

Report No. CDOT-DTD-R-97-3

Special Polymer Modified Asphalt Cement (Final Report)

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U.S. Department of Transportation
Federal Highway Administration

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1.0 Introduction

Prior to this study the Colorado Department of Transportation (CDOT) had little experience with polymer modified asphalt binders. Laboratory testing had shown the addition of the polymer in asphalt mixes improved the physical properties of the mix when compared to conventional asphalt mixes. These tests indicated that polymer-modified asphalt binders would be more flexible during cold temperature and provide increased stability during warmer temperatures. These enhanced characteristics indicated that pavements containing polymers would retard thermal cracking during cold periods and shoving and rutting during warmer periods.

In 1991 the AASHTO Task Force 31 developed the Guide Specifications for Polymer Modified Asphalt. This guide was a generic, performance-based specification for polymer-modified asphalts. This guide specification described three types of polymer-modified asphalts each based on different types of commonly used polymers. The final Task Force 31 report was issued by AASHTO, Associated General Contractors of America (AGC), and the American Road and Transportation Builders Association (ARTBA) Joint Committee-Subcommittee on New Highway Materials (Appendix A).

In 1991 the Colorado Department of Transportation initiated this study to evaluate the three polymer-modified binder categories developed by the AASHTO Task Force 31.

The Colorado Department of Transportation's project special provisions for polymer were developed using the AASHTO Task Force 31 recommendations. These project special provisions are contained in Appendix B.

This study evaluated and compared the effectiveness of polymer-modified asphalt mixes in improving the performance of the roadway in relation to rutting and cracking as compared to our standard mixes without modified binders.

2.0 Site Selection

Five separate locations were selected for evaluation. Each location contained at least one polymer section for comparison. Two locations contained two of the three categories defined in the AASHTO Task Force 31. The other three locations contained only one category defined in the AASHTO Task Force 31 (Appendix A). A description of each category contained in AASHTO Task Force 31 follows:

Type I Polymer Modified Asphalt is based on properties of conventional asphalt cements after modification with styrene block copolymers.

Type II Polymer Modified Asphalt is based on properties of conventional asphalt cements after modification with styrene butadiene rubber latex (SBR) or neoprene latex.

Type III Polymer Modified Asphalt is based on properties of conventional asphalt cements after modification with ethylene vinyl acetate or polyethylene.

Table 1 lists the different binders and modifiers used at each location for this study. The criteria used to select the evaluation sites was based on traffic and environment. Sites were selected to represent the range of temperatures that are found across Colorado. Each site selected had significant traffic loadings to determine the effectiveness of the polymer modified asphalt with respect to rutting.

3.0 Projects Selected for Evaluation

The five projects selected for evaluation under this study were located on I-70 near Flagler, I-25 near Pueblo, I-25 in Denver, Santa Fe Drive in Littleton, and Brighton Boulevard in Denver. Each location contained at least one polymer section and one section containing the standard mix design (See Table 1). Descriptions of each location are summarized in section 7.0.

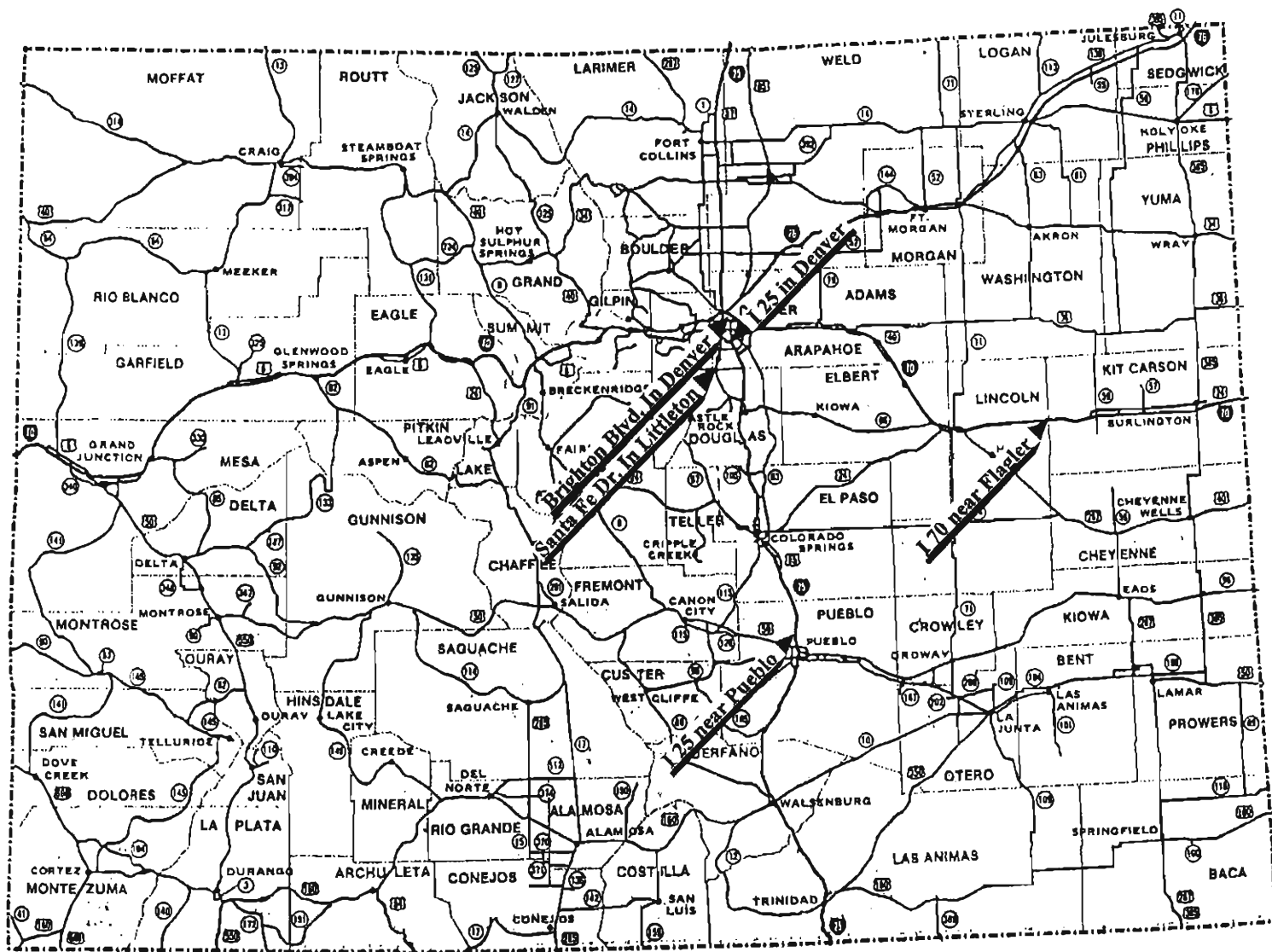
Figure 1 shows the location of each project in Colorado. Evaluations were performed prior to construction, during construction and in the spring and fall of each year during the evaluation period. The spring evaluation included deflection measurements (using the dynaflect), cracking measurements, rutting measurements (using a six foot straight edge), and a visual observation. The fall evaluations included rut depth measurements and cores. The cores were used to determine the in-place voids and how they changed with time.

Table 1. Asphalt Binder and Modifier

Location	Asphalt Binder Used	Gradation ¹	Task Force 31 Type and Grade ²	Modifier
I-70 near Flagler	AC20 Conoco Denver	C, CX, G,	--	--
	AC20P ELF Pueblo	C	Type I-D	SB
I-25 near Pueblo	AC20 Diamond Shamrock	C	--	--
	AC20R ELF Pueblo	C	Type II-B	SB Tri-Block
	AC20P ELF Pueblo	C	Type I-D	SB
I-25 In Denver	AC20 Conoco	SC	--	--
	AC20P ELF Pueblo	SC	Type I-D	SB
Santa Fe Drive in Littleton	AC20 Conoco Denver	SC	--	--
	AC20P ELF Pueblo	SC	Type I-D	SB
Brighton Boulevard in Denver	AC10 Conoco Denver	SF	--	--
	AC20P ELF Pueblo	SF	Type I-D	SB
	AC20P ELF Pueblo	SF	Type III-D	EVA

¹ The gradation specifications can be found in Appendix C² AASHTO Task Force 31 can be found in Appendix A

Figure 1. Locations of Projects In Colorado



4.0 Pre-construction

A pre-construction evaluation was performed at each location. Comparable roadway sections at each location were selected for evaluation by identifying sections with similar pavement distresses (such as the magnitude of cracking and rutting). The evaluation included establishing a 152 to 183 meter (500 to 600 foot) control section containing the current standard mix design and a 152 to 183 meter (500 to 600 foot) test section for each type of polymer used. When applicable, crack maps were drawn, rut measurements were taken, and the overall roadway condition was noted for both the test and control sections. Rut depth measurements were taken every 15 meters (50 feet) throughout the test sections using a 1.83 meter (6 foot) straight edge. Typical distresses found prior to construction on these projects are shown in Figure 2 and Figure 3.

5.0 Construction

Construction at each location was monitored in order to document construction placement, delivery, temperatures, rolling techniques, and results of density testing. Field samples were collected from each test and evaluation section to verify conformance with approved mix designs. Testing was performed at the Colorado Department of Transportation's central laboratory.

Four of the five projects were constructed during the 1991 construction season. The four projects constructed in 1991 were I-70 near Flagler, I-25 near Pueblo, I-25 in Denver, and Santa Fe Drive in Littleton. The fifth location (Brighton Blvd in Denver) was constructed during the 1992 construction season. Evaluation sections were marked in the field for future evaluations.

6.0 Post-Construction Evaluations

Following construction, field evaluations were conducted twice a year. In the spring of each year, deflection measurements, rutting measurements, cracking measurements and visual observations were made. Rutting measurements and 100 mm (4") diameter cores were taken each fall. This post-construction evaluation established the baseline and was used to compare to subsequent evaluations in order to determine the performance of each section.



Figure 2. Typical cracking pattern found prior to construction on the Santa Fe Drive project.



Figure 3. Typical cracking pattern found prior to construction on the Brighton Boulevard project.

7.0 Project Identification

The various Hot Bituminous Pavement's (HBP) gradings used on these projects can be found in Appendix C. In-depth construction detail can be found in Report No. CDOT-DTD-R-92-5 "Special Polymer Modified Asphalt Cement"(1).

7.1 I-70 near Flagler

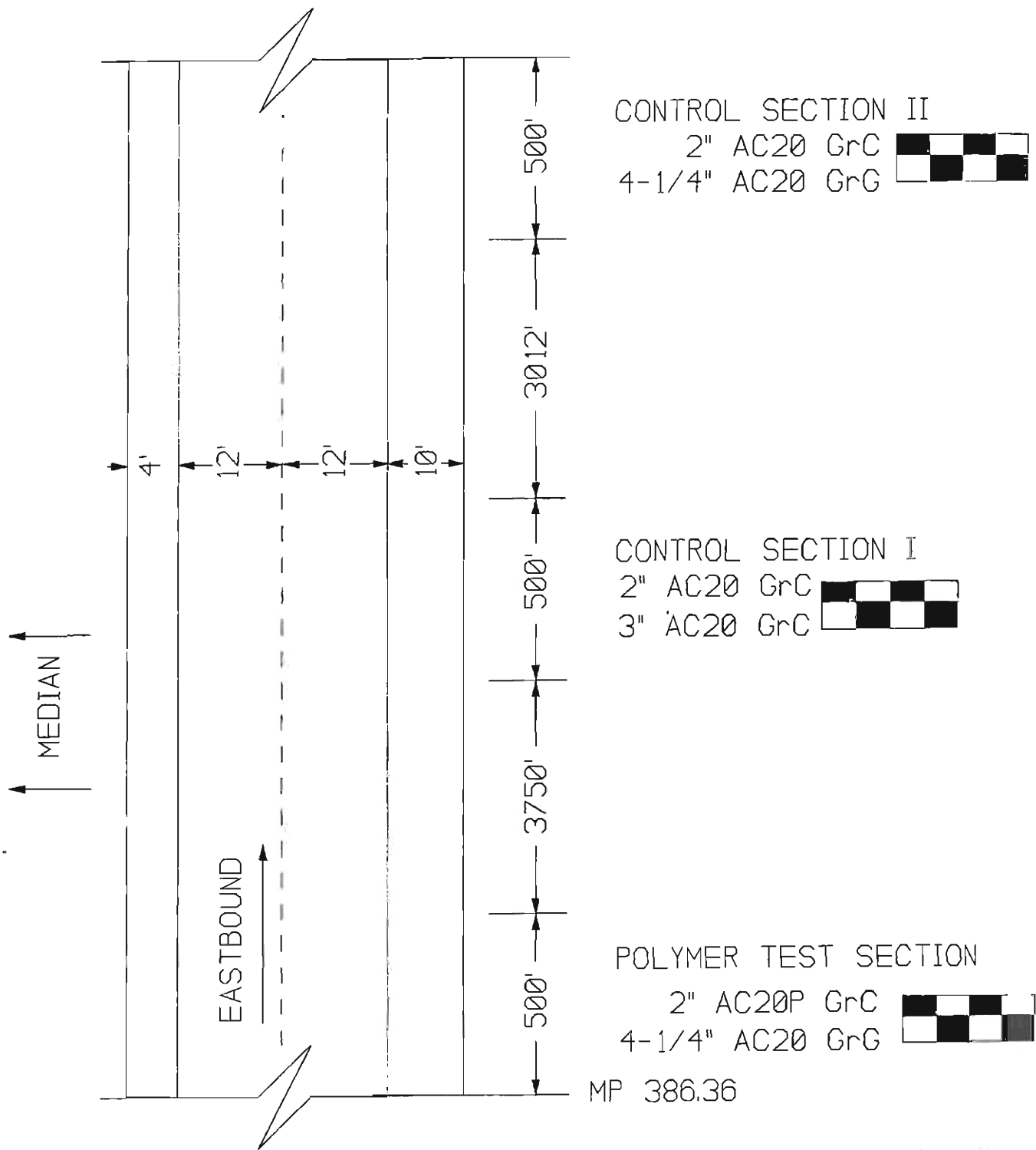
Project FRI(CX) 070-5-56 is located in the eastbound lanes of I-70 east of Flagler. The project extends from MP 386 to MP 395.1. The Annual Average Daily Traffic (AADT) in 1995 was 7,150 vehicles with 40% trucks. The design lane 18 kip Equivalent Single Axle Loads (ESAL) over the study period (1991 to 1996) were 1,881,000 ESALs.

