

Report No. CDOT-DTP-R-83-12

EVALUATION OF REFLECTION CRACKING
IN BITUMINOUS OVERLAYS ON
CONCRETE PAVEMENTS

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16. Abstract This report documents the construction and evaluation of an experimental project to determine if a stress absorbing membrane, a high quality-low abrasion aggregate and a Carbon Black additive would control reflection cracking. This project included the placement of an asphalt concrete leveling course, stress absorbing membrane and a plant mix seal over an old concrete highway. None of the experimental features are recommended as future construction items.					
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INTRODUCTION

A section of Interstate highway 25 north of Monument Hill was in need of repair and resurfacing in 1977. The 21 year old concrete highway with an average daily traffic count of 19,600 was badly cracked with slabs faulting, some spalling at the corners of joints and a considerable number of longitudinally cracked slabs. Figure 1 is a location map of the project.

An experimental project was designed to include: 1) An "EX" special grading hot bituminous pavement leveling course, 2) a SAM (stress absorbing membrane) which is similar to a chip seal in that it is composed of AC-10 and crumb rubber covered with chips, and 3) a 3/4 inch plant mix seal type "B" using rubberized AC 20 and a special hard aggregate requiring a maximum of 25 on the L.A. abrasion test. Another experimental feature, Carbon Black was incorporated into four 500 foot test sections. Carbon Black has been used as a reinforcing agent in the manufacture of rubber tires since the 1920's. The manufacturers claims and expected advantages gained by the addition of Carbon Black included: 1) reduced thermal cracking in cold weather, 2) reduced studded tire wear and 3) a blacker surface to provide better contrast with traffic marking lane lines.

The objectives of this project were to determine if the stress absorbing membrane used to reduce or eliminate reflective cracking could be used effectively on portland cement concrete pavements and to evaluate the effectiveness of Carbon Black as an asphalt additive.

Experimental test sections were set up to evaluate each of the four variables 1) SAM, 2) Carbon Black 3) high quality aggregate and 4) Standard aggregate. Eight 500 foot test sections were laid out in order to evaluate each variable separately as indicated by the X's in Table A.

FIGURE 1
 LOCATION MAP
 Project I-25-2(120)
 El Paso-Douglas Co. Line North

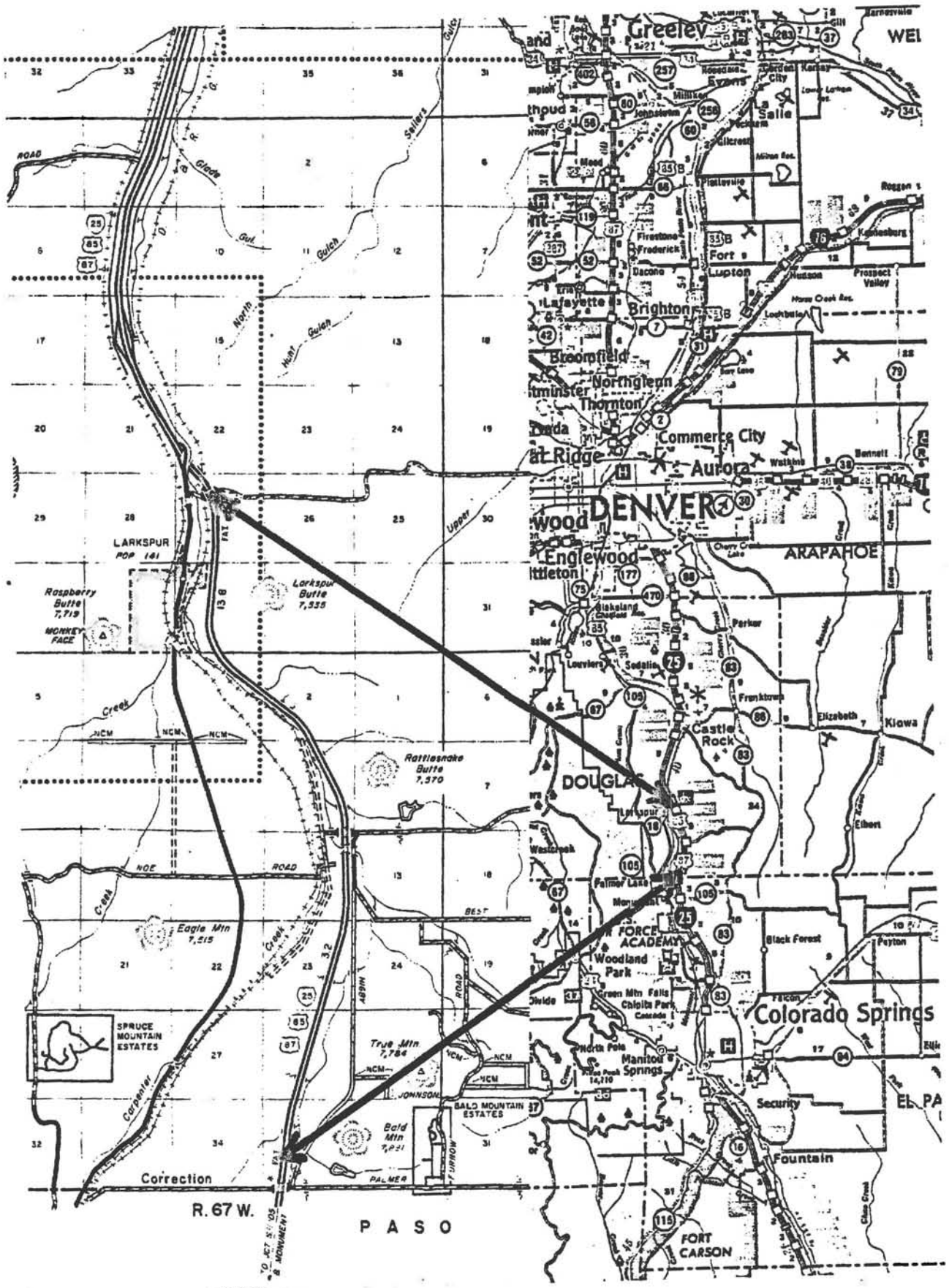


TABLE A
 Test Sections and
 Experimental Features

Test Section	High Quality Aggregate				Standard Aggregate			
	1	2	3	4	5	6	7	8
SAM*	X	X	0	0	X	X	0	0
Carbon Black	0	X	X	0	0	X	X	0

*Stress Absorbing Membrane

Section #1 is the standard design for the construction project.

