltic concrete pavement recycled was approximately 20 years old. The reclaimed pavement had a high minus 200 content and a low asphalt content. A high percentage of minus 200 reduces the availability and the effectiveness of the asphalt binder.
2. Aging and transverse thermal cracking of the asphaltic concete pavement has been related to asphalt and mix properties. These factors have been improved by fortifying the asphalt binder with a recycling agent, the addition of lime to decrease water susceptibility of the mix, and adding course aggregate to improve gradation characteristics.
3. The subbase material consisted of cement treated base which was very rigid and contributed to the cracking phenomenon. This problem was corrected by scarifying the CTB and adding untreated base.
4. Standard mix design procedures, using extracted gradations, Abson recoveries, Marshall procedures, Immersion-compression and a simple laboratory test to indicate the susceptibility of asphalt aggregate mixtures to moisture damage during repeated freeze-thaw cycles are applicable to recycling.
5. The Barber-Greene RX-75 Dynaplane was well suited for the removal of the 7.5 inches of asphaltic concrete pavement. The Dynaplane did produce some large chunks of reclaimed asphalt that the contractor scooped off with a 2 inch screen. Although we had plenty of material because of the ratio of reclaimed to virgin material used, this over size material could have become a problem if a higher ratio had been used.

6. The hydrated lime and the asphalt were converged in a knockout box at the rear of the drum. This produced a very favorable dispersion of the hydrated lime.
7. Recycling through a dryer drum, equipped to recycle, proved to be an acceptable process. A high quality paving mixture was achieved while finally meeting environmental standards. The CMI hot plant was factory and field equipped for recycling and produced acceptable opacity and particulate levels while maintaining a production rate of 300 tons per hour with an output temperature of 240°F.
8. The extracted gradations were a little finer than we had anticipated. It would have been better to have split the reclaimed material on the number four screen. This would allow us to have better gradation control of the reclaimed material.
9. The performance of the CMI 1900 UDM dryer drum was a disappointment. Ratios of 40/60 are unacceptable to contractors in the West. Because of pollution problems with the drum, the project required two seasons to complete. Based on the bid prices, there was a savings to the Department but the bid price reflected a 70/30 ratio not a 40/60 ratio. In other words, there must be an economic benefit to both the buyer and the seller.
10. A recycled asphalt concrete pavement can be achieved that exhibits the properties and characteristics of a virgin mix and, in addition, will have a lower rate of hardening. The Marshall stabilities and flows indicate a stable mix. The penetration, viscosity, and ductility tests indicate good asphalt performance; the resilient modulus, and creep compliance tests indicate good mix performance. The uniform mix produced in the dryer drum hot plant posed no special problems during laydown.

11. The contractor thought the concept with the mix-proportion chart worked very well.

12. The contractor thought too much money was being spent on air quality in these remote areas and he was sure that the State-of-the-Art of recycling with respect to air quality is not at the level the EPA thinks it is.

13. Most big businesses are given a target date to meet air quality standards. Road contractors are given, maybe, one project per State to solve all the problems. That is like saying all hot plants and reclaimed material are the same across the country. The potential horizon for hot-mix recycling is unlimited but it looks as through regulatory agencies are going to over kill.

14. For plant calibration and adjustment at the start of production and for the possible construction of any test section, the contractor should be allowed 10% of the tonnage outside of the air quality standards.

15. From an ecological and economic standpoint, when you can reduce the consumption of asphalt by 45 percent and the use of new aggregate by 70 percent when hot-mix recycling is employed, the taxpayer has to be informed.

16. A literature search was made on other states recycling projects to determine the State-of-the-Art of the ratio of reclaimed to virgin material. This was interesting. Basically in the East there was a 50/50 ratio or less and in the west there was a 70/30 ratio. The lower ratio in the east was attributed to the use of batch plants rather than the dryer drum used in the west.

REFERENCES

1. Canessa, William, P.E. "The Chemical Aspects of Pavement Recycling Affecting Engineering Consideration", AAPT Vol. 48, 1979, Denver, Colorado.

2. "Recycling Asphalt Pavements", National Asphalt Pavement Association, Promotional Series 11.

3. Betenson, Wade B., P.E., "Five Year Probe of Hot-Mix Recycling" Rural and Urban Roads, July 1980.

4. Betenson, Wade B., P.E., "Recycling Asphaltic Concrete Pavement," AAPT Vol. 48, 1979, Denver, Colorado.

5. Plancher, H., Miyahe, G., Venable, R.L., and Petersen, J.C., "A Simple Laboratory Test to Indicate the Susceptibility of Asphalt-Aggregate Mixture to Moisture Damage During Repeated Freeze-Thaw Cycles," CTAA, Nov. 1980, Victoria, B.C.

6. Plancher, H., Green, E.L., and Petersen, J.C., "Reduction of Oxidative Hardening of Asphalts by Treatment with Hydrated Lime -- A Mechanistic Study." Proc. Assoc. Asphalt Paving Technol., V. 45, 1976, pp. 1-24.

7. Chachas, C.V., Liddle, W.J., Peterson, D.E., and Wiley, M.L., "Use of Hydrated Lime in Bituminous Mixtures to Decrease Hardening of the Asphalt Cement." Final Report, Utah State Department of Highways, Materials and Test Division, Distributed as NTIS Report No. P6-213 170, December 1971.

8. Scherocman, James A., P.E., Chief Paving Engineer. Barber Green, Conversation October 1980.

9. Vaswaini, N.K., "Method for Separately Evaluating Structural Performance of Subgrades and Overlaying Flexible Pavements; Virginia Highway Research Council, HRR Number 362, 1971.

APPENDIX A

SPECIAL PROVISIONS AND SPECIFICATIONS

Sheet # 1

SPECIAL PROVISION

I-IR-15-3(18)121

Pre-Bid Conference

A Pre-bid Conference will be held to discuss with bidders the Special Provisions and job requirements that are somewhat unique with the project. This conference will be held in Room 614 of the State Office Building on September 19, 1978, at 9:00 a.m. All prospective bidders are requested to attend.

8/30/78

SPECIAL PROVISION

I-IR-15-3(18)121

Energy Consumption

One of the fundamental objectives of this project is to evaluate asphalt pavement recycling processes by collecting data pertaining to energy consumption. The contractor shall be required to furnish a breakdown of the total energy required for the recycling and conventional mix operation of this project, including energy required to manufacture the asphalt and softening agent at the refinery. The energy consumption for various fuels and electrical power usage shall be reported in gallons, cubic feet, and kilowatt hour.

The contractor shall supply this data on a monthly basis to the project engineer in consultation with the pavement design engineer of the Materials Section.

No separate payment shall be made to the contractor for submitting the above required information, the cost of which should be included in the bid prices for the various items of work.

8/25/78

SPECIAL PROVISION
I-IR-15-3(18)121
Stack Tests

Description: To determine compliance with air quality standards, the contractor shall arrange for six stack tests to be conducted on a schedule supplied by the project engineer in cooperation with the Executive Secretary, Utah Air Conservation Committee and the Pavement Design Engineer of the Materials and Research Sections. One stack test shall be required to be taken for the material produced for each of the test sections which are described in the Special Provision covering "Experimental Test Sections."