The 152 meter (500 foot) test section located on the west end of the project consisted of an HBP Grading CX leveling coarse, 106 mm (4-1/4") HBP Grading G lift with a 50 mm (2") polymerized HBP (AASHTO Task Force 31 - Type I-D) Grading C lift on the wearing surface. The first control section (Control I) is a 152 meter (500 foot) section (SHRP-SPS 080504) contained an HBP CX leveling coarse with 125 mm (5") of HBP Grading C. This section was constructed in two lifts, a 75 mm (3") lift and a 50 mm (2") lift respectively. Control section II (CDOT-SPS 080510) contained an HBP Grading CX leveling coarse, 106 mm (4-1/4") HBP Grading G lift placed in one lift, with a 50 mm (2") HBP Grading C lift for the wearing surface. The evaluation sections were established in the driving lane of the eastbound direction. The site map (Figure 4) illustrates the location of each evaluation section.

This project was also one of the locations under the Strategic Highway Research Program (SHRP) SPS 5 study. The SHRP SPS 5 study was a SHRP experimental study which was designed to study the effectiveness of various rehabilitation techniques on asphalt concrete pavements(2). The SHRP SPS 5 study contained nine sections at this location.

This polymer study evaluated only two of the nine SHRP sections being evaluated under the SHRP SPS 5 study. An additional polymer section, which was established specifically for this study, was evaluated and compared to two of the SHRP test sections.

Figure 4. I-70 near Flagler -- Project No. FRI(CX) 070-5-56



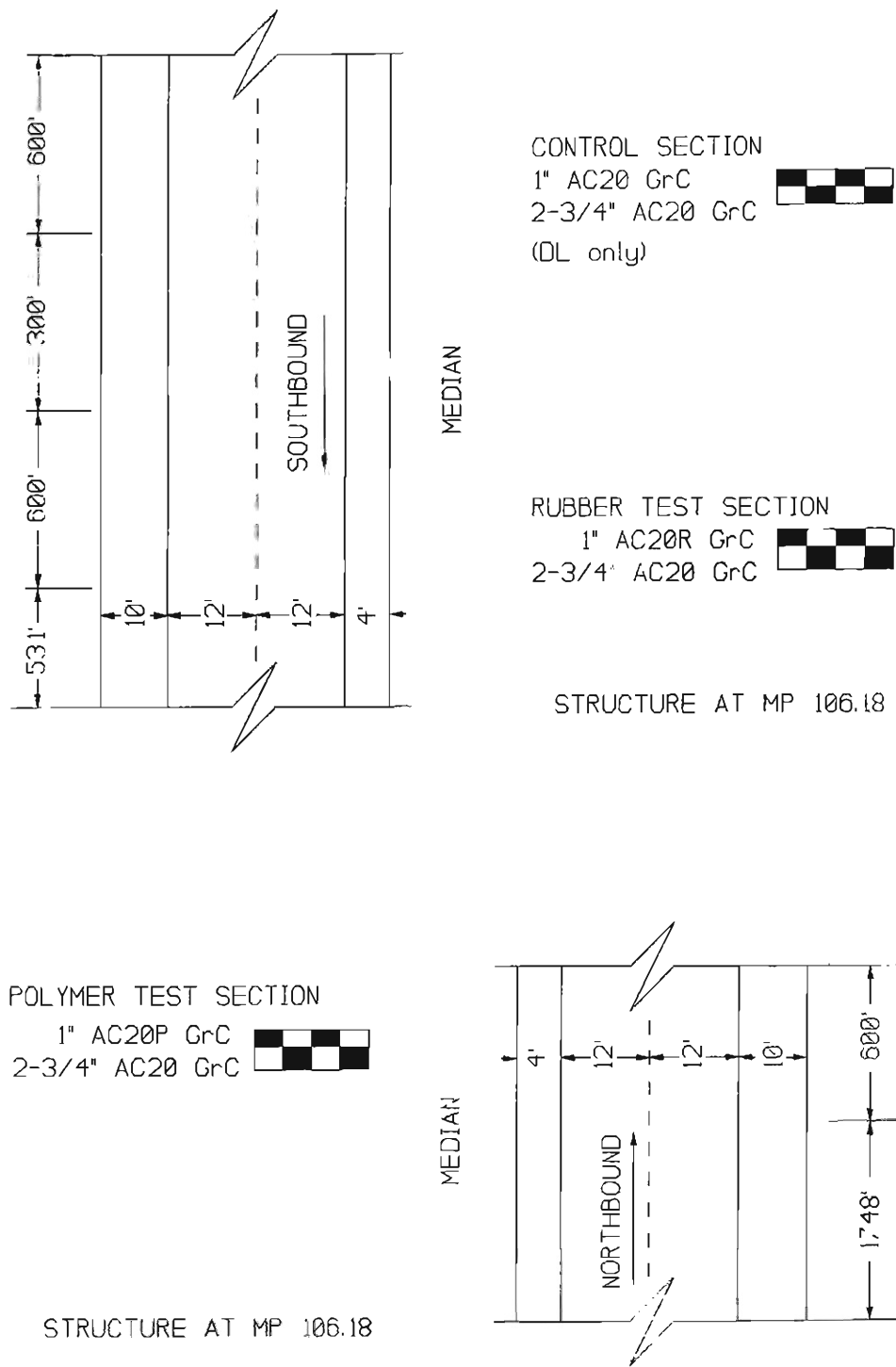
7.2 I-25 near Pueblo

Project CXIR 02-0025-30 is located north of Pueblo on I-25 and is 12.9 kilometers (8 miles) long. This project extends between MP 101 and MP 109 in both the southbound and northbound directions. The annual average daily traffic (AADT) for the year 1995 was 23,000 vehicles with 11% truck. The design lane 18 kip Equivalent Single Axle Loads (ESAL) over the study period (1991 to 1996) were 1,864,000 ESALs.

Rehabilitation of this roadway included heater scarifying the top 1" of the existing pavement in both the southbound and northbound directions.

Two test sections were established on this project. The first test section located in the northbound direction consisted of a 69 mm (2-3/4") HBP Grading C lift with a 25 mm (1") HBP Grading C top mat containing a polymer-modified asphalt cement (AASHTO Task Force 31 - Table I-D). The second test section was located in the southbound direction. In this section a 69 mm (2-3/4") HBP Grading C lift was placed with a 25 mm (1") HBP Grading C top mat containing AC-20R (AASHTO Task Force 31 - Table II-B). The control section which was established in southbound direction was approximately 183 meter (600 feet) in length. This section consisted of 94 mm (3-3/4 inches) of HBP Grading C placed in two lifts and containing a standard AC-20 binder for comparison purposes. The location of each evaluation section on this project is shown in Figure 5.

Figure 5. I-25 near Pueblo – Project No. CXIR 02-0025-30



7.3 I-25 in Denver

Project No. CX 01-0025-58 is located on I-25 between Colorado Boulevard and 6th Avenue. The project was approximately 8 kilometers (5 miles) in length and included both the northbound and southbound lanes. The Annual Average Daily Traffic (AADT) for 1995 was 166,400 with 5% trucks. The design lane 18 kip Equivalent Single Axle Loads (ESAL) over the study period (1991 to 1996) were 3,088,000.

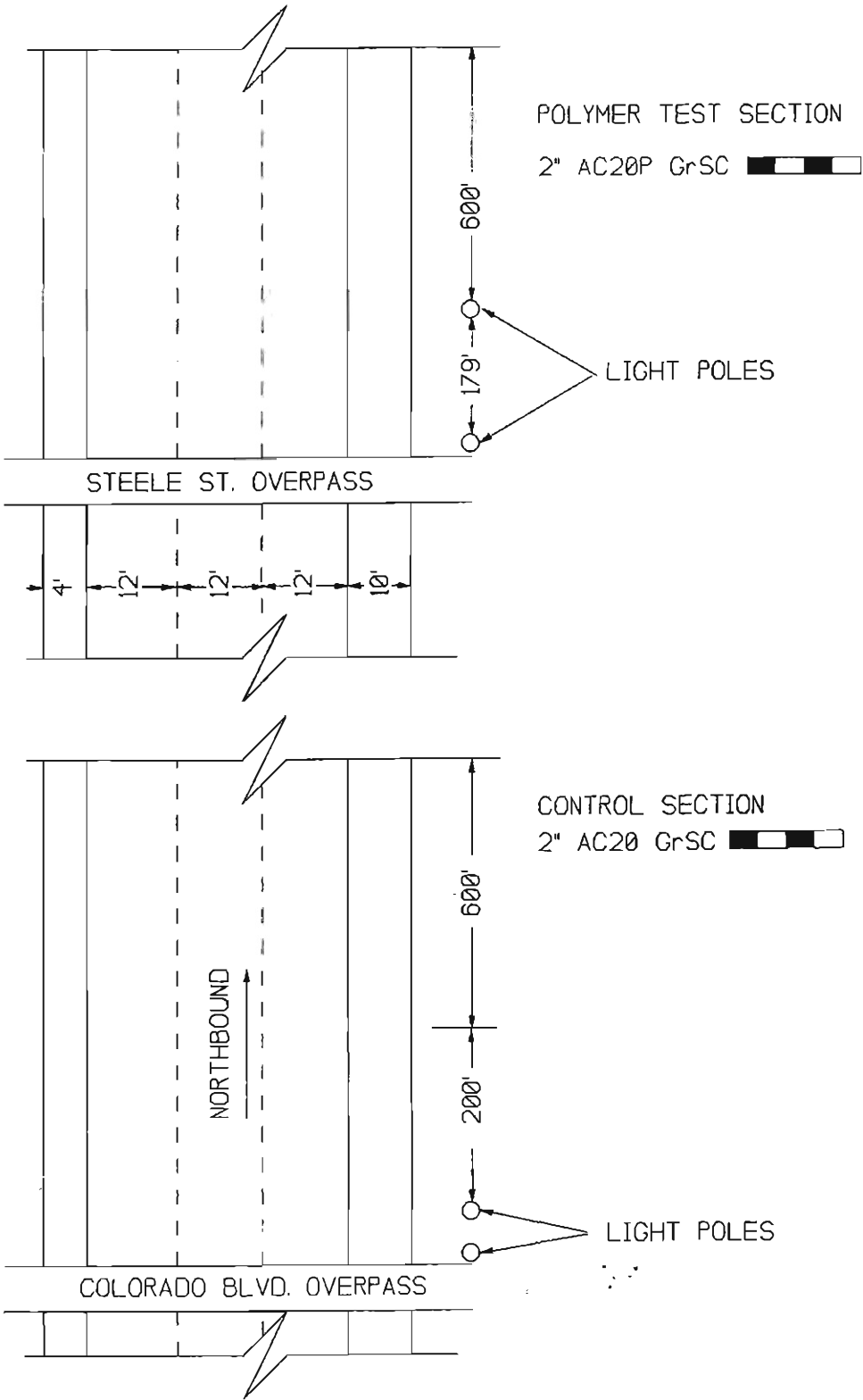
Construction on this project consisted of milling the entire width of the mainline to 6 mm (1/4") below the wheel ruts. Following milling, the roadway was overlaid with 50 mm (2") (Grading SC) of Hot Bituminous Pavement.

Because of paving restrictions (due to daytime volumes) in the Denver Metropolitan area, all the construction was done at night.

Two 183 meters (600 foot) sections were established for evaluation. The sections were established in the center lane of the three lane highway. The center lane was selected for evaluation because along this section of the I-25 corridor there are a number of entrance and exit ramps and the trucks tend to drive in the center lane.

The control section contained the non-polymerized experimental Strategic Highway Research Program (SHRP) coarse gradation (see Appendix C). The test section contained a polymerized (AASHTO Task Force 31 - Type I-D) SHRP coarse (SC) gradation pavement, which was used throughout the remainder of the project. Both evaluation sections are located in the northbound direction. Figure 6 is a site map showing the location of the evaluation sections.

