Report No. CDOT-DTD-R-95-14

A Documentation of Hot Mix Asphalt Overlays on I-25 in 1994

Tim Aschenbrener
Colorado Department of Transportation
4201 E. Arkansas Avenue
Denver, Colorado 80222

Final Report
June 1995

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

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

Acknowledgements

Dave Price (CDOT - Research) and Nava Far (CDOT - Staff Materials) performed the laboratory testing of the HMA. Benja Bemelen (CDOT - Staff Materials) performed the SHRP binder testing.

The CDOT research panel provided many excellent comments and suggestions for the study. It included: Kevin Stuart (FHWA - Turner Fairbank Highway Research Center), Frank Rich (FHWA - Region 8), Richard Zamora (FHWA - Colorado Division), Bernie Paiz and Bob LaForce (CDOT - Staff Materials), Gerry Peterson (CDOT - Region 1 Materials), Dave Gonser (CDOT - Region 2 Materials), Ken Wood (CDOT - Region 4 Materials), Sid Motchan (CDOT - Region 6 Materials) and Donna Harmelink (CDOT - Research).

Special thanks to the panel of Colorado asphalt paving experts who provided numerous ideas and suggestions which made this study more informational: Bud Brakey (Brakey Consulting Engineers), Jim Fife (Western Colorado Testing), Joe Proctor (Morton International), Scott Shuler (Colorado Asphalt Pavement Association) and Eric West (Western Mobile).

REPORT DOCUMENTATION PAGE

FORM APPROVED
OMB NO. 0704-0188

1. AGENCY USE ONLY (Leave Blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	June 1995	Final Report

4. TITLE AND SUBTITLE
A Documentation of Hot Mix Asphalt Overlays on I-25 in 1994

5. FUNDING NUMBERS

6. AUTHORS(S)
Tim Aschenbrener

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(S)
Colorado Department of Transportation
4201 E. Arkansas Ave.
Denver, Colorado 80222

8. PERFORMING ORGANIZATION REPORT NUMBER
CDOT-DTD-R-95-14

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(S)
Colorado Department of Transportation
4201 E. Arkansas Ave.
Denver, Colorado 80222

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES
Prepared in Cooperation with the U.S. Department of Transportation, Federal Highway Administration

12a. DISTRIBUTION/AVAILABILITY STATEMENT
No Restrictions: This report is available to the public through the National Technical Information Service. Springfield, VA 22161

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

In 1994 there were significant changes to the Colorado Department of Transportation's (CDOT's) hot mix asphalt program. Several programs culminated at this time. These programs included 1) aggregate and mix specifications, 2) variable laboratory compactive efforts, 3) field verification, and 4) European testing equipment. Furthermore, the use of the new SUPERPAVE binder tests and and gyratory compactor will be implemented soon in Colorado.

Coincidentally, 1994 was one of the busiest paving seasons for the CDOT in quite some time. As a result, nine different projects were paved on the 1-25 corridor. Furthermore, the use of the new SUPERPAVE binder tests and gyratory compactor will be implemented soon in Colorado.

The purpose of this paper is to document the HMA properties used on the projects for I-25. This will provide information that can be correlated to the long-term performance of these pavements 5, 10, and hopefully even 15 years into the future. The tracking of these pavements' performance will then provide valuable information for the development or modification of specifications in the future. They may also provide new data for the use of life-cycle cost analysis, and the use of life-cycle cost analysis, and the implementation of the SUPERPAVE binder and gyratory recommendations.

14. SUBJECT TERMS
Hot Mix Asphalt (HMA), Field Performance, European Testing Equipment, SUPERPAVE Gyratory, SUPERPAVE Compactor

15. NUMBER OF PAGES
88

16. PRICE CODE

17. SECURTITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	

Table of Contents

Appendices

List of Tables

List of Figures

A Documentation of Hot Mix Asphalt Overlays on I-25 in 1994

Tim Aschenbrener

1.0 Introduction

1.1 Background

In 1994 there were significant changes to the Colorado Department of Transportation's (CDOT's) hot mix asphalt program. Several programs culminated at this time. These programs included:

1) Aggregate and Mix Specifications. In 1994, the recommendations of the Asphalt Institute (*1*) and FHWA's Technical Advisory (*2*) for material specifications for aggregates and hot mix asphalt (HMA) were used by the CDOT. This included everything from the sand equivalent test (AASHTO T 176) to the voids in the mineral aggregate using the bulk specific gravity of the aggregate.

2) Variable Laboratory Compactive Efforts. The CDOT had adopted the use of the Texas gyratory (ASTM D 4013) using a 1030 kPa (150 psi) end-point stress for all projects in 1991. A study performed by Aguirre Engineers, Inc. (*3*) recommended using the Texas gyratory compactor with end-point stresses that were related to the traffic volume and environmental conditions. This recommendation was validated by Aschenbrener (*4*). A total of five different laboratory compactive efforts were recommended and adopted. In 1994, higher trafficked highways were designed with high laboratory compactive efforts and lower trafficked highways were designed with low laboratory compactive efforts. For example, HMAs for highways with high traffic were designed with the 860 kPa (125 psi) end-point stress, and HMAs for highways with very low traffic were designed with the 170 kPa (25 psi) end point stress.

3) Field Verification. The CDOT had previously field verified plant produced material for the mix design properties at the Central Laboratory. Unfortunately, the field verification test results were often completed after the project was finished. This did not allow inferior HMAs to be identified so adjustments could be made in a timely manner.

In 1994, each Region had the equipment and trained personnel to field verify plant produced material for the mix design properties. This allowed for reporting the test results quickly, and in many instances adjustments were made to inferior HMAs to prevent its placement on the project. Each Region had a laboratory in their Region headquarters; one Region also had a field trailer, and 4 additional field trailers had been ordered.

4) European Testing Equipment. The CDOT and FHWA Turner-Fairbank Highway Research Center were selected to demonstrate several pieces of European equipment. This equipment included the French rutting tester to evaluate HMA for permanent deformation and the Hamburg wheel-tracking device to evaluate HMA for moisture damage. This equipment is described elsewhere (*5*). Previously, this equipment has been used to develop and validate the new aggregate and HMA specifications (*4*) and to demonstrate the importance of field verification (*6*). In 1994, this equipment was used on the I-25 corridor projects to validate many of the mix designs, field verify the plant produced material, and provide confidence in mix adjustments that were made on these projects.

Furthermore, the use of the new SUPERPAVE binder tests and gyratory compactor will be implemented soon in Colorado. Tests were performed with this equipment in order to get an idea of their impact on the HMA currently specified by the CDOT.

Coincidentally, 1994 was one of the busiest paving seasons for the CDOT in some time. As a result, nine different projects were paved on the I-25 corridor. These projects included:

- 80.5 center-line km (49.93 miles),
- 334.8 lane km (207.58 miles),
- 425,000 tons of HMA, and
- the cost of these projects totaled $21,325,000.

The projects are summarized in Table 1.

Table 1. Summary of Projects Placed on I-25 In 1994.

Project	Name	Location	Subaccount	Contractor
STA 0251-133	N.M. State Line - North	New Mexico State Line	93249	Corn Construction
NH(CX) 025-1(125)	Trinidad Bypass	Trinidad	92029	Kiewit Western
ACIM 0251-137	Butte Creek Int. - N.	North of Walsenburg	10643	D.G. Huskins
STA 0251-131	Jct SH-165, N & S	Colorado City	92410	Western Mobile-Northern
C 0252-265	I-25, Woodman Road - S.	Colorado Springs	10132	Broderick and Gibbons
IM 0252-266	I-25, South AFA Entrance - N.	Air Force Academy	10133	Rocky Mountain Materials
IM 0252-269 IM 0252-263	El Paso C.L. - N Monument Hill - S	Monument	93201 10056	Schmidt Construction
C 253-117	I-25, US-36 to 84th Ave.	Denver	10149	Bituminous Roadways of CO
IM 0253-116	SH-7 to SH-66	Longmont	10125	Brannan Sand and Gravel

1.2 Purpose

The purpose of this paper is to document the HMA properties used on the projects for I-25. This will provide information that can be correlated to the long-term performance of these pavements 5, 10, and hopefully even 15 years into the future. The tracking of these pavements' performance will then provide valuable information for the development or modification of specifications in the future. They may also provide new data for the use of life-cycle cost analysis.

2.0 New Mexico State Line: M.P. 0.0 to 7.57

2.1 General

This project is on I-25 and extends from the New Mexico State Line to the north for approximately 12.2 km (7.5 miles) in Region 2. The total project cost was bid at $3,725,000. The 20-year ESALs in the design lane are 4,955,000. A summary of the general overlay information is shown in Table 2.

Table 2. Overlay Information for the New Mexico State Line Project

Grading	Tons	Cost per Ton	Thickness
CX	35,000	$29.25	50 mm
C	56,000	$22.85	50 to 114 mm
Milling	NA	NA	50 mm

2.2 Pavement Management

The plans specified milling 50 mm (2 inches) of the existing mat and replacing it with a 50-mm thick overlay of Grading C. A second lift of Grading C was placed 0 to 64-mm (2.5-in.) thick depending on the location in the project. Finally, a 50-mm lift of Grading CX was placed on the surface and had a polymer modified asphalt cement.

2.3 Mix Designs

The aggregate and asphalt cement properties are summarized in Table 3. The rock and crushed sand came from the Tortorice sand and gravel pit. The blend sand was a natural sand that came from Emerald Vista that was naturally clean.

The HMA properties are summarized in Table 4. The HMA was designed with the 520 kPa (75 psi) end point stress on the Texas gyratory compactor (ASTM D 4013).

The Central Laboratory mix design had an optimum asphalt content of 6.5%. However, the aggregates submitted for the mix design had a much higher water absorption than the aggregates in the stockpile. Preliminary testing of the plant produced material in the Region

Laboratory identified this problem. This was a good example of the benefit of the Region Laboratory.

Table 3. Aggregate and Asphalt Cement Summary

Grading	Rock	Inter-mediate Rock	Crushed Sand	Blend Sand	Hydrated Lime	Asphalt Cement	SUPERPAVE Performance Grade
CX	13%	31%	35%	20%	1%	Conoco AC-20R	64-28
C	30%	25%	37%	7%	1%	Conoco AC-10	58-22*

* Based on testing of Conoco AC-10 from other projects.

Table 4. Mix Design Summary

Grading	Asphalt Content (%)	Air Voids (%)	VMA (%)	Hveem Stability	AASHTO T 283 (TSR)
CX (Min)	5.8 *	4.0 *	13.7 (15.0)	49 (39)	0.83 (0.80)
C (Min)	5.4 *	4.0 *	14.1 (13.0)	46 (39)	0.83 (0.80)

* Not Applicable

2.4 Field Verification

A Form 43 is a contract document between the contractor and the CDOT. The Form 43 is used to define the job mix formula which includes gradation, asphalt content, asphalt grade and source, and the theoretical maximum specific gravity. Any time the job mix formula needs to be adjusted, a new Form 43 must be issued. One Form 43 for each mix was used for the entire project; no adjustments were made to the HMA.

The field verification results were tested in the Region laboratory and are shown in Table 5. The air voids were at the target value for most of the production of the Grading C, but lowered significantly towards the end of the placement. Although there was a loss of 1.3% air voids for the Grading C HMA, this was mainly at the end of placement. There was a loss of 1.2% VMA for the Grading C HMA, but even after the loss, the VMA remained extremely close to the minimum specified value 13.0%.

Table 5. Field Verification Summary

Grading	Air Voids (%)			VMA (%)			Hveem Stability		
	Avg.	S.D.	n	Avg.	S.D.	n	Avg.	S.D.	n
CX	4.1	0.42	4	13.8	0.32	4	51	2.1	4
C	2.7	0.49	7	12.9	0.31	7	43	5.0	7

For the Grading CX HMA, the air voids and VMA stayed at the design values. Unfortunately, the design value of VMA was about 1.0% lower than the specified value.

The AASHTO T 283 test results (modified Lottman) indicated the HMAs were marginally acceptable to prevent moisture damage. For the Grading C, the TSR averaged 0.85 with a standard deviation of 0.11. For the Grading CX, the TSR averaged 0.76 with a standard deviation of 0.18. TSRs as low as these are not typically encountered when using hydrated lime. The aggregates from the Tortorice pit have a history of being moisture susceptible.

2.5 QC/QA Results

The pay factor for this project was based on the quality level analysis (percent within specification limits) of field compaction, asphalt content and gradation. Field compaction is based on the maximum theoretical specific gravity (AASHTO T 209). The pay factor is determined by weighting the field compaction 50%, the asphalt content 30%, and the gradation 20%. The results from each of the three elements are shown in Table 6. The contractor received a bonus for both the Grading C and CX HMAs of 3.2% and 2.5%, respectively.

Table 6. QC/QA Data Summary

Grading	Field Compaction(%)			Asphalt Content (%)			Gradation			Total
	Avg.	S.D.	n	Avg.	S.D.	n	Avg.	S.D.	n	
CX	93.0	0.97	39	5.82	0.14	11	*	*	10	
Pay Factor	1.016			1.050			1.008			1.025
C	93.9	1.19	108	5.45	0.12	23	*	*	23	
Pay Factor	1.025			1.047			1.028			1.032

* Not Applicable

2.6 European Equipment Results

2.6.1 French Rutting Tester

The results from the French rutting tester are shown in Figure 1 for the top lift. A passing result is less than 10%. The HMA passed at both the 55°C (131°F) and 60°C (140°F) test temperatures with a rutting depth of 2.9% at both temperatures. The test results indicate the HMA should be rut resistant.

2.6.2 Hamburg Wheel-Tracking Device

The results from the Hamburg wheel-tracking device are shown in Figure 2 for the top lift. A passing result is less than 10 mm after 20,000 passes. The HMA failed at the 45°C (113°F) test temperature, and did not even make 20,000 passes. The stripping inflection point occurred at 2500 passes. The test results indicate that there may be moisture problems with the HMA. The Tortorice pit does have a history of providing moisture susceptible aggregates.

2.7 Gyratory Results

Field produced HMA that was tested in the French rutting tester and Hamburg wheel-tracking device was also compacted in the SUPERPAVE gyratory. The results from the SUPERPAVE gyratory compactor are shown in Table 7. The gyratory results of the HMA met all of the specifications that would be recommended by the SUPERPAVE design system. In fact, the air voids at the design gyrations were slightly high, indicating that approximately 0.2% or 0.3% additional asphalt cement would be acceptable.

Table 7. Test Results from the SUPERPAVE Gyratory Compactor

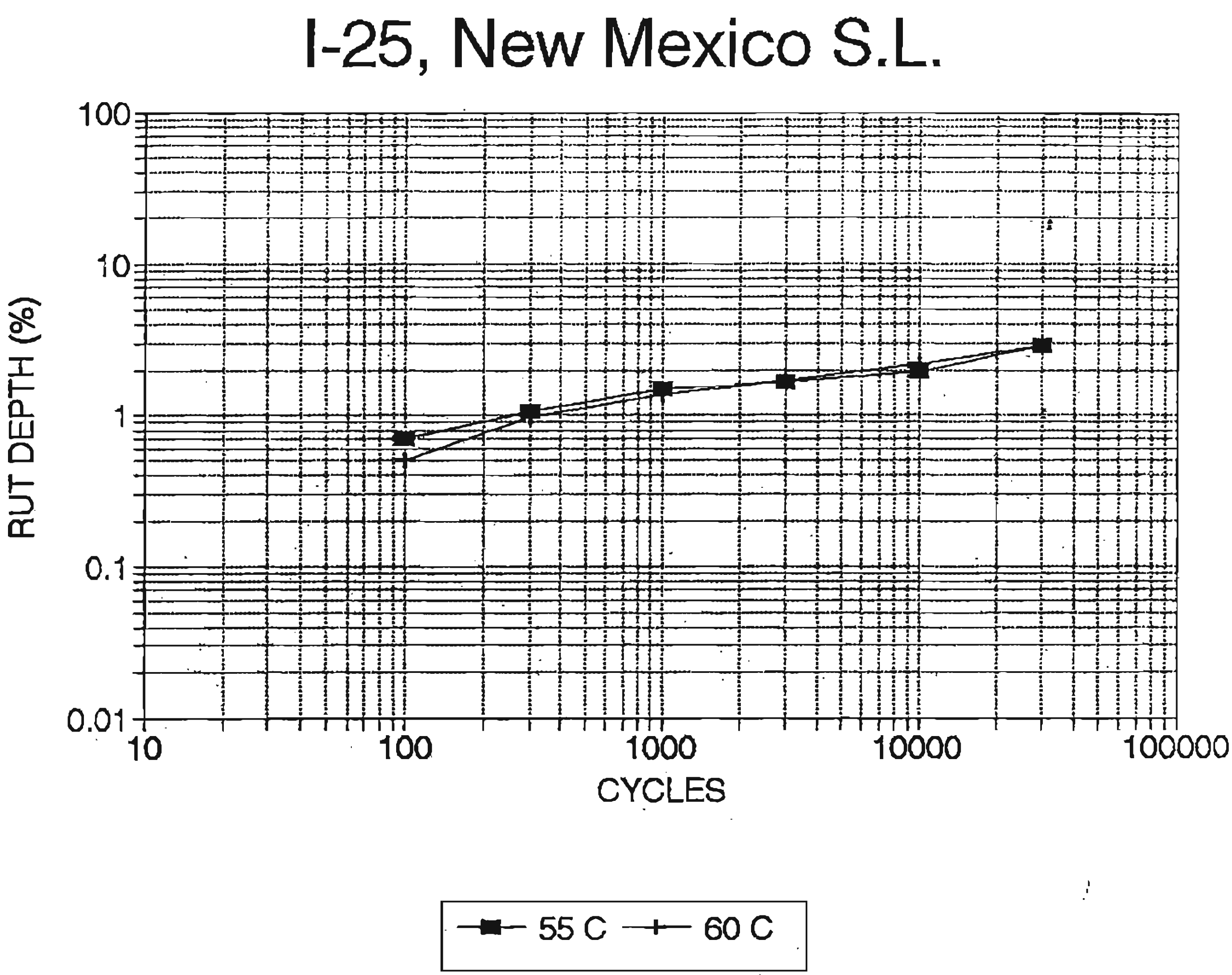
	Air Voids (%)	
	Specification	Test Result
N_{init} = 7	≥ 11.0	13.2
N_{design} = 86	= 4.0	4.6
N_{max} = 134	≥ 2.0	3.6

The HMA placed on this project used the 520 kPa (75 psi) end point stress on the Texas gyratory. This was approximately equivalent to an N_{design} of 105 gyrations.

2.8 Summary

The HMA on this project was produced and placed on the project as designed based on gradation and volumetric properties. Based on the French rutting tester, the HMA pavement should not rut from plastic flow. However, the marginally acceptable AASHTO T 283 results and very poor results in the Hamburg wheel-tracking device indicate that there may be a problem with moisture damage in the future.

This project received the 1994 CAPA award for workmanship for projects over 20,000 tonnes.



Temperature = 55°C
Slope = 0.225
Intercept = 1.303

Temperature = 60°C
Slope = 0.283
Intercept = 1.188

Figure 1. Results from the French Rutting Tester for the New Mexico Project

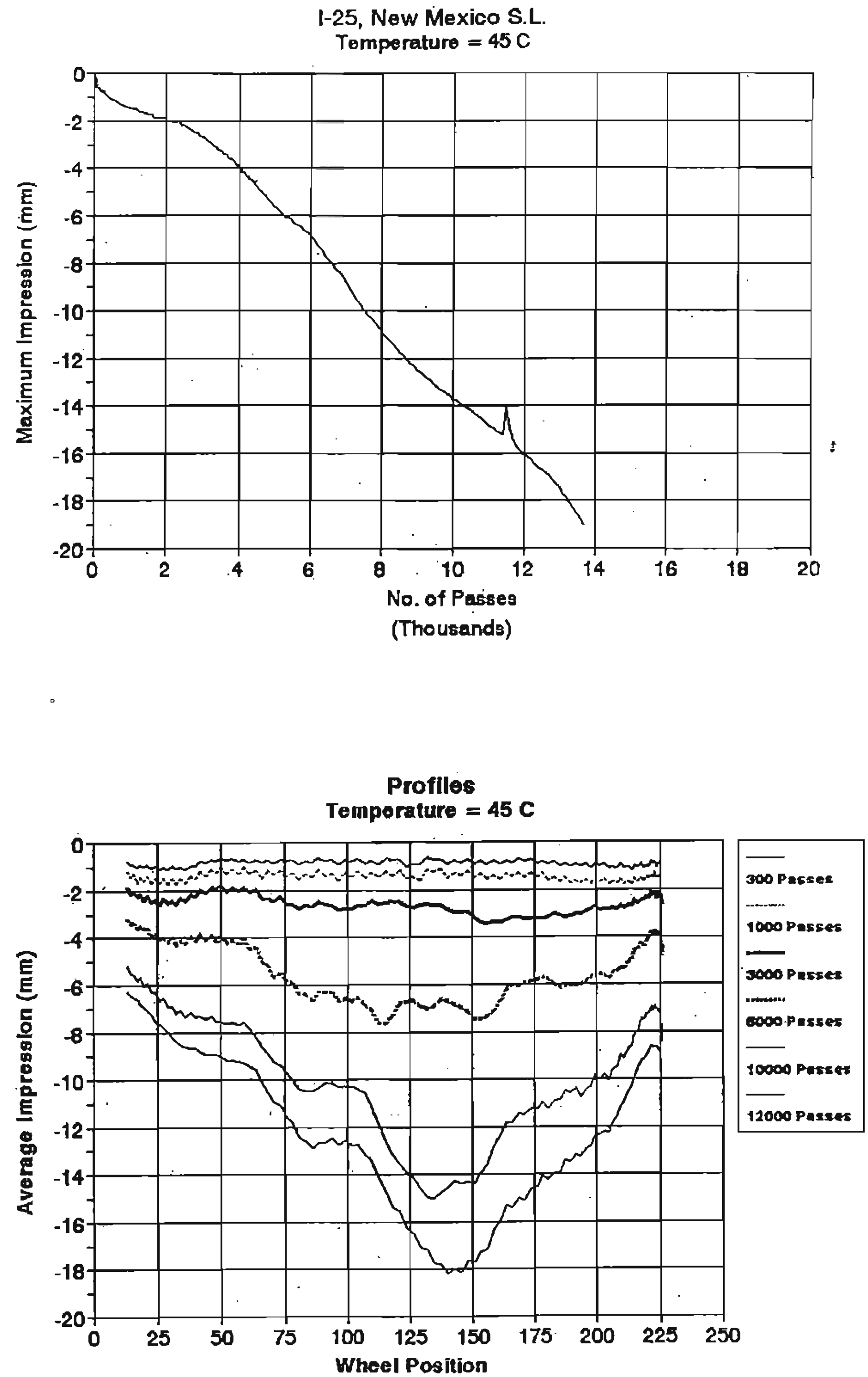


Figure 2. Results from the Hamburg Wheel-Tracking Device for the New Mexico Project

3.0 Trinidad: M.P. 13.21 to 15.56

3.1 General

This project is on I-25 and goes through Trinidad for approximately 3.8 km (2.35 miles) in Region 2. The total project cost was bid at $5,976,000, but the roadway work on I-25 was estimated at $2,173,000. The 10-year ESALs in the design lane are 1,285,000. A summary of the general overlay information is shown in Table 8.

Table 8. Overlay Information for the Trinidad Project

Grading	Quantity	Cost per Unit	Thickness
C	16,000 tons	$31.00	50 mm
CIPR	94,000 yd^2	$1.80	100 mm

3.2 Pavement Management

The plans specified cold in-place recycling (CIPR) 100 mm (4 inches) of the existing mat and overlaying it with a 50-mm (2-inch) thick overlay of Grading C.

3.3 Mix Designs

The aggregate and asphalt cement properties are summarized in Table 9. The rock and crushed sand came from the Tortorice sand and gravel pit.