Construction Methods: Tests must be witnessed by the Utah Bureau of Air Quality and conducted by an approved stack testing firm such as, but not limited, to the following:

York Research Corporation
7100 Broadway
Building 3A
Denver, Colorado 80221

Air Pollution Technology, Inc.
4901 Morena Boulevard
Suite 402
San Diego, California 92117

Stephen W. Upson, Associates, Inc.
2361 Wehrle Drive
Buffalo, New York 14221

American Chemical and Research
32 East 335 South
Salt Lake City, Utah

Arthur Young & Company
Surety Life Building
Denver, Colorado 80202

Dames & Moore
605 Parfet Street
Denver, Colorado

Pollution Control Science, Inc.
6015 Manning Road
Miamisburg, Ohio 45342

Engineers Testing Laboratories, Inc.
2525 E. Indian School Road
Phoenix, Arizona 85016

Kimball Laboratories & Consulting
40 North 400 West
Salt Lake City, Utah

Ute Research Laboratory
Fort Duchesne, Utah

Stack tests shall be performed in accordance with Method 5, described in 40 CFR, Part 60, and shall be reviewed by the Executive Secretary of the Utah Air Conservation Committee.

Method of Measurement: One complete testing procedure including required reporting of results shall constitute onestack test.

Basis of Payment: This item shall be paid for at the contract unit price per each for "Stack Tests," which payment shall be full compensation for all work, equipment, materials, and mobilization necessary to complete the item.

8/25/78

SPECIAL PROVISION

I-IR-15-3(18)121

AIR QUALITY REQUIREMENTS FOR STATIONARY SOURCES

The Contractor's mixing plant for production of bituminous mixes shall be required to meet the applicable air quality requirements for new stationary sources except as modified herein. Federal standards of performance for new stationary sources allow visual emissions not to exceed 20 percent opacity, and particulate matter emissions not to exceed 0.04 grains per dry standard cubic foot.

The Contractor will be allowed to exceed the above requirements as necessary for plant calibration and adjustment at the start of production, and for construction of test sections No. 5 and 6 as detailed elsewhere in these Special Provisions. This variance in air quality standards shall be limited to production of the initial 5300 cubic yards of paving mix produced on the project.

Prior to initiation of construction of any portion of this project, any mixing plant intended for use in production of bituminous paving mixes and associated air cleaning equipment must be approved by the Executive Secretary, Utah Air Conservation Committee in accordance with the provisions of Section 1.6, Utah Air Conservation Regulations. Such approval requires submission of equipment plans and specifications to the Executive Secretary for his review. The review and approval process requires a minimum of sixty days.

6/28/78

SPECIAL PROVISION
I-IR-15-3(18)121
Experimental Test Sections to be Constructed

To continue the development of hot-mix recycling technology, the contractor, as part of this contract, shall be required to construct six test sections Each test section shall be 1600' in length and shall be constructed to the cross section and depth shown for "Recycled Asphalt Concrete Pavement" on the typical section.

The mix proportion chart included in the Special Provision titled "Recycled Asphalt Concrete Pavement" shall be used to determination and control the proportions of reclaimed material, softening agent, coarse aggregate, fine aggregate, and asphalt cement used in the test sections. The six tests shall be constructed in accordance with the proportions shown on the chart corresponding to the following percentages of reclaimed material.

Test Section No.	% Reclaimed Material
1	0
2	50
3	60
4	70
5	80
6	100

The contractor shall be required to meet air quality standards during production of the recycled bituminous concrete pavement to be placed in the test sections, therefore, test sections 5 and 6, corresponding to 80% and 100% reclaimed material, shall be constructed during the initial 5300 cu.yd. (approximately 10,000 ton) calibration period when variance from air quality standards is allowed.

The attention of the contractor is directed to the fact that all test sections in which air quality standards cannot be met, must be produced during this initial 5300 cu.yd. calibration period.

Construction of the six test sections shall be done as scheduled by the project engineer in cooperation with the pavement design engineer of the Utah Department of Transportation's Materials and Research Section.

Materials and Construction Methods: The Special Provision titled "Recycled Bituminous Concrete Pavement" shall control except as modified by this Special Provision.

Method of Measurement: This item shall be measured by the cubic yard. Quantities for payment shall be determined from the neat line cross sectional area shown on the typical section and labeled recycled asphalt concrete pavement, and the station to station limits, along the control line, of pavement placed and accepted.

Basis of Payment: This item shall be paid for at the contract unit price per cubic yard, for "Recycled Asphalt Concrete Pavement," which may be adjusted in accordance with the Special Provision for that item, which price shall be full compensation for all materials, equipment, labor and incidentals necessary to complete the item, except crushing and stockpiling of the existing pavement shall be paid separately.

8/29/78

SPECIAL PROVISION

I-IR-15-3(18)121

Remove, Crush, and Stockpile Existing Bituminous Pavement

Description: This item shall consist of scarifying and removing the existing bituminous pavement on the northbound lane and southbound lane including ramp tapers, crushing the material so removed, and stockpiling it at the site of the central mixing plant.

Construction Methods

Removal of Existing Pavement: All existing bituminous pavement of the northbound lane, southbound land, and ramp tapers within the project limits shall be removed from the roadway. Removal shall be done in a manner that will prevent unnecessary intermixing with the underlying portland cement treated base course. All existing bituminous pavement shall be removed down to the top of the portland cement treated base course within 1/2"±, regardless of the depth shown on the plans.

Gradation: All existing bituminous material shall be removed and processed such that 95% of the material shall have a least dimension of 1-1/2". It shall also be required that this material before being introduced into the mixing plant be passed through a 2" scalping screen. Removal and processing shall be done in such a manner that degradation of the aggregate does not occur. If the engineer determines that crushing of the reclaimed pavement is, in fact, causing degradation of the aggregate to an extent that the proportion of course aggregate in the recycled asphalt concrete pavement must be increased to compensate for the increase in fines due to degradation, the Engineer shall revise the mix proportion chart for the recycled asphalt concrete pavement as required to provide the necessary increased proportion of course aggregate. The contractor shall then produce recycled asphalt concrete pavement in accordance with the proportions as revised, and no adjustments of the contract unit price for that item shall be made as a consequence of this revision.

The processed reclaimed pavement shall be acceptable for use in accordance with the proportions shown on the mix proportion chart if the gradation falls within the following specified limits when tested in accordance with Department Test Procedure 8-946 and 8-947.

Sieve Size	Maximum % Passing
3/4"	100
3/8"	98
No. 4	66
No. 16	36
No. 50	24
No. 200	13

Determination of compliance with the above gradation shall be based on the average of five samples taken from a test lot at the stockpile. A test lot shall be the quantity of reclaimed material in the stockpile at the time of sampling. The stockpile shall be sampled as often as deemed necessary by the engineer but a minimum of once a week during crushing and stockpiling of the reclaimed pavement.

Testing by the Department indicates the gradation of the existing bituminous pavement to be as follows:

Sieve Size	% Passing
1"	100
3/4"	99±1
1/2"	91±3
3/8"	82±3
No. 4	58±3
No. 8	43±2
No. 16	33±2
No. 50	18±1
No. 200	11.4±0.5

If a roto-mill or similar equipment is used in place of crushing, the above provisions shall apply. In addition, the equipment shall be capable of controlling dust created by the cutting and removing operation, and shall have a manual system for varying the depth of cut while the equipment is in motion.

Stockpiling: The reclaimed bituminous pavement removed and crused in accordance with this Special Provision shall be stockpiled at the location selected by the contractor for his mixing plant. The stockpile shall be constructed and located so as to be readily available for use in the recycled bituminous surface course. The area where the stockpile is to be placed shall be cleared, graded and compacted or otherwise prepared to provide a firm level base for the stockpile and prevent contamination with soils or other deleterious materials. The stockpile site shall be approved by the engineer prior to stockpiling. Layer placing, stacking conveyors or other approved methods shall be used for stockpiling to prevent coning or segregation of the stockpiled material.

The Transportation Commission has obtained a free use permit on five acres of land located approximately 500' left of Station 1271± southbound lane. This area will be available to the contractor as a site for his central mixing plant and for stockpiling materials. In the event the contractor chooses some location other than that described above for a plant site, all reclaimed pavement not used in the production of recycled asphalt concrete pavement shall be transported to and stockpiled at the above described location in the manner specified above prior to the notice of completion of the project. There will be no extra compensation for transporting and stockpiling materials from the contractor's plant site to the location designated above.

