Report No. CDH-DTP-R-83-10

HOT MIX RECYCLING
NORTH OF BUENA VISTA, COLORADO

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Final Report
September, 1983

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

The contents of this report reflect the views of the authors who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views of the Colorado Department of Highways or the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

TABLE OF CONTENTS

LIST OF FIGURES AND TABLES

Technical Report Documentation Page

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16. Abstract

This final report documents the performance of Colorado's first full scale project to recycle an asphalt pavement. Detailed information regarding the construction experiences, conservation analysis and initial evaluation was documented in the Interim Report published in March 1979. This publication documents the pavement distress measurements taken over the five year life of the project. Laboratory tests of cores taken from the asphalt cores is also reported.

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INTRODUCTION

Colorado's first field test of recycled asphalt pavement was constructed in 1978 on Project TQFC 024-1(14) located approximately 6 miles northwest of Buena Vista, Colorado. Not only did this project allow the state to evaluate recycled asphalt, but the evaluation was performed in an extreme environment. The 8,500 elevation roadway is subjected to large variations in temperature and traffic loads. Figure 1 contains a map of the project located in the upper Arkansas River Valley.

The average daily traffic on this project was 2,300 in 1978 with a 20-year design ADT of 3,750. Design 18 kip Equivalent Daily Load Application is 53.

The standard design for the project consisted of removal of the original asphalt pavement with rippers and front end loaders. The pavement was then crushed and stockpiled. The base material was mostly undisturbed except for required shoulder widening and minor alignment changes for safety. Except in the area identified for test sections plans called for a 1 3/4 inch bottom lift of recycled asphalt pavement and a 1 1/4 inch top lift of Grading E material.

Shortly after the project was completed an Interim Report, "Hot Mix Recycling North of Buena Vista," March 1979, (Reference 1) was written to document the design, construction and initial evaluation of the project. This Final Report documents the long-term performance of the project from 1978 until 1983.

BACKGROUND

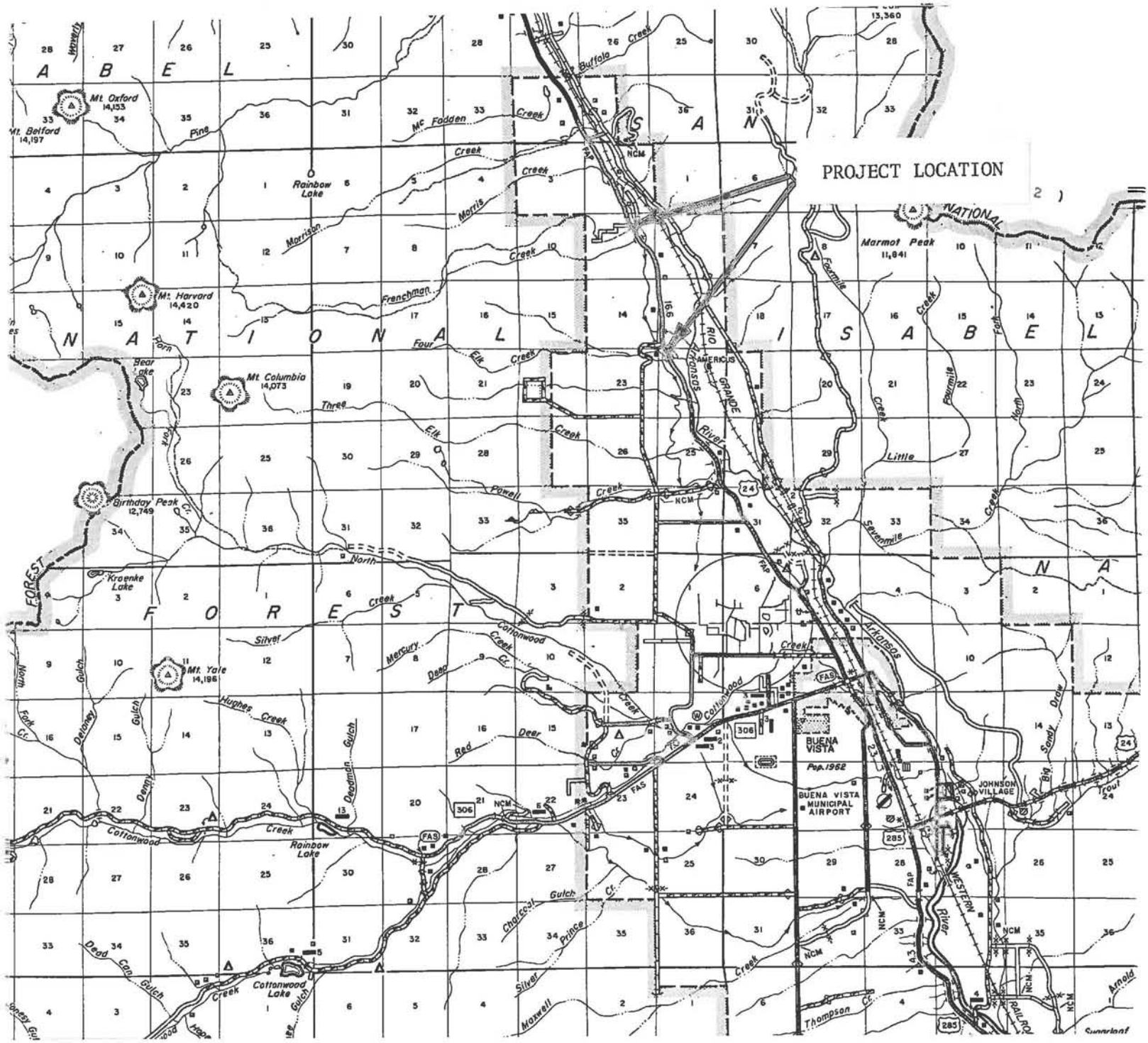
Construction/Materials

On this 3 mile long project, over 7,000 tons of bituminous concrete pavement were recycled. The original material contained a lot of old road mix

FIGURE I

Project TQFC (024-1C14)

Asphalt Pavement Recycling North of Buena Vista



(cut-back liquid asphalt, MC-800 type) and was badly deteriorated and cracked. Table A contains the material properties of the original pavement and the new material as placed on the job.