The high quality aggregate was used on the project to insure a longer life and protect the added investment of the rubberized materials.

Section #8 is considered to be a control section, i.e., a normal plant mix seal. The standard aggregate had a percentage of wear from 30 to 45 when tested in accordance with AASHTO T-96. The high quality aggregate had a maximum of 25 percent wear on this test.

PRECONSTRUCTION TESTING

Cracking maps were made and the total lineal feet of cracks and joints were determined for each 500 foot test section. Table B shows the results of this cracking survey and the materials used in each section.

TABLE B

Pre Construction Crack and Joint Survey December 1977

<u>Section</u>	<u>Material</u>	<u>Expansion Joints</u>		<u>Random Cracks</u>	
		<u>Longitudinal</u>	<u>Transverse</u>	<u>Longitudinal</u>	<u>Transverse</u>
1	L & S	1500'	480'	226'	150'
2	L.S. & B	1500'	480'	465'	310'
3	L & B	1500'	480'	495'	210'
4	L	1500'	504'	273'	292'
5	C & S	1500'	480'	233'	312'
6	C.S. & B	1500'	480'	237'	373'
7	C & B	1500'	480'	225'	344'
8	C	1500'	456'	197'	304'
9	L & S	1500'	480'	471'	264'

MATERIAL LEGEND

L = Low Abrasion Aggregate
C = Conventional Aggregate
S = SAM (crumb rubber)
B = Carbon Black

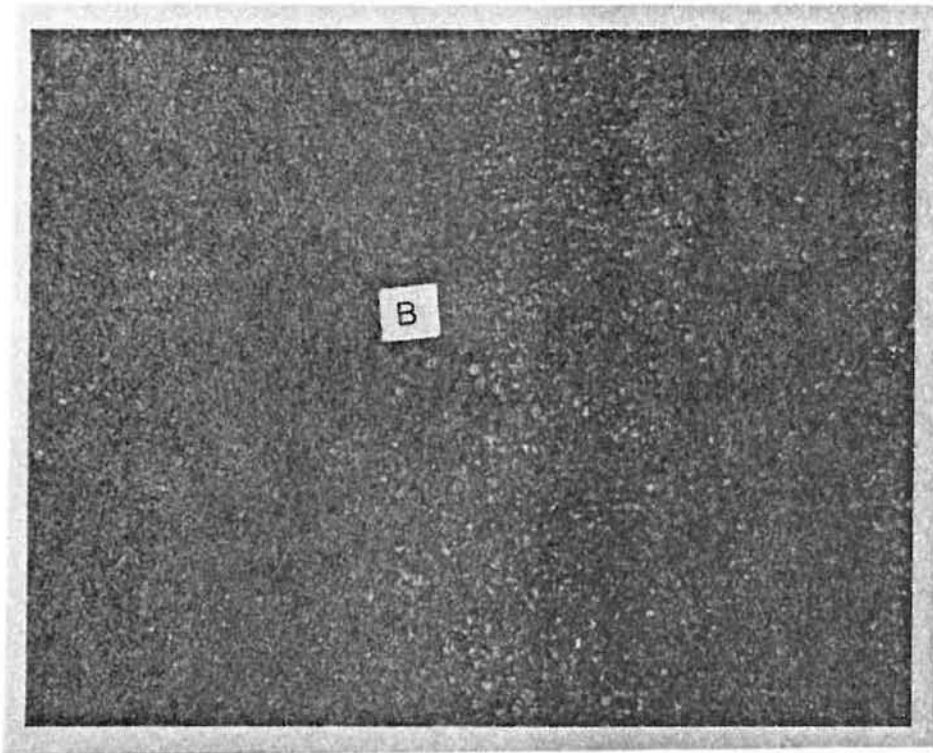
Rut depth measurements were taken to document the wear which had occurred in the wheel paths. The measured rut depths ranged from 0.2 to 0.4 inches and averaged 0.3 inches.

CONSTRUCTION EXPERIENCES

A leveling course of Hot Bituminous Pavement (Grading EX) was placed during late June of 1978 with no particular problems encountered. The average thickness measured in the wheelpaths was 1.5 inches.

On August 1, the Stress Absorbing Membrane placement began. The 13 feet nearest the median was placed first. In this area the blotter material was damp in spots but dried quickly. The second pass, 13 feet wide, covered the center portion of the highway from approximately the center of the passing lane to the center of the driving lane. Traffic was allowed on this second pass after several hours of curing the membrane. By the next day 98% of the cover coat material was lost from the surface due to traffic. Representatives from Sahuaro suggested that the high moisture content of the cover coat caused poor adhesion and loss of the well rounded material. Aggregate having angular fractured faces may have stuck into the AC-10 crumb rubber and been retained longer and better. The high volume and speed of traffic on this Interstate highway undoubtedly was a contributing factor to the failure of this material. On Tuesday, August 8, an additional 0.25 gallons per square yard of AC-10 crumb rubber was placed over the previous 0.60 gallons which was devoid of cover coat material. An additional 25 pounds per square yard of pre-dried cover coat material was placed and rolled. Within two days most of this second application of cover coat eroded and was lost in some large areas as is shown in photograph 1.