Method of Measurement: The quantity of this item shall be measured by the square yard of material in place on the roadway prior to removal. On the northbound lane and southbound lane, the width for payment shall be 41.0' as shown on the typical section, and the length shall be determined by the station to station limits, along control lines, of material actually removed and processed in accordance with this Special Provision. On ramp tapers, the quantity shall be determined by horizontal measurements, prior to removal, with measurements on side slopes taken to a line representing the average width of the course being removed.

Basis of Payment: This item shall be paid at the contract unit bid price per square yard for "Remove, Crush, and Stockpile Existing Bituminous Pavement," which price shall be full compensation for all labor, equipment, materials and incidentals necessary to complete the work.

9/19/78

SPECIAL PROVISION

I-IR-15-3(18)121

SCARIFYING AND RECONSTRUCTING EXISTING BASE COURSE

DESCRIPTION: This item shall consist of scarifying the upper 3 inches of the existing portland cement treated base course, processing the scarified material to reduce particle size to 1-1/2 inch maximum, watering, spreading, and compacting the processed material, overlaying the compacted material with Untreated Base Course as required to obtain a smooth riding surface, and finishing and compacting the reconstructed base course in conformance with the requirements below.

SCARIFYING: After removal of the existing bituminous pavement, the upper 3 inches of the existing portland cement treated base course shall be scarified and processed to reduce the size of the component particles to 1-1/2 inches or less.

If the method of scarifying and processing used by the contractor causes cracking, loosening or any other distrubance to the portland cement treated base course below the specified 3 inches depth, all of the distrubed portions of the portland cement treated base course shall be processed and reconstructed in the same manner as the upper 3 inch layer. No separate payment whall be made for necessary work below the specified upper 3 inch layer.

RECONSTRUCTING: The scarified and processed base material shall be uniformly mixed with water, placed on the roadway in its original thickness, finished to a relatively smooth surface and recompacted. Care must be taken to maintain a uniform thickness and maintain the original cross-slope of the roadway.

A leveling course of Untreated Base Course with an average thickness of 2 inches shall be placed over the reconstructed base material as required to provide a smooth riding surface. Areas of settlement will require sufficient Untreated Base Course to match the grade line of adjacent sections. The Untreated Base Course shall be mixed with water, compacted and finished to provide a smooth riding surface by means of a land plane at least 40 feet in length, or a similar leveling device approved by the engineer. The leveling device shall be capable of carrying sufficient material to fill low spots, shall be operated in conjunction with an approved finish roller and shall continue leveling operations until the roadway surface is approved by the engineer. Water shall be applied as needed to maintain the Untreated Base Course in a workable and compactable condition.

Prior to placing prime coat, the leveling course shall be fine graded by means of a motor patrol or other approved fine grading equipment, and rolled with an approved steel-wheel roller.

The scarified and processed portland cement treated base course shall be uniformly compacted to the density specified below. Maximum laboratory density shall be determined in accordance with AASHTO Designation T-180, Method D.

Acceptance with respect to density shall be based on the average of all density determinations made in a lot. A lot shall be the number of square yards completed and compacted each production day. The test lot shall be subdivided into sublots of approximately 1600 square yards. One density test, randomly selected by use of a suitable random number table, shall be taken within each sublot.

The lot shall be accepted when the mean of all density determinations made within the lot is not less than 96 percent of maximum laboratory density, and when no single determination is lower than 92 percent of maximum laboratory density.

If an individual determination falls below 92 percent of maximum laboratory density, the material represented by the determination will be considered defective and the contractor shall further compact the sublot. After further compaction, the original lest site and one other randomly selected site, within the sublot, shall be tested. The average of the two test results shall be included in the computation of the mean density of the lot. The original test results shall not be included in that computation. If the sublot still does not meet the required density, the process of recompacting and retesting shall be repeated.

In addition to the above acceptance tests, the engineer may test any area which appears defective, and shall require further compaction and retesting of areas where test results show the density to be less than 92 percent of maximum laboratory density.

If the mean density of the scarified and processed portland cement treated base course in any lot does not equal or exceed 96 percent of maximum laboratory density, the lot may be rejected or accepted at the option of the engineer. If accepted it will be paid for at 90% of the contract unit price for "Scarifying and Reconstructing Existing Base Course." Acceptance at this reduced price must be requested, in writing, by the contractor.

FINISHING: The reconstructed base shall be finished to a smooth, uniform line and grade with surface deviations not exceeding 0.5 inches, plus or minus, in ten feet. The determination of compliance with smoothness tolerances may be made with a straight edge, chalk-line or surveying equipment at the option of the engineer.

The finished base shall be maintained to line and grade, and well compacted until covered by the prime coat and recycled asphalt concrete pavement. Any base course that becomes soft, washboarded, or distorted under public or construction traffice shall be corrected at the contractor's expense.

METHOD OF MEASUREMENT: This item shall be measured by the square yard of material in place on the roadway prior to scarifying and reconstructing. On the southbound lane and northbound lane the width for payment shall be 44.5 feet as shown on the typical section. The length shall be determined by the station to station limits, along control lines, of material actually scarified and reconstructed in accordance with this Special Provision. On ramp tapers the quantity shall be determined by horizontal measurement, prior to removal, with measurements on side slopes taken to a line representing the average width of the course to be scarified and reconstructed.

BASIS OF PAYMENT: This item shall be paid for at the contract unit price per square yard for "Scarifying and Reconstucting Existing Base Course", which price shall be full compensation for all labor, equipment, materials and incidentals including watering and compaction necessary to complete the work, except Untreated Base Course shall be paid for at the contract unit price per ton for that item.

June 22, 1978

SPECIAL PROVISION

I-IR-15-3(18)121

Recycled Asphalt Concrete Pavement

Description: This item shall consist of construction of a surface course composed of reclaimed bituminous pavement, softening agent, mineral aggregates and bituminous binder, mixed at a central mixing plant and spread and compacted on a prepared base in reasonably close conformance with the lines, grades, and dimensions shown on the plans, and in conformance with the Standard Specifications and this Special Provision.

Materials

Bituminous Material: The bituminous material shall be AC-10 Viscosity Graded Asphalt Cement conforming to the requirements of AASHTO Designation M-266, Table 2, with the following modifications: The viscosity at 135° C (274° F) for AC-5 shall be changed from 200 to 175. The loss on heating requirements on residue from Thin-Film Oven Test shall be deleted. Ductility at 25° C (77° F) shall be deleted and replaced with Ductility at 4° C (39.2° F) with values as detailed below:

	AC-2.5	AC-5	AC-10	AC-20
Ductility, 4° C (39.2° F.) ICM/MIM,CM.	50+	25+	15+	15+

The grade specified may be changed one step by the engineer at no change in the unit bid price for "Recycled Asphalt Concrete Pavement."

Hydrated lime shall be added to the total mix of the recycled asphalt concrete pavement material to serve as an anti-stripping agent. The lime shall be added at the rate of 1.00% by weight.

No separate payment shall be made for bituminous material or for the required hydrated lime. The cost of these materials shall be included in the contract unit price for "Recycled Asphalt Concrete Pavement."