The dryer drum hot plant was made and modified by the Boeing Company. The modifications included a vented cyclindrical flame deflector to set the burner back from the main drum where the cold feed was introduced.

Production of hot bituminous pavement using 100% recycled asphalt required adjustments in production rates, moisture content of the input aggregate, and output temperatures in an attempt to produce acceptable material and at the same time reduce air pollution. The production rate of the plant was varied from 100 to 300 tons per hour using the 100% recycled material. One hundred tons per hour proved to be too low a rate for the plant, and the material produced was damaged by overheating. Acceptable pavement material was produced at rates between 150 and 300 tons per hour. The water introduced into the feed material was varied from 6 to 9 % moisture with the bulk of the project using 6.5% moisture. This water was added to help prevent burning the asphalt as it dropped through the burner flame. The discharge temperature varied from 200 to 240^{o} F with most material placed at 230^{o} F.

The majority of both the 100% recycled and the 70-30 % blend were produced at a rate of 275 tons per hour. Approximately 1.0% AC-10 and 1.0% Dutrex 739 were added to the 100% recycled material and the 70-30 % blend required 2.5% AC-10 and 0.7% Dutrex 739 to bring the finished mix to approximately 6.5% asphalt.

Meeting the air quality standards was one of the major problems encountered in this asphalt pavement recycling project. On the first day's operation (100 tons/hour, 100% recycled material, minimum flame output) the opacity was 90-100% and the material being produced was burnt and not usable

TABLE A

MATERIAL ASPHALT PROPERTIES

	Reclaimed Material*	100% Reclaimed Mix	70% Reclaimed 30% New Mix	100% New Grading E
Percent Asphalt	5.11	4.80	4.80	6.71
Percent Moisture	.29	.19	.19	.26
Mix Temp ^{o}F	--	240	240	270
Placement Temp	--	230	230	250
Percent Passing				
3/4"	100	98	99	100
1/2	100	90	87	94
3/8	94	82	76	85
#4	73	67	58	70
8	59	55	48	59
50	21	24	21	23
200	11	12	11	11

*Notes: New material data taken from first 10,000 ton production.

for anything but patching the base course on the roadway. With additional plant adjustments including production rates of 150 tons/hour the air quality standards were exceeded during the three days 100% recycled material was produced. The 70% recycled-30% new material mix showed significant improvement; however, the 20% opacity air quality standard was still greatly exceeded. Using new material, the opacity was well within the standards. Particulate measurements in the asphalt plant stack followed similar trends.

Complete details of the emission tests are documented in "Report of Investigation for Peter Kiewit & Sons Recycle Asphalt Plant Buena Vista, Colorado" by Enviro-Test Ltd. (Reference No. 2)

Natural Resources/Energy/Economics

The 7,127 tons of hot bituminous mix from the 100% recycled material and to 5,286 tons of new grading E used on this job total 12,413 tons. If recycling were not considered, all new aggregate with 6.5% asphalt would have required 807 tons of asphalt cement and 11,606 tons of new aggregate. By recycling the old mat, 6,251 tons of new aggregate and 504 tons of asphalt cement were saved. This represents a unit savings of 2,016 tons of new aggregate and 97.7 tons of asphalt cement per mile of 40 foot roadway with a 3 1/2 inch pavement depth.

The energy analysis used on this project includes processing and transportation of the natural resources to the site; removal, crushing and burner fuel at the asphalt plant; and the amount of energy in the asphalt cement. The energy used on this project to produce hot bituminous pavement for 100% recycled, 70-30% blend and new Grading E is respectively 33.3, 30.9 and 28.4 x 10^4 BTUs per ton. These values are the reverse of what may be

expected due primarily to the fact that this project is located close to a source of natural aggregate. The short haul causes a skew in the amount of energy consumption.

Cost for material estimated for this project were based on $11.50 per ton for 100% recycled material, $7.50 per ton for new hot bituminous pavement (Grading E) and $10.80 per ton for the 70-30 blend. Based on these unit costs the New Grading E material would have cost $169,451.40 if it had been used exclusively. However, comparable quantities as used on this job cost $163,357.60 with an economic savings of $6,093.80.

Since 1978, when this project was constructed, other asphalt recycling plants have become available and contractors are more familiar with the concept and process. Modification costs have been greatly reduced as well as the removal of uncertainties in the final product. Consequently greater benefits in energy and economic savings have been realized by the contractors and public agencies.

Complete details of the analysis of savings for natural resources, energy and economics have been documented in the Interim Report (Reference No. 1) published for this project.