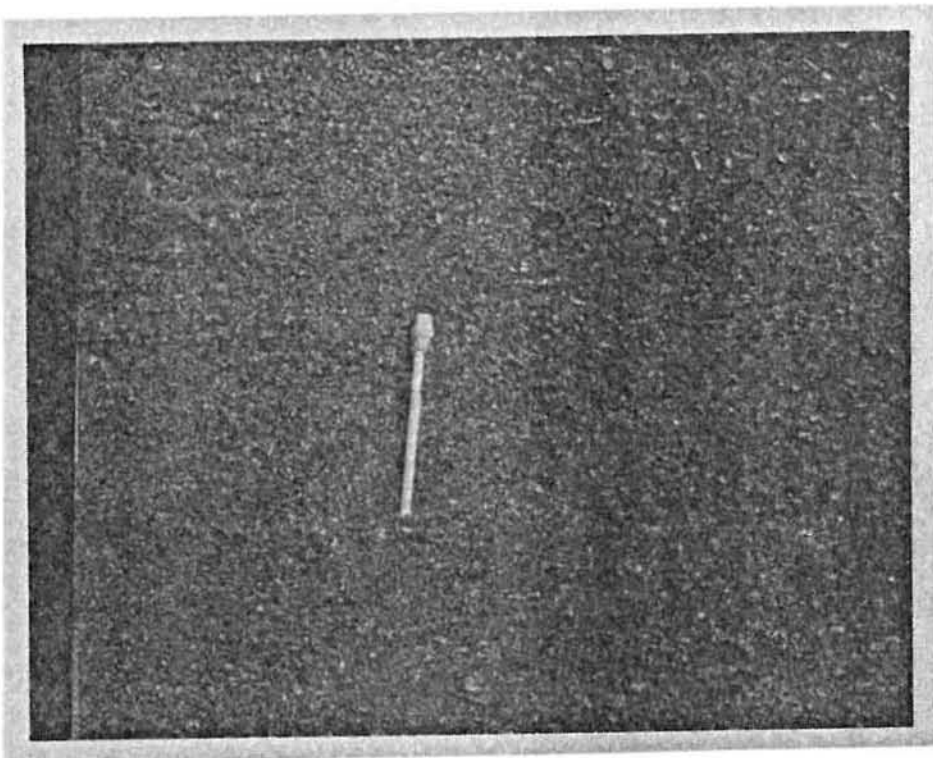
Other areas where dry cover coat was used looked good, however the traffic was kept off of all of this material since the loss of the first application. The Engineer and the Contractor elected to cover all of the SAM with the plant mix seal before allowing traffic on the roadway. This caused delay of several days before the SAM could be applied to the remaining right 12 foot pass.



Photograph 1
Stress Absorbing
Membrane
99% of cover
coat lost after
only one day

An additional
0.20 (Crumb
Rubber AC-10)
was added and
dry cover coat
replaced.

75% of this
additional cover
coat material
was lost after
another day
under traffic.



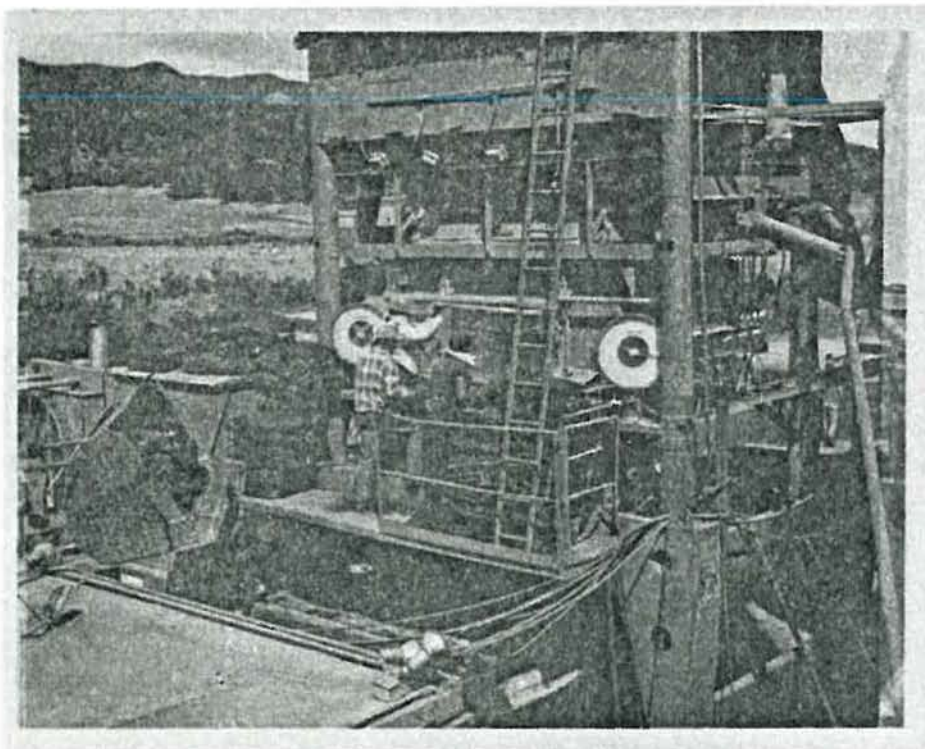
Photograph 2
Plant mix seal
in place.

Low abrasion
aggregate on the
left. (Less
than 25)