Softening Agent: The softening agent shall conform to the following specifications:

Softening Agent Specifications

Kinematic Viscosity 100° F C.S.	1000-5000
Kinematic Viscosity 140° F. C.S.	150-300
Kinematic Viscosity 210° F. C.S.	10-30
Specific Gravity 60° F	1.00-1.040
Pounds/Gallon	8.33-8.66
Flash Point, C.O.C. ° F.	390 Minimum
R.T.F.O., Loss, %	3.0 Maximum
Mixed Aniline Pt., ° F.	75-100
Refractive Index / 20° C.	1.57-1.63
Rostler Analysis	
Asphaltenes	Less Than 1%
Nitrogen	15 Minimum
A1 + A2	67 Minimum
Saturates	15 Maximum

No separate payment shall be made for softening agent. The cost of this material shall be included in the contract unit price for "Recycled Asphalt Concrete Pavement."

RECLAIMED BITUMINOUS PAVEMENT: This material shall consist of reclaimed pavement from the northbound and southbound lanes within the project limits, removed crushed and stockpiled in accordance with the typical sections shown in the plans and the Special Provision titled "Remove, Crush and Stockpile Existing Bituminous Pavement."

MINERAL AGGREGATES: New material to be mixed with the recycled material shall conform to the following specifications:

(a) Coarse aggregate shall consist of crushed stone, crushed gravel or crushed slag composed of clean, hard, tough, durable and sound fragments, and shall be free from vegetable matter or other deleterious substances. That portion of the coarse aggregate retained on a No. 4 sieve shall have not less than 50 percent of particles by weight with at least one mechanically fractured face or clean angular face, when tested in accordance with Department Test Procedure 8-929.

Prior approval of the aggregate source is required. In addition to the routine project control requirements above, the following are necessary for approval of the aggregate source:

(1) Crushed slag, if used, shall be of uniform density and quality and shall have a rodded weight of not less than 75 lbs. per cubic foot when tested in accordance with AASHTO Designation T-19.

(2) The aggregate shall have a percentage of wear not exceeding 40 when tested in accordance with AASHTO Designation T-96.

(3) The aggregate shall have a weighted loss not to exceed 16 percent by weight when subjected to fine cycles of sodium sulfate and tested in accordance with AASHTO Designation T-104.

Coarse Aggregate shall be uniformly graded and of such a size that it will meet the following gradation specifications when tested in accordance with AASHTO Designation T-27. That portion of coarse aggregate passing the No. 200 seive shall be determined by washing with water in accordance with AASHTO Designation T-11. Samples for acceptance shall be taken from the conveyor belt leading to the stockpile.

Sieve Size	% Passing
3/4"	100
1/2"	60 ± 22
#4	8 ± 8
#16	4 ± 4
#50	3 ± 3
#200	2 ± 2

(b) Fine aggregate may be either a natural or manufactured product. It shall be clean, hard grained and moderately sharp and shall contain not more than 2 percent by weight of vegetable matter or other deleterious substances. That portion passing the #40 sieve shall be non-plastic when tested in accordance with AASHTO Designation T-90.

Fine aggregate shall be uniformily graded, and of such a size that it will meet the following gradation specifications when tested in accordance with AASHO Designation T-27. That portion of fine aggregate passing with No. 200 sieve shall be determined by washing with water in accordance with AASHO Designation T-11. Samples for acceptance shall be taken from the conveyor belt leading to the stockpile.

Sieve Size	% Passing
1/2 "	100
#4	92 ± 8
#16	44 ± 10
#50	27 ± 9
#200	10 ± 2

Adequate supplies of coarse aggregate and fine aggregate shall be produced and separately stockpiled sufficiently in advance of construction operations, to permit sampling and testing before use. The stockpiles shall be of such size as to adequately supply the mixing plant when it is operating at full capacity, and to provide continuous production of the paving mix.

Acceptance of aggregates with respect to gradation shall be based on individual test samples. At least 5 samples shall be taken for each production shift. The samples shall be chosen on a random basis through the use of a suitable random number table. In addition, the samples shall be uniformly distributed in time throughout the shift. If a test indicates the material is out of specification, no additional material will be incorporated into the stockpile until a passing test is obtained. Material produced while the retest is being performed shall be wasted. Marginal or borderline crushing operations will not be permitted.

CONSTRUCTION METHODS

EQUIPMENT: The mixing plant shall be capable of independently controlling and proportioning the reclaimed pavement, softening agent, coarse aggregate, fine aggregate, and asphalt cement in conformance with designated and approved proportions, and shall be equipped with means of independently and continuously displaying and recording the proportions or quantities of all materials being introduced into the mix. The plant shall be capable of compliance with all applicable air quality standards after the prescribed calibration and adjustment period.

If a continuous plant is used, continuous operation shall be required. If stopping and starting is inevitable, all improperly mixed material shall be wasted. Continuous plants shall have a positive means of wasting improperly mixed material.

Proportioning of Mix: Recycled Asphalt Concrete Pavement shall consist of reclaimed bituminous pavement, softening agent, coarse aggregate, fine aggregate, and asphalt cement containing the required additive, combined by weight, in accordance with the proportions shown on a designated line of the mix proportion chart as follows:

(1) It shall be the responsibility of the contractor to choose and designate the percentage of reclaimed material to be used in the Recycled Asphalt Concrete Pavement.

(2) The contractor shall adjust and calibrate his mixing plant to produce Recycled Asphalt Concrete Pavement containing recycled material, softening agent, coarse aggregate, fine aggregate, and asphalt cement conforming to the applicable specifications, and proportioned, by weight, in accordance with the factors shown on the "Mix Proportion Chart" corresponding to the designated percentage of reclaimed material.

(3) During the production of the initial 5300 cubic yards of Recycled Asphalt Concrete Pavement produced on the project, the contractor shall adjust his plant and change the designated percentage of reclaimed material in the mix as necessary to arrive at a product that can be produced in conformance with air quality requirements, that will contain a maximum proportion of recycled material, and that can be produced at a reasonable and desirable rate. Recalibration to conform to the factors shown on the "Mix Proportion Chart" will be required each time the designated percentage of reclaimed material is changed.

(4) After production of the initial 5300 cubic yards of Recycled Asphalt Concrete Pavement, changes in the designated percentage of recycled material in the mix, and recalibration of the mixing plant to conform with proportion requirements shall be made only prior to the start of a days production and shall require concurrance of the Engineer.

(5) If the Engineer determines that the contractor's operation is not in compliance with air quality requirments, he shall require the contractor to make appropriate changes in the designated percentage of reclaimed material or in his methods or procedures in order to obtain compliance.

(6) If the Engineer determines that the proportions shown on the mix proportion chart are not producing a satisfactory product, he may prepare a new chart to adjust the proportions of softening agent and/or asphalt cement in the mix. The contractor shall then adjust and calibrate his mixing plant to conform to the proportions shown on the revised chart. Whenever Recycled Asphalt Concrete Pavement is produced in accordance with proportions shown on a revised proportions chart, the contract unit price for that item shall be adjusted in accordance with the following:

Adjusted Unit Price = Original contract unit price plus A plus B
where A = unit price adjustment for softening agent
B = unit price adjustment for asphalt cement.

The unit price adjustment for softening agent (A) shall be determined as follows:

A = $340x(revised softening agent proportion - original softening agent proportion)

The unit price adjustment for asphalt cement (B) shall be determined as follows:

B = $200(revised asphalt cement proportion - original asphalt cement proportion)

All computations shall be made algebraically with the final unit price rounded to the nearest one cent, and may result in an increased or decreased unit price.