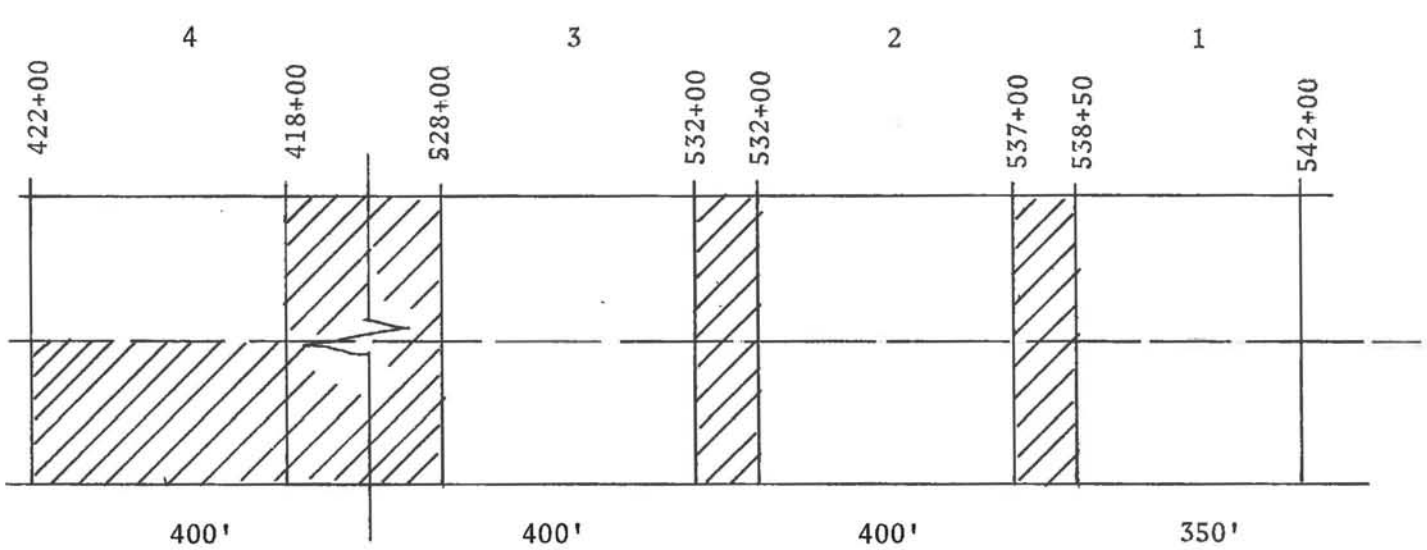
PROJECT PERFORMANCE

Four test sections have been identified on this project to evaluate the long term performance. They include: (1) the 100% recycled pavement on both the top and bottom mat, (2) 100% new Grading E on both the top and bottom mate, (3) 100% recycled material on the bottom and new on the top mat, and (4) the 70-30% blend on bottom with new Grading E on the top mat. Figure 2 shows a schematic diagram of the test section layout.

FIGURE 2

Project TQFC (024-1C14) North of Buena Vista

Test Section Layout



Length	400'	400'	400'	350'
Top Mat	Grading E	Grading E	Grading E	100% Recycled
Bottom Mat	70-30	100% Recycled (Project Standard)	Grading E	100% Recycled

Table B lists the pavement distress data observed on the project since construction. Data elements include pavement deflection as measured with the Dynaflect, lineal feet of cracking, Present Serviceability Index measured with the CHLOE profilometer and Skid Number measured with the ASTM skid trailer.

Table C contains data obtained from asphalt core samples extracted from each test section. As part of the distress survey cases were taken to the central laboratory for the following tests on the specified lifts: (1) Stabilometer and Resilient Moduluus, (2) Extraction and Abson Recoveries, and (3) Asphalt Composition Analysis. In addition, gradation of the aggregate was also determined. The most complete data sets are listed in Tables B and C.

The data indicates that there is a gradual hardening of the asphalt pavement beginning in 1981. This is reflected in the penetration and viscosities as well as the pavement deflection and observed cracking.

The penetration and viscosity of the recycled material indicates a softer material which explaines the absence of cracking in that Section (1). The New Grading E material is hardest in the laboratory and shows the most cracking in the field.

Stability and strength values show relatively little if any change over the 4 year life of the project in which asphalt samples were analyzed.

Rut depths averages 0.1 inch or less and can be attributed primarily to the abrasion by studded tires as can be observed in the close-up photographs. The original base and subgrade on this roadway appear to be performing satisfactorily.

Figure 3 contains a series of photographs of the pavement after 5 years of performance. Overall the project appearance and ride is very good. Skid resistance is believed to be quite high resulting from the hard aggregates

TABLE B
PROJECT TQFC 024-1(14), NORTH OF BUENA VISTA
FIELD DATA SUMMARY

Section	Sept. '78	Apr. '79	May '80	Apr. '81	May '82	Sept. '83
			Pavement Deflection*, mils			
1 WB	0.775	0.781	0.778	0.640	0.658	--
1 EB	0.913	0.906	0.916	0.758	0.780	--
2 WB	0.653	0.659	0.693	0.555	0.557	--
2 EB	0.808	0.799	0.818	0.646	0.647	--
3 WB	0.646	0.653	0.707	0.571	0.580	--
3 EB	1.004	0.997	1.119	0.880	0.909	--
4 WB	0.756	0.815	0.845	0.705	0.719	--
			Cracking, Lineal Ft/400 Ft			
1 WB	0	0	0	0	0	0
1 EB	0	0	0	3	3	3
2 WB	0	0	8	8	9	47
2 EB	0	0	15	10	9	3
3 WB	0	0	9	10	51	80
3 EB	0	0	9	23	55	86
4 WB	0	0	0	0	0	0
			PSI, CHLOE			
1 WB	3.30	3.79	3.35	--	--	--
1 EB	3.15	3.60	3.20	--	--	--
2 WB	3.79	4.13	3.77	--	--	--
2 EB	3.36	3.63	3.43	--	--	--
3 WB	3.62	3.89	3.64	--	--	--
3 EB	3.75	3.83	3.62	--	--	--
4 WB	4.19	4.19	4.10	--	--	--
			Skid No.			
1 WB	46	63	--	53	--	--
1 EB	49	67	--	53	--	--
2 WB	38	63	--	53	--	--
2 EB	50	65	--	53	--	--
3 WB	41	67	--	53	--	--
3 EB	48	64	--	53	--	--
4 WB	46	67	--	59	--	--

Note: *Deflection data reflects average of 5 maximum deflection readings (Sensor No. 1) and have been corrected to 70° F.

