MATERIAL TRANSFER DEVICE SHOWCASE IN EL PASO, TEXAS

DHT-47

DEPARTMENTAL RESEARCH

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16. Abstract

Material transfer devices (MTD) are used to transfer HMAC from the haul truck to the paver without segregation and at a uniform temperature. Different MTDs use different techniques to accomplish this task.

A Material Transfer Device Showcase was conducted in El Paso, Texas. The project was to build a Type A asphalt concrete base for a continuously reinforced concrete pavement on IH 10. The showcase was sponsored by the East El Paso Area Office, El Paso District of the Texas Department of Transportation in cooperation with Dan Williams Company and Jobe Concrete Products, Inc. The demonstration project was conducted for five days and involved five different MTDs.

The five MTDs that participated were: 1) Barber-Greene, Model BG-650; 2) Blaw-Knox. Model MC-330; 3) Cedarapids, Model CR 461; 4) Lincoln, Model 880-HP; 5) Roadtec, Model SB-2500B.

The primary objectives of the showcase were to evaluate the effectiveness of the MTDs in reducing segregation in HMAC and to compare the effectiveness of the different techniques to measure and to quantify segregation. Four different methods were used to quantify segregation in this showcase: 1) In-Place Density; 2) Infrared Thermal Imaging; 3) Visual Rating; and 4) Smoothness or Ride Data.

Some of the findings were that MTDs alone cannot cure all problems related to segregation, that ground penetrating radar has the potential to identify and to quantify segregation, and that infrared thermal imaging was found to be an excellent quality control tool.

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IN EL PASO, TEXAS

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Texas Department of Transportation

DEMONSTRATION PROJECT CONDUCTED
In El Paso, Texas
October 18,1999 – October 22, 1999

CONDUCTED BY:
TEXAS DEPARTMENT OF TRANSPORTATION
El PASO DISTRICT

IN COOPERATION WITH
DAN WILLIAMS COMPANY
AND
JOBE CONCRETE PRODUCTS, INC.,

December 1999

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EXECUTIVE SUMMARY

A Material Transfer Device (MTD) showcase was conducted in El Paso, Texas. The project was to build a Type A asphalt concrete base for a Continuously Reinforced Concrete Pavement on IH10. The showcase was sponsored by the East El Paso Area Office, El Paso District of the Texas Department of Transportation in cooperation with Dan Williams Company and Jobe Concrete Products Inc. The demonstration project was conducted for the duration of five (5) days in October 1999.

Material Transfer Devices (MTD) or Material Transfer Vehicles (MTV) are gaining popularity as a means for reducing segregation. This is especially true in the case of reducing truck-end segregation. The showcase involved five different MTDs by five different manufacturers.

The five MTDs, which participated in the showcase, are:

1. Barber-Greene, Model BG-650
2. Blaw-Knox, Model MC-330
3. Cedarapids, Model CR 461
4. Lincoln, Model 880-HP
5. Roadtec, Model SB-2500B

The Material Transfer Device (MTD) is used to transfer the HMAC from the haul truck to the paver. Different MTDs use different techniques to accomplish this task. Most MTDs re-mix the asphalt concrete in the process of transferring the mixture to the paver. The re-mixing process is believed to ensure that the asphalt concrete that might have been segregated at the plant and/or during transport is a uniform mixture of coarse and fine aggregate. Re-mixing also ensures the temperature of the HMAC is uniform at time of discharge into the paver hopper. Uniform temperatures result in relatively uniform density. MTDs can potentially provide a mix with reduced aggregate particle segregation and a uniform temperature.

The primary objectives of this showcase are to evaluate the effectiveness of the MTDs in reducing segregation in HMAC and compare the effectiveness of the different techniques to measure and quantify segregation.

The four different techniques/methods utilized to quantify segregation in this study are:

1. In-Place Density
   - Density profiles using Nuclear Density Gauge
   - Road Cores
   - Ground Penetrating Radar (GPR)
2. Infrared Thermal Imaging
3. Visual Rating

4. Smoothness or Ride Data
   - Profilograph
   - Profiler

Data was collected utilizing all the above techniques and in accordance with standard test methods and procedures. The summary of the data analyzed is listed below.

- None of the MTDs eliminated all segregation-related problems.
- The screed extensions in the paver caused segregation in this project. There was also centerline segregation caused by the paver.
- MTDs with larger on-board mix storage capacity are more effective in reducing truck-end segregation.
- The proposed test method for identifying segregation by establishing density profiles does not appear to be a very effective tool. Additional research is needed to make a more precise conclusion.
- Ground penetrating radar has the potential to identify and quantify segregation.
- The Infrared thermal imaging technique was found to be an excellent Quality Control tool.
- All four thermal cameras used in this study appear to yield the same result.
- MTDs alone cannot cure all problems related to segregation.

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CHAPTER 1
INTRODUCTION

A Material Transfer Device (MTD) demonstration project was conducted in El Paso District of Texas Department of Transportation on a section of IH10. The demonstration project was conducted by El Paso District of TxDOT in cooperation with Dan Williams Company and Jobe Concrete Products. Several manufacturers of MTD's were invited to participate in the demonstration project. The project was to build asphalt concrete base, Type A, for a Continuously Reinforced Concrete Pavement on IH10. The demonstration project was started on October 18th and concluded on October 22nd 1999.

The objectives of demonstration project were:
1. Evaluate the effectiveness of various MTDs' in reducing segregation, and
2. To compare the effectiveness of different techniques to quantify segregation.

A brief background on segregation and Material Transfer Devices is provided in this Chapter.

Segregation

Segregation can be defined as the separation of coarse and fine aggregate particles in the hot mix asphalt concrete mixture (HMAC). Segregation has a direct impact on the long-term performance of the asphalt concrete pavement by increasing the air void content of the mix, thus increasing the potential for moisture damage. Segregated locations are susceptible to raveling and total disintegration of the mix.

Segregation can primarily take place when the mix is delivered from asphalt plant to surge silo or when the mix is deposited from the surge silo to the haul truck or when the mix is transferred from the haul truck to the paver hopper. Segregation that is evident behind the paver screed generally takes one of the following three forms.

i. randomly occurring pockets of coarse aggregate
ii. longitudinally on the sides and center of the paver and
iii. transversely across the lane (at the end-of-the-truck-load).

Material Transfer Devices (MTD) or Material Transfer Vehicles (MTV) are gaining popularity as means for reducing segregation. This is especially true in the case of reducing truck-end segregation.

Material Transfer Devices

The Material Transfer Device (MTD) is used to transfer the HMAC from the haul truck to the paver. Different MTDs use different techniques to accomplish this task. Most MTDs re-mix the asphalt concrete in the process of transferring the mixture to the paver. The re-mixing process is believed to ensure that the asphalt concrete that might have been segregated at the plant and/or during transport is a uniform mixture of coarse and fine aggregate. Re-mixing also ensures the temperature of the HMAC is uniform at time of discharge into the paver hopper. Uniform temperatures result in relatively uniform density. MTDs can potentially offer dual advantage of reducing aggregate particle segregation as well as yielding a mix with uniform temperature.

At the present time several companies that manufacture and market MTDs. Table 1.1 lists the manufacturers represented in this project.

Table 1.1: List of Manufacturers Participated in the Showcase

Manufacturer	**MTD Model Number***
Barber-Greene	BG-650
Blaw-Knox	MC-330
Cedarapids	CR 461 (MS-2)
Lincoln	880-HP
Roadtec	SB-2500B

* - Specifications of the MTDs participated in this study are enclosed in the Appendices.

Figure 1.1 shows the paving operation using the above mentioned five (5) MTDs. Barber-Greene Model 260C paver was used in combination with all the above mentioned MTDs. The project started at Station 157+00 and ended at Sta. 273+00. The construction of the project was done in two phases. Phase one consisted of paving all three lanes West of the Bridge and Phase two consisted of paving all three lanes East of the Bridge.

In this five-day demonstration project, each day was dedicated to one MTD. Table 1.2 lists the day and MTD used. As seen in Figure 1.1, the length of paving is not uniform for all the MTDs. This is primarily because of the inclement weather and/or MTD breakdown.

Table 1.2: Day of Construction with Individual MTDs

Day of Construction	**MTD**
1 (Date – 10/18/199)	Barber-Greene
2 (Date – 10/19/199)	Roadtec
3 (Date – 10/20/199)	Lincoln
4 (Date – 10/21/199)	Cedarapids
5 (Date – 10/22/199)	Blaw-Knox

Evaluating the Effectiveness of MTD

MTDs were evaluated primarily in two aspects – ability to reduce material segregation and ability to produce a uniform temperature profile and to reduce temperature segregation.

There are several different methods/techniques available to evaluate material or temperature segregation. The methods used in this study are:

1. In-place density – densities were obtained using the following three methods.
   a) Nuclear Gauge – density plots as per Test Method Tex-207-F Part V
   b) Road Cores
   c) Ground Penetrating Radar
2. InfraRed Thermal Imaging
3. Profilograph Data
4. Visual Rating

Each of these methods were performed for all 5 MTDs. All the methods are explained in detail in the following Chapters. Test results and analysis of the data are also discussed. Along with evaluating MTDs, four different InfraRed Thermal Cameras were also evaluated for their ability to detect the thermal segregation. Results of these are also discussed.

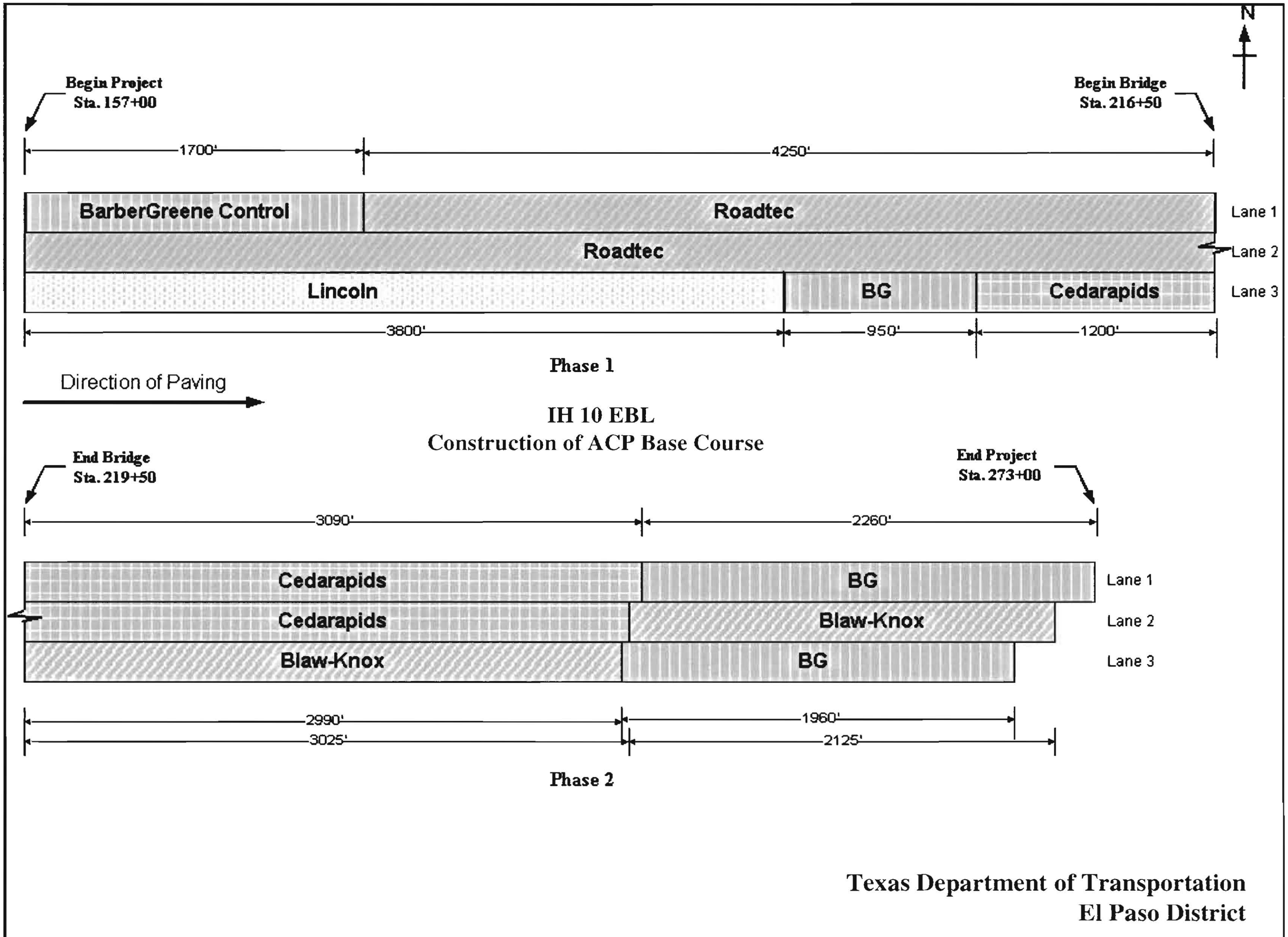


Figure 1.1: Schematic Diagram Showing Paving Operation

CHAPTER 2
DENSITY PROFILES

Several attempts have been made in the past to identify and quantify segregation during and after the lay down process of Hot Mix Asphalt Concrete (HMAC). One method to identify/quantify segregation is to measure in-place density and generate density profiles during the lay down process. Kansas Department of Transportation uses a test procedure to identify segregation using density profiles. Texas DOT is evaluating this procedure (Texas Test Method Tex-207-F Part V, Appendix A) with some minor variations. This method is explained briefly in this Chapter and the test results for all the MTDs are tabulated and presented in Appendix A.

Description

The purpose of establishing density profiles is to provide a means to identify segregation in HMAC after placement and compaction. A density profile is established behind the paver by taking multiple readings within 50' section using a nuclear density gauge. Results from the readings are used to plot a density profile, which is used to check for a reduction in density caused by segregation. In addition, the roadway location is visually inspected for segregation.

A segregation profile starting point is established at a point location where the screed stops. Any visibly identifiable segregated areas are also profiled. Nuclear density gauge readings are taken approximately every 5' in the longitudinal direction. The first reading is located approximately 10' behind the screed. Readings are taken at a uniform transverse offset from the centerline for the complete length of a single profile section. The transverse offset is more than 2' from either edge of placement and at a location believed to be most likely to detect segregation. If there is no visible segregation, then transverse offset distance is randomly selected. With the nuclear density gauge in the backscatter mode, three one-minute readings are taken and the average of these 3 readings is taken as the density for that point. Nuclear density readings are taken at a minimum of 10 locations along the profile section.

The drop in density caused by segregation is calculated by subtracting the lowest density from the average profile density. The average density is calculated using all density determinations in the profile section. The density range is calculated by subtracting the lowest from the highest profile density. A copy of the special provision and the test procedure are included in Appendix-A.

Discussion of Test Results

Density profiles were established using TxDOT Standard Test Method Tex-207-F Part V. A minimum of six (6) density profiles were established for each MTD that participated in the demonstration project. Road cores were taken to measure density in the laboratory for comparison purposes. Three (3) cores were taken in each profile to measure density in the laboratory. Test results for each MTD is discussed separately in the following paragraphs.

Nuclear Density

Nuclear density profiles were established as described in the previous sections. All the locations selected for density profile exhibited low to severe segregation with few exceptions. A summary of the nuclear profile data for each MTD is discussed below. Detailed field Nuclear Density Profile Data Collection forms are attached in Appendix A.

Based on TxDOT proposed special provision (Appendix A) for the type of mix used in this project, maximum allowable density range is 8.0lb./c.f. and the maximum allowable decrease in density is 5.0lb./c.f.

Barber-Greene (Model BG-650)

As shown in Table 2.1, all six locations selected for testing were visually segregated. Only in one location (Location 6) both proposed specification criteria for density range and decrease in density were exceeded. In other five (5) locations the procedure did not detect segregation.

Table 2.1: Summary of Nuclear Density Profile Data for Barber-Greene MTD

Profile #	High (lbs./cf)	Low (lbs./cf)	Average (lbs./cf)	Visible Segregation	Density Range High-Low (lbs./c.f.)	Decrease in Density Average-Low (lbs./c.f.)
1	149.3	141.6	144.5	Yes	7.7	2.9
2	145.3	140.0	143.3	Yes	5.3	3.3
3	149.0	144.3	147.3	Yes	4.7	3.0
4	149.2	144.4	147.1	Yes	4.8	2.7
5	148.8	144.3	146.7	Yes	4.5	2.4
6	147.2	130.8	140.9	Yes	16.4	10.1
Specification Maximum Allowable					8.0	5.0

Roadtec (Model SB-2500B)

As shown in Table 2.2, four out of eight locations (Locations 1, 3, 7 and 8) met the specification requirement for decrease in density due to segregation and density range even though all of these locations exhibit some level of visible segregation.

Table 2.2: Summary of Nuclear Density Profile Data for Roadtec MTD

Profile #	High (lbs/cf)	Low (lbs/cf)	Average (lbs/cf)	Visible Segregation	Density Range High-Low (lbs/cft)	Decrease in Density Average-Low (lbs/cf)
1	149.4	145.9	147.3	Yes	3.5	1.4
2	151.9	141.4	144.7	Yes	10.5	3.3
3	146.9	141.3	143.6	Yes	5.6	2.3
4	144.2	137.5	141.3	No	6.7	3.8
5	144.4	134.1	138.9	Yes	10.3	4.8
6	145.9	135.4	142.4	Yes	10.5	7.0
7	146.7	141.5	144.1	Yes	5.2	2.6
8	145.2	142.3	143.3	Yes	2.9	1.0
Specification Maximum Allowable					8.0	5.0

Lincoln (Model 880-HP)

As shown in Table 2.3, five of the six locations the density profile procedure correctly identified the segregated spots.

Table 2.3: Summary of Nuclear Density Profile Data for Linclon MTD

Profile #	High (lbs/cf)	Low (lbs/cf)	Average (lbs/cf)	Visible Segregation	Density Range High-Low (lbs/cft)	Decrease in Density Average-Low (lbs/cf)
1	145.7	136.8	141.8	Yes	8.9	5.0
2	143.9	134.9	139.0	Yes	9.0	4.1
3	148.3	139.9	143.2	Yes	8.4	3.3
4	145.3	133.6	140.6	Yes	11.7	7.0
5	144.4	139.2	142.5	Yes	5.2	3.3
6	145.1	133.4	139.4	Yes	11.7	6.0
Specification Maximum Allowable					8.0	5.0

Cedarapids (Model CR-461 (MS-2))

As shown in Table 2.4, four of the six locations (Locations 4 and 5) that had visible segregation passed the specification requirements for drop in density.

Table 2.4: Summary of Nuclear Density Profile Data for Cedarapids MTD

Profile #	High (lbs/cf)	Low (lbs/cf)	Average (lbs/cf)	Visible Segregation	Density Range High-Low (lbs/cft)	Decrease in Density Average-Low (lbs/cf)
1	145.1	133.4	139.4	Yes	11.7	6.0
2	144.6	135.0	140.7	Yes	9.6	5.7
3	142.3	133.1	139.6	Yes	9.2	6.5
4	147.1	141.6	144.5	Yes	5.5	2.9
5	147.2	139.7	143.4	Yes	7.5	3.7
6	150.0	137.3	144.2	Yes	12.7	6.9
Specification Maximum Allowable					8.0	5.0

Blaw-Knox (Model MC-330)

As shown in Table 2.5, three of the six locations that had visible segregation passed the specification requirements.

Table 2.5: Summary of Nuclear Density Profile Data for Blaw-Knox MTD

Profile #	High (lbs/cf)	Low (lbs/cf)	Average (lbs/cf)	Visible Segregation	Density Range High-Low (lbs/cft)	Drop in Density Average-Low (lbs/cf)
1	147.1	139.7	144.0	Yes	7.4	4.3
2	149.4	140.5	145.7	Yes	8.9	5.2
3	147.5	143.7	145.6	Yes	3.8	1.9
4	143.3	134.5	140.3	Yes	8.8	5.8
5	142.5	137.5	140.0	Yes	5.0	2.5
6	140.4	126.0	131.5	Yes	14.4	5.5
Specification Maximum Allowable					8.0	5.0

Road Core Density

Road core densities were determined in the laboratory according to TxDOT test procedure Tex-207-F, Part I. Core densities from all the density profile locations are shown in Appendix A. Core densities from all the locations for all the MTDs that participated in this study are compared to the corresponding Nuclear Gauge Densities and are plotted in Figure 2.1. From Figure 2.1, there does not appear to be a good correlation between the lab core density and field nuclear density at the same location. This is likely due to the fact that nuclear density gauge was not calibrated for the type of mix which was placed on the project.

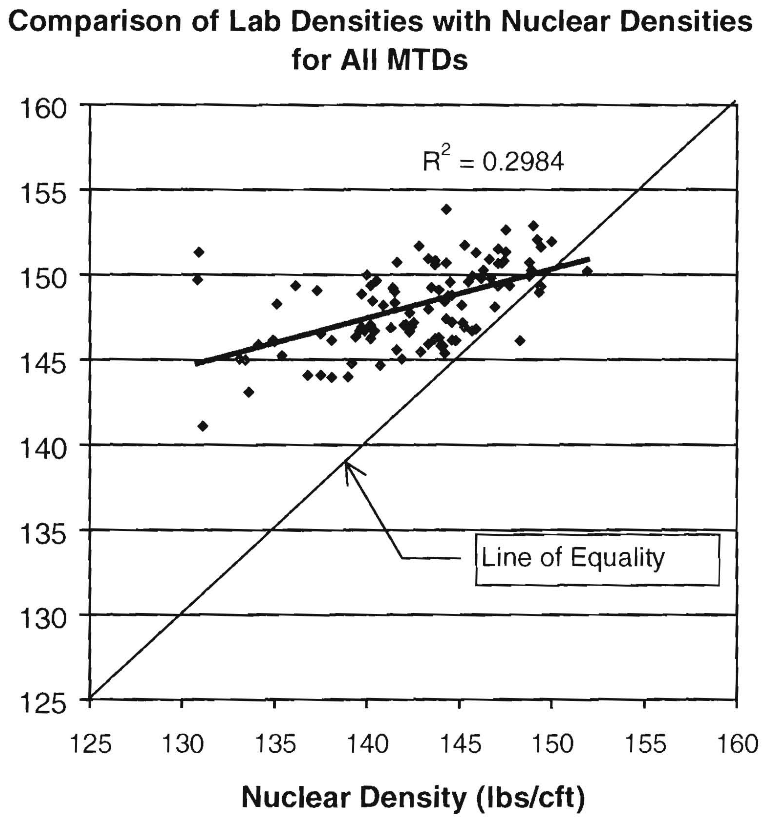


Figure 2.1: Comparison of Lab Densities with Nuclear Densities for all MTDs.

Summary

The following Table summarizes the findings.

Table 2.6: Summary of Findings from Nuclear Density Profiles

MTD	**No of Density Profiles**	**Number of Visible Segregated Spots**		
		Identified By the Density Profile	*Not* Identified By the Density Profile	Success Rate
Barber Greene	6	1	5	17%
Roadtec	8	3	5	38%
Lincoln	6	5	1	83%
Cederapids	6	4	2	67%
Blaw-Knox	6	3	3	50%

Success rate is defined as the percentage of times the density profile procedure correctly identified segregated spots.

CHAPTER 3
INFRARED THERMAL IMAGING

Infrared thermal imaging technique has a wide range of applications and has extensively been used in industrial engineering and medical fields for several decades. Thermal imaging has been used in Civil Engineering for almost two decades primarily in the construction of bridge decks to detect delaminations, asphalt concrete overlay de-bonding and defects in portland cement concrete. In recent years, there has been an increasing interest in utilizing this technique to identify thermal segregation in the construction of asphalt concrete pavements. A brief background on this infrared thermography is explained in the following paragraphs.

All objects emit infrared radiation in the form of heat that can be detected using an infrared scanner. These natural impulses are converted and processed to create an image of the object's thermal energy. Colors are used to represent the thermal image. These colors can be selected from an array of color bands to represent the surface temperatures.

Today, there are wide varieties of thermal cameras available to be used for different purposes and applications. Three essential components in any thermal imaging system are:

1. Optical scanner – to detect radiation in infrared spectrum
2. Display monitor – to display images
3. Computer and Software – for data acquisition and analysis

Past research studies in this area suggest that infrared thermography appears to have potential to detect and measure segregation. Several research studies are underway at the present time to utilize infrared thermography. In this demonstration project, infrared thermal imaging is one of the tools utilized to evaluate the effectiveness of Material Transfer Devices (MTD). Research performed by National Center for Asphalt Technology suggests that the areas with temperature differentials greater than 38°F are likely to have high levels of segregation. Low levels of segregation can be expected for the temperature differential between 18 °F to 29 °F and medium levels of segregation for temperature differential of 29 °F to 38 °F.

One of the objectives of this study is to evaluate different MTDs' ability to produce a uniform mix temperature behind the paver. In this project, Inframetrics' ThermaSnap type infrared thermal camera was used by TxDOT to capture thermal images. Several thermal images were taken during this weeklong demonstration project. These images were analyzed using TherMonitor Lite 95 Software. Figures 3.1 through 3.6 are representative of the thermal images that were captured for 5 different MTDs.

Equipment manufacturers were also present and they also obtained thermal images using their own equipment. Some of the manufacturers made their thermal images available to TxDOT and those images are presented in Appendix B.

Roadtec MTD

Pictures R1 through R6 shown in Figure 3.1 are representative thermal images of the lay down process using RoadTec MTD. The following preliminary observations may be made from these pictures.

1. Temperature distribution in the longitudinal direction is relatively uniform.
2. Temperature distribution in transverse direction is uniform for a given location on the mat.
3. Individual low temperature spots on the mat were observed very rarely.

Temperature variations observed from these seven thermal images are summarized and listed in Table 3.1. The maximum and minimum temperatures were selected from the total mat area.

Table 3.1: Temperature Variations Observed from Figure 3.1

Picture	Maximum (°F)	Minimum (°F)	Range (°F)	Segregation*
R1	236.7	223.0	13.7	None
R2	233.2	204.5	28.7	Low
R3	247.5	195.8	51.7	High
R4	286.3	255.7	30.6	Medium
R5	267.7	235.2	32.5	Medium
R6	258.7	254.4	4.3	None
Average	255.0	228.1	26.9	Low

* - Segregation as defined by NCAT criteria.

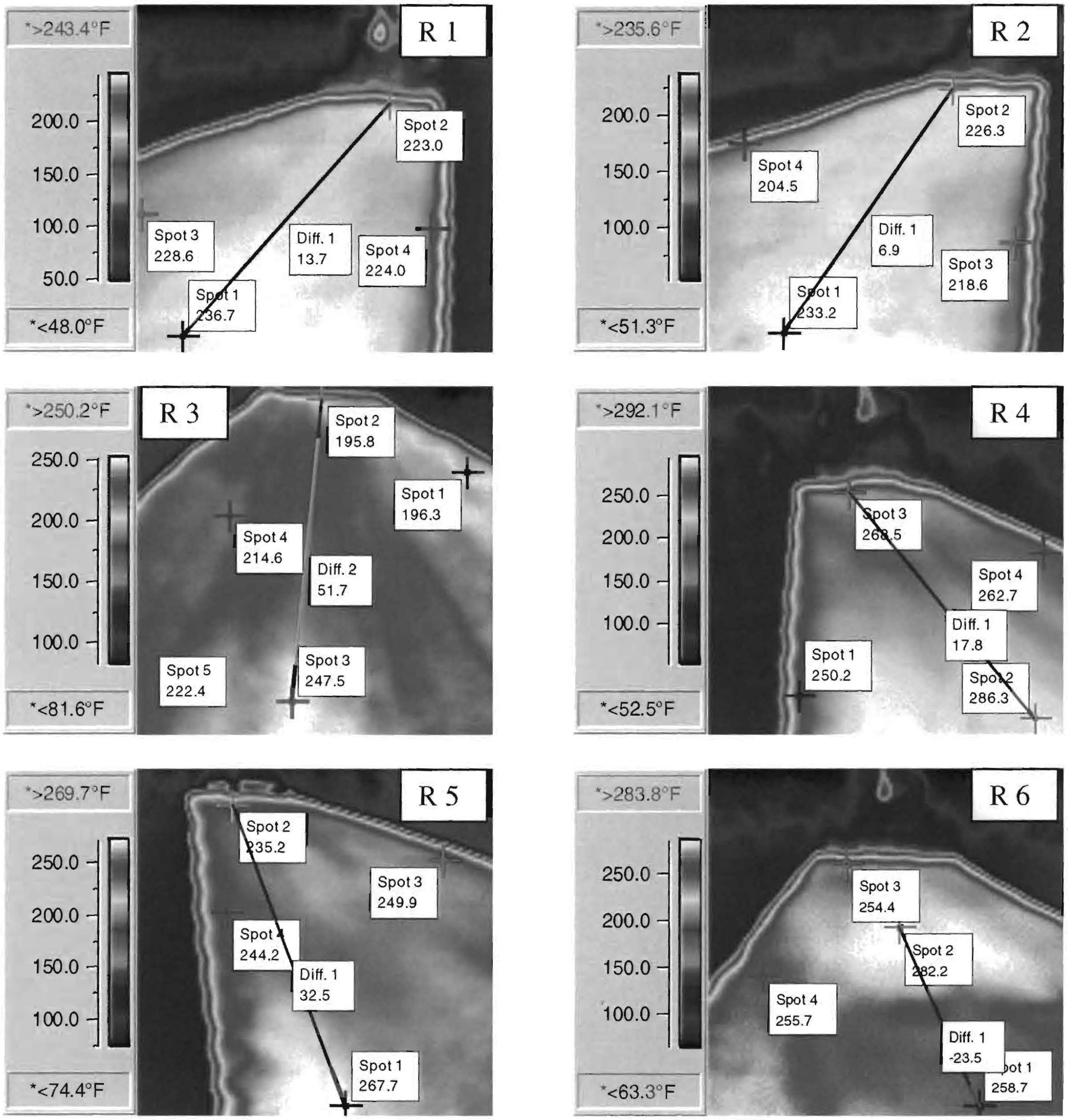


Figure 3.1: Representative Images for Roadtec MTD

Lincoln MTD

Pictures L1 through L6 shown in Figure 3.2 are representative thermal images of the lay down process using Lincoln MTD. The following preliminary observations may be made from these pictures.

1. Temperature distribution in the longitudinal direction is relatively uniform.
2. Temperature distribution in transverse direction is variable.
3. Occasional low temperature spots in the mat are observed.

Temperature variations observed from these six thermal images are summarized and listed in Table 3.2.

Table 3.2: Temperature Variations Observed from Figure 3.2

Picture	Maximum (°F)	Minimum (°F)	Range (°F)	Segregation*
L1	323.7	291.0	32.7	Medium
L2	322.9	291.0	31.9	Medium
L3	275.7	257.4	18.3	Low
L4	244.1	214.1	30.0	Medium
L5	281.2	245.9	35.3	Medium
L6	286.3	251.9	34.4	Medium
Average	289.0	258.6	30.4	Medium

* - Segregation as defined by NCAT criteria.

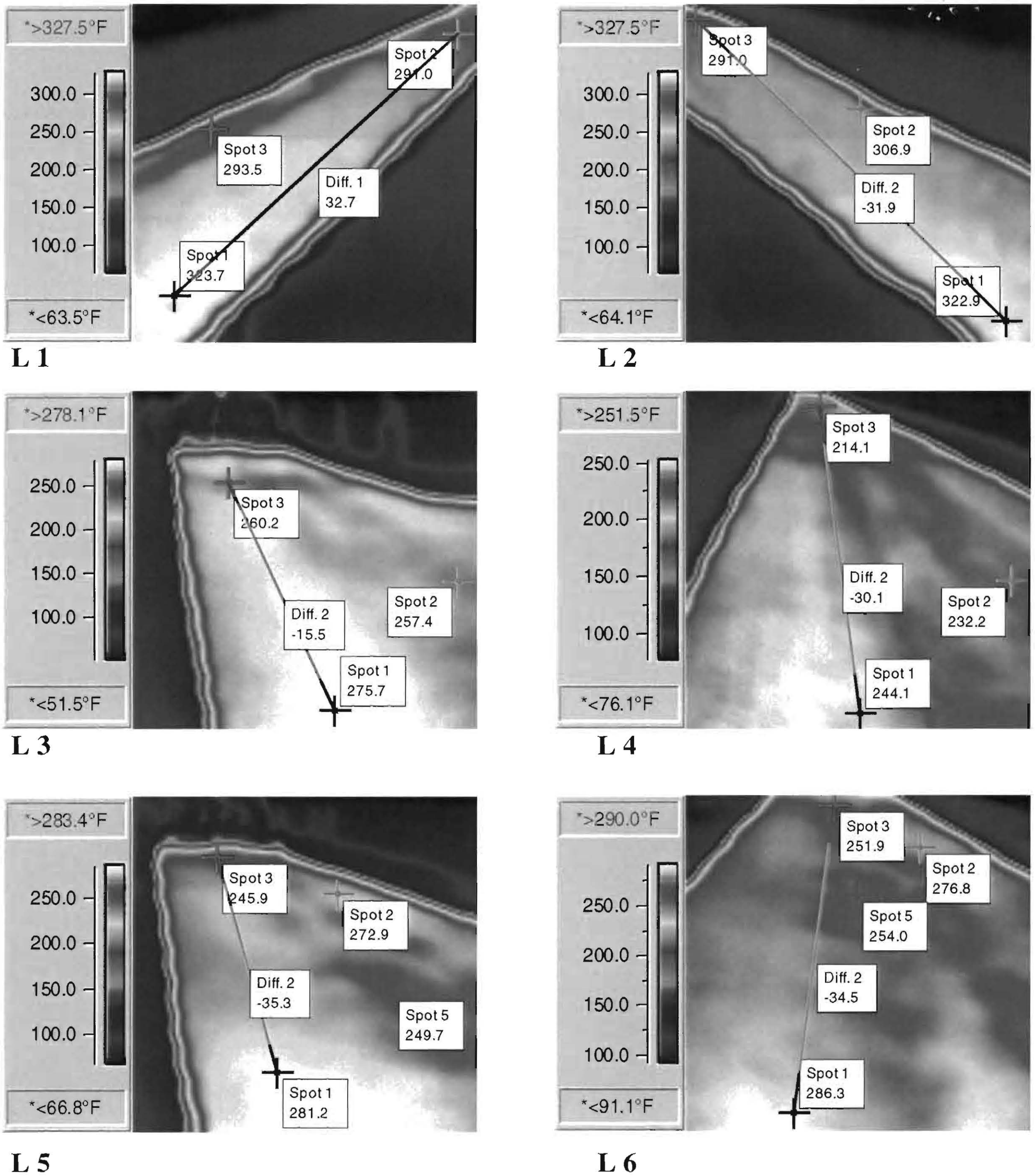


Figure 3.2: Representative Thermal Images for Lincoln MTD

Cederapids MTD

Pictures C1 through C20 shown in Figure 3.3 are representative thermal images of the lay down process using Cedarapids MTD. The following preliminary observations may be made from these pictures.

1. Temperature distribution in the longitudinal direction is relatively uniform.
2. Temperature distribution in transverse direction shows significant variation.
3. Several low temperature spots in the mat are observed.

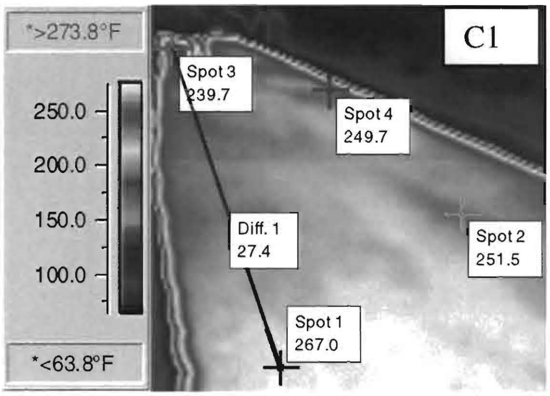
Temperature variations observed from these twenty thermal images are summarized and listed in Table 3.3. The maximum and minimum temperatures were selected from the total mat area to calculate the range.

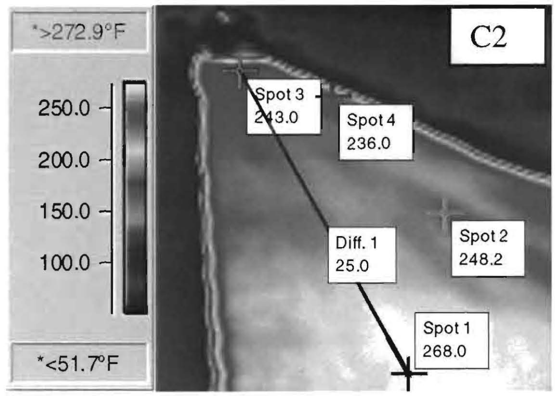
Table 3.3: Temperature Variations Observed from Figure 3.3

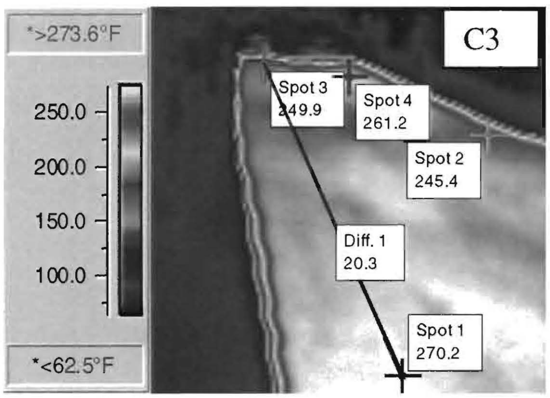
Picture	Maximum (°F)	Minimum (°F)	Range (°F)	Segregation*
Cederapids with Auger Extenstion				
C1	267.0	239.7	27.3	Low
C2	268.0	236.0	32.0	Medium
C3	270.2	245.4	24.8	Low
C4	258.2	210.4	47.8	High
C5	257.4	218.9	38.5	High
C6	215.2	176.6	38.6	High
C7	279.2	257.9	21.3	Low
C8	238.8	198.3	40.5	High
C9	289.7	238.3	51.4	High
C10	267.5	234.5	33.0	Medium
C11	288.8	253.2	35.6	Medium
C12	281.8	257.2	24.6	Low
Cederapids without Auger Extenstion				
C13	291.0	267.7	23.3	Low
C14	266.0	242.3	23.7	Low
C15	266.7	243.0	23.7	Low
C16	286.8	241.8	45.0	High
C17	287.0	274.0	13.0	None
C18	279.5	242.7	36.8	Medium
C19	268.0	234.3	33.7	Medium
C20	260.0	249.4	10.6	None
Average	269.3	238.1	31.3	Medium

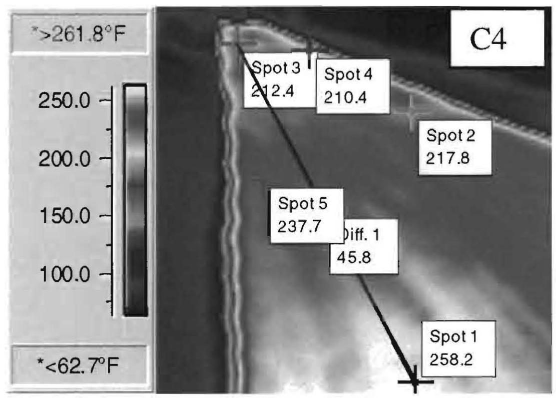
* - Segregation as defined by NCAT criteria.