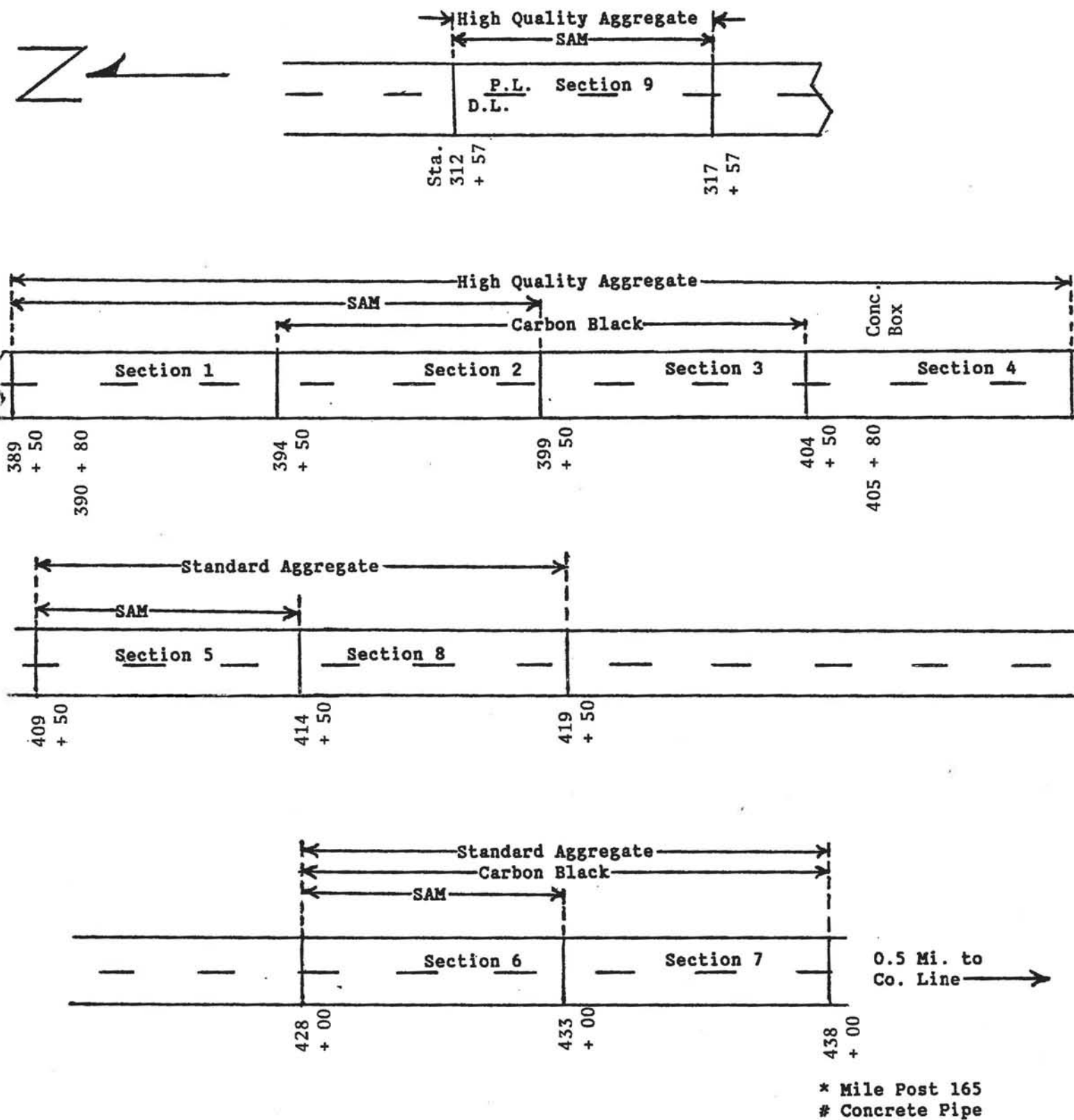
Normal aggregate
on the right.
(Abrasion 30 to
45)

The plant mix seal, approximately 3/4 inch thick, was placed in the test sections on August 22. The Contractor mixed and prepared the materials in a slightly different order than was indicated in Table A, which resulted in switching test section numbers and their locations in the field. An additional standard (test section #9) was also added in the field. Photograph 2 shows plant mix seals in place. Figure 2 shows the final configuration, including stationing and mileposts, of the test sections.

Carbon Black was delivered to the hot plant in 25 lb. bags which were added to the batch plant (bag and all) as shown in Photograph 3. All other operations for mixing and placing materials in the test sections were the same as other paving and membrane projects. The final surface and the project looked very good.



Photograph 3
Carbon Black was delivered in 25 lb. bags. Two bags were added to each batch of 5000 lbs. of plant mix seal.

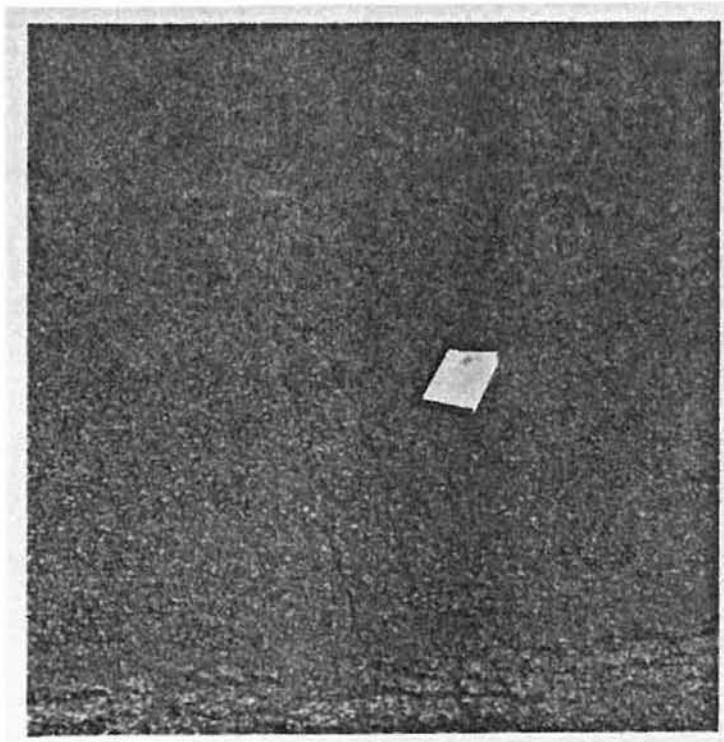


Test Section Lay out with Stationing

Figure 2

PROJECT PERFORMANCE

Cracking surveys, rut depth measurements and skid tests were made on the test sections each spring since the completion of the construction. Each year the project was revisited to determine if the same cracks were present and to document any changes in the project. The reflected cracking and the surface conditions were unchanged for the most part through the warmer months of the year. Table C is a tabulation of the crack survey data. The first winter of 1978-79 was one of the coldest on record, contributing to high thermal cracking potential to most pavements in Colorado. Sixty five percent to 84% of the original transverse joints in the concrete did reflect through the asphalt surface course that first winter. The transverse joints reflected through at a gradual but steady rate to an average of 55% of the original concrete joints. Random transverse cracks have reflected through at an increasing rate and are currently at 56%. Random longitudinal cracks didn't reflect at all during the first year but increased substantially during the second and third year and average 78% after five years.