Figure 6. I-25 in Denver -- Project No. CX01-0025-58



7.4 Santa Fe Drive in Littleton

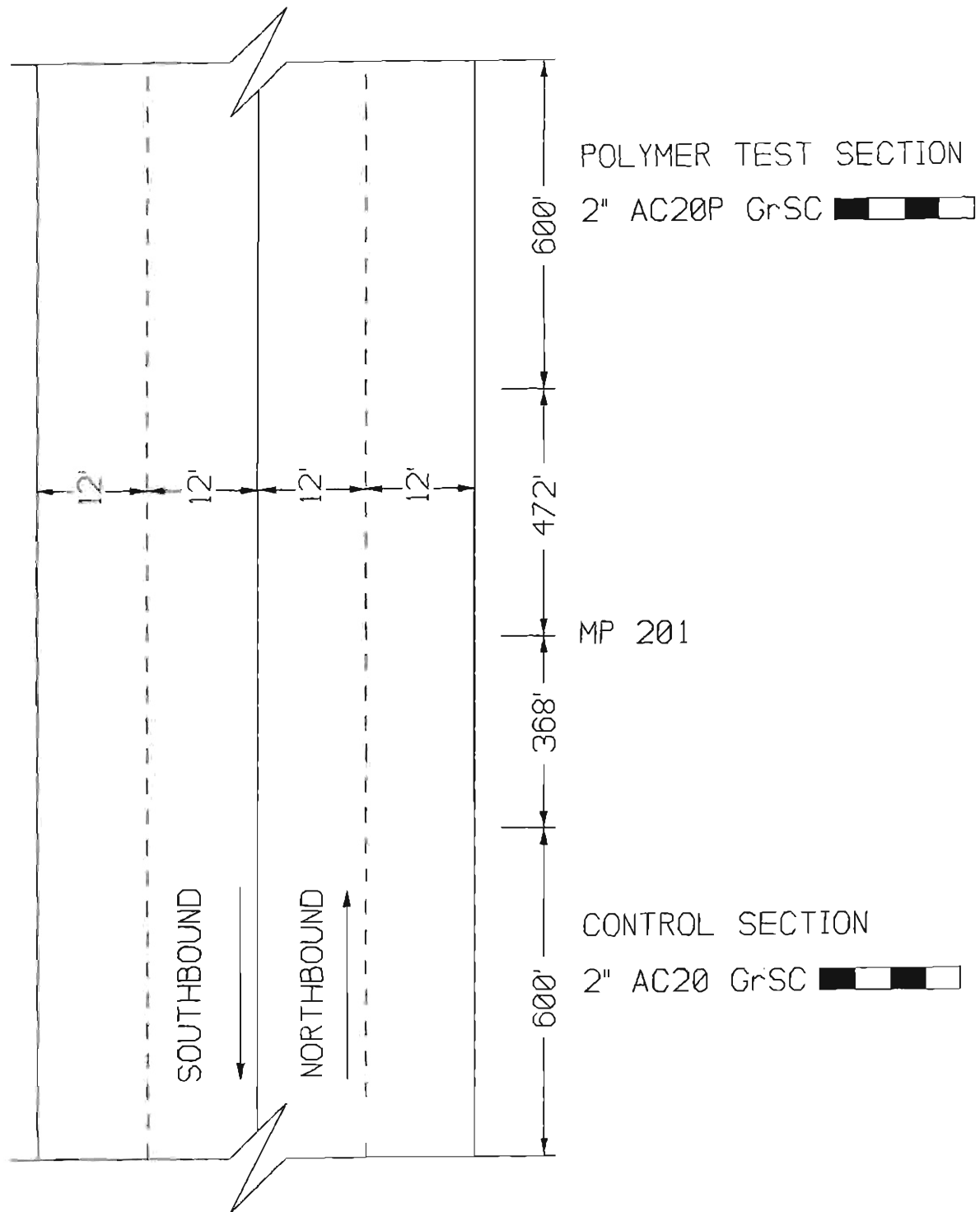
Project CX 10-0085-17 is located between MP 200 and MP 204.45 on State Highway 85 (Santa Fe Drive). The project consisted of roto-milling the existing pavement in the driving and passing lane and then placing a 50 mm (2") lift of Grading SC. The Annual Average Daily Traffic (AADT) for 1995 was 31,900 vehicles with 7% trucks. The design lane 18 kip Equivalent Single Axle Loads (ESAL) over the study period (1991 to 1996) were 871,000 ESALs.

Two 183 meter (600 foot) evaluation sections were established on this project. The control section contained the non-polymerized experimental SHRP coarse gradation (SC) (Appendix B). The test section contained a polymerized (AASHTO Task Force 31 - Type I-D) SHRP coarse gradation (SC).

Figure 7 shows the location of the evaluation sections with respect to each other and the project. The mix specifications for this project are the same as incorporated on the I-25 in Denver project. This project was also constructed by the same contractor.

Both the control and test section were established in the northbound driving lane.

Figure 7. Santa Fe Drive in Littleton -- Project No. CX 10-0085-17



7.5 Brighton Boulevard in Denver

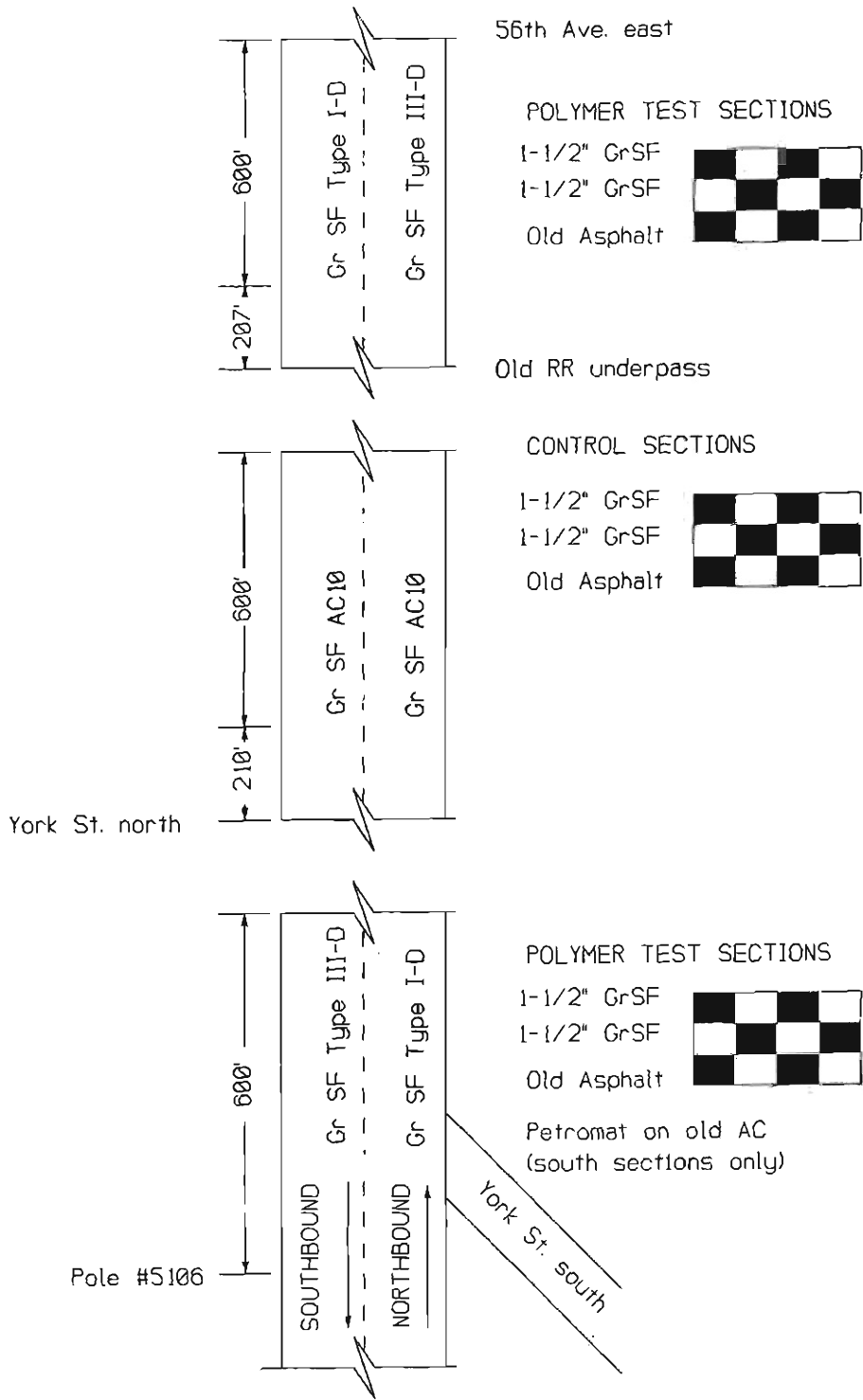
Project CX 01-0265-01 is located on Brighton Blvd (SH 265) and extends from I-70 to Sand Creek. The Annual Average Daily Traffic (AADT) for 1995 was 9050 vehicles with 10% trucks. The design lane 18 kip Equivalent Single Axle Loads (ESAL) over the study period (1991 to 1996) were 681,000 ESALs.

The project consisted of roto-milling the entire roadway to 13 mm (1/2") below the bottom of the deepest existing rut. Following the milling, two, 38 mm (1-1/2") HBP Grading SF lifts were placed.

Six evaluation sections were established at this location, three in the southbound direction and three directly opposite in the northbound direction.

Evaluation sections were constructed in three different areas (northern, middle and southern). The northern test section contained a polymerized asphalt (AASHTO Task Force 31 - Type I-D) in both lifts southbound, and a polymerized asphalt (AASHTO Task Force 31 - Type IIID) northbound in both lanes. The middle control section had AC-10 in both directions. The southern test section had a polymerized asphalt (AASHTO Task Force 31 - Type IIID) southbound, and a polymerized asphalt (AASHTO Task Force 31 - Type ID) northbound. The southern test section had geotextile (Petromat) paving fabric between the milled surface and the first lift on new pavement. The polymer was incorporated in both of the 38 mm (1-1/2") lifts in the test evaluation section. A site map of the location of the evaluation sections is shown in Figure 8.

Figure 8. Brighton Boulevard In Denver -- Project No. CX 01-0265-01



8.0 Summary of Evaluations

8.1 Rutting

At the conclusion of the study, it was determined that rutting was not a significant distress found in any of the projects. The magnitude of rutting at each location was similar for both the test and control sections. It appears that the polymer-modified asphalt used for this evaluation did not enhance the performance of the pavement with respect to rutting.

In addition, all the mixes used in this study were designed using an end point stress of 150 psi on the Texas Gyratory(3). This design creates mixes that are more rut resistant, because they have a low percentage of asphalt cement, and are typically used on high volume facilities that are more prone to rutting.

8.2 Voids

Cores were taken in the fall of each year during the study period to determine in-place voids. Over the four year evaluation period the in-place voids did not change significantly in any of the evaluation sections. The in-place voids over the duration of this study did not change more than 1%. Without a reduction of in-place voids, rutting was not evident. This explains why rutting was not significant and was independent of the polymer.

8.3 Cracking

Cracking data indicated that the polymers enhanced the overall performance of the pavement. Graphs showing the cracking at the five locations evaluated under this study can be found at the end of this section.

Cracking at all the locations prior to construction was extensive. Alligator and block cracking were found throughout the evaluation sections.

Cracking found in the test sections at the conclusion of the study was compared to the cracking found in the control sections at the conclusion of the study. Generally, cracking was found to be

less in the test sections as compared to the control sections. In most cases the cracking was at least 50% less in the test section as compared to the control section. This was true for both longitudinal and transverse cracking.

The rehabilitation techniques used on these projects such as roto-milling and heater scarifying were not intended to provide crack reduction treatment. Therefore reduction in cracking is not attributed to these various rehabilitation techniques. All sections that were compared were rehabilitated using the same technique.

8.3.1 I-70 near Flagler

The polymer (AASHTO Task Force - Type I-D) section had a minor reduction in cracking at the conclusion of the study as compared to the other two sections. However at each evaluation section the thickness of the new section was at least 5 inches. An informal evaluation at this location should continue to allow for reflective cracking to propagate to the surface of the five inches before a conclusion is drawn (Figure 9).

8.3.2 I-25 near Pueblo

At the conclusion of the evaluation period, the test section containing the polymer (AASHTO Task Force 31 - Type I-B) had about 2/3 less transverse cracking than was found in the rubber test (AASHTO Task Force 31 - Type II-B) section and about 3/4 less than what was found in the control section (Figure 10).

The longitudinal cracking found in the polymer (Type I-B) and rubber (Type II-B) test sections was almost twice as much as that found in the control section (Figure 10). However, after visually inspecting the evaluation sections, it was noted that the longitudinal cracking in the polymer (Type I-B) and rubber (Type II-B) test sections was attributed to the longitudinal joints made during construction. When this longitudinal cracking was eliminated from the evaluation cracking in the polymer test section, the polymer section had approximately 1/3 less cracking than that found in the control section. Longitudinal cracking in the rubber test section was about equal to the control section when the longitudinal cracking attributed to construction was removed (Figure 11).

Figure 9.