Section 1 - 100% Recycled Material
Section 2 - New Grading E
Section 3 - New (Top), 100% Recy (Bottom)
Section 4 - New (Top), 40/30 (Bottom)

TABLE C Sheet 1 of 2

PROJECT TQFC 024-1(14), NORTH OF BUENA VISTA
ASPHALT CORE SAMPLE DATA ANALYSIS

Laboratory Test	As Constructed	April '79	May '80	April '81	May '82
100% Recycled Material (Section 1)					
Percent Asphalt	4.8	5.6	--	5.5	5.7
Sp. Gravity	--	2.15	2.36	2.34	2.28
Void	--	11.95	--	4.46	6.70
Stability	--	17	19	24	22
Coch. Value	--	136	202	220	196
R_t Value	--	77	82	89	86
Res. Mod (x1000)	--	93.7	148.5	151.3	147.8
Str. Coef.	--	.25	.25	.35	.30
Penetration	--	--	195	180	120
Viscosity @ 140F	--	--	458	506	880
Viscosity @ 275F	--	--	162	167	206
Percent Passing					
3/4"	98	99	99	100	100
1/2	90	94	92	93	93
3/8	82	88	85	86	86
#4	67	74	70	72	72
8	55	62	59	60	61
50	24	27	26	26	27
200	12	14.6	14.1	13.5	14.1
70/30 % Blend (Section 4)					
Percent Asphalt	4.80	5.9	--	6.4	5.8
Sp. Gravity	--	2.20	2.28	2.28	2.21
Void	--	10.87	--	5.37	9.19
Stability	--	17	23	19	22
Coch Value	--	145	171	133	132
R_t Value	--	77	86	79	83
Res Mod (x 1000)	--	93.9	263.5	217.7	174.2
Str. Coef.	--	.25	.30	.25	.25
Penetration	--	--	82	125	92
Viscosity @ 140F	--	--	1584	833	1369
Viscosity @ 275F	--	--	297	230	266
Percent Passing					
3/4"	99	100	99	100	97
1/2	87	100	93	93	88
3/8	76	98	87	85	80
#4	58	88	73	68	66
8	48	79	61	56	55
50	21	55	26	24	24
200	11	24.0	15.3	12.2	12.0

TABLE C (Continued) Sheet 2 of 2

PROJECT TQFC 024-1(14), NORTH OF BUENA VISTA

ASPHALT CORE SAMPLE DATA ANALYSIS

100% New Grading E (Section 2)

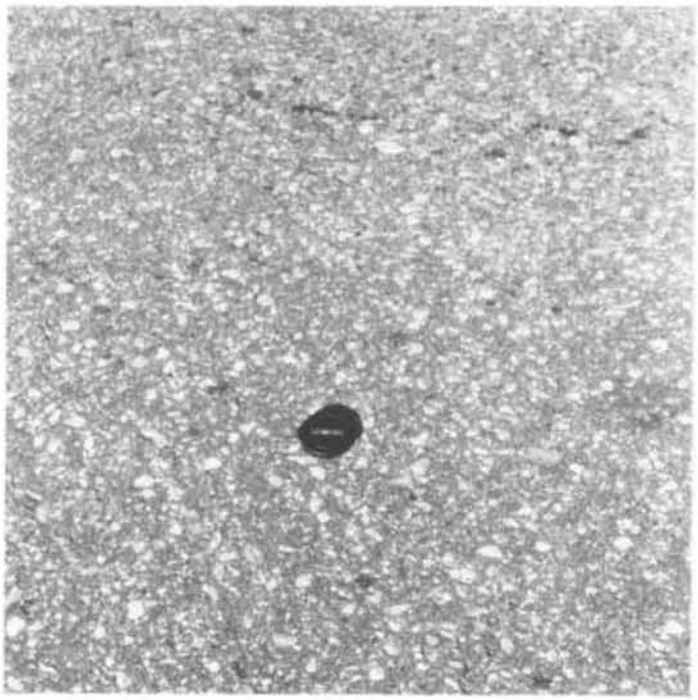
Percent Asphalt	6.7	5.6	--	6.2	6.4
Sp. Gravity	--	2.25	2.36	2.36	2.29
Void	--	8.01	--	2.36	5.02
Stability	--	28	26	25	28
Coch. Value	--	135	226	136	207
R_t Value	--	88	91	86	91
Res. Mod (x1000)	--	236.2	208.4	173.3	343.5
Str. Coef.	--	.35	.40	.30	.40
Penetration	--	--	72	66	42
Viscosity @ 140F	--	--	1949	2245	4637
Viscosity @ 275F	--	--	418	395	522
Percent Passing					
3/4"	100	100	100	100	100
1/2	94	90	90	86	87
3/8	85	77	73	70	72
#4	70	54	53	48	54
8	59	44	42	39	42
50	23	17	17	15	16
200	11	7.4	8.4	6.7	6.5

FIGURE 3

Photographs of Five Year Old Pavement

ASPHALT PAVEMENT RECYCLING NORTH OF BUENA VISTA

Overall View of Section 1.