I-IR-15-3(18)121

WILDCAT TO PINE CREEK

Recycled Asphalt Concrete Pavement-Mix Proportion Chart

% Reclaimed Material	Reclaimed Material	Softening Agent	Coarse Aggregate	Fine Aggregate	Asphalt Cement
0	.0000	.0000	.4688	.4688	.0625
50	.4845	.0060	.3246	.1599	.0250
51	.4942	.0061	.3198	.1551	.0248
52	.5040	.0062	.3150	.1502	.0246
53	.5137	.0063	.3102	.1454	.0244
54	.5235	.0064	.3054	.1406	.0242
55	.5332	.0065	.3005	.1357	.0240
56	.5430	.0066	.2957	.1309	.0238
57	.5527	.0067	.2909	.1261	.0236
58	.5625	.0068	.2861	.1212	.0234
59	.5722	.0069	.2813	.1164	.0232
60	.5820	.0070	.2765	.1116	.0230
61	.5918	.0071	.2717	.1067	.0227
62	.6016	.0072	.2669	.1019	.0224
63	.6115	.0073	.2621	.0971	.0221
64	.6213	.0074	.2573	.0922	.0218
65	.6312	.0075	.2525	.0874	.0215
66	.6410	.0076	.2477	.0826	.0212
67	.6508	.0077	.2429	.0777	.0209
68	.6606	.0079	.2380	.0729	.0206
69	.6705	.0080	.2332	.0680	.0203
70	.6804	.0080	.2284	.0632	.0200
71	.6905	.0080	.2237	.0584	.0195
72	.7006	.0080	.2189	.0535	.0190
73	.7107	.0080	.2142	.0487	.0185
74	.7208	.0080	.2094	.0438	.0180
75	.7309	.0080	.2046	.0390	.0175
76	.7410	.0080	.1999	.0341	.0170
77	.7511	.0080	.1951	.0293	.0165
78	.7613	.0080	.1903	.0244	.0160
79	.7714	.0080	.1855	.0195	.0155
80	.7816	.0080	.1807	.0147	.0150
100	.9875	.0075	.0000	.0000	.0050

7/18/79
WBB

Whenever a revised mix proportion chart is being used to proportion the ingredients in the recycled asphalt concrete pavement, a separate adjusted contract unit price shall be determined and applied each time a change in the designated percentage of reclaimed material is made.

Mixing: The five material elements of the mix; reclaimed material, softening agent, coarse aggregate, fine aggregate, and asphalt cement, properly proportioned, shall be heated and mixed in a central mixing plant. Mixing time shall be sufficient to meet temperature requirements, and to produce a uniform product, free of cold lumps, rich or lean sports, and to coat all aggregate with bitumen. The aggregate shall be considered satisfactorily coated when all particles passing the #4 sieve and 98 percent of the particles retained on a #4 sieve are coated with bitumen as determined visually by the engineer. The mositure content of the recycled asphalt concrete pavement, sampled behind the paver prior to compaction, shall not exceed 1 percent by weight.

If a continuous plant is used by the contractor, it shall be equipped with an adequate and approved surge bin, capable of discharging the mix directly into hauling equipment. The surge bin shall be loaded in such a manner that segregation will be kept to a minimum. Dumping of the bituminous mixture on the ground and reloading will not be permitted.

Temperature Control: The temperature of the bituminous mixture at discharge from the mixing plant shall not be less than 220° F. nor greater than 265° F. Spreading and compaction shall be completed before the temperature of the mixture falls below 180° F.

Spreading and Compaction: The bituminous mixture shall be spread with self-propelled mechanical spreading and finishing equipment capable of spreading at least a 20' width. The mixture shall be spread and struck off in such a manner that the finished pavement, including side slopes conforms to the dimensions shown on the typical section, and meets smoothness and density requirements.

The bituminous mixture shall be placed in three lifts with no lift exceeding three inches in total compacted thickness. Longitudinal joints in succeeding lifts shall be offset at least six inches transversely from the longitudinal joint in the preceeding lift.

Full width or echelon paving shall be required for the multi-lane portions of this project. Echelon paving being defined as two or more paving machines moving in the same direction, concurrently at a desirable maximum separation distance of 200', such that the entire width of the roadway is covered with surfacing material. In case of breakdown of one of the machines when paving in echelon, the entire paving operations shall be suspended until the full width operations can be continued.

Where echelon paving cannot be performed, such as at ramp tapers, and crossovers, the following requirements shall be applied:

Immediately prior to making a subsequent pass of the paving machine, 0.5 foot of the previously layed and compacted surfacing material shall be cut off. The cut shall be vertical and follow a smooth line. The material cut off shall be removed and placed in the reclaimed pavement stockpile. The longitudinal joint shall only need to be cut back on the top lift. The lower lifts of surfacing material shall be fully rolled and tack coat applied along the longitudinal joint prior to making the additional passes of the paving machine. Traffic, including construction vehicles, shall be prevented from crossing the vertical joint cut. Tack coat shall be applied to the vertical edge prior to placing the adjoining material.

Equipment used to made the vertical cut joint shall be capable of making a smooth even cut, without any tearing, and shall be approved by the Engineer prior to use.

Pavers shall be equipped with a control system capable of automatically controlling the paver screed at the required corss-slope and at an elevation necessary to obtain the required thickness. The control system shall be automatically actuated from reference surfaces on both sides of the paver through a system of mechanical sensors or sensor directed mechanisms or devices. The control system shall be capable of working in conjunction with a short ski or shoe for matching the pavement placed by a previous pass of the paver, and/or a ski-type device or travelling stringline at least forty feet in length.

On the initial paver pass of each lift, elevation and corss-slope shall be controlled by means of ski-type devices or travelling stringlines operating on both sides of the paver. On the succeeding pass, elevation and cross-slope shall be controlled by means of a joint matching shoe on the side of the paver adjacent to the longitudinal joint and a ski-type device or travelling stringline operating on the opposite side of the paver.

Should the automatic control system become inoperative during a production day, the contractor shall take immediate and diligent action to repair or replace the defective system. During the time that repairs are in progress, the contractor will be permitted to use manual controls. The use of manual controls shall not be permitted to continue beyond the end of the shift in progress when the control system becomes inoperative.

If, in the opinion of the Engineer, the contractor does not take immediate and diligent action to repair and replace an inoperative automatic control system, or if the contractor's control system is found to be unsatisfactory due to poor results, frequent breakdowns, or any other cause, the Engineer shall order the paving operation discontinued until an automatic control system capable of continuous satisfactory operation is provided.

Smoothness tolerances specified herein shall apply whether using automatic or manual controls.

After the paving mix has been spread, the surface shall be longitudinally rolled, beginning at the outside edge or lower side and proceeding toward the higher side. Each pass of the roller shall overlap the preceeding pass by at least one-half the width of the roller. Rolling operations shall be conducted in such a manner that shoving or distortion will not develop beneath the roller. A rolling pattern shall be developed and followed that will result in a uniform pavement meeting snoothness and density requirements.

The forward speed of pavers shall be adjusted to the plant production and delivery so that a continuous, uninterrupted forward paving operation is obtained. Unnecessary stopping and starting of the spreading machine will not be permitted.

Acceptance of Recycled Asphalt Concrete Pavement with respect to density shall be based on the average of all density determinations made in a lot. A lot shall equal the number of cubic yards of Recycled Asphalt Concrete Pavement placed and compacted each production day. The test lot shall be divided into sublots of approximately 1600 square yards. One density test, randomly selected by use of a suitable random number table, shall be taken within each sublot.

The lot shall be accepted when the mean of all density determinations made in sublots is not less than 96 percent of maximum laboratory density or 93 percent of Measured Maximum Density (Rice Method), and when no single determination is lower than 92 percent of the maximum laboratory density or 89 percent of Measured Maximum Density (Rice Method).

If an individual test result falls below 92 percent of maximum laboratory density or 89 percent of Measured Maximum Density, the surface course material represented by that test will be considered defective, and the contractor shall further compact the sublot. After further compaction, the original test site and one other randomly selected site within the sublot shall be tested. The average of the two test results shall be included in determining the mean density for the lot. The original test result shall not be included. If the sublot still does not meet the required density, the process of recompacting and retesting may be repeated until the minimum compaction temperature is reached.

