Report No. CDH-DTP-R-83-5

HOT MIX RECYCLING
CLIFTON-WEST
PROJECT IR 70-1(57)

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Final Report
June, 1983

Prepared in cooperation with the
U.S. Department of Transportation
Federal Highway Administration

Technical Report Documentation Page

1. Report No. CDOH-DTP-R-83-5	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Hot Mix Recycling Clifton-West Project IR 70-1(57)		5. Report Date June, 1983 6. Performing Organization Code
7. Author(s) Robert F. LaForce		8. Performing Organization Report No. CDOH-DTP-R-83-5
9. Performing Organization Name and Address Colorado Department of Highways Division of Transportation Planning 4201 East Arkansas Avenue Denver, Colorado 80222		10. Work Unit No. (TRAIS) 11. Contract or Grant No. 1585
12. Sponsoring Agency Name and Address Colorado Department of Highways 4201 East Arkansas Avenue Denver, Colorado 80222		13. Type of Report and Period Covered Final - 3 years 14. Sponsoring Agency Code

15. Supplementary Notes

Prepared in cooperation with the U.S. Department of Transportation Federal Highway Administration

16. Abstract

This is a final report covering mix design, construction experiences, and three years of post construction evaluation of Colorado's Hot Mix Recycling Project north of Grand Junction. The construction experiences contain mix testing, air pollution monitoring, and energy, economic, and natural resource analyses. The post construction evaluations contain deflections, surface evaluations for skid resistance, PSI, cracking, and rut measurements. Annual measurements of stability and asphalt composition analysis of the mixes produced on the project were also taken from core samples.

Colorado has adopted standard provisions accepting recycled asphalt pavement because of successful recycling projects like this.

17. Key Words Pavement Asphalt, Recycling, Hot Mix	18. Distribution Statement No restrictions. This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	46	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

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Hot Mix Recycling

Clifton - West

Project IR 70-1(57)

INTRODUCTION

The recycling of asphalt pavement has become a standard part of the paving programs in many states because of the findings and experiences gained from experimental projects. Following the oil embargo in 1973, the rapidly rising cost of petroleum products along with a desire to conserve energy and natural resources led to a great deal of experimental work by highway departments, contractors, and equipment manufacturers in the area of hot mix recycling of asphalt pavements. This report documents the construction and performance over three years of the second hot mix recycling project constructed by the Colorado Department of Highways. This was Colorado's first project using dual feed dryer drum equipment.

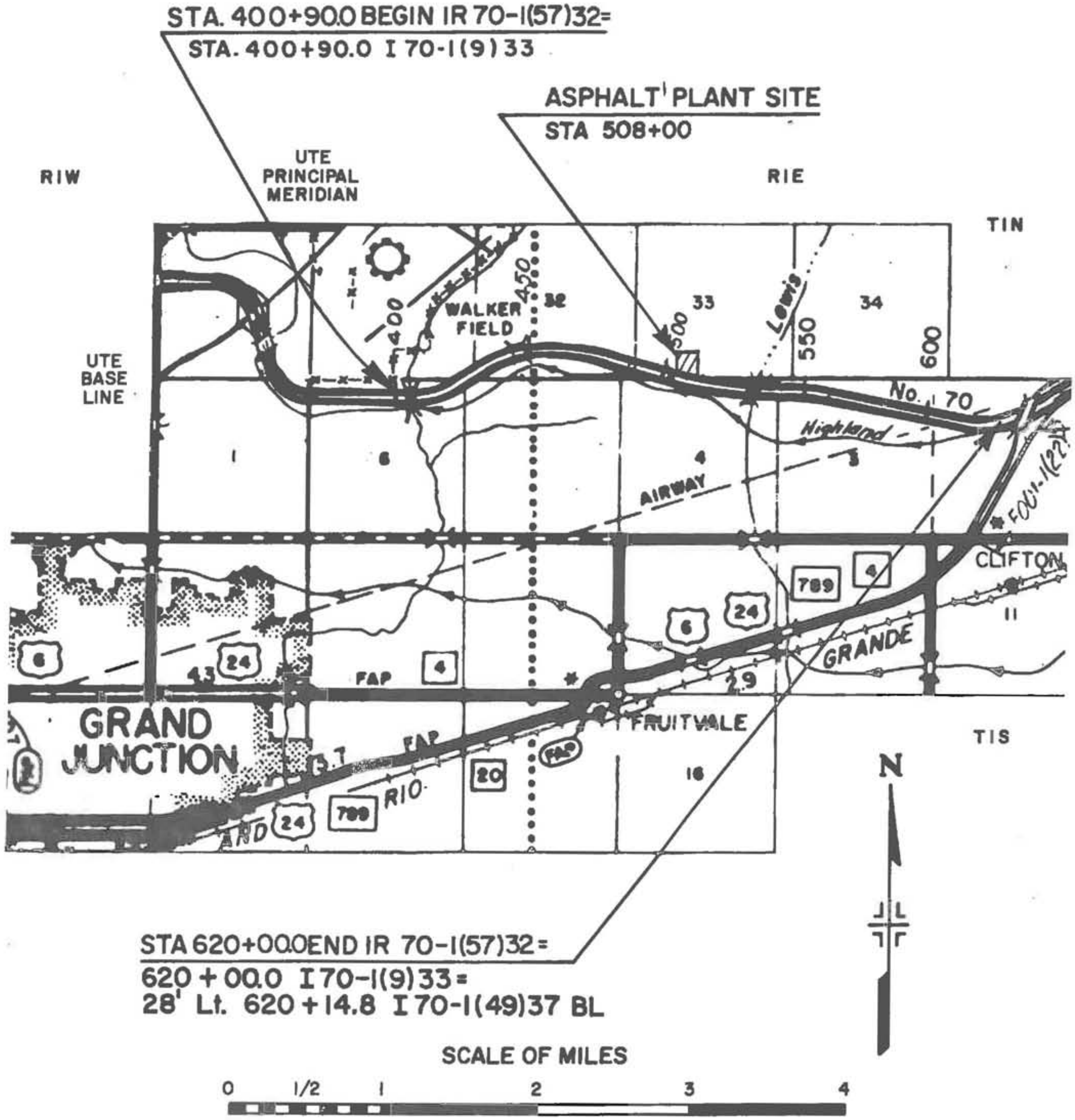
This project is located on I 70 north of Grand Junction, Colorado (See Figure 1). The roadway was originally constructed in 1964 and 1965 and the current Average Daily Traffic volume is 3,550. Since the original construction the pavement had become badly distorted because of swelling shales in the roadway cuts and collapsing soils in adjacent alluvial areas. The original pavement was badly deteriorated and major work needed to be undertaken to improve this 4.15 mile section of interstate highway. Various alternatives for rehabilitation in addition to recycling were considered such as leveling course and overlay with and without a stress absorbing membrane. Recycling of the entire mat was chosen as the best alternative because pavement removal allowed access for extensive work on the subgrade and more longevity (reduced maintenance

FIGURE 1

PROJECT LOCATION

PROJECT IR 70-1(57)
HORIZON DRIVE - CLIFTON INTERCHANGE

ASPHALT PAVEMENT RECYCLING



costs) was anticipated with the new recycled pavement. Additionally, a savings through recycling was anticipated.

Early in 1978, District 3 personnel sent pavement samples to the Central Materials Laboratory for mix design, and preliminary design work started for this project. The Research Section submitted a study proposal to the FHWA which was approved in September 1978, and the construction contract was awarded in late 1978.

MIX TESTING AND DESIGN

The pavement samples submitted to the Central Laboratory were tested to determine the feasibility of recycling on this project. From this preliminary testing, the specifications for the modifying agent were determined. A modifying agent was needed to restore the properties of the asphalt cement in the reclaimed pavement so that it would perform the same as a new asphalt cement. These specifications appear in Appendix A of the Interim Report.