Table 9. Aggregate and Asphalt Cement Summary

Grading	19.0 mm (3/4") Rock	12.5 mm (1/2") Rock	Crushed Sand	Hydrated Lime	Asphalt Cement	SUPERPAVE Performance Grade
C	26%	18%	55%	1%	Diamond Shamrock AC-10	58-16

For this project a mix design using the 520 kPa (75 psi) end point stress was used for the Trinidad bypass, and a mix design using the 690 kPa (100 psi) end point stress was used on the interstate. The HMA was designed with the 690 kPa (100 psi) end point stress on the Texas gyratory compactor (ASTM D 4013). The HMA properties are summarized in Table 10.

Table 10. Mix Design Summary

Grading	Asphalt Content (%)	Air Voids (%)	VMA (%)	Hveem Stability	AASHTO T 283 (TSR)
C (Min)	5.0 *	4.0 *	14.1 (13.0)	44 (42)	0.84 (0.80)

* Not Applicable

3.4 Field Verification

For the HMA placed on the interstate, two Form 43's were used. Since the air voids were high for the first two tests, the optimum asphalt content was increased from 5.0% to 5.4%. The field verification results from the 690 kPa (100 psi) end point stress HMA that were tested in the Region laboratory are shown in Table 11.

Table 11. Field Verification Summary

Grading	Air Voids (%)			VMA (%)			Hveem Stability		
	Avg.	S.D.	n	Avg.	S.D.	n	Avg.	S.D.	n
C	4.6	0.6	7	15.4	0.60	7	49	1.7	7

The AASHTO T 283 test results (modified Lottman) indicated the HMAs were marginally acceptable to prevent moisture damage. The TSR averaged 0.81 with a standard deviation of 0.09. TSRs as low as these are not typically encountered when using hydrated lime. The aggregates from the Tortorice pit have a history of being moisture susceptible.

3.5 QC/QA Results

The pay factor for this project was based on the quality level analysis (percent within specification limits) of field compaction, asphalt content and gradation. Field compaction is based on the maximum theoretical specific gravity (AASHTO T 209). The results from each of the three elements are shown in Table 12. The contractor received a price reduction of 3.3%.

Table 12. QC/QA Data Summary

Grading	Field Compaction(%)			Asphalt Content (%)			Gradation			Total
	Avg.	S.D.	n	Avg.	S.D.	n	Avg.	S.D.	n	
C	92.4	1.13	57	5.55	0.28	29	*	*	30	
Pay Factor	0.956			0.991			0.959			0.967

* Not Applicable

It should be noted that the numbers in Table 12 were calculated from all of the test results from the project. The tests used to determine the actual pay for the contractor may be slightly different; therefore, the resulting pay factor may be slightly different.

3.6 European Equipment Results

3.6.1 French Rutting Tester

The results from the French rutting tester are shown in Figure 3. The HMA passed at both the 55°C (131°F) and 60°C (140°F) test temperatures with a rutting depth of 5.0% and 6.2%, respectively. The test results indicate the HMA should be rut resistant.

3.6.2 Hamburg Wheel-Tracking Device

The results from the Hamburg wheel-tracking device are shown in Figure 4. The HMA failed at the 45°C (113°F) test temperature, and did not even make 20,000 passes. The stripping inflection point occurred at 4000 passes. The test results indicate that there may be moisture problems with the HMA. The Tortorice pit does have a history of providing moisture susceptible aggregates.

At the 40°C (122°F) test temperature, the rutting depth was 10.4 mm.

3.7 Gyratory Results

Field produced HMA that was tested in the French rutting tester and Hamburg wheel-tracking device was also compacted in the SUPERPAVE gyratory. The results from the SUPERPAVE gyratory compactor are shown in Table 13. The gyratory results of the HMA met all of the specifications. In fact, the air voids at the design gyrations were high, indicating that approximately 0.3% or 0.4% additional asphalt cement would be acceptable.

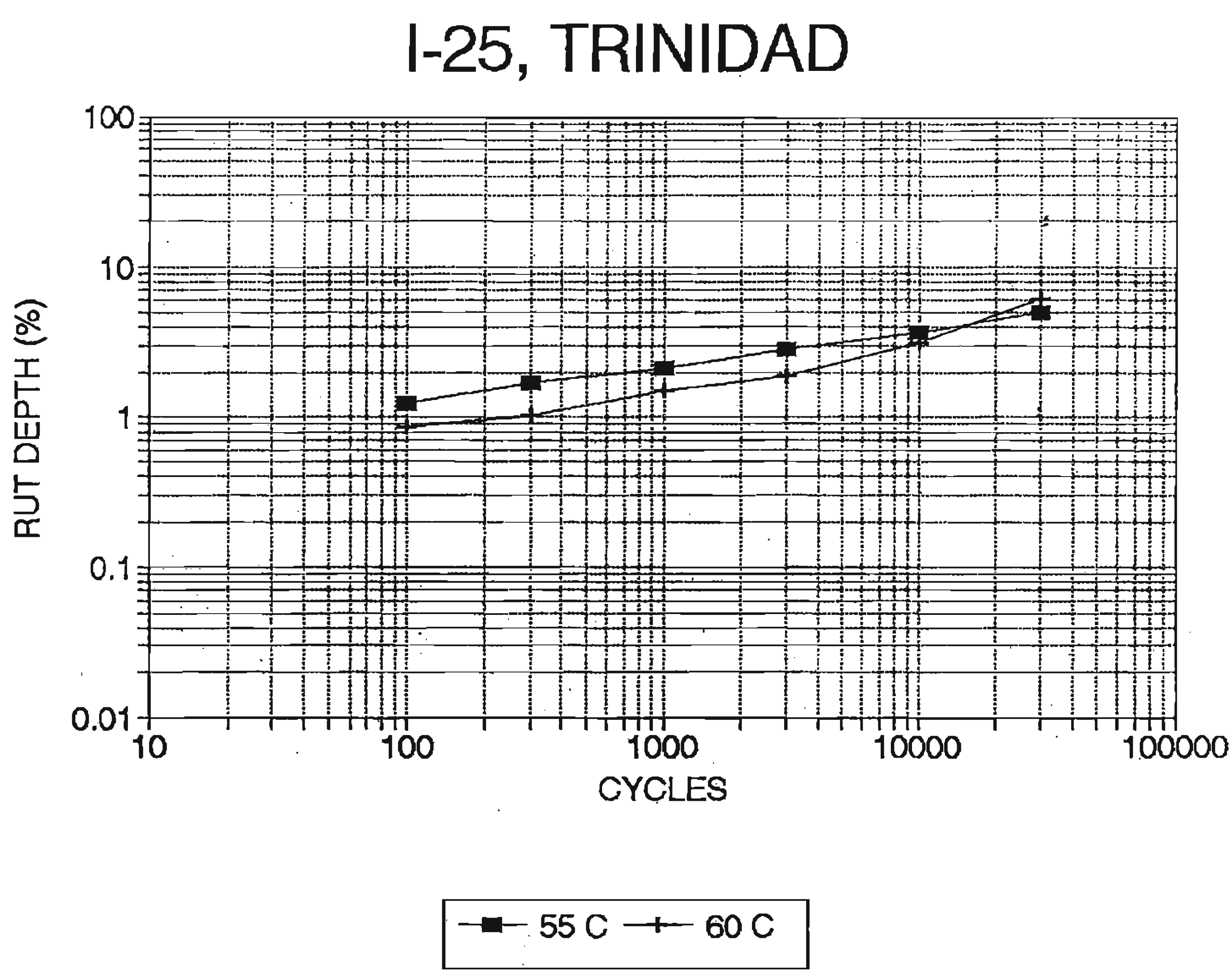
Table 13. Test Results from the SUPERPAVE Gyratory Compactor

	Air Voids (%)	
	Specification	Test Result
$N_{init} = 7$	≥ 11.0	15.5
$N_{design} = 86$	= 4.0	5.3
$N_{max} = 134$	≥ 2.0	3.9

The HMA placed on this project used the 690 kPa (100 psi) end point stress on the Texas gyratory. This was approximately equivalent to an N_{design} of 104 gyrations.

3.8 Summary

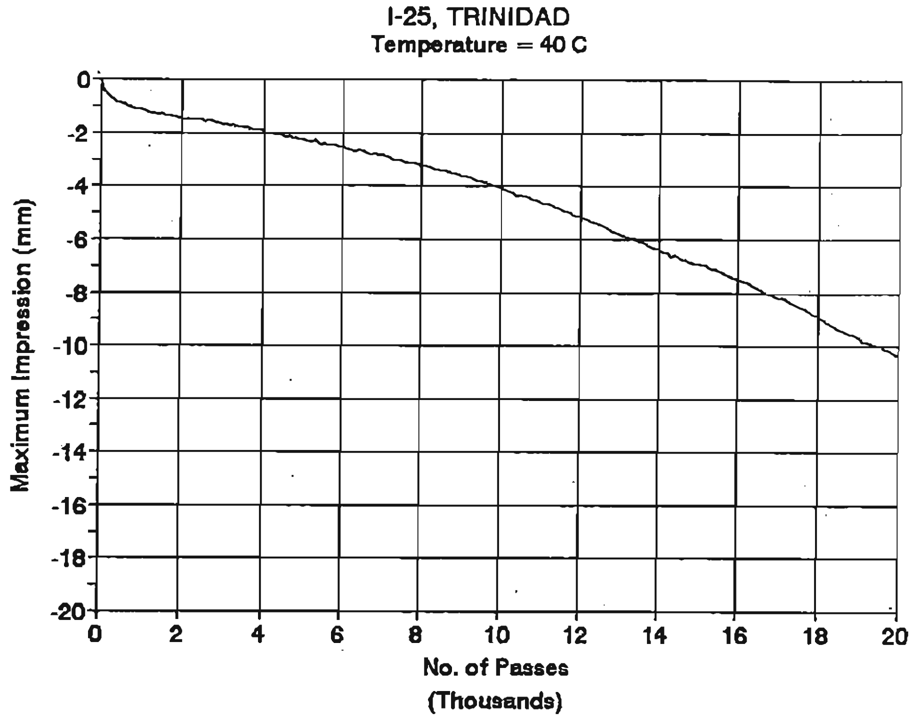
The HMA on this project was produced and placed on the project as designed based on gradation and volumetric properties. Based on the French rutting tester, the HMA pavement should not rut from plastic flow. However, the marginally acceptable AASHTO T 283 results and very poor results in the Hamburg wheel-tracking device indicate that there may be a problem with moisture damage in the future.



Temperature = 55°C
Slope = 0.243
Intercept - 2.146

Temperature = 60°C
Slope = 0.335
Intercept = 1.579

Figure 3. Results from the French Rutting Tester for the Trinidad Project



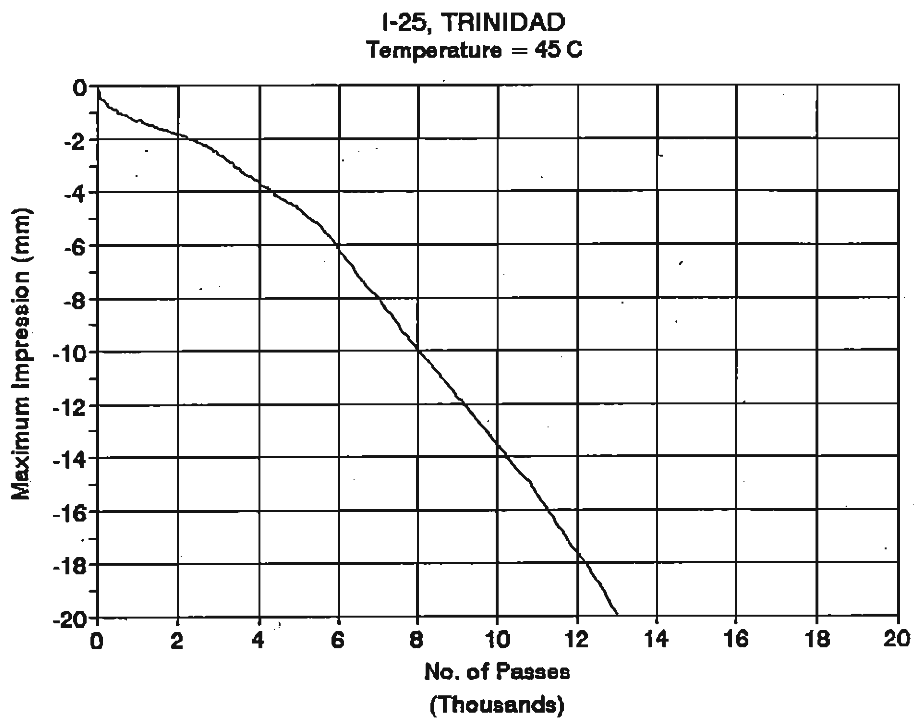


Figure 4. Results from the Hamburg Wheel-Tracking Device for the Trinidad Project

4.0 Walsenburg: M.P. 58.7 to 65.9

4.1 General

This project is on I-25 and is north of Walsenburg in Region 2. It begins at M.P. 58.7 and extends 11.6 km (7.2 miles) north. The total project cost was bid at $2,432,000. The 10-year ESALs in the design lane are 2,382,000. A summary of the general overlay information is shown in Table 14.

Table 14. Overlay Information for the Walsenburg Project

Grading	Quantity	Cost per Unit	Thickness
CX	47,000 tons	$32.39	50 mm
HIPR	198,000 yd^2	$1.88	50 mm

4.2 Pavement Management

The plans specified hot-in-place recycling (HIPR) 50 mm (2 inches) of the existing mat and replacing it with a 50-mm thick overlay of Grading CX with polymer modified asphalt cement.

4.3 Mix Designs

The aggregate and asphalt cement properties are summarized in Table 15. The aggregates came from the Franciscotti sand and gravel pit.

Table 15. Aggregate and Asphalt Cement Summary

Grading	Rock	Crushed Sand	Natural Sand	Hydrated Lime	Asphalt Cement	SUPERPAVE Performance Grade
CX	42%	37%	20%	1%	Koch AC-20P	76-28

The HMA properties are summarized in Table 16. The HMA was designed with the 690 kPa (100 psi) end point stress on the Texas gyratory compactor (ASTM D 4013).

Table 16. Mix Design Summary

Grading	Asphalt Content (%)	Air Voids (%)	VMA (%)	Hveem Stability	AASHTO T 283 (TSR)
CX (Min)	5.3 *	4.0 *	15.1 (14.0)	42 (42)	0.98 (0.80)

* Not Applicable

4.4 Field Verification

The field verification results from the 690 kPa (100 psi) end point stress HMA that were tested in the Region laboratory are shown in Table 17.

Table 17. Field Verification Summary

Grading	Air Voids (%)			VMA (%)			Hveem Stability		
	Avg.	S.D.	n	Avg.	S.D.	n	Avg.	S.D.	n
CX	3.8	0.75	6	14.1	0.55	6	51	2.2	6

The AASHTO T 283 test results (modified Lottman) indicated the HMA was resistant to moisture damage. The TSR averaged 0.91 with a standard deviation of 0.05.

4.5 QC/QA Results

The results from each of the three elements are shown in Table 18. The contractor received a bonus of 2.8%.

Table 18. QC/QA Data Summary

Grading	Field Compaction(%)			Asphalt Content (%)			Gradation			Total
	Avg.	S.D.	n	Avg.	S.D.	n	Avg.	S.D.	n	
CX	93.2	1.08	87	5.3	0.13	19	*	*	19	
Pay Factor	1.011			1.049			1.037			1.028

* Not Applicable

4.6 European Equipment Results

4.6.1 French Rutting Tester

The results from the French rutting tester are shown in Figure 5. The Grading CX passed at the 60°C (140°F) test temperatures with a rutting depth of 2.1%. The test results indicate the HMA should be resistant to rutting.

4.6.2 Hamburg Wheel-Tracking Device

The results from the Hamburg wheel-tracking device are shown in Figure 6. The Grading CX HMA was tested at the 50°C (122°F) and 55°C (131°F) test temperature and had a 2 mm and 8 mm rut depth, respectively. The test results indicate that the HMAs should be resistant to moisture damage.

4.7 Gyratory Results

Field produced HMA that was tested in the French rutting tester and Hamburg wheel-tracking device was also compacted in the SUPERPAVE gyratory. The results from the SUPERPAVE gyratory compactor are shown in Table 19. The gyratory results of the HMA met all of the specifications. In fact, the HMA nearly matched the criteria as if it were designed on the SUPERPAVE gyratory.

Table 19. Test Results from the SUPERPAVE Gyratory Compactor

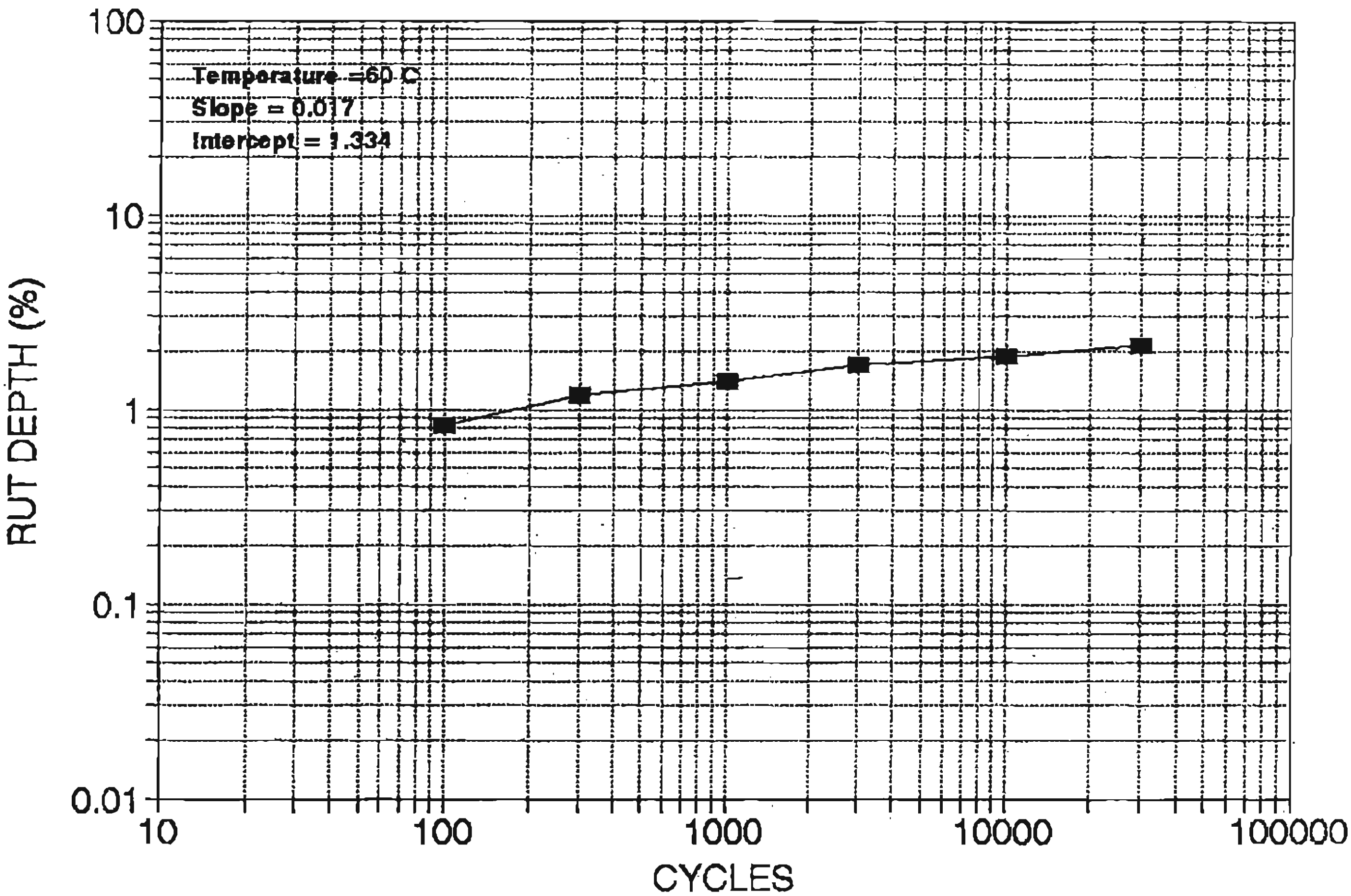
	Air Voids (%)	
	Specification	Test Result
$N_{init} = 8$	≥ 11.0	12.8
$N_{design} = 96$	= 4.0	4.1
$N_{max} = 152$	≥ 2.0	3.0

The HMA placed on this project used the 690 kPa (100 psi) end point stress on the Texas gyratory. This was approximately equivalent to an N_{design} of 100 gyrations.

4.8 Summary

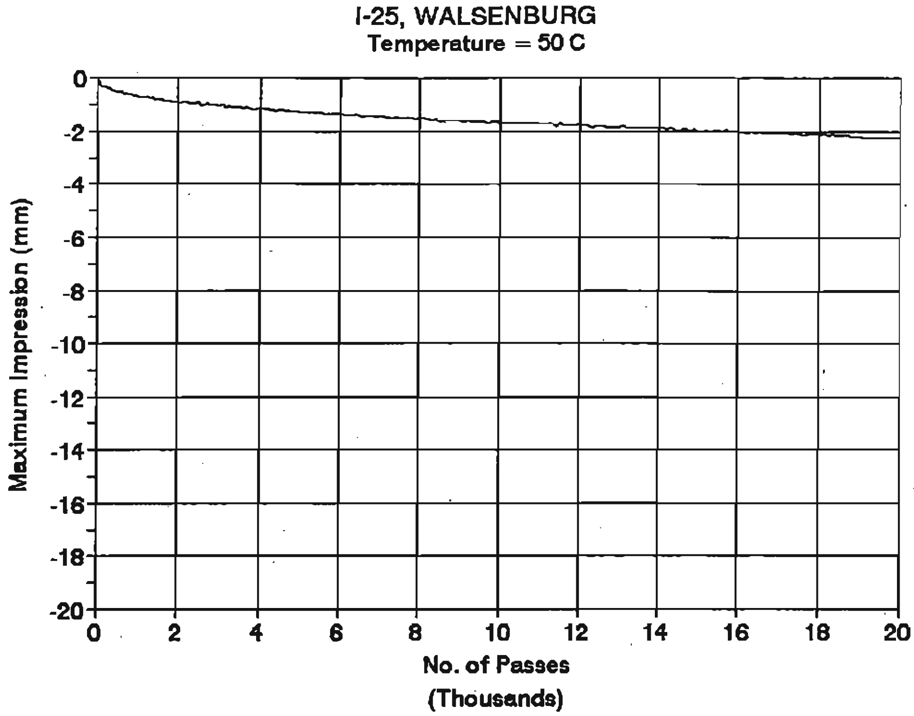
The HMA on this project was produced and placed on the project as designed based on gradation and volumetric properties. Based on the French rutting tester, the HMA pavement should not rut from plastic flow. Additionally, the test results from the Hamburg wheel-tracking device indicated that the HMA should be resistant to moisture damage in the future.

Smoothness was a specification for this project. The contractor received a $8000 bonus. Overall, the project had a ride index of 106 mm/km (6.7 in/mile).