In addition to the above acceptance tests, the engineer reserves the right to test any areas which appear defective and to require further compaction of areas that do not meet at least 92 percent of maximum laboratory density or 89 percent of Measured Maximum Density.

If the mean density of the surface coarse placed on any production day does not equal or exceed 96 percent of maximum laboratory density or 93 percent of Measured Maximum Density, but is not below 92 percent of maximum laboratory density or 89 percent of Measured Maximum Density, the lot may be accepted at a reduced price upon written request from the contractor. The computation of the adjusted unit price for the Recycled Asphalt Concrete Pavement with respect to density shall be based upon a pay factor of 0.90. Any lot or sublot with a density below 92 percent of maximum laboratory density or 89 percent of Measured Maximum Density shall be considered defective. The engineer may order the removal of any or all of the bituminous mix in that lot or sublot. The pay factor for any such surface course which is allowed to remain in place shall be 0.50.

Placing of the bituminous mix shall be as continuous as possible. Rollers shall not pass over the unprotected end of freshly placed mix unless authorized by the engineer, and if so authorized and the end will be subjected to traffic, the end shall be left at a level of approximately 50:1 (horizontal to vertical). Transverse joints shall be formed by cutting back on the previous run to expose the full depth of the layer or course. A light coat of bituminous material shall be applied on contact surfaces just before fresh bituminous mix is placed against previously compacted mix. At bridge ends or at ends of other rigid type structures, compaction shall be in transverse as well as longitudinal directions, as directed by the engineer.

The Recycled Asphalt Concrete Pavement shall be finished to a smooth, uniform line and grade. The use of any equipment that leaves defects in the finished surface which cannot be eliminated shall be discontinued.

Construction joints shall be measured with a 10-foot straightedge. When tested longitudinally across the joint, the surface shall not vary more than 0.013' in 10'. The joint shall be brought into specification tolerance immediately after the paving machine has moved away. The repair of the joint shall be diligently pursued by an adequate crew or the contractor will not be allowed to continue his paving operation.

The pavement surface shall be tested for smoothness as the work progresses, and shall be accepted in lots equal to the number of square yards placed each day. A lot shall be tested at selected locations longitudinally and transversely. Longitudinal and transverse measurements shall be made with a 25-foot stringline and 10-foot straightedge, respectively.

The variation of the surface from the testing edge of the stringline between any two contacts with the surface shall at no point exceed 0.025 feet for longitudinal measurements. The variation of the surface from the testing edge of the straightedge between any two contacts with the surface shall at no point exceed 0.01 feet for transverse measurements. All humps or depressions exceeding the specified tolerances shall be corrected at the expense of the Contractor as directed by the Engineer.

On projects where more than one course of Recycled Asphalt Concrete Pavement will be placed, only the top course shall be tested for smoothness. Leveling courses, overlays, and cushion courses shown on the plans or designated by the Engineer, will not require smoothness determinations.

Spot leveling, when required, shall be placed, spread, and compacted prior to placing subsequent pavement courses.

Acceptance of the completed Recycled Asphalt Concrete Pavement with respect to thickness shall be on the basis of test areas selected by the Engineer, not to exceed 50,000 square feet in size. Thickness determinations shall be made, after placing of the top lift of pavement, by coring in a random pattern, with not less than four cores per test area. A test area shall be accepted when the average thickness of all cores taken within the area is equal to or greater than the designated thickness, with the tolerance specified below, and when no test shows a deficient thickness of more than 3/4 inch.

Test areas where the average thickness is less than the designated thickness shall be subject to the following price reduction:

Deficiency in Average Core Thickness In Inches	Pay Factor To Be Applied To The Unit Price
0 To 0.375	1.00
0.376 To 0.500	0.90
0.501 To 0.750	0.85

The pay factors above shall be applied to the unit price for the full thickness of the pavement. The unit price for this item, after any other required price adjustments have been applied, shall be multiplied by the appropriate factor listed above to arrive at the final unit price for the deficient test area.

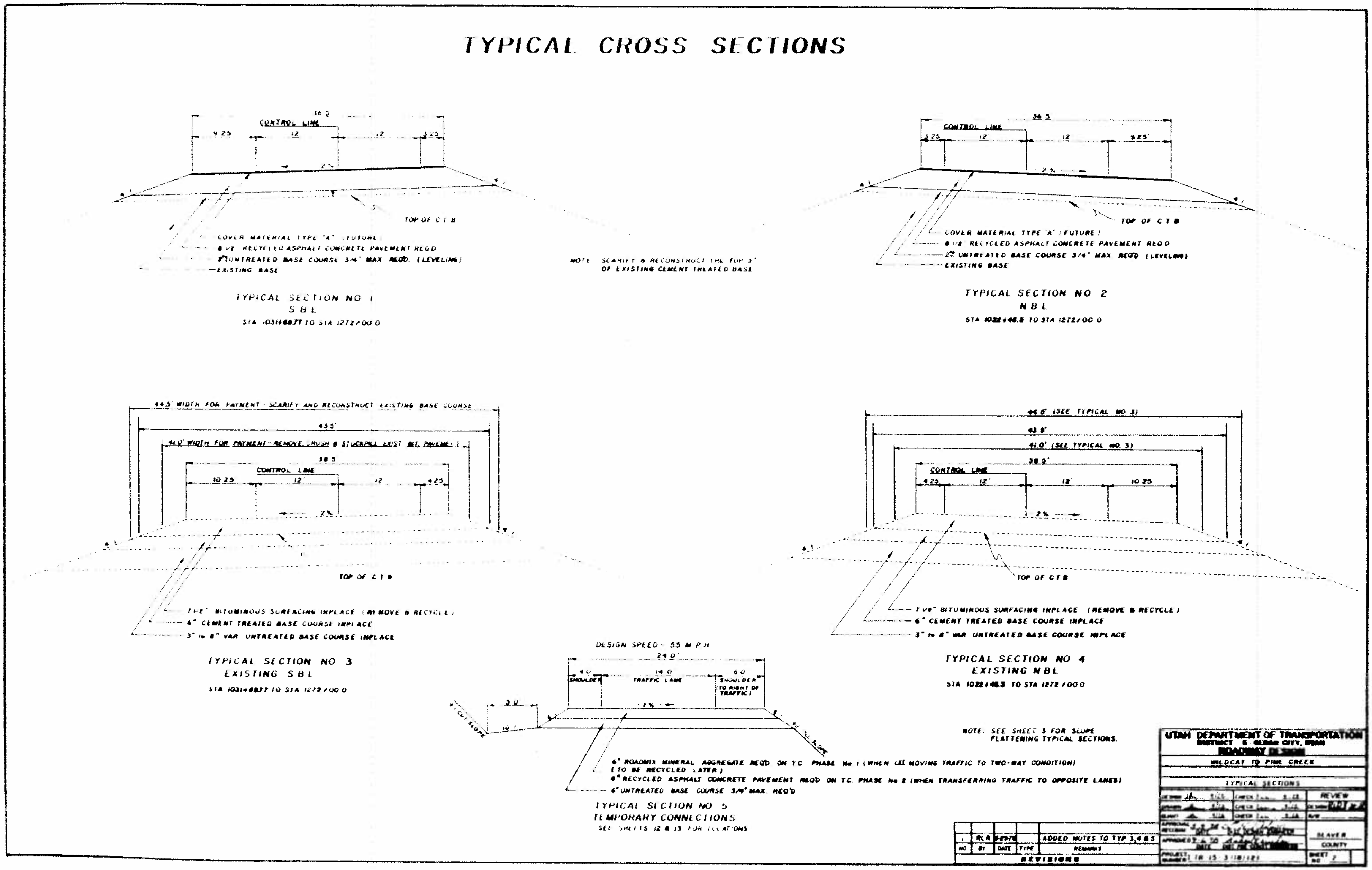
No payment shall be made if the average core deficiency of a test area exceeds 3/4 inch. Any such test area shall be corrected by the contractor, at his expense, by applying a tack coat in accordance with the specifications for that item and an additional lift of Recycled Asphalt Concrete Pavement not less than $1\frac{1}{2}$ inches in thickness.