Shortly after pavement removal began, the crushed reclaimed pavement, modifying agent, virgin aggregate, and new asphalt cement from the project were sampled and submitted to the Central Materials Laboratory for final mix design. The modifying agent chosen by the contractor was Cyclogen-L.

First, Abson Recoveries were run on the reclaimed pavement from the stockpile to determine the existing percent asphalt cement and its penetration and viscosity. The following properties were determined from two tests of the stockpiled material and the modifying agent.

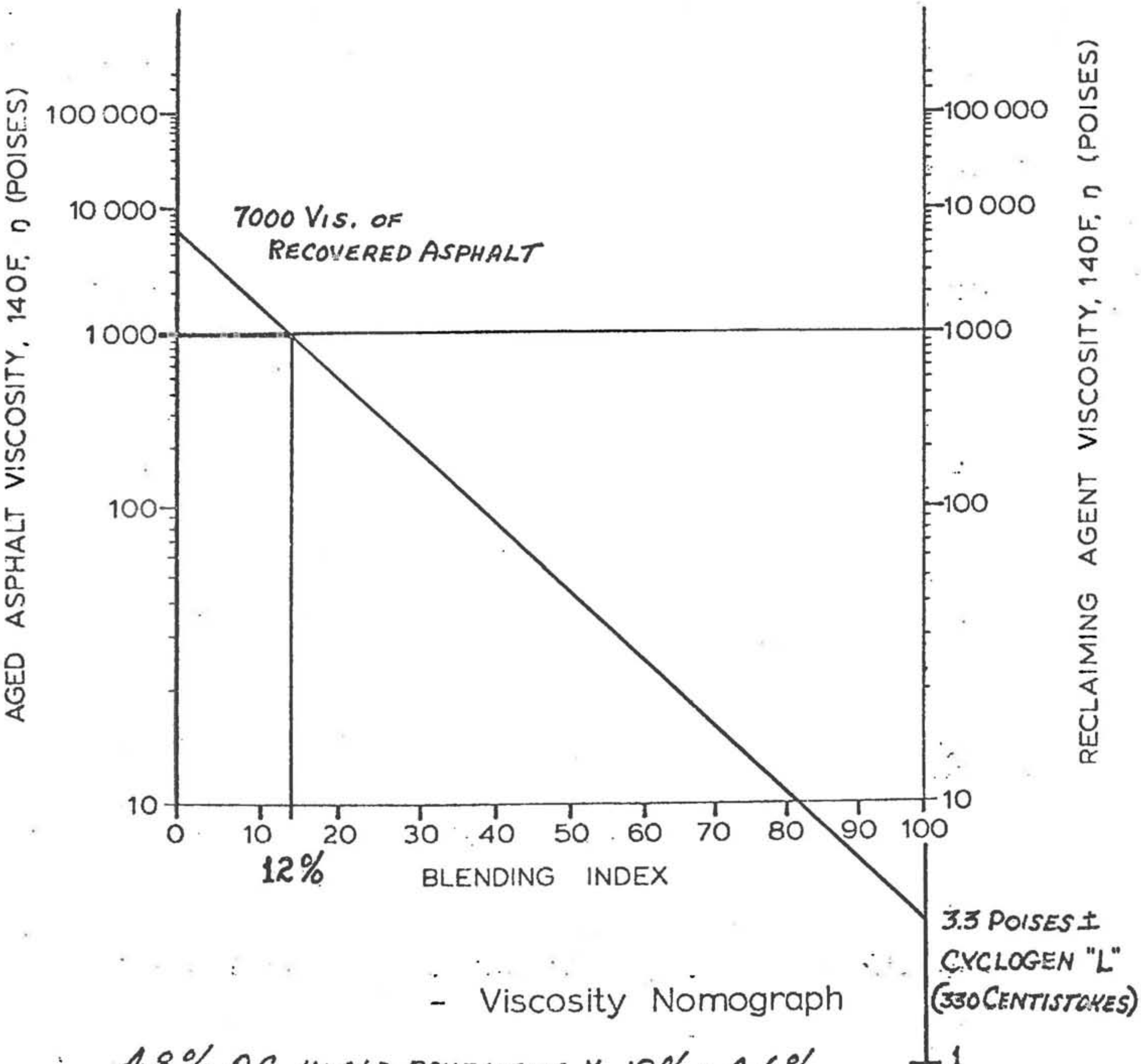
Sample	#1	#2	Cyclogen-L
% AC	4.8	4.8	
Viscosity 140 F	5726 poises	7146 poises	287.2 CS
Viscosity 275 F	357 CS	392 CS	
Penetration	29	28	

This preliminary testing was to determine the appropriate amount of Cyclogen to be added. This step is very important, since the modifying agent is used to restore the chemical and physical properties of the old asphalt cement.

Using the method[1] demonstrated in the nomograph in Figure 2, a blending factor was determined and from this factor the percent Cyclogen by weight of the reclaimed pavement was determined to be 0.6%. Following this calculation, test samples were made to verify the calculation.

The 70% reclaimed asphalt pavement-30% virgin aggregate mix was designed by mixing the 30% virgin aggregate with the reclaimed pavement, adding the rejuvenating agent, and then adding enough AC-10 to obtain the desired percent asphalt in the final mix. Lab samples were made using 0.2%, 0.4%, and 0.6% Cyclogen with total asphalt contents of 5.0%, 5.5%, and 6.0% asphalt. Appendix A shows the mix design resulting from the test data. This design, based on a 70/30 blend called for the addition of 0.6% Cyclogen by weight of the reclaimed pavement, and 6.0% AC-10 by weight of the virgin aggregate to yield a total mix content of 5.6% AC. The complete mix design and test data are listed in the interim report for this Experimental Project (Report No. CDOH-DTP-R-79-13).

Figure 2



\- Viscosity Nomograph

4.8% AC IN OLD PAVEMENT X 12% = 0.6% CYCLOGEN "L" ADDED TO RECYCLED PORTION.

CONSTRUCTION EXPERIENCES

Traffic was diverted to the westbound lanes of I 70 during the week of March 5, 1979 for the entire length of the project. Starting the following week, Cat 633 scrapers were used to remove the old pavement. The original pavement was 5 inches thick in the driving lanes with 3 1/2 inch thickness on the shoulders, however, because of numerous areas with maintenance leveling courses, pavement thickness varied greatly. The use of scrapers for pavement removal worked very well for picking up the pavement with very little contamination. Starting approximately 6 feet inside the edge of the pavement, the scrapers picked up a strip approximately 6 feet wide. By starting on the pavement, the wheels of the scraper were on the same level making pavement pickup easier, with only the scraper teeth entering the base course material. Alternate 6 foot strips of same level and helping prevent contamination of the pavement to be recycled. The scrapers moved very slowly and the pavement came up in 1 1/2 to 2 foot slabs allowing approximately 15 cubic yards per load. The pavement missed by the scrapers was windrowed with a motor grader, picked up with a front end loader, and hauled to the plant site by truck. The pavement removal is shown in photos 1, 2, and 3.

Following pickup, the pavement was hauled in the scrapers and stockpiled at the plant site near the middle of the project. Using this method, the pavement was removed at a rate of about 2000 lineal feet per day on the 38 foot wide eastbound lanes. It took 11 days to remove all of the pavement on one lane of the 4.15 mile project.

At the plant site, the pavement stockpile was worked with a bull dozer and sheepsfoot roller to break up the large blocks prior to being crushed to minus 1 1/2" using a standard jaw roller-crusher. Also at the plant site, a working platform approximately 6 inches thick was made from the reclaimed pavement to minimize contamination of the reclaimed pavement stockpile. This platform, located under the reclaimed pavement stockpile was completed prior to stockpiling. Photos 4, 5, and 6 show the pavement at the plant site before and after crushing.