CRACKING

I 70 near Flagler

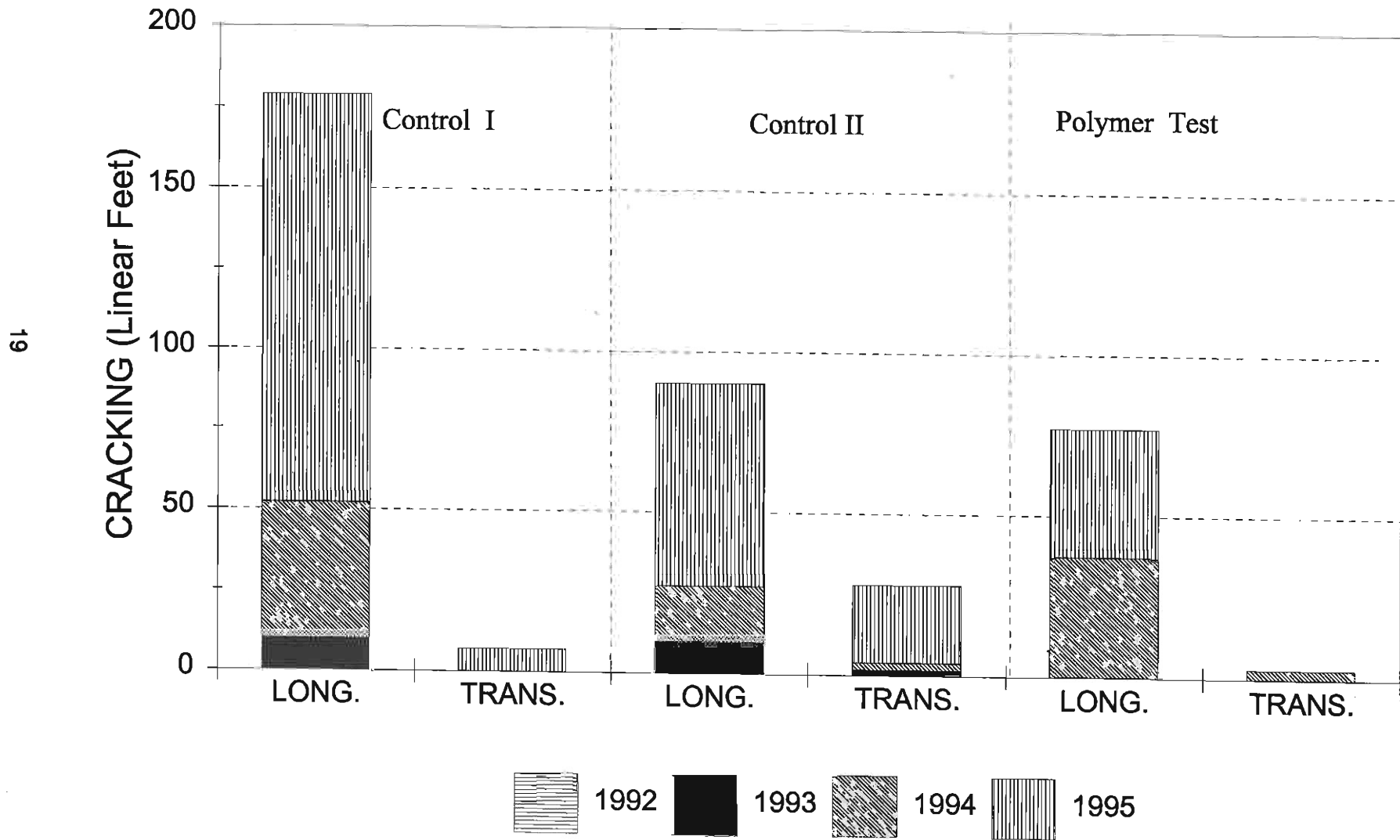
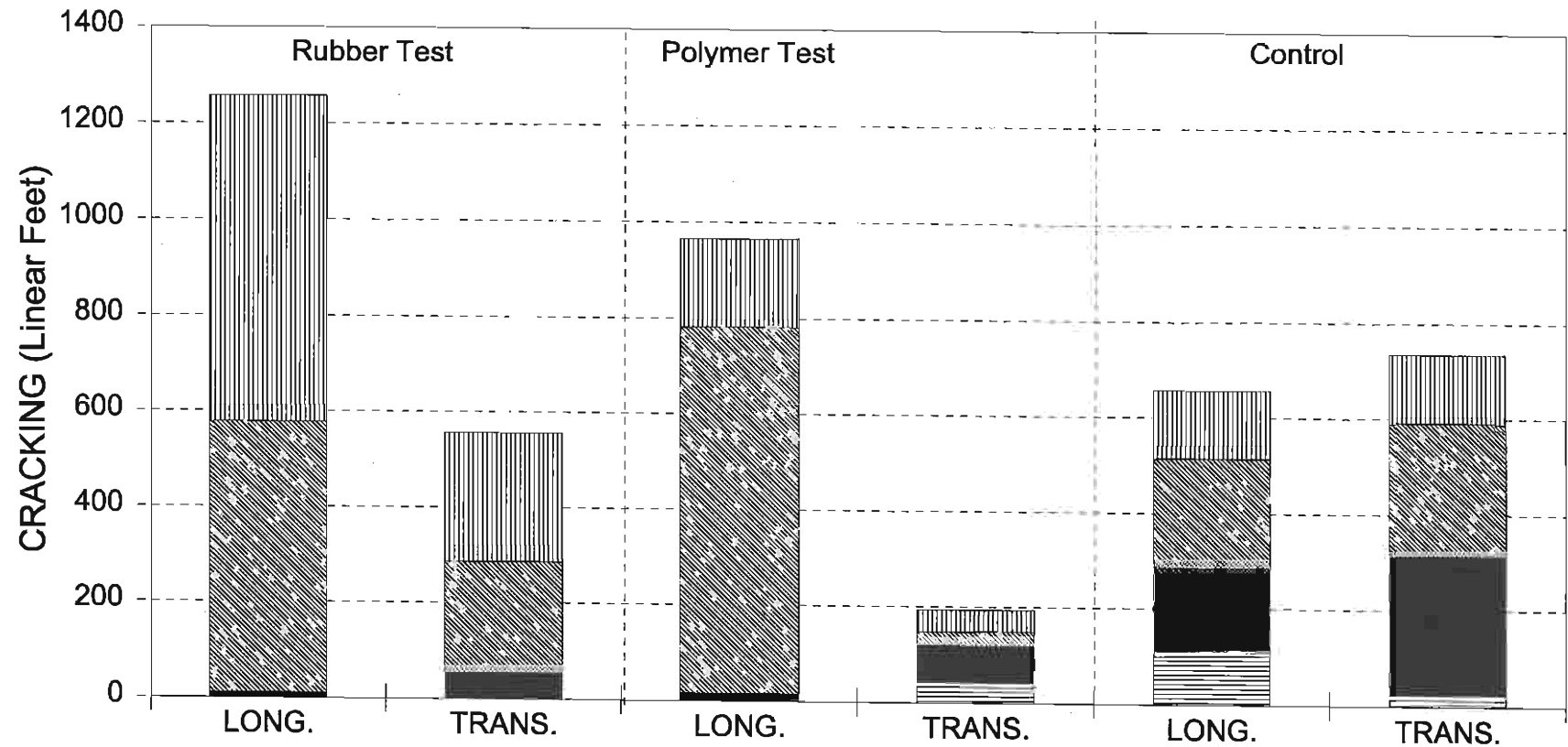


Figure 10.
CRACKING
I 25 near Pueblo



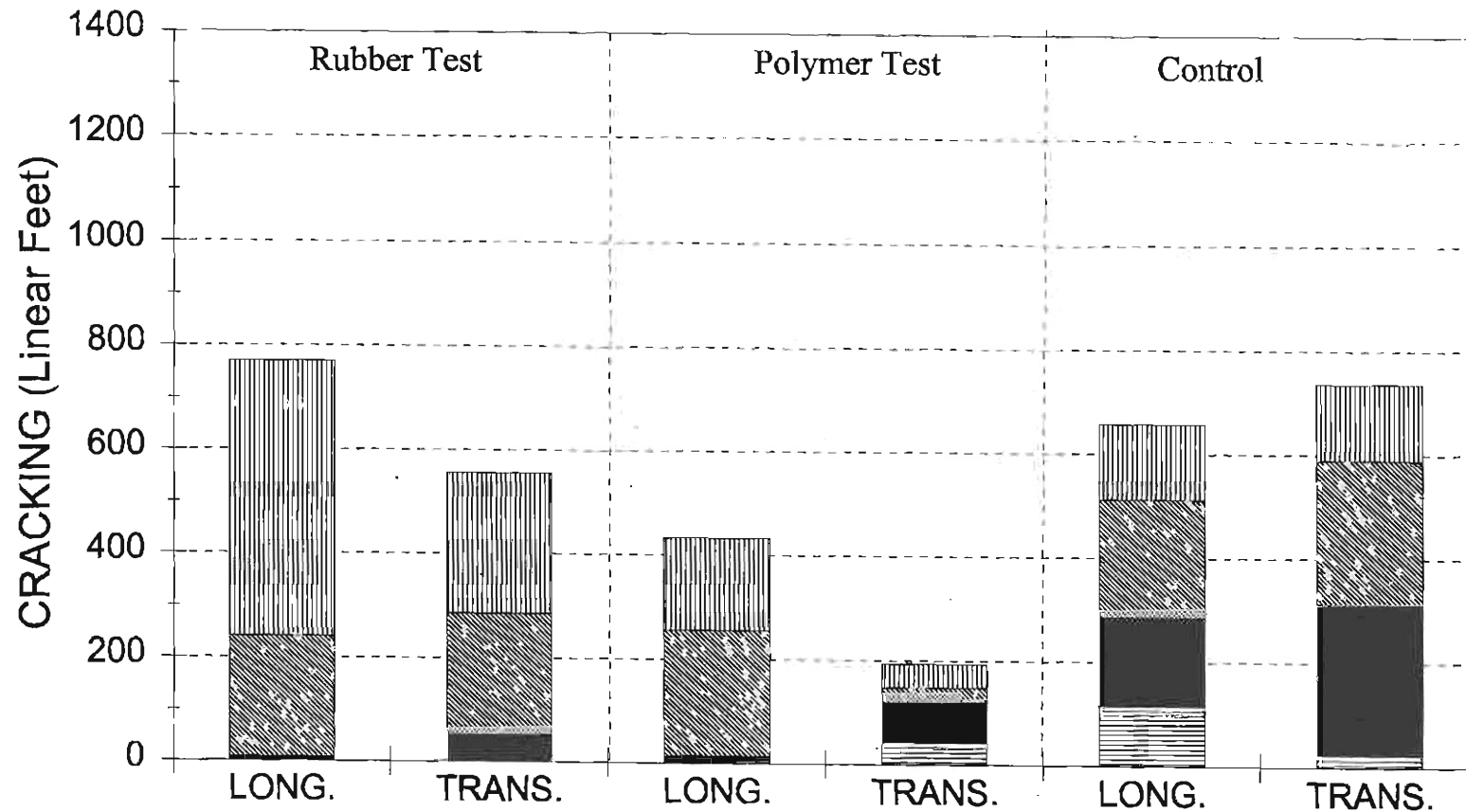
NOTE: BEFORE CONSTRUCTION ALL SECTIONS WERE EXTENSIVELY BLOCK AND ALLIGATOR CRACKED IN THE WHEEL PATHS. LONGITUDINAL CRACKING IN THE RUBBER & POLYMER SECTIONS CAN BE ATTRIBUTED TO THE LONGITUDINAL JOINTS MADE DURING CONSTRUCTION.



Figure 11.

CRACKING

I 25 near Pueblo (revised)



NOTE: BEFORE CONSTRUCTION ALL SECTIONS WERE EXTENSIVELY BLOCK AND ALLIGATOR CRACKED IN THE WHEEL PATHS. LONGITUDINAL CRACKING IN THE RUBBER & POLYMER SECTIONS THAT WAS ATTRIBUTED TO THE LONGITUDINAL JOINTS MADE DURING CONSTRUCTION ARE NOT SHOWN ON THIS GRAPH.