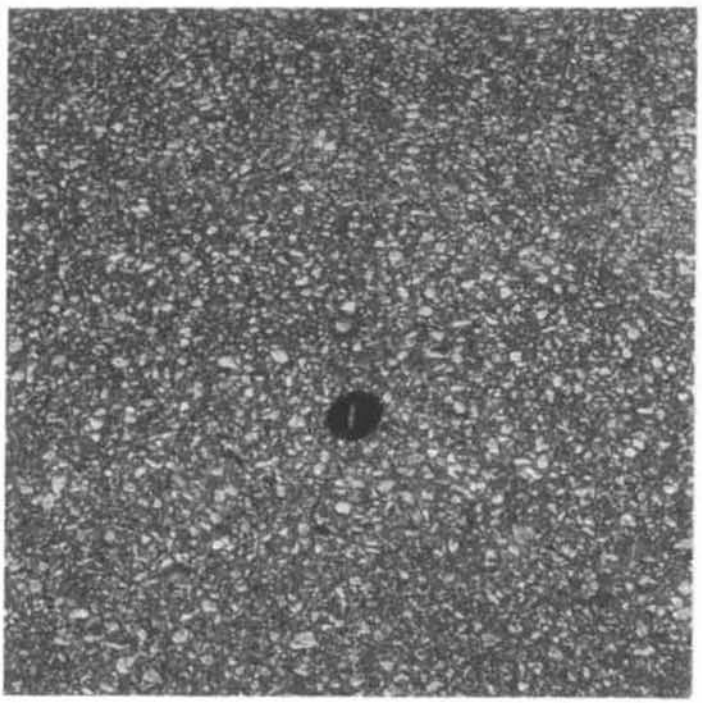
Close up of Section 1 (100% Recycled), showing good surface condition.

FIGURE 3

Photographs of Five Year Old Pavement

ASPHALT PAVEMENT RECYCLING NORTH OF BUENA VISTA

Overall View of Section 2.



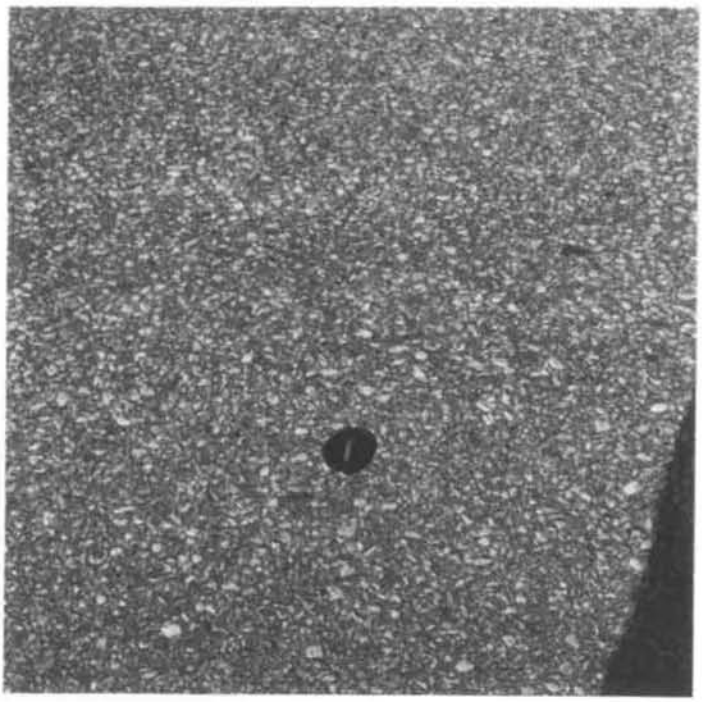
Closeup of Section 2 (Grading E) showing good surface performance in this area.

FIGURE 3

Photographs of Five Year Old Pavement

ASPHALT PAVEMETN RECYCLING NORTH OF BUENA VISTA

Overall view of Section 3.



Closeup of Section 3 (Grading E-Top, 100% Recycled-Bottom) with no distress in this area.

FIGURE 3

Photographs of Five Year Old Pavement

ASPHALT PAVEMENT RECYCLING NORTH OF BUENA VISTA

Closeup of Alligator cracks beginning to appear in Section 3.

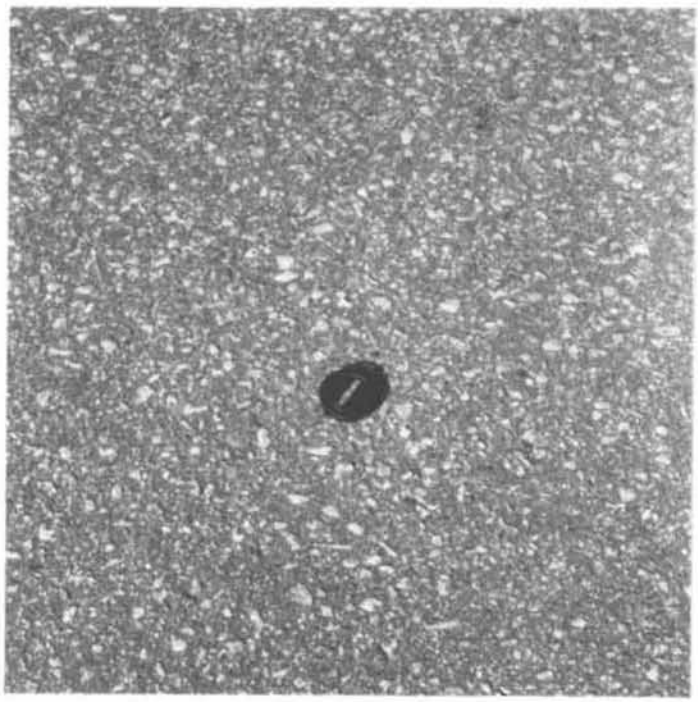
Typical longitudinal cracks observed in Section 3.