I-25, WALSENBURG

Figure 5. Results from the French Rutting Tester for the Walsenburg Project



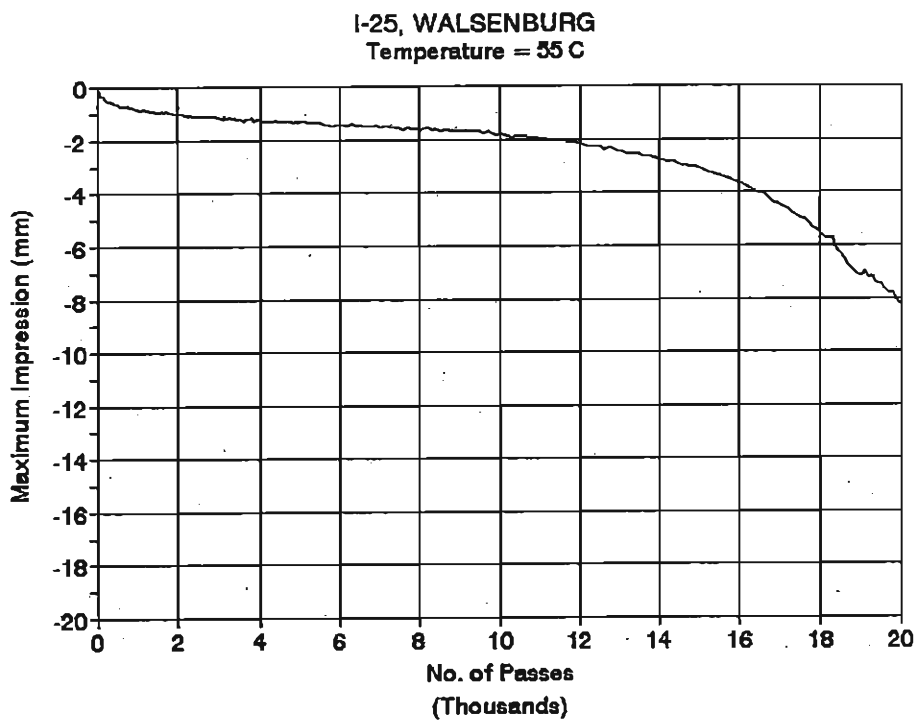


Figure 6. Results from the Hamburg Wheel-Tracking Device for the Walsenburg Project

5.0 Colorado City: M.P. 70.0 to 79.6

5.1 General

This project is on I-25 and goes through Colorado City in Region 2. It begins 7.1 km (4.39 miles) south of the Junction of SH-165 at Colorado City and extends 15.5 km (9.6 miles) north. The total project cost was bid at $5,893,000. The 20-year ESALs in the design lane are 5,245,000. A summary of the general overlay information is shown in Table 20.

Table 20. Overlay Information for the Colorado City Project

Grading	Quantity	Cost per Unit	Thickness
CX	54,000 tons	$28.20	50 mm
C	64,000 tons	$21.90	50 mm
CIPR	428,000 yd^2	$1.05	100 mm

5.2 Pavement Management

The plans specified cold-in-place recycling (CIPR) 100 mm (4 inches) of the existing mat and replacing it with a 50-mm thick overlay of Grading C. A second lift of Grading CX was placed 50-mm thick and had a polymer modified asphalt cement.

5.3 Mix Designs

The aggregate and asphalt cement properties are summarized in Table 21. The rock and crushed sand came from the Franciscotti sand and gravel pit for the Grading C HMA. For the Grading CX HMA, a crushed sand from the Chantala sand and gravel pit was also used.

The HMA properties are summarized in Table 22. The mix design used the 690 kPa (100 psi) end point stress on the Texas gyratory compactor (ASTM D 4013).

5.4 Field Verification

The field verification results were tested in the Region laboratory and are shown in Table 23 for both the Grading C and CX HMAs. The Grading C HMA was built as it was designed.

Table 21. Aggregate and Asphalt Cement Summary

Grading	Rock	Crushed Sand (FSCT)	Crushed Sand (CTLA)	Natural Sand	Hydrated Lime	Asphalt Cement	SUPERPAVE Performance Grade
CX	39%	25%	15%	20%	1%	Koch AC-20P	70-28
C	45%	34%	0%	20%	1%	Conoco AC-20	64-22*

* Based on testing of Conoco AC-20 from other projects.

Table 22. Mix Design Summary

Grading	Asphalt Content (%)	Air Voids (%)	VMA (%)	Hveem Stability	AASHTO T 283 (TSR)
CX (Min)	5.4 *	4.0 *	14.7 (14.0)	41 (42)	(0.80)
C (Min)	4.9 *	4.0 *	13.3 (13.0)	45 (42)	1.03 (0.80)

* Not Applicable

Seven different Form 43s were used for the Grading C HMA. After initial production, there was an increase in the air voids in the field produced material compared with the laboratory mix design. The second Form 43 increased the asphalt content by 0.5% to 5.4%. The third Form 43 was used to adjust the asphalt content to 5.3% where it stayed for most of the project. The fourth and fifth Form 43s were used by the contractor to produce the HMA at 5.1% asphalt content for two days, and then switched back to 5.3%. The final two Form 43's were used to adjust the maximum theoretical specific gravity (AASHTO T 209) used to control field compaction.

For the Grading CX HMA there were two Form 43s. One of the HMAs had the Koch AC-20P with 5.1% asphalt content and was used in the travel lanes. The second Form 43 had Conoco AC-20 with 5.5% asphalt content and was used in the shoulders and on the ramps.

For the Grading CX HMA, the air voids stayed at the design value. Unfortunately, the VMA was about 1.0% lower than the specified value.

Table 23. Field Verification Summary

Grading	Air Voids (%)			VMA (%)			Hveem Stability		
	Avg.	S.D.	n	Avg.	S.D.	n	Avg.	S.D.	n
CX	3.4	0.42	55	13.2	0.42	55	48	4.5	55
C	3.8	0.58	59	13.2	0.26	59	45	1.8	59

The AASHTO T 283 test results (modified Lottman) indicated the HMAs were very good. For the Grading C, the TSR averaged 0.94 with a standard deviation of 0.04. For the Grading CX, the TSR averaged 0.99 with a standard deviation of 0.06.

5.5 QC/QA Results

This project used a quality level analysis of volumetric test results for the pay factor. The five elements were field compaction, air voids, VMA, asphalt content and Hveem stability. The results from each of the elements are shown in Table 24. The contractor received a bonus of 2.3% on the Grading C HMA. Even though the asphalt content element had a disincentive of 6.2%, its weight was only 5%. All of the other elements were incentives. A disincentive of 1.7% was assessed on the Grading CX HMA. The disincentive was controlled primarily by the field compaction element that had a 7.0% disincentive and a weight of 40%.

Table 24. QC/QA Data Summary

Grading	Field Compaction(%)			Asphalt Content (%)			Air Voids (%)	VMA (%)	Hveem Stab.	Total
	Avg.	S.D.	n	Avg.	S.D.	n				
CX	93.1	1.36	110	5.22	0.23	55				
Pay Factor	0.930			1.041			1.029	0.996	1.050	0.983
C	93.1	1.10	113	5.34	0.25	59				
Pay Factor	1.007			0.938			1.037	1.047	1.047	1.023

5.6 European Equipment Results

5.6.1 French Rutting Tester

The results from the French rutting tester are shown in Figures 7 and 8. The Grading C HMA passed at the 55°C (131°F) with a rut depth of 4.4%. The Grading CX passed at both the 55°C (131°F) and 60°C (140°F) test temperatures with a rutting depth of 2.0% and 2.9%, respectively. The test results indicate the HMAs should be resistant to rutting.

5.6.2 Hamburg Wheel-Tracking Device

The results from the Hamburg wheel-tracking device are shown in Figures 9 and 10. The Grading C HMA had a rut depth of 6 mm at the 45°C (113°F) test temperature. The Grading CX HMA was tested at the 50°C (122°F) test temperature and had an 11 mm rut depth. The test results indicate that the HMAs should be resistant to moisture damage.

5.7 Gyratory Results

Field produced HMA that was tested in the French rutting tester and Hamburg wheel-tracking device was also compacted in the SUPERPAVE gyratory. The results from the SUPERPAVE gyratory compactor are shown in Table 25. The gyratory results of the HMA met all of the specifications. In fact, the HMA nearly matched the criteria as if it were designed on the SUPERPAVE gyratory.

Table 25. Test Results from the SUPERPAVE Gyratory Compactor

	Air Voids (%)	
	Specification	Test Result
N_{init} = 8	≥ 11.0	13.0
N_{design} = 96	= 4.0	4.3
N_{max} = 152	≥ 2.0	3.1

The HMA placed on this project used the 690 kPa (100 psi) end point stress on the Texas gyratory. This was approximately equivalent to an N_{design} of 135 gyrations.

5.8 Summary

The HMA on this project was produced and placed on the project as designed based on gradation and volumetric properties. Based on the French rutting tester, the HMA pavement should not rut from plastic flow. Additionally, the test results from the Hamburg wheel-tracking device indicated that the HMA should be resistant to moisture damage in the future.

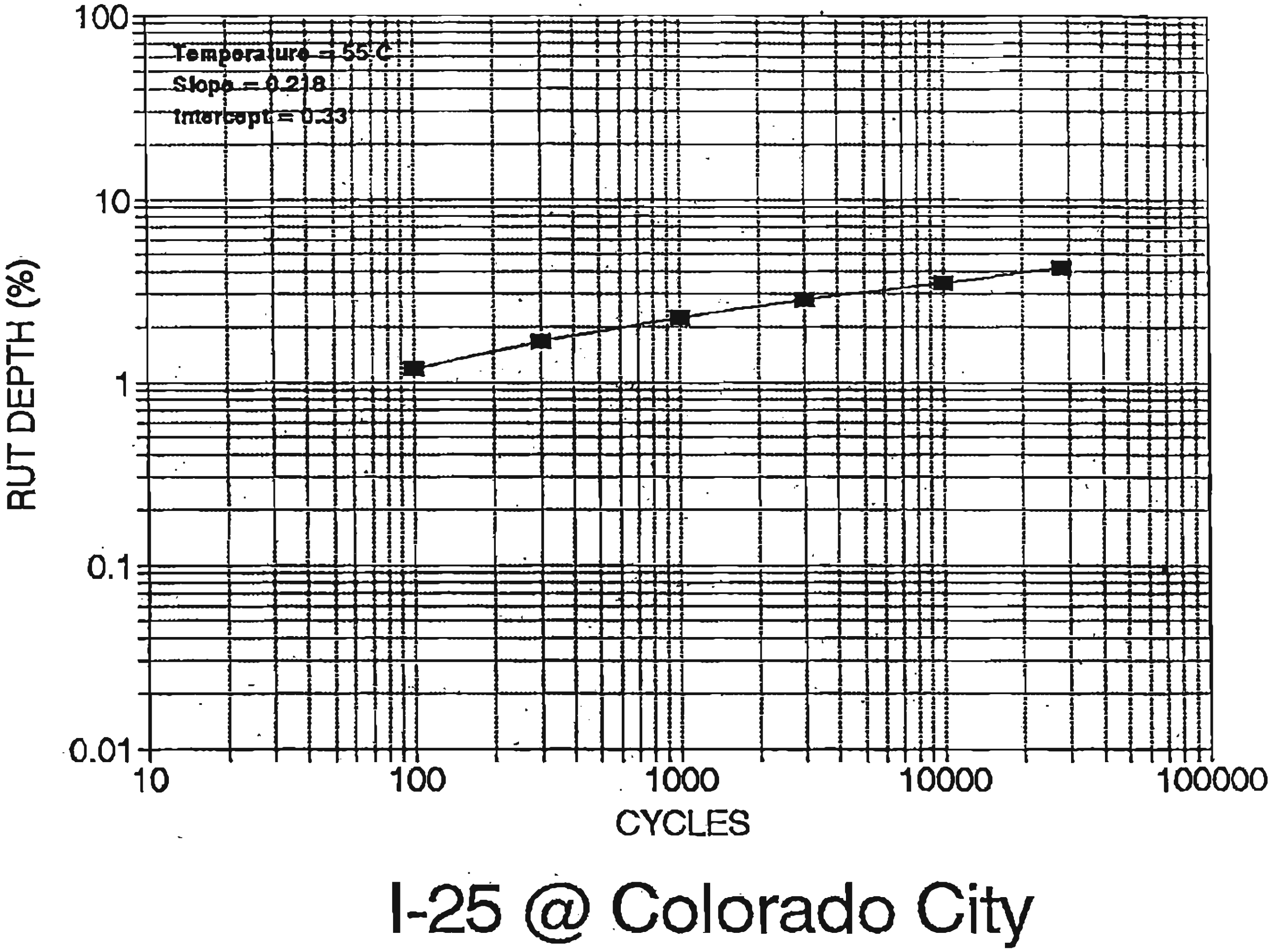
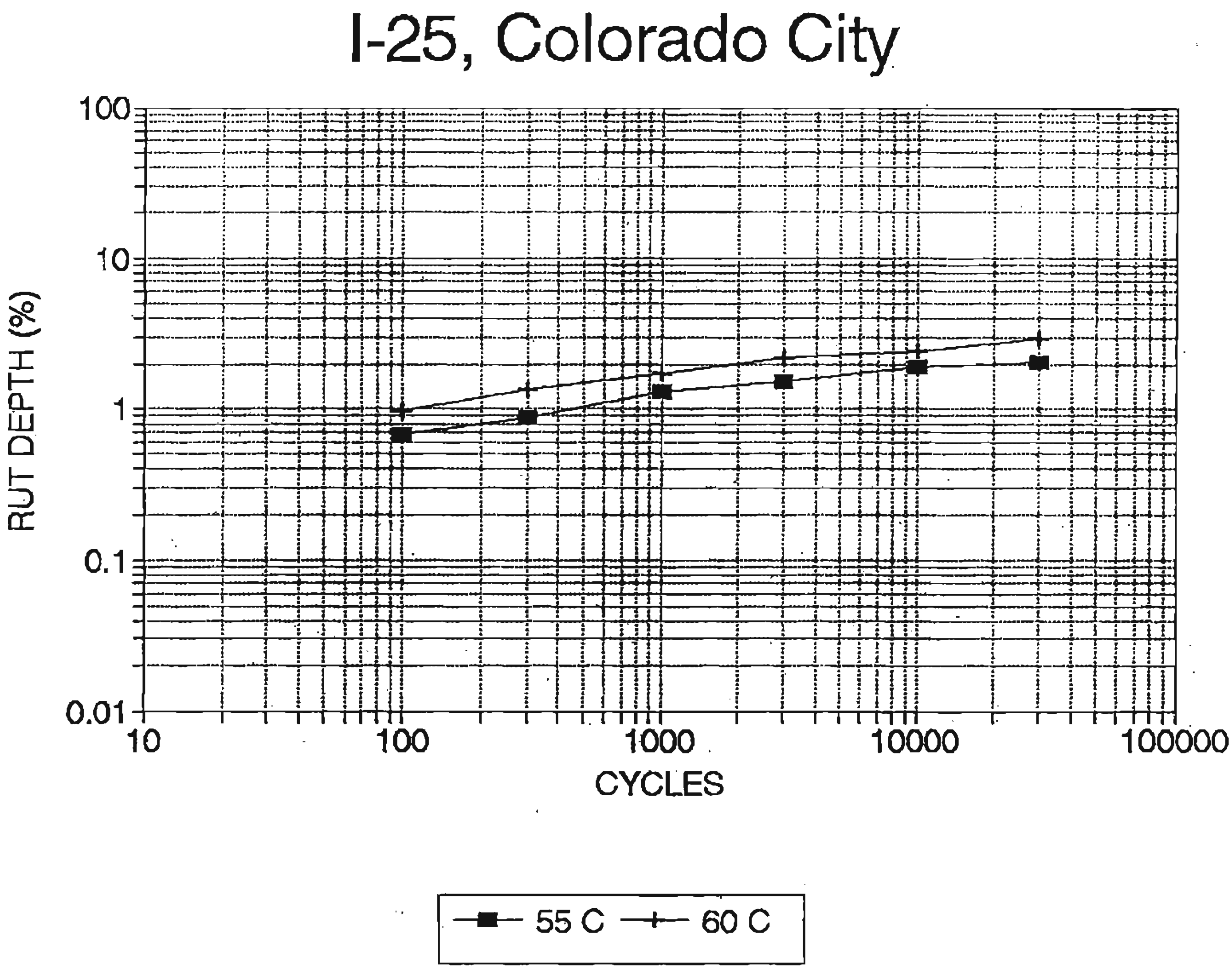
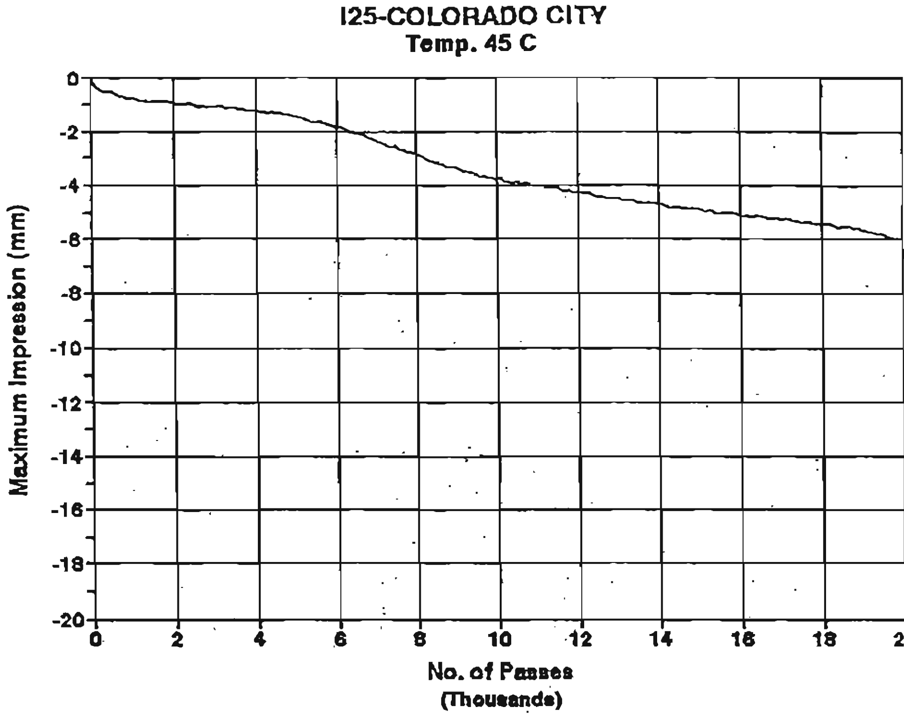


Figure 7. Results from the French Rutting Tester (Grading C) for the Colorado City Project




```
Temperature = 55°C          Temperature = 60°C
Slope = 0.197               Slope = 0.186
Intercept = 1.157           Intercept = 1.612
```

Figure 8. Results from the French Rutting Tester (Grading CX) for the Colorado City Project



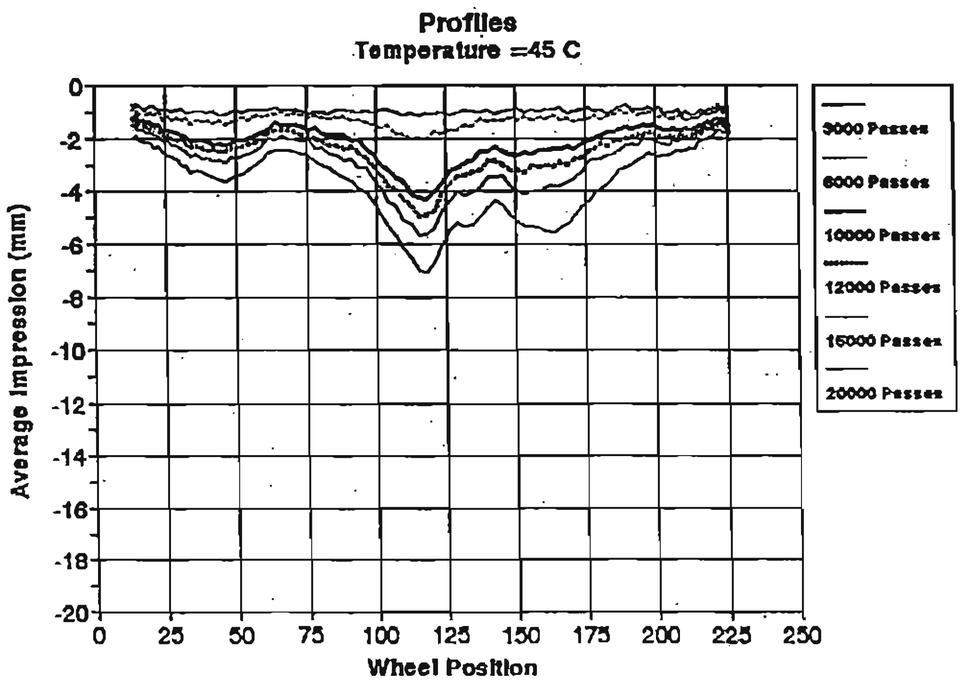
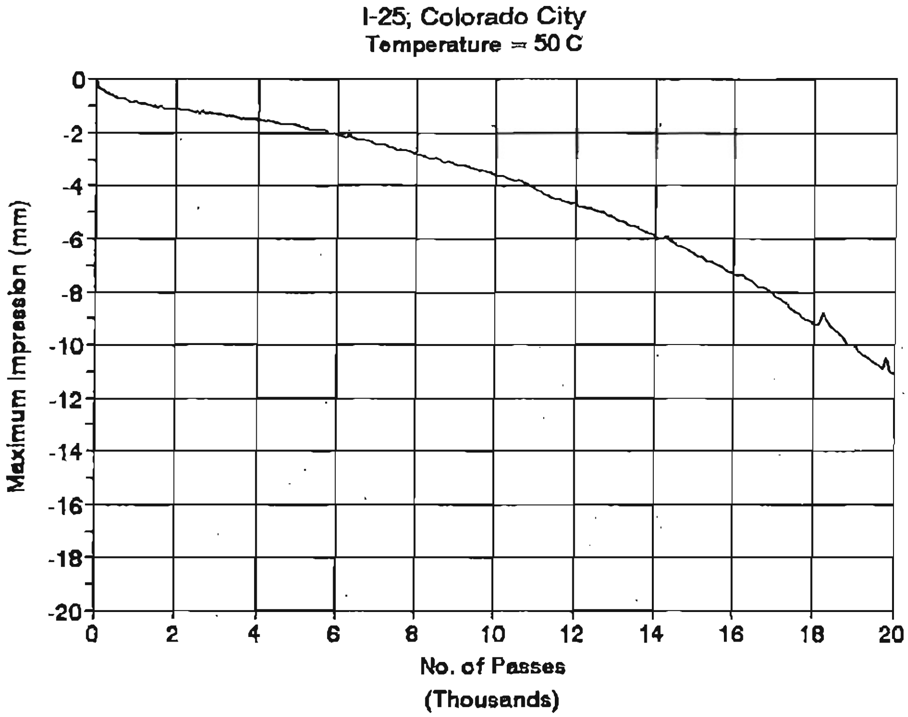


Figure 9. Results from the Hamburg Wheel-Tracking Device (Grading C) for the Colorado City Project



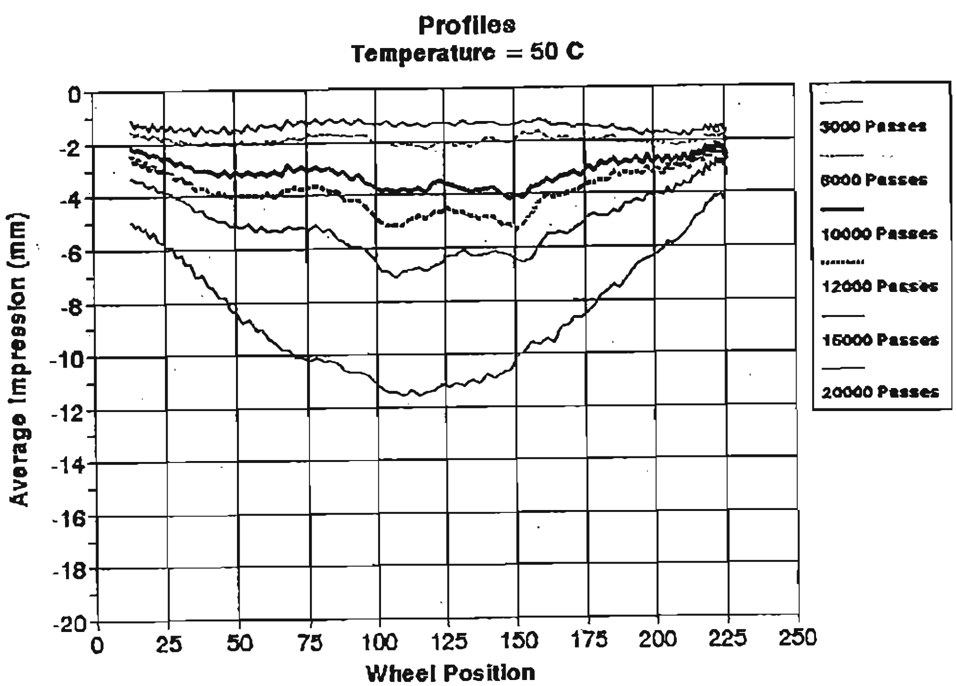


Figure 10. Results from the Hamburg Wheel-Tracking Device (Grading CX) for the Colorado City Project

6.0 Colorado Springs: M.P. 139.6 to 148.0

6.1 General

This project is on I-25 and goes through Colorado Springs in Region 2. It begins approximately 0.2 km (0.15 miles) south of Nevada Avenue and extends 13.5 km (8.4 miles) north, approximately 1.3 km (0.8 miles) south of Woodman Road. This project was extended to M.P. 150.36 in order to connect to the project at the Air Force Academy. The project length was 17.4 km (10.8 miles). The total project cost was bid at $1,319,000. The 10-year ESALs in the design lane are 6,482,000. A summary of the general overlay information is shown in Table 26. This was a night paving operation.