8.3.3 I-25 in Denver and Santa Fe Drive in Littleton

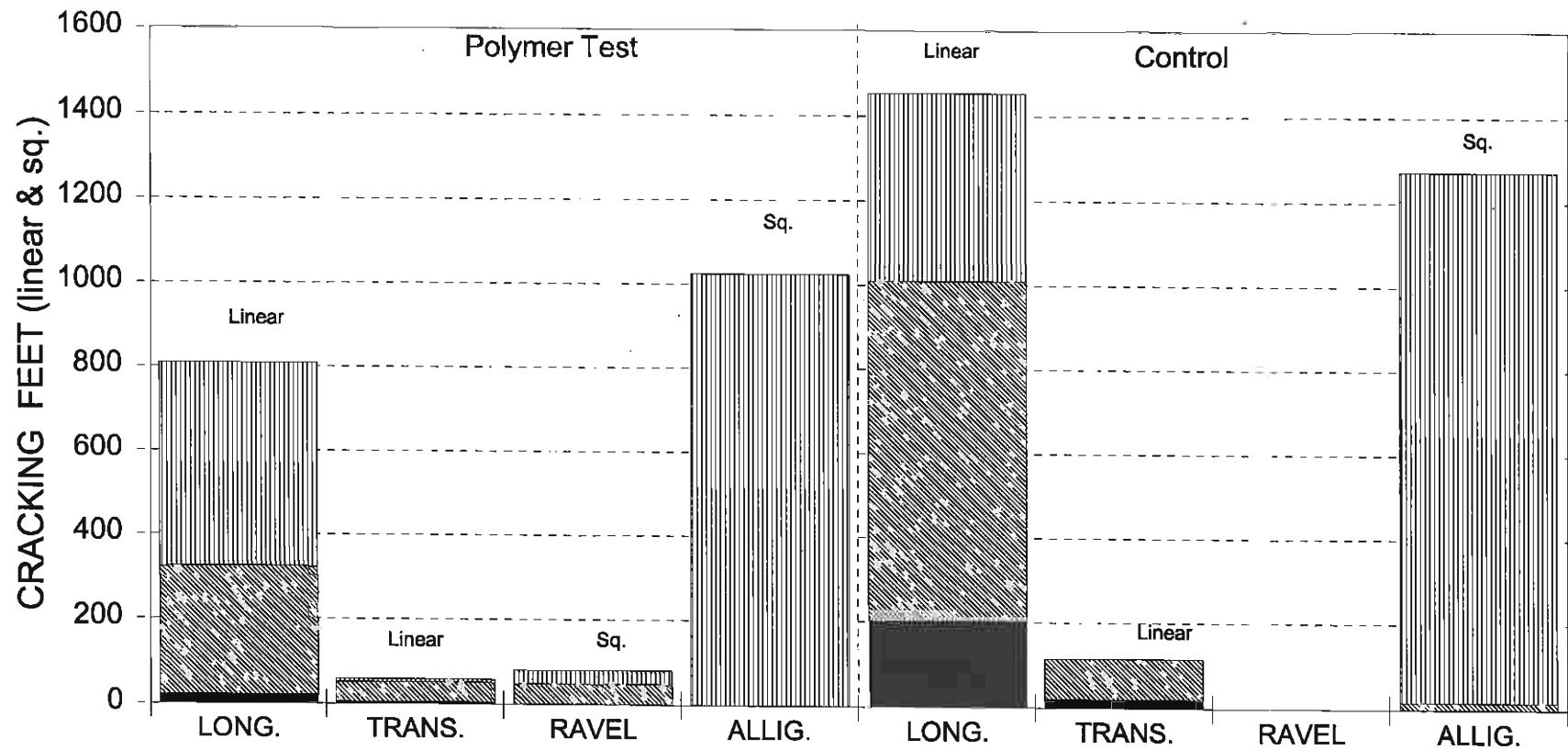
Prior to the conclusion of this study the I-25, Colorado Blvd project and the project located on Santa Fe Drive in Littleton were roto-milled and overlaid due to premature pavement failure. The failure mechanism was unrelated to the polymer and was attributed to the low asphalt content as recommended in the mix design used on these projects.

At the conclusion of the evaluation on the I-25 project, cracking in the polymer test section was approximately 1/3 less than the control section (Figure 12).

At the conclusion of the evaluation on the Santa Fe Drive, project the effects of the addition of the polymer was inconclusive. As stated previously the premature pavement failure can not be attributed to the polymer (Figure 13).

Figures 14, 15, and 16 show the extent of the cracking found on I-25 in Denver, and on Santa Fe Drive in Littleton, which required removal of existing wearing surface and a new overlay prior to the conclusion of this study.

Figure 12.
CRACKING
I 25 in Denver



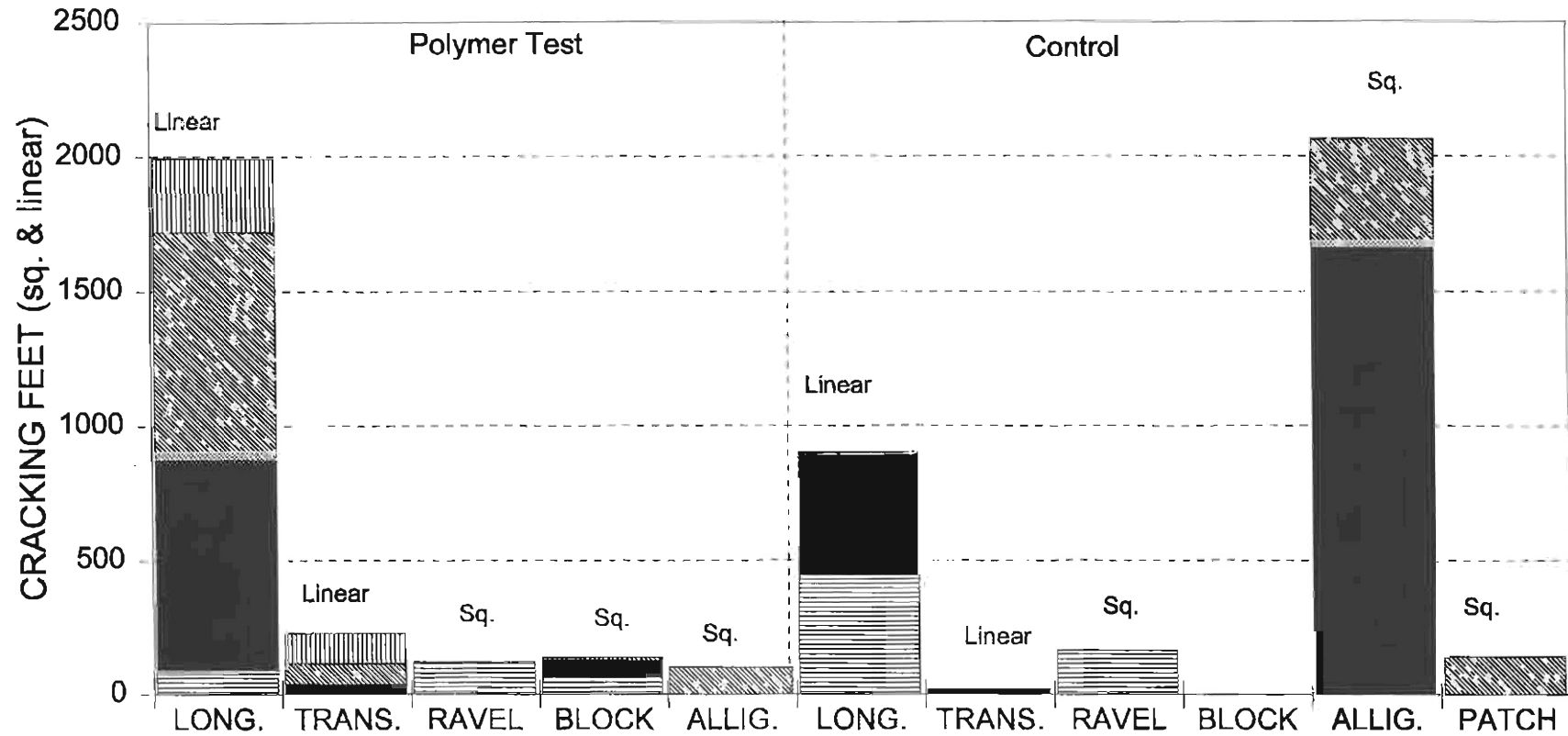
NOTE: BEFORE CONSTRUCTION ALL SECTIONS WERE EXTENSIVELY BLOCK AND ALLIGATOR CRACKED IN THE WHEEL PATHS



Figure 13.

CRACKING

Santa Fe Drive in Littleton



NOTE: BEFORE CONSTRUCTION BOTH SECTIONS WERE EXTENSIVELY BLOCK AND ALLIGATOR





Figure 14. This photograph shows the extent of cracking found on the I-25 in Denver prior to rehabilitation.



Figure 15. Close up of section shown in Figure 14.



Figure 16. This photograph shows the extent of cracking found on the Santa Fe Drive in Littleton project prior to rehabilitation.

8.3.4 Brighton Boulevard in Denver

The effectiveness of the polymers is shown in Figure 17. This photograph was taken one year after construction. It shows the appearance of a transverse reflective cracking in the polymer (AASHTO Task Force 31 - Type III-D) section on the northern end of the project. Directly opposite the polymer (AASHTO Task Force 31 - Type III-D) section the polymer (AASHTO Task Force 31 - Type I-D) was placed in the southbound direction. The transverse crack had not reflected through the polymer (AASHTO Task Force 31 - Type I-D) section. At the conclusion of this study (4 years later), transverse cracks that appeared early in the evaluation were just beginning to propagate into the polymer (AASHTO Task Force 31 - Type ID) section. The Type I-D out performed the Type III-D in regards to the amount of transverse cracking after a 4 year evaluation.

In the southern sections on the Brighton Blvd, project a paving fabric was placed between the rotc-milled surface and the first lift of HBP. At the conclusion of the study, the section containing the fabric demonstrated significantly less longitudinal cracking than the comparable northern section, which did not contain paving fabric. The reduction in cracking (over the 4 years) can be attributed to the fabric (Figure 18).

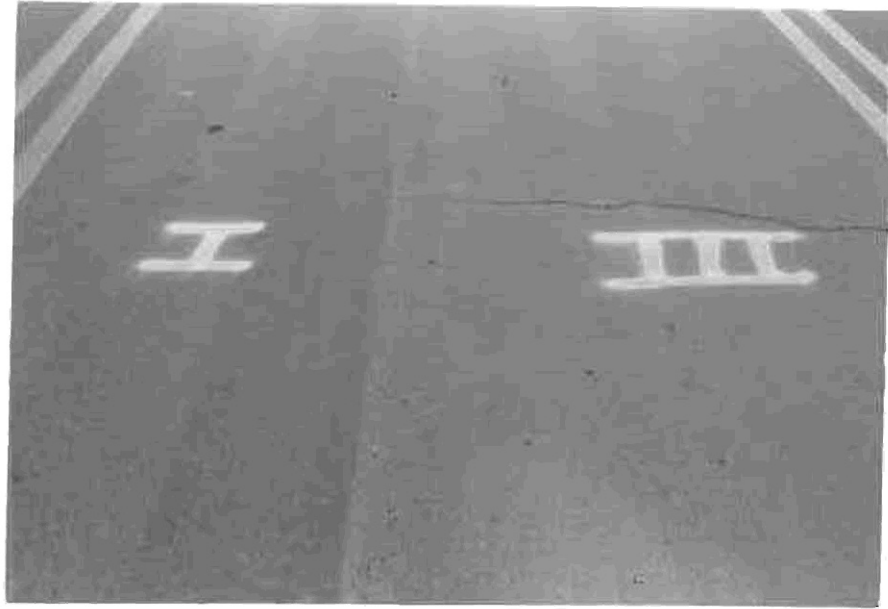
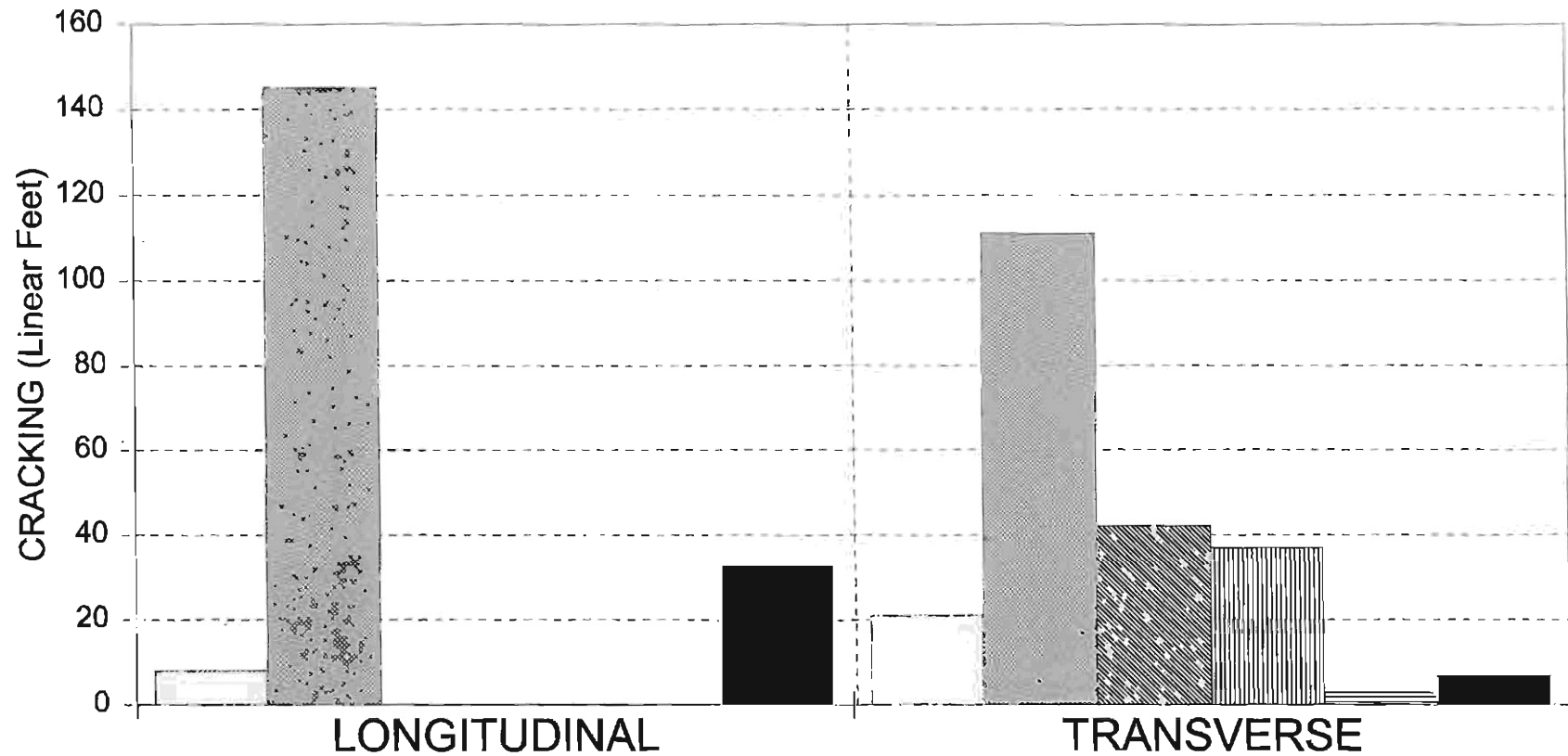


Figure 17. Reflective transverse cracking found in the northern section of this project. Notice the crack stops at the paving joint between the Type III-D and Type II-D section.