Approximately 7,600 tons of reclaimed pavement was used as leveling material in the base course. The base course was leveled, compacted, and primed with MC-70. Photos 7 and 8 show the base course ready for priming. The eastbound lanes were primed in preparation to paving on April 6 and 18, 1979.

A CMI Roto-Cycler™ 9' x 36' drum dryer plant was set up during the first week of April. This asphalt plant has dual feeds to allow separate entry of the recycled and virgin aggregate. New material enters through a standard drum inlet next to the burner, and reclaimed material is added downstream from the burner, thus eliminating contact with the flame. The downstream entry of the recycled aggregate is permitted by use of a flop gate mechanism shrouded with a metal collar. The gates are opened and closed by gravity as the drum rotates allowing the reclaimed pavement to enter the drum without contacting the flame and also not allowing the hot gasses in the drum to escape. The plant is shown in photos 9 and 10. The plant also contains special flighting to maximize the heat transfer to the virgin aggregate and also protect the reclaimed material from the flame. A detailed explanation of the plant operation is presented in the interim report.

The modifying agent was added to the mix using a 'Y' in the asphalt cement line. The modifying agent was stored in a separate tank and forced into the AC feed line using a separate pump.

On Thursday, April 12, the plant was fired up producing a blend of 55% reclaimed pavement and 45% virgin aggregate. Following some minor adjustments to the AC and modifying agent pumps, the mix was of acceptable quality. Paving started at the plant site near the center of the project in the eastbound direction with a 20' X 2" bottom lift. The paver and haul trucks are shown in photo 11. During the following 11 days, various blends and production rates were made while paving the bottom two lifts of the eastbound lanes and obtaining acceptable stack emissions from the plant. The air pollution aspects of these variations will be discussed in another section of this report.

The paving of the bottom two lifts of the eastbound lanes was completed on April 24, 1979. Traffic was then diverted to these lanes so that pavement could be removed from the westbound lanes.

Pavement removal and crushing of the old mat on the westbound lanes started during the first week of May. The pavement was removed on the westbound lanes in the same manner as on the eastbound lanes and the paving resumed on May 23, 1979. The west half of the westbound lanes was primed on May 18, and the east half on May 30. The crushing of the old pavement was completed on June 5.

Paving of three lifts on the westbound lanes was completed on June 6 and following striping, the lanes were opened to traffic.

Paving of the top mat in the eastbound lanes proceeded with traffic coned onto one lane. A 16' X 2" lift was paved for the entire length of the project on June 7 and on June 11 a 22' X 2" top lift was paved for the entire length of the project (4.15 miles) to complete the paving. The finished roadway is shown in photo 12.

The pavement removal, crushing, basecourse leveling, and compaction went very smoothly on this project with no requirements for special equipment. The paving and rolling also proceeded using belly dump trucks for hauling the pavement mix and a Blaw Knox PF 220 paver plus CMI windrow elevator.

The production of the asphalt mix was often delayed. Since this was the first large production recycling project using this plant for both the contractor and CMI, numerous adjustments and experiments were made to obtain acceptable air pollution emission rates and optimize burner fuel usage. Many of these adjustments delayed production, however, there were several days when excellent production rates were obtained while meeting air quality requirements.

AIR POLLUTION

A. Stack Emissions

Meeting air pollution standards has been one of the major problems in hot mix asphalt pavement recycling. This plant had not yet been used for recycling on any previous projects by either the contractor or CMI, so a special provisions permit was sought from the Colorado Air Pollution Control Division to allow time to "tune" the plant. A special provision permit was granted by the Air Pollution Control Division to allow 21 days of experimental operation by which time this plant would have to be in compliance with state air quality standards for opacity (20%) and stack particulate emisions (0.04 grains/dry standard cubic foot).

This plant has a wet scrubber with a venturi and a 10' X 40' stack. Production started on April 12 with the plant making mix from a blend of 55% reclaimed asphalt pavement-45% virgin aggregate. The opacity averaged 60-70% during this days production with production rates at 300-400 tons/hour. During the following 4 days inclement weather prevented paving, and numerous changes were made to the plant. New flighting was installed, and adjustments were made to the burner and the scrubber. On April 19, stack particulate testing was started using a 60% reclaimed pavement/40% virgin aggregate blend at a rate of 500-600 tons/hour. Opacity at this time was 10-20% with no Cyclogen (modifying agent) being added to the mix. The following day, the Cyclogen was added to the mix via a 'Y' in the AC line. A blend of 55/45 was made with opacities well within the standards. Some further minor adjustments were made to the plant and additional stack particulate sampling was done during the following two days of operation. As a result of the low opacities and good stack particulate data, this plant was issued a permanent permit by the Air Pollution Control Division to operate, making recycled mix, using up to 60% reclaimed asphalt pavement. Table A is a summary of the stack monitoring and opacity data. The production rate at the time of this testing was 500-600 tons per hour with a mix temperature of 200-230° F. On April 24, the bottom two lifts of the eastbound lanes were completed after making approximtely 17,000 tons of mix. The plant was then shut down for approximately four weeks while the pavement was removed from the westbound lanes.

Production resumed on May 23, 1979. Following the start of production, some further experimentation was done with this plant, sometimes causing the opacities to exceed the 20% state standard. When the plant was returned to the 60% reclaimed asphalt pavement-40% virgin aggregate blend, opacities were from 5-10% for continuous production rates from

Table A

Stack Monitoring and Opacity Data
Clifton West Recycle

Stack Particulate Emissions

Test No.	Concentration	Opacity
3	0.043 gr/DSCF*	8-12%
4	0.033	8-12%
5	0.015	6%
Average	0.030	-
Allowable	0.040	20%

*grains/dry standard cubic foot

400-600+ tons per hour. Plant adjustments and experimentation to improve air quality are documented in the Interim report along with the complete emissions and opacity records.

B. Ambient Particulates

In addition to the opacity and stack monitoring done for compliance with state air pollution standards, two Hi-Vol samplers were used to sample ambient particulate concentrations in the plant area. Sampler No. 1 was set up near the asphalt discharge point next to the dryer drum approximately 20' from the storage bin. Sampler No. 2 was set up behind the supply trailer where one haul road was the only activity near the sampler. Table B lists the ambient particulate concentrations measured in the plant area.

The particulate concentrations measured on this project are typical of the concentrations measured at other similar construction sites in Colorado and other states.

SAVINGS THROUGH RECYCLING

A. Natural Resources

The total amount of recycled mix placed on this project was 52,791.5 tons. Table C lists the quantities for aggregate, reclaimed pavement, and asphalt cement used on this project, as well as the quantities that would be required if virgin mix were used.

A review of Table C shows that a savings of 25,813.5 tons of virgin aggregate and 2,065.8 tons of AC-10 was realized in the use of recycled mix. An additional savings of virgin aggregate was realized from the 7,576 tons of reclaimed pavement used as basecourse. An equal amount of virgin aggregate would have been required without recycling.