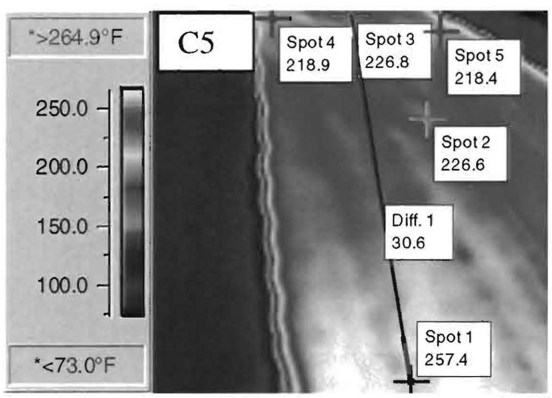
Cederapids with Auger Extension

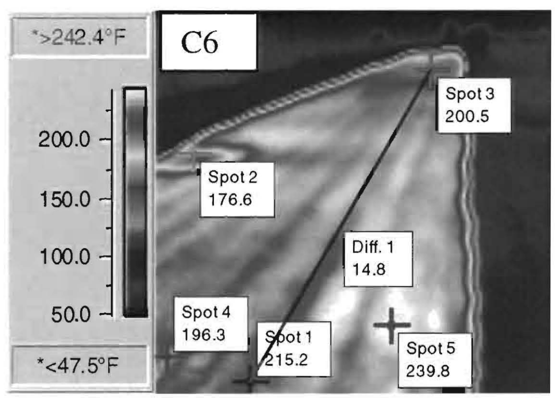


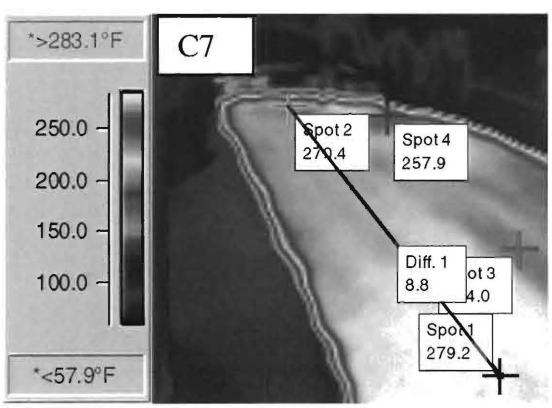


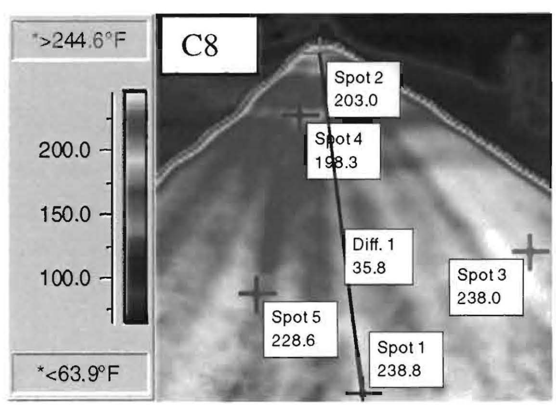


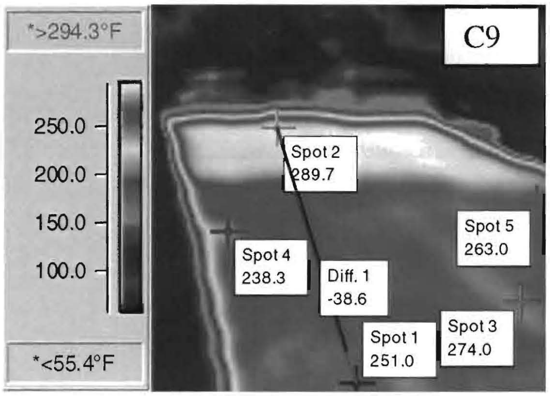


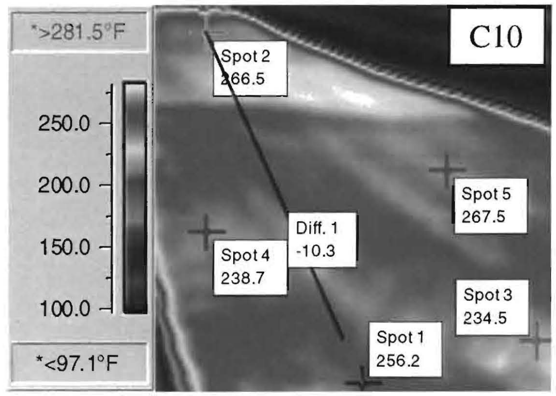


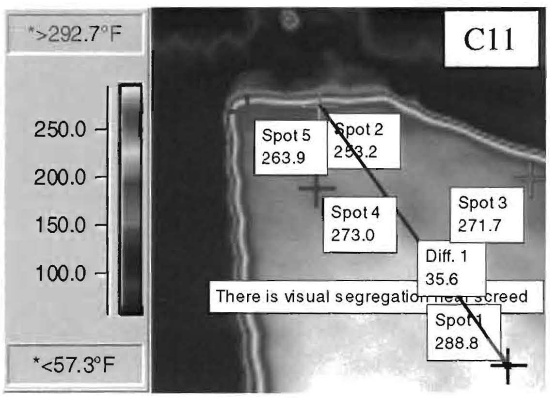


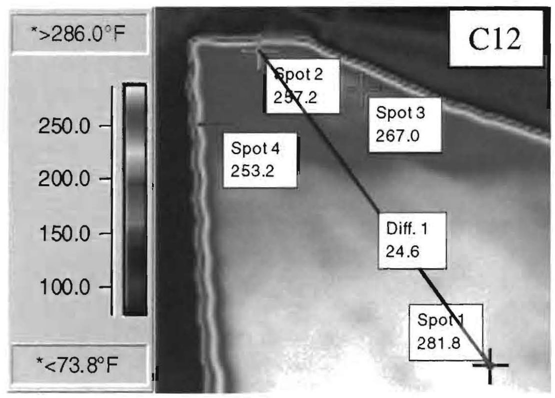





C9
*>294.3°F
250.0
200.0
150.0
100.0
*<55.4°F
Spot 2 289.7
Spot 4 238.3
Diff. 1 -38.6
Spot 5 263.0
Spot 1 251.0
Spot 3 274.0


C10
*>281.5°F
250.0
200.0
150.0
100.0
*<97.1°F
Spot 2 266.5
Spot 5 267.5
Diff. 1 -10.3
Spot 4 238.7
Spot 3 234.5
Spot 1 256.2


C11
*>292.7°F
250.0
200.0
150.0
100.0
*<57.3°F
Spot 5 263.9
Spot 2 253.2
Spot 4 273.0
Spot 3 271.7
Diff. 1 35.6
There is visual segregatio
Spot 1 288.8


C12
*>286.0°F
250.0
200.0
150.0
100.0
*<73.8°F
Spot 2 257.2
Spot 3 267.0
Spot 4 253.2
Diff. 1 24.6
Spot 1 281.8

Cederapids without Auger Extension

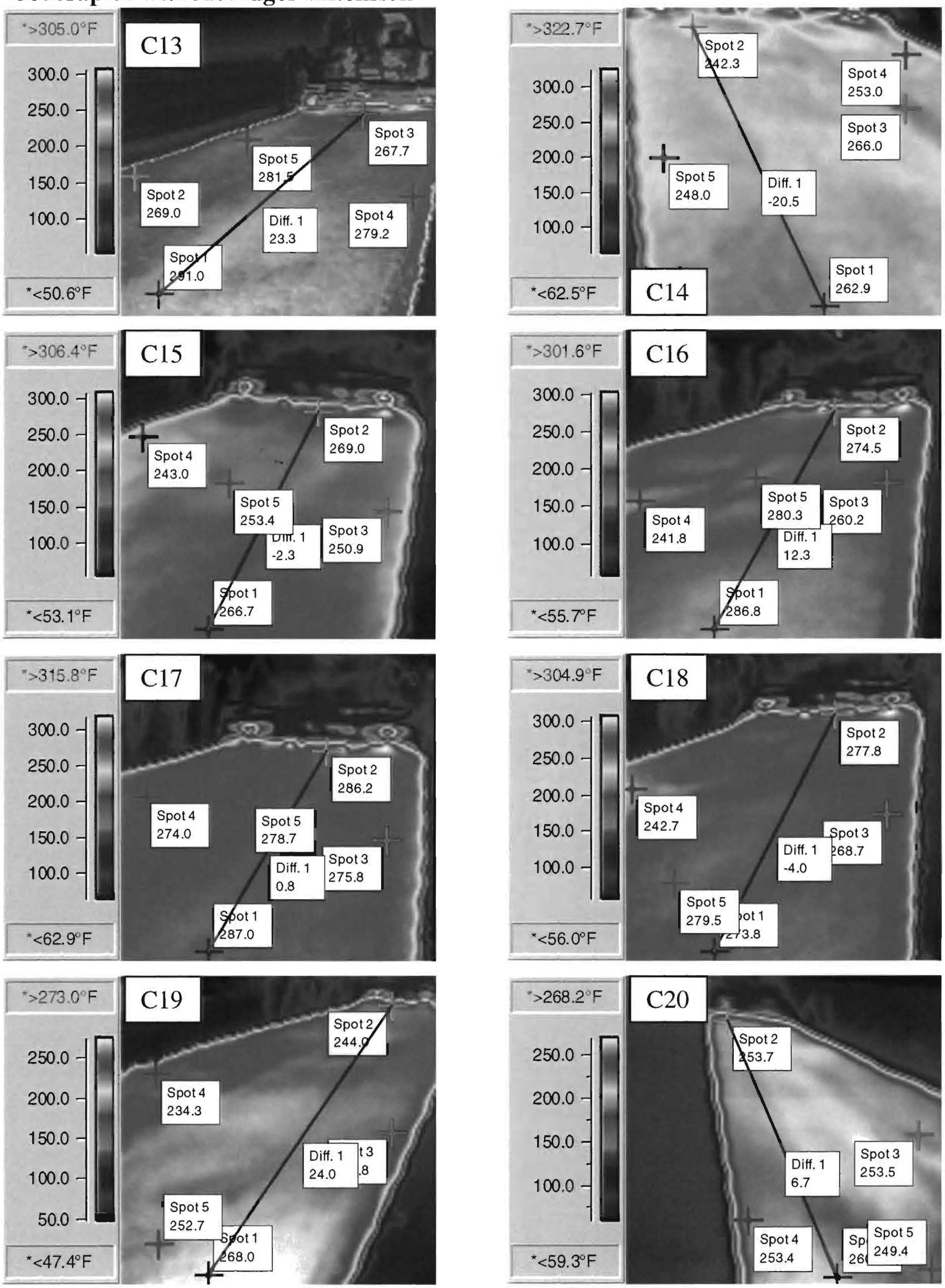


Figure 3.3: Representative Thermal Images for Cederapids MTD

BarberGreene MTD

Pictures B1 through B19 shown in Figure 3.4 are representative thermal images of the lay down process using BarberGreen MTD. The following preliminary observations may be made from these pictures.

1. Temperature distribution in the longitudinal direction is relatively uniform.
2. Temperature distribution in transverse direction is variable.
3. Individual low temperature spots on the mat were observed.

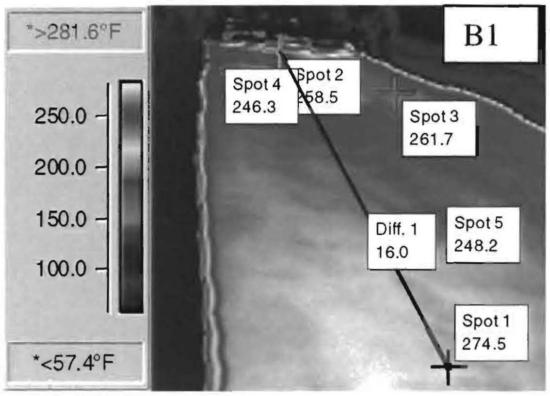
Temperature variations observed from these nineteen thermal images are summarized and listed in Table 3.4. The maximum and minimum temperatures were selected from the total mat area.

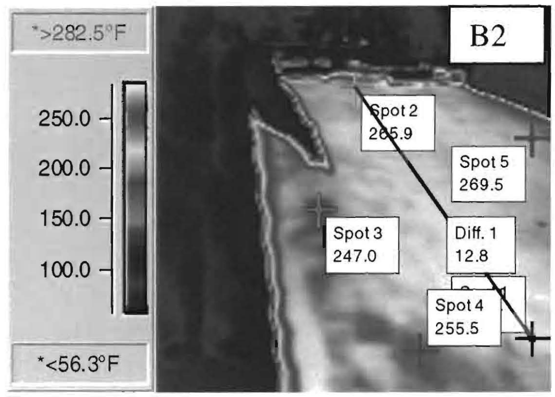
Table 3.4: Temperature Variations Observed from Figure 3.4

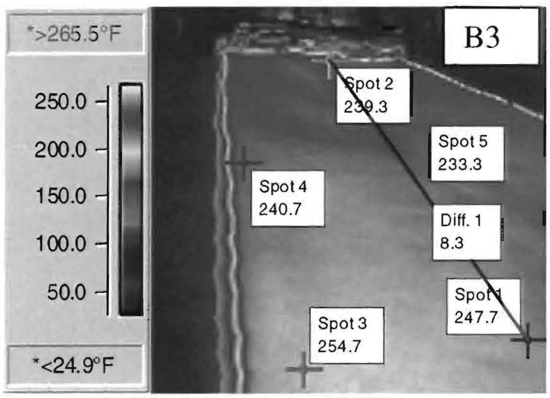
Picture	Maximum (°F)	Minimum (°F)	Range (°F)	Segregation*
Control 1				
1	274.0	246.3	27.7	Low
2	269.5	247.0	22.5	Low
3	254.7	233.3	21.4	Low
4	276.2	246.5	29.7	Medium
5	270.0	221.9	48.1	High
6	266.8	212.8	54.0	High
7	304.3	265.4	38.9	High
8	265.4	229.0	36.4	Medium
9	265.4	229.0	36.4	Medium
10	264.7	247.7	17.0	None
11	259.1	227.5	31.6	Medium
12	241.4	207.1	34.3	Medium
13	228.3	188.1	40.2	High
14	234.5	187.6	46.9	High
Control 2				
15	283.5	255.0	28.5	Low
16	274.9	243.0	31.9	Medium
17	285.8	236.6	49.2	High
18	259.2	216.9	42.3	High
19	305.8	278.7	27.1	Low
Average	267.6	232.6	35.0	Medium

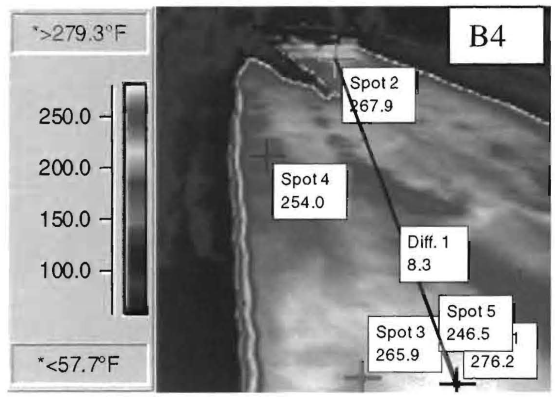
* - Segregation as defined by NCAT criteria.

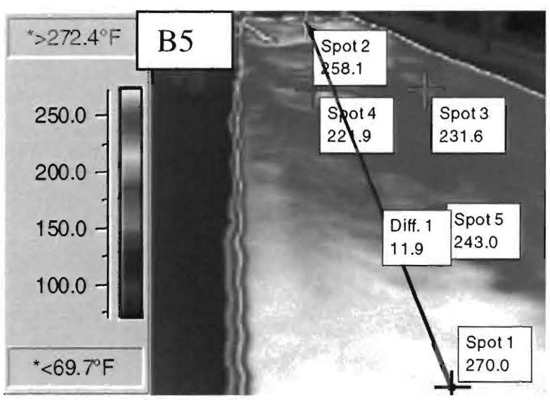
BarberGreene Control 1

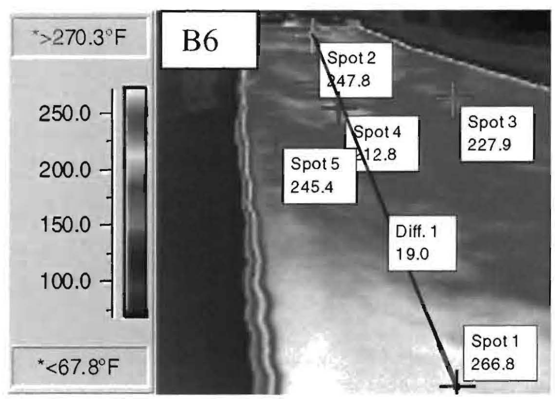


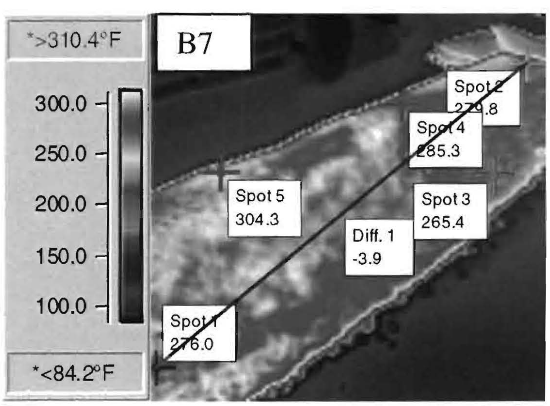


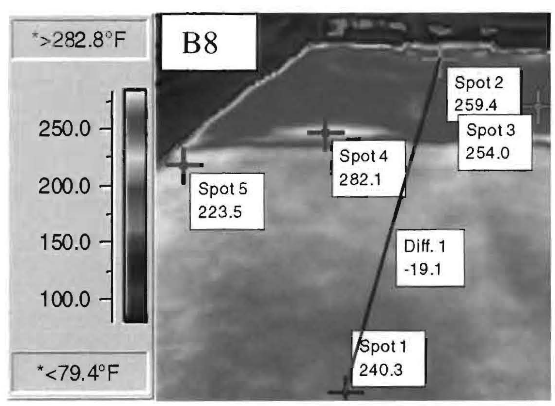


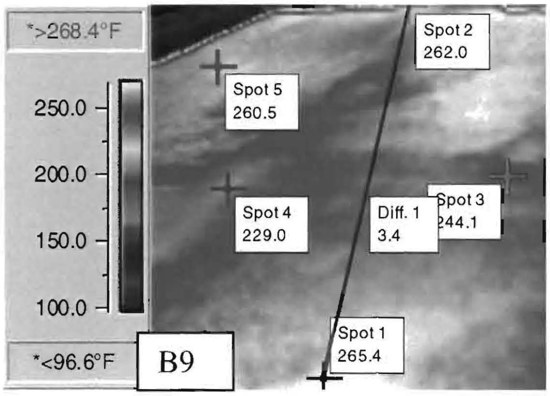


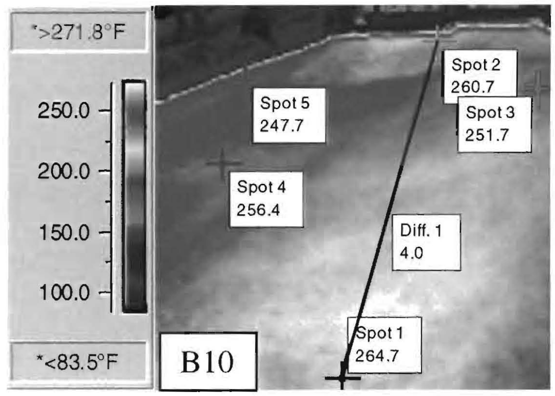


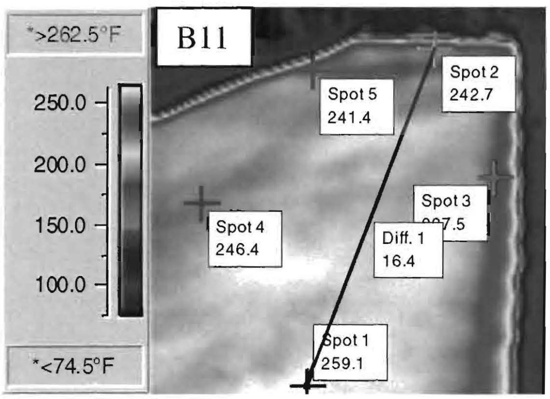


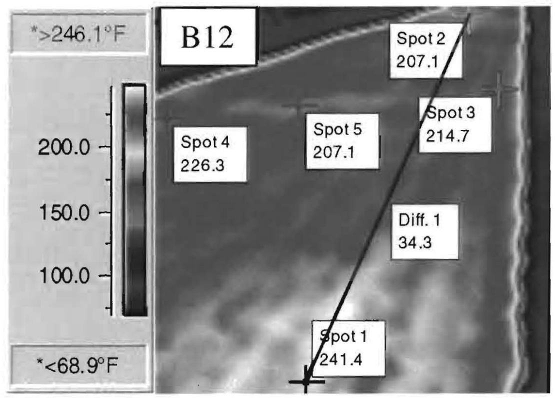


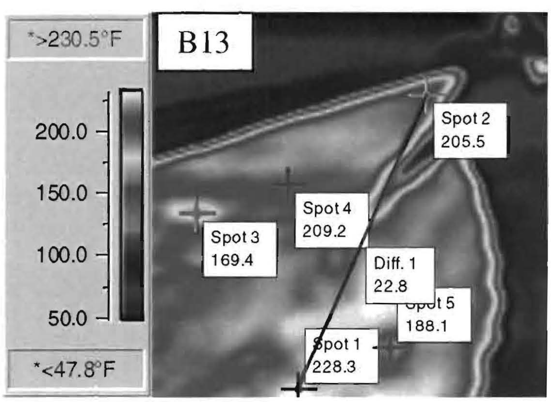


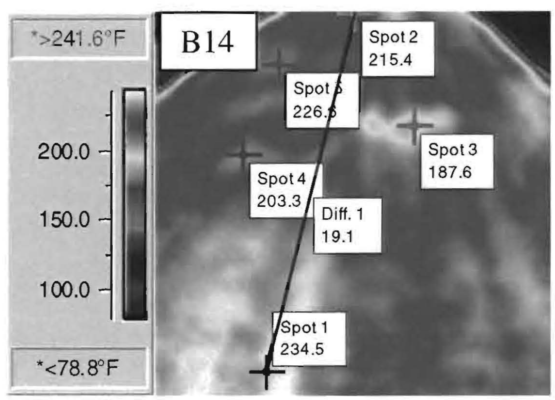

*>268.4°F
250.0
200.0
150.0
100.0
*<96.6°F
B9
Spot 2
262.0
Spot 5
260.5
Spot 4
229.0
Diff. 1
3.4
Spot 3
Spot 1
265.4


*>271.8°F
250.0
200.0
150.0
100.0
*<83.5°F
B10
Spot 2
260.7
Spot 3
251.7
Spot 5
247.7
Spot 4
256.4
Diff. 1
4.0
Spot 1
264.7


*>262.5°F
250.0
200.0
150.0
100.0
*<74.5°F
B11
Spot 2
242.7
Spot 5
241.4
Spot 3
Spot 4
246.4
Diff. 1
16.4
Spot 1
259.1


*>246.1°F
200.0
150.0
100.0
*<68.9°F
B12
Spot 2
207.1
Spot 3
214.7
Spot 4
226.3
Spot 5
207.1
Diff. 1
34.3
Spot 1
241.4


*>230.5°F
200.0
150.0
100.0
50.0
*<47.8°F
B13
Spot 2
205.5
Spot 4
209.2
Spot 3
169.4
Diff. 1
22.8
188.1
Spot 1
228.3


*>241.6°F
200.0
150.0
100.0
*<78.8°F
B14
Spot 2
215.4
Spot 3
187.6
Spot 4
203.3
Diff. 1
19.1
Spot 1
234.5

BarberGreene Control 2

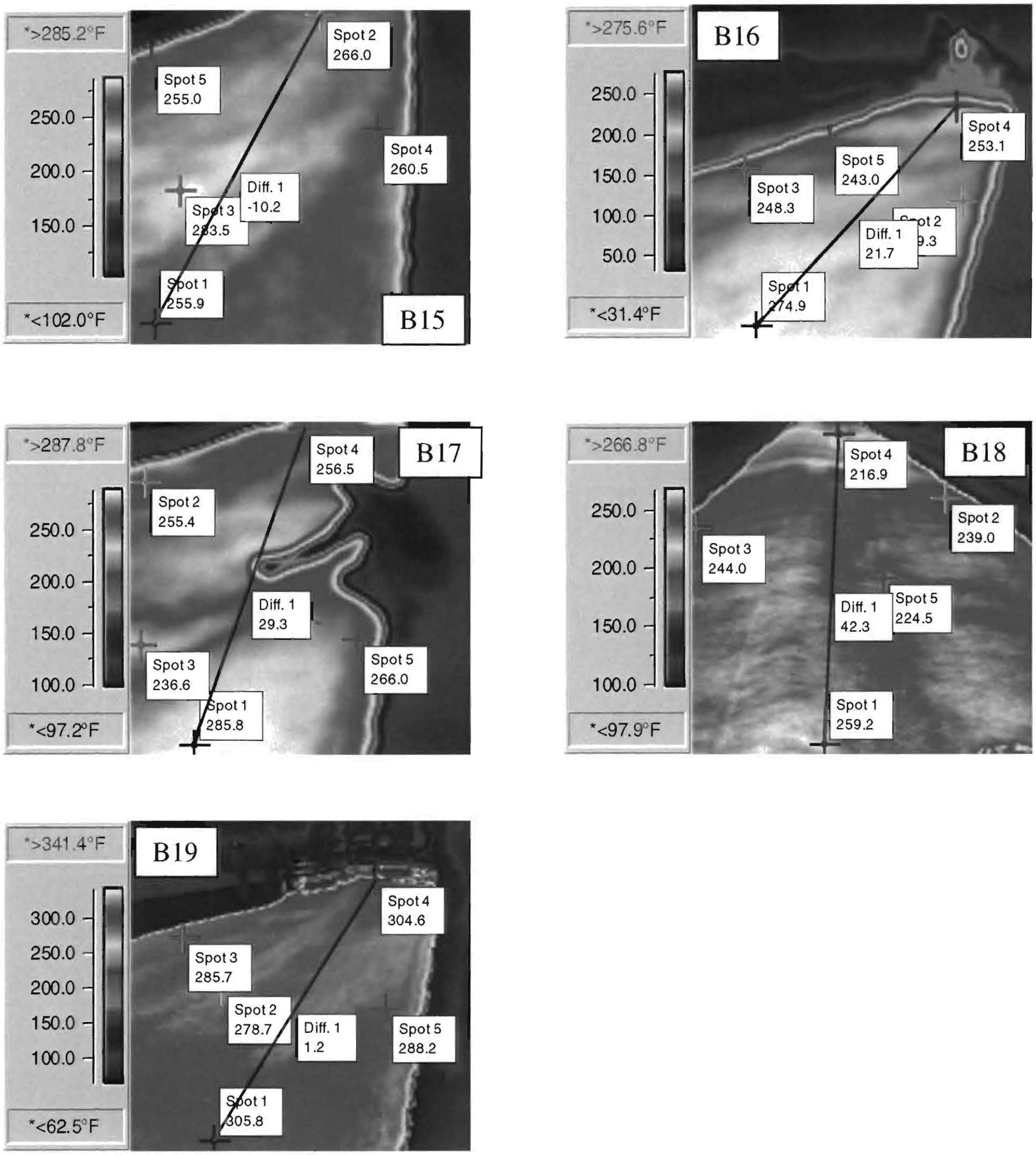


Figure 3.4: Representative Thermal Images for BarberGreene MTD

Blaw-Knox MTD

Pictures BK1 through BK14 shown in Figure 3.5 are representative thermal images of the lay down process using Blaw-Knox MTD. The following preliminary observations may be made from these pictures.

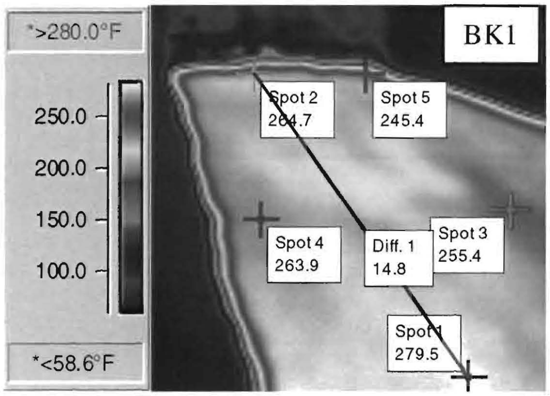
1. Temperature distribution in the longitudinal direction is relatively uniform.
2. Temperature distribution in transverse direction is variable.
3. Individual low temperature spots on the mat were observed.

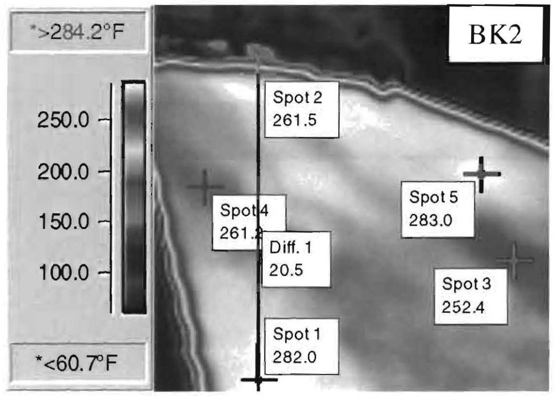
Temperature variations observed from these fourteen thermal images are summarized and listed in Table 3.5. The maximum and minimum temperatures were selected from the total mat area.

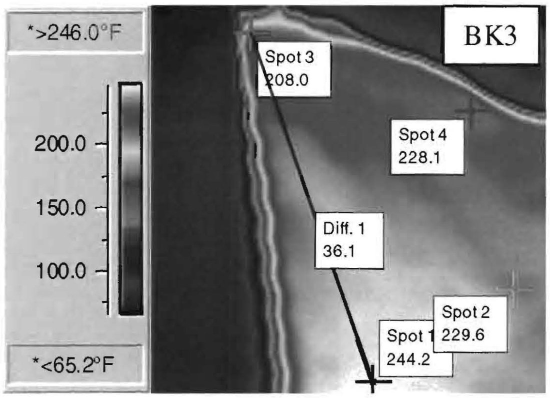
Table 3.5: Temperature Variations Observed from Figure 3.5

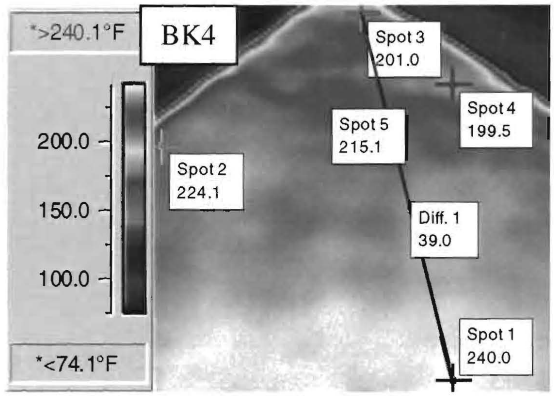
Picture	Maximum (^oF)	Minimum (^oF)	Range (^oF)	Segregation*
1	279.5	245.4	34.1	Medium
2	282.0	252.4	29.6	Medium
3	244.2	208.0	36.2	Medium
4	240.0	199.5	40.5	High
5	211.6	185.2	26.4	Low
6	226.3	183.8	42.5	High
7	291.5	260.5	31.0	Medium
8	278.3	256.7	21.6	Low
9	296.0	271.9	24.1	Low
10	312.7	246.3	66.4	High
11	291.1	274.8	16.3	None
12	287.7	262.9	24.8	Low
13	282.7	262.9	19.8	Low
14	284.5	263.2	21.3	Low
Average	272.0	241.0	31.0	Medium

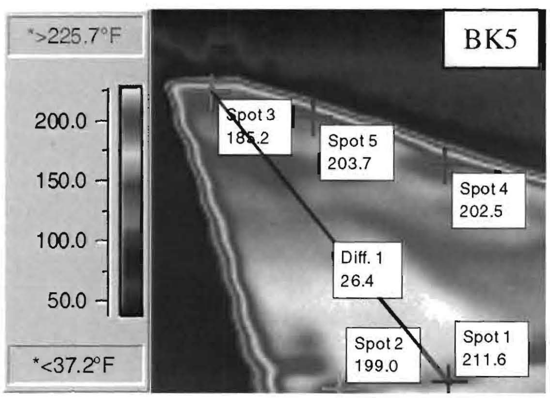
* - Segregation as defined by NCAT criteria.

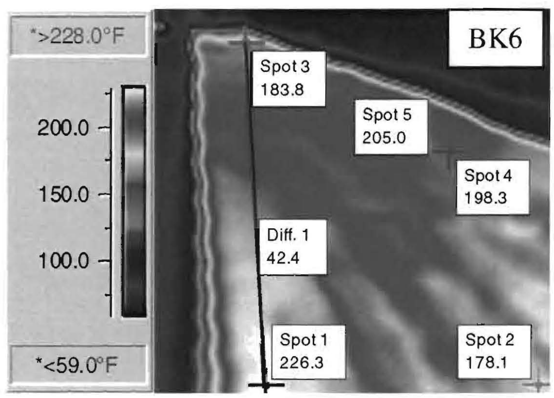

BK1
*>280.0°F
250.0
200.0
150.0
100.0
*<58.6°F
Spot 2
26‑.7
Spot 5
245.4
Spot 4
263.9
Diff. 1
14.8
Spot 3
255.4
Spot 1
279.5

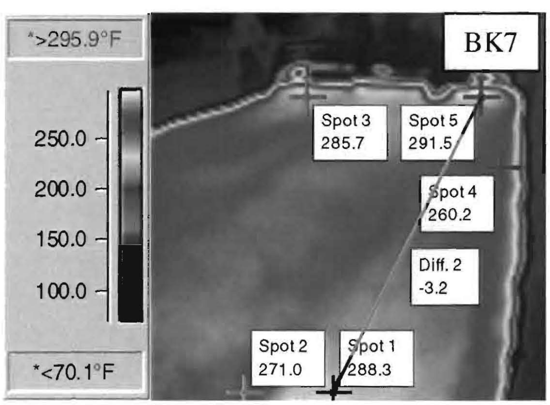

BK2
*>284.2°F
250.0
200.0
150.0
100.0
*<60.7°F
Spot 2
261.5
Spot 4
261.2
Diff. 1
20.5
Spot 5
283.0
Spot 3
252.4
Spot 1
282.0

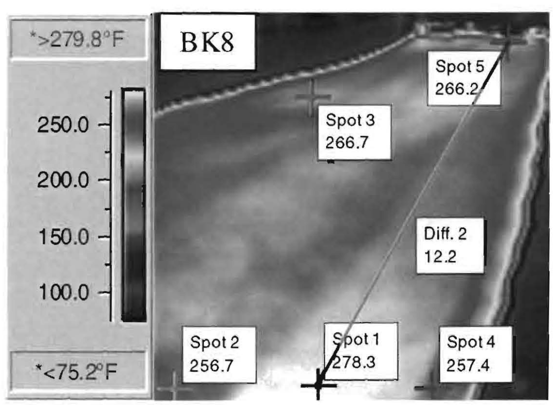

BK3
*>246.0°F
200.0
150.0
100.0
*<65.2°F
Spot 3
208.0
Spot 4
228.1
Diff. 1
36.1
Spot 2
229.6
Spot 1
244.2


BK4
*>240.1°F
200.0
150.0
100.0
*<74.1°F
Spot 3
201.0
Spot 4
199.5
Spot 5
215.1
Spot 2
224.1
Diff. 1
39.0
Spot 1
240.0


BK5
*>225.7°F
200.0
150.0
100.0
50.0
*<37.2°F
Spot 3
18‑.2
Spot 5
203.7
Spot 4
202.5
Diff. 1
26.4
Spot 2
199.0
Spot 1
211.6


BK6
*>228.0°F
200.0
150.0
100.0
*<59.0°F
Spot 3
183.8
Spot 5
205.0
Spot 4
198.3
Diff. 1
42.4
Spot 1
226.3
Spot 2
178.1


BK7
*>295.9°F
250.0
200.0
150.0
100.0
*<70.1°F
Spot 3
285.7
Spot 5
291.5
Spot 4
260.2
Diff. 2
-3.2
Spot 2
271.0
Spot 1
288.3


BK8
*>279.8°F
250.0
200.0
150.0
100.0
*<75.2°F
Spot 5
266.‑
Spot 3
266.7
Diff. 2
12.2
Spot 2
256.7
Spot 1
278.3
Spot 4
257.4

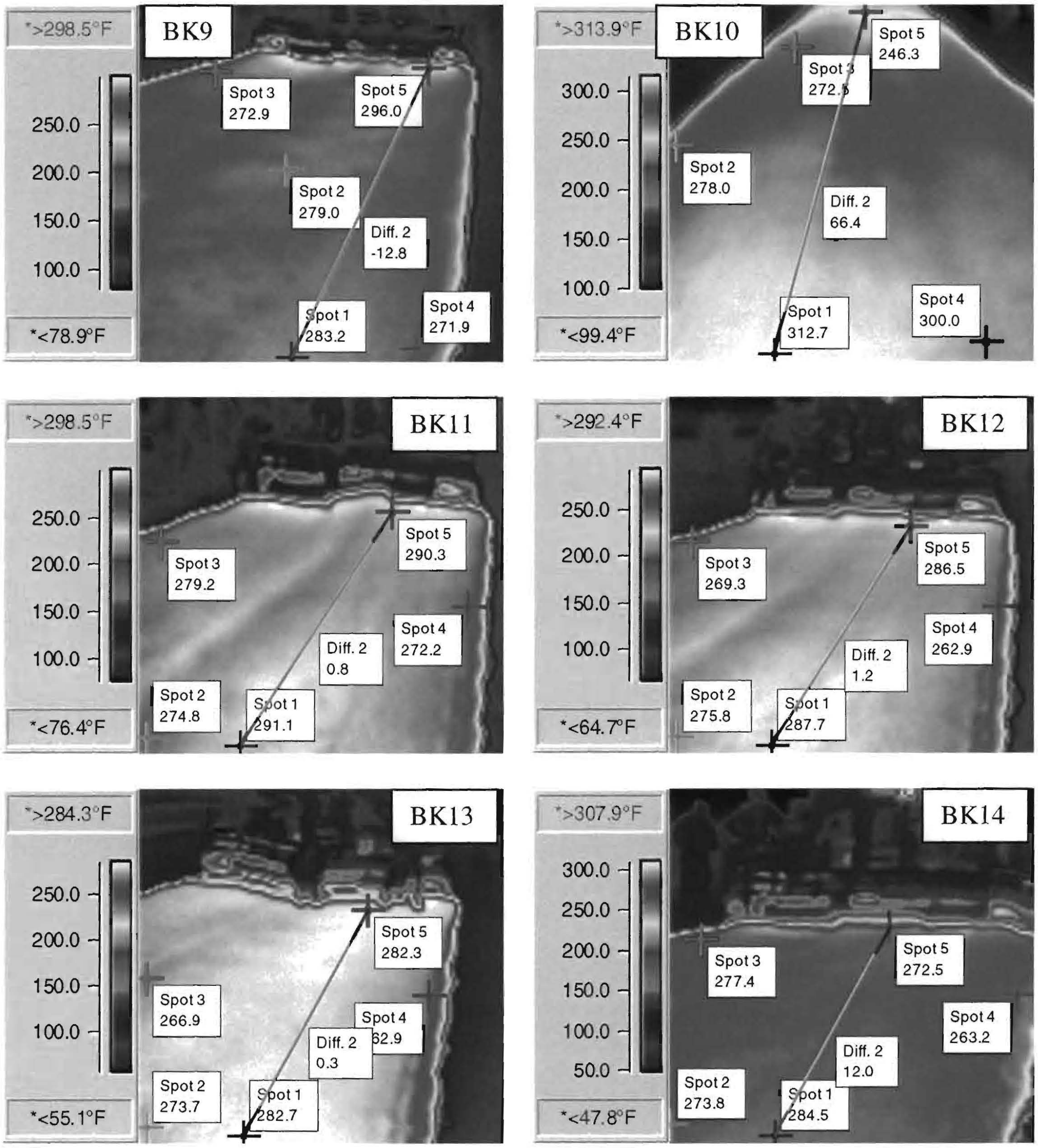


Figure 3.5: Representative Thermal Images for Blaw-Knox MTD

CHAPTER 4
GROUND PENETRATING RADAR TO DETECT SEGREGATION

Ground Penetrating Radar (GPR) has been used extensively in the past several years. GPR has been a valuable tool in detecting voids, excess moisture, layer thickness etc., in the pavement structures. An attempt has been made by the Texas Transportation Institute (TTI) to estimate and quantify the amount of segregation and the extent of segregation using GPR. This chapter describes a brief background on GPR and the data collected is presented. A full report by TTI is found in Appendix C.