Photograph #4 A random crack reflected through. Double cracks frequently appear at the surface where only one crack was present in the concrete.

TABLE C

I-25 South Crack Survey Results
Percent of Cracks and Joints Reflected Through The
New Surfacing from the Old Concrete Pavement

Section # Material	Date	1 L&S	2 LS&B	3 L & B	4 L	5 C&S	6 CS&B	7 C&B	8 C	9 L&S
LONGITUDINAL JOINTS	1979	4	3	4	12	2	20	33	3	1
	1980	16	6	16	49	36	27	37	56	18
	1981	16	9	17	54	36	34	48	60	23
	1982	34	44	57	76	43	38	56	66	52
	1983	40	44	70	78	43	38	58	66	61
TRANSVERSE JOINTS	1979	70	71	84	77	67	76	72	77	64
	1980	80	78	91	79	69	79	91	90	82
	1981	85	79	96	86	71	85	98	97	86
	1982	96	92	97	91	84	93	98	100	91
	1983	96	93	97	91	86	93	99	100	91
LONGITUDINAL CRACKS	1979	0	0	0	0	0	0	0	0	0
	1980	27	18	68	29	59	55	35	47	6
	1981	77	18	84	66	85	81	63	75	14
	1982	81	22	90	81	94	88	92	110	27
	1983	81	22	90	81	104	88	92	110	31
TRANSVERSE CRACKS	1979	0	9	3	13	19	22	13	12	0
	1980	9	13	21	23	28	32	33	16	9
	1981	23	13	46	67	39	44	50	37	16
	1982	23	17	56	98	66	69	75	46	23
	1983	28	19	56	100	75	69	79	46	33

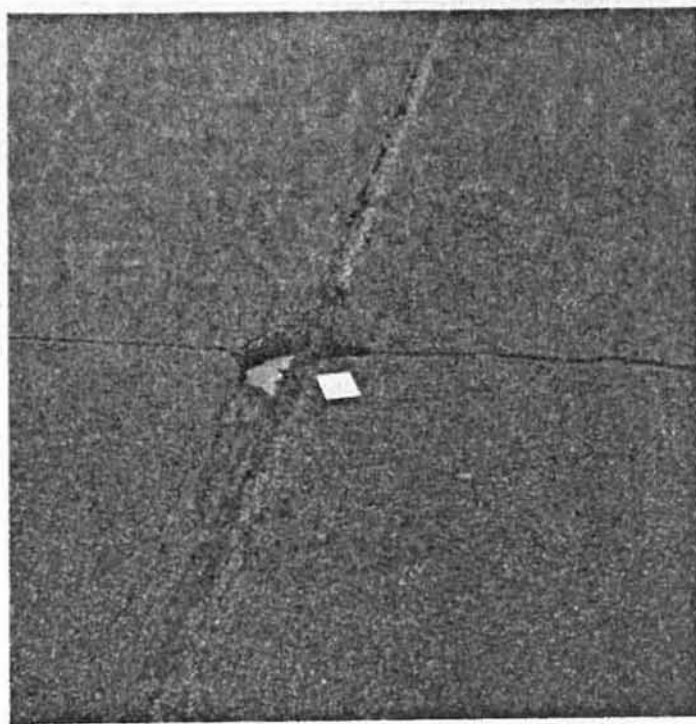
MATERIAL LEGEND

L = Low Abrasion Aggregate

C = Conventional Aggregate

S = SAM (crumb rubber)

B = Carbon Black



Photograph #5

Transverse and longitudinal joints reflected through. The plant mix seal and other asphaltic materials have spalled out to form a pothole at the junction of the joints.

All treatments failed in controlling reflection cracking of joints in the first winter and in controlling reflection cracking of all joints and random cracks within three to five years. Photos 4 and 5 show typical reflected cracks after five years. Mixes containing low abrasion aggregates performed slightly better than conventional aggregate in this respect.

The pavement surface is in good condition even though most of the transverse cracks and joints have reflected through. The ride was good and transverse cracks couldn't be detected at highway speeds. This was also the comment from various highway engineers driving over the project.

Figure 3 is a graphical representation of the crack reflection through the membrane and the asphalt surface course.