Table 26. Overlay Information for the Colorado Springs Project

Grading	Tons	Cost per Ton	Thickness
CX	44,000	$21.40	50 mm
Milling	NA	NA	25 mm

6.2 Pavement Management

The plans specified milling 25 mm (1 inch) of the existing mat and replacing it with a 50-mm thick overlay of Grading CX.

6.3 Mix Designs

The aggregate and asphalt cement properties are summarized in Table 27. The aggregate came from the Fountain sand and gravel pit.

Table 27. Aggregate and Asphalt Cement Summary

12.5 mm (1/2") Rock	Crushed Fines	Natural Sand	RAP	Hydrated Lime	Asphalt Cement	SUPERPAVE Performance Grade
25%	39%	20%	15%	1%	Conoco AC-10	58-22

The HMA properties are summarized in Table 28. The mix design used the 1030 kPa (150 psi) end point stress on the Texas gyratory compactor (ASTM D 4013).

Table 28. Mix Design Summary

Grading	Asphalt Content (%)	Air Voids (%)	VMA (%)	Hveem Stability	AASHTO T 283 (TSR)
CX (Min)	5.4 *	4.0 *	14.4 (14.0)	44 (42)	1.01 (0.80)

* Not Applicable

6.4 Field Verification

One Form 43 was used for the entire project; no adjustments were made.

The field verification results were tested in the Region laboratory and are shown in Table 29. The HMA was built as designed. Although there was a slight loss in air voids, this was not a concern. The design compactive effort was greater than it should have been since it was a project from 1993.

Table 29. Field Verification Summary

Grading	Air Voids (%)			VMA (%)			Hveem Stability		
	Avg.	S.D.	n	Avg.	S.D.	n	Avg.	S.D.	n
CX	3.2	0.44	7	14.1	0.31	7	44	1.8	7

The AASHTO T 283 test results (modified Lottman) indicated the HMA was resistant to moisture damage. The six tests had an average TSR of 1.19 with a standard deviation of 0.10.

6.5 QC/QA Results

The pay factor for this project was based on the quality level analysis of field compaction, asphalt content, and gradation. The results from each of the three elements are shown in Table 30. The contractor received a bonus of 2.0%.

Table 30. QC/QA Data Summary

Grading	Field Compaction(%)			Asphalt Content (%)			Gradation			Total
	Avg.	S.D.	n	Avg.	S.D.	n	Avg.	S.D.	n	
CX	93.0	0.97	106	5.4	0.17	43	*	*	37	
Pay Factor	1.007			1.045			1.014			1.020

* Not Applicable

6.6 European Equipment Results

6.6.1 French Rutting Tester

The results from the French rutting tester are shown in Figure 11. The Grading CX HMA passed at both the 55°C (131°F) and 60°C (140°F) test temperatures with a rutting depth of 5.3% and 6.2%, respectively. The test results indicate the HMAs should be resistant to rutting.

6.6.2 Hamburg Wheel-Tracking Device

The results from the Hamburg wheel-tracking device are shown in Figure 12. The Grading CX HMA had a rut depth of 2.8 mm at the 40°C (104°F) test temperature and at the 45°C (113°F) test temperature had an 9.2 mm rut depth. The test results indicate that the HMAs should be resistant to moisture damage.

6.7 Gyratory Results

Field produced HMA that was tested in the French rutting tester and Hamburg wheel-tracking device was also compacted in the SUPERPAVE gyratory. The results from the SUPERPAVE gyratory compactor are shown in Table 31. The gyratory results of the HMA met all of the specifications. In fact, the HMA probably had 0.2% to 0.3% too much asphalt cement.

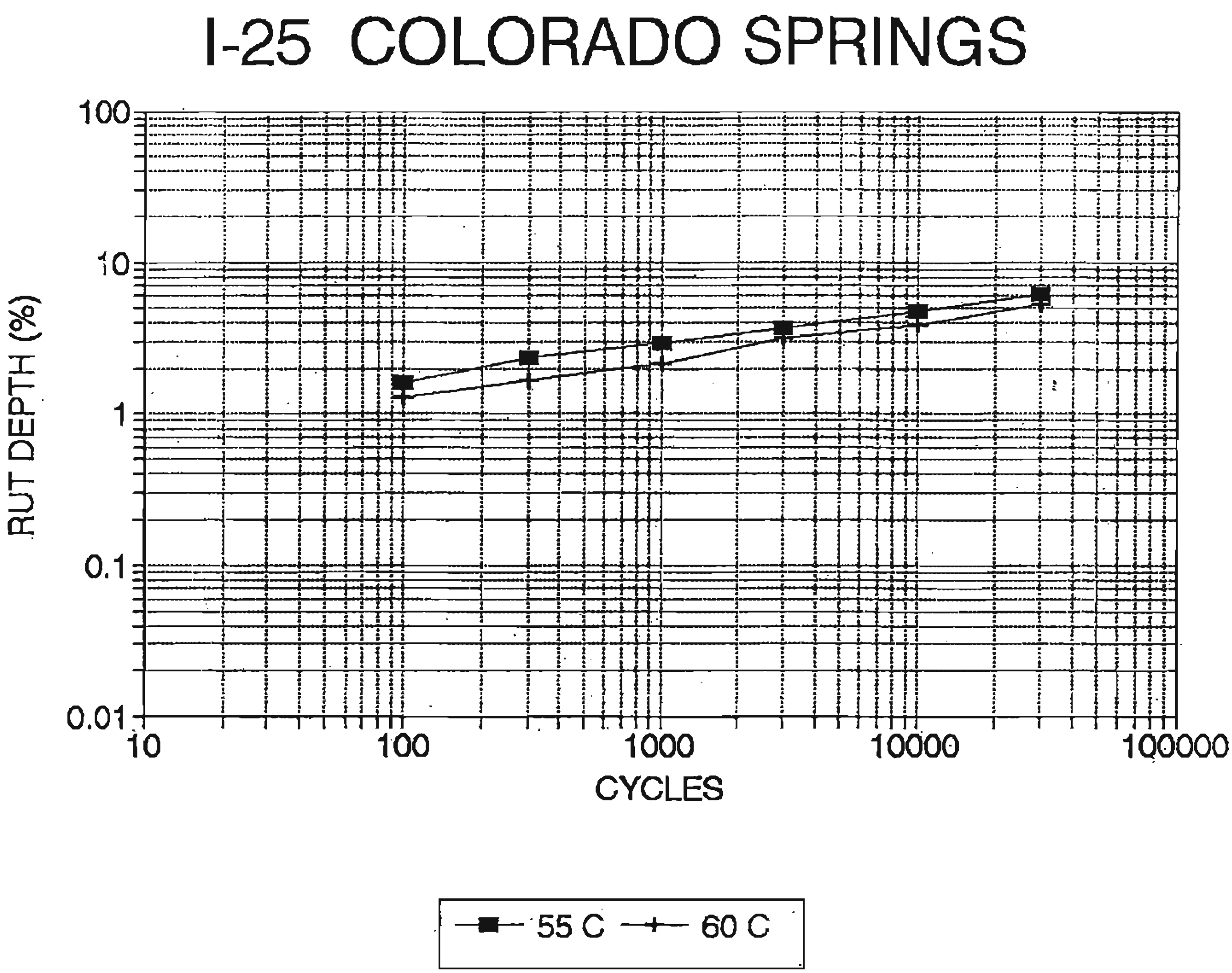
Table 31. Test Results from the SUPERPAVE Gyratory Compactor

	Air Voids (%)	
	Specification	Test Result
$N_{init} = 8$	≥ 11.0	11.1
$N_{design} = 96$	= 4.0	3.3
$N_{max} = 152$	≥ 2.0	2.4

The HMA placed on this project used the 1030 kPa (150 psi) end point stress on the Texas gyratory. This was approximately equivalent to an N_{design} of 101 gyrations.

6.8 Summary

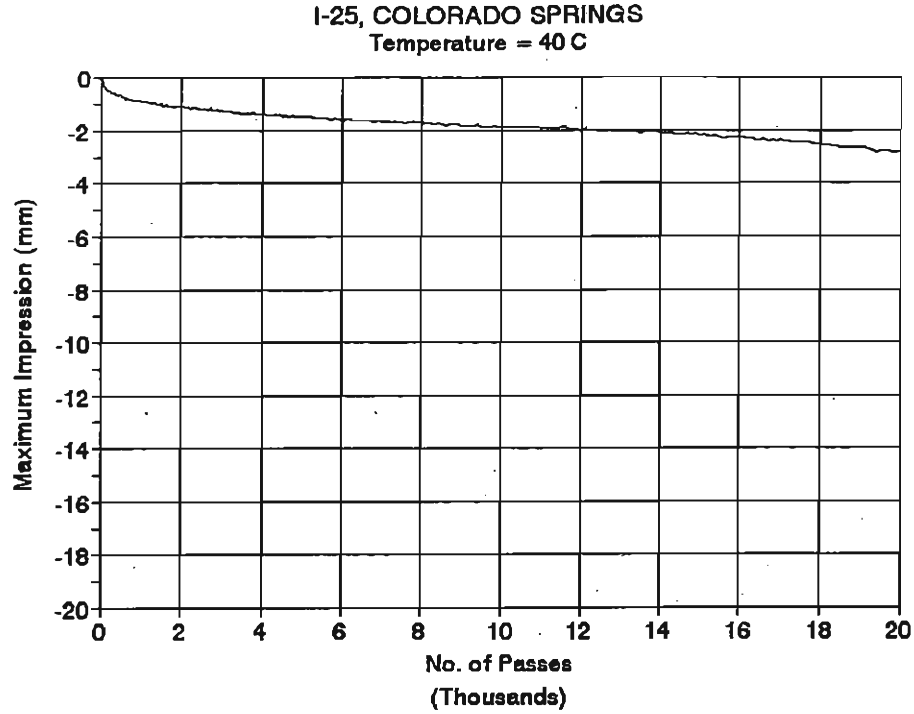
The HMA on this project was produced and placed on the project as designed based on gradation and volumetric properties. Based on the French rutting tester, the HMA pavement should not rut from plastic flow. Additionally, the test results from the Hamburg wheel-tracking device indicated that the HMA should be resistant to moisture damage in the future.



Temperature = 55°C
Slope = 0.250
Intercept = 2.232

Temperature = 60°C
Slope = 0.226
Intercept = 2.869

Figure 11. Results from the French Rutting Tester for the Colorado Springs Project



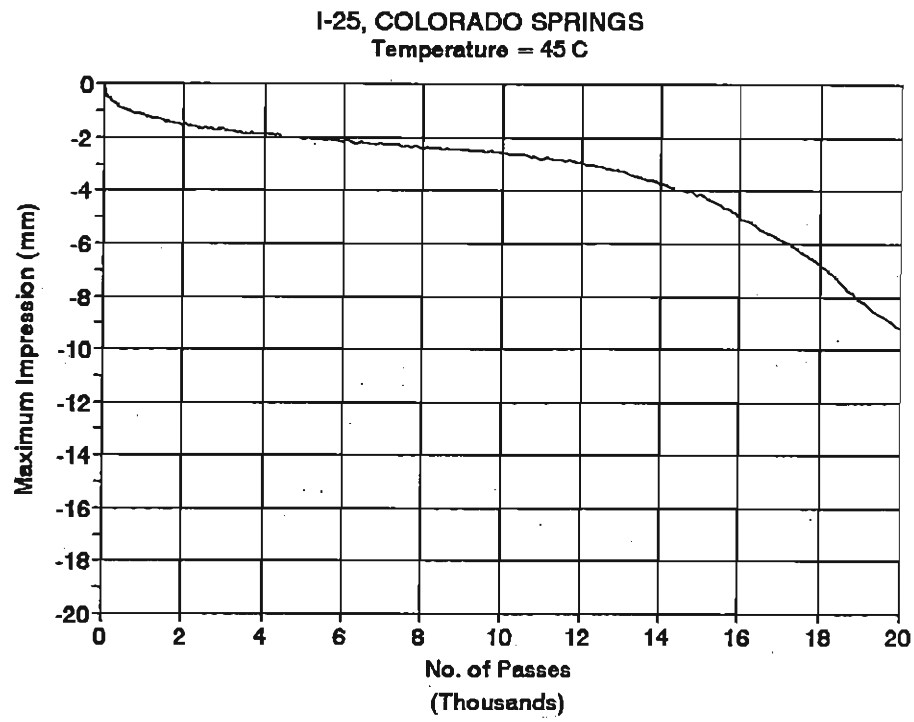


Figure 12. Results from the Hamburg Wheel-Tracking Device for the Colorado Springs Project

7.0 Air Force Academy: M.P. 150.36 to 155.60

7.1 General

This project is on I-25 and goes by the Air Force Academy (AFA) in Region 2. It begins at the intersection of SH-83 (Black Forest/South AFA Entrance) and extends 8.5 km (5.24 miles) to the north. The total project cost was bid at $1,090,000. The 10-year ESALs in the design lane are 6,932,000. A summary of the general overlay information is shown in Table 32. This was a night paving operation.

Table 32. Overlay Information for the Air Force Academy Project

Grading	Tons	Cost per Ton	Thickness
C	30,000	$28.59	50 mm
Milling	NA	NA	25 mm

7.2 Pavement Management

The plans specified milling 25 mm (1 inch) of the existing mat and replacing it with a 50-mm thick overlay of Grading C with a polymer modified asphalt cement.

7.3 Mix Designs

The aggregate and asphalt cement properties are summarized in Table 33. The coarse aggregate came from the Pikeview quarry. The crushed fine aggregate came from the Eightmile Breeze sand and gravel pit. A washed concrete sand from the Blue Heron sand and gravel pit was also used.

Table 33. Aggregate and Asphalt Cement Summary

19.0mm (3/4") Rock	12.5mm (1/2") Rock	Crushed Fines	Concrete Sand	RAP	Hydrated Lime	Asphalt Cement	SUPERPAVE Performance Grade
20%	17%	19%	23%	20%	1%	Koch AC-20P	64-28

The HMA properties are summarized in Table 34. The mix design used the 690 kPa (100 psi) end point stress on the Texas gyratory compactor (ASTM D 4013).

Table 34. Mix Design Summary

Grading	Asphalt Content (%)	Air Voids (%)	VMA (%)	Hveem Stability	AASHTO T 283 (TSR)
C (Min)	5.1 *	4.0 *	15.1 (14.0)	48 (42)	0.98 (0.80)

* Not Applicable

7.4 Field Verification

Two different HMAs were used for the project. Initially, the HMA produced did not match the mix design at all, as shown in Table 35. The contractor and project personnel tried several different alternatives to improve the mix. The alternatives included adjusting RAP quantity, gradation, and asphalt content. The HMA finally selected for the majority of the project was the HMA with the slightly lower (0.3%) asphalt content.

Table 35. Field Verification Summary

Grading	Air Voids (%)			VMA (%)			Hveem Stability		
	Avg.	S.D.	n	Avg.	S.D.	n	Avg.	S.D.	n
C (5.1% AC)	2.2	0.39	5	13.4	0.38	5	51	3.3	5
C (4.9% AC)	3.6	0.54	8	13.7	0.18	8	53	1.7	8

The AASHTO T 283 test results (modified Lottman) indicated the HMA was resistant to moisture damage. The five tests had an average TSR of 1.06 with a standard deviation of 0.10.

7.5 QC/QA Results

The pay factor for this project was based on the quality level analysis of field compaction, asphalt content, and gradation. The results from each of the three elements are shown in Table 36.

The contractor received a bonus of 2.1%.

Table 36. QC/QA Data Summary

Grading	Field Compaction(%)			Asphalt Content (%)			Gradation			Total
	Avg.	S.D.	n	Avg.	S.D.	n	Avg.	S.D.	n	
C (5.1% AC)	93.7	0.30	14	5.1	0.15	10	*	*	8	1.013
Pay Factor	1.004			1.050			0.981			
C (4.9% AC)	93.5	0.86	45	4.8	0.18	29	*	*	22	1.024
Pay Factor	1.033			1.043			0.975			

* Not Applicable

7.6 European Equipment Results

7.6.1 French Rutting Tester

The results from the French rutting tester are shown in Figure 13. The Grading C HMA passed at both the 55°C (131°F) and 60°C (140°F) test temperatures with a rutting depth of 3.9% and 4.5%, respectively. The test results indicate the HMA should be resistant to rutting.

7.6.2 Hamburg Wheel-Tracking Device

The results from the Hamburg wheel-tracking device are shown in Figure 14. The Grading C HMA had a rut depth of 2.4 mm at the 45°C (113°F) test temperature and at the 50°C (122°F) test temperature had an 9.3 mm rut depth. The test results indicate that the HMA should be resistant to moisture damage.

7.7 Gyratory Results

Field produced HMA that was tested in the French rutting tester and Hamburg wheel-tracking device was also compacted in the SUPERPAVE gyratory. The results from the SUPERPAVE gyratory compactor are shown in Table 37. The gyratory results of the HMA did not meet any of the specifications. In fact, the HMA probably had 0.6% to 0.8% too much asphalt cement.

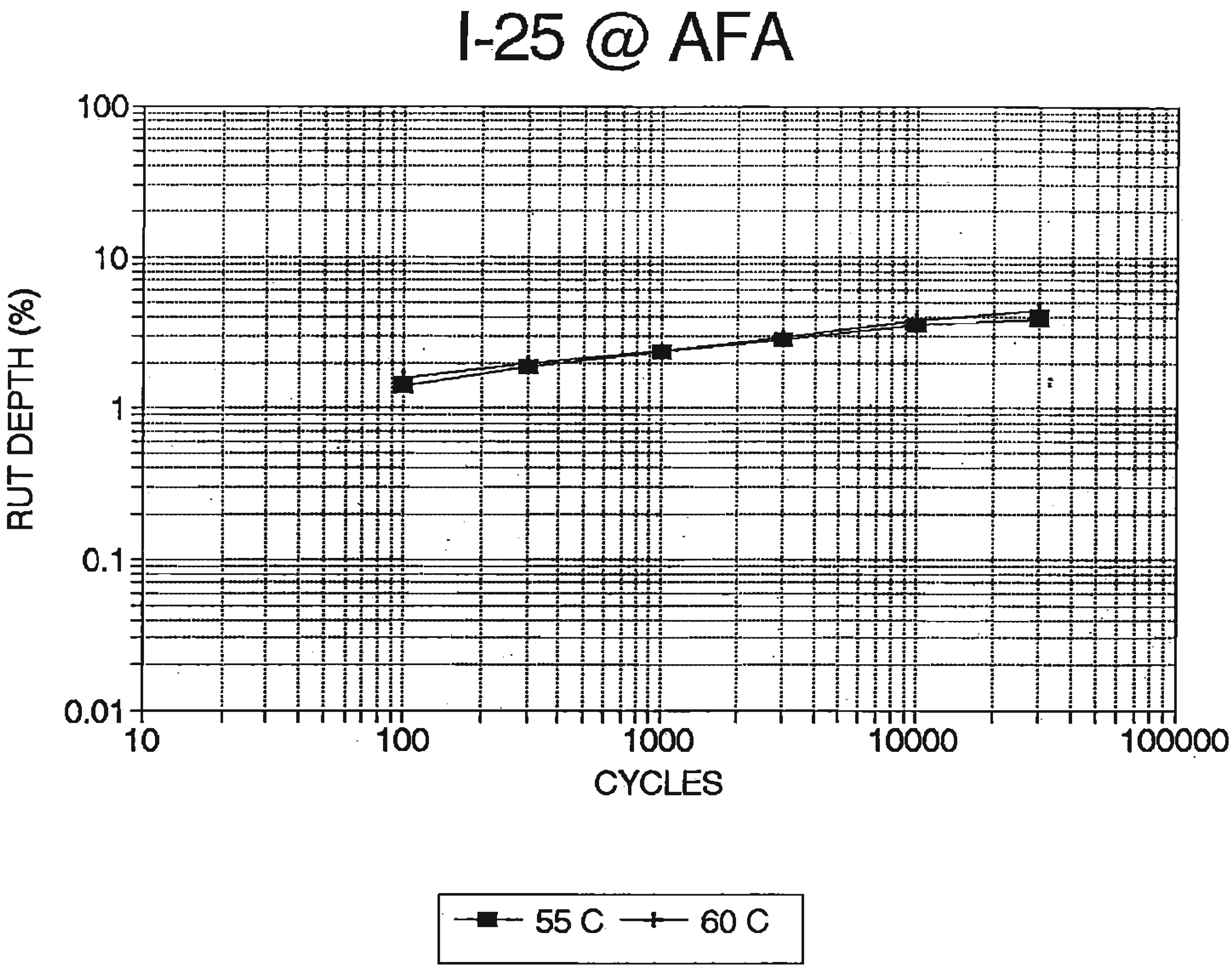
Table 37. Test Results from the SUPERPAVE Gyratory Compactor

	Air Voids (%)	
	Specification	Test Result
N_{init} = 8	≥ 11.0	8.6
N_{design} = 96	= 4.0	1.3
N_{max} = 152	≥ 2.0	1.0

The HMA placed on this project used the 690 kPa (100 psi) end point stress on the Texas gyratory. This was approximately equivalent to an N_{design} of 27 gyrations.

7.8 Summary

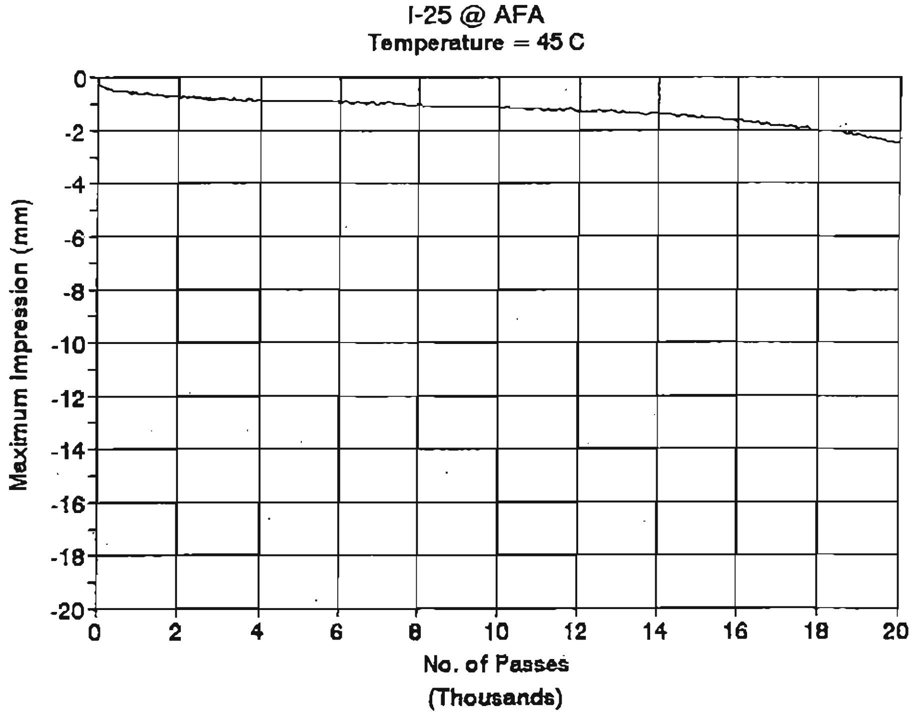
The HMA on this project was produced and placed on the project as designed based on gradation and volumetric properties. Based on the French rutting tester, the HMA pavement should not rut from plastic flow. Additionally, the test results from the Hamburg wheel-tracking device indicated that the HMA should be resistant to moisture damage in the future.