Figure 18.

CRACKING

Brighton Boulevard in Denver



NOTE: BEFORE CONSTRUCTION ALL SECTIONS WERE EXTENSIVELY BLOCK AND ALLIGATOR CRACKED
CRACKING SHOWN ON GRAPH IS VALUES AT THE CONCLUSION OF EVALUATION AFTER 4 YEARS



8.4 Deflection

Deflection measurements were taken with the Dynaflect equipment. The measurements were taken each year in both the test and control sections. The purpose of these measurements was not to determine if the addition of the polymer increased the structural characteristic of the pavement structure, but were taken to be used if the pavement began to show distress which could be related to structural failure. However the pavement did not fail structurally and the deflection measurements were not a factor.

9.0 Conclusions

Results from this study indicate that cracking is reduced when polymer-modified asphalts are used. However this study did not make clear when a polymer is needed or whether it was always cost-effective. With the introduction of SHRP performance graded asphalt binders, CDOT will be able to better evaluate the effects of both temperature and traffic and how they relate to the performance gradings.

The addition of various polymers used in this study did not enhance the rut resistance potential of the mix, however the addition of the polymer did reduce the amount of transverse and longitudinal cracking to some extent.

Performance was not the only issue identified by this study.

Contractors were concerned that the higher mixing temperatures required for mixing would cause emissions problem; however, the projects evaluated under this study did not experience any "blue smoke" during the operation of the plants.

Contractors interviewed during construction indicated that there was not any significant difference in working with the polymerized mix as compared to the standard mix, in fact, several contractors felt that the higher mixing and compacting temperatures improved the workability.

No major construction problems related to the polymers were noted on any of the projects.

Standard CDOT specifications require the use of pneumatic rollers; however, since CDOT began using polymerized ACs the use of pneumatic rollers has been discontinued. Pneumatic tire rollers tend to pick up the mat. Figure 19 illustrates an extreme case of the rubber tire roller picking up the mat.

The polymer-modified asphalt mixes used in this study averaged 6 dollars higher per ton than CDOT's standard non-polymerized asphalt mixes.



Figure 19. Pneumatic tire rollers tend to pick up the mat. This photo shows an extreme case.

10.0 Future Evaluations

Through the addition of polymers in asphalt cement, the Colorado Department of Transportation has developed a high confidence in the ability of polymer modified asphalt cements to reduce cracking. However, it was not always known to what extent the polymers were helping a particular asphalt cement or whether or not the addition of the polymer was cost-effective. This has made it very difficult to determine prior to construction whether the polymer-modified asphalt cement will improve the performance of a particular pavement.

Since the initiation of this study the SHRP program introduced performance graded (PG) asphalt binder specifications.

Through the development of performance graded asphalt binders, testing equipment was also developed. The equipment that was developed through the SHRP program included: The Rolling Thin Film Oven (RTFO) and the Pressure Aging Vessel (PVA) which simulates binder aging (hardening) characteristics; the Dynamic Shear Rheometer (DSR) which measures binder properties at high and intermediate temperatures; the Rotational Viscometer (RV) which measures the binder properties at high temperatures and the Bending Beam Rheometer (BBR) and the Direct Tension Tester (DTT) which measures binder properties at low temperatures. This equipment together simulates the field performance of the Superpave performance graded asphalt binder. CDOT has acquired most of the Superpave binder equipment.

The performance graded asphalt binder specifications were developed to allow the designer to select the appropriate asphalt binder for a given project based on environmental criteria (temperature differentials) and traffic considerations. CDOT is in the process of implementing PG asphalt and the SHRP performance graded criteria will replace the current practice of specifying polymer modified asphalt cements in viscosity graded ACs.

The polymer modified asphalt binders used in this study have been compared to the Superpave performance graded asphalt binder. Table 2 shows the correlation between the binders used in this study and the corresponding SHRP Performance Grading.

Table 2. Current CDOT Asphalt Binders and the Corresponding SHRP Performance Grading

Location	Asphalt Cement Binder Used	Corresponding SHRP Grading	% Rutting Reliability	% Cracking Reliability
I-70; near Flagler	AC20 Conoco Denver	PG 64 -22	98	> 50
	AC20P ELF Pueblo	PG 70 -28	98	60
I-25; near Pueblo	AC20 Diamond Shamrock	PG 58 -16	67	> 50
	AC20R ELF Pueblo	PG 64 -28	98	67
	AC20P ELF Pueblo	PG 70 -28	98	67
I-25; in Denver	AC20 Conoco	PG 64 -22	98	60
	AC20P ELF Pueblo	PG 70 -28	98	96
Santa Fe Drive; in Littleton	AC20 Conoco	PG 64 -22	98	60
	AC20P ELF Pueblo	PG 70 -28	98	96
Brighton Boulevard; in Denver	AC10 Conoco Denver	PG 58 -22	98	60
	AC20P Type III-D ELF Pueblo	PG 70 -28	98	?
	AC20P Type I-D ELF Pueblo	PG 70 -28	98	96
Brighton Boulevard	AC10 Conoco Denver	PG 58 -22	98	60

Performance graded asphalt binders will be specified on approximately 75% of projects awarded in 1997.

With the implementation of SHRP, the Colorado Department of Transportation will have the ability to better predict the performance of an asphalt binder. The Colorado Department of Transportation has begun to adopt the SHRP technology. The majority of the projects constructed in 1997 will specify SHRP performance graded binder. These binders may include polymer modified asphalts, however, modified binders will not be specified based on AASHTO Task Force 31 requirements.

Several projects containing the performance graded asphalt binders have already been constructed. These projects are currently being evaluated. A number of projects will be constructed in the future containing both the performance graded asphalt binders and Superpave Level I mix design. These projects will enable the department to fine tune the SHRP specifications to fit Colorado's needs.

Future research considerations which need to be addressed include:

- What is the effectiveness (both cost and performance) of specifying different performance gradings in the different lifts of a given project?
- What effects do the higher mixing temperature required when using polymers have on obtaining the required field compaction?
- What are the effects of the high temperature and low temperature of the performance graded asphalt binders on the performance of the pavement?
- What are the effects of the performance graded asphalt binders on the emissions compliance requirements?

11.0 References

1. Harmelink, D.S. (1992), "Special Polymer Modified Asphalt Cement," Colorado Department of Transportation, CDOT-DTD-R-92-5, 52 pages.
2. Federal Highway Administration, (October 1994), Long Term Pavement Performance, Specific Pavement Studies, Colorado SPS-5, Construction Report on SHRP 080500, Colorado Department of Transportation, Draft, Western Region Contractor, Nichols Consulting Engineers, Chtd.,
3. Aschenbrener, T. (December 1993), "Determining Optimum Asphalt Content with the Texas Gyratory Compactor," Colorado Department of Transportation, CDOT-DTD-R-93-23, 78 pages.

Appendix A
Guide Specifications Polymer Modified Asphalt AASHTO Task Force 31

AASHTO-AGC-ARTBA Joint Committee

Subcommittee On New Highway Materials

Task Force 31 Report

GUIDE SPECIFICATIONS POLYMER MODIFIED ASPHALT



TASK FORCE 31

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AASHTO-AGC-ARTBA JOINT COMMITTEE PROPOSED SPECIFICATIONS FOR POLYMER MODIFIED ASPHALT

INTRODUCTION

The American Association of State Highway and Transportation Officials, the Associated General Contractors, and the American Road and Transportation Builders Association formed a working relationship called the AASHTO-AGC-ARTBA Joint Committee whose functions according to the by-laws are:

- A. To promote harmonious relations between state highway and transportation officials and highway contractors that are in the public interest;
- B. To discuss jointly those matters which relate to or affect the actual construction of highways. To this end the Joint Committee shall be responsible for considering any matters of general interest and application that affect both contractors and state highway officials; and
- C. To promote an increased scope of joint cooperative activities between state highway departments and highway contractors at the state level.

The Subcommittee on New Highway Materials under the auspices of the AASHTO-ARTBA-AGC Joint Committee authorized the formation of a task force to develop generic guide specifications for polymer modified asphalts. Task Force No. 31 - Polymer Modified Asphalts was formed as a result. Members of the Task Force were selected from industry, user-agencies and academic interests in an attempt to tap resources of as much technical expertise regarding polymer modified asphalts as possible. In this sense, the resulting guide specification represents a consensus of those involved with pavement construction utilizing these types of modified asphalt products.

Work by the task force to develop a generic, performance-based specification for polymer modified asphalts has resulted in three descriptive specifications for polymer modified asphalts. Although these specifications are not performance

oriented in a mechanistic sense, materials which could meet these specifications are being used in the construction of asphalt concrete pavements, and therefore, have an empirical connection with field performance.

Each of the materials described are generic in the sense that requirements for a specific polymer, its quantity and its method of manufacture are not included in the specification. A wide variety of materials, material quantities and methods of manufacture can be used to meet these specifications.

It is the hope of the Task Force that the polymer modified asphalt guide specifications provided will aid user agencies in the development of their specifications for polymer modified asphalts.

SPECIFICATION DEVELOPMENT

There are hundreds of potential polymers which can be used to modify asphalt cement properties. The specification described herein has been developed to describe the characteristics of certain specific types of polymer modified asphalt (PMA) which have been used successfully in practice, to date. The list of potential polymer modified asphalts was limited to include:

- those used in practice with success on at least a semi-routine basis and,
- those for which specifications had been written which describe properties of the resulting modified binder in common terms which could be verified by users.

The result of this work is a guide specification describing three types of polymer modified asphalts each based on different types of commonly used polymers. Therefore, this specification is not a performance-based document in the sense that fundamental material properties are described which might be satisfied by any type or combination of materials. Instead, the specification describes materials for which satisfactory performance has been documented. It is the hope of the task force that this information will be used as a guide for agencies wishing to use polymer modified asphalts. A more desirable, generic specification will only be possible as

additional field experience is gained by practitioners or as truly fundamental material properties emerge from ongoing research in asphalt technology, for example the Strategic Highway Research Program (SHRP).

Each of the three types of polymer modified asphalts are specified differently due to the various types of polymers which could be used for modification. Therefore, the guide specifications do not necessarily have common tests or test requirements. At first, these differences make the specification seem less objective, by describing specific types of products. However, one premise of the guide specification that various polymers may provide beneficial asphalt behavior by different mechanisms. Therefore, setting the same tolerances in a given empirical test for each type of polymer modified binder did not seem rational. Until additional data is collected for the various modified systems which can be correlated to field performance, a truly performance oriented specification will not be possible. This information is being collected in the SHRP program, and when the specifications from SHRP are generated they should be incorporated into this guide specification, as well. The guide specification is designed for such modification.

The properties of the binders have been described, in most cases, by conventional ASTM or AASHTO test procedures, or by procedures that are currently being evaluated by these organizations for standardization. It is realized that more sophisticated evaluation procedures could, and in the future should, be used to describe properties of polymer modified binders. However, much of the equipment necessary to conduct more fundamental evaluations is not readily available to user agencies and perhaps, more importantly, have not been developed fully in a theoretical sense so that limiting criteria could be applied in a practical specification.

The specifications include several grades of polymer modified asphalt within each type. This grading is an attempt to describe polymer modified binders which might be usable in different climates. A significant amount of work by the West Coast User-Producer Group has been done to develop a performance-based asphalt specification for differing climatic conditions. The activities of this group have been observed closely with respect to specifying for specific purposes and climates, in fact some of the materials described herein agree closely with certain materials described in the sixth version of the West Coast User-Producer PBA specifications.

There has been an attempt to control or limit several types of pavement behavior in the specification. These parameters and a description of how controls are imposed are as follows:

- Low temperature cracking
- Permanent deformation
- Binder homogeneity
- Safety
- Fatigue cracking
- Aging
- Purity
- Workability

Low Temperature Cracking/Fatigue Cracking

Low temperature properties of the polymer modified binders are controlled by either penetration or ductility at 39.2F (4C) depending on the type of binder specified. For example, Types I and III use penetration and Type II, ductility. Because some evidence suggests that low temperature penetration may also correlate to fatigue properties, this requirement may also help limit fatigue cracking in some asphalt mixtures.