PERCENT CRACKS REFLECTED

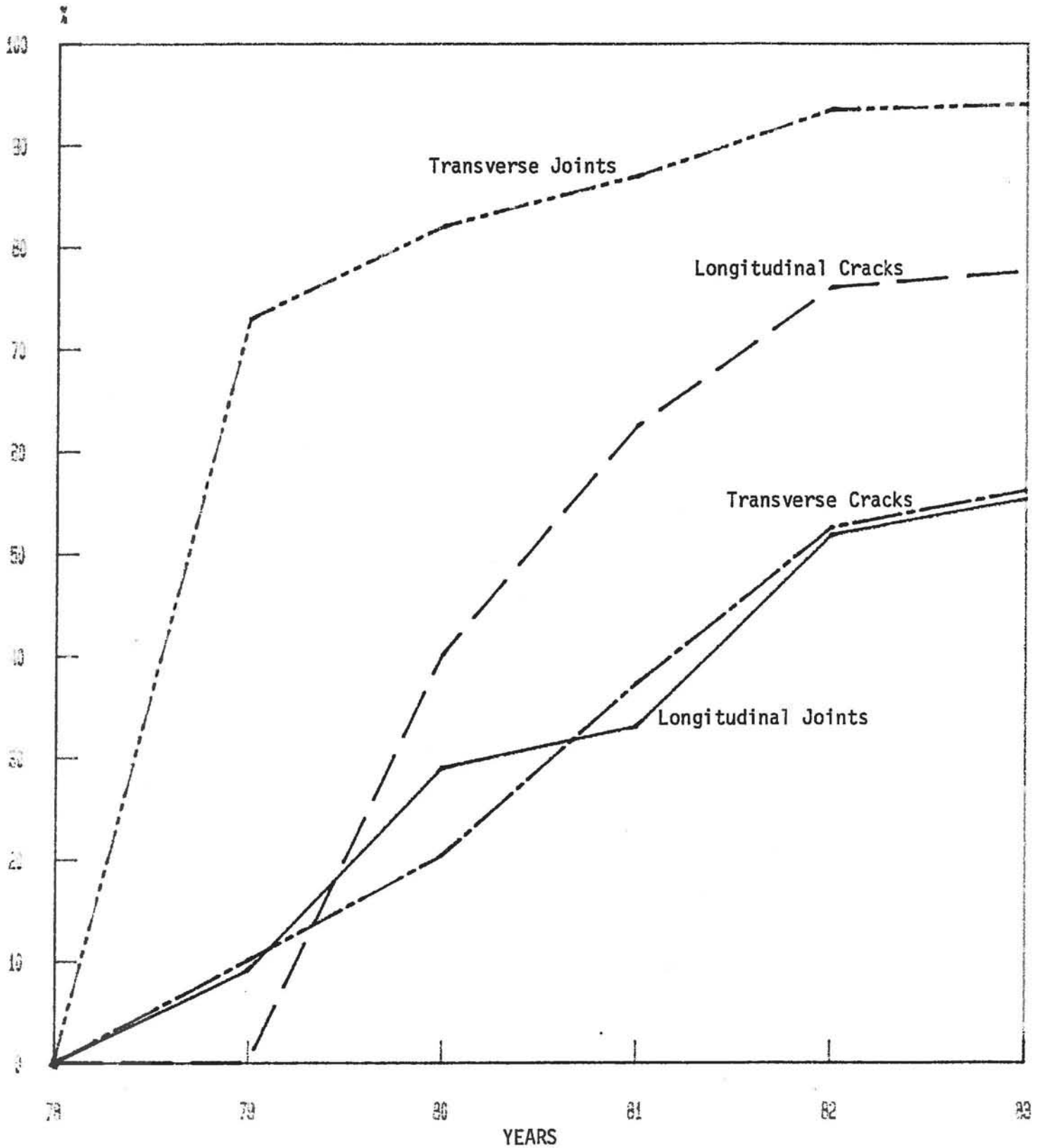


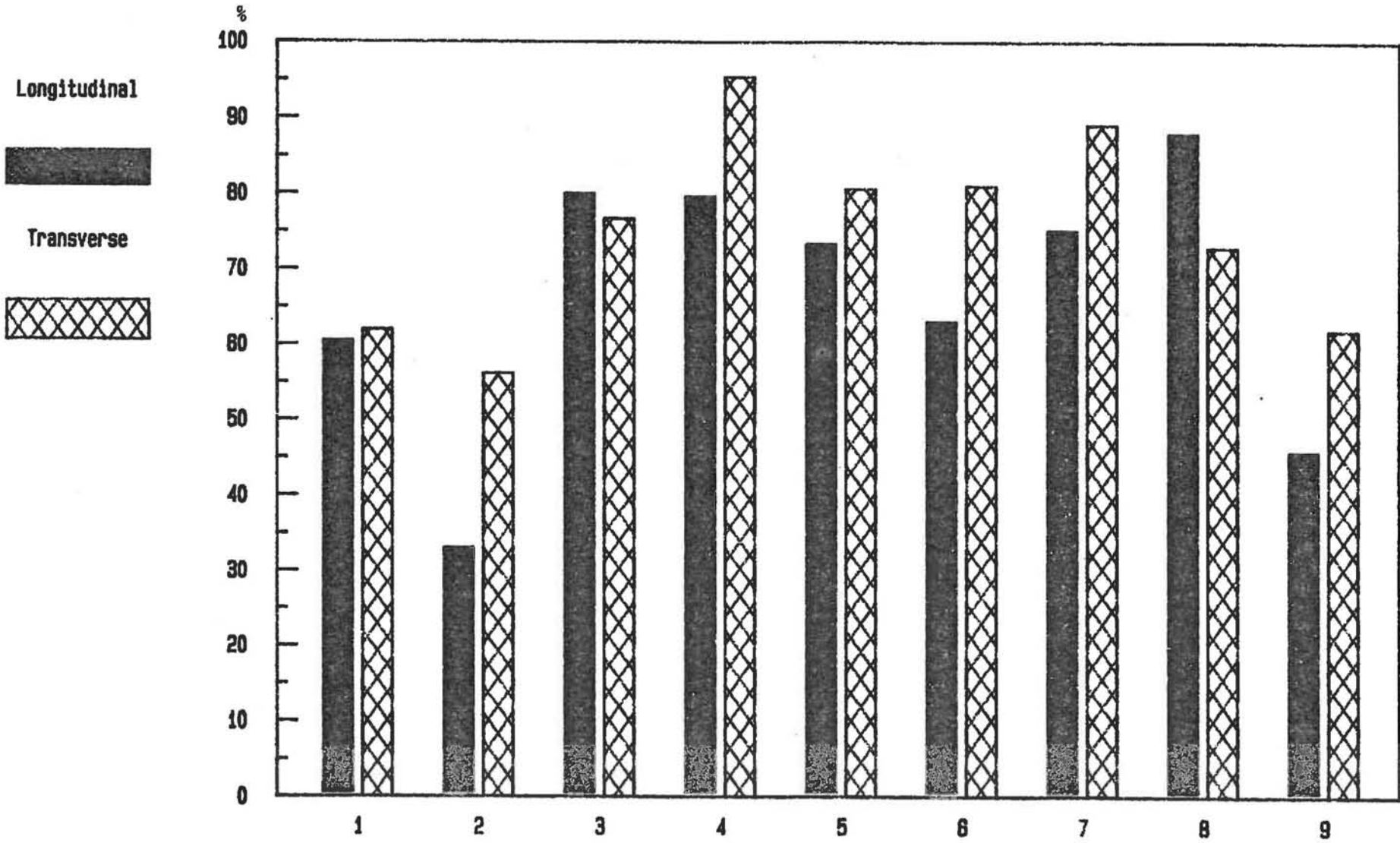
Figure 3

Figure 4 is a bar graph of the percentage of reflected cracks and joints in 1983. The lowest percent reflected was in section two which had high quality aggregate, SAM and carbon black. There is no known reason that this section performed better than the others since other sections also contained each of these variables and didn't perform as well. Reflected cracks and joints of more than 10% to 20% are not considered acceptable, therefore none of the experimental features separately or in combination as in section #2 have performed satisfactorily.