Ground Penetrating Radar

Ground Penetrating Radar (GPR) system sends discrete pulses of radar energy into the pavement system and captures the reflections from each layer interface within the pavement structure. GPR units operate at highway speeds (approx. 60mph), transmit and receive 50 pulses per second, and can effectively penetrate to a depth of 2 feet.

Amplitudes of reflection and the time delays between reflections are used to calculate both layer dielectrics and layer thickness. The dielectric constant of a material is an electrical property which is most influenced by moisture content and density. If the moisture content for a layer increases, then the dielectric of the layer will increase which will result in an increase in the energy reflected from the top of the layer. An increase in air voids would have the opposite effect. If the amount of air in a layer increased, the energy reflected and the resulting dielectric would decrease.

TTI has established a range of typical dielectric constants for most paving materials. For example, HMA layers normally have dielectric value between 4.5 and 6.5, depending on the coarse aggregate type. Measured values significantly higher than this would indicate the presence of excessive moisture. Lower values indicate a density problem or indicate that unusual aggregate, such as lightweight aggregate in the mix.

Results and Discussion

Results discussed in this section mostly are excerpts from the report submitted by TTI. In this study, plots of surface dielectric are produced for each of the Material Transfer Devices (MTD) used in the demonstration project.

It is proposed that variations in surface dielectric are indicators of variations in the air void content of the top layer. For a homogeneous well-compacted surface layer the dielectric plot versus distance should be a relatively flat horizontal line as shown in Figure 4.1. Recent studies at the TTI have found that the sharp localized decreases in the surface dielectric are associated with areas of low density in surface layer. Therefore the quality of the mat is judged in terms of the overall variations in the surface dielectric and the absence of sudden dips.

Representative surface dielectric plots from each of the 5 MTD's are shown in Figures 4.2 through 4.7. Note two different Barber-Greene sections (Figure 4.2 and 4.3) were established and tested. Each section was approximately 1490 ft long and the distance scale is shown as the x-axis in each figure. The dips are marked on the Figures and correspond to segregated areas.

Based on this criteria the best performer was the Roadtec MTD shown in Figure 4.4. The plot shows some variation in dielectric but no major localized dips. The high dielectric measured in the middle of the section should be ignored, it was attributed to a thin piece of metallic foil placed on the surface of the pavement for the profile measuring equipment. The next best performer was Barber-Greene 1 shown in Figure 4.2, which had a major problem area at one end of the section but this was a transition point between MTD devices. A few minor dips are marked on Figure 4.2. The surface dielectric plots shown in Figures 4.5, 4.6 and 4.7, all show major periodic dips in the surface dielectric plots.

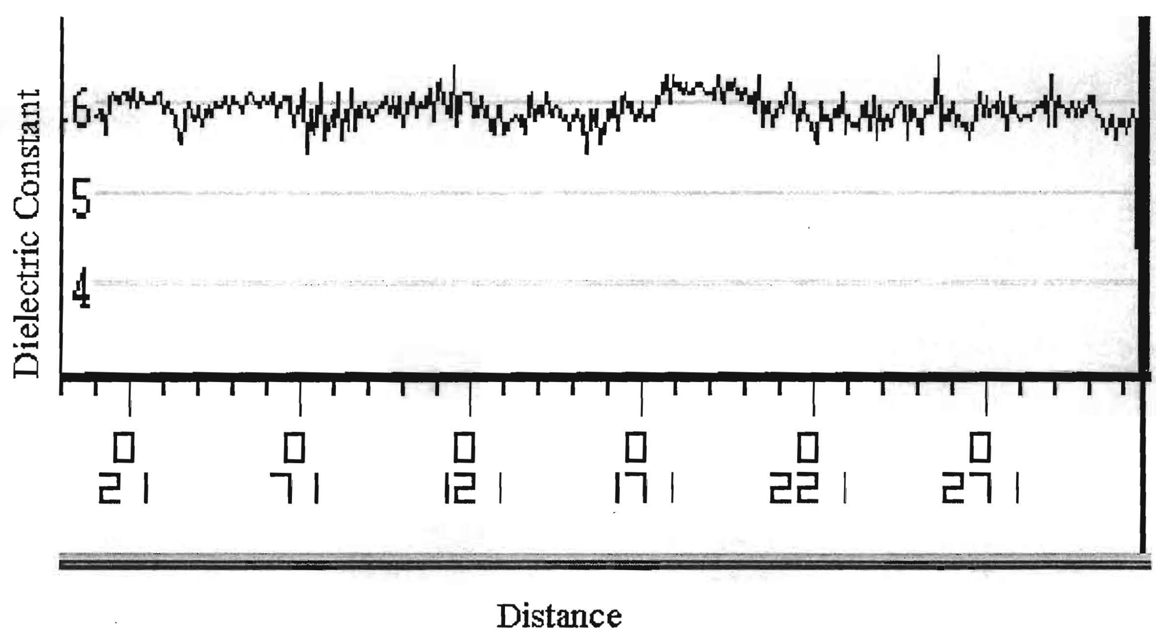


Figure 4.1: Surface Dielectric Constant with Distance

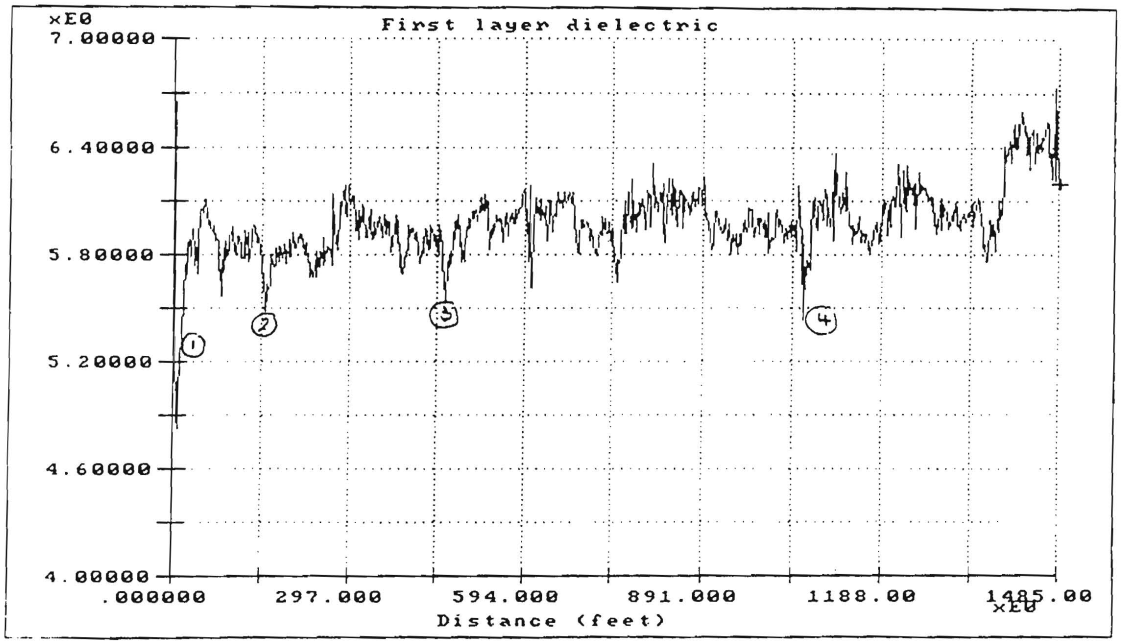


Figure 4.2 Surface Dielectric Plot of BARBER-GREENE 1 MTD.
(Note: Very low values at start of section, this was a transition area. Dips marked throughout section).

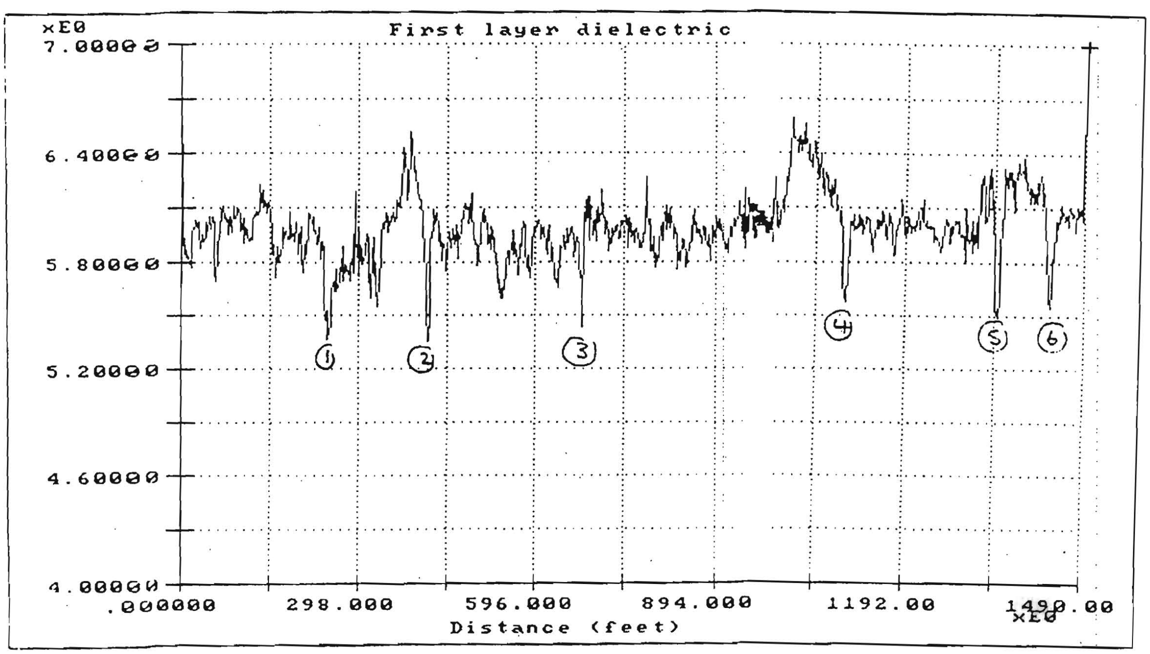


Figure 4.3 Surface Dielectric Plot of BARBER-GREENE 2 MTD.
(Note: Periodic dips marked, 1, 2, etc.)

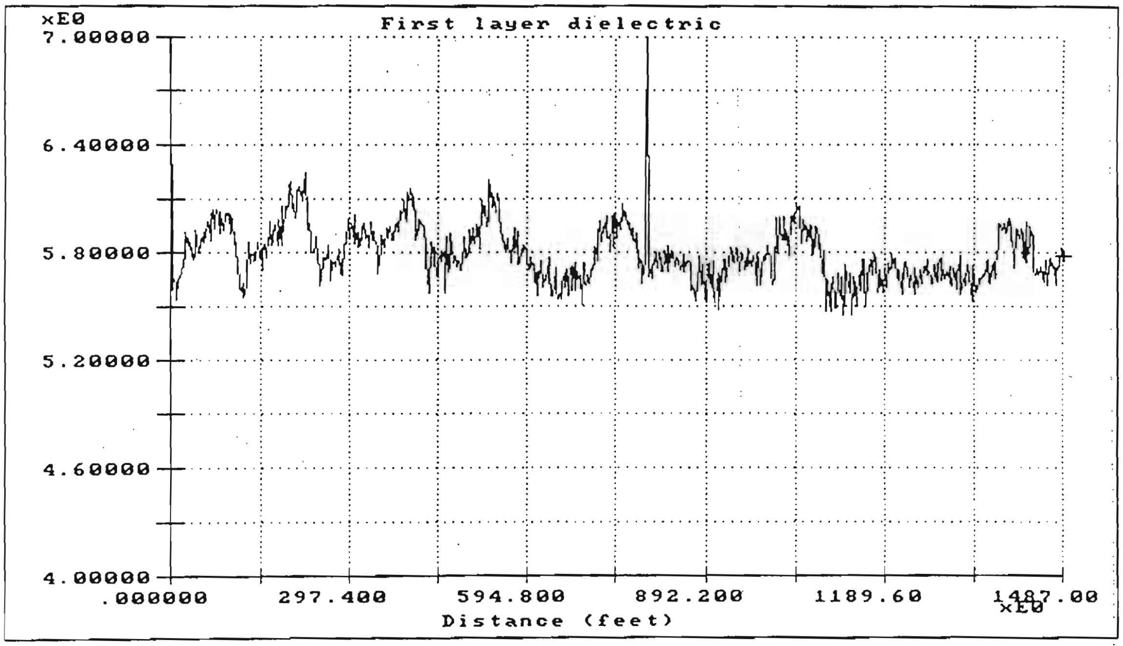


Figure 4.4 Surface Dielectric Plot of ROAD TECH MTD.

(Note: Absence of any localized dips indicating uniformity. High value in middle of run associated with metal foil strip on surface)

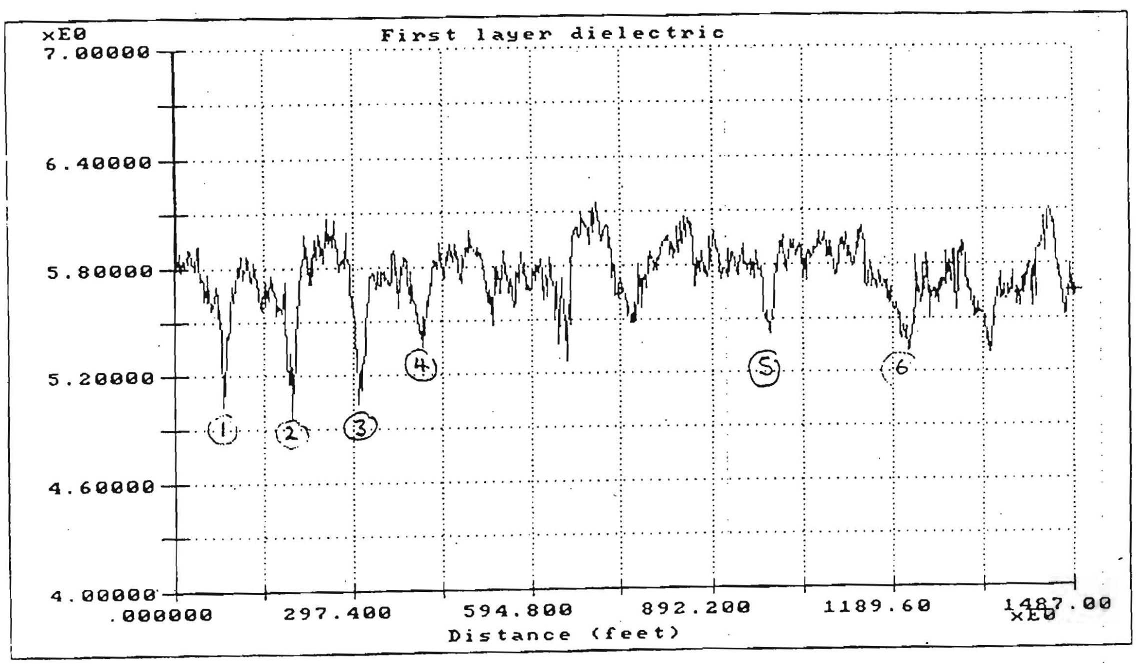


Figure 4.5 Surface Dielectric Plot for LINCOLN MTD.
(Note: Regular dips in plot, marked 1, 2, etc.)

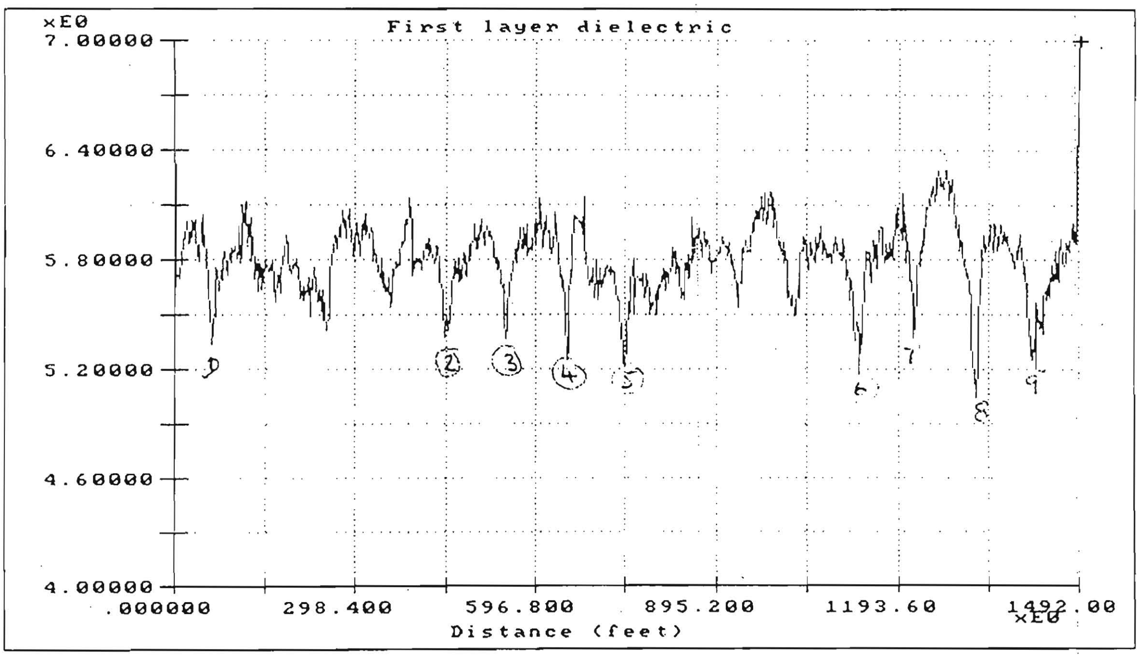


Figure 4.6 Surface Dielectric Plot of CEDAR RAPIDS MTD.
(Note: Regular dips in lot, marked 1, 2, etc.)

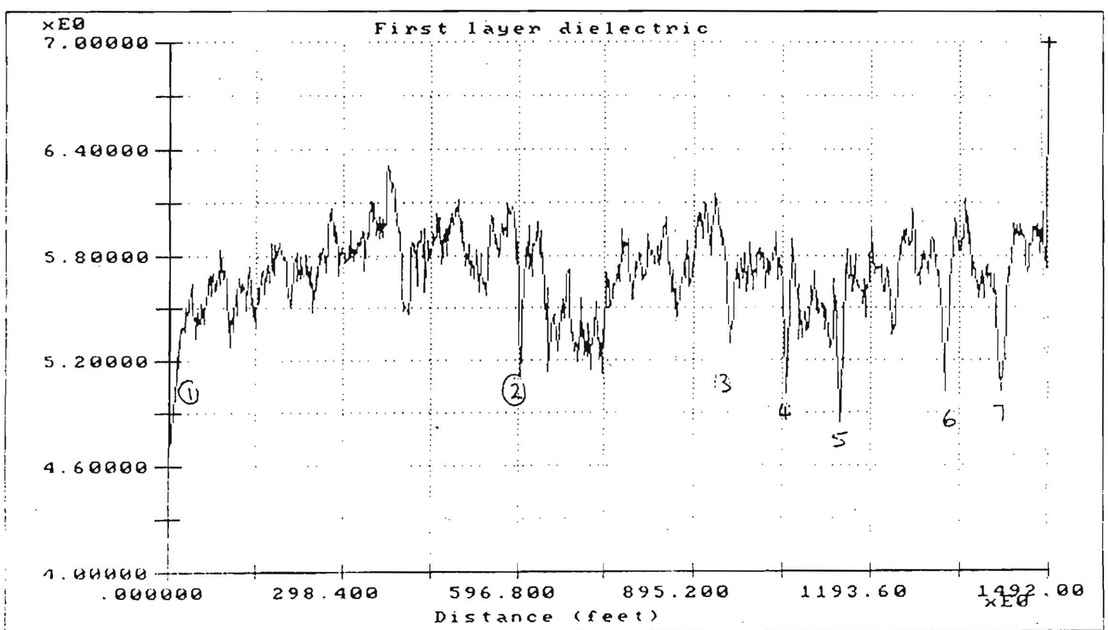


Figure 4.7 Surface Dielectric Plot of BLAW-KNOX 1 MTD.

Conclusions and Recommendations

The conclusions and recommendations listed here are excerpts from the report submitted by TTI, which can found in its entirety in Appendix C.

1. Based on the laboratory densities there appears to be a good correlation between surface dialectics computed from the GPR reflections and the laboratory measured core densities. As expected from theory, low surface dielectric correlate to low density.
2. The quality of a HMA mat can be related to the uniformity of the surface dielectric plot and the number of segregated areas can be estimated from the number of sudden localized dips in surface dielectric.

CHAPTER 5
VISUAL RATING

Visual rating was conducted to detect all three forms of segregation described in Chapter 1. Visual rating is a subjective process. It can still be an effective tool when used with caution. In this instance care was taken so that all raters use similar rating protocol. Five individuals from TxDOT, FHWA and Industry participated in the visual rating process.

All five raters rated 5 different MTDs. Data from all the raters were collected, tabulated and analyzed. Table 5.1 lists the segregated areas by each of the raters for all 5 MTDs. The data was normalized to account for different lengths of each section. Table 5.2 shows the number of segregated areas detected by each individual rater per 1000' section of the lane. This is plotted for all 5 MTDs. Figure 5.1 shows the average number of segregated areas for each MTD.

From Table 5.2, the following preliminary observations can be made. There is quite a bit of variation among individual raters. Even with the variation in the number of segregated areas a trend can be seen in the performance of different MTDs. As shown in Figure 5.1 that the performance of Roadtec in two different locations is very similar and is better than other MTDs.

Table 5.1: Number of Segregated Areas for 5 MTDs

MTV	Distance Paved (ft)	Rater 1	Rater 2	Rater 3	Rater 4	Rater 5
BG Control 1	1,700	16	10	16	9	8
Roadtec 1	4,200	9	3	9	10	7
Roadtec 2	4,800	8	3	6	12	12
Ceder Rapids w/o AE	1,100	7	8	7	9	5
Ceder Rapids w AE	2,100	10	10	7	15	24
Ceder Rapids w AE	3,100	17	33	36	19	33
Loncoln	3,800	26	25	18	18	13
BG Control 2	3,100	28	29	28	22	-
Blow Knox w/o AE	3,100	27	20	-	24	11

BG – Barber-Greene
W/o – without
W/ - with
AE – Auger Extension

Table 5.2: Number of Segregated Areas for 5 MTDs – Normalized for 1000'

MTV	Rater 1	Rater 2	Rater 3	Rater 4	Rater 5	Average
BG Control 1	9.4	5.9	9.4	5.3	4.7	6.9
Roadtec 1	2.1	0.7	2.1	2.4	1.7	1.8
Roadtec 2	1.7	0.6	1.3	2.5	2.5	1.7
Ceder Rapids w/o AE	6.4	7.3	6.4	8.2	4.5	6.6
Ceder Rapids w AE	4.8	4.8	3.3	7.1	11.4	6.3
Ceder Rapids w AE	8.7	6.5		7.7	3.5	6.6
Loncoln	6.8	6.6	4.7	4.7	3.4	5.2
BG Control 2	9.0	9.4	9.0	7.1		8.6
Blow Knox w/o AE	5.5	10.6	11.6	6.1	10.6	8.9

BG – Barber-Greene
W/o – without
W/ - with
AE – Auger Extension

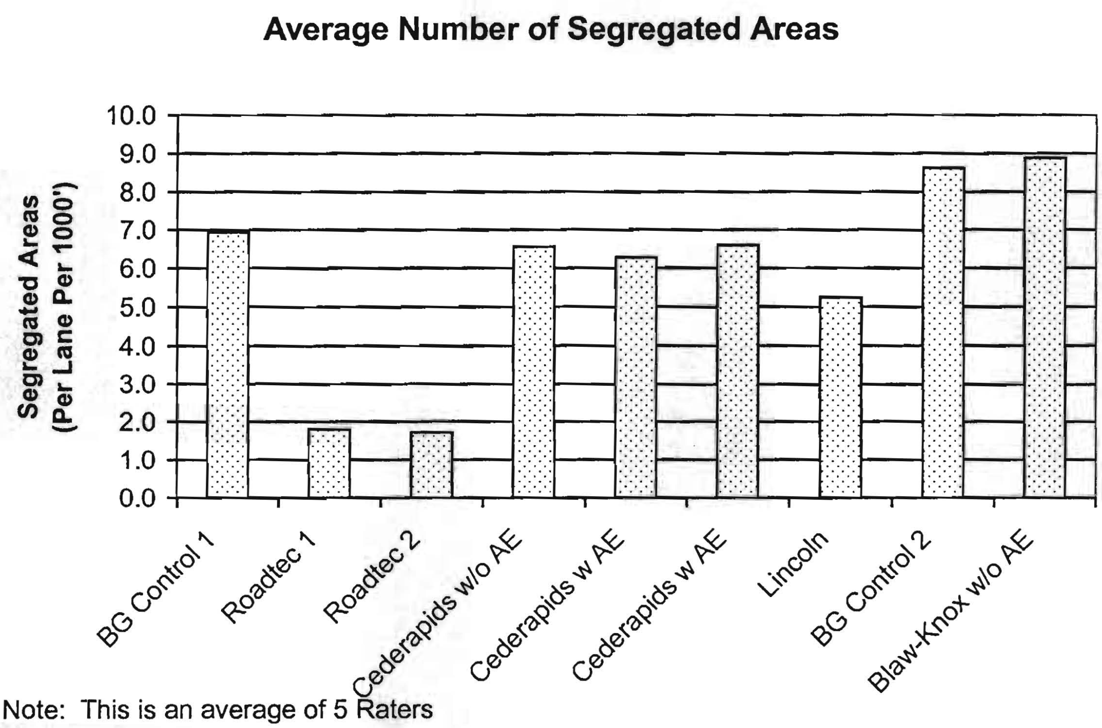


Figure 5.1: Variation of Average Number of Segregated Areas

CHAPTER 6
RIDE QUALITY

Ride quality or Surface Smoothness for this project was measured using a Profilograph. In addition, an alternative Ride measurement was made using a surface Profiler. Ride data collected from both of these test methods are presented here.

Profilograph

Ride quality was measured using the profilograph method. The test was conducted in accordance with TxDOT Standard Test Method Tex-1000-S. In this test method, the Profile Index (PI) is used as a measure of surface smoothness. PI is calculated by summing all the vertical deviations in excess of a 0.2 inches blanking band from the profilograph trace obtained during testing. Lower PI values indicate better ride quality. In addition, a bump template is used to detect the bumps in excess of 0.3" over a 25' base length. The number of bumps detected were normalized to account for the different lengths of paved sections using the different MTDs. Table 6.1 lists the Profile Index (PI) and the number of bumps greater than 0.3" detected per mile. Figures 6.1 and 6.2 show the Profile Index and Number of bumps for different MTDs respectively.

Table 6.1: Profile Index and No. Of Bumps Excess of 0.3 Inches

MTD	PI (inch/mile)	No. of Bumps >0.3" Per mile
Barber Greene	2.8	5
Roadtec Location 1	10.1	15
Roadtec Location 2	7.2	17
Lincoln	35.6	38
Cedarapids	11.4	16
Blaw-Knox	16.9	29

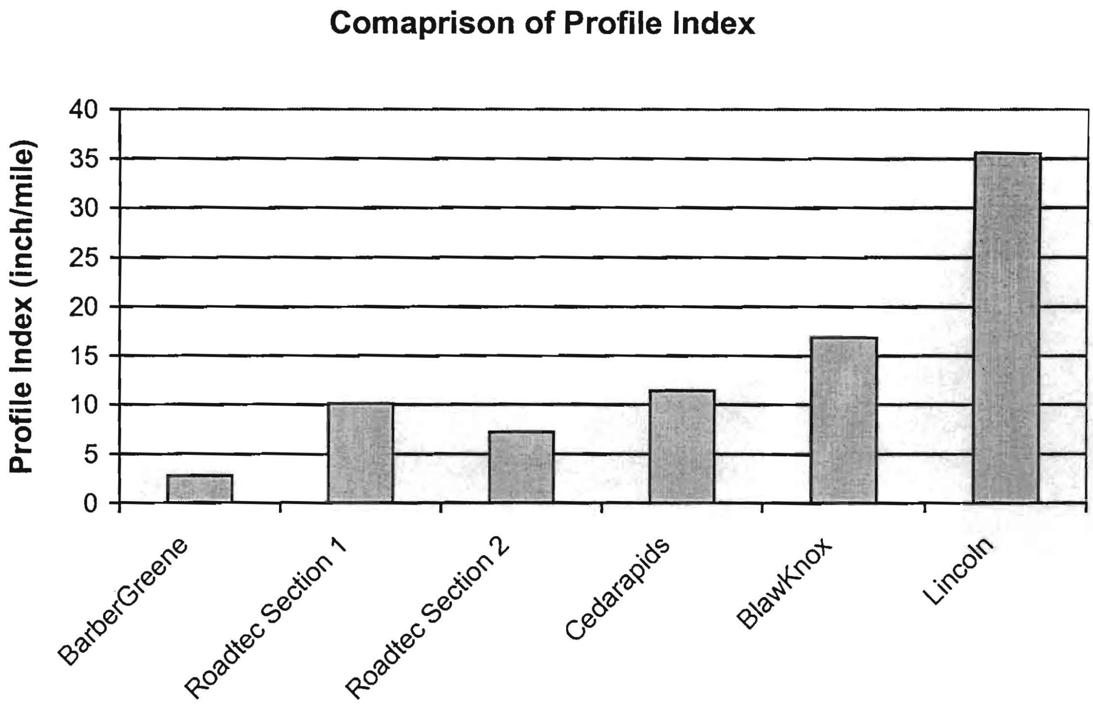


Figure 6.1: Variation in Profile Index

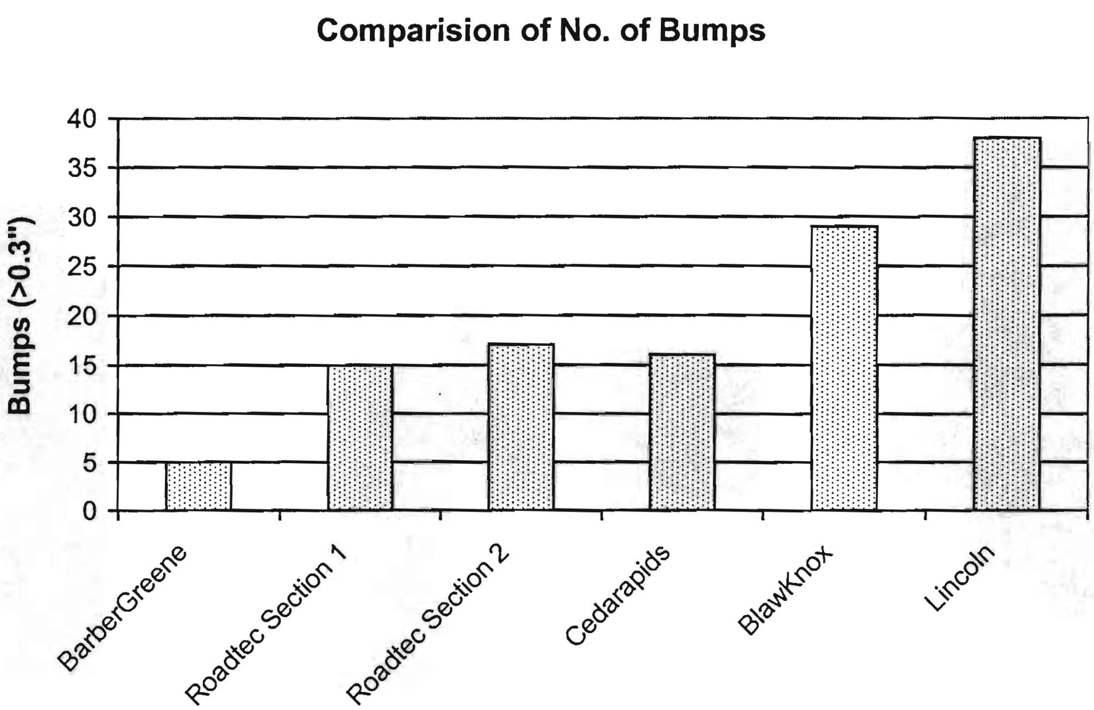


Figure 6.2: Variation in Bumps Greater Than 0.3"

Profiler

Surface Profiler is a tool used in Pavement Management Information Systems (PMIS). Profiler uses lasers and accelerometers to measure the inertial profile of each wheel path. Roughness is measured along the longitudinal profile of the roadway. The test is performed 3 times and average of these 3 measurements is considered for the acceptance purposes. The two parameters measured using this method are: International Roughness Index (IRI) and Present Serviceability Index (PSI). Table 6.2 lists the average IRI and PSI for the five MTDs for the sections listed. Lower IRIs indicate better ride while higher PSI values are better. Figure 6.3 shows the variation of IRI for left and right wheel path.

Table 6.2: International Roughness Index (IRI) and Present Serviceability Index (PSI)

MTD	Length (Feet)	IRI (inch/mile)		PSI
		Left Wheel Path	Right Wheel Path	
Barber Greene	1450	110.6	96.6	3.6
Roadtec Section 1	3000	120.7	115.6	3.4
Roadtec Section 2	3750	101.1	103.3	3.6
Cedarapids Section 1	1000	120.1	96.6	3.5
Cedarapids Section 2	2000	117.2	166.6	3.4
Cedarapids Section 3	2640	75.4	83.1	4.1
BlawKnox Section 1	2650	134.8	105.6	3.3
BlawKnox Section 2	1900	100.4	111.5	3.6
Lincoln	2800	105.4	123.9	3.5

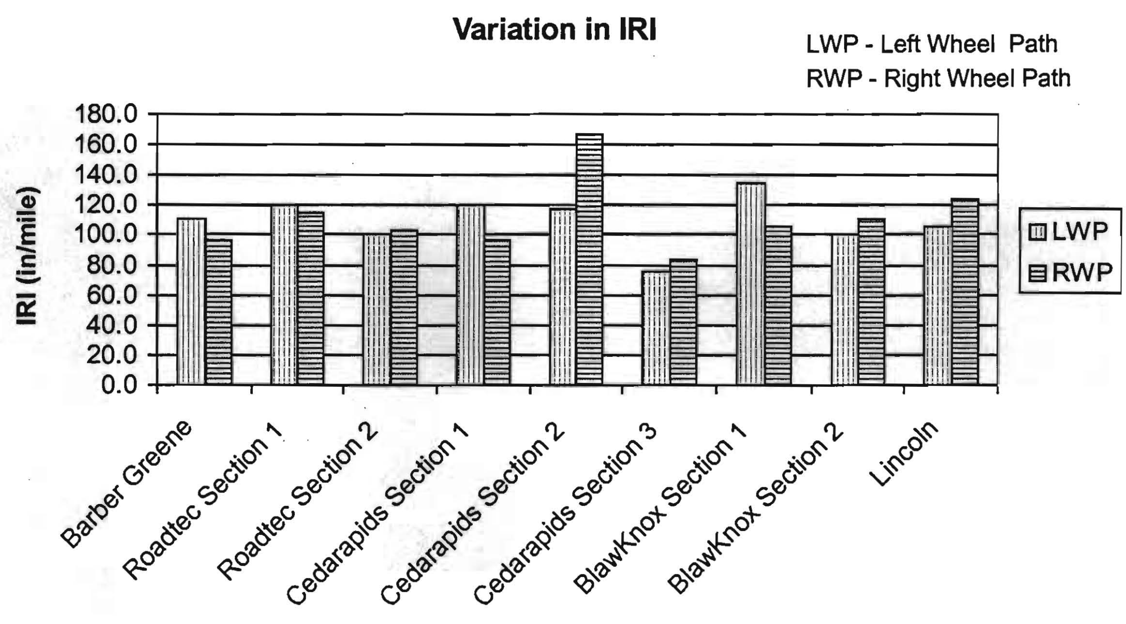


Figure 6.3: Variation in IRI

CHAPTER 7
EVALUATION OF THERMAL CAMERAS

As Part of this study four different thermal Infrared Cameras were evaluated for their ability to measure temperature precisely for a given location. Background on these cameras was explained in Chapter 5. Four cameras evaluated in this study are:

1. Inframetrics ThermaSnap
2. IR SnapShot Model # 525
3. Flir Agema Model # 550
4. Inframetrics Thermacam Model PM 280

Three locations were selected to evaluate the cameras. At each location, a shovel was placed in the transverse direction on the freshly laid asphalt concrete mat. At each location two images were taken. The following figure illustrates the angles for the two images.

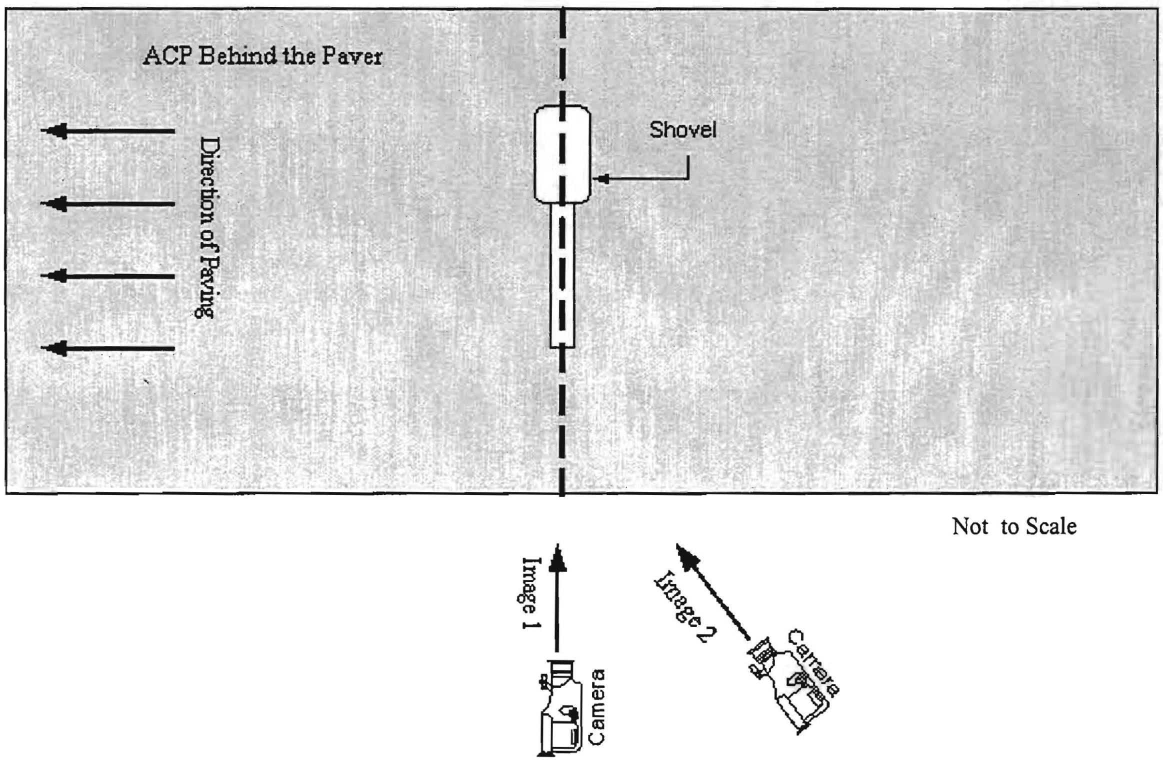


Figure 7.1: Angle of Images

As shown in Figure 7.1, Image 1 is perpendicular to the mat and Image 2 is at an angle to the mat. Care was taken such that a given image at all the three locations was captured from the same spot by all four individuals.

The images captured by all four cameras were analyzed. All the images are attached in Appendix D. The objective of this analysis is to compare the maximum, minimum and average temperatures along the dashed line shown in Figure 7.1 for both angles for all four cameras. Temperatures for Location 1, 2 and 3 are listed in Tables 7.1, 7.2 and 7.3 respectively.