Permanent Deformation

An attempt has been made to provide higher binder stiffness and/or increased elasticity at elevated temperatures. These characteristics are addressed by including ring and ball softening point for materials described in Types I and III, and including an elastic recovery requirement for Type I. Presently, high temperature properties for Type II materials are controlled indirectly by limiting temperature susceptibility through penetration and viscosity tests and by specifying a lower limit on toughness. To date, these empirical methods appear to be suitable for most polymer modified materials.

Aging

All materials have requirements for retention of certain consistency parameters after artificial aging. The rolling thin film (RTFO) and thin film oven (TFO) tests

are used to produce aged binders. After conditioning by either of these methods each binder has a required minimum retained consistency or elastic component. It is recognized that RTFO and TFO aging may not be ideal methods for producing realistic aging of asphalt binders. In fact, for some modified binders, where "skinning" of the surface can occur, artificially low indications of aging can occur. Also, some polymer modified binders exhibit Weissenberg properties in which the material has been observed to "flow uphill" in response to the shearing action as the fluid rotates in the RTFO bottles.

Homogeneity

Polymer modified asphalts are generally multiple-phase systems in which the polymers are dispersed in the asphalt liquid phase. Many of these systems require a certain amount of incompatibility between the phases for the polymers to provide any benefit. However, excessive incompatibility is not desirable for proper storage and handling. Therefore, all of the systems have requirements for limiting separation of the asphalt-polymer blend either by separation tests or by ductility after aging in the rolling thin film oven.

Actual limits are reported when sufficient data exist to support such criteria. However, a separation test for one material may not be appropriate for other materials. Therefore, for example, Type I has a suggested procedure and criteria, while Type II does not. This is not an indication that Type II does not have a tendency for incompatibility, just that the state-of-the-art has not been well developed for measuring incompatibility of this material.

Safety

Safety aspects of the polymer modified asphalts are addressed by minimum requirements on Cleveland Open Cup Flash Point. In most cases the lower limit is well below temperatures used in the field.

Purity

Type I and II materials include a minimum requirement for solubility of the original asphalt cement. This requirement is provided to ensure the polymer modified asphalt is not contaminated with mineral fines or fillers. The requirement is not placed on the blended polymer modified asphalt because certain types of polymer modified asphalts do not dissolve readily in conventional solvents presently used in the paving industry. No data is available, to date, which indicates if a single solvent will ever be available for performing solubility on the multitude of possible asphalt polymer blends.

Workability

Ideally, construction of asphalt concrete pavements with polymer modified asphalts should not require unusual procedures in any stage of the construction process. However, because many polymer modified binders can be formulated to produce extremely high stiffnesses, a limit has been placed on the high temperature viscosity for each material. This limit is based on pumpability of the material, and it is believed that the highest limit, 2000 centistokes at 275F (135C) for the I-C material can be handled effectively by conventional pumps used today.

PROPOSED GUIDE SPECIFICATIONS

A description of each of the polymer modified asphalts follows with a brief description of the origin of the specification and suggested purposes for each grade of polymer modified asphalt.

Type I Polymer Modified Asphalt

Description:

Type I Polymer Modified Asphalt is based on properties of conventional asphalt cements after modification with styrene block copolymers. Most styrene block copolymer modified asphalts which meet this specification have butadiene midblocks and could be diblock or triblock, ie SB or SBS, configurations.

		I-A	I-B	I-C	I-D
Penetration, 77F, 100g, 5sec	Min	100	75	50	40
	Max	150	100	75	75
Penetration, 39.2, 200g, 60sec	Min	40	30	25	25
Viscosity, 140F, P	Min	1000	2500	5000	5000
Viscosity, 275F, cSt	Max	2000	2000	2000	2000
Softening Point, R & B, F	Min	110	120	130	140
Flash Point, F	Min	425	425	450	450
Solubility in TCE, %*	Min	99.0	99.0	99.0	99.0
Separation**, R & B difference, F	Max	4	4	4	4
RTFOT Residue					
Elastic Recovery***, 77F, %	Min	45	45	45	50
Penetration, 39.2F, 200g, 60s	Min	20	15	13	13

* Solubility of original asphalt by ASTM D2042.

** Method described in Appendix A

*** Method described in Appendix B

Uses:

Type I-A

Binder for use in hot mix asphalt concrete in cold service conditions and in hot applied surface treatment applications and crack filling.

Type I-B

All purpose grade intended for dense or open graded asphalt concrete and hot applied sealing applications in moderate to hot climates.

Type I-C

All purpose grade intended for dense or open graded asphalt concrete and hot applied sealing applications in hotter climates than I-B.

Type I-D

Hot climate applications where asphalt concrete is to be used in high volume traffic areas carrying large percentages of trucks.

Type II Polymer Modified Asphalt**Description:**

Type II Polymer Modified Asphalt is based on properties of conventional asphalt cements after modification with styrene butadiene rubber latex (SBR) or neoprene latex.

		II-A	II-B	II-C
Penetration, 77F, 100g, 5sec	Min	100	70	80
Viscosity, 140F, P	Min	800	1600	1600
Viscosity, 275F, cSt	Max	2000	2000	2000
Ductility, 39.2, 5 cpm, cm	Min	50	50	25
Flash Point, F	Min	450	450	450
Solubility*, %	Min	99	99	99
Toughness, 77F, 20 ipm, in-lbs	Min	75	110	110
Tenacity, 77F, 20 ipm, in-lbs	Min	50	75	75
RTFOT or TFOT Residue				
Viscosity, 140F, P	Max	4000	8000	8000
Ductility, 39.2, 5 cpm, cm	Min	25	25	8
Toughness, 77F, 20 ipm, in-lbs	Min			110
Tenacity, 77F, 20 ipm, in-lbs	Min			75

* Solubility of original asphalt by ASTM D2042.

Uses:**Type II-A**

Binder for use in hot mix asphalt concrete in cold service conditions and in hot applied surface treatment applications and crack filling.

Types II-B and C

All purpose grade intended for dense or open graded asphalt concrete and hot applied sealing applications in hot climates.

Type III Polymer Modified Asphalt

Description:

Type III Polymer Modified Asphalt is based on properties of conventional asphalt cements after modification with ethylene vinyl acetate or polyethylene.

		III-A	III-B	III-C	III-D	III-E
Penetration, 77F, 100g, 5sec	Min	30	30	30	30	30
	Max	130	130	130	130	130
Penetration, 39.2, 200g, 60sec	Min	48	35	26	18	12
	Max	150	150	150	150	150
Viscosity, 275F, cSt	Min	150	150	150	150	150
	Max	1500	1500	1500	1500	1500
Softening Point, R & B, F	Min	125	130	135	140	145
	Max					
Flash Point, F	Min	425	425	425	425	425
Separation*		Homog	Homog	Homog	Homog	Homog
RTFOT Residue						
Loss, %	Max	1.0	1.0	1.0	1.0	1.0
	Min					
Penetration, 39.2, 200g, 60sec	Min	24	18	13	9	6

* Method described in Appendix C

The Type III asphalts are distinguished by differences in consistency at 39.2F (4C) using the penetration test and at high temperatures using the softening point test. As one moves from left to right in the table, as with the other asphalts, the materials become progressively harder, or stiffer. The philosophy of Type III PMA is to require the softening point be 40F higher than the normal daily maximum air temperature during the hottest month of service. Low temperature penetration is set based on normal daily minimum air temperatures during the coldest month.

APPENDIX A

SEPARATION TEST FOR TYPE I POLYMER MODIFIED ASPHALT

SEPARATION TEST FOR TYPE I POLYMER MODIFIED ASPHALT

II.0 Scope

1.1 The separation of polymer from asphalt during hot storage is evaluated by comparing the ring and ball softening point of the top and bottom samples taken from a conditioned sealed tube of polymer modified asphalt. The conditioning consists of placing a sealed tube of polymer modified asphalt in a vertical position in a 325F oven for a 48 hour period.

2.0 Referenced Documents

- 2.1 ASTM D36: Softening Point of Bitumen (Ring and Ball Apparatus).
- ASTM E11: Specifications for Wire Cloth Sieves for Testing Purposes

3.0 Apparatus

- 3.1 Aluminum Tubes¹ - 1 inch diameter by 5-1/2 inch length blind aluminum tubes. Used to hold the test sample during the conditioning.
- 3.2 Oven - An oven capable of maintaining $325 \pm 10\text{F}$.
- 3.3 Freezer - A freezer capable of maintaining $20 \pm 10\text{F}$.
- 3.4 Rack - A rack capable of supporting the aluminum tubes in a vertical position in the oven and freezer.
- 3.5 Spatula and Hammer - The spatula must be rigid and sharp to allow cutting of the tube containing the sample when at a low temperature.

4.0 Procedure

- 4.1 Place the empty tube with sealed end down in the rack.
- 4.2 Carefully heat the sample until sufficiently fluid to pour. Care should be taken to avoid localized overheating. Strain the melted sample through a No. 50 sieve conforming to ASTM E11. After thorough stirring, pour 50.0 grams

¹ Aluminum tubes may be obtained from Sheffield Industries, P. O. Box 351, New London, CT 06320, 203-442-4451. Observations have been reported regarding leakage of asphalt from the bottom of these tubes during the conditioning period. Other tubes may be required if this leakage is significant.

into the vertically held tube. Fold the excess tube over two times and crimp and seal.

4.3 Place the rack containing the sealed tubes in a $325 \pm 10^\circ\text{F}$ oven. Allow the tubes to stand undisturbed in the oven for a period of 48 ± 1 hour. At the end of the heating period, remove the rack from the oven and immediately place in the freezer at $20 \pm 10^\circ\text{F}$ taking care to keep the tubes in a vertical position at all times. Leave the tubes in the freezer for a minimum of 4 hours to completely solidify the sample.

4.4 Upon removing the tube from the freezer, place the tube on a flat surface. With the spatula and hammer, cut the tube into three equal length portions. Place the beakers in a $325 \pm 10^\circ\text{F}$ oven until sufficiently fluid to remove the pieces of aluminum tube.

4.5 After a thorough stirring, pour the top and bottom samples into appropriately marked rings for the ring and ball softening point test. Prepare the rings and apparatus as described in ASTM D36²

4.6 The top and bottom sample from the same tube should be tested at the same time in the softening point test.

5.0 Report

5.1 Record the softening point of the top and bottom portions of the sample. Duplicate separation tests should be run.

² Other physical and chemical residue tests may be run at this time, if desired.

APPENDIX B

**ELASTIC RECOVERY TEST FOR TYPE I
POLYMER MODIFIED ASPHALT**

ELASTIC RECOVERY TEST

1.0 Scope

1.1 The elastic recovery of a polymer modified asphalt cement is evaluated by the percentage of recoverable strain measured after elongation during a conventional ductility test. Unless otherwise specified, the test shall be made at a temperature of $77\text{F} \pm 0.9\text{F}$ ($25 \pm 0.5\text{C}$) and with a speed of $5 \text{ cm/min} \pm 5.0\%$.

2.0 Referenced Documents

- 2.1 ASTM D113: Ductility of Bituminous Materials.
- ASTM E11: Specification for ASTM Thermometers.

3.0 Apparatus

- 3.1 Mold - The mold shall be similar in design to that described for use in the ductility test (ASTM D113), Figure 1, except that the sides of the mold assembly, parts a and a' shall have straight sides producing a test specimen with cross-sectional area of 1 cm^2 .
- 3.2 Water Bath - The water bath shall be maintained at the specified test temperature, varying not more than 0.18F (0.1C) from this temperature. The volume of water shall be not less than 10 liters, and the specimen shall be immersed to a depth of not less than 10 cm and shall be supported on a perforated shelf not less than 5 cm from the bottom of the bath.
- 3.3 Testing Machine - For pulling the briquet of bituminous material apart, any apparatus may be used which is so constructed that the specimen will be continuously immersed in water as specified while the two clips are pulled apart at a uniform speed without undue vibration.
- 3.4 Thermometer - An ASTM 63C or 63F thermometer shall be used.
- 3.5 Scissors - Any type of conventional scissors capable cutting polymer modified asphalt at the test temperature.

4.0 Procedure

- 4.1 Prepare test specimens and condition as prescribed by ASTM D113.
- 4.2 Elongate the test specimen at the specified rate to a deformation of 10 cm.
- 4.3 Immediately cut the test specimen into two halves at the midpoint using the scissors. Keep the test specimen in the water bath in an undisturbed condition for 1 hour.

4.4 After the one hour time period, move the elongated half of the test specimen back into position near the fixed half of the test specimen so the two pieces of polymer modified asphalt just touch. Record the length of the test specimen as X.