Table B

Ambient Particulate Concentrations during Plant Operation
Clifton West Recycle

Date Removed	Number of hours	Sampler #1 mg/m^3*	Sampler #2 mg/m^3*
4-13-79	24	147	--
4-16-79	72	80	195
4-19-79	71	471	240
4-20-79	26	908	630
4-21-79	24	--	204
4-23-79	70	202	803
4-24-79	25	1019	710
5-13-79	24	2217	1517
6-1-79	24	759	362
6-4-79	72	608	221
6-5-79	25.5	798	420
6-6-79	24.5	1021	764
6-7-79	22.5	1388	1039
6-8-79	24	1200	545

All concentrations are in micrograms per cubic meter (mg/m^3)

Table C

Savings in Natural Resources

Quantities Used on Recycle Project			%
27,696.2 tons	-	Crushed Pavement	52.5
23,810.5 tons	-	Virgin Aggregate	45.1
1,101.7 tons	-	AC-10	2.1
183.1 tons	-	Cyclogen	0.3
52,791.5 tons	-	Total Mix	100.0

Quantities Required for Virgin Mix		
49,624.0 tons	-	Virgin Aggregate
3,167.5 tons	-	AC-10 (6.0%)
52,791.5 tons	-	Total Mix

Quantities Saved by Recycling

49,624.0 - 23,810.5 = 25,813.5 tons of virgin aggregate (52%) from Mix
3,167.5 - 1,101.7 - 2065.8 tons AC-10 (65%)

7,576 tons of virgin aggregate - used for basecourse

Total Aggregate Savings - 33,389.5 tons

The modifying agent used in the recycled mix has to be subtracted from the savings since it is not used in virgin mix.

An additional savings of both asphalt cement and aggregate was realized from the 9,300 yd.^{3} of reclaimed pavement not used directly on the project. This excess reclaimed pavement was mixed with MC-70 and used as road mix to overlay a badly deteriorated secondary highway west of Grand Junction.

B. Energy Analysis

The interim report on this project presented a detailed, step by step analysis of the energy required to produce and transport the 60/40 recycled pavement and an equivalent amount of virgin mix for comparison. A summary of this data is presented in Table D and shows that on this project, the recycled pavement required energy equivalent to 0.02 gallons of gasoline/ton more than the use of virgin materials. This represents energy equivalent to 0.02 gal/ton X 52,791.5 = 1,056 gallons of gasoline for the pavement or approximately 1% more energy to produce the recycled pavement.

C. Economics

The quantities used in the following discussion were taken from Colorado Highway Department records listing the quantities paid for under the project contract. Because of the Special Provisions of the contract relating to a 70-30 blend, costs for part of the virgin aggregate and AC-10 used were paid by the contractor instead of the Department. The contractors extra costs for using a predominantly 60/40 blend are not considered in this discussion, however, the total quantities are included in the energy and natural resources sections of this report. The prices used in the analysis in Table E were taken from the contract

Table D

Energy for Recycled versus Virgin Aggregate Mix

Energy to Produce one ton of 60/40 Blend

	BTU/ton*				BTU	Equivalent Gal of gasoline
Remove and stockpile old mat	53,793	X	0.6 ton	=	32,275.8	0.26
Crushing of Recycled Mat	27,383	X	0.6 ton	=	16,429.8	0.13
Crushing of Virgin Aggregate	39,198	X	0.4 ton	=	15,679.2	0.12
Haul of Virgin Aggregate	15,190	X	0.4 ton	=	6,076.0	0.05
Burner Fuel	180,635	X	1.0 ton	=	180,635.0	1.45
Process and Delivery of AC-10	1,539,000	X	0.02 tons	=	30,780.0	0.25
Process and Delivery of Cyclogen	1,723,171	X	0.003 tons	=	5,169.5	0.04
					287,045.3	2.30

Energy to Produce one ton of Virgin Mix

	BTU/ton				BTU	Equivalent Gal of Gasoline
Crushing of Virgin Aggregate	39,198	X	1 ton	=	39,198	0.31
Haul of Virgin Aggregate	15,190	X	1 ton	=	15,190	0.12
Process and delivery of AC-10	1,539,000	X	.06 ton	=	92,340	0.74
Burner Fuel**	139,000	X	1 ton	=	139,000	1.11
					285,728	2.28

*Conversions used for fuels.

Diesel Fuel #2	139,000 BTU/gal.
Propane Gas	91,000 BTU/gal.
Gasoline	125,000 BTU/gal.

**Burner Fuel Energy to produce virgin mix on project north of Buena Vista.

Table E

Cost for Recycled Mix versus Virgin Mix

Qualtities paid under project contract

Pavement Removal	184,174 yd^2	X	$0.94/$yd^2$	=	$173,123.56
Virgin Aggregate	15,837.45 tons	X	$4.23/ton	=	66,992.41
AC–10	855.22 tons	X	$92.00/ton	=	78,680.24
Cyclogen	183.08 tons	X	$170.00/ton	=	31,123.60
HBP (Recycled)	52,791.5 tonx	X	$6.20/ton	=	327,307.30
Haul	60,030 ton mile	X	$0.38/ton-mile	=	22,811.40
Cost of Recycled Pavement					$700,038.51

Cost for Virgin Mix

Pavement Removal	184,174 yd^2	X	$0.94	=	$173,123.56
HBP (Grading E)	52,791.5 tons	X	$17.17	=	906,430.06
					$1,079,553.62

bid tabulations. Items such as leveling, compaction, and priming are not included since they would be required whether recycled or virgin mix was used. The price for HBP (Grading'E') was taken from the 1978 Cost Data Book (the same year this construction contract was awarded). It represents the average price for HBP, Grading E, from an undesignated pit with AC-10 and haul included.

Since one of the major reasons for recycling the old mat was so that subbase could be releveled to compensate for swelling and collapsing soils, pavement removal was included in the estimate for the use of virgin mix. The same bid price for pavement removal was used, because it was (approximately $0.10/yd^2) lower than most other projects during 1978 and should be a representative price if the contractor had to dispose of the material instead of recycling it.

As can be seen from a comparison of the costs in Table E, recycling is approximately 35% less than replacing the old pavement with virgin mix. However, prior to the decision to recycle the old pavement, several construction alternatives were considered to rehabilitate this roadway. Table F lists cost evaluations for four construction alternatives. These estimates included all of the quantities related to the paving of the project and show that the initial cost of recycling is approximately 14% more than the lowest priced alternatives. Maintenance costs for the recycled pavement are expected to be less than maintenance costs for the other alternatives.

Table F

September 27, 1979

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ALTERNATE COST EVALUATION

A.	3-INCH OVERLAY PLUS AVERAGE 1-INCH LEVELING	$900,000 (ESTIMATED)
B.	2-INCH OVERLAY (SAME ALLOWANCE FOR LEVELING) PLUS A STRESS ABSORBING MEMBRANE INTERLAYER	$1,000,000 (ESTIMATED)
C.	PLANE 2-INCHES FROM EXISTING ROADWAY. RECYCLE WITH 35% NEW AGGREGATE AND PLACE 3-INCHES RECYCLED OVERLAY (NO SAMI). ADD 10% FOR IRREGULARITIES.	$900,000 (ESTIMATED)
D.	REMOVE 5-INCHES FROM EXISTING ROADWAY. CRUSH AND COMBINE WITH 30% NEW AGGREGATE, 1.5% AC-10, 0.6% SOFTENING AGENT. PLACE 5-INCHES RECYCLED PAVEMENT.	$1,025,000

NOTE: ALTERNATE D SELECTED (COST IS ACTUAL BID FOR PLANNED QUANTITIES OF PAVEMENT RELATED ITEMS).

CONSTRUCTION COMPLIANCE TESTING

Standard acceptance testing of the recycled mix was performed in the field laboratory throughout the paving operation. A listing of the field lab analyses for percent moisture, percent asphalt, aggregate gradation, and density is contained in Appendix E of the interim report. Additionally, mix temperatures were also recorded at both the drum dryer discharge and at the paver.

The average values from the field data summary show that the gradation of the mix was very close to design values. The asphalt content for the first two lifts of the eastbound lanes is slightly higher than the design value (.09%) and slightly low for the remainder of the job (0.12%).