Table 7.1: Comparison of Temperatures at Location 1

Camera	Image 1 (Perpendicular to the Mat)			Image 2 (At an Angle to the Mat)		
	Min (° F)	Max (° F)	Mean (° F)	Min (° F)	Max (° F)	Mean (° F)
Inframetrics ThermaSnap	123.8	290.0	258.0	228.0	271.0	263.0
IR SnapShot Model # 525	117.8	282.2	256.9	165.6	260.7	244.3
Flir Agema Model # 550	131.5	293.2	271.0	158.7	273.3	258.2
Inframertrics Thermacam	*	293.2		*	283.7	

* - Minimum value was out of the spectrum, so minimum value and mean could not be obtained.

Table 7.2: Comparison of Temperatures at Location 2

Camera	Image 1 (Perpendicular to the Mat)			Image 2 (At an Angle to the Mat)		
	Min (° F)	Max (° F)	Mean (° F)	Min (° F)	Max (° F)	Mean (° F)
Inframetrics ThermaSnap	135.7	291.1	265.8	217.8	276.0	262.9
IR SnapShot Model # 525	161.8	287.6	274.8	161.3	273.7	255.3
Flir Agema Model # 550	138.1	294.0	251.1	172.8	283.8	271.9
Inframertrics Thermacam	*	288.9		*	267.2	

* - Minimum value was out of the spectrum, so minimum value and mean could not be obtained.

Table 7.3: Comparison of Temperatures at Location 3

Camera	Image 1 (Perpendicular to the Mat)			Image 2 (At an Angle to the Mat)		
	Min (° F)	Max (° F)	Mean (° F)	Min (° F)	Max (° F)	Mean (° F)
Inframetrics ThermaSnap	143.1	292.0	271.0	211.9	280.8	267.3
IR SnapShot Model # 525	135.4	295.6	266.4	175.6	271.1	251.5
Flir Agema Model # 550	145.1	285.7	251.0	170.8	286.5	270.1
Inframertrics Thermacam	*	288.0		*	283.3	

* - Minimum value was out of the spectrum, so minimum value and mean could not be obtained.

Discussion

From the temperature data listed in Tables 7.1, 7.2 and 7.3 the following observations can be made:

- Maximum temperatures recorded by the four cameras are reasonable close.
- The maximum temperature is less for pictures taken at an angle versus perpendicular.
- There is a large variability in minimum temperatures. This is most likely due to the slight differences in times when pictures were taken and the shovel getting hot on the mat.
- All four cameras appear to yield the same results.

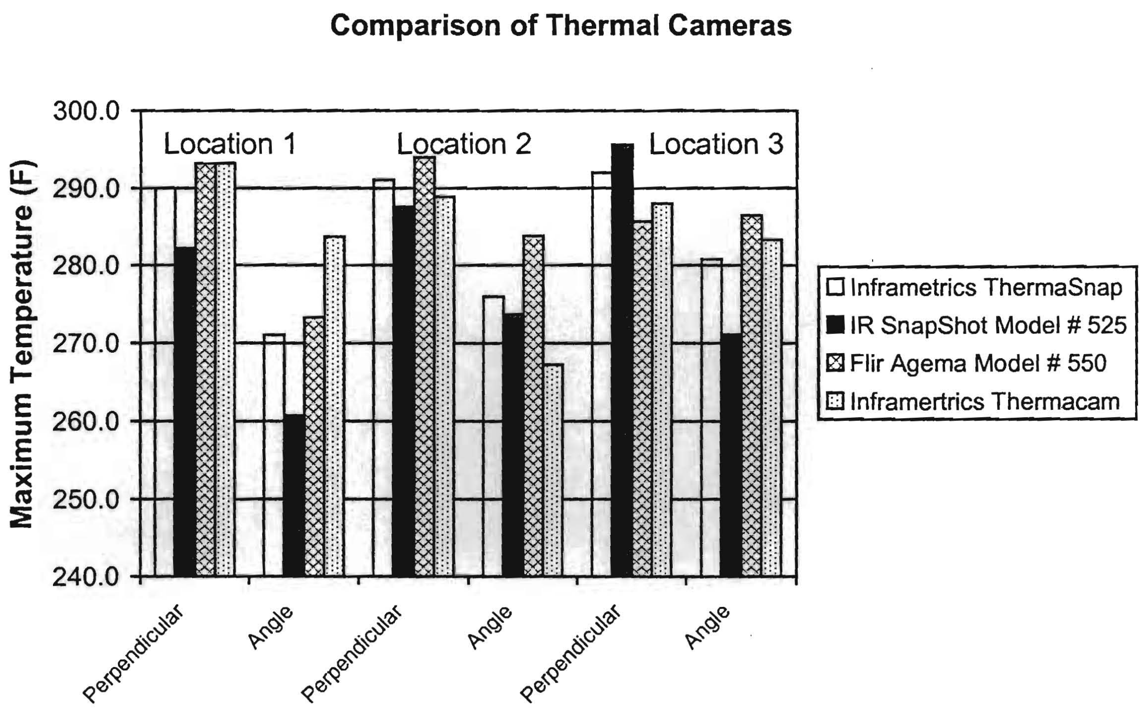


Figure 7.1: Comparison of Cameras

CHAPTER 8
SUMMARY AND CONCLUSIONS

A Material Transfer Device (MTD) showcase was conducted on a section of IH10 in El Paso, Texas. This demonstration project was conducted for the duration of five (5) days in October 1999. The showcase involved five different MTDs by five different manufacturers. The two primary objectives for this showcase are to evaluate the effectiveness of the MTDs in reducing segregation in HMAC and compare the effectiveness of the different techniques to measure and quantify segregation.

The five MTDs, which participated in the showcase, are:

1. Barber-Greene, Model BG-650
2. Blaw-Knox, Model MC-330
3. Cedarapids, Model CR 461
4. Lincoln, Model 880-HP
5. Roadtec, Model SB-2500B

The four different techniques/methods utilized to quantify segregation in this study are:

1. In-Place Density
   - Density profiles using Nuclear Density Gauge
   - Road Cores
   - Ground Penetrating Radar (GPR)
2. Infrared Thermal Imaging
3. Visual Rating
4. Smoothness or Ride Data
   - Profilograph
   - Profiler

Conclusions

Data from the above mentioned test methods and techniques were collected and analyzed. The following preliminary conclusions can be drawn from the data collected during this MTD showcase.

1. None of the MTDs eliminated all segregation-related problems.
2. The screed extensions in the paver caused segregation in this project. There was also centerline segregation caused by the paver.
3. MTDs with larger on-board mix storage capacity are more effective in reducing truck-end segregation.
4. The proposed test method to identifying segregation by establishing density profiles does not appear to be a very effective tool. Additional research is needed to make a more precise conclusion.
5. Ground penetrating radar has the potential to identify and quantify segregation.

6. The Infrared thermal imaging technique was found to be an excellent Quality Control tool.
7. All four thermal cameras used in this study appear to yield the same result.
8. MTDs alone cannot cure all segregated related problems.

APPENDIX – A

1. **TEST METHOD FOR DETERMINATION OF MAT SEGREGATION USING NUCLEAR DENSITY GAUGE**
2. **SPECIAL PROVISION TO SPECIAL SPECIFICATION QC/QA OF HOT MIX ASPHALT**
3. **LABORATORY ROAD CORE DENSITIES**
4. **NUCLEAR DENSITY PROFILE FIELD REPORTS**

Tex-207-F -Part V Determination of Mat Segregation Using a Nuclear Density Gauge

Overview

This test method is to provide a means of identifying segregation in hot-mix asphalt pavement after placement on the roadway.

Apparatus

- Thin Lift Density Gauge
- Measuring Tape (Optional)
- Forms

Steps	Actions
1.	Refer to gauge manufacturer's recommendations for operating the gauge. It is not necessary that the gauge be calibrated to the mix.
2.	A profile section is defined as a 50-foot length of mat with readings taken approximately every five feet. Additional longitudinal readings may be taken along the transverse offset where visible segregation is noticed.
3.	Identify a location where the lay-down machine has stopped paving. Mark and record this location as the beginning of the profiled section, also called the zero point. The first reading location should be approximately ten feet behind the zero point. When profiling a section where the location that the paver stopped is unknown, a randomly selected area may be picked. It is intended that an area with visible segregation be chosen.
4.	Determine the transverse offset two feet or more from the pavement edge. Do not vary from this line. Visually observe the mat and note surface texture in the section to be profiled. Make note of areas that appear to be segregated. Visually segregated areas, if any, must be included in the section to be profiled.
5.	Take three one-minute readings with the nuclear density gauge in the same location and record.
6.	Before moving the gauge, average the three readings. Compare each individual reading to the average. Discard any single readings that vary more than 1 lb./c.f. from the average. Take additional readings to replace any that are discarded until three readings have been obtained that are within 1 lb./c.f. of the average.
7.	Move the gauge approximately 5 feet forward in the direction of the paving operation. If a segregated are is visible in between the 5-ft. distance, take an additional set of readings at that location.
8.	Repeat steps 5, 6 and 7. Continue to take readings until a minimum of ten sets of three readings has been completed.
9.	Determine the average density from all the locations.
10.	Determine the difference between the highest and lowest average density
11.	Determine the difference between the average and lowest average density.
12.	Record and plot the data. Report.

PROPOSED

SPECIAL PROVISION

TO

SPECIAL SPECIFICATION

ITEM 3146

QUALITY CONTROL/QUALITY ASSURANCE OF HOT MIX ASPHALT

For this project, Special Specification Item 3146, "Quality Control/Quality Assurance of Hot Mix Asphalt", is hereby amended with respect to the clauses cited below and no other clauses or requirements of this Item are waived or changed hereby.

Article 3146.7 Construction Methods, Subarticle (6), Placing.
The first paragraph is supplemented by the following:

If segregation or irregularities occur in the pavement surface, the contractor shall review the plant, hauling and paving operations and take corrective action. A "Segregation Check Points" list is available from the Engineer. Segregation may be identified visually or in accordance with Test Method Tex–207–F, Part V "Determination of Mat Segregation Using a Nuclear Density Gauge".

At the start of the project, the paving unit will be allowed to pave for a distance of 1,000 linear feet with each individual mix designation before implementing a profile analysis. The Contractor shall perform a minimum of four segregation checks each day for each mix type used on the project. The density profile must meet the criteria shown in Table 1 to be considered acceptable. The profile location shall be recorded to permit future evaluation of the segregation section. A segregation profile starting point shall be established at each location where the screed stops due to discontinuous mix delivery and at visibly segregated areas as directed by the Engineer. If the lay down operation continues to progress without stopping and no visible segregation is noted and four consecutive profiles are within established tolerances, then the test frequency will be reduced to one profile per placement lot. The Engineer may further reduce the frequency of testing at the Contractor's request. If both the Contractor and the Engineer agree that segregation exists and the Contractor agrees to immediate mitigation of the problem, then the density profile will not be required.

Table 1: Density Profile Acceptance Criteria

Nominal Max. Aggregate Size	**Maximum Allowable Density Range** (highest to lowest)	**Maximum Allowable Density Range** (average to lowest)
5/8" or less	6.0 lbs./c.f.	3.0 lbs./c.f.
5/8" or greater	8.0 lbs./c.f.	5.0 lbs./c.f.

The Engineer will be provided results of the segregation profiles as they are completed. Whenever one of the profiles fails the acceptance criteria, the contractor will be allowed to make changes to the operations before the next profile evaluation is made. Any changes must be made within the first hour of production following determination of a failing evaluation. Production of the hot mix asphalt shall cease whenever two consecutive profiles fail unless otherwise approved by the Engineer. The Contractor shall make changes to the mix or process before production is restarted. The Contractor may produce enough mixture to place approximately 2,000 linear feet of pavement one paver width wide. Two segregation profiles shall be taken within these 2,000 linear feet of production and if both profiles meet the acceptance criteria, the Contractor may resume normal operations. However, if one or both of the segregation profiles fail, the Contractor shall make additional changes as approved by the Engineer and an additional 2000 linear feet of pavement shall be laid and evaluated as before. This procedure of placing and evaluating 2,000 linear feet sections will be continued until both segregation profiles pass. The Engineer may require the Contractor to provide specialized mixing or material transfer devices for remixing of the mixture prior to placement if the segregation has not been eliminated through plant and process adjustments. Normal production and segregation checks will resume when both profile results pass. Although it will be the Contractor's responsibility to perform the segregation check described above using the nuclear density gauge, the Engineer may make as many independent or confirmation nuclear density checks as deemed necessary. The Engineer's results will be used to determine segregated sections when available.

Table A.1: Laboratory Road Core Densities for Barber Greene MTD

Specimen #	Sta.	Distance from 0	Bulk Density (%)	Density (lbs/c.ft.)	
				Core	Nuclear
1	165+60	50	97.7	152.7	147.5
2		25	97.1	151.7	142.8
3		5	96.9	151.3	130.9
6	167+00	50	96.0	149.9	145.7
4		40	97.4	152.1	149.2
5		10	95.3	148.8	144.4
9	168+00	30	96.0	150.0	140.0
8		10	96.7	151.0	143.3
7		5	97.2	151.8	145.3
12	171+00	50	96.0	150.0	148.8
11		40	96.5	150.7	144.3
10		30	96.2	150.3	146.3
15	189+00	50	96.3	150.2	151.9
14		20	95.9	149.5	144.5
13		0	95.7	149.2	141.4
18	163+30	30	96.0	149.8	146.2
17		5	95.5	149.0	149.3
16		0	94.4	147.2	144.6
21	184+00	25	97.2	151.7	149.4
20		10	97.0	151.3	145.9
19		5	96.7	150.8	147.4
24	165+00	40	98.0	152.9	149.0
23		15	98.6	153.8	144.3
22		-10	97.1	151.5	147.1

Table A.2: Laboratory Road Core Densities for RoadTec MTD

Specimen #	Sta.	Distance from 0	Bulk Density (%)	Density (lbs/cft)	
				Core	Nuclear
3	193+50	50	95.3	148.8	144.6
2		10	95.0	148.4	141.5
1		-10	95.9	149.8	146.7
4	186+50	10	93.0	145.3	135.4
5		5	94.6	147.7	142.3
6		-10	94.0	146.8	145.9
7	182+00	50	93.4	145.9	134.1
8		30	92.2	144.0	138.1
9		20	93.6	146.1	138.1
10	167+00	30	92.3	144.1	137.5
11		20	92.9	145.0	141.9
12		5	93.1	145.4	144.2
13	200+00	50	94.1	147.0	140.2
14		15	94.2	147.2	145.2
15		0	94.7	148.0	143.3
16	204+00	50	94.0	146.9	141.3
17		20	94.8	148.1	146.9
18		10	95.6	149.3	143.5

Table A.3: Laboratory Road Core Densities for Lincoln MTD

Specimen #	Sta.	Distance from 0	Bulk Density (%)	Density (lbs/cft)	
				Core	Nuclear
1	194+00	50	92.3	144.0	139.0
2		20	93.3	145.6	141.6
3		-10	93.2	145.5	142.9
6	160+00	20	94.0	146.7	145.7
5		10	94.3	147.1	142.1
4		-10	92.3	144.1	136.8
7	185+00	40	91.7	143.1	133.6
8		15	92.7	144.7	140.7
9		5	94.2	146.9	145.3
10	181+00	50	93.5	145.8	144.0
11		40	92.8	144.8	139.2
12		15			144.4
15	163+00	25	94.0	146.7	139.6
14		20	93.7	146.1	134.9
13		-10	93.8	146.3	143.9
16	170+00	50	93.7	146.1	148.3
17		5	94.0	146.7	139.9
18		-10	95.2	148.5	140.3

Table A.4: Laboratory Road Core Densities for Cederapids

Specimen #	Sta.	Distance from 0	Bulk Density (%)	Density (lbs/cft)	
				Core	Nuclear
1	267+00	0	94.3	148.3	135.1
2		5	95.2	149.7	130.8
3		-10			147.2
6	246+50	30	96.6	151.9	150.0
5		5	94.8	149.1	137.3
4		-10	94.4	148.4	144.2
9	214+00	25	95.9	150.7	141.6
8		0	92.9	146.1	144.8
7		-10	95.8	150.7	147.1
12	246+00	30	93.7	147.4	144.3
11		10	95.0	149.4	147.7
10		5	95.0	149.4	140.2
13	206+50	30	94.3	148.2	145.1
14		10	95.0	149.4	136.1
15		5	92.2	145.0	133.4
18	224+00	25	93.4	146.9	142.4
17		20	93.0	146.2	143.7
16		15	93.4	146.9	139.7
21	240+00	30	95.9	150.7	148.8
20		25	94.8	149.0	141.5
19		10	95.6	150.3	148.9
23	213+00	30	93.3	146.6	142.3
22		25	92.2	145.0	133.1
24		0	93.1	146.3	139.4
27	236+00	50	92.7	145.8	144.1
26		10	95.9	150.8	143.7
25		-10	95.8	150.7	147.3
30	209+50	40	93.0	146.2	144.6
29		20	94.2	148.2	140.9
28		10	92.9	146.1	135.0

Table A.5 Laboratory Road Core Densities for Blaw-Knox MTD

Specimen #	Sta.	Distance from 0 (ft)	Bulk Density (%)	Density (lbs/cft)	
				Core	Nuclear
1	229+50	30	93.5	147.0	142.0
2		25	93.6	147.2	142.5
3		10	93.2	146.5	137.5
4	252+30	40	95.1	149.6	145.5
6		25	95.8	150.6	143.7
5		0	96.2	151.3	147.5
7	250+00	50			134.5
8		25	93.0	146.2	140.2
9		0	92.8	145.9	143.3
10	222+00	30	89.7	141.1	131.1
11		10			126.0
12		-10	93.3	146.7	140.4
2	264+75	15	95.0	149.1	147.1
1		10	94.8	149.3	143.9
3		5	94.7	148.9	139.7
4	255+00	50	95.1	149.6	140.5
5		15	96.0	150.9	146.6
6		-10	94.9	149.3	149.4

TXDOT
Construction Division
Data Collection Form
July 1999

Temp. Gadan
Ave. 285°F

START 4:38 pm
FINISH 5:23 p.m.

Nuclear Density Profile Form

Asphaltic Concrete Pavement

2.50"
476 THIN LIFT

District: 24	CSJ: 2121-5-34	Location Information for 1st Reading
County: EL PASO	Profile No.: 1	Station: 163+30
Highway: IH TORNILLO	Test Date: 10-18-99	Lane Direction:* NB SB EB WB
Tested By: TxDOT ☑	Contractor: DAN WILLIAMS	Lane:* INSIDE (ML) FR (1) 2 3 4
Contractor ☐	Mix Type: A	Distance From Inside
Tester: REDDINI GRADO	Spec. Item: 3022	Edge of Lane or Joint (ft): 3 1/2"
Brand and Model of Paver: BARBER GREENE	Visible Segregation: Yes ☑ No ☐	Lift: (1st) 2nd 3rd Lift Thickness: 3"
Describe Type of Remix Equipment Used In or Ahead of Paver: BARBER GREENE		

	Feet from Prev. Read.	Readings (lbs/cf)			Avg.
1	10.0	143.3	143.6	143.8	143.6
2	0	141.2	141.2	142.6	141.6
3	5	148.5	150.2	149.1	149.3
4	5	146.1	146.8	146.9	146.6
5	5	144.0	144.0	144.3	144.1
6	5	143.4	144.4	144.0	143.9
7	5	144.3	144.0	143.5	143.9
8	5	146.6	146.0	146.0	146.2
9	10	143.6	143.6	142.9	143.4
10	10	142.4	143.6	142.3	142.7
11					
12					
13					
14					
15					
16					
17					
18					
		Total			144.5

Average Reading	144.5
High Reading	149.3
Low Reading	141.6

1st 1000 FT WITHIN

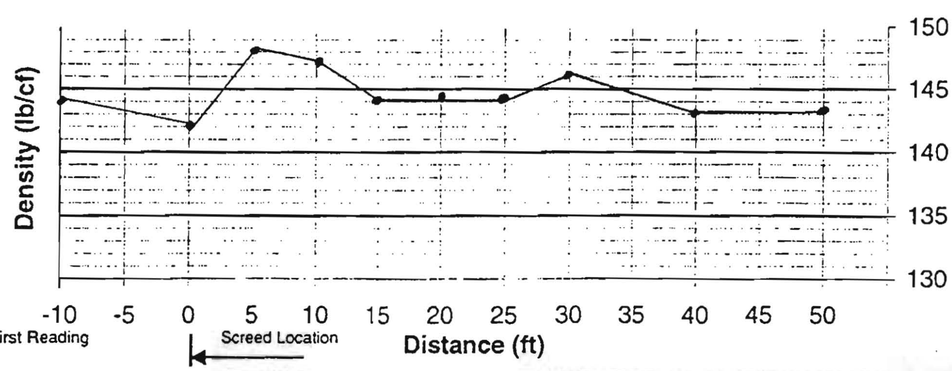
Max Density Ranges:		
High - Low	4.8	[Max allowable = 6.0 lbs/cf]
Average - Low	7.7	[Max allowable = 3.0 lbs/cf]

Notes:

* NB = North Bound, ML = Main Lane, FR = Frontage Road
Lanes numbered from centerline of facility (e.g. 1 = inside lane)
- Use a separate form for each density profile.
- A density profile is a series of density readings taken longitudinally approximately every 5 lf in a 50' section.
- Profile one 50' section after the first 1000 feet of project placement (Select the 50' section by method discussed in the specification).
- Profile a section each time the screed stops, including end of day.
- Profiles must be at least 2 ft from joints and edges
- First reading of each profile must be 10 ft behind the screed.
- Minimum of 4 density profiles per mix per project must be performed by the contractor.

HMAC START
at 157+00

Density Profile Plot



TXDOT
Construction Division
Data Collection Form
July 1999

START 9:28 A.M.
FINISH 10:30 A.M.

Nuclear Density Profile Form

Asphaltic Concrete Pavement

476 THIN LIFT

District: 24	CSJ: 2121-5-39	Location Information for 1st Reading	
County: El Paso	Profile No.: 3	Station: 168400	
Highway: TH TORNILLO	Test Date: 10-1999	Lane Direction:* NB SB (EB) WB	
Tested By: TxDOT ☑	Contractor: DAN WILLIAMS	Lane:* INSIDE	(ML) FR (1) 2 3 4
Contractor ☐	Mix Type: A	Distance From Inside Edge of Lane or Joint (ft): 3 1/2	
Tester: REIDO/BRADY	Spec. Item: 3022		
Brand and Model of Paver: BARBER GREENE	Visible Segregation: Yes ☑ No ☐	Lift: (1st) 2nd 3rd	
		Lift Thickness: 1-3"	

Describe Type of Remix Equipment Used In or Ahead of Paver: BARBER GREENE

	Feet from Prev. Read.	Readings (lbs/cf)			Avg.
1	10.0	144.9	143.6	144.1	144.2
2	0	144.3	144.1	145.4	144.6
3	5	144.6	145.7	145.7	145.3
4	5	143.3	143.1	143.5	145.3
5	5	142.0	142.1	141.6	141.9
6	5	145.0	144.2	143.6	144.2
7	5	144.1	144.3	144.5	144.3
8	5	140.0	140.3	139.7	140.0
9	10	142.8	142.4	142.7	142.6
10	10	142.3	142.6	143.5	142.8
11					
12					
13					
14					
15					
16					
17					
18					
			Total		1433

Average Reading	143.3
High Reading	145.3
Low Reading	140.0

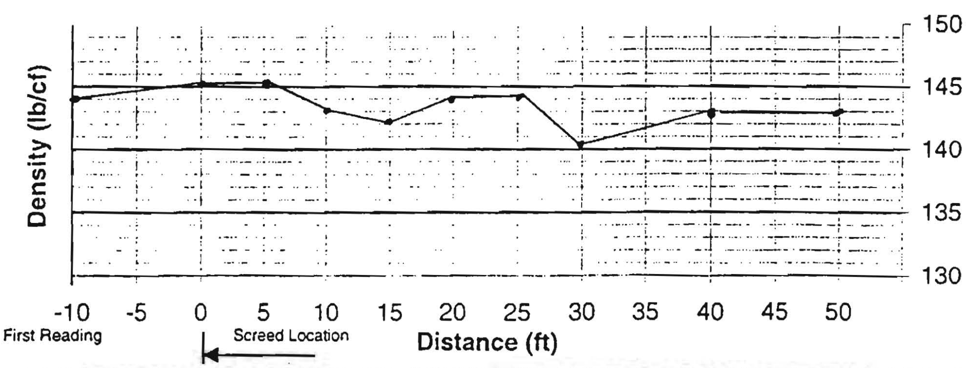
Max Density Ranges:		
High - Low	5.3	[Max allowable = 6.0 lbs/cf]
Average - Low	3.3	[Max allowable = 3.0 lbs/cf]

Notes:

* NB = North Bound, ML = Main Lane, FR = Frontage Road
Lanes numbered from centerline of facility (e.g. 1 = inside lane)

- Use a separate form for each density profile.
- A density profile is a series of density readings taken longitudinally approximately every 5 lf in a 50' section.
- Profile one 50' section after the first 1000 feet of project placement (Select the 50' section by method discussed in the specification).
- Profile a section each time the screed stops, including end of day.
- Profiles must be at least 2 ft from joints and edges
- First reading of each profile must be 10 ft behind the screed.
- Minimum of 4 density profiles per mix per project must be performed by the contractor.

Density Profile Plot



TXDOT
Construction Division
Data Collection Form
July 1999

✓

START 8:30 A.M.
FINISH 9:20 AM

Nuclear Density Profile Form

Asphaltic Concrete Pavement

476 FLAT LANE

District: 24	CSJ: 2121-5-39	Location Information for 1st Reading
County: El Paso	Profile No.: 1 (4)	Station: 165+00
Highway: IH TORNILLO	Test Date: 10-20-99	Lane Direction:* NB SB (EB) WB
Tested By: TxDOT ☑	Contractor: DAN WILLIAMS	Lane:* INSIDE (ML) FR (1) 2 3 4
Contractor ☐	Mix Type: A	Distance From Inside
Tester: RENDON / GIRADO	Spec. Item: 3022	Edge of Lane or Joint (ft): 5 1/2"
Brand and Model of Paver: BARBER GREENE	Visible Segregation: Yes ☑ No ☐	Lift: (1st) 2nd 3rd
		Lift Thickness: +3"

Describe Type of Remix Equipment Used In or Ahead of Paver: BARBER GREENE

	Feet from Prev. Read.	Readings (lbs/cf)			Avg.
1	10.0	146.9	147.1	147.8	147.1
2	0	148.9	148.6	149.5	148.7
3	5	148.9	149.1	148.9	148.9
4	5	145.2	145.1	145.3	145.2
5	5	144.6	144.0	144.4	144.3
6	5	146.2	145.4	145.8	145.8
7	5	147.5	147.4	147.0	147.3
8	5	147.5	148.1	147.1	147.6
9	10	148.9	149.2	149.0	149.0
10	10	148.5	148.7	148.6	148.6
11					
12					
13					
14					
15					
16					
17					
18					
			Total		1473

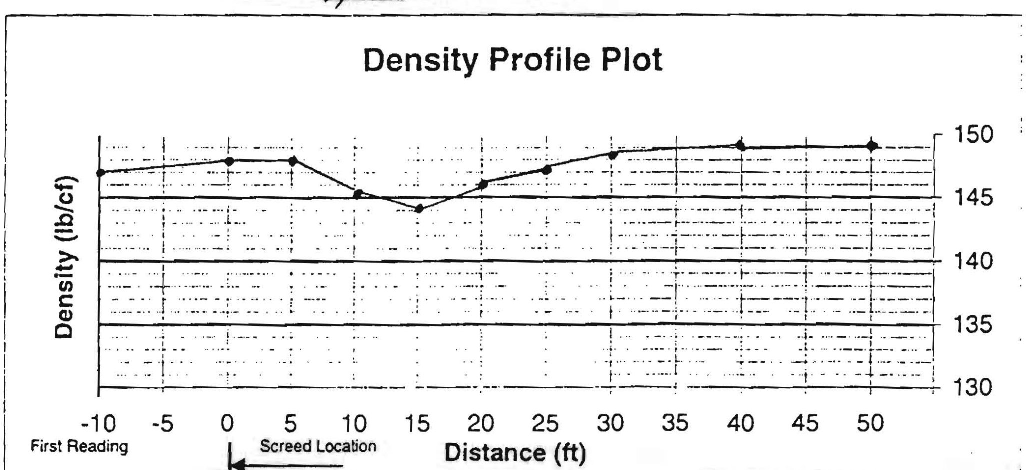
Average Reading	147.3
High Reading	149.0
Low Reading	144.3

Max Density Ranges:		
High - Low	4.7	[Max allowable = 6.0 lbs/cf]
Average - Low	3.0	[Max allowable = 3.0 lbs/cf]

Notes:

* NB = North Bound, ML = Main Lane, FR = Frontage Road
Lanes numbered from centerline of facility (e.g. 1 = inside lane)

- Use a separate form for each density profile.
- A density profile is a series of density readings taken longitudinally approximately every 5 lf in a 50' section.
- Profile one 50' section after the first 1000 feet of project placement (Select the 50' section by method discussed in the specification).
- Profile a section each time the screed stops, including end of day.
- Profiles must be at least 2 ft from joints and edges
- First reading of each profile must be 10 ft behind the screed.
- Minimum of 4 density profiles per mix per project must be performed by the contractor.



TXDOT
Construction Division
Data Collection Form
July 1999

START 9:50 A.M.
FINISH 10:37 A.M.

Nuclear Density Profile Form

Asphaltic Concrete Pavement

496 THIN LIFT

District: 24	CSJ: 2121-5-39	Location Information for 1st Reading
County: El Paso	Profile No.: 1 (5)	Station: 167+00
Highway: 11 - TORNILLO	Test Date: 10-20-99	Lane Direction:* NB SB (EB) WB
Tested By: TxDOT ☑	Contractor: DAN WILLIAMS	Lane:* MIDDLE (ML) FR (1) 2 3 4
Contractor ☐	Mix Type: A	Distance From Inside
Tester: KENDON GRADO	Spec. Item: 3022	Edge of Lane or Joint (ft): 9'
Brand and Model of Paver: BARBER GLEEN	Visible Segregation: Yes ☑ No ☐	Lift: (1st) 2nd 3rd Lift Thickness: ± 3"

Describe Type of Remix Equipment Used In or Ahead of Paver: BARBER GREENE

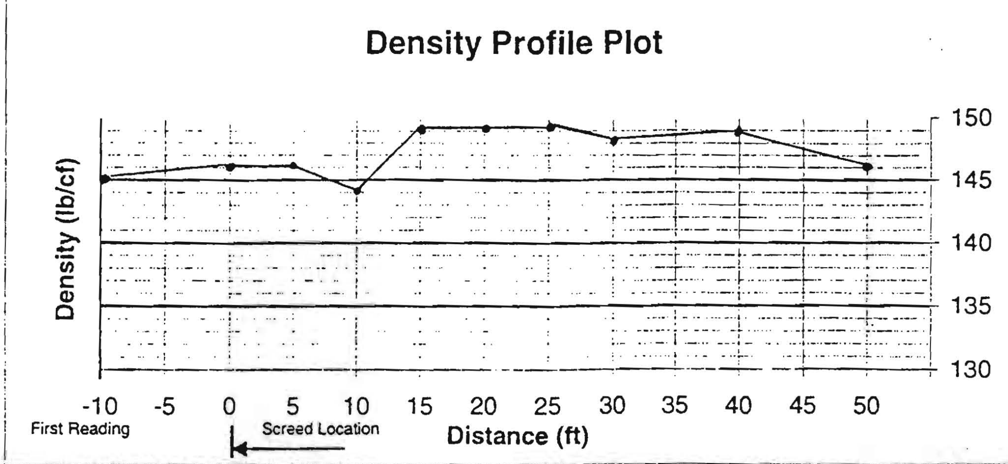
	Feet from Prev. Read.	Readings (lbs/cf)			Avg.
1	10.0	145.5	144.5	145.5	145.2
2	C	145.8	146.4	146.1	145.7
3	5	145.7	145.9	146.0	145.7
4	5	144.5	144.3	144.4	144.4
5	5	148.4	149.3	148.9	148.9
6	5	148.9	148.5	148.7	148.7
7	5	148.7	148.7	150.0	149.1
8	5	147.4	148.5	148.4	148.1
9	10	148.7	149.5	149.3	149.2
10	10	145.0	146.4	145.7	145.7
11					
12					
13					
14					
15					
16					
17					
18					
			Total		147.1

Average Reading	147.1
High Reading	149.2
Low Reading	144.4

Max Density Ranges:		
High - Low	4.8	[Max allowable = 6.0 lbs/cf]
Average - Low	2.7	[Max allowable = 3.0 lbs/cf]

Notes:

* NB = North Bound, ML = Main Lane, FR = Frontage Road
  Lanes numbered from centerline of facility (e.g. 1 = inside lane)
- Use a separate form for each density profile.
- A density profile is a series of density readings taken longitudinally approximately every 5 lf in a 50' section.
- Profile one 50' section after the first 1000 feet of project placement (Select the 50' section by method discussed in the specification).
- Profile a section each time the screed stops, including end of day.
- Profiles must be at least 2 ft from joints and edges
- First reading of each profile must be 10 ft behind the screed.
- Minimum of 4 density profiles per mix per project must be performed by the contractor.



TXDOT
Construction Division
Data Collection Form
July 1999

START 10:53
FINISH 11:50

Nuclear Density Profile Form

Asphaltic Concrete Pavement

476 THIN LIFT FLAT LANE (INSIDE)

District: 24	CSJ: 2121-5-39	Location Information for 1st Reading
County: El Paso	Profile No.: 1 (6)	Station: 171+00
Highway: IH 10	Test Date: 10-20-99	Lane Direction:* NB SB (EB) WB
Tested By: TxDOT ☑	Contractor: Dan Williams	Lane:* INSIDE (ML) FR (1) 2 3 4
Contractor ☐	Mix Type: A	Distance From Inside
Tester: Rendon / Grado	Spec. Item: 3022	Edge of Lane or Joint (ft): 10 1/2'
Brand and Model of Paver: Barber Greene	Visible Segregation: Yes ☑	Lift: (1st) 2nd 3rd
	No ☐	Lift Thickness: 1.3"

Describe Type of Remix Equipment Used In or Ahead of Paver:
DUCo (BG260C) REMIXER (BG 650)

	Feet from Prev. Read.	Readings (lbs/cf)			Avg.
1	10.0	148.6	148.2	148.3	148.4
2	0	145.9	144.7	146.2	145.6
3	5	145.3	145.8	146.1	145.7
4	5	146.4	145.1	146.1	145.9
5	5	148.2	147.9	148.5	148.2
6	5	148.5	148.7	147.9	148.4
7	5	146.0	144.6	145.6	145.4
8	5	146.3	145.9	146.6	146.3
9	10	144.4	144.7	143.9	144.3
10	10	149.0	149.0	148.3	148.8
11					
12					
13					
14					
15					
16					
17					
18					
			Total		146.7

Average Reading	146.7
High Reading	148.8
Low Reading	144.3

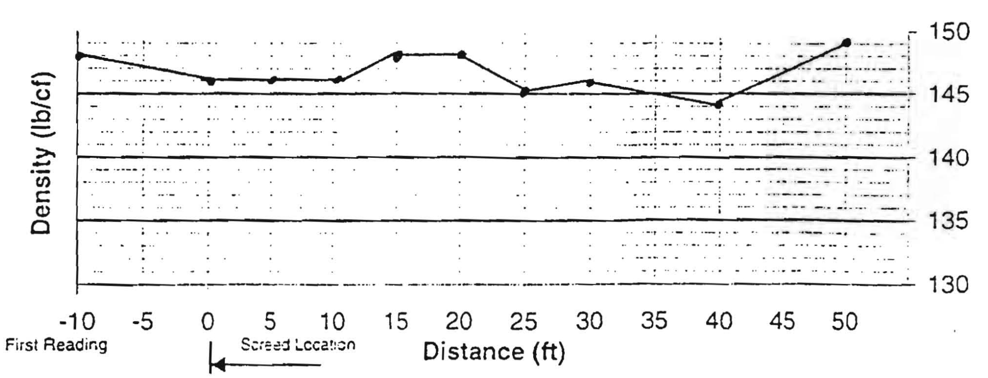
Max Density Ranges:

High - Low	4.5	[Max allowable = 6.0 lbs/cf]
Average - Low	2.4	[Max allowable = 3.0 lbs/cf]

Notes:

* NB = North Bound, ML = Main Lane, FR = Frontage Road
Lanes numbered from centerline of facility (e.g. 1 = inside lane)
- Use a separate form for each density profile.
- A density profile is a series of density readings taken longitudinally approximately every 5 lf in a 50' section.
- Profile one 50' section after the first 1000 feet of project placement (Select the 50' section by method discussed in the specification).
- Profile a section each time the screed stops, including end of day.
- Profiles must be at least 2 ft from joints and edges
- First reading of each profile must be 10 ft behind the screed.
- Minimum of 4 density profiles per mix per project must be performed by the contractor.

Density Profile Plot



TXDOT
Construction Division
Data Collection Form
July 1999

SVARI 12:14
FINISH 1:11

Nuclear Density Profile Form

Asphaltic Concrete Pavement

10-22-99 THIN LIFT 4/6

District: 24	CSJ: 2121 05 039	Location Information for 1st Reading
County: El Paso	Profile No.: 5	Station: 267+00
Highway: IH Tornillo	Test Date: 10-25-99	Lane Direction:* NB SB (EB) WB
Tested By: TxDOT ☑	Contractor: Dal Williams	Lane:* Left (ML) FR (1) 2 3 4
Contractor ☐	Mix Type: A	Distance From Inside
Tester: [illegible] Grado	Spec. Item: 3322	Edge of Lane or Joint (ft): 7'
Brand and Model of Paver: Barber Greene	Visible Segregation: Yes ☑ No ☐	Lift: (1st) 2nd 3rd Lift Thickness: 1-3

Describe Type of Remix Equipment Used In or Ahead of Paver: Barber Greene

	Feet from Prev. Read	Readings (lbs/cf)			Avg.
1	10.0	147.4	146.6	147.6	147.2
2	0	135.3	134.7	135.4	135.1
3	5	131.3	131.2	[illegible]	130.8
4	5	139.1	138.4	139.9	139.1
5	5	142.0	142.7	142.5	142.4
6	5	136.8	137.8	[illegible]	137.6
7	5	146.7	146.9	147.4	147.0
8	5	142.7	143.2	143.8	143.2
9	10	142.9	[illegible]	142.8	142.9
10	10	144.0	143.3	[illegible]	143.5
11					
12					
13					
14					
15					
16					
17					
18					
			Total		140.9

Average Reading	140.9
High Reading	147.2
Low Reading	130.8

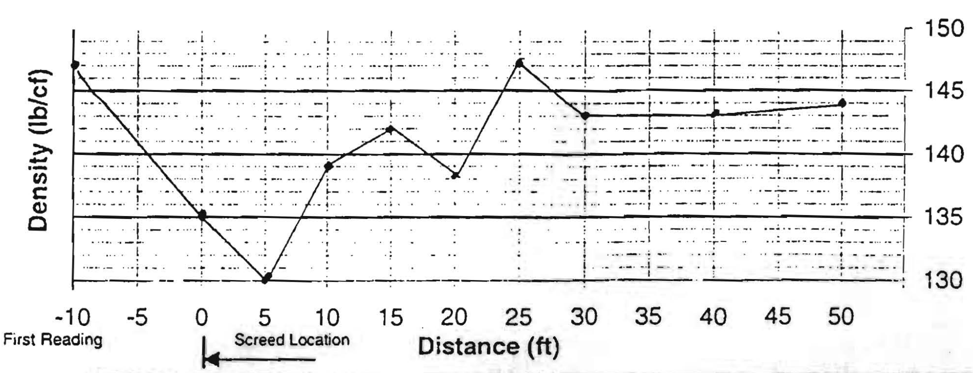
Max Density Ranges:

High - Low	16.4	[Max allowable = 6.0 lbs/cf]
Average - Low	10.1	[Max allowable = 3.0 lbs/cf]

Notes:

- * NB = North Bound, ML = Main Lane, FR = Frontage Road
  Lanes numbered from centerline of facility (e.g. 1 = inside lane)
- Use a separate form for each density profile.
- A density profile is a series of density readings taken longitudinally approximately every 5 lf in a 50' section.
- Profile one 50' section after the first 1000 feet of project placement (Select the 50' section by method discussed in the specification).
- Profile a section each time the screed stops, including end of day.
- Profiles must be at least 2 ft from joints and edges
- First reading of each profile must be 10 ft behind the screed.
- Minimum of 4 density profiles per mix per project must be performed by the contractor.