FIGURE 4

Photographs of Five Year Old Pavement

ASPHALT PAVEMENT RECYCLING NORTH OF BUENA VISTA

Overall view of Section 4.



Closeup of Section 4 (Grading E-Top, 70/30 Blend-Bottom) showing no distress.

used on the project. Photos were taken of the most severe cracking observed in Section 3-- the New Grading E material. Both types of cracking appear to be fatigue related with the longitudinal cracking resulting from the drying out of the pavement and the alligator cracking resulting in distress in the surface as well as the underlying pavement layers.

CONCLUSIONS/IMPLEMENTATION

The following series of conclusions can be drawn as a result of experiences gained on this project:

1. Good asphalt pavement material can be made using recycled asphalt pavement. Modifications in the hot plant appear to be the only change necessary with the remainder of the paving operation proceeding as usual.
2. The asphalt plant used on this project, from an air quality standpoint, was unacceptable for recycling material. However, recent uses of dual aggregate feed and other systems are environmentally acceptable in recycling asphalt pavements.
3. This project proved to be marginally effective in saving cost and natural resources. Energy savings were not realized due to the project's location relative to new materials. However, all three conservation elements have found to be saved on subsequent projects located in Colorado and at the national level.
4. A beneficial sidelight use of recycled asphalt found on this project is maintenance related uses. Material rejected from the plant during its tuning process was used to patch base course areas. In addition, extra asphalt pavement removed but not recycled has since been used satisfactorily as a cold mix patch material.

5. This project has demonstrated the versatility of recycled pavement. Considering the extreme mixing temperatures used at the beginning of the project (Section 1) the performance to date has been excellent.

6. Experiences gained from this and other similar asphalt recycle projects have led to a standard acceptance of recycled asphalt pavements in Colorado. Figure 4 contains a revised construction specification available to a contractor who chooses to recycle asphalt pavement. This alternative is used in place of the standard specification for new asphalt concrete.

   Figure 5 contains a draft revision to the standard specification for asphalt plant mix pavements. It contains the standard options to be used by the contractor in producing hot mix <u>including</u> the use of recycled material. Thus, an alternative hot bituminous pavement specification need not be considered when recycled material is used. This concept liberalizes recycling asphalt pavements.

REVISION OF SECTION 403
HOT BITUMINOUS PAVEMENT
COLORADO PROJECT NO.

Section 403 of the Standard Specifications is hereby revised for this project as follows:

Subsection 403.02 shall include the following:

The job-mix formula as defined in subsection 401.02 for the Hot Bituminous Pavement (Grading EX AND PATCHING) shall be as follows:

Passing 1/2"	Sieve	-	100%
Passing #4	Sieve	-	65%
Passing #8	Sieve	-	50%
Passing #200	Sieve	-	7%

Asphalt Cement Viscosity Grade . . . . . AC -10
Temperature of mixture when emptied from the mixer . . . . . 280°F.

The source of materials is not designated. The job-mix formula asphalt content for the Contractor's proposed source of materials will depend on the physical characteristics of the proposed aggregate and will be established by the Laboratory on aggregate actually produced for the project. The estimated asphalt content is 6.0% by weight of mix. Due to variations in materials from different sources, this percentage can vary as much as one-half percent with no adjustment in contract unit price.

Initial approval of the Contractor's source of materials will be contingent on the job-mix formula mixture, using aggregate from the proposed source, meeting the specifications listed in the table below. If after initial approval of the source of materials, the job-produced material fails to meet the specifications shown in this table, the Engineer will suspend use of such material until laboratory tests indicate that the corrective measures taken by the Contractor yield material that is in compliance with this specification.

The Division will process a maximum of three asphalt design mixes at no charge to the Contractor. In the event additional design mix tests are required, the cost of such tests shall be borne by the Contractor and will be deducted from payments made to him.

The Contractor may use an additive such as an anti-stripping material, hydrated lime, or fillers to meet the mix design specifications. Additives will not be measured and paid for separately, but shall be included in the work.

When ordered by the Engineer, a tack coat shall be applied between the courses of pavement to improve bond.

Subsection 403.05 shall include the following:

Material used for tack coat will be measured and paid for as provided in Section 411.

-continued-

-2-
REVISION OF SECTION 403
HOT BITUMINOUS PAVEMENT
COLORADO PROJECT NO.

MIX DESIGN SPECIFICATIONS
HOT BITUMINOUS PAVEMENT (GRADING EX AND PATCHING)

Property	Test Method	Value	
Job-Mix Formula Asphalt Content, min., %	CP 42	Below Top	5.2
		Top Layer	5.7
Percent Voids	CPL 5105	Below Top	2-6
		Top Layer	2-5
Stability, min.	CPL 5105	34	
Strength Coefficient, * min.	CPL 5105	0.44	
Index of Retained Strength, min.	CPL 5104	75	
Accelerated Moisture Susceptibility Retained Tensile Strength, min.	CPL 5109	--	

* CDOH Design Manual

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 Recycling Agent. The recycling agent, if required, shall conform to the following requirements:

Specification Designation	Test Method	Requirements
Viscosity @ 140°F cSt	ASTM D2170	200-800
Specific Gravity	ASTM D70	Report
Flash Point C.O.C., °F	ASTM D92	400 min.
Oven Weight Change, 5 hrs. @ 325°F	ASTM D1754	4.0% max.
Viscosity Ratio **	ASTM D2170	3.0% max.
Saturates, wt.	*	30% max.