The skid testing history has not shown any difference between types of aggregate or those with and without Carbon Black. Skid numbers have always been acceptable ranging in the 40s in 1978 to the 60s in 1979 and in the 50s since then. Rut depth measurements taken throughout the evaluation period have shown no trend and no difference between sections with or without Carbon Black or between sections of different aggregate types. The rut depths in 1983 averaged 0.1 to 0.2 inches in the driving lane.

Twenty shades of gray to black as compared to an artists color chart were used to evaluate the effectiveness of Carbon Black to increase the contrast between the pavement surface and the traffic marking lines. Over the evaluation period the Carbon Black sections were subjectively rated to be an average of only one shade or 1/20th darker than adjacent section. This is not enough difference to be noticeable to the traveling public.

I25 South Crack Survey Results
 Percent of Cracks and Joints Reflected Through The
 New Surfacing from the Old Concrete Pavement



TEST SECTIONS

Figure 4

COSTS

It has been calculated from the project bid sheets that the Stress Absorbing Membrane cost $\$0.88/\text{yd}^2$ and the aggregate blotter cost $\$0.38/\text{yd}^2$ which added $\$1.26$ per square yard to the cost of the project.

The Stress Absorbing membrane increased the cost of the asphalt overlay by 31% (note this does not include mobilization and other start up costs) therefore a 31% longer life or better performance would be expected.

One bag or 25 lbs of Carbon Black cost $\$5.00$; therefore, at one percent of the mix the added cost to the 3/4 inch Plant mix seal is approximately $\$0.19$ per square yard, or a 4 1/2% increase.

CONCLUSIONS

The planning and construction of this experimental project were accomplished with little difficulty. The blotter materials require special consideration under the conditions of high speed and volume traffic. The crack reduction treatment Stress Absorbing Membrane was rather expensive at 31% of the cost of all bituminous items. Neither the Stress Absorbing Membrane nor the Carbon Black improved the ability of the plant mix seal in reducing reflective cracking. Carbon Black didn't reduce studded tire wear enough to measure, and made only a slight difference in color contrast.

The data indicates that slightly higher percentages of cracks have reflected through the sections with standard aggregate; however, since all sections are considered to have failed in this respect, the high quality aggregate was of little added value.

RECOMMENDATIONS

Neither Stress Absorbing membrane nor Carbon Black are recommended to reduce reflection of joints or cracks in portland cement concrete or to reduce studded tire wear. This is especially true when the cost effectiveness of these materials is considered.

High quality, low abrasion aggregate would be a positive attribute to any project, however, it cannot be recommended over standard aggregates if there is a significant cost differential.

In conclusion, the use of the experimental features on this project were not cost effective when compared to the standard materials used. Unless the experimental features can be justified because of unusual circumstances they should not be considered on this type of construction project.

APPEXDIX A

August 16, 1977

REVISION OF SECTION 304
AGGREGATE BASE COURSE (BLOTTER MATERIAL)
COMBINED COLORADO PROJECT NOS. I 25-2(120) & IR 25-2(122)

Section 304 of the Standard Specifications is hereby revised to include blotter material for stress absorbing membrane on this project as follows:

The source of aggregate for Aggregate Base Course is not designated.

Subsection 304.02 shall include the following:

Blotter material shall consist of Aggregate Base Course with gradation requirements as follows:

Passing #4 Sieve	-	100%
Passing #50 Sieve	-	0 - 30%
Passing #200 Sieve	-	0 - 3%

Subsection 304.04 shall include the following:

Blotter material shall be placed in accordance with Revision of Section 407, Stress Absorbing Membrane.

Section 304.07 shall include the following:

Blotter material will be measured by the ton.

Subsection 304.08 shall include the following:

<u>Pay Item</u>	<u>Pay Unit</u>
Aggregate Base Course (Blotter Material) (Haul)	Ton

September 27, 1977

REVISION OF SECTION 407
STRESS ABSORBING MEMBRANE
COMBINED COLORADO PROJECT NOS. I 25-2(120)
AND IR 25-2(122)

Section 407 of the Standard Specifications is hereby revised to include Stress Absorbing Membrane for this project as follows:

Delete subsection 407.01 and replace with the following:

407.01 This work shall consist of furnishing and applying bituminous-rubber membrane material and blotter material in accordance with the following specifications and in reasonably close conformity with the lines shown on the plans or established. After completion and acceptance of the membrane, plant mixed seal coat shall be placed over it in accordance with the plans and Section 410.

Subsection 407.02, Bituminous Material, shall include the following:

The bituminous material for stress absorbing membrane shall be Asphalt Cement (Viscosity Grade AC-10) meeting the applicable requirements of subsection 702.01.

The rubber material shall be ground tire rubber as described under the applicable mixture designated below. The asphalt and rubber shall be mixed and spread in accordance with the mixture.

MIXTURE

Rubber. The ground vulcanized scrap tire rubber shall meet the following specifications:

1. 95% of the granular rubber shall pass a No. 16 sieve and no more than 10% shall pass a No. 25 sieve.
2. The granular rubber particles (regardless of diameter) shall be less than 0.25 inches in length.
3. The ground tire rubber shall have a specific gravity ranging from 1.13 to 1.17 and shall be essentially free of fabric, wire, or other contaminating material.

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August 16, 1977

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REVISION OF SECTION 407
STRESS ABSORBING MEMBRANE
COMBINED COLORADO PROJECT NOS. I 25-2(120)
AND IR 25-2(122)

4. Calcium carbonate content (by weight of rubber) shall not exceed 4% of the mixture.

NOTE: Calcium carbonate prevents the rubber particles from sticking together.

Asphalt-Rubber Mixing and Spreading.

(a) Proportions

1. The proportions of materials by weight shall be 75 \pm 2% asphalt cement and 25 \pm 2% rubber.

(b) Mixing

1. The materials shall be rapidly combined and thoroughly mixed for at least 5 minutes until the consistency becomes fluid enough for spreading. Spreading may proceed immediately if the temperature of the mix is within the temperature range prescribed for spreading, unless dilution by solvent is to be done as outlined below.
2. The temperature of the asphalt cement shall be between 350°F. and 450°F. before mixing with scrap rubber begins.