Density Profile Plot



TXDOT
Construction Division
Data Collection Form
July 1999

START 11:10 am
FINISH

Nuclear Density Profile Form

Asphaltic Concrete Pavement

10-22-99   479 WIND 4 Pl

District: 24	CSJ: 2121-539	Location Information for 1st Reading
County: El Paso	Profile No.: 3	Station: 264+75
Highway: Tillo Tornillo	Test Date: 10-25-99	Lane Direction:* NB SB (EB) WB
Tested By: TxDOT ☑	Contractor: Dan Williams	Lane:* Middle (ML) FR 1 2 3 4
Contractor ☐	Mix Type: A	Distance From Inside
Tester: Danny Cra	Spec. Item: 3022	Edge of Lane or Joint (ft): 18'
Brand and Model of Paver: Barber Greene	Visible Segregation: Yes ☑ No ☐	Lift: 1st 2nd 3rd
		Lift Thickness: 1-3'

Describe Type of Remix Equipment Used In or Ahead of Paver: Ingersol Big Knox

	Feet from Prev. Read.	Readings (lbs/cf)			Avg.
1	10.0	142.8	143.6	143.3	143.2
2	5	142.8	143.7	143.4	143.3
3	5	139.9	139.6	139.5	139.7
4	5	144.0	143.8	143.8	143.9
5	5	146.3	147.4	147.7	147.1
6	5	146.5	146.0	147.3	146.6
7	5	146.0	146.2	145.8	146.0
8	5	142.6	142.0	142.8	142.5
9	10	142.5	143.7	143.7	143.3
10	10	144.7	144.0	144.5	144.4
11					
12					
13					
14					
15					
16					
17					
18					
			Total		

Average Reading	144.0
High Reading	147.1
Low Reading	139.7

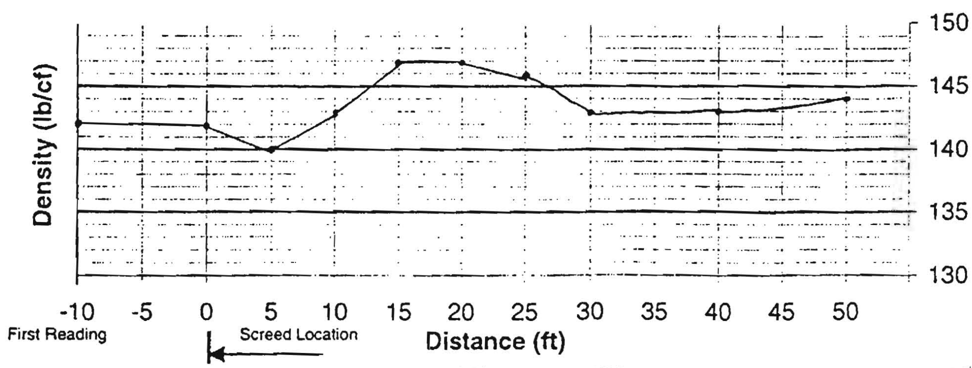
Max Density Ranges:

High - Low	7.4	[Max allowable = 6.0 lbs/cf]
Average - Low	4.3	[Max allowable = 3.0 lbs/cf]

Notes:

* NB = North Bound, ML = Main Lane, FR = Frontage Road
  Lanes numbered from centerline of facility (e.g. 1 = inside lane)
- Use a separate form for each density profile.
- A density profile is a series of density readings taken longitudinally approximately every 5 lf in a 50' section.
- Profile one 50' section after the first 1000 feet of project placement (Select the 50' section by method discussed in the specification).
- Profile a section each time the screed stops, including end of day.
- Profiles must be at least 2 ft from joints and edges
- First reading of each profile must be 10 ft behind the screed.
- Minimum of 4 density profiles per mix per project must be performed by the contractor.

Density Profile Plot



TXDOT
Construction Division
Data Collection Form
July 1999

3rd LV 11'22
FINISH 12'10

Nuclear Density Profile Form

Asphaltic Concrete Pavement

10-22-99

District: 24	CSJ: 2121-05-039	Location Information for 1st Reading
County: El Paso	Profile No.: 4	Station: 255+00
Highway: FM 10RNILLO	Test Date: 10-25-99	Lane Direction:* NB SB EB WB
Tested By: TxDOT ☑ Contractor ☐	Contractor: DAN WILLIAMS	Lane: MIDDLE ML FR 1 2 3 4
	Mix Type: A	Distance From Inside Edge of Lane or Joint (ft): 18'
Tester: KENDON GLADO	Spec. Item: 3028	Lift: 1st 2nd 3rd
Brand and Model of Paver: BARBER GREENE	Visible Segregation: Yes ☑ No ☐	Lift Thickness: 1-3"

Describe Type of Remix Equipment Used In or Ahead of Paver: INGERSOLL BLAWKNOX

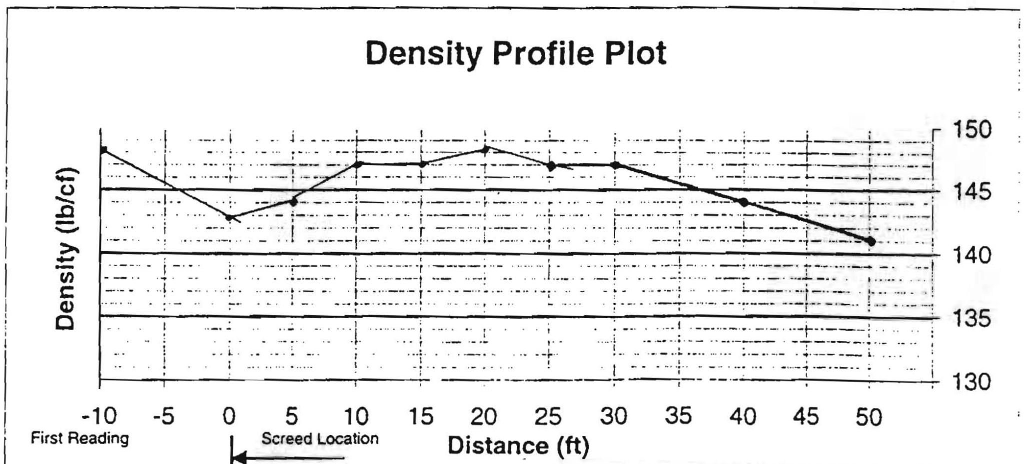
	Feet from Prev. Read.	Readings (lbs/cf)			Avg.
1	10.0	149.9	148.8	149.4	149.4
2	0	142.9	143.6	142.8	143.1
3	5	143.8	143.8	143.2	143.6
4	5	146.6	147.2	146.6	146.8
5	5	146.6	146.6	146.6	146.6
6	5	148.7	147.9	147.9	148.2
7	5	146.6	147.3	149.1	147.0
8	5	147.0	146.8	147.0	146.9
9	10	144.9	144.3	143.9	144.4
10	10	140.7	140.4	140.5	140.5
11					
12					
13					
14					
15					
16					
17					
18					
				Total	145.7

Average Reading	145.7
High Reading	149.4
Low Reading	140.5

Max Density Ranges:		
High - Low	8.9	[Max allowable = 6.0 lbs/cf]
Average - Low	5.2	[Max allowable = 3.0 lbs/cf]

Notes:

* NB = North Bound, ML = Main Lane, FR = Frontage Road
Lanes numbered from centerline of facility (e.g. 1 = inside lane)
- Use a separate form for each density profile.
- A density profile is a series of density readings taken longitudinally approximately every 5 lf in a 50' section.
- Profile one 50' section after the first 1000 feet of project placement (Select the 50' section by method discussed in the specification).
- Profile a section each time the screed stops, including end of day.
- Profiles must be at least 2 ft from joints and edges
- First reading of each profile must be 10 ft behind the screed.
- Minimum of 4 density profiles per mix per project must be performed by the contractor.



TXDOT
Construction Division
Data Collection Form
July 1999

START 9:17 A.M.
FINISH 9:58

Nuclear Density Profile Form

Asphaltic Concrete Pavement

10-22-99 4½ HIW LIFT OUTSIDE LANE

District: 24	CSJ: 2121-05034	Location Information for 1st Reading	
County: El Paso	Profile No.: 2	Station: 252+30	
Highway: I-10 TORNILLO	Test Date: 10-25-99	Lane Direction:* NB SB (EB) WB	
Tested By: TxDOT ☑	Contractor: DAN WILLIAMS	Lane:* RT MIDDLE ML FR 1 2 (3) 4	
Contractor ☐	Mix Type: A	Distance From Inside	
Tester: RENDON GRADO	Spec. Item: 3022	Edge of Lane or Joint (ft): 8'	
Brand and Model of Paver: BARBER GREENE	Visible Segregation: Yes ☑ No ☐	Lift: (1st) 2nd 3rd	Lift Thickness: 1-3"

Describe Type of Remix Equipment Used In or Ahead of Paver: INGERSOLL [illegible]

	Feet from Prev. Read.	Readings (lbs/cf)			Avg.
1	10.0	144.2	144.3	143.9	144.1
2	0	147.5	147.9	147.3	147.5
3	5	145.5	145.1	145.8	145.5
4	5	145.1	145.5	145.4	145.3
5	5	146.1	146.6	146.9	146.5
6	5	146.2	146.4	146.1	146.2
7	-	143.8	143.8	143.5	143.7
8	5	145.8	145.8	145.4	145.7
9	10	145.4	145.5	145.5	145.5
10	10	145.9	145.5	145.5	145.6
11					
12					
13					
14					
15					
16					
17					
18					
		Total			145.6

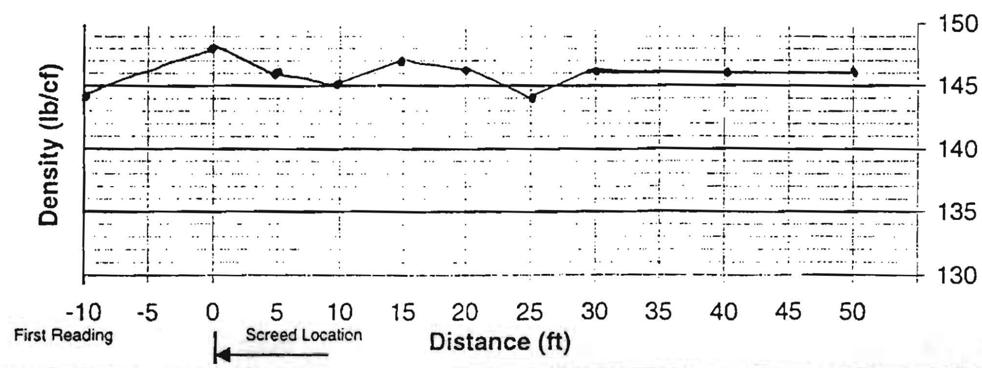
Average Reading	145.6
High Reading	147.5
Low Reading	143.7

Max Density Ranges:		
High - Low	3.8	[Max allowable = 6.0 lbs/cf]
Average - Low	1.9	[Max allowable = 3.0 lbs/cf]

Notes:

* NB = North Bound, ML = Main Lane, FR = Frontage Road
  Lanes numbered from centerline of facility (e.g. 1 = inside lane)
- Use a separate form for each density profile.
- A density profile is a series of density readings taken longitudinally approximately every 5 lf in a 50' section.
- Profile one 50' section after the first 1000 feet of project placement
  - (Select the 50' section by method discussed in the specification).
- Profile a section each time the screed stops, including end of day.
- Profiles must be at least 2 ft from joints and edges
- First reading of each profile must be 10 ft behind the screed.
- Minimum of 4 density profiles per mix per project must be performed by the contractor.

Density Profile Plot



TXDOT
Construction Division
Data Collection Form
July 1999

START 8:20
FINISH 9:05

Nuclear Density Profile Form

Asphaltic Concrete Pavement

10-22-99 476 TURN LIFT

District: 24	CSJ: 2121-39	Location Information for 1st Reading
County: EL PASO	Profile No.: 1	Station: 350+00
Highway: FM TORNILLO	Test Date: 10-25-99	Lane Direction:* NB SB (EB) WB
Tested By: TxDOT ☑	Contractor: DAN WILLIAMS	Lane:* OUTSIDE (ML) FR 1 2 (3) 4
Contractor ☐	Mix Type: A	Distance From Inside
Tester: RENDON/GRADO	Spec. Item: 3022	Edge of Lane or Joint (ft): 8
Brand and Model of Paver: BARBER GREEN	Visible Segregation: Yes ☑ No ☐	Lift: 1st 2nd 3rd
		Lift Thickness: 1-3"

Describe Type of Remix Equipment Used In or Ahead of Paver: INGERSOL BLOW KNOX

	Feet from Prev. Read.	Readings (lbs/cf)			Avg.
1	10.0	142.7	142.7	140.0	141.8
2	0	142.3	144.4	143.3	143.3
3	5	142.1	142.0	142.2	142.1
4	5	143.9	143.0	142.9	143.3
5	5	141.0	141.4	141.0	141.1
6	5	139.8	140.1	139.4	139.8
7	5	140.1	140.3	140.3	140.2
8	5	138.0	138.5	138.8	138.4
9	10	139.0	137.8	138.1	138.3
10	10	134.2	134.8	134.4	134.5
11					
12					
13					
14					
15					
16					
17					
18					
			Total		140.3

Average Reading	140.3
High Reading	143.3
Low Reading	134.5

Max Density Ranges:		
High - Low	8.8	[Max allowable = 6.0 lbs/cf]
Average - Low	5.8	[Max allowable = 3.0 lbs/cf]

Notes:

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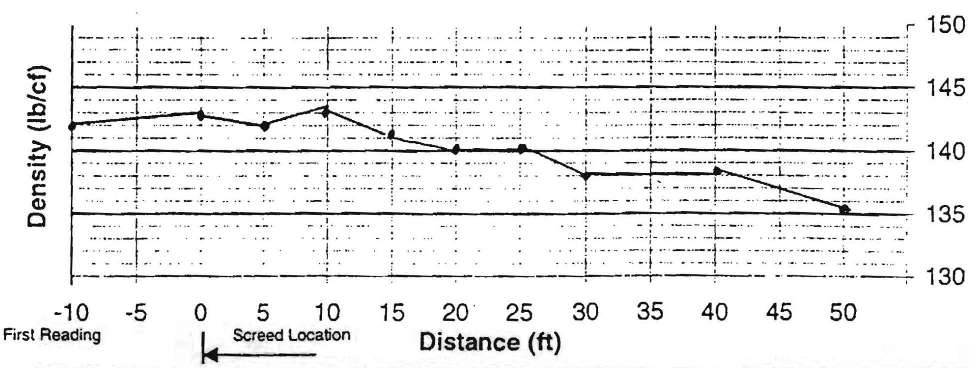
Lanes numbered from centerline of facility (e.g. 1 = inside lane)
- Use a separate form for each density profile.
- A density profile is a series of density readings taken longitudinally approximately every 5 lf in a 50' section.
- Profile one 50' section after the first 1000 feet of project placement (Select the 50' section by method discussed in the specification).
- Profile a section each time the screed stops, including end of day.
- Profiles must be at least 2 ft from joints and edges
- First reading of each profile must be 10 ft behind the screed.
- Minimum of 4 density profiles per mix per project must be performed by the contractor.

Density Profile Plot



TXDOT
Construction Division
Data Collection Form
July 1999

START 9:55
FINISH 10:40

Nuclear Density Profile Form

Asphaltic Concrete Pavement

1000' FROM BEGINNING 4½ THIN LIFT

District: 24	CSJ: 2121-05-037	Location Information for 1st Reading
County: El Paso	Profile No.: 2	Station: 229+50
Highway: IH-10 TORNILLO	Test Date: 10-22-99	Lane Direction:* NB SB (EB) WB
Tested By: TxDOT [x]	Contractor: DAN WILLIAMS	Lane:* R ML/FR 1 2 (3) 4
Contractor [ ]	Mix Type: A	Distance From Inside
Tester: REDMON/SERADO	Spec. Item: 3022	Edge of Lane or Joint (ft): 5'
Brand and Model of Paver: BARBER GREENE IND CO.	Visible Segregation: Yes [x] No [ ]	Lift: (1st) 2nd 3rd
		Lift Thickness: 1-3'

Describe Type of Remix Equipment Used In or Ahead of Paver: MC-330 BLAW-KNOX, BG 260C CUSHING TRUCK CO, DELTA TX, INGERSOLL-RAND REMIXER

	Feet from Prev. Read.	Readings (lbs/cf)			Avg.
1	10.0	139.8	139.1	139.5	139.5
2	0	135.6	136.1	135.5	135.7
3	5	140.0	141.1	140.9	140.4
4	5 10	137.4	137.3	137.8	137.5
5	5	140.1	140.4	140.0	140.2
6	5	140.9	142.4	142.0	141.8
7	5 25	142.3	142.6	142.6	142.5
8	5 30	143.0	141.5	141.5	142.0
9	10	139.8	139.5	138.6	139.3
10	10	140.7	140.8	140.1	140.5
11					
12					
13					
14					
15					
16					
17					
18					
				Total	140.0

Average Reading	140.0
High Reading	142.5
Low Reading	137.5

Max Density Ranges:

High - Low	5	[Max allowable = 6.0 lbs/cf]
Average - Low	2.5	[Max allowable = 3.0 lbs/cf]

Notes:
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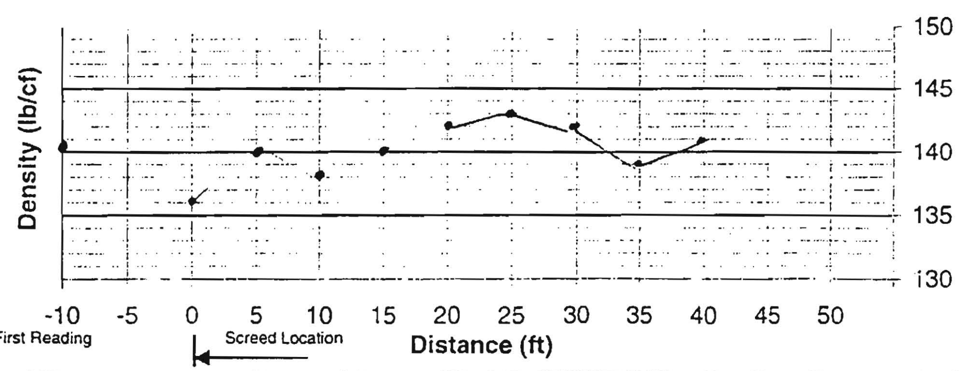
  Lanes numbered from centerline of facility (e.g. 1 = inside lane)
- Use a separate form for each density profile.
- A density profile is a series of density readings taken longitudinally approximately every 5 lf in a 50' section.
- Profile one 50' section after the first 1000 feet of project placement (Select the 50' section by method discussed in the specification).
- Profile a section each time the screed stops, including end of day.
- Profiles must be at least 2 ft from joints and edges
- First reading of each profile must be 10 ft behind the screed.
- Minimum of 4 density profiles per mix per project must be performed by the contractor.

Density Profile Plot



TxDOT
Construction Division
Data Collection Form
July 1999

Nuclear Density Profile Form

Asphaltic Concrete Pavement

224 center 222
mid out Blonot

District: 24	CSJ: 2121-05-03	**Location Information for 1st Reading**
County: El Paso	Profile No.:	Station: 222+
Highway: I-10 - Tornillo	Test Date: 10-22-99	Lane Direction:* NB SB EB WB
Tested By: TxDOT ☑	Contractor: Ow Co	Lane:* Outside ML FR 1 2 ③ 4
Contractor ☐	Mix Type: A	Distance From Inside
Tester:	Spec. Item: 3022	Edge of Lane or Joint (ft): 7' outside
Brand and Model of Paver: Blaw Knox	Visible Segregation: Yes ☑ No ☐	Lift: ⓵st 2nd 3rd
		Lift Thickness: 1-3"
Describe Type of Remix Equipment Used In or Ahead of Paver: BLAW KNOX		

	Feet from Prev. Read.	Readings (lbs/cf)			Avg.
1	0.0-10	140.5	140.8	139.9	140.4
2	0	134.3	133.0	132.8	133.4
3	5	130.8	130.8	131.2	130.9
4	5 10	126.3	126.0	125.6	126.0
5	5	132.0	132.0	132.5	132.2
6	5	126.9	126.8	127.6	127.1
7	5	128.8	129.2	128.4	128.8
8	5 30	131.0	130.9	131.3	131.1
9	10	130.1	132.9	131.1	130.7
10	10	134.5	134.0	134.5	134.3
11					
12					
13					
14					
15					
16					
17					
18					
				Total	131.5

Average Reading	131.5
High Reading	140.4
Low Reading	126.0

start 10:25
end 11:15

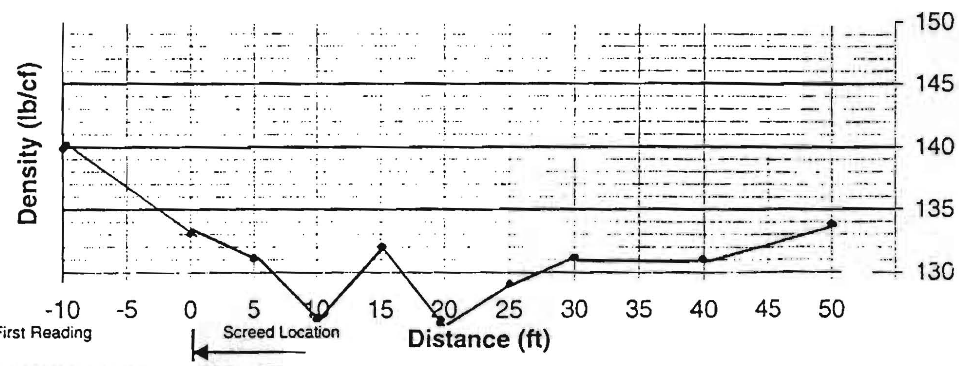
Max Density Ranges:

High - Low	14.4	[Max allowable = 6.0 lbs/cf]
Average - Low	5.5	[Max allowable = 3.0 lbs/cf]

Notes:

* NB = North Bound, ML = Main Lane, FR = Frontage Road
Lanes numbered from centerline of facility (e.g. 1 = inside lane)
1180.2
- Use a separate form for each density profile.
- A density profile is a series of density readings taken longitudinally approximately every 5 lf in a 50' section.
- Profile one 50' section after the first 1000 feet of project placement (Select the 50' section by method discussed in the specification).
- Profile a section each time the screed stops, including end of day.
- Profiles must be at least 2 ft from joints and edges
- First reading of each profile must be 10 ft behind the screed.
- Minimum of 4 density profiles per mix per project must be performed by the contractor.

Density Profile Plot



TXDOT
Construction Division
Data Collection Form
July 1999

START 2:40
FINISH 3:44

Nuclear Density Profile Form

Asphaltic Concrete Pavement

476

District: 24	CSJ: 2121-5-39	Location Information for 1st Reading
County: El Paso	Profile No.: 1 (7)	Station: 206+50
Highway: Loop Tornillo	Test Date: 10-21-99	Lane Direction:* NB SB (EB) WB
Tested By: TxDOT ☑	Contractor: Dan Williams	Lane:* (ML) FR 1 2 (3) 4
Contractor ☐	Mix Type: A	Distance From Inside
Tester: Reimon G'rado	Spec. Item: 3022	Edge of Lane or Joint (ft): 10
Brand and Model of Paver: Cedarapids	Visible Segregation: Yes ☑ No ☐ (Very)	Lift: (1st) 2nd 3rd
		Lift Thickness: ± 3"

Describe Type of Remix Equipment Used In or Ahead of Paver: Remix Anti Segregation System Cedarapids Grayhound Lay Down Machine

	Feet from Prev. Read.	Readings (lbs/cf)			Avg.
1	10.0	141.2	140.3	140.2	140.6
2	0	135.6	135.1	134.6	134.4
3	5	133.1	133.6	133.4	133.4
4	5	136.1	136.4	135.8	136.1
5	5	135.1	136.4	135.0	135.5
6	5	140.8	140.0	140.0	140.3
7	5	142.7	142.1	143.0	142.6
8	5	145.2	145.3	144.7	145.1
9	10	144.1	144.5	145.6	144.7
10	10	141.4	141.9	141.6	141.6
11					
12					
13					
14					
15					
16					
17					
18					
				Total Avg.	139.4

Average Reading	139.4
High Reading	145.1
Low Reading	133.4

Max Density Ranges:		
High - Low	11.7	[Max allowable = 6.0 lbs/cf]
Average - Low	6	[Max allowable = 3.0 lbs/cf]

Notes:

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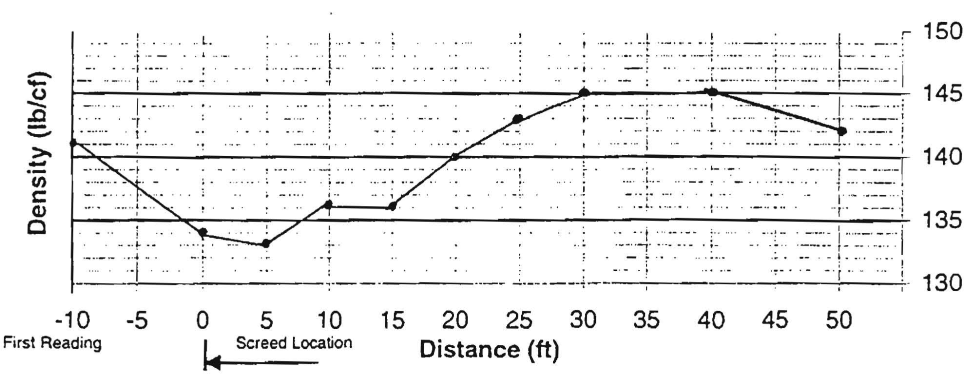
- A density profile is a series of density readings taken longitudinally approximately every 5 lf in a 50' section.
- Profile one 50' section after the first 1000 feet of project placement (Select the 50' section by method discussed in the specification).
- Profile a section each time the screed stops, including end of day.
- Profiles must be at least 2 ft from joints and edges
- First reading of each profile must be 10 ft behind the screed.
- Minimum of 4 density profiles per mix per project must be performed by the contractor.

Density Profile Plot



TXDOT
Construction Division
Data Collection Form
July 1999

Nuclear Density Profile Form

Asphaltic Concrete Pavement

District: 24	CSJ: 2121-05-03	Location Information for 1st Reading
County: El Paso	Profile No.:	Station: 209+50
Highway: I-10 Tornillo	Test Date: 10-21-99	Lane Direction:* NB SB (EB) WB
Tested By: TxDOT ☑	Contractor: DW CO	Lane:* middle (ML) FR 1 (2) 3 4
Contractor ☐	Mix Type: A	Distance From Inside
Tester: zuniga	Spec. Item: 3022	Edge of Lane or Joint (ft): 17' inside edge
Brand and Model of Paver: cederapids	Visible Segregation: Yes ☑ No ☐	Lift: (1st) 2nd 3rd
		Lift Thickness: 1-3"

Describe Type of Remix Equipment Used In or Ahead of Paver: Cedarapids

		Feet from Prev. Read.	Readings (lbs/cf)			Avg.
138.8	1	~~0.0~~ -10	143.7	144.3	144.4	144.1
134.2	2	0	140.9	140.8	140.6	140.8
126.5	3	5	135.5	135.5	135.5	135.5
125.3	4	5 10	135.0	135.0	134.9	135.0
132.3	5	5	137.6	137.8	134.	138.1
139.5	6	5 20	140.5	141.2	141.0	140.9
138.5	7	5	143.7	143.5	143.4	143.5
137.7	8	5	142.0	141.7	142.3	142.
140.8	9	10 40	144.1	145.1	144.7	144.6
140.8	10	10	141.9	142.5	142.7	142.4
	11					
	12					
	13					
135.4	14					
	15					
	16					
	17					
	18					
			Total			140.7

Average Reading	140.7
High Reading	144.6
Low Reading	135.0

start 1:30
end 2:32

Max Density Ranges:		
High - Low	9.6	[Max allowable = 6.0 lbs/cf]
Average - Low	5.7	[Max allowable = 3.0 lbs/cf]

Notes:

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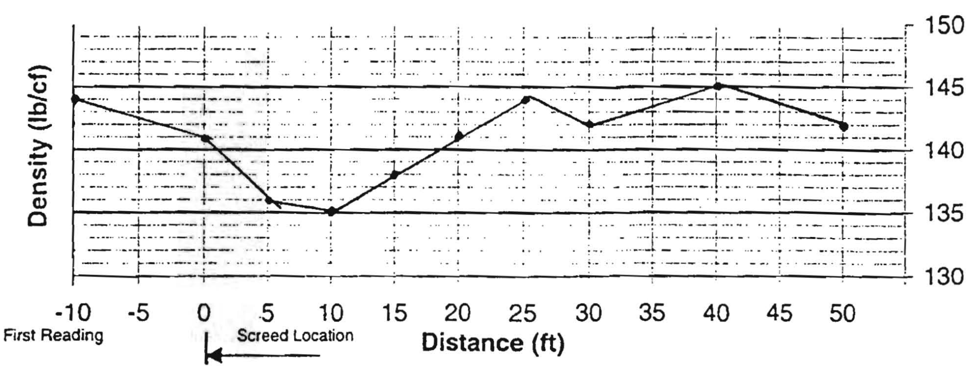
- Profile a section each time the screed stops, including end of day.
- Profiles must be at least 2 ft from joints and edges
- First reading of each profile must be 10 ft behind the screed.
- Minimum of 4 density profiles per mix per project must be performed by the contractor.

Density Profile Plot



TXDOT
Construction Division
Data Collection Form
July 1999

Start 1:33 P.
Finish 2:20

Nuclear Density Profile Form

Asphaltic Concrete Pavement

204+50 - 216+50

District: 24	CSJ: 2121-5-39	Location Information for 1st Reading
County: El Paso	Profile No.: 1 (6)	Station: 213+00
Highway: I-10 Tornillo	Test Date: 10-31-99	Lane Direction:* NB SB (EB) WB
Tested By: TxDOT ☑	Contractor: Dan Williams	Lane:* (ML) FR 1 (2) 3 4
Contractor ☐	Mix Type: A	Distance From Inside
Tester: Rendon / Grado	Spec. Item: 3022	Edge of Lane or Joint (ft): 6 1/2 20
Brand and Model of Paver: Cedarapids	Visible Segregation: Yes ☑ No ☐	Lift: (1st) 2nd 3rd
		Lift Thickness: 1-3"

Describe Type of Remix Equipment Used In or Ahead of Paver: Remix Anti Segregation System Cedarapids (Grayhound Lay Down Machine)

	Feet from Prev. Read.	Readings (lbs/cf)			Avg.
1	10.0	140.00	139.7	139.7	139.8
2	0	139.2	139.5	139.4	139.4
3	5	136.2	136.7	135.9	136.3
4	5	141.7	141.7	141.1	141.5
5	5	140.8	141.9	141.6	141.4
6	5	138.4	139.0	139.7	139.0
7	5	133.4	132.8	133.1	133.1
8	5	142.1	142.3	142.4	142.3
9	10	142.2	142.0	141.5	141.9
10	10	141.1	141.0	141.2	141.1
11					
12					
13					
14					
15					
16					
17					
18					
			Total	Avg	139.6

Average Reading	139.6
High Reading	142.3
Low Reading	133.1

Max Density Ranges:		
High - Low	9.2	[Max allowable = 6.0 lbs/cf]
Average - Low	6.5	[Max allowable = 3.0 lbs/cf]

Notes:
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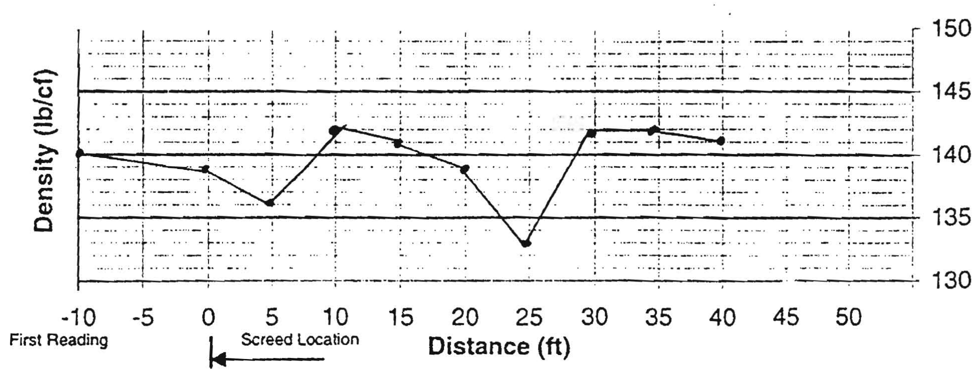
- Profile a section each time the screed stops, including end of day.
- Profiles must be at least 2 ft from joints and edges
- First reading of each profile must be 10 ft behind the screed.
- Minimum of 4 density profiles per mix per project must be performed by the contractor.

Density Profile Plot



TXDOT
Construction Division
Data Collection Form
July 1999

10,1

Nuclear Density Profile Form

Asphaltic Concrete Pavement

District: 24	CSJ: 2121-05-03	Location Information for 1st Reading
County: El Paso	Profile No.:	Station: 214+00
Highway: I-10 Tornillo	Test Date: 10-21-99	Lane Direction:* NB SB (EB) WB
Tested By: TxDOT ☑	Contractor: OWCO	Lane:* Outside (ML) FR 1 2 (3) 4
Contractor ☐	Mix Type: A	Distance From Inside
Tester: Zuniga	Spec. Item: 3022	Edge of Lane or Joint (ft): 7' outside
Brand and Model of Paver: Cedarapids	Visible Segregation: Yes ☑ No ☐	Lift: (1st) 2nd 3rd Lift Thickness: 1-3"

Describe Type of Remix Equipment Used In or Ahead of Paver:
Cedarapids

	Feet from Prev. Read.	Readings (lbs/cf)			Avg.
1	0.0-10	147.2	147.2	146.9	147.1
2	0	144.1	144.8	145.4	144.8
3	5	146.2	147.1	146.7	146.7
4	5	145.4	145.6	145.1	145.4
5	5	145.5	145.7	144.6	145.3
6	5	143.6	143.7	143.9	143.7
7	5 25	141.2	141.7	142.0	141.6
8	5	142.3	141.7	143.3	142.4
9	10	143.4	142.9	142.7	143
10	10	145.1	144.9	145.9	145.3
11					
12					
13					
14					
15					
16					
17					
18					
	Total				144.5

Average Reading	144.5
High Reading	147.1
Low Reading	141.6

start 2:48
end 3:30

Max Density Ranges:		
High - Low	5.5	[Max allowable = 6.0 lbs/cf]
Average - Low	2.9	[Max allowable = 3.0 lbs/cf]

Notes: 1014.6

* NB = North Bound, ML = Main Lane, FR = Frontage Road
1320
Lanes numbered from centerline of facility (e.g. 1 = inside lane)
- Use a separate form for each density profile.
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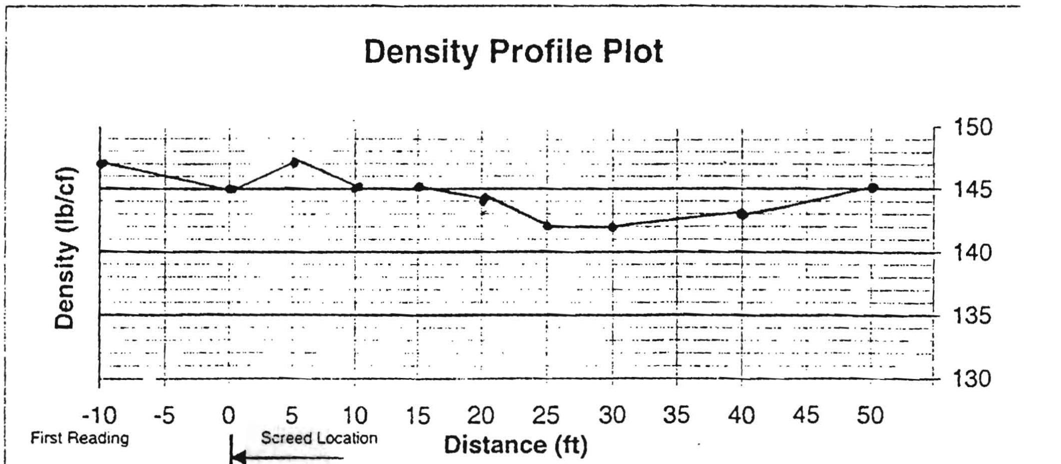

TXDOT
Construction Division
Data Collection Form
July 1999

OK 10-9 20 21

Nuclear Density Profile Form

Asphaltic Concrete Pavement

District: 24	CSJ: 2121-05-03	Location Information for 1st Reading
County: El Paso	Profile No.:	Station: 224+00
Highway: 10 Tornillo	Test Date: 10-22-99	Lane Direction:* NB SB (EB) WB
Tested By: TxDOT ☑	Contractor: DW CO	Lane:* middle ML FR 1 (2) 3 4
Contractor ☐	Mix Type: A	Distance From Inside
Tester: Zuniga	Spec. Item: 3022	Edge of Lane or Joint (ft): 21ft outside
Brand and Model of Paver: Cedarapids	Visible Segregation: Yes ☑ No ☐	Lift: 1st 2nd 3rd
		Lift Thickness:

Describe Type of Remix Equipment Used In or Ahead of Paver: (Cedarapids)

	Feet from Prev. Read.	Readings (lbs/cf)			Avg.
1	0.0-10	146.4	146.2	146.0	146.2
2	0	143.7	143.9	142.7	143.4
3	5	143.9	144.1	143.8	144.0
4	5	142.7	143.1	141.7	142.5
5	5 15	140.2	139.6	139.3	139.7
6	5 20	143.8	143.7	143.5	143.7
7	5 25	147.1	146.7	147.8	147.2
8	5	142.5	142.8	142.0	142.4
9	10	142.6	142.9	143.1	142.9
10	10	141.3	142.3	141.3	141.6
11					
12					
13					
14					
15					
16					
17					
18					
				Total	143.4

Average Reading	143.4
High Reading	147.2
Low Reading	139.7

start 1120
end 12:00

Max Density Ranges:

High - Low	7.5	[Max allowable = 6.0 lbs/cf]
Average - Low	3.7	[Max allowable = 3.0 lbs/cf]

Notes:

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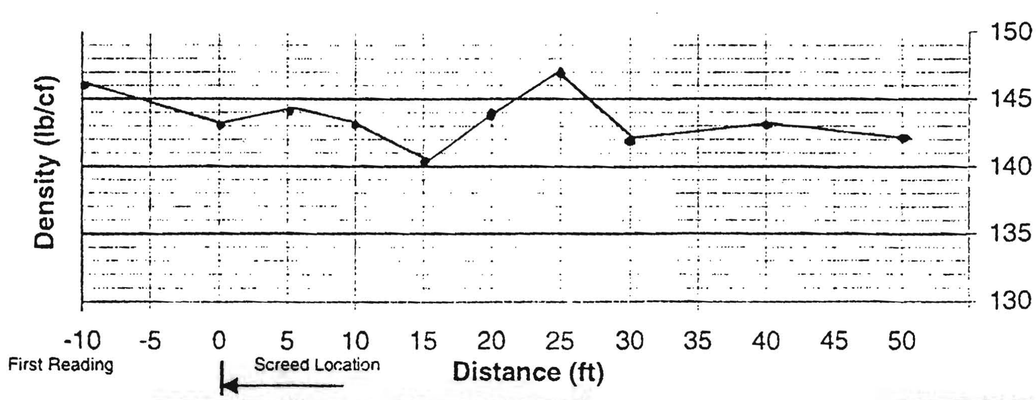
  Lanes numbered from centerline of facility (e.g. 1 = inside lane)
- Use a separate form for each density profile.
- A density profile is a series of density readings taken longitudinally approximately every 5 lf in a 50' section.
- Profile one 50' section after the first 1000 feet of project placement (Select the 50' section by method discussed in the specification).
- Profile a section each time the screed stops, including end of day.
- Profiles must be at least 2 ft from joints and edges
- First reading of each profile must be 10 ft behind the screed.
- Minimum of 4 density profiles per mix per project must be performed by the contractor.