* Proposed ASTM Procedure for Asphalt Composition Analysis - Part 15, 1981 Edition.

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

The Contractor shall furnish the Engineer written documentation that the material supplied complies with the above requirements.

-continued-

-2-
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 recycling 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% by weight of new aggregate. Due to variations in materials from different sources, this percentage can vary as much as one-half percent with no adjustment in contract unit price.

Recycling 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 recycling agent shall be added at the Laboratory established rate ($\pm$ 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 recycling 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 recycling agent and all other work necessary to complete 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.

REVISION OF SECTION 401 DRAFT 9/12/83
PLANT MIX PAVEMENTS-GENERAL

Section 401 of the Standard Specifications is hereby revised for this project as follows:

Subsection 401.08 shall be deleted and replaced with the following:

401.08 Bituminous Mixing Plant. The bituminous mixing plant shall be capable of producing a uniform material and shall have adequate capacity.

The plant shall be maintained in good mechanical condition. Any defective parts shall be replaced or repaired immediately if, in the opinion of the Engineer, they adversely affect the proper functioning of the plant or plant units, or adversely affect the quality of the hot mix in any manner.

Acceptable safety equipment shall be provided by the contractor to accommodate testing and sampling and shall be subject to approval by the Engineer.

Storage Time of Hot Mix. Hot mix shall not be stored longer than nine hours, unless additional protective measures are used and approved by the Engineer.

Subsection 401.14 shall be deleted and replaced with the following:

401.14 Preparation of Aggregates. Heating and drying of the aggregates shall be accomplished in a manner that does not damage the aggregate.

When hydrated lime is required, it shall be added to the aggregate and the mixture stockpiled to undergo an aging process in accordance with the following:

(a) Dry Hydrated Lime Added to Wet Aggregates. A minimum of one percent hydrated lime (by dry weight of total aggregate) shall be added to the aggregate. Hydrated lime, water and aggregate shall be thoroughly mixed in an approved mechanical mixer and shall then be stockpiled in one or more stockpiles. The mixture shall contain between 5 percent and 8 percent moisture at the time it is stockpiled. If the aggregate contains excess moisture, the excess shall be removed before adding hydrated lime. The mixed material shall remain in the stockpile(s) for a minimum of 5 days before being processed to produce hot mix.

(b) Lime Slurry Added to Aggregate. A minimum of one percent hydrated lime (by dry weight of total aggregate) shall be added to the aggregate. The lime shall be added to the aggregate in the form of a slurry. The lime slurry shall contain a minimum of 70 percent water by weight. The slurry and aggregate shall be thoroughly mixed in an approved mechanical mixer and shall then be stockpiled in one or more stockpiles. The mixed material shall remain in the stockpile(s) for a minimum of 1 day before being processed to produce hot mix.

REVISION OF SECTIONS 401 AND 703 DRAFT 9/12/83
PLANT MIX PAVEMENTS, UNDESIGNATED SOURCE

Sections 401 and 703 of the Standard Specifications are hereby revised for this project as follows:

Subsection 401.02 shall be deleted and replaced with the following:

401.02 Composition of Hot Bituminous Mix. The hot mix shall be composed of aggregate, bituminous material, filler or additives if required, and reclaimed material if used.

Hot mix containing reclaimed material or containing all new material will be accepted on an equal basis provided that all the requirements for hot bituminous pavement are met.

When more than 40% reclaimed material is used in the mix, a modifying agent or softer grade of asphalt shall be added to soften the asphalt cement of the reclaimed material to the consistency of the new asphalt cement specified for the the project. Asphalt modifying agent shall be added at the Laboratory established rate ±0.2%. The reclaimed material shall meet the requirements of subsection 703.04. Asphalt cement modifying agent shall meet the requirements of subsection 702.04.

The job-mix formula for each grading to be used will be established by the Laboratory using aggregates and, when applicable, reclaimed material actually produced and stockpiled for use on the project.

The Contractor shall submit the following to the Engineer:

(a) A proposed job-mix gradation which shall be wholly within the Master Range Table, Table 703-1, when the tolerances shown in Table 401-1 are applied.
(b) Source, approximate gradation, and percentage of each element used in producing the final mix.
(c) The name of the refinery which will supply the asphalt cement.
(d) A quantity of each aggregate, mineral filler, reclaimed material, and/or additive proposed for use which is sufficient for the required Laboratory tests.

The Division will process a maximum of three asphalt design mixes at no charge to the Contractor. A charge will be made for the testing and evaluating of each additional design mix submitted by the Contractor.

REVISION OF SECTIONS 401 AND 703 DRAFT 9/12/83
PLANT MIX PAVEMENTS, UNDESIGNATED SOURCE

When Laboratory tests indicate that a proposed job-mix formula meets Table 403-1, as revised for the project, a DOH Form 43 shall be executed between the Engineer and the Contractor. The DOH Form 43 will establish the job-mix formula (gradation, asphalt content, hot mix discharge temperature).