Temperature = 55°C
Slope = 0.179
Intercept = 2.244

Temperature = 60°C
Slope = 0.182
Intercept = 2.426

Figure 13. Results from the French Rutting Tester for the Air Force Academy Project



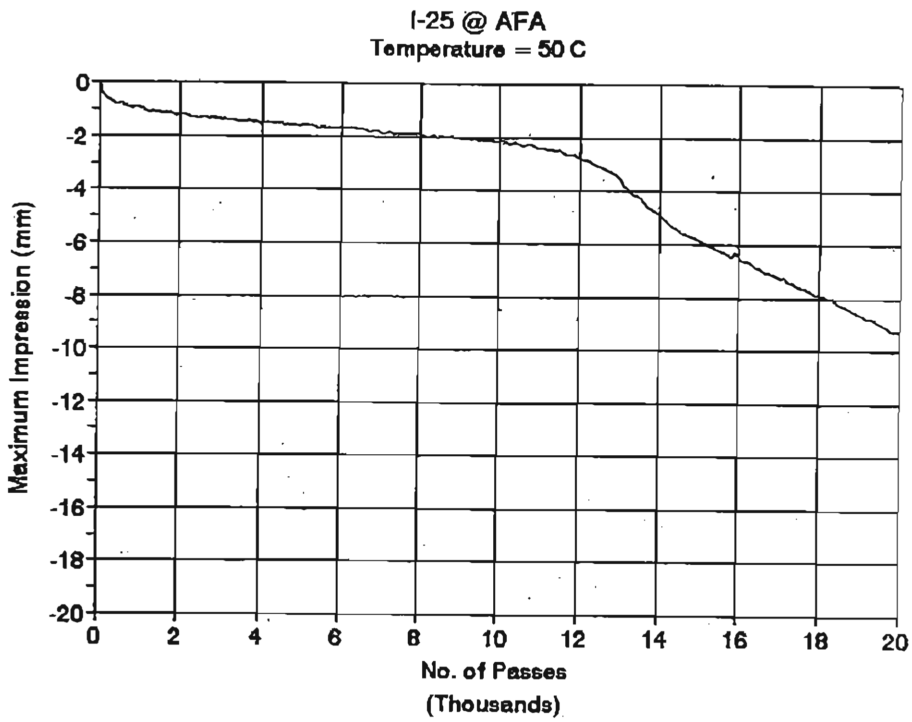


Figure 14. Results from the Hamburg Wheel-Tracking Device for the Air Force Academy Project

8.0 Monument: M.P. 159.92 to 167.42

8.1 General

This project is on I-25 and goes through Monument. It is the combination of two different projects; one developed by Region 1, and the other developed by Region 2. The combined project begins 5.6 km (3.45 miles) south of the Douglas County Line and extends 12.1 km (7.5 miles) north. The total project cost was bid at $4,424,000. The 10-year ESALs in the design lane are 6,343,000. A summary of the general overlay information is shown in Tables 38 and 39.

Table 38. Overlay Information for the Monument Project: M.P. 159.92 to 163.37

	Grading	Tons	Cost per Ton	Thickness
Northbound	C	18,000	$29.70	64 mm
	Milling	NA	NA	50 mm
Southbound	C	25,000	$29.70	100 mm
	Milling	NA	NA	100 mm

Table 39. Overlay Information for the Monument Project: M.P. 163.37 to 167.42

	Grading	Tons	Cost per Ton	Thickness
Northbound	C	12,000	$29.70	50 mm
Southbound	PMSC	6,000	$32.60	25 mm

8.2 Pavement Management

The portion of the project extending from M.P. 159.92 to 163.37 was designed by Region 2. In the northbound lanes, the plans specified milling 50 mm (2 inches) of the existing mat and replacing it with one, 64-mm (2.5-inch) thick overlay. The overlay is Grading C with a polymer modified asphalt cement. In the southbound lanes, the plans specify milling 100 mm (4 inches) of the existing mat and replacing it with two, 50-mm thick lifts of Grading C with polymer modified asphalt. The southbound lanes were over an existing concrete pavement.

The portion of the project extending from M.P. 163.37 to 167.42 was designed by Region 1. In the northbound lanes a 50-mm thick overlay was placed on the existing pavement. The overlay is Grading C with a polymer modified asphalt cement. In the southbound lanes, a 25-mm thick plant mixed seal coat (PMSC), Type B, was placed on the existing pavement.

8.3 Mix Designs

The aggregate and asphalt cement properties are summarized in Table 40. The aggregate came from the Menzer quarry. The fine aggregates were either a granite sand that came straight out of the quarry or a washed granite sand.

Table 40. Aggregate and Asphalt Cement Summary

19.0 mm (3/4") Rock	Crushed Fines	Washed Fines	Hydrated Lime	Asphalt Cement	SUPERPAVE Performance Grade
45%	24%	30%	1%	Koch AC-20P	64-28

The HMA properties are summarized in Table 41. The mix design used the 690 kPa (100 psi) end point stress on the Texas gyratory compactor (ASTM D 4013).

Table 41. Mix Design Summary

Grading	Asphalt Content (%)	Air Voids (%)	VMA (%)	Hveem Stability	AASHTO T 283 (TSR)
C (Min)	5.5 *	4.0 *	15.3 (13.0)	44 (42)	1.01 (0.80)

* Nct Applicable

8.4 Field Verification

Two Form 43s were used for the entire project. When paving started, the field verification air voids were approximately 1.5%. The contractor adjusted the gradation to use 54% of the washed granite sand and the optimum asphalt content was 5.0%. The contractor then produced the HMA at the 5.0% asphalt content and was near the target of 4.0% air voids. The field verification laboratory test results were tested in the Region and are shown in Table 42.

Table 42. Field Verification Summary

Grading	Air Voids (%)			VMA (%)			Hveem Stability		
	Avg.	S.D.	n	Avg.	S.D.	n	Avg.	S.D.	n
C	4.0	0.54	46	13.9	0.39	46	51	2.7	46

The AASHTO T 283 test results (modified Lottman) indicated the HMA was resistant to moisture damage. The three tests had an average TSR of 1.04 with a standard deviation of 0.05.

8.5 QC/QA Results

The pay factor for this project was based on the quality level analysis of field compaction, asphalt content, and gradation. The results from each of the three elements are shown in Table 43. The contractor received a bonus of 2.9%.

Table 43. QC/QA Data Summary

Grading	Field Compaction(%)			Asphalt Content (%)			Gradation			Total
	Avg.	S.D.	n	Avg.	S.D.	n	Avg.	S.D.	n	
C	93.5	0.92	75	5.1	0.17	31	*	*	21	
Pay Factor	1.034			1.035			1.008			1.029

* Not Applicable

8.6 European Equipment Results

8.6.1 French Rutting Tester

The results from the French rutting tester are shown in Figure 15. The Grading C HMA passed at both the 55°C (131°F) and 60°C (140°F) test temperatures with a rutting depth of 3.6% and 4.8%, respectively. The test results indicate the HMAs should be resistant to rutting.

8.6.2 Hamburg Wheel-Tracking Device

The results from the Hamburg wheel-tracking device are shown in Figure 16. The Grading C HMA had a rut depth of 2.8 mm at the 45°C (113°F) test temperature and at the 50°C (122°F) test temperature had an 5.0 mm rut depth. The test results indicate that the HMA should be resistant to moisture damage.

8.7 Gyratory Results

Field produced HMA that was tested in the French rutting tester and Hamburg wheel-tracking device was also compacted in the SUPERPAVE gyratory. The results from the SUPERPAVE gyratory compactor are shown in Table 44. The gyratory results of the HMA were within reasonable compliance of the specifications. In fact, the HMA probably had 0.2% to 0.3% too much asphalt cement.

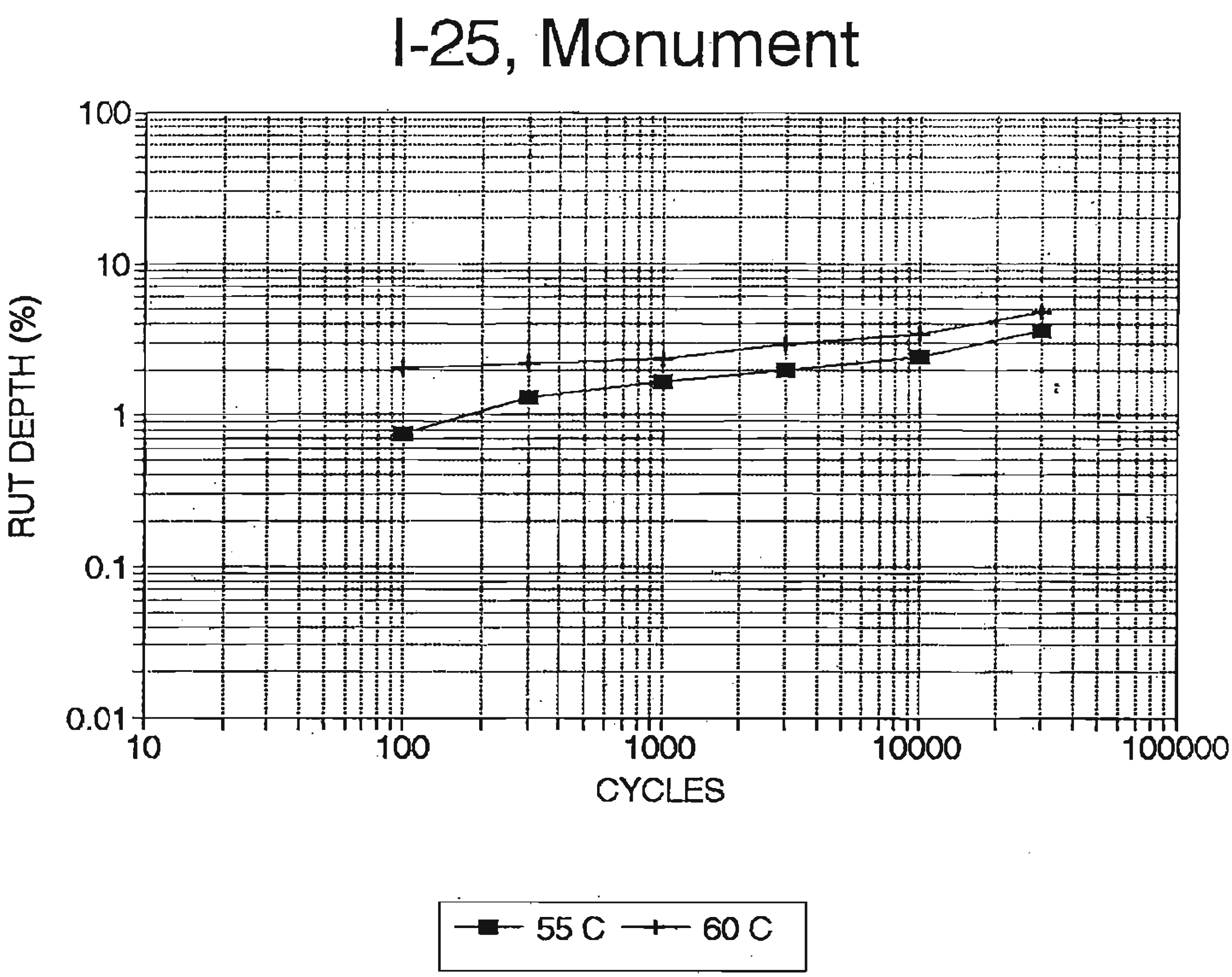
Table 44. Test Results from the SUPERPAVE Gyratory Compactor

	Air Voids (%)	
	Specification	Test Result
N_{init} = 8	≥ 11.0	9.7
N_{design} = 96	= 4.0	2.9
N_{max} = 152	≥ 2.0	2.5

The HMA placed on this project used the 690 kPa (100 psi) end point stress on the Texas gyratory. This was approximately equivalent to an N_{design} of 63 gyrations.

8.8 Summary

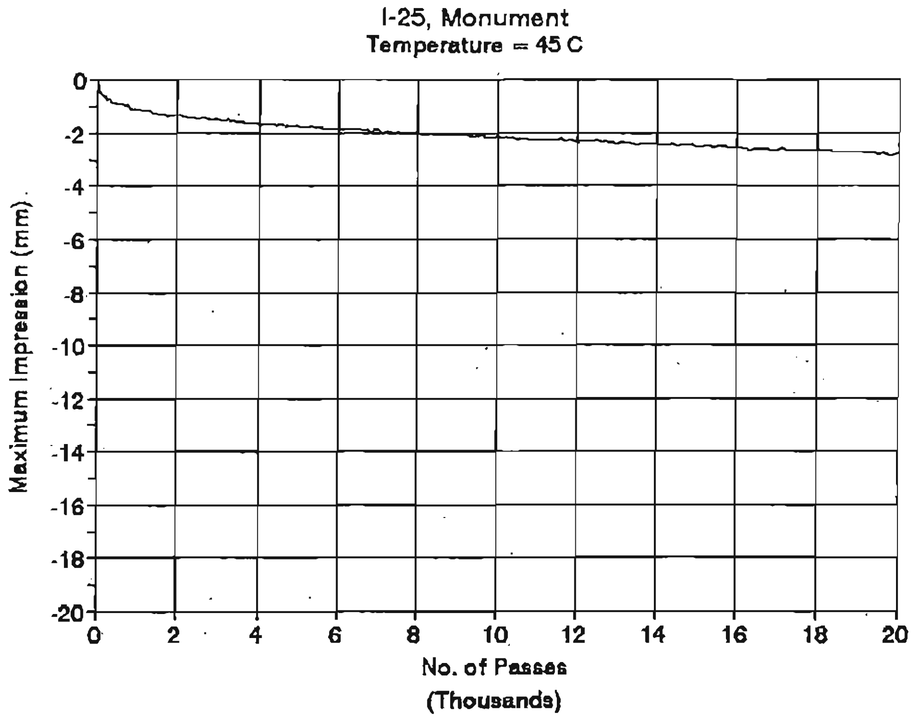
The HMA on this project was produced and placed on the project as designed based on gradation and volumetric properties. Based on the French rutting tester, the HMA pavement should not rut from plastic flow. Additionally, the test results from the Hamburg wheel-tracking device indicated that the HMA should be resistant to moisture damage in the future.



Temperature = 55°C
Slope = 0.248
Intercept = 1.526

Temperature = 60°C
Slope = 0.143
Intercept = 2.604

Figure 15. Results from the French Rutting Tester for the Monument Project



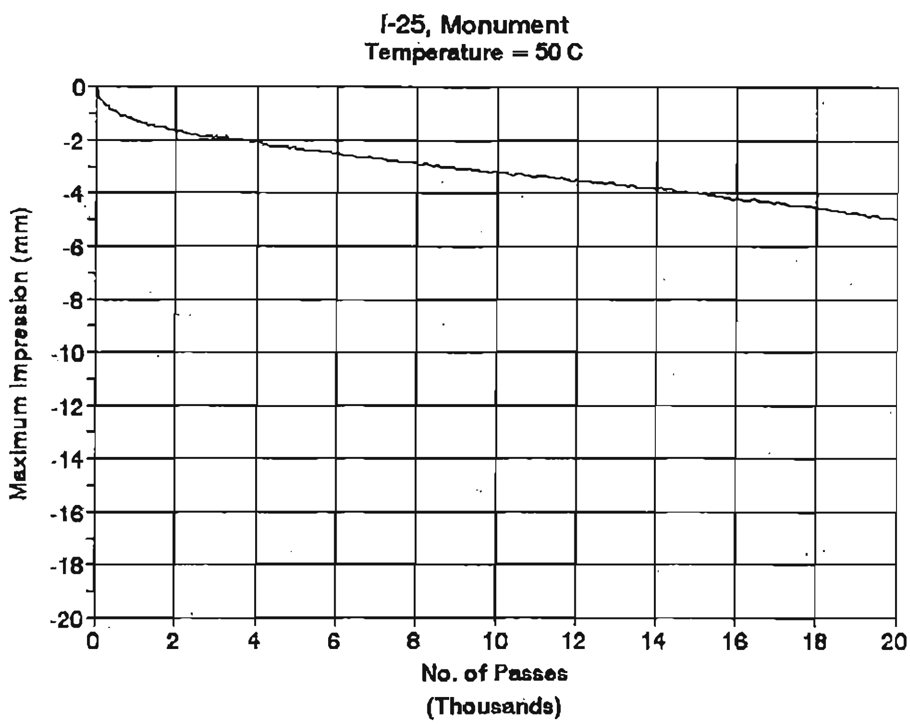


Figure 16. Results from the Hamburg Wheel-Tracking Device for the Monument Project

9.0 Denver: M.P. 216.63 to 218.70

9.1 General

This project is on I-25 and is in the north portion of Denver in Region 6. It begins at the north end of the Clear Creek Bridge (just south of the US-36 interchange) and extends 3.3 km (2.07 miles) to the north (just north of 84th Avenue). The total project cost was bid at $967,000. The 10-year ESALs in the design lane is 9,574,000. A summary of the general overlay information is shown in Table 50. This was a night paving operation.

Table 50. Overlay Information for the Denver Project

Grading	Tons	Cost per Ton	Thickness
C	18,000	$24.15	50 mm
Milling	NA	NA	25 mm

9.2 Pavement Management

The plans specified milling 25 mm (1 inch) of the existing mat and replacing it with a 50-mm thick overlay of Grading C.

9.3 Mix Designs

The aggregate and asphalt cement properties are summarized in Table 51. The rock and granite sand came from the Cooley Morrison quarry and the washed concrete sand came from the Cooley Thornton sand and gravel pit.

Table 51. Aggregate and Asphalt Cement Summary

19.0 mm (3/4") Rock	Granite Sand	Washed Concrete Sand	Hydrated Lime	Asphalt Cement	SUPERPAVE Performance Grade
34%	45%	20%	1%	Sinclair AC-10	58-22

The HMA properties are summarized in Table 52. The mix design used the 860 kPa (125 psi) end point stress on the Texas gyratory compactor (ASTM D 4013).

Table 52. Mix Design Summary

Grading	Asphalt Content (%)	Air Voids (%)	VMA (%)	Hveem Stability	AASHTO T 283 (TSR)
C (Min)	5.0 *	4.0 *	15.6 (13.0)	47 (42)	0.94 (0.80)

* Not Applicable

9.4 Field Verification

One Form 43 was used for the entire project; no adjustments were made.

The field verification results were tested in the Region laboratory and are shown in Table 53. Although there was a loss of 1.3% air voids, no corrective adjustments were considered. There was a loss of 1.8% VMA, but even after the loss, the VMA remained higher than the minimum specified value by 0.8%.

Table 53. Field Verification Summary

Grading	Air Voids (%)			VMA (%)			Hveem Stability		
	Avg.	S.D.	n	Avg.	S.D.	n	Avg.	S.D.	n
C	2.7	0.31	6	13.8	0.28	6	45	5.5	6

The AASHTO T 283 test results (modified Lottman) indicated the HMA was resistant to moisture damage. The three tests had an average TSR of 1.04 with a standard deviation of 0.05.

9.5 QC/QA Results

The pay factor for this project was based on the quality level analysis of field compaction, asphalt content, and gradation. The results from each of the three elements are shown in Table 54. The contractor received a bonus of 2.6%.

Table 54. QC/QA Data Summary

Grading	Field Compaction(%)			Asphalt Content (%)			Gradation			Total
	Avg.	S.D.	n	Avg.	S.D.	n	Avg.	S.D.	n	
C	93.1	1.04	38	4.9	0.18	24	*	*	10	
Pay Factor	1.015			1.033			1.045			1.026

* Not Applicable

9.6 European Equipment Results

9.6.1 French Rutting Tester

The results from the French rutting tester are shown in Figure 17. The HMA failed at both the 55°C (131°F) and 60°C (140°F) test temperatures with a rutting depth of 15.5% and 28.5%, respectively. These test results indicate that there may be problems with a rutting pavement in the future.

9.6.2 Hamburg Wheel-Tracking Device

The results from the Hamburg wheel-tracking device are shown in Figure 17. The HMA failed at both the 40°C (104°F) and 45°C (113°F) test temperature. The stripping inflection point occurred at 5300 passes for the sample tested at 45°C.

9.7 Gyratory Results

Field produced HMA that was tested in the French rutting tester and Hamburg wheel-tracking device was also compacted in the SUPERPAVE gyratory. The results from the SUPERPAVE gyratory compactor are shown in Table 55. The gyratory results of the HMA met all of the specifications except for N_{Init}. This indicated the HMA may have a tenderness problem during construction. The HMA probably had 0.2% to 0.3% too much asphalt cement.

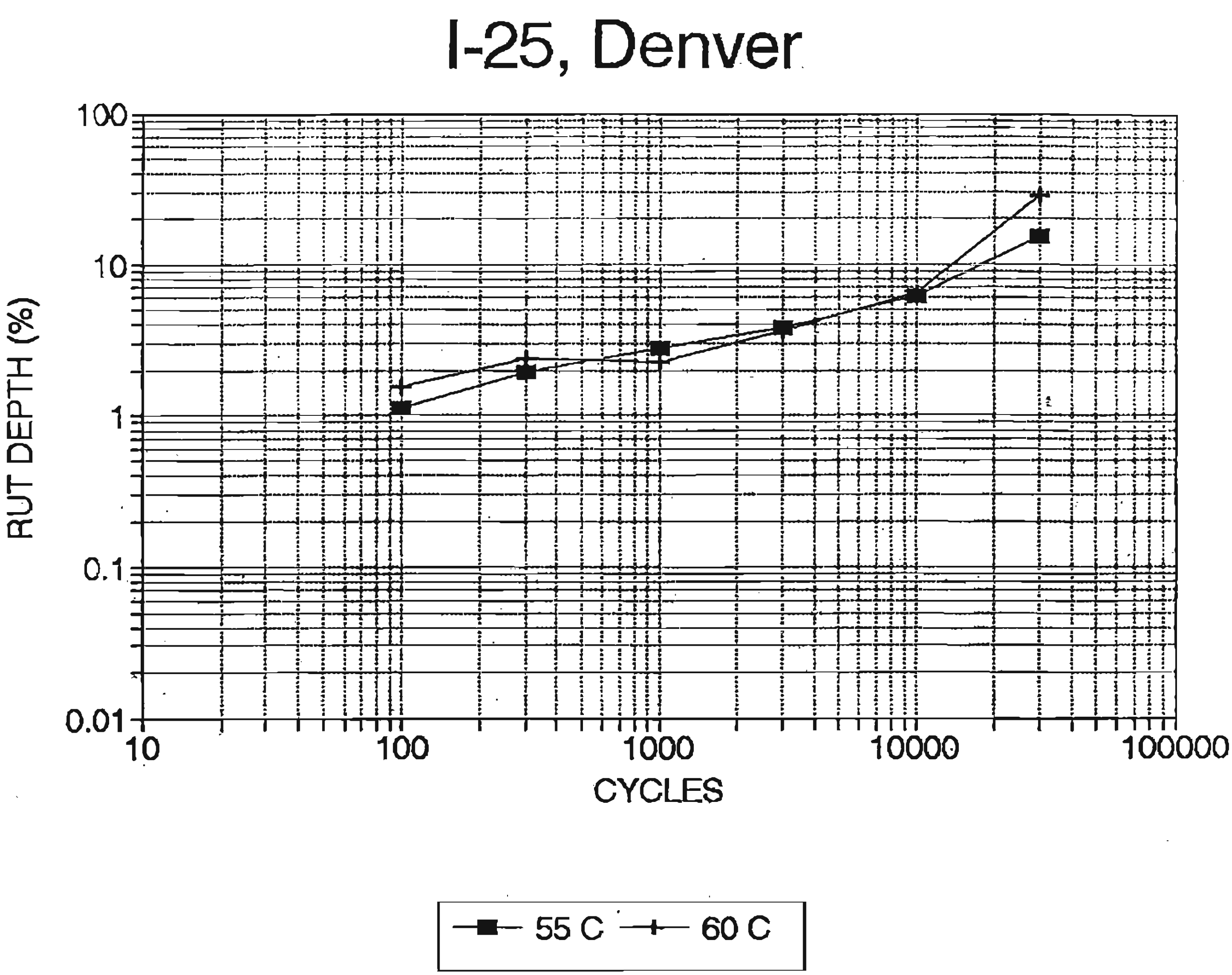
Table 55. Test Results from the SUPERPAVE Gyratory Compactor

	Air Voids (%)	
	Specification	Test Result
N_{init} = 8	≥ 11.0	10.5
N_{design} = 96	= 4.0	3.0
N_{max} = 152	≥ 2.0	2.2

The HMA placed on this project used the 860 kPa (125 psi) end point stress on the Texas gyratory. This was approximately equivalent to an N_{design} of 109 gyrations.