Density Profile Plot



TXDOT
Construction Division
Data Collection Form
July 1999

OK

START 10:20
FINISH 10:40

Nuclear Density Profile Form

Asphaltic Concrete Pavement

District: El Paso	CSJ: 2121-05-03	Location Information for 1st Reading
County: El Paso	Profile No.:	Station: 246+50
Highway: I-10 Tornillo	Test Date: 10-22-99	Lane Direction:* NB SB (EB) WB
Tested By: TxDOT ☑	Contractor: DWCO	Lane:* Middle ML FR 1 (2) 3 4
Contractor ☐	Mix Type: A	Distance From Inside Edge of Lane or Joint (ft): 18' center
Tester: [illegible]	Spec. Item: 3022	
Brand and Model of Paver: Cedarapids	Visible Segregation: Yes ☑ No ☐	Lift: (1st) 2nd 3rd; Lift Thickness: 1-3"

Describe Type of Remix Equipment Used In or Ahead of Paver: Cedar Rapids

	Feet from Prev. Read.	Readings (lbs/cf)			Avg.
1	~~0.0~~ 10	144.3	143.5	144.8	144.2
2	0	139.6	139.9	139.8	139.8
3	5	136.5	137.7	137.7	137.3
4	5	144.1	145.4	144.4	144.6
5	5	144.2	145.0	144.6	144.6
6	5	146.7	146.1	146.1	146.3
7	5	147.5	148.5	147.8	147.9
8	5	149.5	150.3	150.3	150.0
9	10	142.0	142.2	142.4	142.2
10	10	144.9	145.3	145.0	145.1
11					
12					
13					
14					
15					
16					
17					
18					
		Total			144.2

Average Reading	144.2
High Reading	150.0
Low Reading	137.3

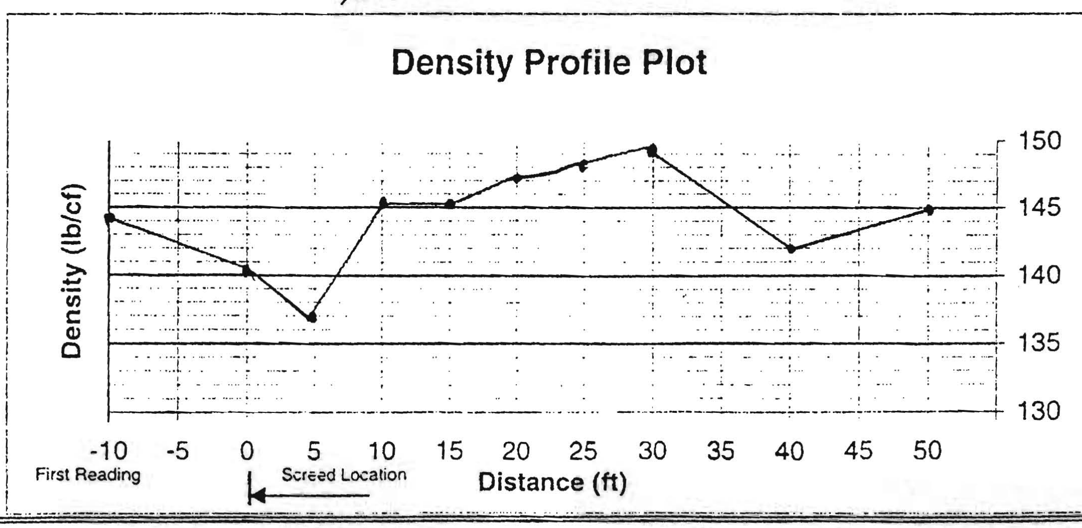
Start + Stop
end

Max Density Ranges:

High - Low	12.7	[Max allowable = 6.0 lbs/cf]
Average - Low	6.9	[Max allowable = 3.0 lbs/cf]

→ 476 FINISH LIFT

Notes:
- NB = North Bound, ML = Main Lane, FR = Frontage Road
- Lanes numbered from centerline of facility (e.g. 1 = inside lane)
- Use a separate form for each density profile.
- A density profile is a series of density readings taken longitudinally approximately every 5 lf in a 50' section.
- Profile one 50' section after the first 1000 feet of project placement (Select the 50' section by method discussed in the specification).
- Profile a section each time the screed stops, including end of day.
- Profiles must be at least 2 ft from joints and edges
- First reading of each profile must be 10 ft behind the screed.
- Minimum of 4 density profiles per mix per project must be performed by the contractor.



TXDOT
Construction Division
Data Collection Form
July 1999

√

1:15 pm
F-1 2:10 pm.

Nuclear Density Profile Form

Asphaltic Concrete Pavement

476 THIL LIFT

District: 24	CSJ: 2121-05-021	Location Information for 1st Reading
County: El Paso	Profile No.: 1	Station: 160+00
Highway: FM TORNILLO	Test Date: 10-20-99	Lane Direction:* NB SB (EB) WB
Tested By: TxDOT ☑	Contractor: DAL WILLIAMS	Lane:* OUTSIDE — ML FR — 1 2 (3) 4
Contractor ☐	Mix Type: A	Distance From Inside
Tester: REDDEN GRALO	Spec. Item: 3022	Edge of Lane or Joint (ft): 3 1/2"
Brand and Model of Paver: BARBER GREENE	Visible Segregation: Yes ☑ No ☐	Lift: (1st) 2nd 3rd
		Lift Thickness: 3 1/2"

Describe Type of Remix Equipment Used In or Ahead of Paver:
LINCOLN BBO-HPN PUGMILL AUGER 7 VC 46

	Feet from Prev. Read.	Readings (lbs/cf)			Avg.
1	10.0	136.7	136.4	137.3	136.8
2	0	139.0	138.0	138.5	138.5
3	5	141.6	141.2	141.4	141.4
4	5	142.1	142.0	142.3	142.1
5	5	143.2	142.8	143.1	143.0
6	5	145.4	146.1	145.5	145.7
7	5	143.5	143.3	143.3	143.3
8	5	142.0	142.2	142.2	142.1
9	10	143.3	142.7	142.9	142.9
10	10	142.5	142.4	143.0	142.6
11					
12					
13					
14					
15					
16					
17					
18					
				Total	141.8

Average Reading	141.8
High Reading	145.7
Low Reading	136.8

Max Density Ranges:		
High - Low	8.9	[Max allowable = 6.0 lbs/cf]
Average - Low	5.0	[Max allowable = 3.0 lbs/cf]

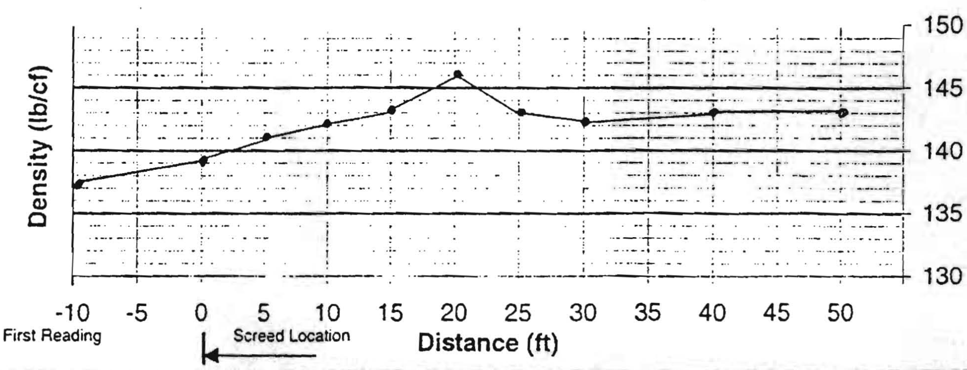
Notes:

* NB = North Bound, ML = Main Lane, FR = Frontage Road
Lanes numbered from centerline of facility (e.g. 1 = inside lane)
- Use a separate form for each density profile.
- A density profile is a series of density readings taken longitudinally approximately every 5 lf in a 50' section.
- Profile one 50' section after the first 1000 feet of project placement (Select the 50' section by method discussed in the specification).
- Profile a section each time the screed stops, including end of day.
- Profiles must be at least 2 ft from joints and edges
- First reading of each profile must be 10 ft behind the screed.
- Minimum of 4 density profiles per mix per project must be performed by the contractor.

Roller - DYNAPAC

Density Profile Plot

On location Very Segregated



TXDOT
Construction Division
Data Collection Form
July 1999

START 2:15 pm.
FINISH 3:15 pm

Nuclear Density Profile Form

Asphaltic Concrete Pavement

476 T(1I) 4FV FIN LANE

District: 24	CSJ: 2121-05-039	Location Information for 1st Reading
County: El Paso	Profile No.: 2	Station: 163+00
Highway: IH Tornillo	Test Date: 10-20-99	Lane Direction:* NB SB (EB) WB
Tested By: TxDOT ☑	Contractor: Dan Williams	Lane: Inside (ML) FR 1 2 (3) 4
Contractor ☐	Mix Type: A	Distance From Inside
Tester: Rendon/Grado	Spec. Item: 3022	Edge of Lane or Joint (ft): 11½
Brand and Model of Paver: Barber Greene	Visible Segregation: Yes ☑ No ☐	Lift: (1st) 2nd 3rd
		Lift Thickness: 1-3"

Describe Type of Remix Equipment Used In or Ahead of Paver: Lincoln BBO-APN Pugmail

	#	Feet from Prev. Read.	Readings (lbs/cf)			Avg.
136.1	1	0.0	144.1	143.8	144.0	143.9
130.3	2	0	136.3	137.6	137.0	136.?
130.4	3	5	135.2	135.9	137.1	136.1
126.6	4	5	135.7	134.9	135.2	135.3
134.0	5	5	137.1	137.9	137.0	137.3
128.4	6	5	134.4	135.0	135.2	134.9
133.1	7	5	139.4	139.8	139.6	139.6
137.0	8	5	141.2	141.6	141.0	141.3
141.6	9	10	144.0	143.5	144.7	144.1
138.2	10	10	140.2	141.4	141.1	140.9
	11					
	12					
	13					
	14					
	15					
	16					
	17					
	18					
			Total			139.0

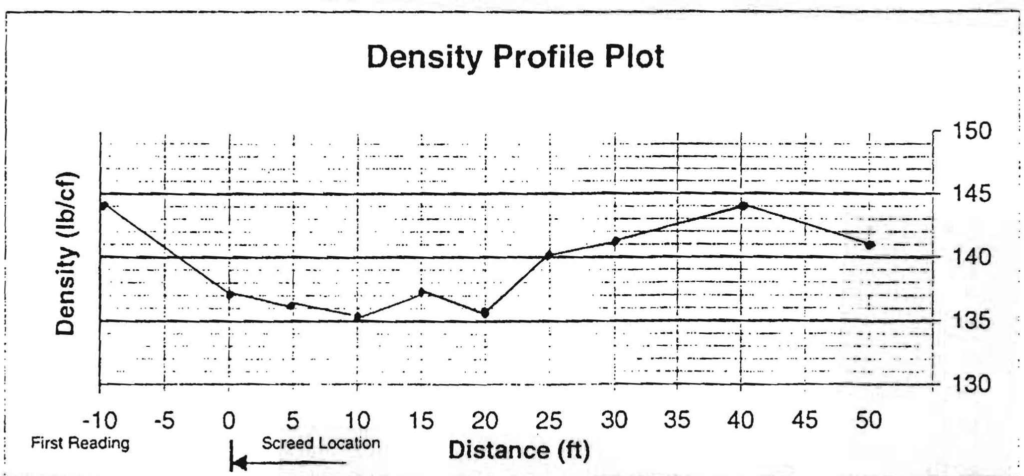
Average Reading	139.0
High Reading	143.9
Low Reading	134.9

Max Density Ranges:

High - Low	9.0	[Max allowable = 6.0 lbs/cf]
Average - Low	4.1	[Max allowable = 3.0 lbs/cf]

Notes:

* NB = North Bound, ML = Main Lane, FR = Frontage Road
  Lanes numbered from centerline of facility (e.g. 1 = inside lane)
- Use a separate form for each density profile.
- A density profile is a series of density readings taken longitudinally approximately every 5 lf in a 50' section.
- Profile one 50' section after the first 1000 feet of project placement (Select the 50' section by method discussed in the specification).
- Profile a section each time the screed stops, including end of day.
- Profiles must be at least 2 ft from joints and edges
- First reading of each profile must be 10 ft behind the screed.
- Minimum of 4 density profiles per mix per project must be performed by the contractor.



TXDOT
Construction Division
Data Collection Form
July 1999

✓

START 3:34 pm
FINISH 4:40 pm

Nuclear Density Profile Form

Asphaltic Concrete Pavement

ON ✓ — 476 T(/N) LIFT — FLAT LANE

District: 24	CSJ: 2121-5-39	Location Information for 1st Reading
County: El Paso	Profile No.: 3	Station: 170+00
Highway: IH 10 (loop 400)	Test Date: 10-20-99	Lane Direction:* NB SB (EB) WB
Tested By: TxDOT ☑	Contractor: DAN WILLIAMS	Lane:* MIDDLE (ML) FR 1 2 3 4
Contractor ☐	Mix Type: A	Distance From Inside
Tester: PEDMN / GRADO	Spec. Item: 3022	Edge of Lane or Joint (ft): 9'
Brand and Model of Paver: BARBER GREENE	Visible Segregation: Yes ☑	Lift: 1st 2nd 3rd
	No ☐	Lift Thickness: 1-3

w/6 SAND

Describe Type of Remix Equipment Used In or Ahead of Paver: LINCOLN BBQ. HYD PUG MILL) AUGER 7 NC 44

	#	Feet from Prev. Read.	Readings (lbs/cf)			Avg.
137.6	1	10.0	140.4	140.4	140.0	140.3
138.7	2	0	142.7	142.5	142.9	142.7
138.6	3	5	139.8	139.9	139.9	139.9
140.8	4	5	143.5	142.9	143.8	143.4
140.9	5	5	142.4	143.0	142.1	142.5
140.7	6	5	142.3	142.3	142.1	142.2
139.0	7	5	142.5	143.4	143.0	142.9
141.7	8	5	144.6	143.2	144.4	144.1
138.8	9	10	146.5	145.6	145.8	145.9
146.8	10	10	148.5	148.1	148.4	148.3
	11					
	12					
	13					
	14					
	15					
	16					
	17					
	18					
					Total	143.2

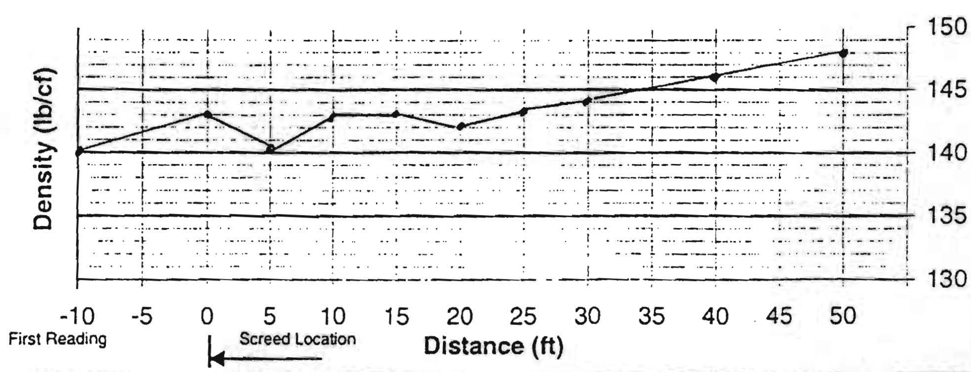
Average Reading	143.2
High Reading	148.3
Low Reading	139.9

Max Density Ranges:		
High - Low	8.4	[Max allowable = 6.0 lbs/cf]
Average - Low	3.3	[Max allowable = 3.0 lbs/cf]

Notes:

* NB = North Bound, ML = Main Lane, FR = Frontage Road
  Lanes numbered from centerline of facility (e.g. 1 = inside lane)
- Use a separate form for each density profile.
- A density profile is a series of density readings taken longitudinally approximately every 5 lf in a 50' section.
- Profile one 50' section after the first 1000 feet of project placement (Select the 50' section by method discussed in the specification).
- Profile a section each time the screed stops, including end of day.
- Profiles must be at least 2 ft from joints and edges
- First reading of each profile must be 10 ft behind the screed.
- Minimum of 4 density profiles per mix per project must be performed by the contractor.

Density Profile Plot



TXDOT
Construction Division
Data Collection Form
July 1999

START 9:45 A.M.
FINISH 11:00 A.M.

Nuclear Density Profile Form

Asphaltic Concrete Pavement

476 TXIN W/F

District: 24	CSJ: 2121-5-34	**Location Information for 1st Reading**
County: El Paso	Profile No.: 18	Station: 185+00
Highway: IH TRANSIT	Test Date: 10-21-99	Lane Direction:* NB SB (EB) WB
Tested By: TxDOT ☑	Contractor: JOD WILLIAMS	Lane:* RT OUTSIDE (ML) FR 1 2 (3) 4
Contractor ☐	Mix Type: A	Distance From Inside
Tester: RENDON / GRADO	Spec. Item: 2022	Edge of Lane or Joint (ft): 5'
Brand and Model of Paver: BARBER GREENE	Visible Segregation: Yes ☑ No ☐	Lift: (1st) 2nd 3rd
		Lift Thickness: 1-3"

Describe Type of Remix Equipment Used In or Ahead of Paver: LINCOLN BBD-VMW PUGMAIL AUGER INC 46

		Feet from Prev. Read.	Readings (lbs/cf)			Avg.
141.6	1	0.0	143.3	143.1	144.0	143.5
144.4	2	0	144.1	146.3	145.3	145.1
141.6	3	5 5	144.9	145.5	145.5	145.3
145.3	4	5	141.3	142.4	141.5	141.7
141.9	5	5 15	140.9	140.1	141.1	140.7
140.6	6	5	140.8	143.3	141.5	141.2
138.5	7	5	141.5	142.6	142.4	142.2
143.2	8	5	137.4	137.4	137.6	137.5
137.7	9	10 40	133.4	133.6	133.8	133.6
130.0	10	10	134.2	135.1	135.3	134.9
	11					
	12					
	13					
	14					
	15					
	16					
	17					
	18				Avg.	
				Total		140.6

Average Reading	140.6
High Reading	145.3
Low Reading	133.6

Max Density Ranges:		
High - Low	11.7	[Max allowable = 6.0 lbs/cf]
Average - Low	7.0	[Max allowable = 3.0 lbs/cf]

Notes:
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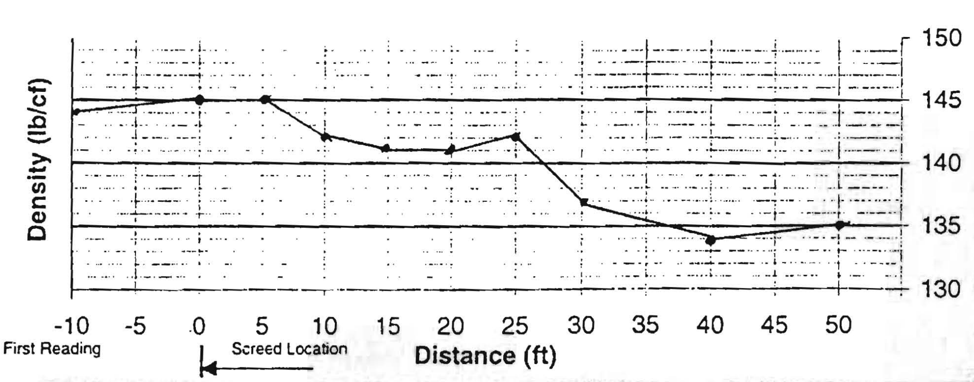
- Use a separate form for each density profile.
- A density profile is a series of density readings taken longitudinally approximately every 5 lf in a 50' section.
- Profile one 50' section after the first 1000 feet of project placement (Select the 50' section by method discussed in the specification).
- Profile a section each time the screed stops, including end of day.
- Profiles must be at least 2 ft from joints and edges
- First reading of each profile must be 10 ft behind the screed.
- Minimum of 4 density profiles per mix per project must be performed by the contractor.

9 FT OFFSET LT
TRAF ONLY 114.1

Density Profile Plot



TXDOT
Construction Division
Data Collection Form
July 1999

START 9:13 a.m.
FINISH 9:26

Nuclear Density Profile Form

Asphaltic Concrete Pavement

OUTSIDE [illegible] LANE

District: 24	CSJ: 2121-5-37	Location Information for 1st Reading
County: El Paso	Profile No.: [illegible]	Station: 181+00
Highway: IH 10 [illegible]	Test Date: 10-21-99	Lane Direction:* NB SB EB WB
Tested By: TxDOT ☑	Contractor: [illegible]	Lane:* Outside ML FR 1 2 3 4
Contractor ☐	Mix Type: A	Distance From Inside
Tester: [illegible]	Spec. Item: 3022	Edge of Lane or Joint (ft): 6
Brand and Model of Paver: BARBER GREENE	Visible Segregation: Yes ☐ No ☐	Lift: 1st 2nd 3rd
		Lift Thickness: 1.5"
Describe Type of Remix Equipment Used In or Ahead of Paver: [illegible] BBO- [illegible] AUGER [illegible]		

		Feet from Prev. Read.	Readings (lbs/cf)			Avg.
144.3	1	10.0	143.7	143.5	143.0	143.4
141.4	2	5	140.9	141.5	141.0	141.1
140.1	3	5	143.8	142.3	142.3	143.5
[illegible]	4	5	141.7	141.3	141.4	141.6
142.7	5	5 15	144.2	143.8	[illegible]	144.4
[illegible]	6	5	143.5	144.5	[illegible]	[illegible]
140.7	7	5	141.2	140.7	141.0	141.0
141.0	8	5	[illegible]	142.4	[illegible]	[illegible]
[illegible]	9	10 40	[illegible]	[illegible]	[illegible]	139.2
[illegible]	10	10 50	144.1	144.1	143.9	144.0
	11					
	12					
	13					
	14					
	15					
	16					
	17					
	18					
			Total			1425

Average Reading	142.5
High Reading	144.4
Low Reading	139.2

Max Density Ranges:

High - Low	5.2	[Max allowable = 6.0 lbs/cf]
Average - Low	3.3	[Max allowable = 3.0 lbs/cf]

Notes:

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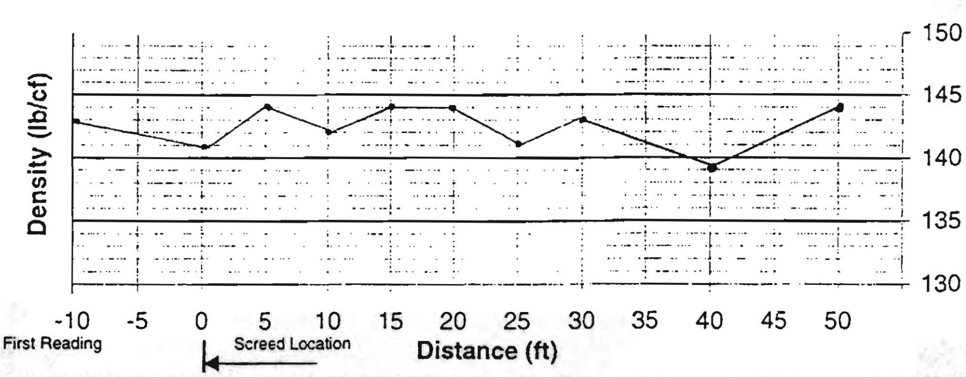
- Lanes numbered from centerline of facility (e.g. 1 = inside lane)
- Use a separate form for each density profile.
- A density profile is a series of density readings taken longitudinally approximately every 5 lf in a 50' section.
- Profile one 50' section after the first 1000 feet of project placement (Select the 50' section by method discussed in the specification).
- Profile a section each time the screed stops, including end of day.
- Profiles must be at least 2 ft from joints and edges
- First reading of each profile must be 10 ft behind the screed.
- Minimum of 4 density profiles per mix per project must be performed by the contractor.

Density Profile Plot



TXDOT
Construction Division
Data Collection Form
July 1999

Nuclear Density Profile Form

Asphaltic Concrete Pavement

District: 24	CSJ: 2121-05-03	Location Information for 1st Reading
County: El Paso	Profile No.:	Station: 194+00
Highway: I-10	Test Date: 10-21-99	Lane Direction:* NB SB (EB) WB
Tested By: TxDOT [x]	Contractor:	Lane:* Outside ML FR 1 2 (3) 4
Contractor [ ]	Mix Type: A	Distance From Inside
Tester:	Spec. Item: 2022	Edge of Lane or Joint (ft): 6 Ft.
Brand and Model of Paver: BARBER GREENE	Visible Segregation: Yes [x] No [ ]	Lift: (1st) 2nd 3rd; Lift Thickness: 1-3/4

Describe Type of Remix Equipment Used In or Ahead of Paver:

	Feet from Prev. Read.	Readings (lbs/cf)			Avg.
1	10	143.4	142.3	143.1	142.9
2	0	143.6	143.4	142.7	143.2
3	5	142.0	143.6	142.5	142.7
4	5	141.4	140.5	141.3	141.1
5	5	141.8	142.0	141.2	141.7
6	5	141.2	141.3	142.0	141.6
7	5	140.5	140.4	139.5	140.1
8	5	142.3	141.9	142.3	142.2
9	10	141.3	141.7	141.2	141.4
10	10	138.2	139.6	139.1	139.0
11					
12					
13					
14					
15					
16					
17					
18					
		Total			

Average Reading	141.5
High Reading	142.9
Low Reading	139.0

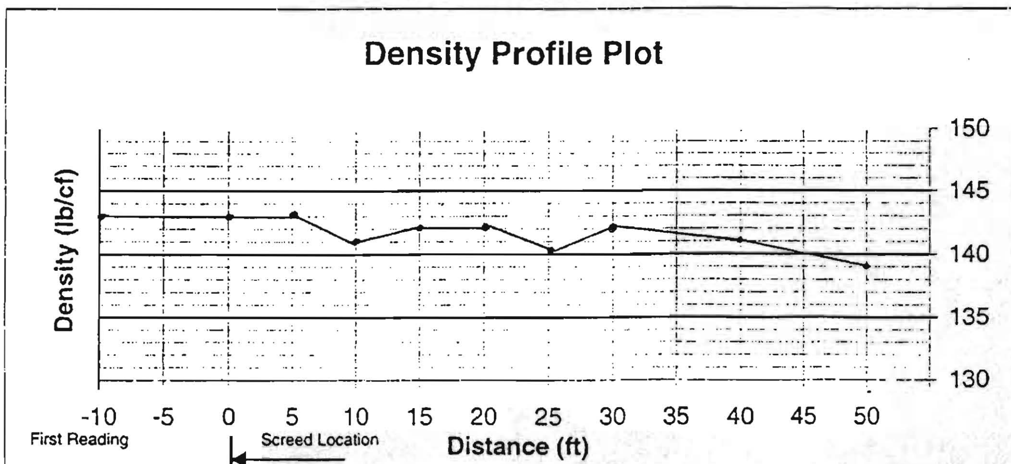
start 8:00
end

Max Density Ranges:		
High - Low	3.9	[Max allowable = 6.0 lbs/cf]
Average - Low	2.5	[Max allowable = 3.0 lbs/cf]

Notes:

* NB = North Bound, ML = Main Lane, FR = Frontage Road
Lanes numbered from centerline of facility (e.g. 1 = inside lane)

- Use a separate form for each density profile.
- A density profile is a series of density readings taken longitudinally approximately every 5 lf in a 50' section.
- Profile one 50' section after the first 1000 feet of project placement (Select the 50' section by method discussed in the specification).
- Profile a section each time the screed stops, including end of day.
- Profiles must be at least 2 ft from joints and edges
- First reading of each profile must be 10 ft behind the screed.
- Minimum of 4 density profiles per mix per project must be performed by the contractor.



TXDOT
Construction Division
Data Collection Form
July 1999

START 10:30 A.M.
FINISH 11:18 AM
4,4,2 ROLLING PATTERN

outside lane
moved away from traffic 4/6 THIN LIFT

Nuclear Density Profile Form

Asphaltic Concrete Pavement

District: 24	CSJ: 2121-05-39	Location Information for 1st Reading
County: El Paso	Profile No.: 1	Station: 184+00
Highway: IH TORNILLO	Test Date: 10-19-99	Lane Direction:* NB SB EB WB
Tested By: TxDOT ☑	Contractor: DAN WILLIAMS	Lane:* OUTSIDE ML FR 1 2 3 4
Contractor ☐	Mix Type: A	Distance From Inside
Tester: REDDON / GRADO	Spec. Item: 3022	Edge of Lane or Joint (ft): 3 1/2
Brand and Model of Paver: Barber Greene	Visible Segregation: Yes ☑ No ☐	Lift: 1st 2nd 3rd
		Lift Thickness: 1-3"

Describe Type of Remix Equipment Used In or Ahead of Paver: Roadtec

	Feet from Prev. Read.	Readings (lbs/cf)			Avg.
1	10.0	146.6	147.2	147.5	147.1
2	0	146.3	146.5	146.5	146.4
3	5	147.5	147.1	147.6	147.4
4	5	146.1	145.2	146.4	145.9
5	5	149.6	148.4	149.0	149.0
6	5	146.3	147.0	146.5	146.6
7	5	149.1	149.3	149.8	149.4
8	5	148.8	148.1	149.0	148.6
9	10	147.0	147.0	146.6	146.8
10	10	145.8	146.3	146.6	146.2
11					
12					
13					
14					
15					
16					
17					
18					
			Total		147.3

Average Reading	147.3
High Reading	149.4
Low Reading	145.9

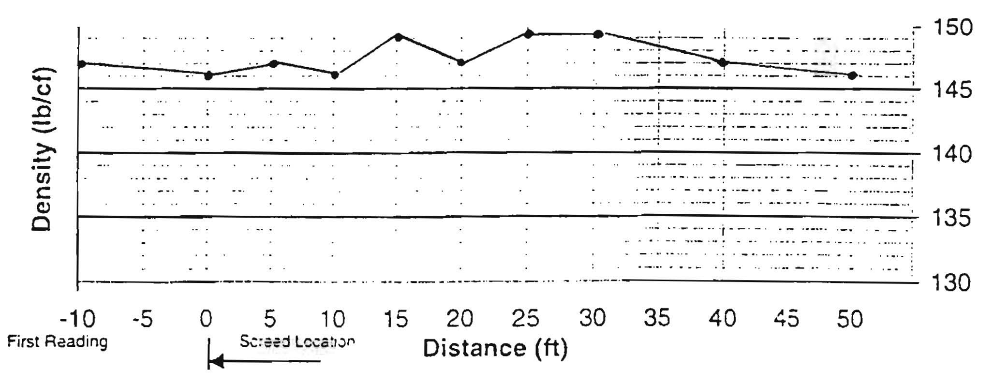
Max Density Ranges:

High - Low	3.5	[Max allowable = 6.0 lbs/cf]
Average - Low	1.4	[Max allowable = 3.0 lbs/cf]

Notes:
* NB = North Bound, ML = Main Lane, FR = Frontage Road
  Lanes numbered from centerline of facility (e.g. 1 = inside lane)
- Use a separate form for each density profile.
- A density profile is a series of density readings taken longitudinally approximately every 5 lf in a 50' section.
- Profile one 50' section after the first 1000 feet of project placement (Select the 50' section by method discussed in the specification).
- Profile a section each time the screed stops, including end of day.
- Profiles must be at least 2 ft from joints and edges
- First reading of each profile must be 10 ft behind the screed.
- Minimum of 4 density profiles per mix per project must be performed by the contractor.

140.3 STA 184+20
-40 145.5

Density Profile Plot



TXDOT
Construction Division
Data Collection Form
July 1999

START 12:00 P.
FINISH 12:52 PM

Nuclear Density Profile Form

Asphaltic Concrete Pavement

476 TWIN LIFT

District: 24	CSJ: 2121-05-039	Location Information for 1st Reading
County: El Paso	Profile No.: 2	Station: 189+00
Highway: TX Tornillo	Test Date: 10-19-99	Lane Direction:* NB SB (EB) WB
Tested By: TxDOT ☑	Contractor: Dan Williams	Lane: Outside (ML) FR (1) 2 3 4
Contractor ☐	Mix Type: A	Distance From Inside
Tester: Rendon/Grado	Spec. Item: 3022	Edge of Lane or Joint (ft): 3 1/2
Brand and Model of Paver: Barber Greene	Visible Segregation: Yes ☑ No ☐	Lift: (1st) 2nd 3rd
		Lift Thickness: 2"

Describe Type of Remix Equipment Used In or Ahead of Paver: ROADTEC

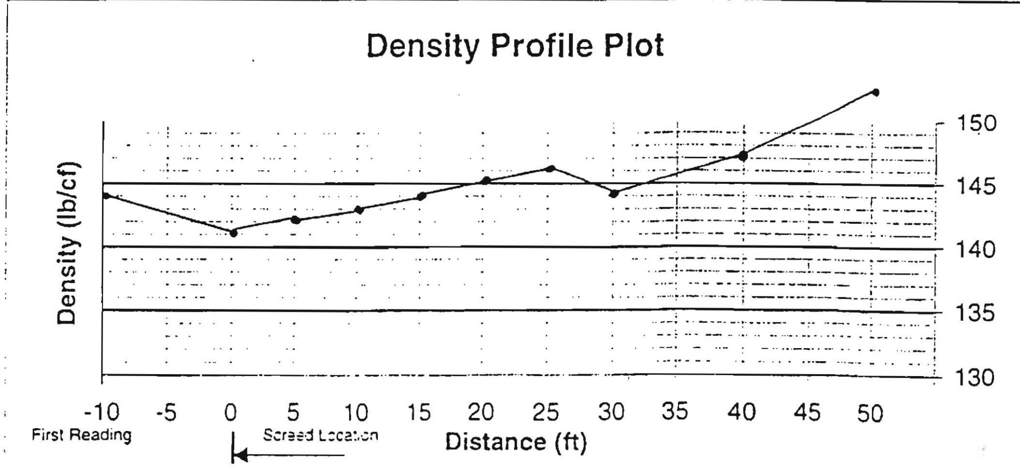
	Feet from Prev. Read.	Readings (lbs/cf)			Avg.
1	10.0	144.3	145.8	143.9	144.2
2	0	141.8	141.8	141.3	141.4
3	5	142.7	142.3	142.8	142.4
4	5	142.2	142.4	143.0	142.5
5	5	144.0	143.2	143.6	143.6
6	5	144.3	144.5	144.8	144.5
7	5	145.1	146.0	145.3	145.5
8	5	144.0	144.3	144.5	144.3
9	10	147.2	147.0	142.6	147.3
10	10	152.7	151.5	151.5	151.9
11					
12					
13					
14					
15					
16					
17					
18					
		Total			144.7

Average Reading	144.7
High Reading	151.9
Low Reading	141.4

Max Density Ranges:

High - Low	10.5	[Max allowable = 6.0 lbs/cf]
Average - Low	3.3	[Max allowable = 3.0 lbs/cf]

Notes:
* NB = North Bound, ML = Main Lane, FR = Frontage Road
  Lanes numbered from centerline of facility (e.g. 1 = inside lane)
- Use a separate form for each density profile.
- A density profile is a series of density readings taken longitudinally approximately every 5 lf in a 50' section.
- Profile one 50' section after the first 1000 feet of project placement (Select the 50' section by method discussed in the specification).
- Profile a section each time the screed stops, including end of day.
- Profiles must be at least 2 ft from joints and edges
- First reading of each profile must be 10 ft behind the screed.
- Minimum of 4 density profiles per mix per project must be performed by the contractor.



TXDOT
Construction Division
Data Collection Form
July 1999

Nuclear Density Profile Form

Asphaltic Concrete Pavement

District: 24	CSJ: 2121-05-037	Location Information for 1st Reading
County: El Paso	Profile No.: 3	Station: 304+00
Highway: IH – Tornillo	Test Date: 10-19-99	Lane Direction:* NB SB (EB) WB
Tested By: TxDOT ☑	Contractor: Dan Williams	Lane:* Inside — ML FR (1) 2 3 4
Contractor ☐	Mix Type: A	Distance From Inside
Tester: Grado / Kendon	Spec. Item: 3022	Edge of Lane or Joint (ft): 3 1/2"
Brand and Model of Paver: BG Barber Green 260C	Visible Segregation: Yes ☑ No ☐	Lift: (1st) 2nd 3rd Lift Thickness: 3

Describe Type of Remix Equipment Used In or Ahead of Paver: 25 Ton Capacity Road Tec SB 2500B C2 mixing hopper w/ triple pitch anti segregation auger

	Feet from Prev. Read.	Readings (lbs/cf)			Avg.
1	10.0	144.2	144.8	144.7	144.6
2	0	146.1	146.5	145.9	146.2
3	5	143.7	144.4	144.4	144.2
4	5	143.8	142.9	143.7	143.5
5	5	142.5	143.0	142.3	142.6
6	5	146.9	147.5	146.5	146.9
7	5	141.6	141.5	142.1	141.7
8	5	142.3	146.9	141.6	141.6
9	10	144.0	143.3	143.7	143.7
10	10	141.2	141.1	141.6	141.3
11					
12					
13					
14					
15					
16					
17					
18					
		Total			143.6

Average Reading	143.6
High Reading	146.9
Low Reading	141.3

Max Density Ranges:

High - Low	5.6	[Max allowable = 6.0 lbs/cf]
Average - Low	2.3	[Max allowable = 3.0 lbs/cf]

Notes:

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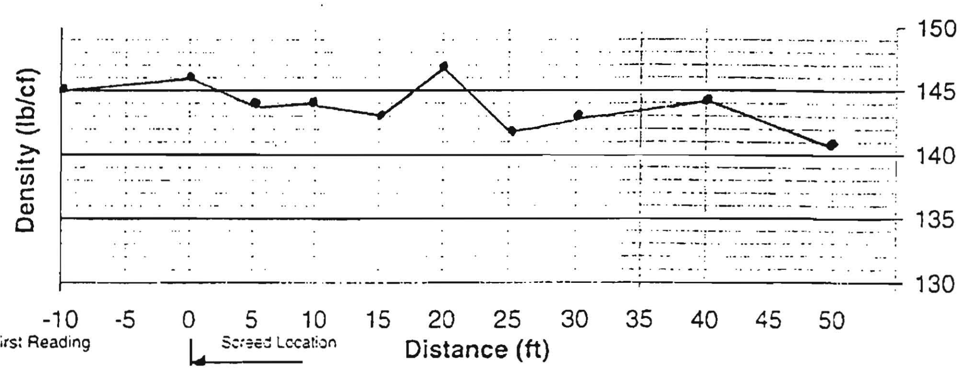
  Lanes numbered from centerline of facility (e.g. 1 = inside lane)
- Use a separate form for each density profile.
- A density profile is a series of density readings taken longitudinally approximately every 5 lf in a 50' section.
- Profile one 50' section after the first 1000 feet of project placement (Select the 50' section by method discussed in the specification).
- Profile a section each time the screed stops, including end of day.
- Profiles must be at least 2 ft from joints and edges
- First reading of each profile must be 10 ft behind the screed.
- Minimum of 4 density profiles per mix per project must be performed by the contractor.