Weather and Seasonal Limitations: This subsection shall be changed to read as follows: Recycled Asphalt Concrete Pavement shall be placed only between April 15th and October 15th, and when the air temperature in the shade and the roadbed temperature are above 50°F. Recycled Asphalt Concrete Pavement shall not be placed during rain, when the roadbed is wet or during other adverse weather conditions. Recycled Asphalt Concrete Pavement placed after October 15th shall be placed only upon written authorization from the engineer, and then only when a proper review has determined that it is in the best public interest of the Department and the public.

Method of Measurement: This item shall be measured by the cubic yard in place. Quantities for payment shall be determined from the neat line cross sectional area shown on the typical section and the station to station distance, along the control line of pavement placed and accepted. On tapers, ramps or other locations not detailed on the typical section, quantities shall be determined from the actual dimensions of material placed and accepted.

Basis of Payment: This item shall be paid for at the contract unit price per cubic yard, or at an adjusted unit price per cubic yard, adjusted in accordance with this Special Provision for accepted quantities of "Recycled Asphalt Concrete Pavement." This price shall be full compensation for all aggregate, softening agent, asphalt cement, including the required hydrated lime, and all other materials, equipment, labor, and incidentals necessary to complete the item, except that removal, crushing and stockpiling of the existing pavement shall be paid for separately in accordance with the Special Provisions for that work.

8/1/78



TYPICAL CROSS SECTIONS
CONTROL LINE
TOP OF C T B
COVER MATERIAL TYPE "A" (FUTURE)
8 1/2" RECYCLED ASPHALT CONCRETE PAVEMENT REQ'D
2" UNTREATED BASE COURSE 3/4" MAX REQ'D (LEVELING)
EXISTING BASE
TYPICAL SECTION NO 1
S B L
TYPICAL SECTION NO 2
N B L
NOTE SCARIFY & RECONSTRUCT THE TOP 3" OF EXISTING CEMENT TREATED BASE
44.5' WIDTH FOR PAYMENT - SCARIFY AND RECONSTRUCT EXISTING BASE COURSE
1 1/2" BITUMINOUS SURFACING INPLACE (REMOVE & RECYCLE)
6" CEMENT TREATED BASE COURSE INPLACE
3" to 8" VAR UNTREATED BASE COURSE INPLACE
TYPICAL SECTION NO 3
EXISTING S B L
TYPICAL SECTION NO 4
EXISTING N B L
DESIGN SPEED - 55 M P H
SHOULDER
TRAFFIC LANE
SHOULDER (TO RIGHT OF TRAFFIC)
4:1 CUT SLOPE
6" ROADMIX MINERAL AGGREGATE REQ'D ON T.C. PHASE No 1 (WHEN ALL MOVING TRAFFIC TO TWO-WAY CONDITION) (TO BE RECYCLED LATER)
4" RECYCLED ASPHALT CONCRETE PAVEMENT REQ'D ON T.C. PHASE No 2 (WHEN TRANSFERRING TRAFFIC TO OPPOSITE LANES)
6" UNTREATED BASE COURSE 3/4" MAX. REQ'D
TYPICAL SECTION NO 5
TEMPORARY CONNECTIONS
SEE SHEETS 12 & 13 FOR LOCATIONS
NOTE: SEE SHEET 3 FOR SLOPE FLATTENING TYPICAL SECTIONS.
ADDED NOTES TO TYP 3,4 & 5
REVISIONS
UTAH DEPARTMENT OF TRANSPORTATION
WILDCAT TO PINE CREEK
TYPICAL SECTIONS
BEAVER COUNTY

APPENDIX B

PRELIMINARY INVESTIGATION AND MARSHALL DESIGN

Memorandum · UTAH DEPARTMENT OF TRANSPORTATION

DATE: August 24, 1977

O : Alex E. Mansour, District Five Director

ROM : Edwin E. Lovelace, Engineer of Materials and Research

BJECT: IR-15-3( )116, Manderfield Interchange to Sulphurdale Interchange
Flexible Pavement Design - Overlay or Recycling

Attached are pavement designs and a proposal to recycle the existing bituminous pavement on the above I-15 project.

We are proposing to remove, stockpile, and recycle the existing bituminous surface. This specific project is 8.8 miles long, 38 feet wide, and consists of sections 6.25 inches and 5.0 inches thick, respectively. It represents approximately 120,533 tons of pavement, composed of 113,301 tons of aggregate and 7232 tons of asphalt. At an average contract price, the asphalt and aggregate have a total value of $1,205,330.

The existing flexible pavement has extensive thermal cracking. Too many overlays cause problems with width and slope and do not eliminate the cracking problem.

ENERGY COSTS OF "ROUGH" PAVEMENTS

Pavements can have many kinds of defects, which in turn may range widely in magnitude, all contributing toward what engineers and the public call "roughness". It seems fairly clear that when pavements conditions begin to bother the user, his entire perception comes from the effects "bothering" his vehicle. It is not generally realized, however, that these actions on the vehicle cause a diversion of useful energy into wasteful tasks, rather than producing forword motion of the vehicle. More energy, that is fuel, is required to maintain the vehicle's forward speed, compensating for that lost in undesired, "destructive" activities -- wearing out tires, pounding suspensions, moving the vehicle up and down, and of course, thumping the pavement, in addition to other undesirable consequences. The wasted energy goes to work in raising maintenance costs for the user's vehicle. Figure 1 shows the relationship of PSI to the percent increase in fuel consumption as the PSI degrades. NCHRP report 111, Running Costs of Motor Vehicles as Affected by Road Design and Traffic, 1971 HRB.

The Dynaflect data indicates that the pavement system is weak and possible reconstruction is suggested. An overlay of 7.0 inches (SLB) and 8.0 inches (NBL) is needed to improve the structural capability. But an overlay of this magnitude causes problems with width, slope guardrail and bridge structures, and doesn't eliminate the two real problems --- the cracking and the depletion of existing materials.

The experts believe that by recycling, the absorption and shrinkage phenomenon which takes place in pavements, will have already taken place and the new recycled pavements will not be subject to thermal cracking.

The benefits inherent in this proposal are expected to be a cost savings to the Department through the preservation of natural resources, especially as related to asphalt products associated with the energy situation. Also, there is not the oxidation from the catalytic action of the aggregates comparing recycled mix and conventional mix. This was evident from the recycled test section on I-70 near Cove Fort and a recent study by Dr. J. Claine Petersen at the Laramie Energy Research Center in Wyoming.

The existing flexible pavement will require close-cycle crushing to minus one inch material and stockpiling. This material has to be crushed to insure uniformity when mixed with the softening agent. Also, special attention should be given to removing from the roadbed and stockpiling, so that bituminous aggregate is not lost or contaminated with underlying soils. Approximately 1.48 miles must be surfaced with regular mix, because the existing tonage will not accomodate the required pavement thickness.

The existing subbase consists of 6 inches of cement treated base. This course is just below the existing BSC. This CTB will have to be scarified and recompacted and 2 inches of UBC added for leveling and reshaping the grade line.

SAMPLING AND TESTING

The existing roadway was cored every half mile with three 6-inch cores taken at each location. These specimens were measured for height and density. It should be noted that approximately one half inch of untreated base gravel was included with the bituminous cores. After measurements and densities were taken, the cores were crushed to minus one inch, the material was then mixed and twenty-four representative samples taken for asphalt content, gradation, and asphalt recoveries. Marshall designs and Immersion compressions were based on repetition of nine samples after the percentage of softening agent had been determined.