The average mix temperatures for the project (215-220^{o} F) are near the bottom of the temperature specification (220-280^{o} F).

Rolling and compaction was one area where some problems were encountered. Forty-five of one hundred-eight areas tested using nuclear equipment had to be rerolled and retested before meeting 93% of laboratory compaction specification.

In addition to the testing in the field laboratory, pavement samples produced on the project were submitted to the Central Materials Laboratory for extensive testing. Samples were tested for voids, stability, and Cohesiometer Value, as well as Immersion-Compression Tests. A summary of this testing also appears in Appendix E of the interim report.

One change was made in the mix design for this project. Following testing of the mix used for the first two lifts on the eastbound lanes, it was found that the stability of the mix was lower than desired so the mix design was changed to increase the stability. The design change resulted in the total asphalt content of the mix being reduced from 5.6% to 5.3%.

Following the mix design change, the stabilities for mix samples show more acceptable values for the remainder of the project. Because of the low stabilities on the first two lifts (3 1/2") of the eastbound lanes, an additional 1/2 inch of pavement thickness was added to the top lift to raise the total roadway strength.

POST CONSTRUCTION EVALUATION

A. Field Testing

In June 1979, the first post construction evaluation was performed on this asphalt pavement recycling project. Two test section locations were picked prior to construction in a fill area which had no problems with swelling or collapsing soils. The two sections, 8S and 5S, had been monitored as standard design sections since 1966 as part of the Clifton-Palisade Swelling Soils study, and were chosen because of the proven long-term stability of the base and subgrade in this area. The sections are six hundred feet long with section 5S in the westbound lanes and 8S located in the eastbound lanes. Measurements taken annually on the test sections include Present Serviceability Index using a CHLOE profilometer, skid tests, rut depths, cracking surveys, and deflections using the Dynaflect. Additionally, core samples of the various mixes from the project were submitted to the Central Materials Laboratory for testing.

Table G lists the Dynaflect deflections taken annually since shortly after construction. A review of these data shows that the pavement structure stiffened approximately 25% during the first year and has remained stable. This increase in stiffness is due to a combination of the asphalt mat curing and drying of the subgrade. All of the readings show that the pavement structure is adequate for the traffic volume (3,550 ADT).

Table G

Dynaflect Deflections of Recycled Pavement

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Section	6/26/79	4/10/80	4/21/81	5/11/82
5S	1.045	0.765	0.729	0.796
8S	0.911	0.727	0.705	0.726

Deflections are for Dynaflect Sensor No. 1 in mils, corrected to 70° F for the appropriate pavement thickness.

Note:

Section 5S is located in the westbound lanes and contains a 5 inch pavement thickness.

Section 8S is located in the eastbound lanes and contains a 5½ inch pavement thickness.

Table H

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Clifton - West

Cracking and Rut Depths

Date	Section 5S Cracking ft²/1000 ft²	Section 5S Rut Depth(in)	Section 8S Cracking ft²/1000 ft²	Section 8S Rut Depth(in)	Section C-1 Cracking ft²/1000 ft²	Section C-1 Rut Depth(in)	Section C-2 Cracking ft²/1000 ft²	Section C-2 Rut Depth(in)
6/26/79	0	0.1	0	0.1	48.2	0.0	49.6	0.0
4/10/80	0	0.3	0	0.1	54.5	0.0	60.3	0.0
4/21/81	0	0.3	5.0	0.2	58.5	0.0	72.7	0.0
5/13/82*	7.5	0.4	13.3	0.3	76.2	0.1	79.7	0.1

* At the time of this evaluation 44% of the cracking in Section 5S and 70% of the cracking in Section 8S had occurred at the seam between the two top lifts at the centerline.

	Section 5S CHLOE PSI	Section 8S CHLOE PSI	Skid Truck PSI for entire project Westbound PSI	Westbound Skid No.	Eastbound PSI	Eastbound Skid No.
6-79	3.5	4.0	4.7	42	4.8	52
4-80	3.8	4.3	--	--	--	--
5-81	--	--	4.0	--	4.1	56
5-82	--	--	3.6	44	3.9	56

* Skid truck PSI are taken using the profilometer used for inventory of the serviceability of the entire state highway system. Slope variance measurements were taken at 40 mph without correction for cracking or rutting.

Table H contains the data on cracking, rutting, skid testing, and PSI. Test sections C-1 and C-2 are located at the Clifton Interchange at the east end of the recycle project. This area received a 2 inch overlay in 1978 because of an interchange modification project (I 70-I(49). These two sections were used to compare cracking in an overlay with the new recycled pavement, as well as aging of the mix which will be discussed later.

As can be seen from a review of Table H, the reflection cracking in the overlay section is much more severe than cracking in the recycled pavement. Most of the cracking which has occurred in the recycled pavement is along the centerline resulting from the cold construction joint at the seam between the two lifts of the top mat. This cracking may also be assisted by the thermal action resulting from the paint stripes in the same area.

The rut depths measured in test sections 5S and 8S are typical for the remainder of the proect. The rutting that has occurred in the recycled pavement is larger than expected but not severe. The rutting is believed to be caused by a combination of the compaction requirement of 93% of the lab mix design, and the finished recycled mix with modifying agent resulting in a pavement that is somewhat softer than normal for this area. Properties of the completed pavement will be discussed in the next report section and the compaction specification for this mix gradation has since been changed to 95% of design mix specific gravity.

The second portion of Table H shows the smoothness measurements and skid resistance data on this project. The CHLOE Profilometer was run in 1979 shortly after construction and again in 1980. This data shows that the two test sections were constructed with a smooth ride, and that the ironing out of the wheel paths during the first year improved the smoothness in the test section area.

The skid truck PSI's are taken using a high speed profilometer at 40 mph for the entire project length. No corrections were made for cracking, rutting, or pavement texture. This equipment is used for roadway inventory work on the sufficiency study. The measurements taken shortly after construction show that the new project had excellent ridability. A review of the table shows that the roadway has deteriorated in the three years since construction, although its ride is still good. The major cause of this deterioration has resulted from swelling and collapsing soils, and is not related to the recycled pavement. The skid numbers were measured with an ASTM locked wheel skid trailer and have remained good since construction.

B. Testing of Pavement Samples

In addition to the field testing, core samples of three different mixes produced on the project and the pavement at the Clifton Interchange were taken and submitted to the Central Materials Laboratory. The mixes tested from the project were a 60% reclaimed asphalt pavement-40% virgin mix from the top mat of the eastbound lanes, a 70% reclaimed pavement-30% virgin mix from the bottom mat of the westbound lanes, and a virgin mix also from the bottom mat of the westbound lanes. The top mat of the virgin mix used for the overlay at the Clifton Interchange was also sampled for comparison. Appendix B contains the complete test data from the cores taken annually from 1979 through 1982. Tests include asphalt cement content, gradation, stabilometer and resilient modulus, abson recoveries and asphalt composition analysis.

A review of the data in Appendix B shows that the gradation of the three mixes is similar except that the virgin mix contains slightly less minus 200 material (0.2 - 0.3%). When the gradation of these mixes is compared to the mix used at the Clifton Interchange in 1978, there is a marked difference in the gradation, starting at the #16 screen and finer. The mix at the interchange is coarser in spite of a similar asphalt content.

The Clifton Interchange pavement was tested in order to have a comparison between the aging of a standard virgin mix and the recycled mix. A review of the Abson Recovery data for this mix shows that it had aged considerably by 1980; the first year that cores were analyzed. The viscosities and penetrations at that time were similar to those in the old pavement before it was recycled and rapid aging is still proceeding as shown by the 1981 and 1982 data.

Because of the hardness of the asphalt cement and rapid aging of the interchange pavement, no further comparison between it and the mixes produced on the project will be presented.