(c) Addition of Solvent (Optional)

1. After the asphalt-rubber mixture has cooled to 350°F. or lower, it may be diluted by approximately 5% (by weight of the mixture) kerosene or other approved petroleum solvent to facilitate application.
2. The diluent shall have a boiling point of not less than 350°F.
3. The solvent and asphalt-rubber mixture shall be thoroughly mixed, brought back to spreading temperature and then may be spread immediately.

-continued-

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REVISION OF SECTION 407
STRESS ABSORBING MEMBRANE
COMBINED COLORADO PROJECT NOS. I 25-2(120)
AND IR 25-2(122)

(d) Storage

1. The completed mixture shall not be re-heated after it has cooled to below 325°F. and shall not be stored longer than 2 hours before spreading.

(e) Spreading

1. The asphalt-rubber blend shall be spread at a temperature ranging from approximately 375°F. to 425°F. Exact spreading temperature and consistency shall be the responsibility of the Contractor. Specified application rate and uniformity of spread shall be the governing criteria. Mixtures damaged by overheating will be rejected.
2. The application rate of the hot asphalt-rubber mixture shall be 4.6 pounds (+ 1.0 or - 0.25 pounds) per square yard or as directed.

Delete subsection 407.03 and replace with the following:

407.03 Blotter Material.

Blotter material shall conform to Revision of Section 304, Blotter Material.

Delete subsection 407.04 and replace with the following:

407.04 Weather Limitations.

The bituminous rubber material shall not be applied on a wet surface; when the ambient temperature is below 60°F. unless otherwise specified, or when weather conditions would prevent the proper construction of the stress absorbing membrane.

Delete subsection 407.05 and replace with the following:

407.05 Equipment.

The equipment and methods used for combining the asphalt and rubber mixture shall be such that percentages of each material may be accurately determined and controlled. In addition, the following shall be furnished:

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REVISION OF SECTION 407
STRESS ABSORBING MEMBRANE
COMBINED COLORADO PROJECT NOS. I 25-2(120)
AND IR 25-2(122)

- (a) A self-powered pressure distributor equipped for heating and applying bituminous material (with rubber added). It shall be so designed that the bituminous-rubber material may be applied uniformly on variable widths up to 12 ft. The distributor shall be equipped with a separately powered distributing pump capable of pumping the bituminous-rubber material at the specified rate through the distributor tips and the circulatory and mixing system. The distributor shall be a full circulating type with nipples and valves so constructed that they are in intimate contact with the circulating asphaltic material in order to prevent any plugging with cooled or congealed material.

The equipment shall include a tachometer, pressure gauge, volume measuring devices, and a thermometer for reading the temperature of tank contents.

- (b) A self-propelled power broom for cleaning the existing pavement surface, and removing excess blotter material.
- (c) A self-propelled aggregate spreader capable of spreading the specified blotter material quantity uniformly and accurately over the full width of the asphaltic material.

Delete subsection 407.06 and replace with the following:

407.06 Preparation of Surface.

Preparation of the surface to be treated shall include all work necessary to provide a reasonably clean surface as determined by the Engineer.

Delete subsection 407.07 and replace with the following:

407.07 Application of Bituminous Rubber Material.

Bituminous rubber material shall be applied by means of a pressure distributor in a uniform, continuous spread over the section to be treated and within the temperature range specified. The quantity of bituminous rubber material to be used per square yard shall be as directed. A strip of

-continued-

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REVISION OF SECTION 407
STRESS ABSORBING MEMBRANE
COMBINED COLORADO PROJECT NOS. I 25-2(120)
AND IR 25-2(122)

of building paper, at least 3 feet in width and with a length equal to that of the spray bar of the distributor plus one foot, shall be used at the beginning of each spread. If the cut-off is not positive, the use of paper may be required at the end of each spread. The paper shall be removed and disposed of in a satisfactory manner. The distributor shall be moving forward at proper application speed at the time the spray bar is opened. Any skipped areas or deficiencies shall be corrected.

The length of spread of bituminous rubber material shall not be in excess of that which trucks loaded with blotter material can immediately cover nor more than 1/2 mile beyond seal coat application.

The spread of bituminous rubber material shall not be more than 6 inches wider than the width covered by the blotter material from the spreading device.

The distributor, when not spreading, shall be parked so that the spray bar or mechanism will not drip bituminous rubber materials on the surface of the traveled way.

Delete subsection 407.08 and replace with the following:

407.08 Application of Blotter Material.

Blotter material shall be applied uniformly over the bituminous-rubber material immediately after its application. Blotter spread rate shall be 10 pounds per square yard or as directed. Before paving begins, all excess blotter material shall be removed from the pavement surface, including adjacent shoulders or gutter sections, and disposed of as approved.

Delete subsection 407.09 and replace with the following:

Stress absorbing membrane (bituminous-rubber material) will be measured and paid for by the contract unit price per square yard, completed and accepted on the roadway.

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August 16, 1977

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REVISION OF SECTION 407
STRESS ABSORBING MEMBRANE
COMBINED COLORADO PROJECT NOS. I 25-2(120)
AND IR 25-2(122)

Payment will be made under:

<u>Pay Item</u>	<u>Pay Unit</u>
Stress Absorbing Membrane	Square Yard

Scrap rubber, extender oil, solvent and all other materials required to produce the pay item will not be paid for separately but shall be included in the work.

Blotter material will be measured and paid for in accordance with Revision of Section 304, Blotter Material of these special provisions.

August 16, 1977

REVISION OF SECTION 411
ASPHALT CEMENT (SCRAP RUBBER)
COMBINED COLORADO PROJECT NOS. I 25-2(120) & IR 25-2(122)

Section 411 of the Standard Specifications is hereby revised for this project as follows:

Subsection 411.02 shall include the following:

Bituminous rubber material shall conform to materials described in the Revision of Section 407, Stress Absorbing Membrane.