9.8 Summary

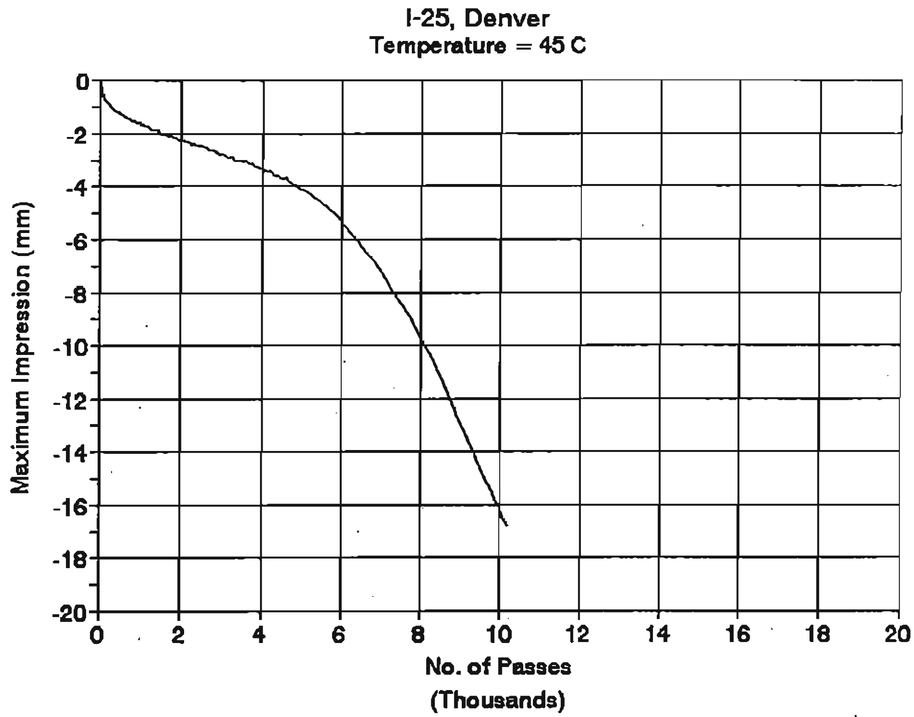
The HMA on this project was produced and placed on the project as designed based on gradation properties. However, the volumetric properties were significantly different. Based on the French rutting tester, the HMA pavement will likely rut from plastic flow. Additionally, the test results from the Hamburg wheel-tracking device indicated that there will be a moisture susceptibility problem. The HMA had a combination of plastic flow and moisture damage.



Temperature = 55°C
Slope = 0.423
Intercept = 2.847

Temperature = 60°C
Slope = 0.449
Intercept = 3 332

Figure 17. Results from the French Rutting Tester for the Denver Project



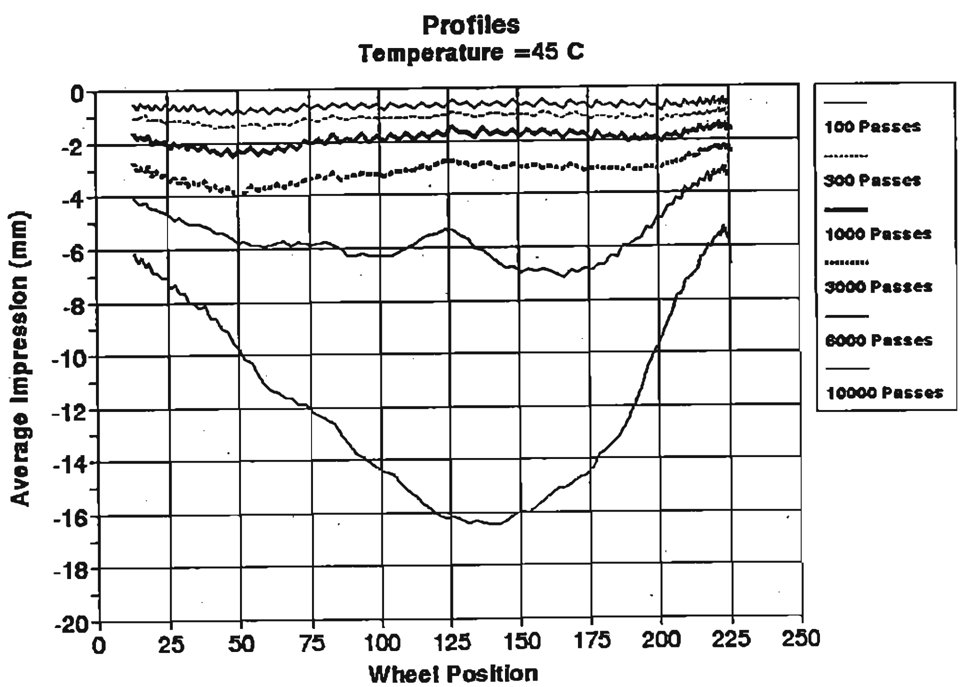


Figure 18. Results from the Hamburg Wheel-Tracking Device for the Denver Project

10.0 Longmont: M.P. 254.0 to 229.1

10.1 General

This project is on I-25 near Longmont in Region 4 and is 40.2 km (24.9 miles) long. The total project cost was bid at $2,446,000. The 10-year ESALs in the design lane are 5,761,000. A summary of the general overlay information is shown in Table 56. This was a night paving operation.

Table 56. Overlay Information for the Longmont Project

Grading	Tons	Cost per Ton	Thickness
C	35,000	$21.40	50 mm
Milling	NA	NA	25 mm

From M.P. 254.0 to 243.6 is a pavement marking test section only. From M.P. 243.6 to 235.11 involves micro-milling 50 mm (2 inches) and then sealing the cracks only.

10.2 Pavement Management

The overlay portion of the project extended from M.P. 235.1 to M.P. 229.1, 9.7 km (6.0 miles) long. The plans specified milling 25 mm (1 inch) of the existing mat and replacing it with a 50-mm thick overlay of Grading C.

10.3 Mix Designs

The aggregate and asphalt cement properties are summarized in Table 57. The aggregate came primarily from the Frei quarry. In addition to the quarried materials, 12.5 mm (1/2") rock from the Brannan Pit 29 was used along with a washed concrete sand from Brannan Pit 10.

The HMA properties are summarized in Table 58. The mix design used the 860 kPa (125 psi) end point stress on the Texas gyratory compactor (ASTM D 4013).

Table 57. Aggregate and Asphalt Cement Summary

19.0mm (3/4") Rock	12.5mm (1/2") Rock	Crushed Fines	Concrete Sand	Hydrated Lime	Asphalt Cement	SUPERPAVE Performance Grade
18%	21%	42%	19%	1%	Conoco AC-20	64-22

Table 58. Mix Design Summary

Grading	Asphalt Content (%)	Air Voids (%)	VMA (%)	Hveem Stability	AASHTO T 283 (TSR)
C (Min)	5.0 *	4.0 *	14.1 (13.0)	45 (42)	1.06 (0.80)

* Not Applicable

10.4 Field Verification

Three Form 43s were used for the entire project. There were two adjustments on the second Form 43: 1) the asphalt content of the HMA was adjusted 0.1% lower, and 2) the gradation was adjusted to be 9% finer on the 4.75 mm (No. 4) sieve. For the third Form 43, the maximum specific gravity of the HMA changed. There were numerous problems with the quality of material on this project.

The field verification results were tested in the Region laboratory and are shown in Table 59. There was a loss of 1.3% air voids.

Table 59. Field Verification Summary

Grading	Air Voids (%)			VMA (%)			Hveem Stability		
	Avg.	S.D.	n	Avg.	S.D.	n	Avg.	S.D.	n
C	2.7	0.70	64	12.7	0.52	64	46	4.0	64

The AASHTO T 283 test results (modified Lottman) indicated the HMA was resistant to moisture damage. The eleven tests had an average TSR of 0.82 with a standard deviation of 0.11.

Towards the end of the project, three of the TSRs did not meet the minimum requirement of 0.70.

10.5 QC/QA Results

During the course of this project, the contractor was shut-down multiple times. After numerous adjustments, the contractor could not consistently meet the gradation and asphalt content specifications. The contractor was eventually required to purchase HMA from a second contractor for the final 2,500 tonnes placed on the project.

The pay factor for this project was based on the quality level analysis of field compaction, asphalt content, and gradation. The results from each of the three elements are shown in Table 60. The contractor received a disincentive of 0.96%. The material purchased from the second contractor is not included in the analyses and pay factors shown in Table 60.

Table 60. QC/QA Data Summary

Grading	Field Compaction(%)			Asphalt Content (%)			Gradation			Total
	Avg.	S.D.	n	Avg.	S.D.	n	Avg.	S.D.	n	
C	93.1	1.40	62	4.9	0.27	30	*	*	31	
Pay Factor	0.979			1.014			0.823			0.958

* Not Applicable

10.6 European Equipment Results

10.6.1 French Rutting Tester

The results from the French rutting tester are shown in Figure 19. The HMA passed at both the 55°C (131°F) and 60°C (140°F) test temperatures with a rutting depth of 4.9% and 4.6%, respectively. These test results indicate the HMA should be resistant to rutting.

10.6.2 Hamburg Wheel-Tracking Device

For this project, the Hamburg wheel-tracking device was used as a specification. The specification would provide the contractor with a 5% incentive if the material produced for the project passed. Five tests were performed, and the most typical results are shown in Figure 20. The HMA failed at both the 45°C (113°F) and 50°C (122°F) test temperature. The 50°C test temperature was specified for the project. The stripping inflection point occurred at approximately 9000 passes for the sample tested at 50°C.

10.7 Gyratory Results

Field produced HMA that was tested in the French rutting tester and Hamburg wheel-tracking device was also compacted in the SUPERPAVE gyratory. The results from the SUPERPAVE gyratory compactor are shown in Table 61. The gyratory results of the HMA met none of the specifications. The HMA probably had approximately 0.5% too much asphalt cement.

Table 61. Test Results from the SUPERPAVE Gyratory Compactor

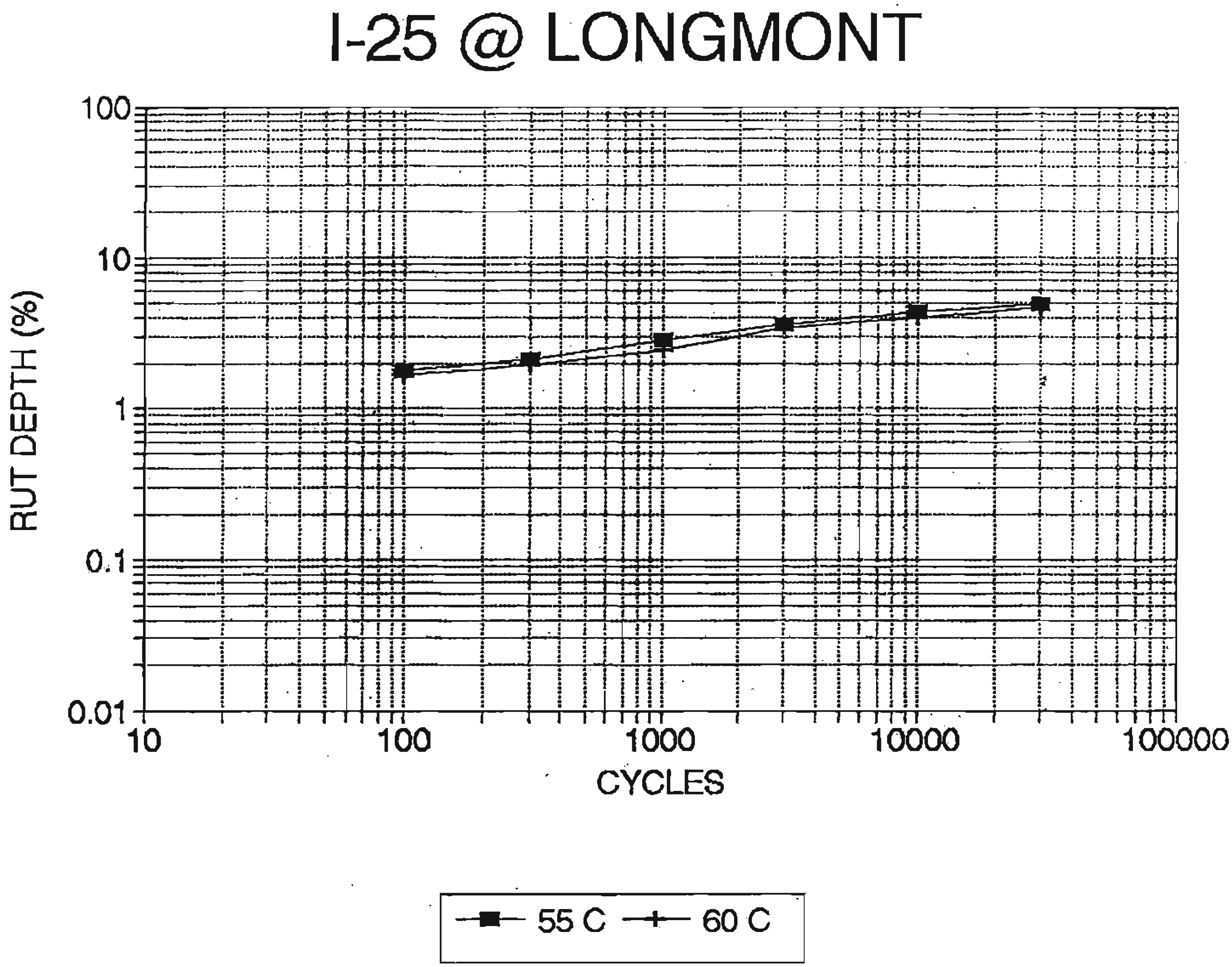
	Air Voids (%)	
	Specification	Test Result
N_{init} = 8	≥ 11.0	8.8
N_{design} = 96	= 4.0	2.1
N_{max} = 152	≥ 2.0	1.3

The HMA placed on this project used the 860 kPa (125 psi) end point stress on the Texas gyratory. This was approximately equivalent to an N_{design} of 68 gyrations.

10.8 Summary

Based on the French rutting tester, the HMA pavement should not rut from plastic flow. Unfortunately, the test results from the Hamburg wheel-tracking device indicated that the HMA may experience moisture damage in the future.

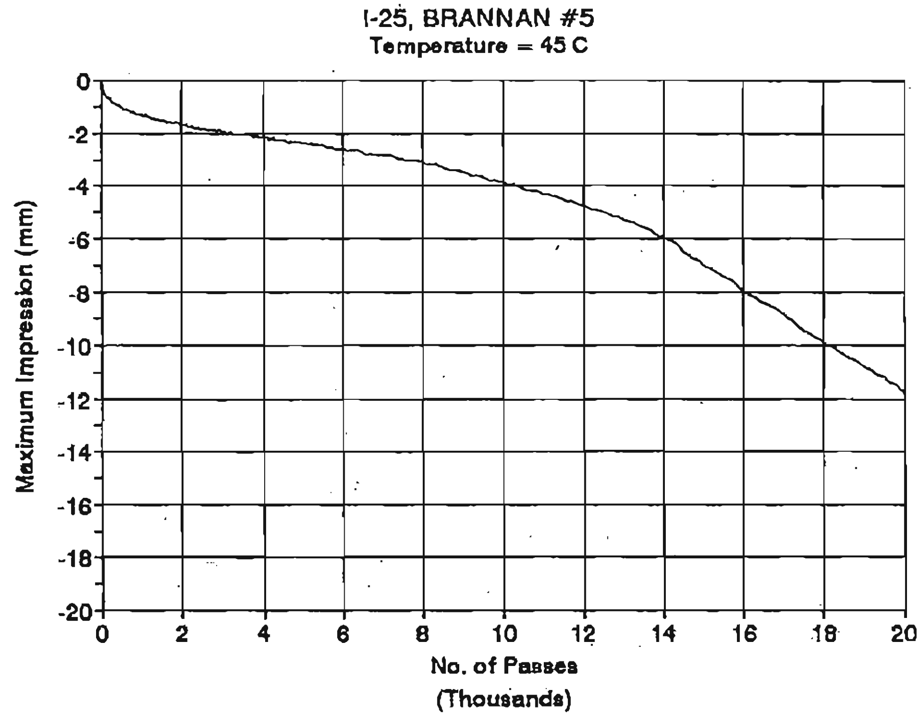
The smoothness was a specification on the project. The average profile index on the southbound lanes was 169 mm/km (10.70 in/mile) and for the northbound lanes was 169 mm/km (10.72 in/mile).



Temperature = 55°C
Slope = 0.186
Intercept = 2.767

Temperature = 60°C
Slope = 0.193
Intercept = 2.512

Figure 19. Results from the French Rutting Tester for the Longmont Project



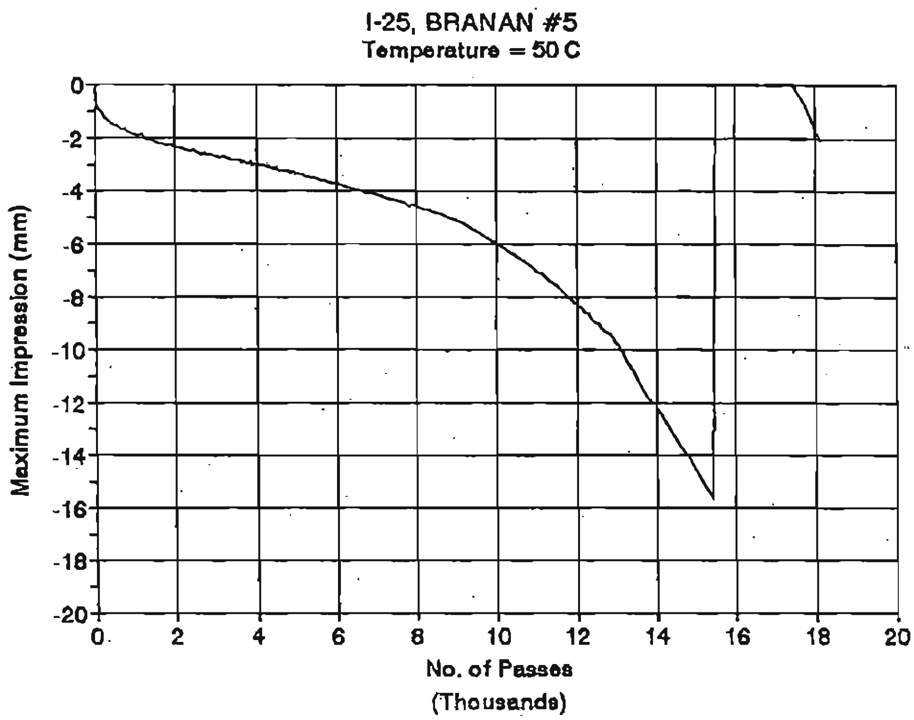


Figure 20. Results from the Hamburg Wheel-Tracking Device for the Longmont Project

11.0 Conclusions

1) Five of the nine projects had acceptable test results from both the gradation and volumetric methods. It should be noted that field adjustments were made to two of the five projects during production in order to achieve acceptable volumetric properties.

Two of the projects (New Mexico State Line (Grading C) and Denver) had poor volumetric properties and acceptable gradation results. The volumetrics from the New Mexico State Line project was highly influenced by very poor test results at the end of the project. One project (Trinidad) had unacceptable gradation results and acceptable volumetric results. One project (Longmont) had unacceptable test results from both the volumetric and gradation tests.

2) Eight of the nine projects tested passed the French rutting tester. The only project to fail was in Denver. In general, there does not appear to be a rutting problem from plastic flow for the high volume roadways with the new mix design system.

(Note: Attempts were made to adjust the HMA placed on the Denver project. However, the contractor was receiving a bonus with the current CDOT specifications, so no adjustment was made.)

3) Five of the nine projects tested passed the Hamburg wheel-tracking device. The four projects that failed were from the New Mexico State Line, Trinidad, Denver, and Longmont. The aggregate source used for the New Mexico State Line and Trinidad projects has a history of poor performance. The failure in the Hamburg wheel-tracking device of the HMA sampled from the Denver project was likely related to the permanent deformation problem. There were numerous quality control problems on the Longmont project. It is believed that these problems contributed to the poor performance the HMA in the Hamburg wheel-tracking device.

(Note: An adjustment has been made to the CDOT moisture susceptibility test in order to better identify poor performing aggregates that were used for the New Mexico State Line and Trinidad projects.)

4) The end point stress from the Texas gyratory compactor was compared to the number of revolutions from the SUPERPAVE gyratory compactor (SGC) to reach the same air void level. For six of the projects, a 690 $\pm$ 170 kPa (100 $\pm$ 25 psi) end point stress was equivalent to 100 $\pm$ 35 revolutions on the SGC. The biggest exception was the Air Force Academy project where 27 gyrations of the SGC was equal to the 690 kPa (100 psi) end point stress on the Texas gyratory compactor.

5) The cold-in-place recycling (CIPR) and hot-in-place recycling (HIPR) costs were compared for the projects in this study. The CIPR average cost was \$1.40 / 100mm or \$0.35 / 25 mm. The HIPR cost was \$1.88 / 50 mm or \$0.94 / 25 mm. The structural layer coefficient used with CIPR is 0.35 and with HIPR is 0.44. These structural layer coefficients indicate that 50 mm of HIPR is "equivalent" to 63 mm of CIPR. When the structural layer coefficient is considered, the ratio of cost of CIPR to HIPR is \$0.46 to \$1.00 per "equivalent" thickness.

12.0 Recommendations

The pavement management strategy and HMA properties were presented for nine projects constructed on I-25 during the 1994 paving season. It is recommended to visually monitor the performance of these pavements over the next 5, 10 and possibly 15 years. Monitoring the pavements will benefit the pavement management and HMA specifications for the future.

Some pavement management strategies are more effective than others and each pavement management strategy likely has potential for improvement. By monitoring these projects, valuable information can be obtained for future specification improvements.

All of the HMA was tested using the new European testing equipment. Based on the field performance of these pavements, more information can be obtained on the ability of this equipment to predict pavement performance. Additionally, all of these projects were tested during production using both the gradation and volumetric tests. These two sets of tests are currently used to accept HMA throughout Colorado. By monitoring these projects, valuable information can be obtained for future specification improvements for the European equipment and the acceptance tests.

13.0 References

1. Mix Design Methods, Manual Series No. 2 (MS-2), Sixth Edition, Asphalt Institute, Lexington, Kentucky, 141 pages.
2. Federal Highway Administration (March 10, 1988), "Asphalt Concrete Mix Design and Field Control," FHWA Technical Advisory T 5040.27, Federal Highway Administration, Washington, D.C., 29 pages.
3. Danielson, B.J., V.E. Aguirre, C.S. Hughes, and M.W. Witczak (1993), "An Investigative Study of the Colorado Department of Transportation Asphalt Mixture Design Procedure," Aguirre Engineers, Inc., Project No. 22,014, 236 pages.
4. Aschenbrener, T. (1993), "Determining Optimum Asphalt Content with the Texas Gyratory Compactor," Colorado Department of Transportation, CDOT-DTD-R-93-23, 78 pages.
5. Aschenbrener, T. and K. Stuart (1992), "Description of the Demonstration of European Testing Equipment for Hot Mix Asphalt Pavement," Colorado Department of Transportation, CDOT-DTD-R-92-10, 23 pages.
6. Aschenbrener, T. (1994), "Demonstration of a Volumetric Acceptance Program for Hot Mix Asphalt in Colorado," Colorado Department of Transportation, CDOT-DTD-R-94-2, 80 pages.