Comparing the three different mixes produced on the project shows that the virgin mix and the 70/30 blend have nearly identical properties throughout the three years of testing. Both are located on the bottom mat, so they are both protected by the upper asphalt layers. The viscosity and penetration data show that they are aging at the same rate and even the asphalt composition analyses are similar.

The 60/40 blend is similar to the other two mixes but has somewhat lower strength coefficients and the Abson Recovery data shows that the mix is aging more rapidly which is expected since it is from the top lift where it is exposed to more ultraviolet light from the sun, as well as more moisture and surface wear.

The asphalt composition analysis of the 60/40 blend shows more variation than the other mixes. Those differences are attributable to different amounts of reclaimed pavement in the individual cores taken.

The recycled and virgin mixes produced on this project are similar in both construction test data, and aging. In the case of the 70/30 blend and the virgin mix they are nearly identical. Based on this data, recycled mixes should perform the same as virgin mixes.

CONCLUSIONS

From the testing done on this project, recycled pavements can be designed and produced with properties equivalent to those of virgin mixes.

Production of recycled mixes can be accomplished while meeting existing air pollution regulations. Following the "tuning" of the asphalt plant emissions from the stacks were well within allowable standards producing a blend of 60% reclaimed asphalt pavement and 40% virgin aggregate. Excellent production rates were also obtained during the project. Numerous recycle projects have been constructed since 1979 with no air pollution problems.

From an energy and economic standpoint, the recycling option was quite competitive with standard construction alternatives. Although the bid price for the recycling alternative was higher than estimates for the other alternatives, the life expectancy of the recycled pavement should be equivalent to construction of a new pavement so lower future maintenance costs are anticipated. This was demonstrated by the large amount of reflection cracking in the Clifton Interchange project. Also better ridability was expected from the recycle option because the pavement removal allowed access to work on the roadway base. The PSI of the project has held up well, and only two small areas have needed maintenance work because of subbase problems.

In addition to these benefits, a large savings of virgin aggregate and asphalt cement was realized over conventional methods.

This project was very successful. A great deal was learned about hot mix recycling and a much improved, longer lasting highway was provided to the public with a savings in dollars and natural resources.

IMPLEMENTATION

The Colorado Department of Highways now accepts recycled asphalt pavement as a standard part of its paving program. Through experimental projects such as this it has been shown to be equivalent to virgin mix and is accepted on an equal basis as long as other mix specifications are met. Appendix C contains the Colorado Department of Highways specifications concerning recycled pavement.

Since the first recycling project in 1978, more than 500,000 tons of recycled pavement has been placed on CDOH projects with the percentage of reclaimed material varying from 20% to 70%.

ASPHALT RECYCLING

HORIZON DRIVE TO CLIFTON INTERCHANGE
PROJECT IR 70-1(57)

Photograph No. 1

Scraper picking up old pavement from roadway

Photograph No. 2

Scrapers picked up alternate six foot wide strips. Only scraper teeth entered base course.

ASPHALT RECYCLING

HORIZON DRIVE TO CLIFTON INTERCHANGE
PROJECT IR 70-1(57)

Photograph No. 3

Base following pavement removal by scrapers. The remaining pavement was windrowed and picked up using a front end loader.

Photograph No. 4

Pavement stockpiled at plant site. Dozer is working old pavement (right), crushed pavement stockpile (center), and start of virgin aggregate stockpile to right of propane tanks.

Photograph No. 5

Close-up of old pavement stockpile at plant site.

·Photograph No. 6

Crushed pavement stockpile. Note: minimal contamination.

HORIZON DRIVE TO CLIFTON INTERCHANGE
PROJECT IR 70-1(57)

Photograph No. 7

Compacted base course ready for priming. Note dark spots where crushed pavement has been added for leveling.

Photograph No. 8

Close-up of base course with crushed pavement.

ASPHALT RECYCLING

HORIZON DRIVE TO CLIFTON INTERCHANGE
PROJECT IR 70-1(57)

Photograph No. 9

View of CMI 9' X 36' Recycle Plant used on Project.

Photograph No. 10

First day of production. Note scaffolding set up next to stack for stack particulate monitoring.

ASPHALT RECYCLING

HORIZON DRIVE TO CLIFTON INTERCHANGE
PROJECT IR 70-1(57)

Photograph No. 11

Paving on project was done with a Blaw-Knox 220 paver and belly dump trucks for hauling mix.

Photograph No. 12

Finished pavement has smooth ride and good skid resistance.

APPENDIX A
MIX DESIGNS

DIVISION OF HIGHWAYS
STATE OF COLORADO
DOH Form No. 43
Revised: February 1972

JOB-MIX FORMULA MODIFICATION ORDER

Contractor: Corn Construction Company — Project No. IR 70-1(57)32

Date: April 19, 1979 — Location: Horizon Drive - Clifton Interchange

The Job Mix Formula(s) As Defined In Subsection 401.02 Of The Standard Specifications For Plant Mix Pavements, Based Upon The Following Reason: To change specific gravity and gradation to conform to first day's production.

Is Hereby Modified From That Shown With The Plans To The Following

APR 1979 LABORATORY C.D.H.

Bottom Layer(s), Grading Recycled (Includes 0 % Mineral Filler)
For Construction Mix Design, See 157# C 25345

	Project Provisions	Modification No. 2
Passing ____ Sieve	%	%
Passing ____ Sieve	%	%
Passing 3/4" Sieve	100 %	100 %
Passing Number 4 Sieve	50 %	60 %
Passing Number 8 Sieve	40 %	49 %
Passing Number 50 Sieve	%	%
Passing Number 100 Sieve	%	%
Passing Number 200 Sieve	8 %	10 %
*Asphalt % by Wt.	6.0	6.0 Includes Additive
Asphalt Grade	(AC-10)	(AC-10) Viscosity ~~or Penetration~~
**Modifying Agent % by Wt.	(0.6)	(0.6)

none
(Mineral Filler Type, If Any)

Sinclair
Asphalt Source (Refinery)

Asphalt Additive Required
Yes ( ) No (x)

*By weight of virgin aggregate at a 30/70 blend.
**By weight of crushed pavement.

***Temperature of Mixture When Emptied From Mixer 220 - 280 °F Spec's. 401.15
***See special provisions
Density (Sp. Gr.) of Lab Spec. 2.36. Required 93 % Compaction Spec's. 401.17

Top Layer, Grading Recycled (Includes 0 % Mineral Filler)
For Construction Mix Design, See 157 # C 25345

	Project Provisions	Modification No. 2
Passing ____ Sieve	%	%
Passing ____ Sieve	%	%
Passing 3/4" Sieve	100 %	100 %
Passing Number 4 Sieve	50 %	60 %
Passing Number 8 Sieve	40 %	49 %
Passing Number 50 Sieve	%	%
Passing Number 100 Sieve	%	%
Passing Number 200 Sieve	8 %	10 %
*Asphalt % by Wt.	6.0	6.0 Include Additive
Asphalt Grade	(AC-10)	(AC-10) ~~PEN~~ Viscosity
**Modifying Agent % by Wt.	(0.6)	(0.6)

none
(Mineral Filler Type, If Any)

Sinclair
Asphalt Source (Refinery)

Asphalt Additive Required:
Yes ( ) No (x)

*By weight of virgin aggregate at a 30/70 blend.
**By weight of crushed pavement.