Density Profile Plot



TXDOT
Construction Division
Data Collection Form
July 1999

Nuclear Density Profile Form

Asphaltic Concrete Pavement

District: 24	CSJ: 2121-5-39	Location Information for 1st Reading
County: El Paso	Profile No.:	Station: 167+00
Highway: FM TORNILLO	Test Date: 10-20-98	Lane Direction:* NB SB EB WB
Tested By: TxDOT ☑	Contractor: DAN WILLIAMS	Lane:* MIDDLE PASSING (ML) FR 1 (2) 3 4
Contractor ☐	Mix Type: A	Distance From Inside
Tester: ZUNIGA/ NESTOR	Spec. Item: 3022	Edge of Lane or Joint (ft): 21'
Brand and Model of Paver: BarberGreene	Visible Segregation: Yes ☐ No ☑	Lift: 1st 2nd 3rd
		Lift Thickness: 1-3"

Describe Type of Remix Equipment Used In or Ahead of Paver: [illegible]

	#	Feet from Prev. Read.	Readings (lbs/cf)			Avg.
134.4	1	10.0	142.9	143.2	142.2	142.7
138.8	2	0	141.7	141.8	142.5	142.0
138.0	3	5	144.5	144.7	143.5	144.2
140.6	4	5	141.5	142.3	142.1	142.0
137.3	5	5	141.0	140.1	140.6	140.6
141.7	6	5	141.6	141.8	142.3	141.9
139.2	7	5	141.9	142.4	143.2	142.5
133.5	8	5	137.6	137.6	137.4	137.5
138.2	9	10	139.6	138.0	139.2	138.9
135.5	10	10	140.6	140.6	140.7	140.6
	11					
	12					
	13					
	14					
	15					
	16					
	17					
	18					
			Total			141.3

Average Reading	141.3
High Reading	144.2
Low Reading	137.5

Max Density Ranges:		
High - Low	6.7	[Max allowable = 6.0 lbs/cf]
Average - Low	3.8	[Max allowable = 3.0 lbs/cf]

Notes:

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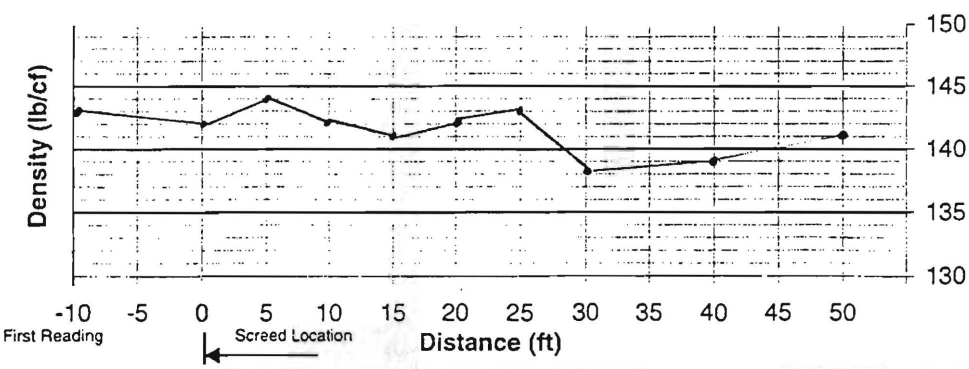
  Lanes numbered from centerline of facility (e.g. 1 = inside lane)
- Use a separate form for each density profile.
- A density profile is a series of density readings taken longitudinally approximately every 5 lf in a 50' section.
- Profile one 50' section after the first 1000 feet of project placement (Select the 50' section by method discussed in the specification).
- Profile a section each time the screed stops, including end of day.
- Profiles must be at least 2 ft from joints and edges
- First reading of each profile must be 10 ft behind the screed.
- Minimum of 4 density profiles per mix per project must be performed by the contractor.

Density Profile Plot



TXDOT
Construction Division
Data Collection Form
July 1999

Nuclear Density Profile Form

Asphaltic Concrete Pavement

District: 24	CSJ: 2121-5-39	Location Information for 1st Reading	
County: El Paso	Profile No.:	Station: 182+00	
Highway: FM Tornillo	Test Date: 10-20-99	Lane Direction:* NB SB EB WB	
Tested By: TxDOT ☑ Contractor ☐	Contractor: Dan Williams	Lane:* Middle	(ML) FR 1 (2) 3 4
	Mix Type: A	Distance From Inside	
Tester: Zuniga / Nestor	Spec. Item: 302.2	Edge of Lane or Joint (ft): 21' Inside	
Brand and Model of Paver: Barber Greene	Visible Segregation: Very — Yes ☑ No ☐	Lift: (1st) 2nd 3rd	
		Lift Thickness: 1-3"	

Describe Type of Remix Equipment Used In/or Ahead of Paver: Roadtec

W/O SAND

		Feet from Prev. Read.	Readings (lbs/cf)			Avg.
135.2	1	0.0	141.3	140.5	141.3	141.0
142.1	2	0	141.9	141.5	141.3	141.6
129.1	3	5	135.4	135.8	135.9	135.7
122.9	4	5	133.8	134.5	134.8	134.4
126.0	5	5	135.8	135.7	135.5	135.7
131.5	6	5	137.9	138.5	137.8	138.1
139.1	7	5	141.6	142.7	142.8	142.4
144.4	8	5	144.5	144.1	144.6	144.4
135.0	9	10	141.0	141.7	141.6	141.4
128.4	10	10	133.6	134.3	134.4	134.1
	11					
	12					
	13					
	14					
	15					
	16					
	17					
	18					
					Total	138.9

Average Reading	138.9
High Reading	144.4
Low Reading	134.1

Max Density Ranges:

2nd High - Low	10.3	[Max allowable = 6.0 lbs/cf]
2nd Average - Low	4.8	[Max allowable = 3.0 lbs/cf]

Notes:

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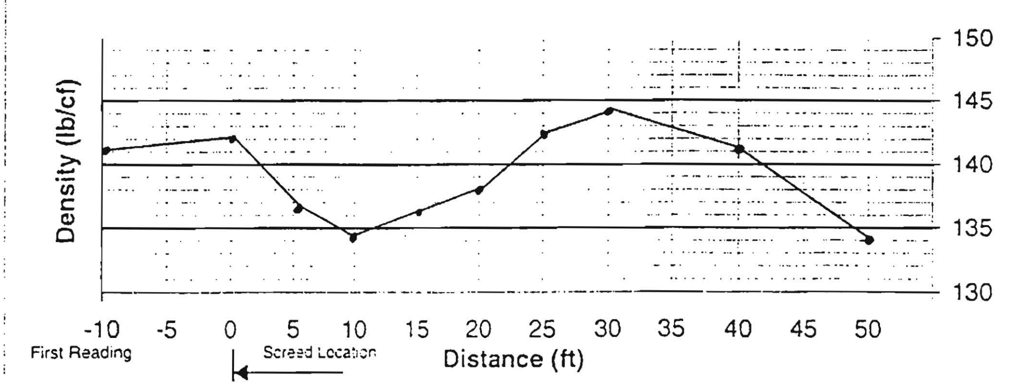
  Lanes numbered from centerline of facility (e.g. 1 = inside lane)
- Use a separate form for each density profile.
- A density profile is a series of density readings taken longitudinally approximately every 5 lf in a 50' section.
- Profile one 50' section after the first 1000 feet of project placement (Select the 50' section by method discussed in the specification).
- Profile a section each time the screed stops, including end of day.
- Profiles must be at least 2 ft from joints and edges
- First reading of each profile must be 10 ft behind the screed.
- Minimum of 4 density profiles per mix per project must be performed by the contractor.

Density Profile Plot



TXDOT
Construction Division
Data Collection Form
July 1999

Nuclear Density Profile Form

Asphaltic Concrete Pavement

District: 24	CSJ: 2121-05-039	Location Information for 1st Reading
County: El Paso	Profile No.:	Station: 186+50
Highway: IH 10	Test Date: 10-20-99	Lane Direction:* NB SB EB WB
Tested By: TxDOT ☑	Contractor: Dan Williams	Lane:* Middle / (ML) FR / 1 (2) 3 4
Contractor ☐	Mix Type: A	Distance From Inside
Tester: Zuniga / Nestor	Spec. Item: 3022	Edge of Lane or Joint (ft): 23 Inside
Brand and Model of Paver: Barber Greene	Visible Segregation: Yes ☑ No ☐	Lift: (1st) 2nd 3rd
		Lift Thickness: 1-3"

Describe Type of Remix Equipment Used In or Ahead of Paver: Roadtec

		Feet from Prev. Read.	Readings (lbs/cf)			Avg.
139.7	1	-0.0	145.8	145.1	146.8	145.9
138.1	2	0	145.0	146.1	144.9	145.3
131.5	3	5	141.9	141.9	143.3	142.3
122.4	4	5	135.6	135.2	135.3	135.4
133.3	5	5	139.8	140.8	140.4	140.3
143.1	6	5	142.4	149.4	143.4	143.1
141.7	7	5	140.3	140.2	141.1	140.5
141.6	8	5	144.7	144.9	144.9	144.8
144.2	9	10	142.6	142.0	143.0	142.5
141.3	10	10	143.8	144.3	143.8	144.0
	11					
	12					
	13					
	14					
	15					
	16					
	17					
	18					
			Total			142.4

Average Reading	142.4
High Reading	145.9
Low Reading	135.4

Max Density Ranges:

High - Low	10.5	[Max allowable = 6.0 lbs/cf]
Average - Low	7	[Max allowable = 3.0 lbs/cf]

Notes:

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 Lanes numbered from centerline of facility (e.g. 1 = inside lane)
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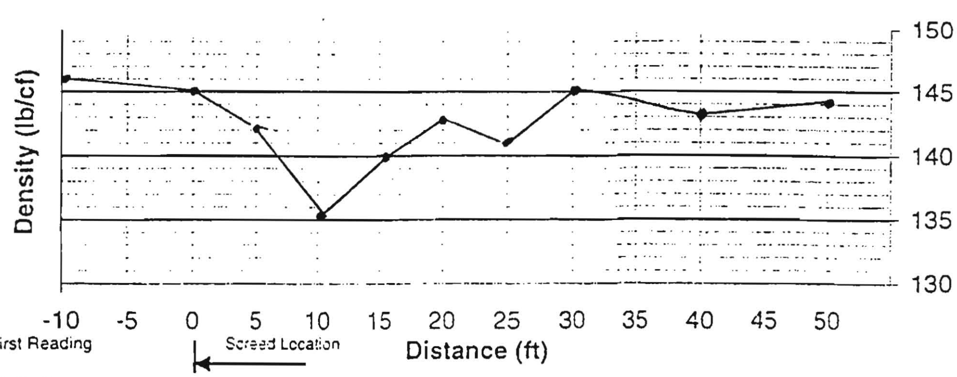
- A density profile is a series of density readings taken longitudinally approximately every 5 lf in a 50' section.
- Profile one 50' section after the first 1000 feet of project placement (Select the 50' section by method discussed in the specification).
- Profile a section each time the screed stops, including end of day.
- Profiles must be at least 2 ft from joints and edges
- First reading of each profile must be 10 ft behind the screed.
- Minimum of 4 density profiles per mix per project must be performed by the contractor.

Density Profile Plot



APPENDIX – B

THERMAL IMAGES BY MANUFACTURERS

Notes About Attachments:

Attached as an enclosure to this summary, analysis pages can be found for each of the figures included in this report. Each analysis page contains the figure in the report referenced by the specific figure number. On each thermal image there are three lines of analysis (LI01, LI02, and LI03) and a single spot (SP01). In a table below the image there is a summary of each line with its max, min, average, and cursor temperatures. The cursor temperature is simply the temperature at the location along the line where the hash mark crosses the line. **A very important point of interest is the fact that for all of the images a single temperature differential of 140F was used. Though the max and mins might vary between images, the 140F ΔT is constant throughout. The varying max and mins is a function of the fact the temperature of the mix coming from the plant varied from one day to the next and often from one hour to the next. By utilizing the 140F differential, this allows the observer to see how the color variances correspond to every other image in the report.** Listed below and on the following page, is a summary of each image in the report and what is of particular interest in that image.

Barber Greene Images:

BG-Fig 1	Clear indication of a truck exchange/end of load. Notice the >30F DT along LI01.
BG-Fig 2	Indication of a truck exchange/end of load. As before, notice >25F DT along LI02.
BG-Fig 3	Indication of longitudinal streaking. Notice that this streak introduced a mat temperature differential of >20F along LI02.
BG-Fig 4	Example of isolated cold spots which randomly appeared from this equipment arrangement. Observe >50F DT along LI02. Small blue area on the far right hand side of the image is caused by compactor path.
BG-Fig 5	Example of the Barber-Greene arrangement laying a fairly consistent mat. Observe <20F DT along lines LI01, LI02 and LI03.

BG-Fig 6	This image illustrates the effects of having to start and stop the paving process. The waiting period between trucks for this image was nearly 11 minutes. Notice there is no less than a 74F differential along each of the lines of analysis.

<u>Roadtec Images:</u>

SB-Fig 1	Clear example of end of load. Notice that there is a 30F DT along LI01, and nearly a 20F DT along LI02.
SB-Fig 2	Longitudinal streaking in mat which exhibits a 40F DT along LI01.
SB-Fig 3	Cold spot in middle of mat laid by paver utilizing the Roadtec SB-2500B. Notice >25F DT along each line of analysis.
SB-Fig 4	Image which illustrates effects of starting and stopping while paving. Lower blue region of image has been sitting for about 8 minutes. Notice large cold slug of material in middle of mat which was allowed to cool while waiting.
SB-Fig 5	Image of mat with wide variety of temperature damage. There appears to be no set pattern to differences.
SB-Fig 6	Image of good mat laid while paving at low speeds and a width of 12 ft.
SB-Fig 7	Image of good mat laid while paving at higher speeds and at a width of 15 ft. Notice that compared to SB-Fig 6, this mat does not look as consistent with respect to minimizing temperature variance.

<u>Lincoln Images:</u>

LN-Fig 1	Obvious indication of truck exchange/end of load. Notice >40F DT along LI01.
LN-Fig 2	Gross indication of end of load. This image illustrates a dramatic example of how a difference in truck temperatures can be conveyed into the mat.
LN-Fig 3	Longitudinal streaking in center of mat. A >30F DT along LI01.
LN-Fig 4	Cold spot in mat that follows the pulling off of a joint. A >60F DT along LI03.
LN-Fig 5	Effects of stopping and starting during paving process.
LN-Fig 6	Best image of temperature consistent mat for this arrangement. Notice still a >20F DT along two of the three lines of analysis.

<u>Cedarapids Images:</u>

CR-Fig 1	Glaringly obvious indication of end of load. Notice >40F DT between average temperature along LI01 and LI02.
CR-Fig 2	Indication of end of load. Nearly 30F DT along LI02.
CR-Fig 3	Effects of stopping and starting paving process. This image illustrates effects of a 6 minute wait.
CR-Fig 4	Example of longitudinal streaking which was often encountered behind this arrangement.
CR-Fig 5	Another example of longitudinal streaking. In both cases there appeared not to be a set pattern the streaking was not more favored on one side of the other, nor was the streaking of any sort of uniform width.

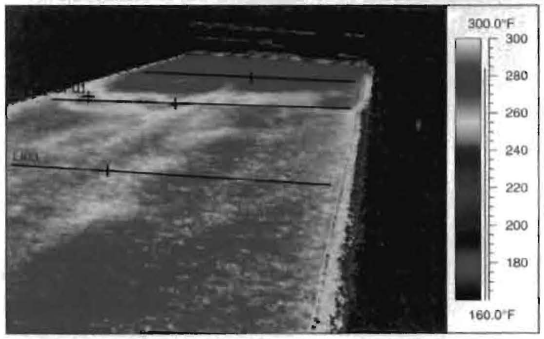
CR-Fig 6	Large random cold spot in mat which did not appear to be caused by end of load.
CR-Fig 7	Example of one of the better sections of mat from the Cedarapids combination. Notice <30F DT along all three lines of analysis.
CR-Fig 8	Another example of a good stretch of mat.

Blaw-Knox Images:

BK-Fig 1	Clearly visible occurrence of end of load while paving the first lane at higher paving speeds and with pug mills not operating properly. Nearly a 30F DT along LI01.
BK-Fig 2	Another indication of end of load. Notice >20F DT along LI01.
BK-Fig 3	Cold spot in mat which occurred when pulling off from a joint. This is consistent with all other machines which had difficulty laying a mat of even temperature when pulling of from a new joint.
BK-Fig 4	Example of longitudinal streaking in mat. Streaking was a for a short duration and did not introduce temperature variances as large as some seen earlier in the week.
BK-Fig 5	Example of Blaw-Knox MC-330 combination laying a mat of even temperature distribution while paving first lane at higher speeds.
BK-Fig 6	Example of Blaw-Knox MC-330 combination laying a mat of even temperature distribution while paving first lane at higher speeds.
BK-Fig 7	Example of Blaw-Knox MC-330 combination laying a mat of even temperature distribution while paving second lane at slower speeds.
BK-Fig 8	Example of Blaw-Knox MC-330 combination laying a mat of even temperature distribution while paving second lane at slower speeds. Notice more temperature distribution when paving at slower speeds and with properly functioning pug mills.

RWB
11/4/99

El Paso, TX: Barber-Greene 260C with a BG-650 Pick Up Machine



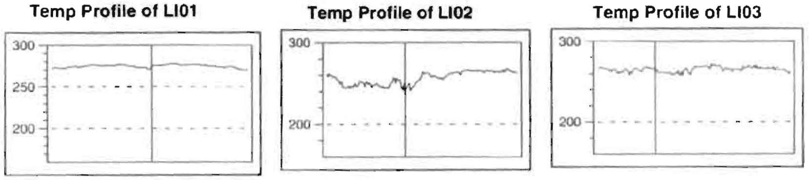
BLAW-KNOX

INGERSOLL-RAND
CONSTRUCTION & MINING

Image Number:
BG-Fig 2

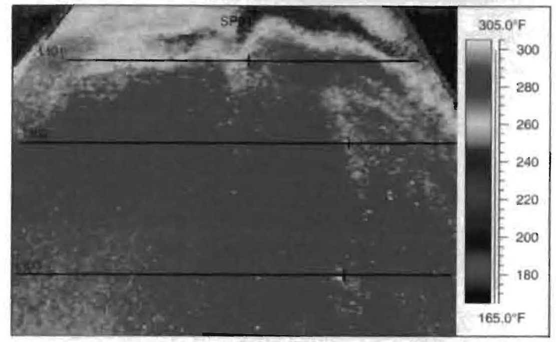
10/18/99

Temp Profile of LI01 | Temp Profile of LI02 | Temp Profile of LI03



	Cursor Temp	Max Temp	Min Temp	Avg Temp
LI01	274.4°F	278.4°F	269.3°F	274.7°F
LI02	243.1°F	268.1°F	241.1°F	256.6°F
LI03	266.3°F	272.1°F	257.6°F	265.3°F
SP01	247.4°F	-	-	-

El Paso, TX: Barber-Greene 260C with a BG-650 Pick Up Machine



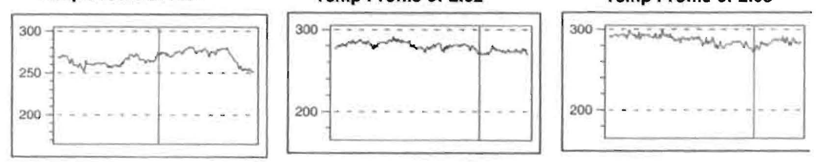
BLAW-KNOX

INGERSOLL-RAND
CONSTRUCTION & MINING

Image Number:
BG-Fig 1

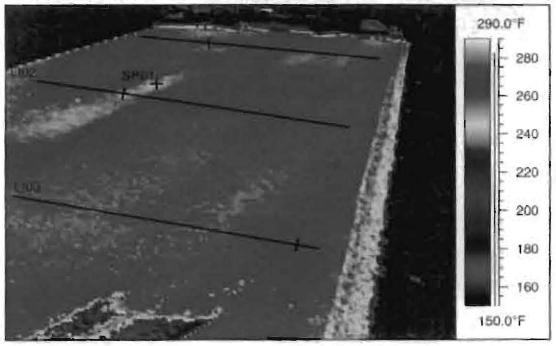
10/18/99

Temp Profile of LI01 | Temp Profile of LI02 | Temp Profile of LI03



	Cursor Temp	Max Temp	Min Temp	Avg Temp
LI01	273.9°F	281.0°F	250.9°F	267.1°F
LI02	270.3°F	291.7°F	269.2°F	279.5°F
LI03	274.2°F	300.4°F	272.1°F	286.7°F
SP01	237.0°F	-	-	-

El Paso, TX: Barber-Greene 260C with a BG-650 Pick Up Machine

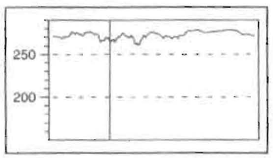


INGERSOLL-RAND
CONSTRUCTION & MINING

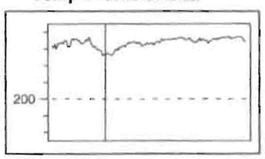
Image Number:
BG-Fig 3

10/18/99

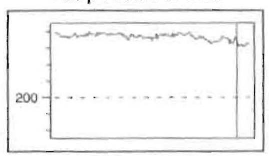
Temp Profile of LI01



Temp Profile of LI02



Temp Profile of LI03



	Cursor Temp	Max Temp	Min Temp	Avg Temp
LI01	264.3°F	278.6°F	260.2°F	272.5°F
LI02	253.8°F	275.1°F	252.4°F	267.9°F
LI03	268.1°F	280.3°F	261.2°F	273.6°F
SP01	256.0°F	-	-	-

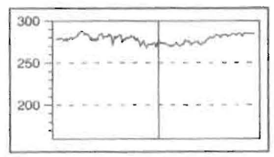
El Paso, TX: Barber-Greene 260C with a BG-650 Pick Up Machine

INGERSOLL-RAND
CONSTRUCTION & MINING

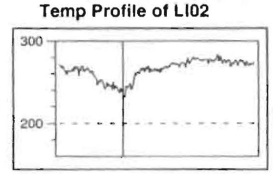
Image Number:
BG-Fig 4

10/18/99

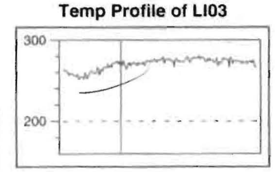
Temp Profile of LI01



Temp Profile of LI02

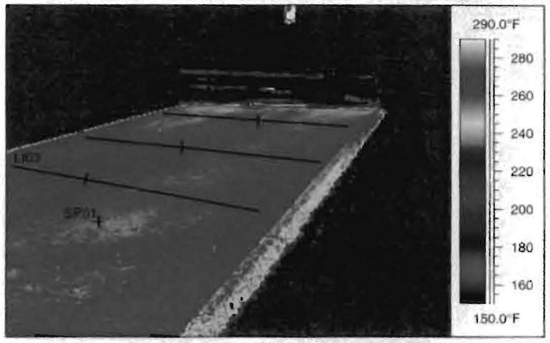


Temp Profile of LI03



	Cursor Temp	Max Temp	Min Temp	Avg Temp
LI01	275.6°F	287.5°F	267.3°F	278.2°F
LI02	234.1°F	283.6°F	232.5°F	265.3°F
LI03	273.6°F	280.7°F	251.3°F	270.6°F
SP01	237.6°F	-	-	-

El Paso, TX: Barber-Greene 260C with a BG-650 Pick Up Machine



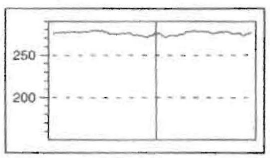
BLAW•KNOX

INGERSOLL-RAND
CONSTRUCTION & MINING

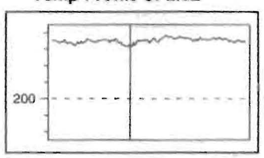
Image Number:
BG-Fig 5

10/18/99

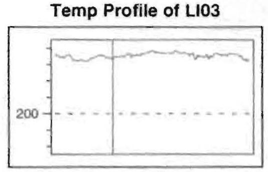
Temp Profile of LI01



Temp Profile of LI02

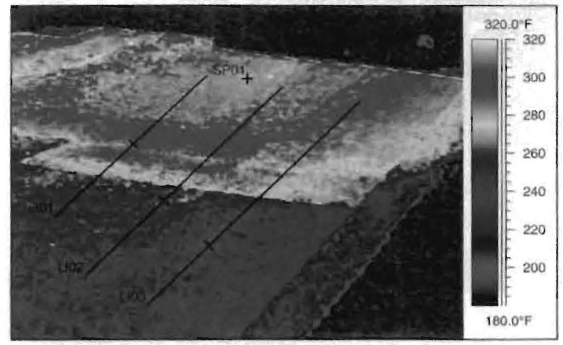


Temp Profile of LI03



	Cursor Temp	Max Temp	Min Temp	Avg Temp
LI01	275.5°F	279.6°F	271.3°F	275.7°F
LI02	265.0°F	276.7°F	263.7°F	270.8°F
LI03	267.0°F	277.3°F	263.3°F	271.0°F
SP01	279.8°F	-	-	-

El Paso, TX: Barber-Greene 260C with a BG-650 Pick Up Machine



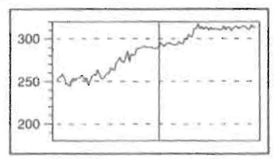
BLAW•KNOX

INGERSOLL-RAND
CONSTRUCTION & MINING

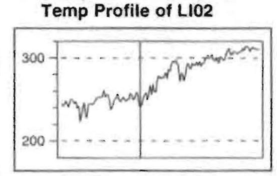
Image Number:
BG-Fig 6

10/18/99

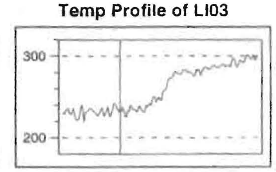
Temp Profile of LI01



Temp Profile of LI02

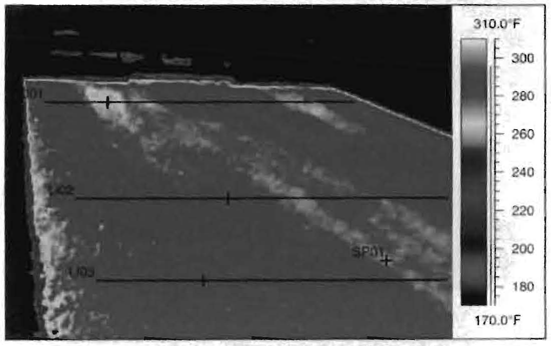


Temp Profile of LI03



	Cursor Temp	Max Temp	Min Temp	Avg Temp
LI01	289.5°F	317.2°F	243.9°F	286.2°F
LI02	240.7°F	314.1°F	224.2°F	273.5°F
LI03	233.6°F	302.1°F	219.7°F	259.6°F
SP01	313.5°F	-	-	-

El Paso, TX: Barber-Greene 260C with a Roadtec SB-2500B and Integrated Pick Up Machine



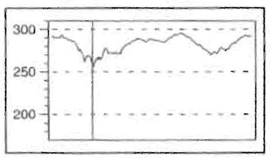
BLAW-KNOX

INGERSOLL-RAND
CONSTRUCTION & MINING

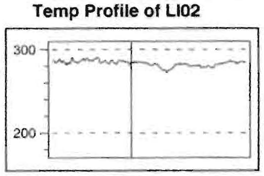
Image Number:
SB-Fig 2

10/19/99

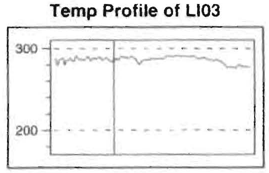
Temp Profile of LI01



Temp Profile of LI02

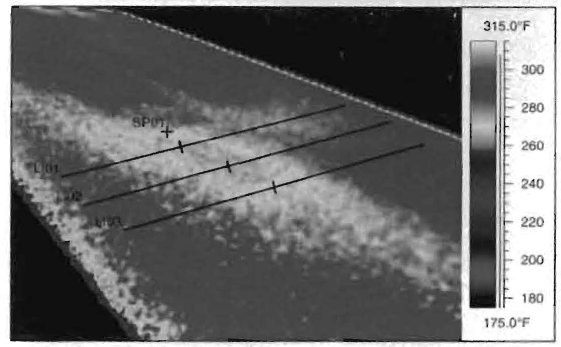


Temp Profile of LI03



	Cursor Temp	Max Temp	Min Temp	Avg Temp
LI01	260.5°F	295.3°F	255.3°F	282.0°F
LI02	284.0°F	290.8°F	272.8°F	283.6°F
LI03	286.5°F	291.5°F	275.5°F	286.0°F
SP01	270.2°F	-	-	-

El Paso, TX: Barber-Greene 260C with a Roadtec SB-2500B and Integrated Pick Up Machine



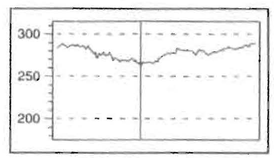
BLAW-KNOX

INGERSOLL-RAND
CONSTRUCTION & MINING

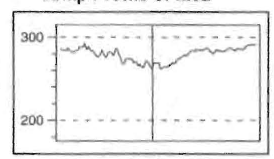
Image Number:
SB-Fig 3

10/19/99

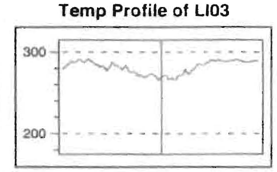
Temp Profile of LI01



Temp Profile of LI02

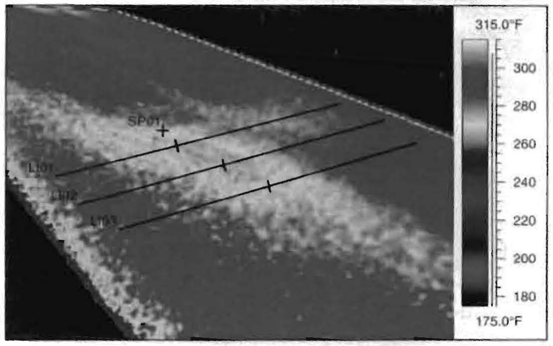


Temp Profile of LI03



	Cursor Temp	Max Temp	Min Temp	Avg Temp
LI01	264.3°F	289.3°F	263.7°F	277.8°F
LI02	263.3°F	293.3°F	262.1°F	279.4°F
LI03	269.8°F	292.2°F	266.0°F	281.9°F
SP01	276.4°F	-	-	-

El Paso, TX: Barber-Greene 260C with a Roadtec SB-2500B and Integrated Pick Up Machine



BLAW•KNOX

INGERSOLL-RAND
CONSTRUCTION & MINING

Image Number:
SB-Fig 3

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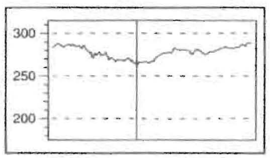
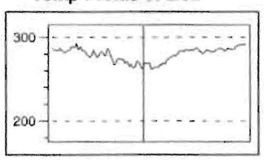
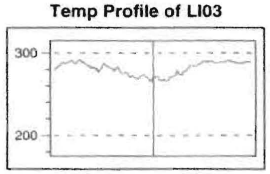
Temp Profile of LI01



Temp Profile of LI02

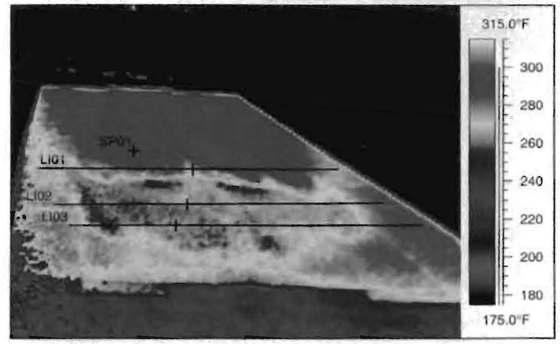


Temp Profile of LI03



	Cursor Temp	Max Temp	Min Temp	Avg Temp
LI01	264.3°F	289.3°F	263.7°F	277.8°F
LI02	263.3°F	293.3°F	262.1°F	279.4°F
LI03	269.8°F	292.2°F	266.0°F	281.9°F
SP01	276.4°F	-	-	-

El Paso, TX: Barber-Greene 260C with a Roadtec SB-2500B and Integrated Pick Up Machine



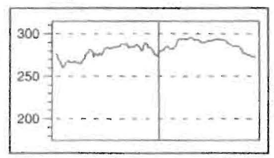
BLAW•KNOX

INGERSOLL-RAND
CONSTRUCTION & MINING

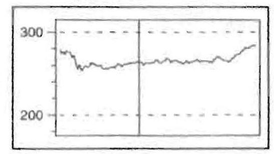
Image Number:
SB-Fig 4

10/19/99

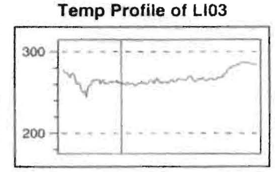
Temp Profile of LI01



Temp Profile of LI02

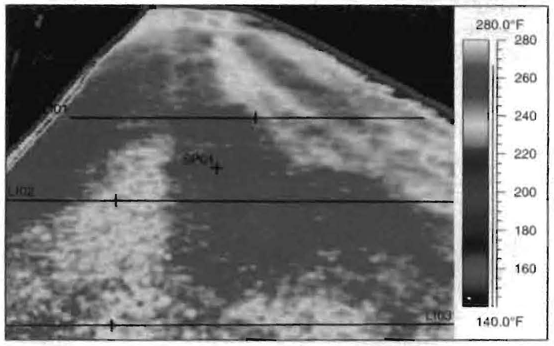


Temp Profile of LI03



	Cursor Temp	Max Temp	Min Temp	Avg Temp
LI01	276.9°F	295.3°F	260.0°F	282.4°F
LI02	264.6°F	284.5°F	253.7°F	265.7°F
LI03	261.5°F	287.6°F	244.1°F	267.5°F
SP01	295.0°F	-	-	-

El Paso, TX: Barber-Greene 260C with a Roadtec SB-2500B and Integrated Pick Up Machine



INGERSOLL-RAND
CONSTRUCTION & MINING

Image Number:
SB-Fig 5

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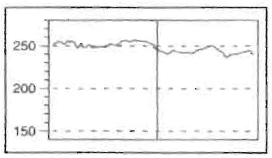
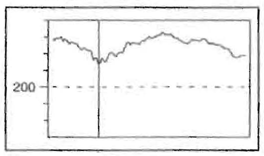
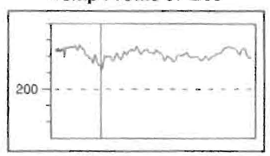
Temp Profile of LI01



Temp Profile of LI02

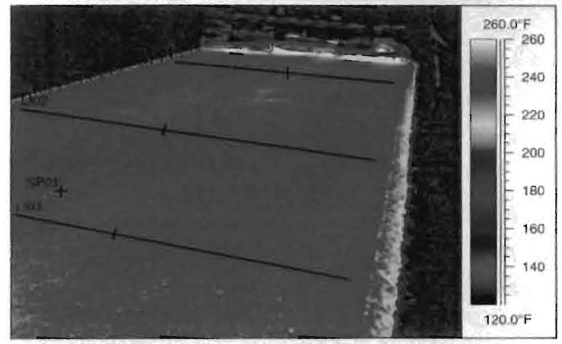


Temp Profile of LI03



	Cursor Temp	Max Temp	Min Temp	Avg Temp
LI01	247.3°F	256.6°F	236.4°F	247.9°F
LI02	228.5°F	265.2°F	227.9°F	250.1°F
LI03	228.1°F	254.1°F	225.0°F	243.1°F
SP01	254.3°F	-	-	-

El Paso, TX: Barber-Greene 260C with a Roadtec SB-2500B and Integrated Pick Up Machine

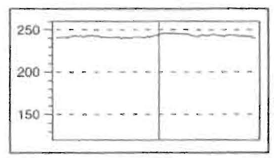


INGERSOLL-RAND
CONSTRUCTION & MINING

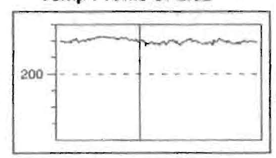
Image Number:
SB-Fig 6

10/19/99

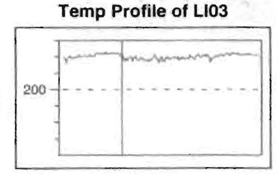
Temp Profile of LI01



Temp Profile of LI02

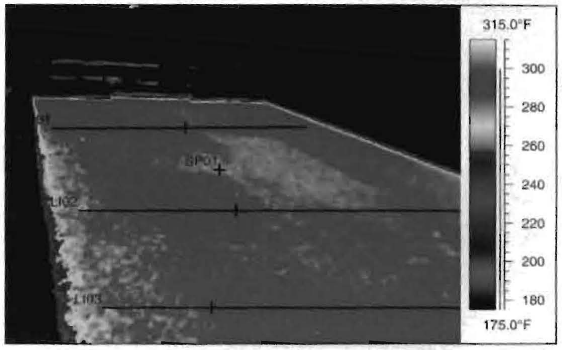


Temp Profile of LI03



	Cursor Temp	Max Temp	Min Temp	Avg Temp
LI01	244.8°F	245.9°F	239.7°F	242.6°F
LI02	239.8°F	245.5°F	233.2°F	239.9°F
LI03	243.3°F	246.7°F	232.1°F	240.3°F
SP01	230.3°F	-	-	-

El Paso, TX: Barber-Greene 260C with a Roadtec SB-2500B and Integrated Pick Up Machine



BLAW-KNOX

INGERSOLL-RAND
CONSTRUCTION & MINING

Image Number:
SB-Fig 7

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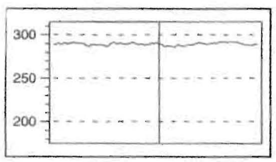
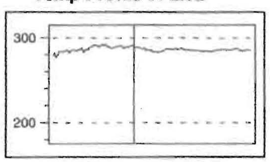
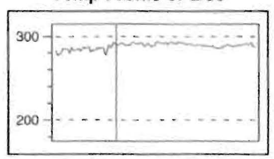
Temp Profile of LI01



Temp Profile of LI02

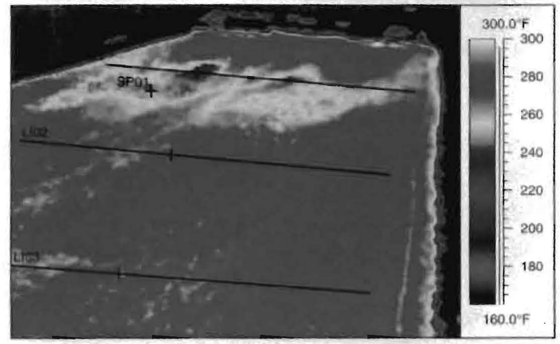


Temp Profile of LI03



	Cursor Temp	Max Temp	Min Temp	Avg Temp
LI01	289.5°F	292.0°F	285.2°F	289.1°F
LI02	290.4°F	292.4°F	276.4°F	286.3°F
LI03	291.4°F	294.7°F	277.5°F	289.0°F
SP01	280.6°F	-	-	-

El Paso, TX: Barber-Greene 260C with a Lincoln 880 Pick Up Machine and Lincoln Twin Pug Mill Insert



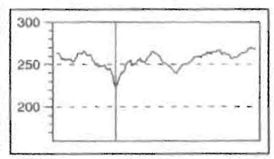
BLAW-KNOX

INGERSOLL-RAND
CONSTRUCTION & MINING

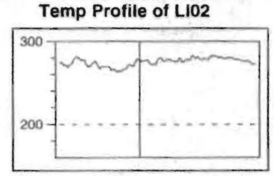
Image Number:
LN-Fig 1

10/20/99

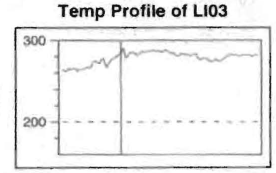
Temp Profile of LI01



Temp Profile of LI02

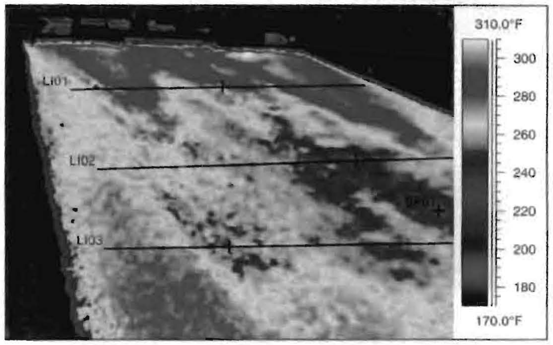


Temp Profile of LI03



	Cursor Temp	Max Temp	Min Temp	Avg Temp
LI01	223.9°F	269.6°F	223.9°F	255.2°F
LI02	278.2°F	283.0°F	262.9°F	275.4°F
LI03	284.4°F	290.9°F	262.2°F	278.8°F
SP01	247.1°F	-	-	-

El Paso, TX: Barber-Greene 260C with a Lincoln 880 Pick Up Machine and Lincoln Twin Pug Mill Insert



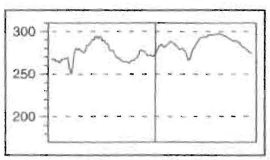
BLAW-KNOX

INGERSOLL-RAND
CONSTRUCTION & MINING

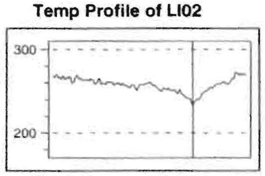
Image Number:
LN-Fig 2

10/20/99

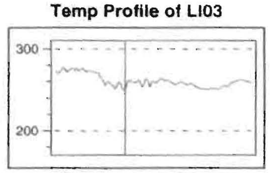
Temp Profile of LI01



Temp Profile of LI02

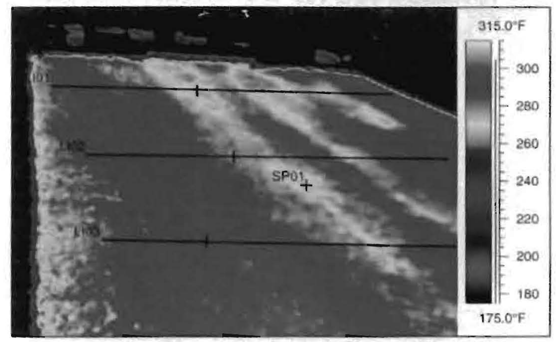


Temp Profile of LI03



	Cursor Temp	Max Temp	Min Temp	Avg Temp
LI01	273.4°F	297.4°F	250.2°F	279.8°F
LI02	233.9°F	273.1°F	233.5°F	257.8°F
LI03	250.8°F	277.8°F	250.5°F	261.1°F
SP01	236.8°F	-	-	-

El Paso, TX: Barber-Greene 260C with a Lincoln 880 Pick Up Machine and Lincoln Twin Pug Mill Insert



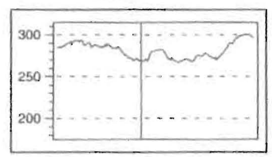
BLAW-KNOX

INGERSOLL-RAND
CONSTRUCTION & MINING

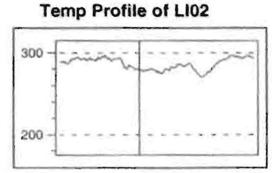
Image Number:
LN-Fig 3

10/20/99

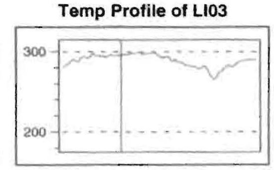
Temp Profile of LI01



Temp Profile of LI02

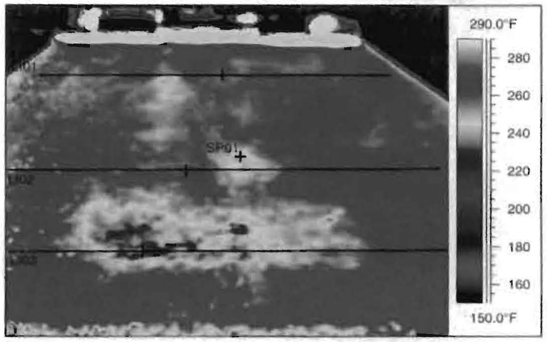


Temp Profile of LI03



	Cursor Temp	Max Temp	Min Temp	Avg Temp
LI01	268.4°F	300.5°F	266.7°F	281.2°F
LI02	279.3°F	297.5°F	270.4°F	286.8°F
LI03	296.4°F	300.2°F	266.0°F	289.4°F
SP01	269.8°F	-	-	..