The job-mix formula shown on the DOH Form 43 shall be in effect, unless modified by the Engineer. All hot mix produced for the project shall conform thereto within the following ranges of tolerances:

Table 401-1

* Passing No. 8 and larger sieves	±8%
Passing No. 16 to No. 100 sieve, inclusive	±6%
Passing No. 200 sieve	±3%
Bitumen content	±0.5%
Hot mix discharge temperature	±20 degrees F

* When 100% passing is designated, there shall be no tolerance.

Deviations in excess of the tolerances shown in Table 401-1 for gradation and bitumen content will be subject to the requirements of subsection 105.03.

At the discretion of the Engineer, the job-produced hot mix may be tested for conformance to the criteria shown in Table 403-1 as revised for the project. Failure to meet any of the criteria shall be grounds to require the Contractor, at his expense, to take corrective action before being permitted to continue production.

If proper corrective measures cannot be readily determined, the Engineer will suspend the use of such material until Laboratory tests indicate that the corrective measures taken by the Contractor yield material that is in compliance with Table 403-1. Corrective measures shall be documented on DOH Form 43.

REVISION OF SECTIONS 401 AND 703 DRAFT 9/12/83
PLANT MIX PAVEMENTS, UNDESIGNATED SOURCE

Subsection 703.04 shall be deleted and replaced with the following:

703.04 Aggregate for Hot Bituminous Pavement. Aggregates for hot bituminous pavement shall be of uniform quality, composed of clean, hard, durable particles of crushed stone, crushed gravel, natural gravel,or crushed slag. The material shall not contain clay balls, vegetable matter , and other deleterious substances. Excess of fine material shall be wasted before crushing. The aggregate for gradings C, E, and EX shall have a percentage of wear of not more than 45 when tested in accordance with AASHTO T 96.

Recaimed material shall be of uniform quality. The material shall not contain clay balls, vegetable matter, or other deleterious substances. The maximum size of the reclaimed material shall be 1-1/2 inches prior to introduction into the mixer.

Table 703-1
MASTER RANGE TABLE FOR HOT BITUMINOUS PAVEMENT

Percent by Weight Passing Square Mesh Sieves

Sieve Designation	Grading C	Grading E	Grading EX	Grading F
1"				100
3/4"	100	100		
1/2"	70-95		100	
3/8"	60-88			
#4	44-72	44-72	50-78	
#8	30-58	30-58	34-60	45-85
#50	7-27			
#200	3-12	3-12	3-12	5-15

Special provisions REVISION OF SECTION 403 DRAFT 9/12/83
Work Sheet 403-2 HOT BITUMINOUS PAVEMENT
Hot Bituminous Pave. UNDESIGNATED SOURCE GRADING _____
September, 1983 COLORADO PROJECT NO. _____
Note: Alter as necessary.

Section 403 of the Standard Specifications is hereby revised for this project as follows:

Subsection 403.02 shall include the following:

The hot bituminous mix shall conform to the following:

TABLE 403-1

PROPERTY	TEST METHOD	VALUE
Percent voids	CPL 5105	_____
Stability, minimum	CPL 5105	_____
Strength Coefficient, minimum	CPL 5105	_____
Index of Retained Strength, minimum	CPL 5104	75
Accelerated Moisture Susceptibility Tensile Strength Retained, minimum	CPL 5109	_____

The asphalt cement for this grading shall be _____.

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

Subsection 403.03 shall include the following:

When ordered by the Engineer, a tack coat shall be applied between pavement courses.

In subsection 403.05, delete the last paragraph and replace with the following:

Haul, asphalt, asphalt cement modifying agent, additives, and all other work necessary to complete the item will not be paid for separately but shall be included in the unit price bid. Material used for tack coat will be measured and paid for as provided in section 411.

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EXAMPLES OF GENERAL NOTES THAT COULD BE INCLUDED

Hot Bituminous Pavement shall not be laid after October 1, 1983, without approval of the Engineer.

The Contractor shall use an approved anti-stripping additive.

REVISION OF SECTIONS 702 DRAFT 9/12/83
BITUMINOUS MATERIALS (ASPHALT MODIFYING AGENT)

Section 702 of the standard Specifications is hereby revised for this poject as follows:

Subsection 702.04 shall include the following:

(c) Asphalt modifying agents shall conform to the following physical and chemical requirements:

Specification Designation	Test Method	Requirements
Viscosity @ 140 F	ASTM D2170	100-300 cSt
Viscosity @ 275 F	ASTM D2170	3- 12 cSt
Specific Gravity	ASTM D 70	0.970-1.040
Flash Point C.O.C.	ASTM D 92	350 F min.
Oven Weight Change, 5 hrs. @ 325 F	ASTM D1754	4.0% max.
Viscosity Ratio **	ASTM D2170	3.0% max.
Asphaltenes	*	1.0% max.
Polar Aromatics	*	15.0% min.
Naphthene Aromatics	*	60.0% min.
Saturates	*	20.0% max.

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

$$**\text{Viscosity Ratio} = \frac{\text{Viscoity after oven wt. change test, measured @140 F}}{\text{Original Viscosity @ 140 F}}$$

References

1. "Hot Mix Recycling North of Buena Vista," LaForce, R.F. and Swanson, H.N., Interim Report, March 1979. Report No. CDOH-DTP-R-79-2, Colorado Department of Highways.

2. "Report of Investigation For Peter Kiewit & Sons Recycle Asphalt Plant Buena Vista, Colorado," Project No. 78-126, Report Date 7-5-78, Enviro-Test Ltd., P.O. Box 15325, Lakewood, CO, 80215.