***Temperature of Mixture When Emptied From Mixer 220 - 280 °F Spec's. 401.15
***See special provisions.
Density (Sp. Gr.) of Lab. Spec. 2.36 Required 93 % Compaction Spec's. 401.17

Distribution:

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Orange .... Staff Construction Division
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Canary Copy... Resident Engineer
FHWA....... Photo Copy

CHANGE DISCUSSED WITH CENTRAL LAB Date April 18, 1979

Signed Robert C. Jones Date April 19, 1979
Authorized-Project Engineer

Signed A R Whittaker Date 4-19-79
Approved-Dist. Materials Engineer

Received Tom Allen Date 4/19/79
Contractor's Authorized Representative

STATE OF COLORADO
DEPARTMENT OF HIGHWAYS
DIVISION OF HIGHWAYS
DOH Form No. 43
Revised: October, 1978

JOB-MIX FORMULA MODIFICATION ORDER

Contractor Corn Construction Co. Project No. IR 70-1(57)32

Date April 9, 1979 Location Horizon Drive - Clifton Interchange

The Job Mix Formula(s) As Defined In Subsection 401.02 Of The Standard Specifications For Plant Mix Pavements, Based Upon The Following Reason: To conform to the construction laboratory design.

Is Hereby Modified From That Shown With The Plans To The Following:

Bottom Layer(s), Grading recycled (Includes Ø % Mineral Filler)
For Construction Mix Design, See DOH Form 157# C25345

APR 1979 LABORATORY C.D.H.

Project Provisions — **Modification No. 1**

	Project Provisions Sieve %	Modification Sieve %
Passing ___		
Passing ___		
Passing 3/4		100
Passing Number 4		50
Passing Number 8		40
Passing Number 50		
Passing Number 100		
Passing Number 200		8
* Asphalt %by Wt.	6.0	6.0 Includes Additive
Asphalt Grade	(AC-10)	(AC-10)
**Modifying agent % by wt.	(1.0)	(0.6)
**Temperature of Mixture When Emptied From Mixer		220° - 280° °F Specs. 401.15

None
(Mineral Filler Type, If Any)

Sinclair
Asphalt Source (Refinery)

Asphalt Additive Required
Yes ( ) No (XX)

*By weight of virgin aggregate
**By weight of crushed pavement

** See special provisions

Density (Sp. Gr.) of Lab Spec. 2.38 Required 93 % Compaction Specs. 401.17

Top Layer, Grading recycled (Includes Ø % Mineral Filler)
For Construction Mix Design, See DOH Form 157# C25345

Project Provisions — **Modification No. 1**

	Project Provisions Sieve %	Modification Sieve %
Passing ___		
Passing ___		
Passing 3/4		100
Passing Number 4		50
Passing Number 8		40
Passing Number 50		
Passing Number 50		
Passing Number 100		
Passing Number 200		8
* Asphalt %by Wt.	6.0	6.0 Include Additive
Asphalt Grade	(AC-10)	(AC-10)
**Modifying agent % by wt.	(1.0))	(0.6)
** Temperature of Mixture When Emptied From Mixer		220 - 280 °F Specs. 401.15

None
(Mineral Filler Type, If Any)

Sinclair
Asphalt Source (Refinery)

Asphalt Additive Required:
Yes ( ) No (X)

*By weight of virgin aggregate
**By weight of crushed pavement

** See special provisions
Density (Sp.Gr.) of Lab. Spec. 2.38 Required 93 % Compaction Specs. 401.17

JP

Distribution

White........Contractor
Pink Copy....Staff Materials Branch
Blue Copy....District Office
Green Copy...District Materials Engineer
Canary Copy...Resident Engineer
Orange.......Staff Construction Branch
FHWA.......Photo Copy

CHANGE DISCUSSED WITH CENTRAL LAB Date 4/9/79

Signed Robert C. [signature] Date 4-9-79
Authorized Project Engineer

Signed James E. Sutherland Date 4-9-79
Approved - Dist. Materials Engineer Rep.

Received Tom [signature] Date 4/9/79
Contractor's Authorized Representative

APPENDIX B

RECYCLED PAVEMENT PROPERTIES

Appendix B-Table A

Properties of Recycled Pavement

Clifton-West
Project IR 70-1(57)

60%Recycled/40% Virgin Mix*

Aggregate Gradation

Sieve-Percent Passing	6-9-79	4-8-80	4-20-81	5-11-82	Average
3/4"	100	100	100	100	100
1/2"	93	91	92	95	93
3/8"	81	79	79	83	81
#4	59	59	56	60	59
#8	47	47	45	48	47
#16	40	40	38	41	40
#50	23	23	21	23	23
#100	15	15	14	15	15
#200	11.3	11.2	10.7	11.1	11.1

Test Results

	6-9-79	4-8-80	4-20-81	5-11-82
% Asphalt Cement	5.7	5.3	5.3	5.5
Max. Sp.Gr. of Mix	2.46	2.48	2.48	2.47
Sp. Gr. of Specimen	2.22	2.23	2.39	2.25
Voids in Specimen	10.03	9.91	3.68	8.81
Stability Value	26	27	23	25
Cohesiometer Value	111	154	174	181
R_T Value	86	88	86	88
Resilient Mod.(x1000)	266.0	322.3	580.1	598.1
Strength Coefficient	.30	.35	.30	.35

Abson Recoveries

	6-9-79	4-8-80	4-20-81	5-11-82
Vis 140^{o} F	2474	2045	1375	4112
Vis 275^{o} F	332	296	238	343
Penn@77^{o} F	53	52	68	36

Asphalt Composition Analysis

	6-9-79	4-8-80	4-20-81	5-11-82
Asphaltenes	19.0%	17.7%	22.5%	18.4%
Saturates	13.9%	13.3%	11.0%	16.0%
Naphthene Aromatics	27.5%	29.0%	29.0%	22.9%
Polar Aromatics	39.6%	40.0%	37.5%	42.7%

* Analysis of core samples taken from project.

Appendix B-Table B

Properties of Recycled Pavement

Clifton-West
Project IR 70-1(57)

<u>Virgin Mix from Clifton Interchange*</u>

Aggregate Gradation

	6-9-79	4-8-80	2-20-81	5-11-82	Average
Sieve-Percent Passing					
3/4"		100	100	100	100
1/2"		95	91	95	94
3/8"		83	78	86	82
#4		60	56	63	60
#8		43	42	45	43
#16		35	35	35	35
#50		17	16	17	17
#100		10	9	10	10
#200		7.1	6.3	6.7	6.7

Test Results

	6-9-79	4-8-80	2-20-81	5-11-82
% Asphalt Cement		5.4	5.5	5.6
Max. Sp. Gr. of Mix		2.48	2.47	2.47
Sp. Gr. of Specimen		2.10	2.22	2.24
Voids in Specimen		15.31	10.23	9.27
Stability Value		21	33	30
Cohesiometer		83	154	179
R_T Value		79	92	92
Resilient Mod.(x1000)		336.7	577.7	622.0
Strength Coefficient		.25	.40	.40

Abson Recoveries

	6-9-79	4-8-80	2-20-81	5-11-82
Vis 140° F		7098	11873	12885
Vis 275° F		525	608	643
Penn @ 77° F		27	22	21

Asphalt Composition Analysis

	6-9-79	4-8-80	2-20-81	5-11-82
Asphaltenes		22.3	28.1	20.3
Saturates		8.2	7.7	13.5
Naphthene Aromatics		28.4	25.0	24.7
Polar Aromatics		41.1	39.2	41.5

* Analysis of cores taken from project.