North Bound Lane

	Percent Passing
1"	100
3/4	99 ± 1
1/2	91 ± 2
3/8	82 ± 2
#4	58 ± 2
#8	43 ± 2
#16	33 ± 1
#50	18 ± 1
#200	11.4 ± .5

Average Asphalt Content
6.01 ± 0.27

Penetration @ 77°F (100 gm)	37+7
Absolute Viscosity @ 140°F (poises)	5354
Kenematic Viscosity @ 275°F (cs)	464
Ductility @ 39.2°F (1cm/min)	2

South Bound Lane

	Percent Passing
1"	100
3/4"	99 ± 1
1/2	90 ± 3
3/8	82 ± 3
#4	58 ± 3
#8	43 ± 2
#16	33 ± 2
#50	19 ± 1
#200	11.0 ± .6

Average Asphalt Content
6.15 ± 0.15

Penetration @ 77°F (100 gm)	49+10
Absolute Viscosity @ 140°F (poises)	4122
Kenematic Viscosity @ 275°F (cs)	371
Ductility @ 39.2°F (1cm/min)	3

Recycled Asphalt

Penetration @ 77°F (100 gm)	90
Absolute Viscosity @ 140°F (poises)	1090
Kenematic Viscosity @ 275°F (cs)	200
Ductility @ 39.2°F (1cm/min)	40+

In reviewing the gradation, we feel it would be to the Departments advantage to add 15% plus 4 material. This would improve the gradation and more closely follow the new specification. It is believed this would also improve the performance of the bituminous material. (See Appendix "A")

SOFTENING AGENT

The particular softening agent used in the laboratory for this project was an aromatic oil with a coc flash point of 425°F. and a viscosity in the range of 200-300 cs at 140°F. The reason for selecting an aromatic oil was to reduce the difference in solubility parameters between the maltene fraction of the asphalt and the asphaltene fraction. In this manner, the rheological properties of the recycled asphalt could be adjusted to be essentially the same as virgin asphalt. See appendix "B" for Specification of Softening agent.

MARSHALL DESIGNS

Marshall Designs were made with and without the addition of a softening agent. The preliminary Marshall designs indicated that 0.75% softening agent and 0.50 AC-10 could be added with a total void content for the mix of 3.0 percent. Also, this would give an asphalt grade equivalalent to an AC-10.

PAVEMENT RECOMMENDATIONS

Manderfield Interchange to Wildcat Interchange

1 "	Plant Mix Bituminous Seal Coat
8.25"	Bituminous Surface Course (Recycled)*
2 "	Untreated Base Course (for reshaping grade)
11.25"	Total

Wildcat Interchange to Sulphurdale Interchange

1 "	Plant Mix Bituminous Seal Coat
8.0 "	Bituminous Surface Course (Recycled)*
2.0 "	Untreated Base Course (for reshaping grade)
11.0 "	Total

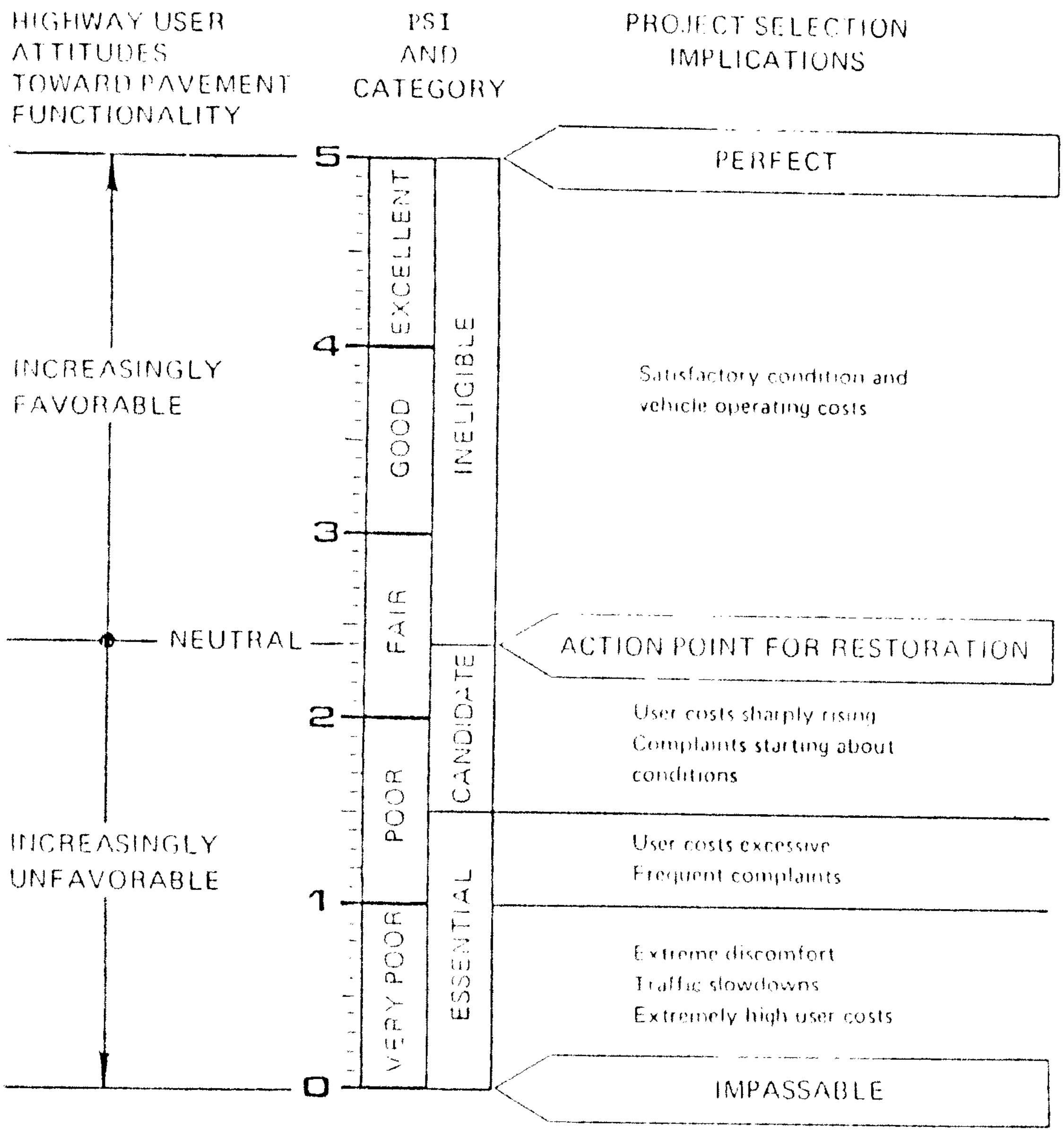
RECOMMENDATIONS

There will be no specification on gradation or AC content. However, the contractor must make every effort to produce a homogenous, uniform mix. There will be separate stockpiling for the existing crushed pavement and for the plus 4 material used to improve the gradation (see attachment "A" for plus 4 specification). There are two methods you might want to consider in placing the bituminous surface: stage construction with future surface or placing the ultimate. Of course, this will depend on the available funding. We hope this report covers the questions you might have about recycling flexible pavements.

Attachments
WBBetenson/ljm
cc: Sheldon McConkie

* 1.48 miles per lane will have to be conventional mix

Significance of the Present serviceability index (PSI) for effective pavement management.



NOTE All PSI values are dependent on travel speed which is taken to be the posted speed; both PSI and User Attitudes vary with travel speeds.

Approximate relationship of posted-speed PSI to increased fuel consumption at various running speeds.