5.0 Report

5.1 Calculate the percent recovery by the following procedure:

$$\text{Recovery, \%} = \frac{10 - X}{10} \times 100$$

APPENDIX C

SEPARATION TEST FOR TYPE III POLYMER MODIFIED ASPHALT

**SEPARATION TEST FOR TYPE III
POLYMER MODIFIED ASPHALT****1.0 Scope**

1.1 This test is a simple qualitative test for compatibility of low density polymers in asphalt.

2.0 Apparatus

2.1 Containers - Standard 6 oz. metal sample cups (1.875"H x 2.75" I.D.).

2.2 Oven - An oven capable of maintaining 275 ± 10 F.

3.0 Procedure

3.1 After a blend of polymer in asphalt has been prepared and is still at elevated temperature, pour enough of the mix into a clean 6 oz. metal test cup to fill it to the formed roll on the cup (approx. 1/4" from top). Place the sample in a controlled temperature oven at 275°F for 15 to 18 hours. Remove carefully from oven without disturbing the surface and observe the sample. After the initial observation, a spatula can be used to gently probe the sample and check consistency of any surface layer and check for sludge on the bottom. These observations and tests should be done while the sample is still hot, within five minutes after removal from the oven.

3.2 Depending on the physical characteristics of the polymer and compatibility of the particular asphalt/polymer system, varying conditions will be noted. These are described and should be reported as follows:

<u>DESCRIPTION</u>	<u>REPORT</u>
Homogeneous, no skinning or sludge	HOMOGENOUS
Slight polymeric skin at edges of cup	SLIGHT EDGE SKINNING
Thin polymeric skin on entire surface	THIN TOTAL SKINNING
Thick polymeric skin (1/32"+) on entire surface	THICK TOTAL SKINNING
No surface skinning but thin sludge at bottom of container	THIN BOTTOM SLUDGE
No surface skinning but thick (1/4"+) sludge at bottom of container	THICK BOTTOM SLUDGE

If these descriptions do not match the particular sample, note the exact phenomena encountered and retain the sample.

Appendix B
The Colorado Department of Transportation's Project Special Provisions for Polymer

REVISION OF SECTION 702
BITUMINOUS MATERIALS

Section 702 of the Standard Specifications is hereby revised for this project as follows:

Subsection 702.01 shall include the following:

Asphalt Cement (Polymer Modified) (Type I-D)

Asphalt Cement (Polymer Modified) (Type I-D) shall conform to the following requirements:

	<u>Min</u>	<u>Max</u>	<u>AASHTO Test No.</u>
Penetration, 77° F, 100g, 5 sec	40	75	T 49
Penetration, 39.2° F, 200g, 60 sec	25	-	T 49
Viscosity, 140° F, Poise	5000	-	T 202
Viscosity, 275° F, cSt.	-	2000	T 201
Softening Point, R & B, F	140	-	T 53
Flash Point, °F	450	-	T 48
Solubility in TCE, %	99.0	-	T 44
Separation, R & B difference, F	-	4	* T 53
<u>Tests on Residue from Thin Film Aging Test</u>			
Elastic Recovery, 77° F, %	50	-	**
Penetration, 39.2° F, 200g, 60s	13	-	T 49

* Method described in Appendix A

**Method described in Appendix B

July 15, 1987

**REVISION OF SECTION 702
ASPHALT CEMENT (AC-20) (RUBBERIZED)**

Section 702 of the Standard Specifications is hereby revised for this project to include the following:

ASPHALT CEMENT (AC-20) (RUBBERIZED)

AC-20 (Rubberized) shall be asphalt cement thoroughly blended with a minimum of two (2) percent by weight of rubber and shall conform to the following requirements:

PROPERTY	SPECIFICATIONS		AASHTO TEST NO.
	Minimum	Maximum	
Viscosity, 140°F, poises	1600		T-202
Viscosity, 275°F, centistokes	210		T-201
Penetration, 77°F (100g, 5 sec.)	40		T-49
Ductility, 39.2°F (5 cm/min), cm	50		T-51
Toughness, Inch-pounds	110		*CP-L 2210
Tenacity, Inch-pounds	75		*CP-L 2210
Tests on residue from thin film oven test:			
Viscosity, 140°F, poises		8000	T-202
Ductility, 39.2°F (5 cm/min), cm	25		T-51

*Colorado Procedure

For this project, Asphalt Cement (Polymer Modified) (Type III-D) shall conform to the following:

Asphalt Cement (Polymer Modified) (Type III-D)

	<u>Min</u>	<u>Max</u>	<u>AASHTO Test No.</u>
Penetration, 77F, 100g, 5 sec	30	130	T 49
Penetration, 39.2F, 200g, 60 sec	18	-	T 49
Viscosity, 140F, Poise	-	-	T 202
Viscosity, 275F, cSt.	150	2000	T 201
Softening Point, R & B, F	140	-	T 53
Flash Point, F	425	-	T 48
Separation*	Homogeneous		
<u>Tests on Residue from Thin Film Aging Test</u>			
Loss, %	-	1.0	T 179
Penetration, 39.2F, 200g, 60s	9	-	T 49

* Method described in Appendix A1

Appendix C
Various Gradations Used On These Projects

Colorado Department of Highways

Project No. IR (CX) 070-5(56)

JOB MIX FORMULA

Location West of Flagler

Date 6-10-91

District 1-15

Field Sheet No. 63288

from Project No. _____

This Job Mix Formula defines the specified gradation, asphalt cement content and admixture dosage for the grading and project shown.

Contractor Popejoy

Pit Cooley Morr./Monks

Grading G Item 403

0 Top layer ☒ Bottom layer

Gradation (% passing)

1 1/2 100

3/4 75

1/2 60

3/8 _____

4 45

8 32

30-50 16

200 5

4.5

Remarks:

1.0 % Hydrated Lime (Pete Lien)
21.0 % Cooley 1 1/2"
29.0 % Cooley #57
35.0 % Cooley Granite Sand
14.0 % Monks Coarse Sand

COX

Lab. Wt. 355.9g
Lab. Time 55 sec
Rise 4.5 - 2.503

% AC 4.7 Source and grade of AC Conoco AC-20

% Additive NONE Source of additive N.A.

Lab Specific Gravity at the above % AC 2.495
Maximum

Signed L.L. Malone Date 6-19-91
Project Engineer

Signed Donald R. [Signature] Date 6/18/91
District Materials Engineer

Signed Donald W. [Signature] Date 6/21/91
Contractors Representative

Distribution:

Materials Engineer
Staff Materials
Resident Engineer (2)
Contractor

Colorado Department of Highways

JOB MIX FORMULA

Date 6-10-91

Project No. IR (CX) 070-5(56)

Location West of Flagler

District 1-15

Field Sheet No. 63287

from Project No. _____

This Job Mix Formula defines the specified gradation, asphalt cement content and admixture dosage for the grading and project shown.

Contractor Popejoy

Pit Cooley Morr./Monks

Grading CX Item 403

0 Top layer ☒ Bottom layer

Gradation (% passing)

3/4 _____

1/2 100

3/8 87

4 58

8 43

30-60 23

200 7

Remarks:

1.0% Hydrated Lime (PeteLien)

34.0% Cooley Chips, Washed

50.0% Cooley Granite Sand

15.0% Monks Coarse Sand

*Rec 5.5-2.464
Jolt Wt 1194g
Jolt Time*

% AC 5.1 Source and grade of AC Conoco AC-20

% Additive NONE Source of additive N.A.

Lab Specific Gravity at the above % AC 2.493
Maximum

Signed L.L. Torline Date 6-19-91

Project Engineer

Signed Arnold Petrie Date 6/18/91

District Materials Engineer

Signed Donald L. Popejoy Date 6-21-91

Contractors Representative

Distribution:

Materials Engineer

Staff Materials

Resident Engineer (2)

Contractor

Colorado Department of Highways

Project No. IR (CX) 070-5(56)

JOB MIX FORMULA

Location West of Flagler

Date 6-10-91

District 1-15

Field Sheet No. 63289

from Project No. _____

This Job Mix Formula defines the specified gradation, asphalt cement content and admixture dosage for the grading and project shown.

Contractor Popejoy

Pit Cooley Morr./Monks

Grading C Item 403

☒ Top layer ☐ Bottom layer

Gradation (% passing)

Remarks:

3/4 100
1/2 87
3/8 77
4 56
8 41
30-50 22
200 7

1.0 % Hydrated Lime (Pete Lien)
36.0 % Cooley 3/4", Unwashed
48.0 % Cooley
15.0 % Monks Coarse Sand

*Rec 50 - 2.46.7
Lobt wt - 1190g
Lobt time - 10 sec*

% AC 4.5 Source and grade of AC Conoco AC-20

% Additive NONE Source of additive U.A.

Lab Specific Gravity at the above % AC 2.487
Maximum

Signed L.L. Tolone Date 6-19-91
Project Engineer

Distribution:

Signed David D. [Signature] Date 6/18/91
District Materials Engineer

Materials Engineer
Staff Materials
Resident Engineer (2)
Contractor

Signed Donald [Signature] Date 6/21/91
Contractors Representative

COLORADO DEPARTMENT OF HIGHWAYS

Project No. CXIR 02-0025-30

JOB MIX FORMULA

Location: JCT SH 50 (PUEBLO) - NORTH

DATE: 10/2/90

DISTRICT II

Field Sheet No. 47110 (COMB #1)

from Project No. CXIR 02-0025-30

This Job Mix Formula defines the specified gradation, asphalt cement content and admixture dosage for the grading and project shown.

Contractor: WALSENBURG SAND AND GRAVEL

Pit: MARTIN

Grading C Item 403

 Top Layer X Bottom Layer

5.5-2.404

Gradation (% passing)

Remarks:

3/4 100

DESIGN BASED ON THE FOLLOWING:

1/2 85

40% ROCK

3/8 70

50% CRUSHER FINES

#4 52

9% NATURAL FINES

#8 38

1% HYDRATED LIME

#30 18

#200 5

%AC 5.4 Source and grade of AC: AC-20 DIAMOND SHAMROCK

% Additive: 0.0 Source of additive: N/A

Max. Specific Gravity (T-209) 2.408

Distribution:

Signed _____ Date _____
Project Engineer

Construction Engineer

Materials Engineer

Signed _____ Date 10/2/90
District Materials Engineer

Staff Materials

Resident Engineer (2)

Contractor

Signed _____ Date _____
Contractors Representative

CDOH FORM #43
9/87

Colorado Department of Highways

Project No.

CX 10-0085-17

JOB MIX FORMULA

Location

Surfacing on Santa Fe

DATE: June 12, 1991

District

6

Field Sheet No.

61234

from Project No.

CX 01-0025-58

Bid: 5/9/91

Award: 5/16/91

This Job Mix Formula defines the specified gradation, asphalt cement content and admixture dosage for the grading and project shown.

Contractor: Kiewit-South

Pit: Frei/Clark

SC(Virgin)(w/o lime)(Polymer Modified)

Grading Item 403

☒ Top layer ☒ Bottom layer

Gradation (% passing)

Remarks:

3/4 100

1/2 75

3/8 61

4 43

8 30

30 12

200 5

% AC 3.7 Source and grade of AC ELF AC-20

% Additive 0.50 Source of additive Pave Bond (Special)

Maximum Specific Gravity at the above % AC 2.57 (T-209)

☐ New mix design with no change☒ Staff Materials was called and concurs with change or reapproval.

Called Dick Hines Date 6/12/91

Staff Materials Representative

Signed William C. [Signature] Date 6/13/91

Project Engineer

Signed R. Locander RPT Date 6/12/91

Asst. District Materials Engineer

Signed [Signature] Date 6-13-91

Contractors Representative

Distribution:

Materials Engineer

Staff Materials

Resident Engineer (2)

Contractor

Colorado Department of Transportation
JOB MIX FORMULA

Mix Design: 61269-1
Date: 06/01/92

Project: CY-CX 01-0265-01
Location: SH 265, I 70 TO SAND CREEK
District: 6 Subaccount: 92426
Bid: / / Award: / /
From Project: CY-CX 01-0025-59

This Job Mix Formula defines the specified gradation, asphalt cement content and admixture dosage for the grading and project shown.

Contractor: BRANNAN S & G
Supplier: BRANNAN Plant:
Pit: 3/4 ROCK - FREI 3/8 ROCK - FREI
FINES - BRANNAN PIT 29

Grading: SF Item: 403 & PATCHING
% RAP: Remarks:
% Lime: 1.0

Gradation (% Passing)			Range	
Sieve	+/-Tol	Virgin		
2"			[	]
1 1/2"			[	]
1"			[	]
3/4"	100		[100	100]
5/8"			[	]
1/2"	6	89	[83	95]
3/8"	5	79	[74	84]
#4	5	61	[56	66]
#8	4	47	[43	51]
#16			[	]
#30	4	23	[19	27]
#50			[	]
#100			[	]
#200	2	7.0	[5	9]
% AC	0.3	5.00	[4.70	5.30]

Rice 6.0 - 2.434
Job wt. 1182g
Job time 10 sec

Grade of AC: AC-10 Source of AC: CONOCO
% Additive: Source of Additive:
Maximum specific gravity at the above % AC: 2.47

[] New mix design with no change
[X] Staff Materials was called and concurs with
change or reapproval

Called: TONY MAESTAS Date: 05/29/92
Staff Materials Representative

Signed: _____ Date: _____
Project Engineer

Signed: SID MOTCHAN *SM* Date: 06/01/92
District Materials Engineer

Signed: _____ Date: _____
Contractors Representative

Distribution:
Staff Materials
Materials Engineer
Resident Engineer (2)
Contractor