Appendix B-Table C

Properties of Recycled Pavement

Clifton-West
Project IR 70-1(57)

New Virgin Mix *

Aggregate Gradation

Sieve-Percent Passing	6-9-79	4-8-80	4-20-81	5-11-82	Average
3/4"	100	100	100	100	100
1/2"	90	94	91	91	92
3/8"	77	81	79	80	79
#4	56	58	56	58	57
#8	44	47	44	46	45
#16	37	40	37	39	38
#50	22	23	21	23	22
#100	15	15	14	15	15
#200	10.9	11.2	10.3	10.9	10.8

Test Results

	6-9-79	4-8-80	4-20-81	5-11-82
% Asphalt Cement	5.6	6.0	5.4	5.5
Max. Sp. Gr. of Mix	2.47	2.45	2.48	2.47
Sp. Gr. of Specimen	2.24	2.24	2.30	2.24
Voids in Specimen	9.36	8.37	7.18	9.25
Stability Value	24	24	33	24
Cohesiometer Value	151	112	201	174
R_T Value	86	83	95	87
Resilient Mod.(x1000)	237.4	263.5	538.0	370.2
Strength Coefficient	.30	.25	.44	.35

Abson Recoveries

	6-9-79	4-8-80	4-20-81	5-11-82
Vis 140° F		1717	2808	2689
Vis 275° F		245	297	283
Penn @ 77° F		55	43	47

Asphalt Composition Analysis

	6-9-79	4-8-80	4-20-81	5-11-82
Asphaltenes		17.5	18.4	19.6
Saturates		26.3	13.0	11.8
Naphthenes Aromatics		14.2	29.6	28.4
Polar Aromatics		42.0	39.0	40.2

* Analysis of core samples taken from project.

Appendix B-Table D

Properties of Recycled Pavement

Clifton-West
Project IR 70-1(57)

70% Recycled/30% Virgin Mix*

Aggregate Gradation

Sieve-Percent Passing	6-9-79	4-8-80	4-20-81	5-11-82	Average
3/4"	100	100	100	100	100
1/2"	91	92	92	92	92
3/8"	81	80	81	80	81
#4	59	59	59	58	59
#8	47	47	47	46	47
#16	40	39	39	39	39
#50	23	23	22	23	23
#100	15	15	15	15	15
#200	11.3	11.2	10.7	10.7	11.0

Test Results

	6-9-79	4-8-80	4-20-81	5-11-82
% Asphalt Cement	5.9	5.5	5.6	5.4
Max. Sp. Gr. of Mix	2.45	2.47	2.47	2.48
Sp. Gr. of Specimen	2.29	2.29	2.33	2.28
Voids in Mix	6.84	7.58	5.47	7.76
Stability Value	29	30	34	31
Cohesiometer Value	161	179	244	179
R_T Value	90	92	97	92
Resilient Mod.(x1000)	272.1	296.7	544.8	445.3
Strength Coefficient	.40	.40	.44	.40

Abson Recoveries

	6-9-79	4-8-80	4-20-81	5-11-82
Vis 140° F		1752	2153	2682
Vis 275° F		245	280	284
Penn @ 77° F		56	51	47

Asphalt Composition Analysis

	6-9-79	4-8-80	4-20-81	5-11-82
Asphaltenes		16.7	17.1	19.1
Saturates		12.6	14.2	12.0
Naphthene Aromatics		27.4	30.1	27.9
Polar Aromatics		43.3	38.6	41.0

* Analysis of core samples taken from project.

APPENDIX C

RECYCLED ASPHALT PAVEMENT SPECIFICATIONS

REVISION OF SECTIONS 403 AND 703
HOT BITUMINOUS PAVEMENT
COLORADO PROJECT NO.

Sections 403 and 703 of the Standard Specifications are hereby revised for this project as follows:

Subsection 403.01 shall include the following:

Hot bituminous paving mixtures containing reclaimed asphalt pavement materials will be accepted on an equal basis as hot bituminous pavement provided that all the requirements of the mix containing all new materials are met.

Delete the second paragraph of subsection 403.01 and replace with the following:

The bituminous pavement shall be composed of a mixture of aggregate, reclaimed asphalt pavement, if used, filler if required, and bituminous material.

Subsection 403.02 shall include the following:

The reclaimed asphalt pavement shall conform to subsection 703.04 of the Standard Specifications and revisions thereof included elsewhere in this Special Provision.

Asphalt Cement Modifying Agent. The modifying agent, if required, shall conform to the following requirements:

Specification Designation	Test Method	Requirements
Viscosity @ 140°F CS	ASTM D2170	100-300
Viscosity @ 275°F CS	ASTM D2170	3-12
Specific Gravity	ASTM D70	0.970-1.040
Flash Point C.O.C., °F	ASTM D92	350 min.
Oven Weight Change, 5 hrs. @ 325°F	ASTM D1754	4.0% max.
Viscosity Ratio **	ASTM D2170	3.0 max.
Asphaltenes	*	1% max.
Polar Aromatics	*	15% min.
Naphthene Aromatics	*	60% min.
Saturates	*	20% max.

* Proposed ASTM Procedure for Asphalt Composition Analysis - Part 15, 1980 Edition.

** Viscosity Ratio = $\frac{\text{Viscosity after Oven Wt. Change Test, measured @ 140°F CS}}{\text{Original Viscosity @ 140°F CS}}$

-continued-

12-7-81

REVISION OF SECTIONS 403 AND 703
HOT BITUMINOUS PAVEMENT
COLORADO PROJECT NO.

Delete subsection 403.03 and replace with the following:

The construction requirements shall be in accordance with subsections 401.07 through 401.20 and, if appropriate, as modified herein.

The job-mix formula for the combination of reclaimed asphalt pavement, new aggregate, asphalt cement, and modifying agent to be used will be established by the Laboratory. The combination of reclaimed asphalt pavement material and new material shall be determined by agreement of the Contractor and the Engineer. Asphalt cement shall be added at the rate of 6% (± 0.5%) by weight of new aggregate.

Modifying agent shall be added to soften the asphalt cement of the reclaimed asphalt pavement to the consistency of the new asphalt specified for the project. Asphalt modifying agent shall be added at the Laboratory established rate (± 0.2%), but not to exceed 1% by weight of the reclaimed asphalt pavement (on a daily yield basis). If 40% or less reclaimed asphalt pavement material is used in the mix, a modifying agent will not be required.

The top lift of the bituminous pavement shall not contain more than 30 percent reclaimed asphalt pavement material.

At the pre-construction conference, the Contractor shall furnish a description of how he intends to introduce the reclaimed asphalt pavement, if used, into the bituminous mixture.

Subsection 403.05 shall include the following:

Haul, asphalt, asphalt cement modifying agent and all other work necessary to complet the item will not be paid for separately but shall be included in the unit price bid.

Section 703 of the Standard Specifications is hereby revised as follows:

Subsection 703.04 shall include the following:

Reclaimed asphalt pavement shall be of uniform quality. The material shall not contain clay balls, vegetable matter, or other deleterious substances. The maximum size of the reclaimed asphalt pavement material shall be 1-1/2 inches prior to introduction into the mixer. The maximum aggregate size contained in the combination of reclaimed asphalt pavement and new aggregate shall be the same as the largest size in the job-mix formula.

REFERENCES

(1) Davidson, D. D. Canessa, W., & Escobar, S.J. "Recycling of Substandard or Deteriorated Asphalt Pavements - A Guideline for Design Procedures" Golden Bear Division, Whitco Chemical Corporation, Oildale, California, February 1977.

(2) "Energy Requirements for Roadway Pavements (MISC 75-3)", The Asphalt Institute, College Park, Maryland, April 1975.

(3) Fels, Margaret Fulton, "Comparative Energy Costs of Urban Transportation Systems," School of Engineering and Applied Science, Princeton University, Princiton, J.J., November 1974, pages 297-308.

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(4) Wall, R. P., "Energy in Roadway Construction", Colorado Department of Highways, August 1979.

(5) Apostolos, J. A., Shoemaker, W. R., and Shirley, E. C., "Energy and Transportation Systems", California Department of Transportation, December 1978.