Appendix A:
SUPERPAVE Binder Test Results

Aging	Test	Test Temp. °C	Units of Results	Site		
				N.M. State Line, N.	Trinidad	Walsenburg
Tank	Sp.Gr.	25		1.0262	0.9917	1.0240
	Flash		°C	230+	353	230+
	Ab.Vis.	60	poises	1837	939	17625
	Pen	25	dmm	96	104	65
	DSR	58	kPa	2.55	1.47	9.38
		64	kPa	1.30	0.71	4.90
		70	kPa	0.68		2.64
		76	kPa			1.49
		82	kPa			0.80
RTFOT	LOH	163	%	0.09	0.07*	0.34
	Ab.Vis.	60	poises		1994*	
	DSR	58	kPa	4.33	3.42*	15.38
		64	kPa	2.23	1.42*	8.34
		70	kPa	1.13		4.51
		76	kPa			2.44
		82	kPa			1.36
PAV	DSR	25	kPa	1706	1540	1954
		22	kPa	2665	2180	2701
		19	kPa	4013	3090	3772
		16	kPa	5823	4280	5098
		13	kPa		5780	
	BBR Stiffness (S)	-12	MPa	75.4	77.0	48.3
		-18	MPa	164.5	148.0	89.0
		-24	MPa	312.7		167.6
	BBR Slope (m)	-12		0.370	0.340	0.331
		-18		0.326	0.296	0.316
		-24		0.261		0.260
SUPERPAVE Performance Grade				64-28	58-16	76-28

* TFOT (AASHTO T 179)

Aging	Test	Test Temp. °C	Units of Results	Site: Colorado City	Site: Colorado Springs	Site: AFA
Tank	Sp.Gr.	25				
	Flash		°C	230+	230+	230+
	Ab.Vis.	60	poises	11573	1099	3580
	Pen	25	dmm	78	99	86
	DSR	52	kPa		4.10	
		58	kPa	3.92	1.81	8.75
		64	kPa	2.02	0.83	4.34
		70	kPa	1.16		2.26
		76	kPa	0.64		
TFOT	LOH	163	%	0.084	0.08	0.08
	Ab.Vis.	60	poises			
	DSR	52	kPa		9.77	
		58	kPa	9.91	4.13	7.40
		64	kPa	5.25	1.64	3.55
		70	kPa	2.81		1.79
		76	kPa	1.53		
PAV	DSR	25	kPa	1729	2780	2183
		22	kPa	2544	4003	3271
		19	kPa	3751	5734	4787
		16	kPa	5364		6874
		13	kPa			
	BBR Stiffness (S)	-12	MPa	60.5	76.6	60.6
		-18	MPa	122.4	146.5	123.5
		-24	MPa			
	BBR Slope (m)	-12		0.366	0.333	0.364
		-18		0.308	0.285	0.312
		-24				
SUPERPAVE Performance Grade				70-28	58-22	64-28

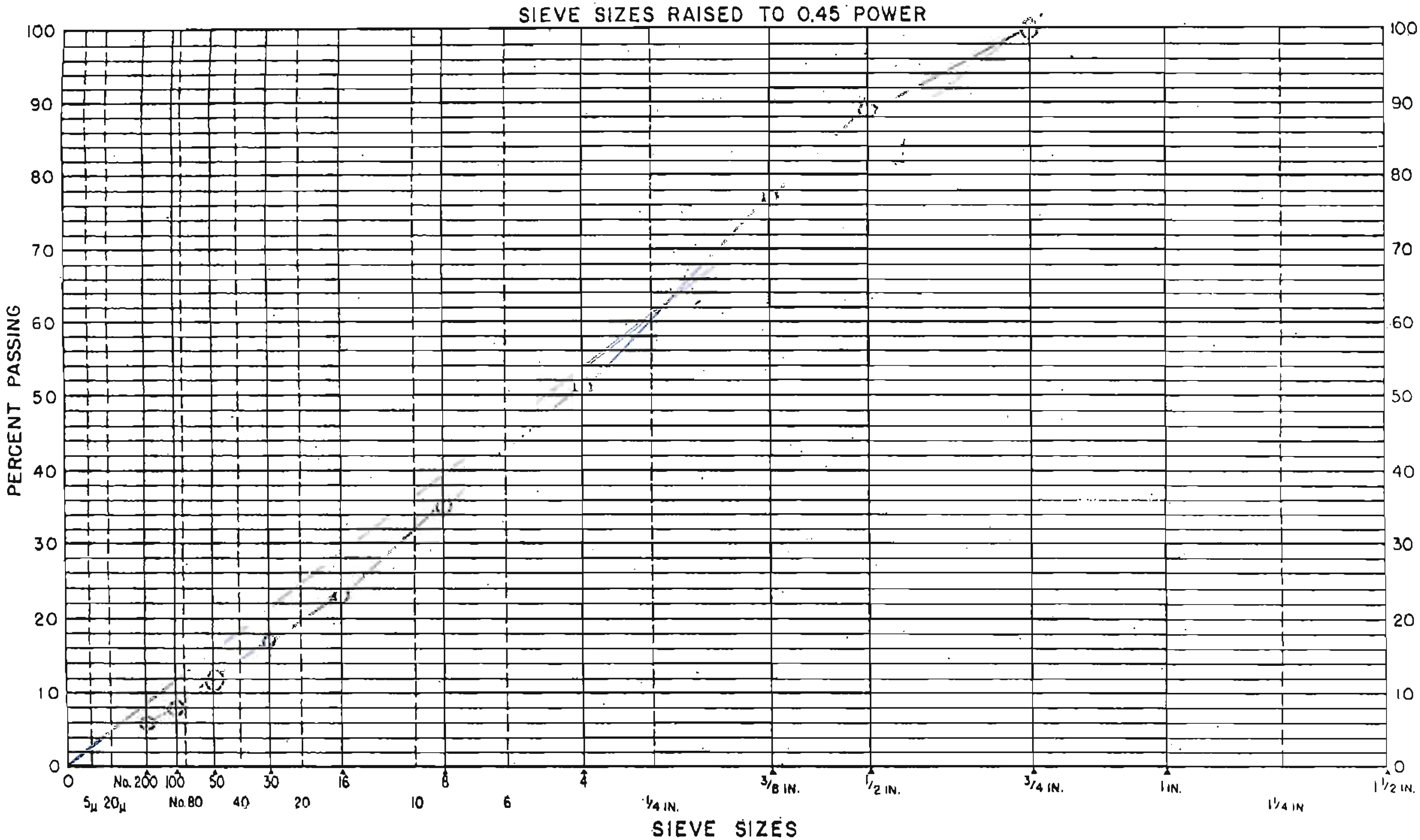
Aging	Test	Test Temp. °C	Units of Results	Site		
				Monument	Denver	Longmont
Tank	Sp.Gr.	25				
	Flash		°C	230+	230+	230+
	Ab.Vis.	60	poises	3580	1074	2015
	Pen	25	dmm	86	99	84
	DSR	52	kPa		4.47	5.62
		58	kPa	8.75	2.19	2.27
		64	kPa	4.34	0.95	0.99
		70	kPa	2.26		
		76	kPa			
TFOT	LOH	163	%	0.84	0.71	+0.0003
	Ab.Vis.	60	poises			
	DSR	52	kPa		7.75	
		58	kPa	7.40	3.52	7.08
		64	kPa	3.55	1.54	3.00
		70	kPa	1.79		1.36
PAV	DSR	25	kPa	2183	3045	3883
		22	kPa	3271	4622	5552
		19	kPa	4787	6674	
		16	kPa	6874		
		13	kPa			
	BBR Stiffness (S)	-12	MPa	60.6	112.4	94.5
		-18	MPa	123.5	204.0	188.2
		-24	MPa			
	BBR Slope (m)	-12		0.364	0.328	0.324
		-18		0.312	0.288	0.278
		-24				
SUPERPAVE Performance Grade				64-28	58-22	64-22

Appendix B:

Aggregate Gradation Plots

COLORADO DEPARTMENT OF TRANSPORTATION

GRADATION CHART



B-1

REMARKS:

STA 0251-133 (c)

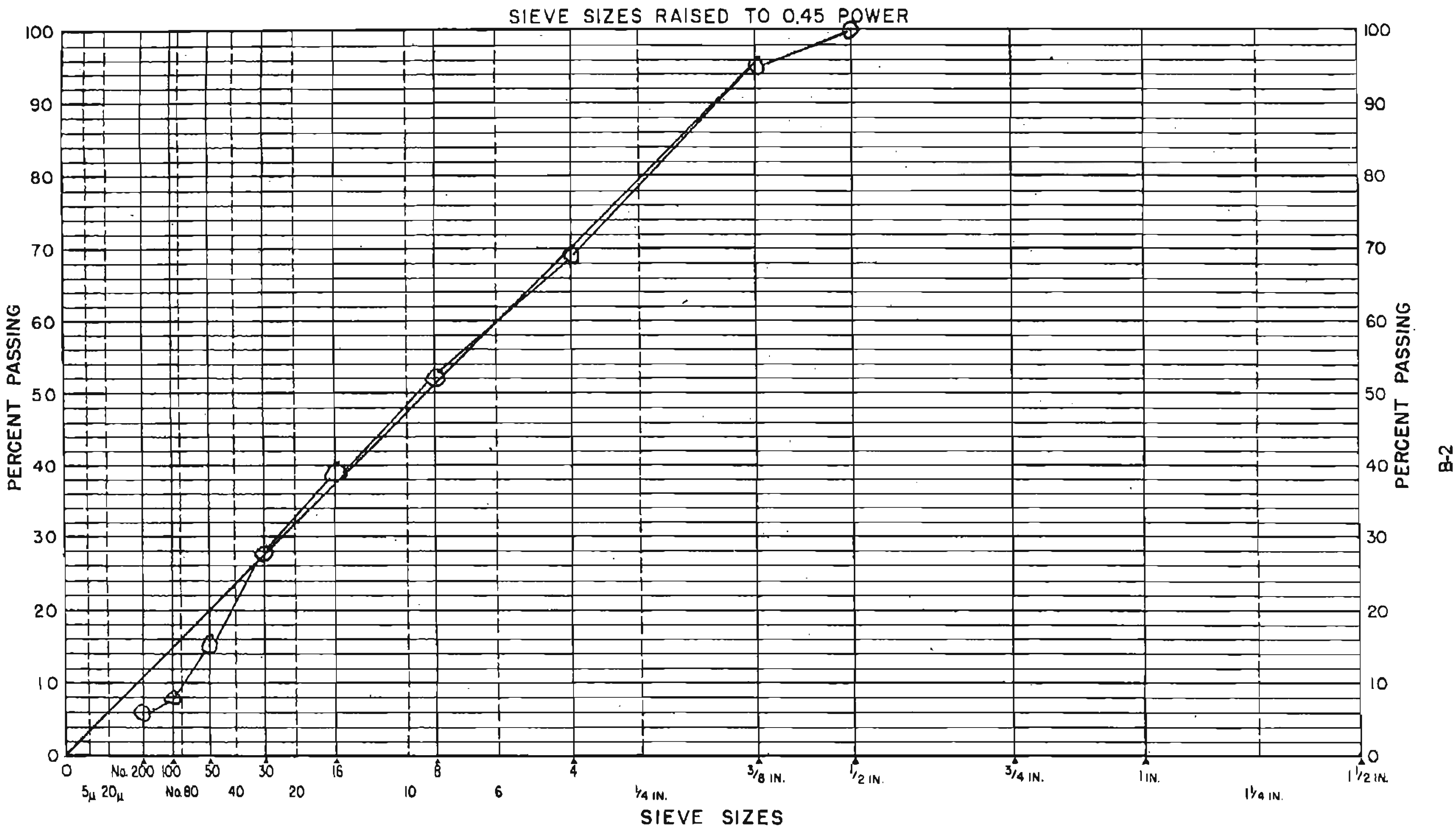
NEW MEXICO STATE LINE-NORTH

F.S. 42832

TORTORICE

COLORADO DEPARTMENT OF TRANSPORTATION

GRADATION CHART



REMARKS:

STA 0251-133 (CX)

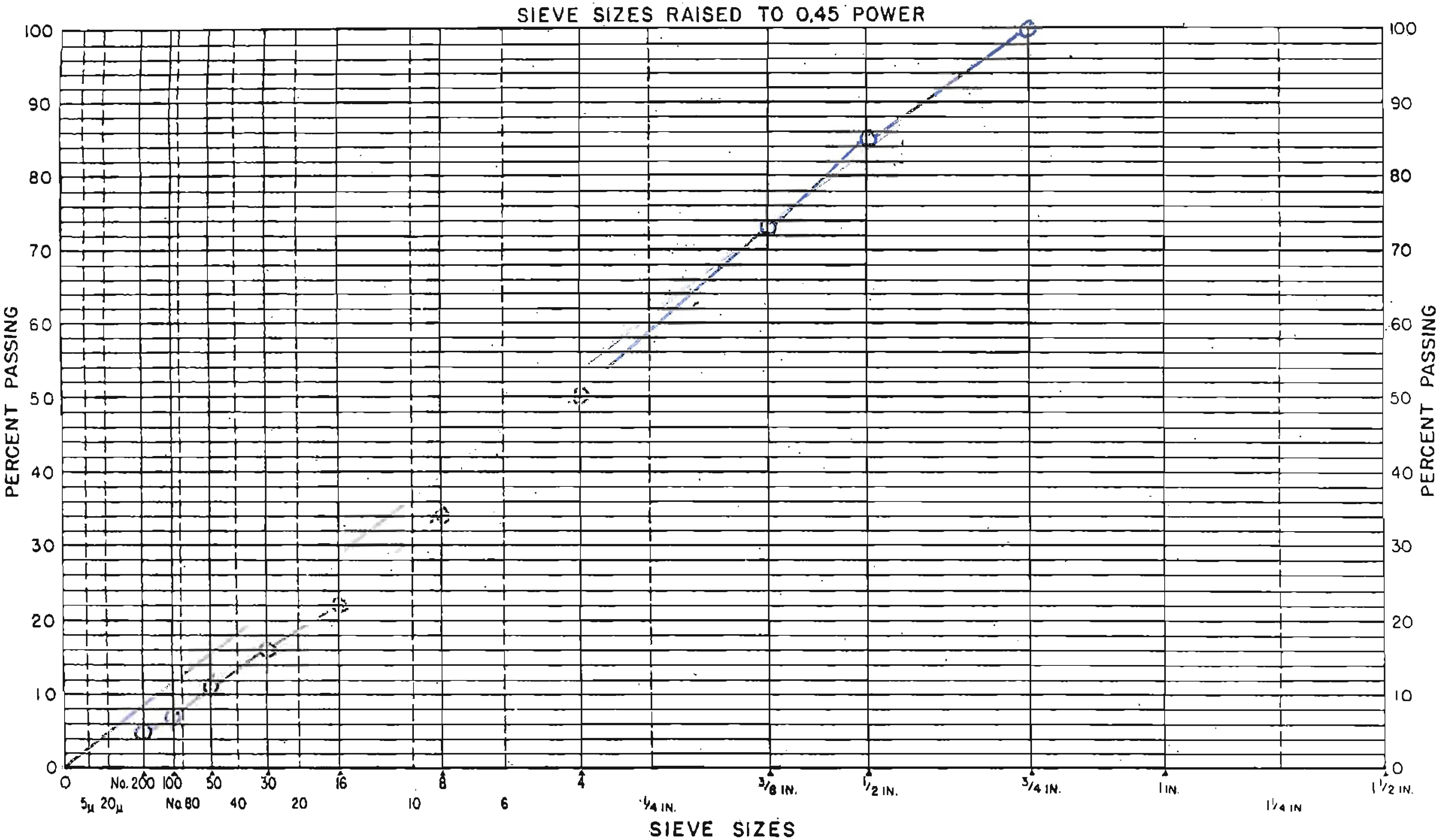
NEW MEXICO-STATE LINE NORTH

F.S. 7522P

TORTORICE

COLORADO DEPARTMENT OF TRANSPORTATION

GRADATION CHART



B-3

REMARKS:

NH(cx)025-1(125)

I25 & SH160 Trinidad Bypass

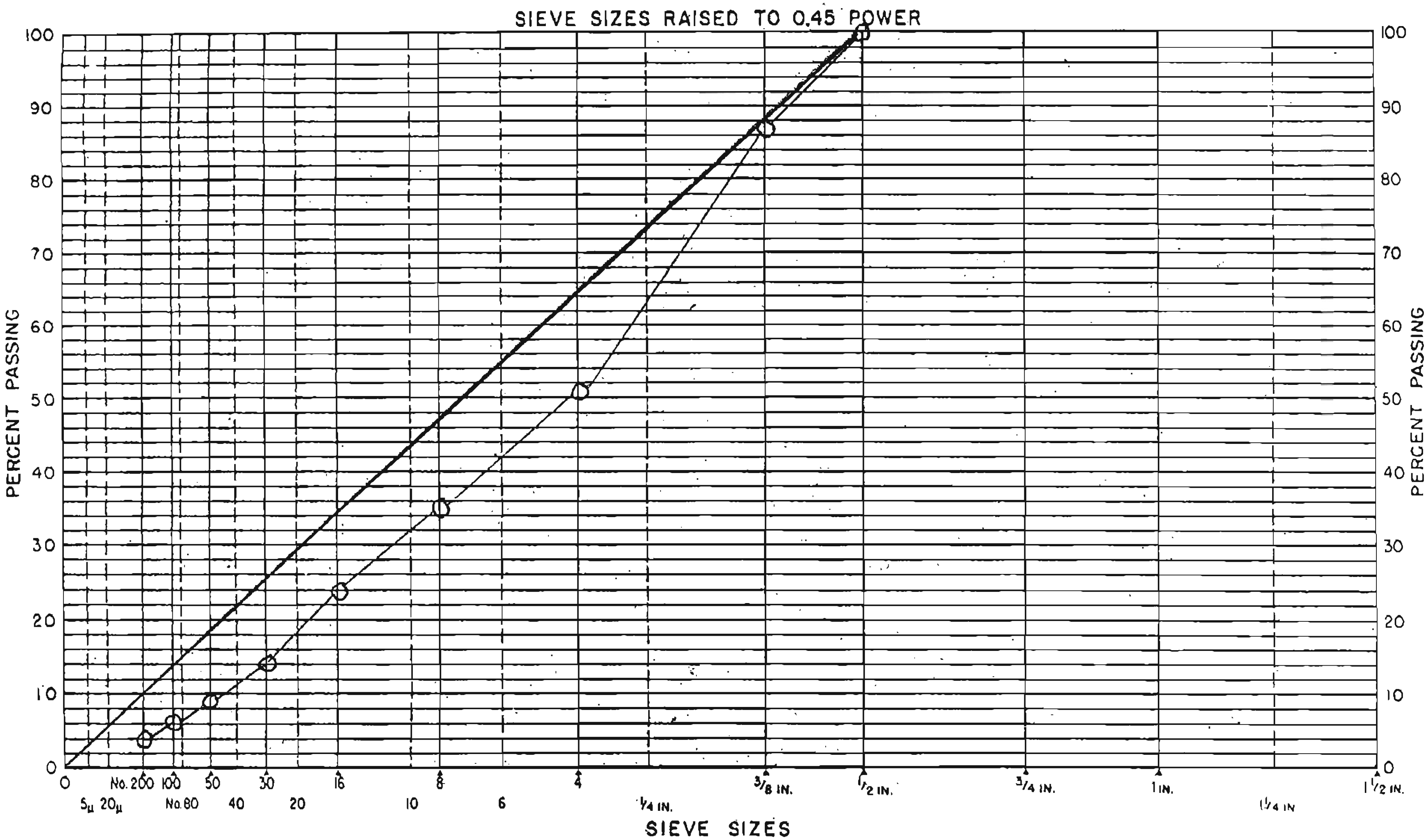
F.S. 72574

TORTORICE

CDOT Form #1007
1/92

COLORADO DEPARTMENT OF TRANSPORTATION

GRADATION CHART



B-4

REMARKS:

ACIM 0251-137

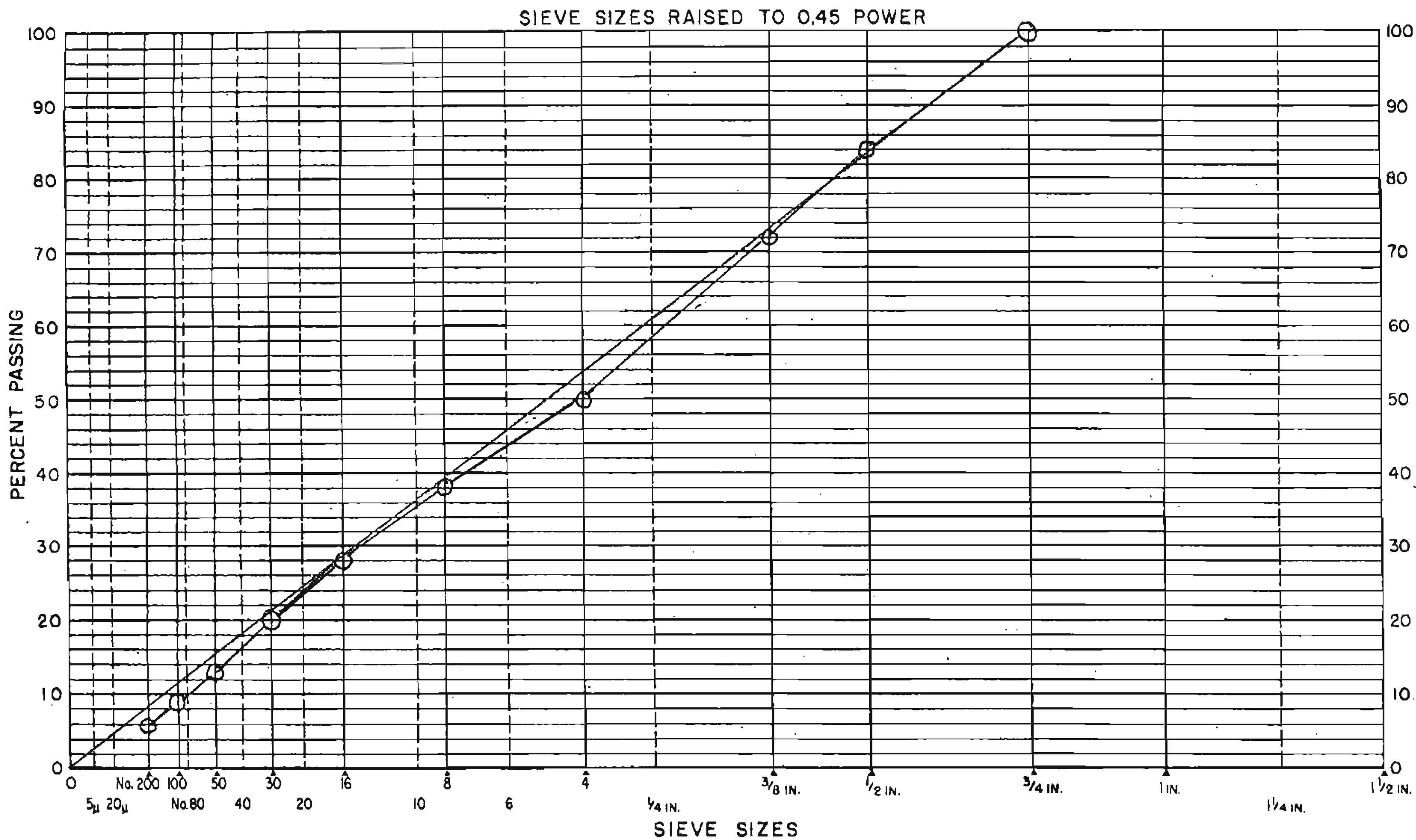
BUTTE CREEK INT. NORTH

E.S. 47524

FRANSISCOTTI

COLORADO DEPARTMENT OF TRANSPORTATION

GRADATION CHART



B-5

REMARKS:

STA 6251-131 (c)

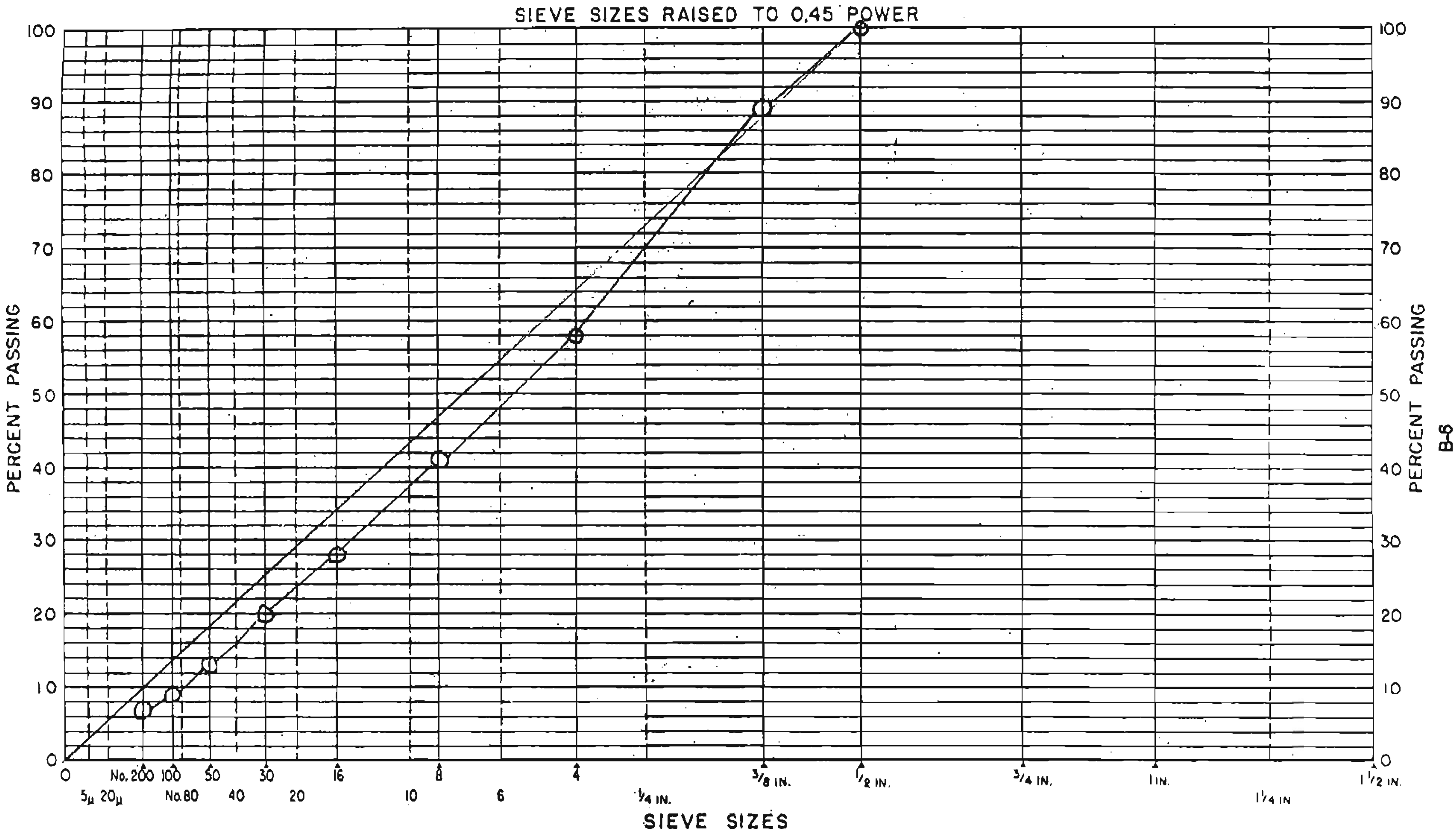
Jct. SH165 N+S

F.S. # 72734

FRANCISCOTTI

COLORADO DEPARTMENT OF TRANSPORTATION

GRADATION CHART



REMARKS:

STA 0251-131 (cx)

JCT SH 165 N&S

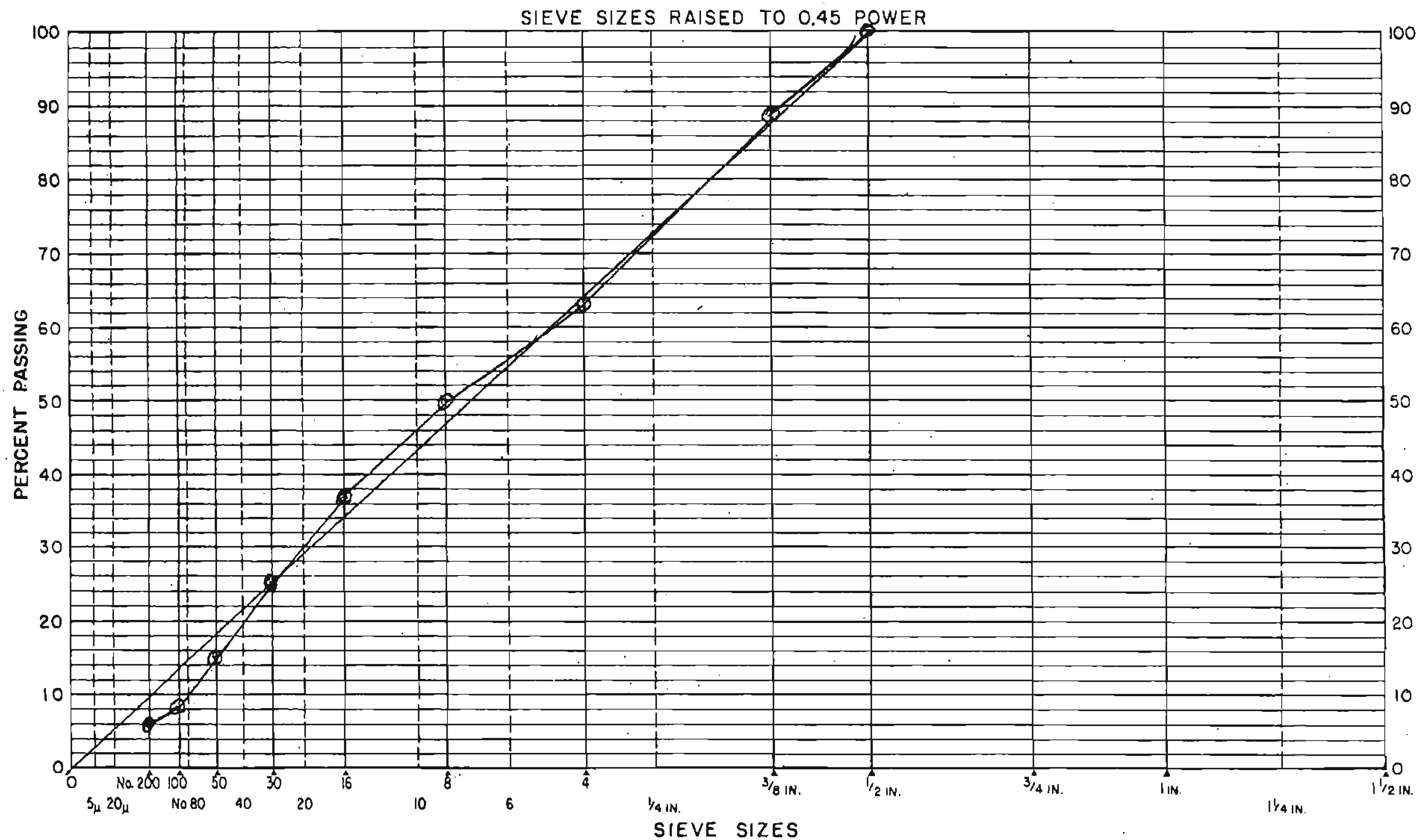
F.S. 72736

FRANCISCOTTI

CDOT Form #1007
1/92

COLORADO DEPARTMENT OF TRANSPORTATION

GRADATION CHART



REMARKS:

C 0252-265

F.S. 69686

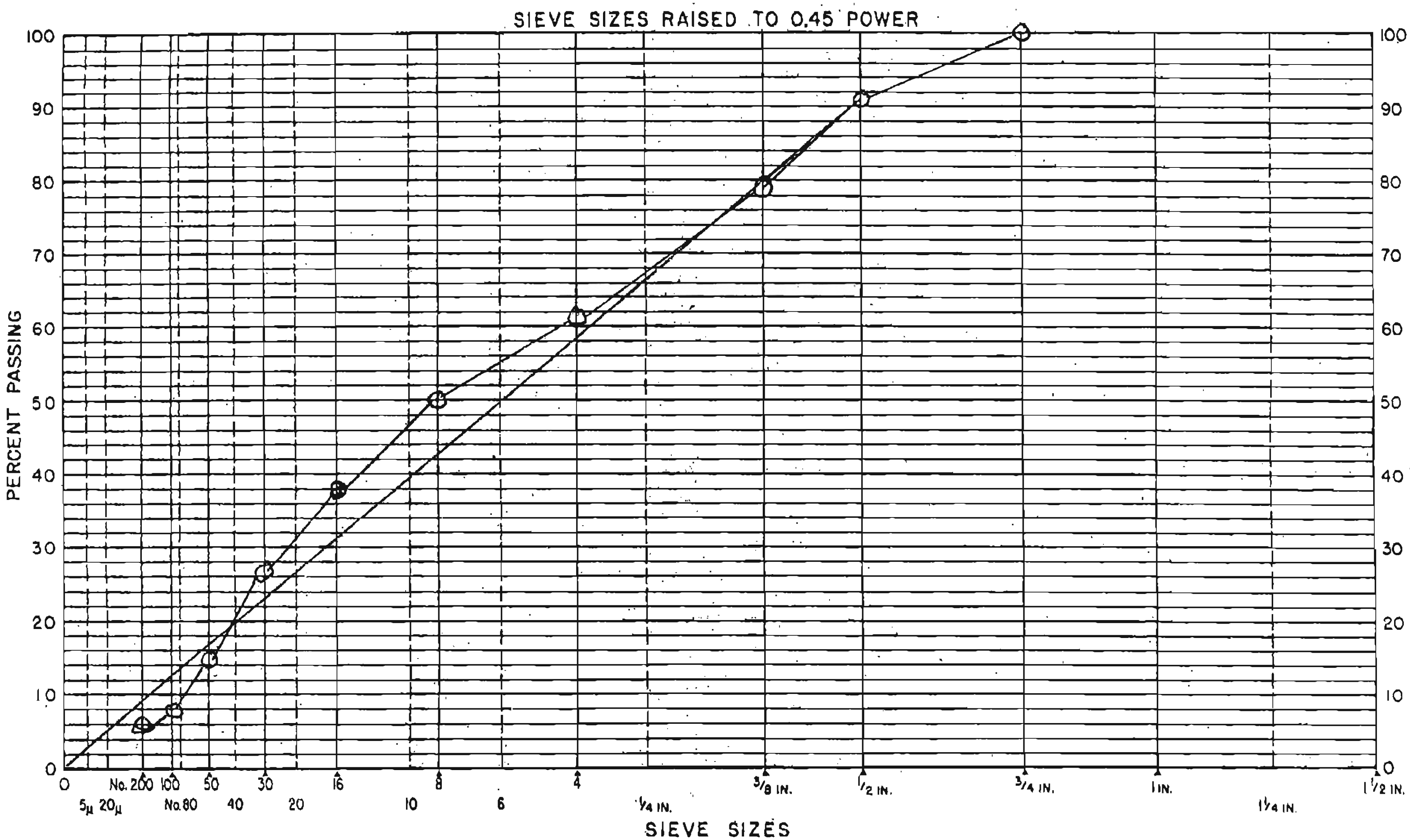
Location: Colo Sprgs Woodman Rd. South

Pit: Fountain - B & G

CDOT Form #1007
1/92

COLORADO DEPARTMENT OF TRANSPORTATION

GRADATION CHART



B-8

REMARKS:

IM 0252-266

I25 So. A.F.A. ENT-NORTH

F.S. 76854

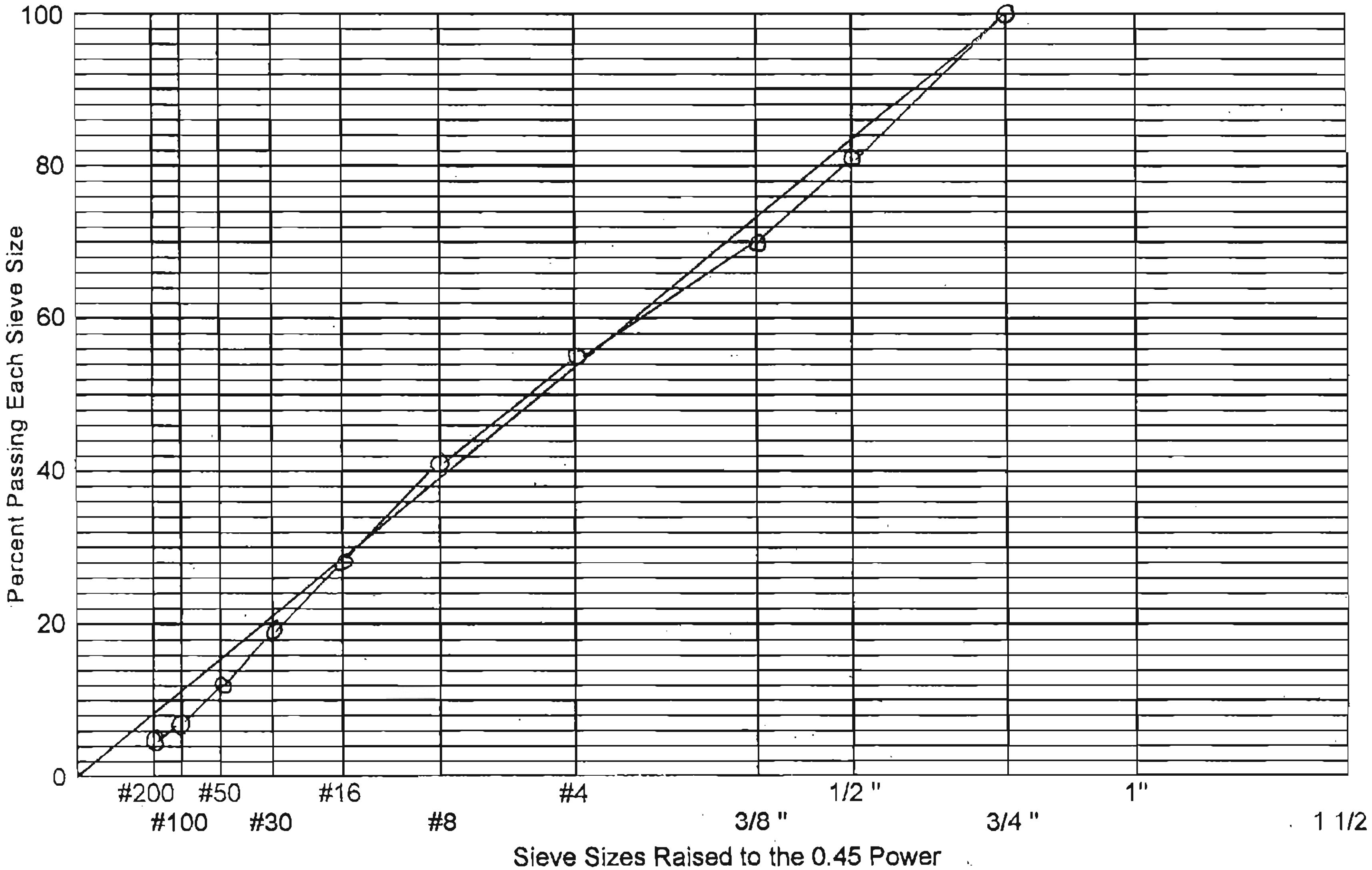
CASTLE / BLUE HERON

CDOT Form #1007

COLORADO DEPARTMENT OF TRANSPORTATION

GRADATION CHART

Subaccount 10056	Project IM 0252-263	157 Number 72421
Location MONUMENT HILL - SO.	Aggregate Source MENZER	

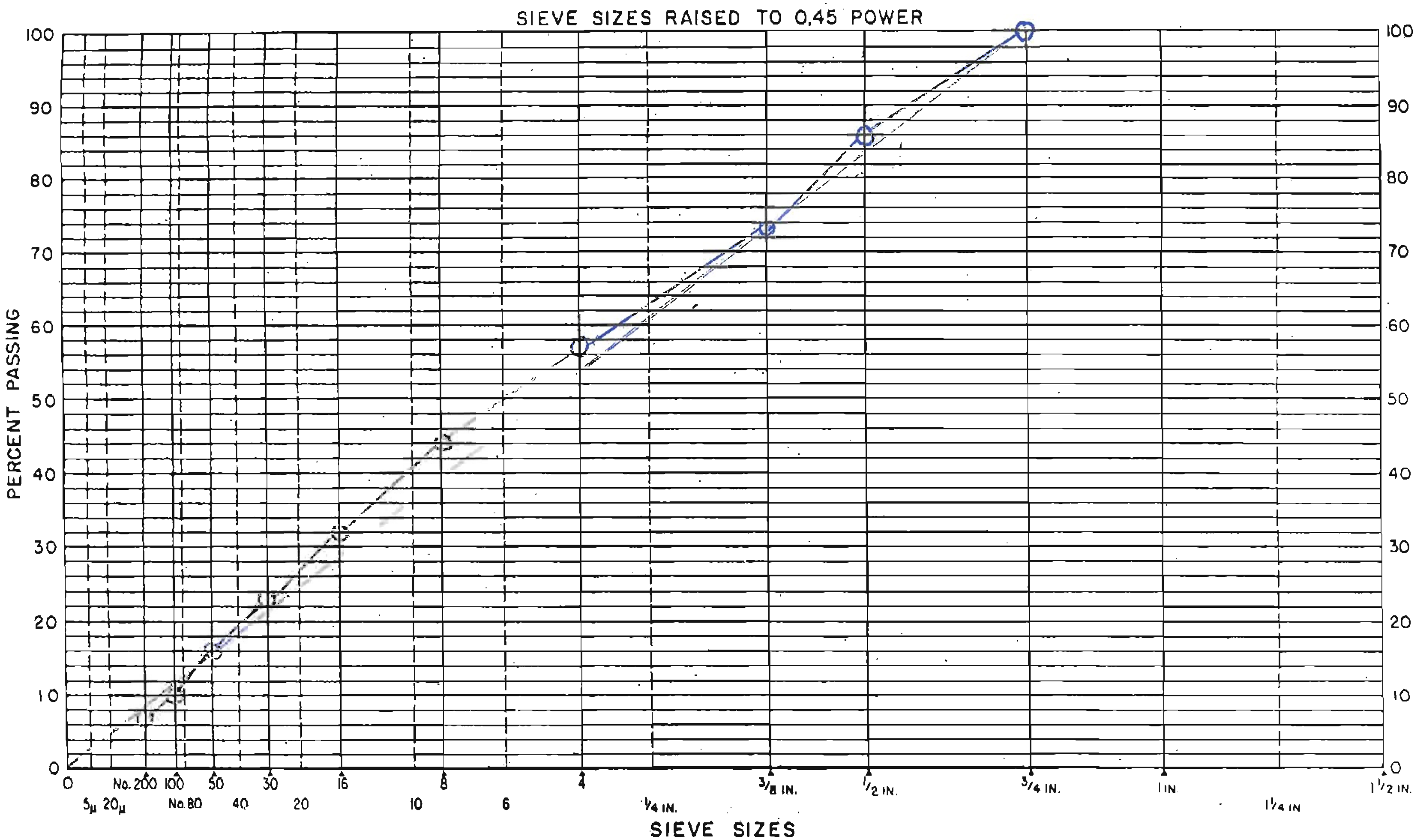


CDOT Form #1007 5/94

B-9

COLORADO DEPARTMENT OF TRANSPORTATION

GRADATION CHART



REMARKS:

C 253.117

I-25, US 36 TO 84th AVE Denver

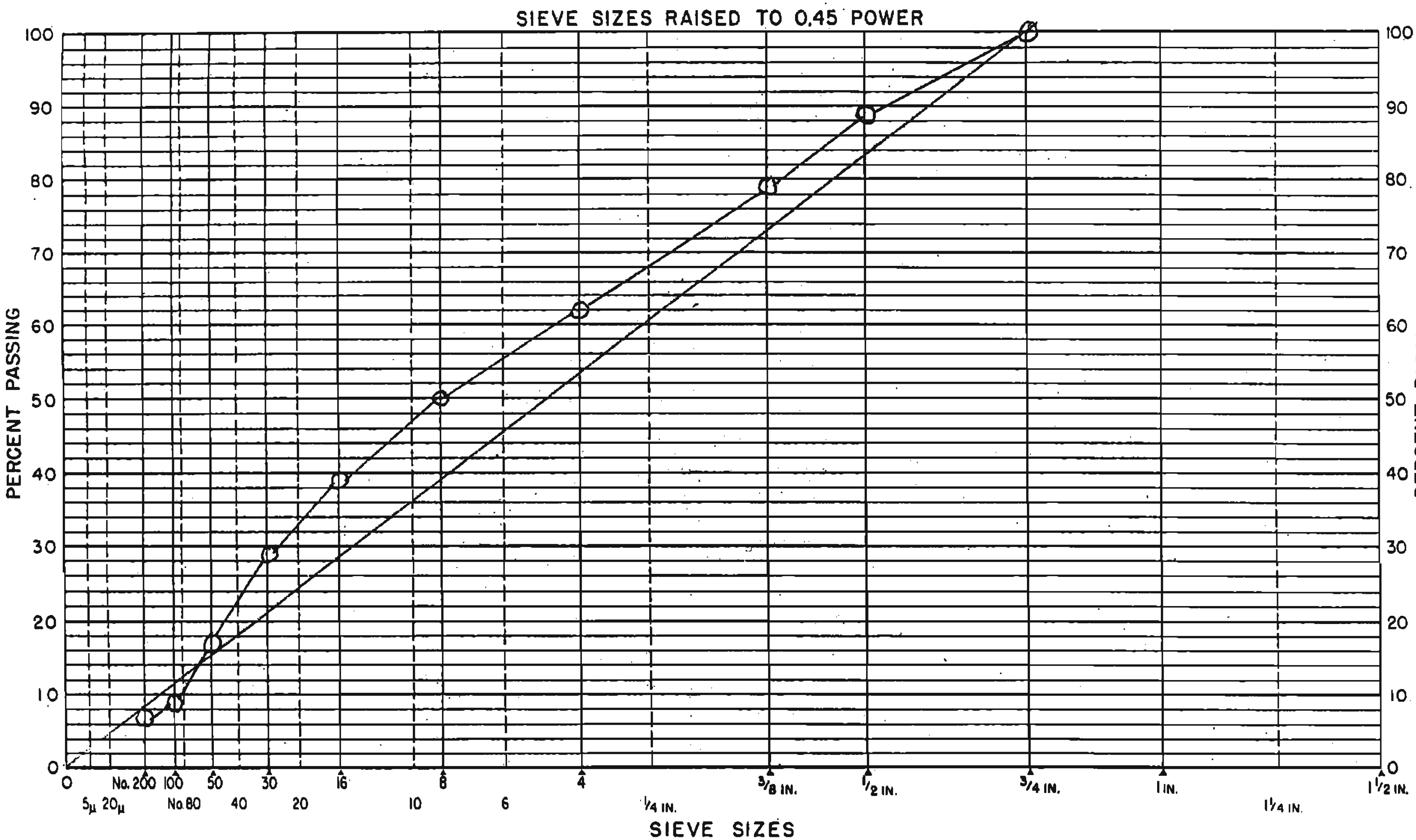
F.S. # 64223

COOLEY MORRISON / THORNTON

COOT Form #1007
1/92

COLORADO DEPARTMENT OF TRANSPORTATION

GRADATION CHART



B-11

REMARKS:

IM 0253-116

SH 7 + SH 66 Longmont

F.S. # 77004

BRANNAN S+G