El Paso, TX: Barber-Greene 260C with a Lincoln 880 Pick Up Machine and Lincoln Twin Pug Mill Insert



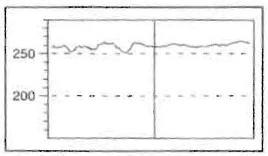
BLAW-KNOX

INGERSOLL-RAND
CONSTRUCTION & MINING

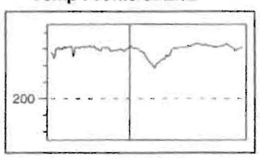
Image Number:
LN-Fig 4

10/20/99

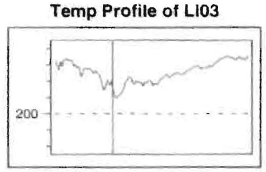
Temp Profile of LI01



Temp Profile of LI02

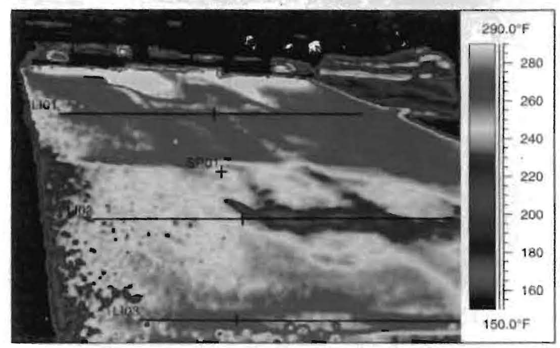


Temp Profile of LI03



	Cursor Temp	Max Temp	Min Temp	Avg Temp
LI01	258.5°F	264.3°F	251.0°F	259.1°F
LI02	262.3°F	267.2°F	237.3°F	259.6°F
LI03	232.3°F	270.6°F	219.0°F	250.9°F
SP01	240.4°F	-	-	-

El Paso, TX: Barber-Greene 260C with a Lincoln 880 Pick Up Machine and Lincoln Twin Pug Mill Insert



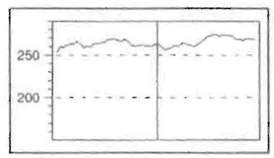
BLAW-KNOX

INGERSOLL-RAND
CONSTRUCTION & MINING

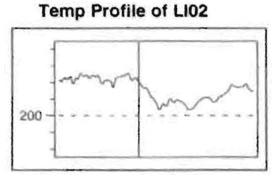
Image Number:
LN-Fig 5

10/20/99

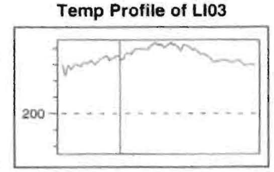
Temp Profile of LI01



Temp Profile of LI02

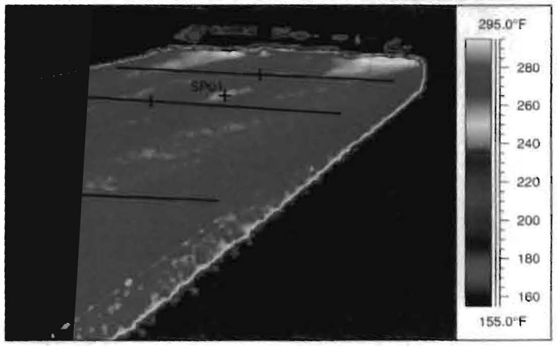


Temp Profile of LI03



	Cursor Temp	Max Temp	Min Temp	Avg Temp
LI01	263.2°F	274.3°F	253.3°F	264.5°F
LI02	240.3°F	251.2°F	206.9°F	232.0°F
LI03	268.2°F	287.2°F	246.6°F	270.1°F
SP01	250.5°F	-	-	-

El Paso, TX: Barber-Greene 260C with a Lincoln 880 Pick Up Machine and Lincoln Twin Pug Mill Insert



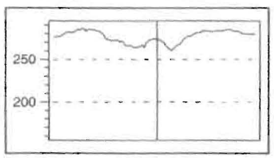
BLAW-KNOX

INGERSOLL-RAND
CONSTRUCTION & MINING

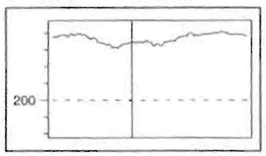
Image Number:
LN-Fig 6

10/20/99

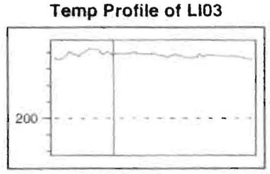
Temp Profile of LI01



Temp Profile of LI02

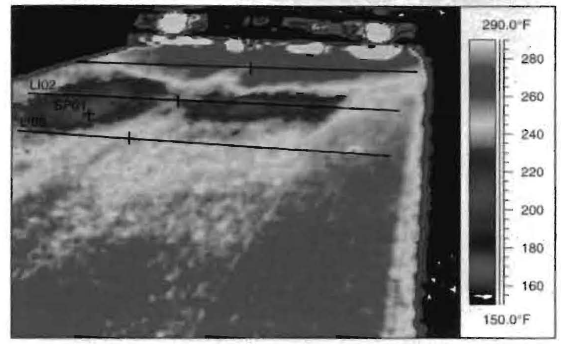


Temp Profile of LI03



	Cursor Temp	Max Temp	Min Temp	Avg Temp
LI01	273.9°F	286.3°F	260.3°F	276.4°F
LI02	269.2°F	282.5°F	262.3°F	273.8°F
LI03	277.7°F	285.5°F	271.5°F	277.4°F
SP01	258.2°F	-	-	-

El Paso, TX: Cedarapids CR-461 AntiSegregation Remix Paver with Cedarapids MS-2 Pick Up Machine



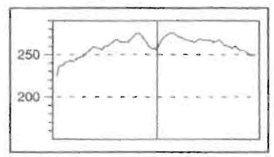
BLAW-KNOX

INGERSOLL-RAND
CONSTRUCTION & MINING

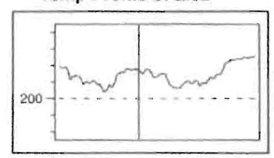
Image Number:
CR-Fig 1

10/21/99

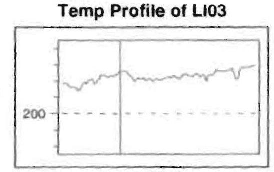
Temp Profile of LI01



Temp Profile of LI02

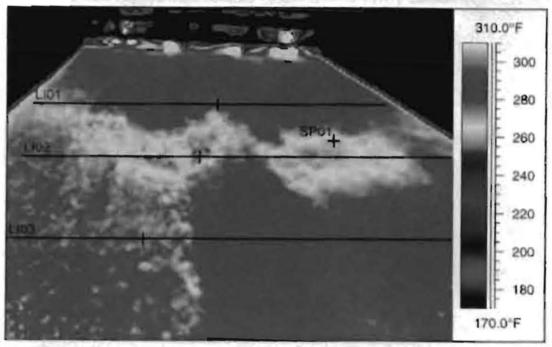


Temp Profile of LI03



	Cursor Temp	Max Temp	Min Temp	Avg Temp
LI01	256.0°F	275.5°F	224.2°F	260.2°F
LI02	234.4°F	251.8°F	208.3°F	228.6°F
LI03	251.3°F	258.7°F	228.1°F	245.2°F
SP01	211.2°F	-	-	-

El Paso, TX: Cedarapids CR-461 AntiSegregation Remix Paver with Cedarapids MS-2 Pick Up Machine



BLAW•KNOX

INGERSOLL-RAND
CONSTRUCTION & MINING

Image Number:
CR-Fig 2

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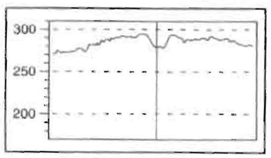
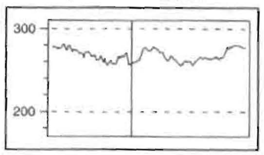
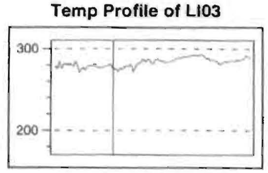
Temp Profile of LI01



Temp Profile of LI02

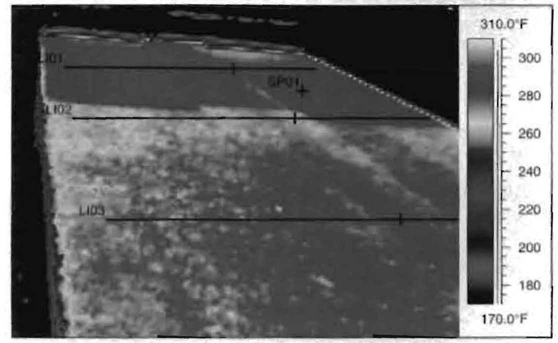


Temp Profile of LI03



	Cursor Temp	Max Temp	Min Temp	Avg Temp
LI01	278.4°F	294.5°F	270.2°F	285.0°F
LI02	257.9°F	282.1°F	255.9°F	268.3°F
LI03	275.5°F	293.7°F	271.1°F	283.1°F
SP01	262.3°F	-	-	-

El Paso, TX: Cedarapids CR-461 AntiSegregation Remix Paver with Cedarapids MS-2 Pick Up Machine



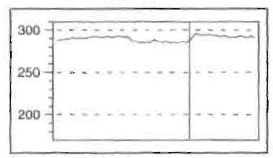
BLAW•KNOX

INGERSOLL-RAND
CONSTRUCTION & MINING

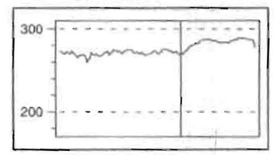
Image Number:
CR-Fig 3

10/21/99

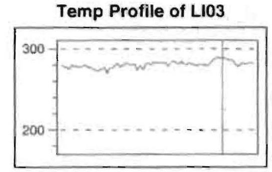
Temp Profile of LI01



Temp Profile of LI02

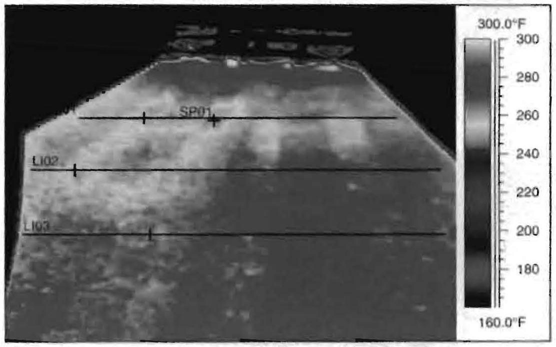


Temp Profile of LI03



	Cursor Temp	Max Temp	Min Temp	Avg Temp
LI01	287.9°F	295.1°F	284.3°F	289.8°F
LI02	270.2°F	289.6°F	260.0°F	276.1°F
LI03	288.6°F	289.5°F	270.2°F	280.6°F
SP01	292.3°F	-	-	-

El Paso, TX: Cedarapids CR-461 AntiSegregation Remix Paver with Cedarapids MS-2 Pick Up Machine



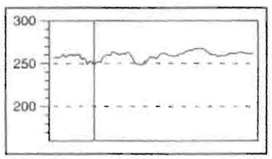
BLAW•KNOX

INGERSOLL-RAND
CONSTRUCTION & MINING

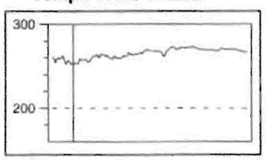
Image Number:
CR-Fig 4

10/21/99

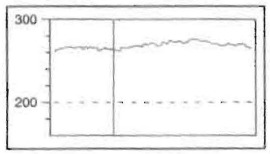
Temp Profile of LI01



Temp Profile of LI02

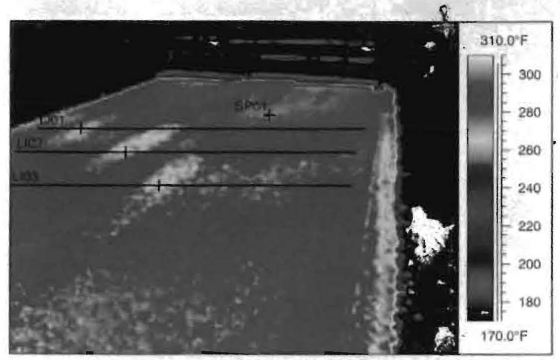


Temp Profile of LI03



	Cursor Temp	Max Temp	Min Temp	Avg Temp
LI01	248.7°F	266.9°F	248.1°F	259.0°F
LI02	253.2°F	273.6°F	252.0°F	265.1°F
LI03	265.6°F	276.4°F	261.1°F	268.9°F
SP01	249.9°F	-	-	-

El Paso, TX: Cedarapids CR-461 AntiSegregation Remix Paver with Cedarapids MS-2 Pick Up Machine



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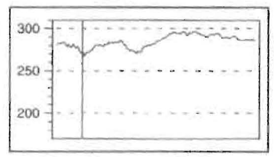
CONSTRUCTION & MINING

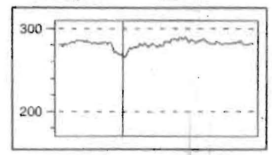
Image Number:
CR-Fig 5

10/21/99

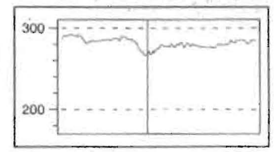
Temp Profile of LI01



Temp Profile of LI02



Temp Profile of LI03



	Cursor Temp	Max Temp	Min Temp	Avg Temp
LI01	272.2°F	296.3°F	267.1°F	284.5°F
LI02	270.2°F	290.3°F	264.9°F	282.0°F
LI03	267.5°F	292.0°F	265.8°F	281.6°F
SP01	299.8°F	-	-	-

El Paso, TX: Cedarapids CR-461 AntiSegregation Remix Paver with Cedarapids MS-2 Pick Up Machine

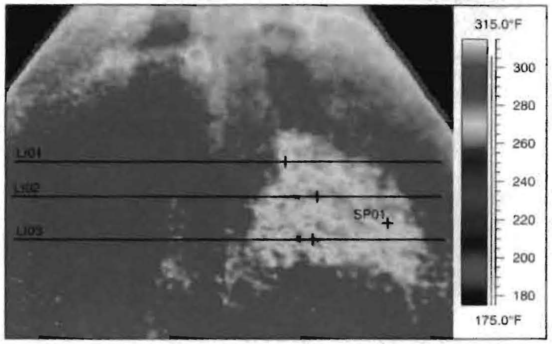


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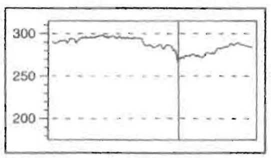
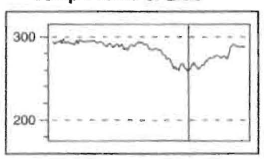
Image Number:
CR-Fig 6

10/21/99

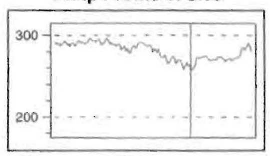
Temp Profile of LI01



Temp Profile of LI02



Temp Profile of LI03



	Cursor Temp	Max Temp	Min Temp	Avg Temp
LI01	267.7°F	298.1°F	266.6°F	287.0°F
LI02	259.0°F	298.0°F	259.0°F	283.6°F
LI03	259.2°F	297.0°F	258.6°F	281.4°F
SP01	265.0°F	-	-	-

El Paso, TX: Cedarapids CR-461 AntiSegregation Remix Paver with Cedarapids MS-2 Pick Up Machine

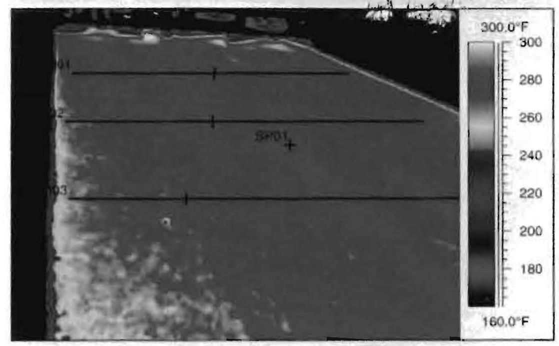


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Image Number:
CR-Fig 7

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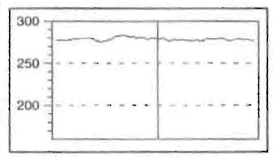
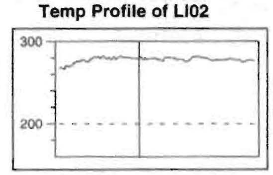
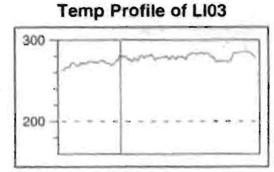
Temp Profile of LI01



Temp Profile of LI02

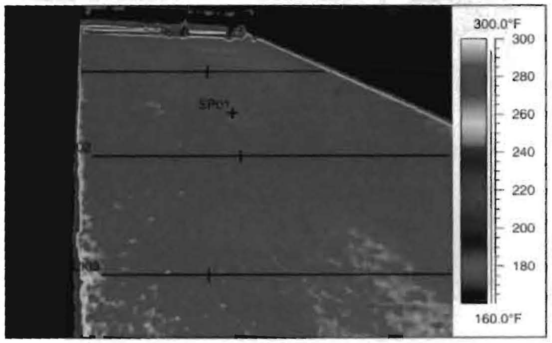


Temp Profile of LI03



	Cursor Temp	Max Temp	Min Temp	Avg Temp
LI01	279.0°F	283.3°F	274.7°F	278.2°F
LI02	279.5°F	282.4°F	266.3°F	278.0°F
LI03	281.1°F	286.1°F	263.2°F	277.4°F
SP01	285.3°F	-	-	-

El Paso, TX: Cedarapids CR-461 AntiSegregation Remix Paver with Cedarapids MS-2 Pick Up Machine



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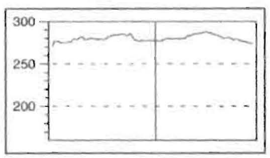
CONSTRUCTION & MINING

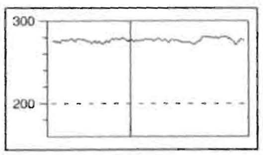
Image Number:
CR-Fig 8

10/21/99

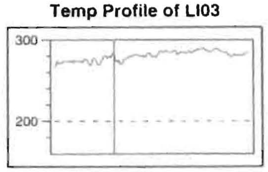
Temp Profile of LI01



Temp Profile of LI02

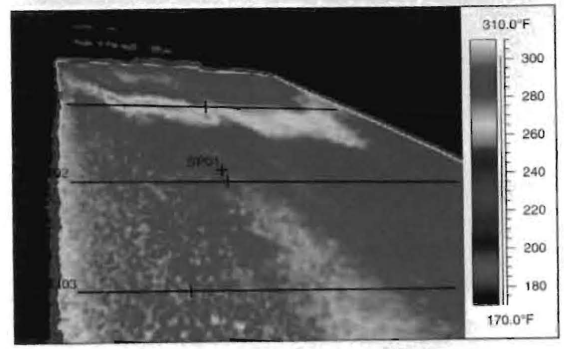


Temp Profile of LI03



	Cursor Temp	Max Temp	Min Temp	Avg Temp
LI01	277.4°F	287.2°F	270.9°F	280.0°F
LI02	277.0°F	281.5°F	270.6°F	276.8°F
LI03	281.8°F	291.0°F	266.4°F	280.6°F
SP01	269.2°F	-	-	-

El Paso, TX: Barber-Greene 260C Using an MC-330 with BG-650 Pick Up and BK Twin Pug Mill Hopper Insert



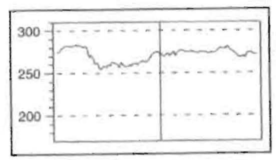
BLAW•KNOX

INGERSOLL-RAND
CONSTRUCTION & MINING

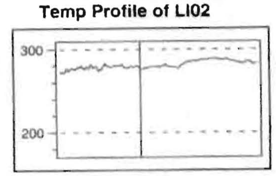
Image Number:
BK-Fig 1

10/22/99

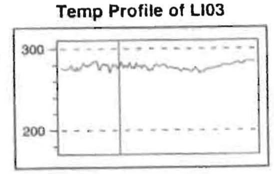
Temp Profile of LI01



Temp Profile of LI02



Temp Profile of LI03



	Cursor Temp	Max Temp	Min Temp	Avg Temp
LI01	272.6°F	283.3°F	254.3°F	270.8°F
LI02	277.5°F	289.4°F	271.8°F	281.6°F
LI03	277.2°F	285.3°F	269.7°F	277.9°F
SP01	281.4°F	-	-	-

El Paso, TX: Barber-Greene 260C Using an MC-330 with BG-650 Pick Up and BK Twin Pug Mill Hopper Insert

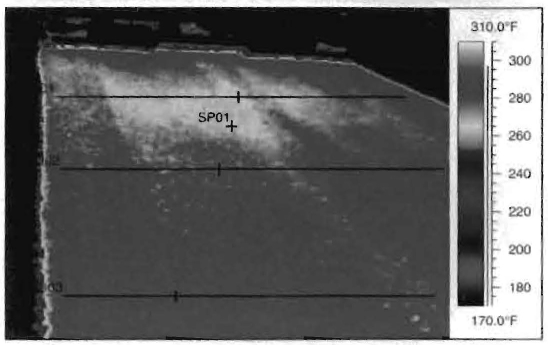


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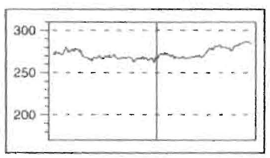
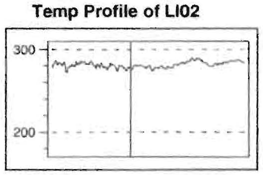
Image Number:
BK-Fig 2

10/22/99

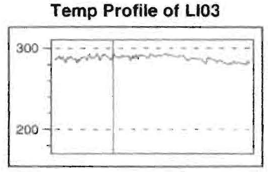
Temp Profile of LI01



Temp Profile of LI02

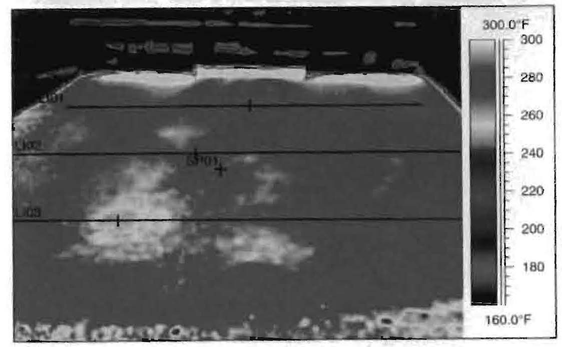


Temp Profile of LI03



	Cursor Temp	Max Temp	Min Temp	Avg Temp
LI01	265.8°F	287.0°F	262.2°F	272.1°F
LI02	278.2°F	290.1°F	272.3°F	281.8°F
LI03	294.3°F	294.3°F	279.4°F	287.6°F
SP01	266.3°F	-	-	-

El Paso, TX: Barber-Greene 260C Using an MC-330 with BG-650 Pick Up and BK Twin Pug Mill Hopper Insert



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CONSTRUCTION & MINING

Image Number:
BK-Fig 3

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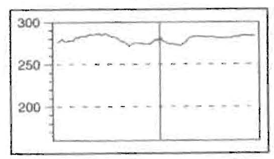
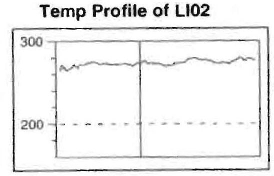
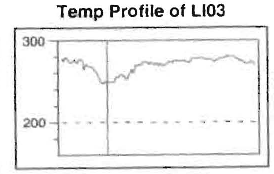
Temp Profile of LI01



Temp Profile of LI02

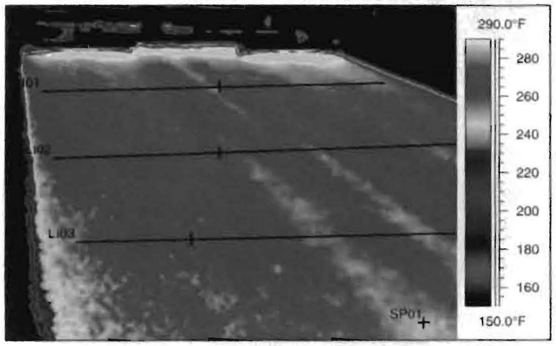


Temp Profile of LI03



	Cursor Temp	Max Temp	Min Temp	Avg Temp
LI01	281.1°F	286.1°F	271.7°F	279.8°F
LI02	273.3°F	280.5°F	264.1°F	273.6°F
LI03	249.4°F	281.5°F	247.3°F	270.3°F
SP01	271.4°F	-	..	-

El Paso, TX: Barber-Greene 260C Using an MC-330 with BG-650 Pick Up and BK Twin Pug Mill Hopper Insert

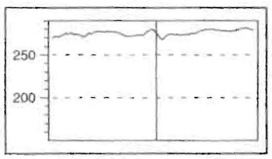


BLAW-KNOX
INGERSOLL-RAND
CONSTRUCTION & MINING

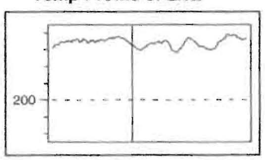
Image Number:
BK-Fig 4

10/22/99

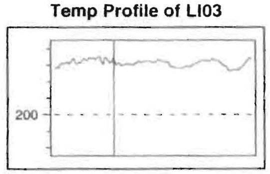
Temp Profile of LI01



Temp Profile of LI02

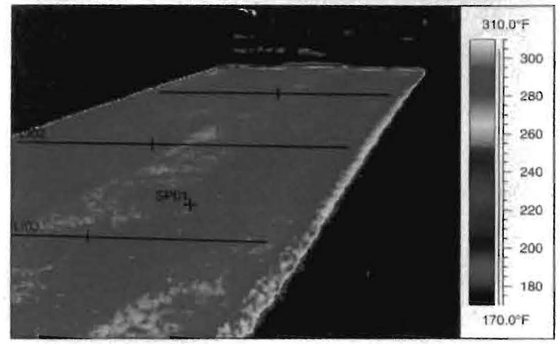


Temp Profile of LI03



	Cursor Temp	Max Temp	Min Temp	Avg Temp
LI01	275.5°F	281.5°F	268.1°F	275.5°F
LI02	266.5°F	278.7°F	256.4°F	269.0°F
LI03	267.4°F	271.1°F	252.8°F	262.6°F
SP01	250.3°F	-	-	-

El Paso, TX: Barber-Greene 260C Using an MC-330 with BG-650 Pick Up and BK Twin Pug Mill Hopper Insert

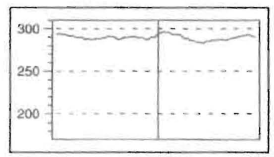


BLAW-KNOX
INGERSOLL-RAND
CONSTRUCTION & MINING

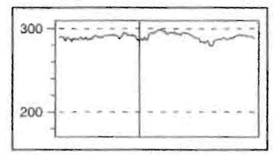
Image Number:
BK-Fig 5

10/22/99

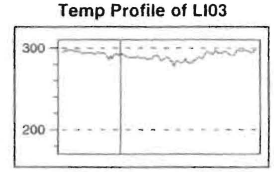
Temp Profile of LI01



Temp Profile of LI02

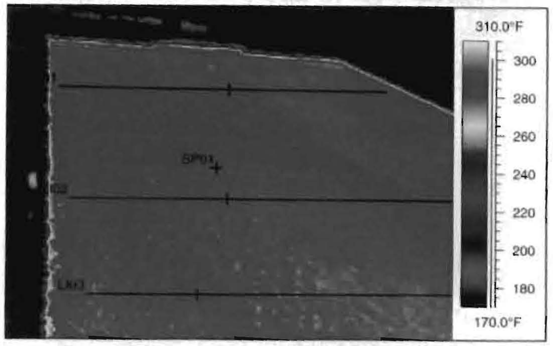


Temp Profile of LI03



	Cursor Temp	Max Temp	Min Temp	Avg Temp
LI01	293.5°F	296.5°F	282.6°F	289.7°F
LI02	287.8°F	299.0°F	279.3°F	290.5°F
LI03	291.0°F	298.5°F	277.7°F	291.0°F
SP01	284.4°F	-	-	-

El Paso, TX: Barber-Greene 260C Using an MC-330 with BG-650 Pick Up and BK Twin Pug Mill Hopper Insert



BLAW•KNOX

INGERSOLL-RAND
CONSTRUCTION & MINING

Image Number:
BK-Fig 6

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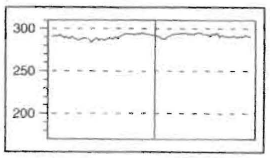
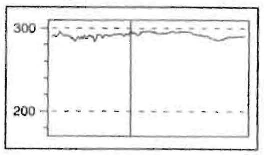
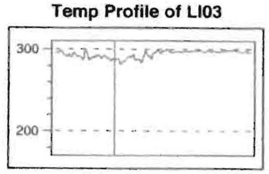
Temp Profile of LI01



Temp Profile of LI02

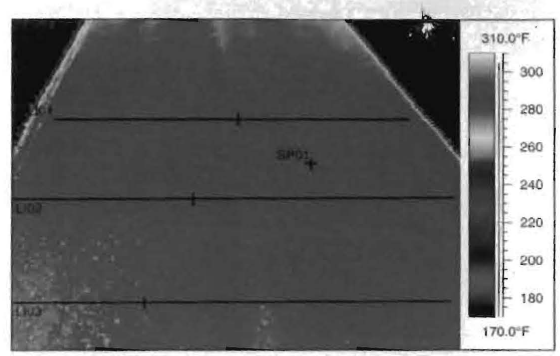


Temp Profile of LI03



	Cursor Temp	Max Temp	Min Temp	Avg Temp
LI01	292.1°F	295.5°F	283.3°F	291.2°F
LI02	296.3°F	297.1°F	284.4°F	291.9°F
LI03	287.3°F	300.2°F	281.8°F	293.9°F
SP01	288.0°F	-	-	-

El Paso, TX: Barber-Greene 260C Using an MC-330 with BG-650 Pick Up and BK Twin Pug Mill Hopper Insert



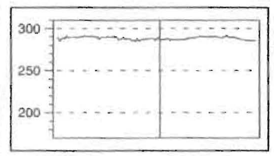
BLAW•KNOX

INGERSOLL-RAND
CONSTRUCTION & MINING

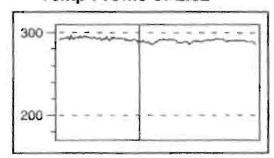
Image Number:
BK-Fig 8

10/22/99

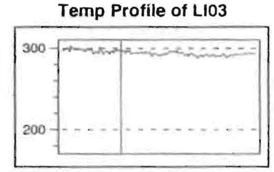
Temp Profile of LI01



Temp Profile of LI02

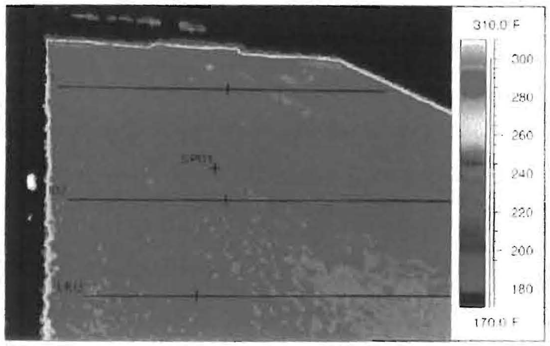


Temp Profile of LI03



	Cursor Temp	Max Temp	Min Temp	Avg Temp
LI01	288.0°F	291.7°F	284.2°F	288.4°F
LI02	289.0°F	297.6°F	285.8°F	291.3°F
LI03	297.4°F	303.4°F	287.8°F	294.0°F
SP01	288.6°F	-	-	-

El Paso, TX: Barber-Greene 260C Using an MC-330 with BG-650 Pick Up and BK Twin Pug Mill Hopper Insert



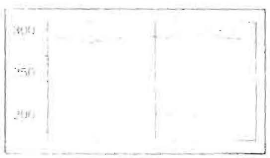
BLAW-KNOX

INGERSOLL-RAND
CONSTRUCTION & MINING

Image Number:
BK-Fig 6

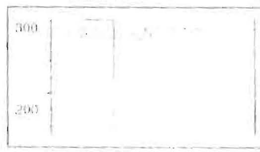
10/22/99

Temp Profile of LI01



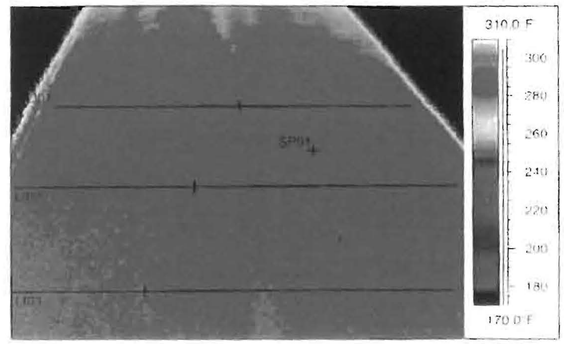
Temp Profile of LI02

Temp Profile of LI03



	Cursor Temp	Max Temp	Min Temp	Avg Temp
LI01	292.1 F	295.5 F	283.3 F	291.2 F
LI02	296.3 F	297.1 F	284.4 F	291.9 F
LI03	287.3 F	300.2 F	281.8 F	293.9 F
SP01	288.0 F	.	.	.

El Paso, TX: Barber-Greene 260C Using an MC-330 with BG-650 Pick Up and BK Twin Pug Mill Hopper Insert



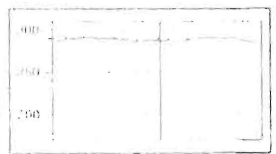
BLAW-KNOX

INGERSOLL-RAND
CONSTRUCTION & MINING

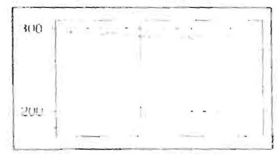
Image Number:
BK-Fig 8

10/22/99

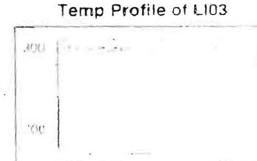
Temp Profile of LI01



Temp Profile of LI02

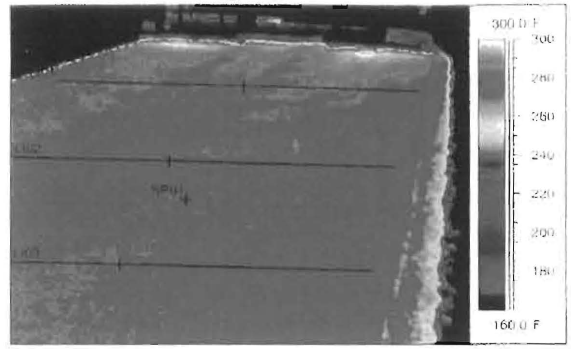


Temp Profile of LI03



	Cursor Temp	Max Temp	Min Temp	Avg Temp
LI01	288.0 F	291.7 F	284.2 F	288.4 F
LI02	289.0 F	297.6 F	285.8 F	291.3 F
LI03	297.4 F	303.4 F	287.8 F	294.0 F
SP01	288.6 F		.	

El Paso, TX: Barber-Greene 260C Using an MC-330 with BG-650 Pick Up and BK Twin Pug Mill Hopper Insert



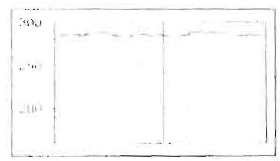
BLAW-KNOX

INGERSOLL-RAND
CONSTRUCTION & MINING

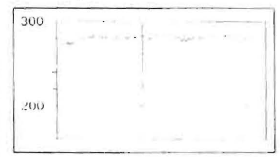
Image Number:
BK-Fig 7

10/22/99

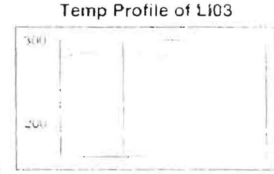
Temp Profile of LI01



Temp Profile of LI02



Temp Profile of LI03



	Cursor Temp	Max Temp	Min Temp	Avg Temp
LI01	285.0 F	290.4 F	282.5 F	286.0 F
LI02	283.3 F	285.6 F	271.5 F	281.0 F
LI03	285.8 F	288.3 F	273.5 F	282.6 F
SP01	284.2 F	-	-	-

APPENDIX – C

REPORT FROM TTI
DETECTING SEGREGATION USING GROUND PENETRATING RADAR (GPR)

GROUND PENETRATING RADAR RESULTS FROM THE MTD RODEO IN EL PASO

1. BACKGROUND

1.1. Basics of Ground Penetrating Radar

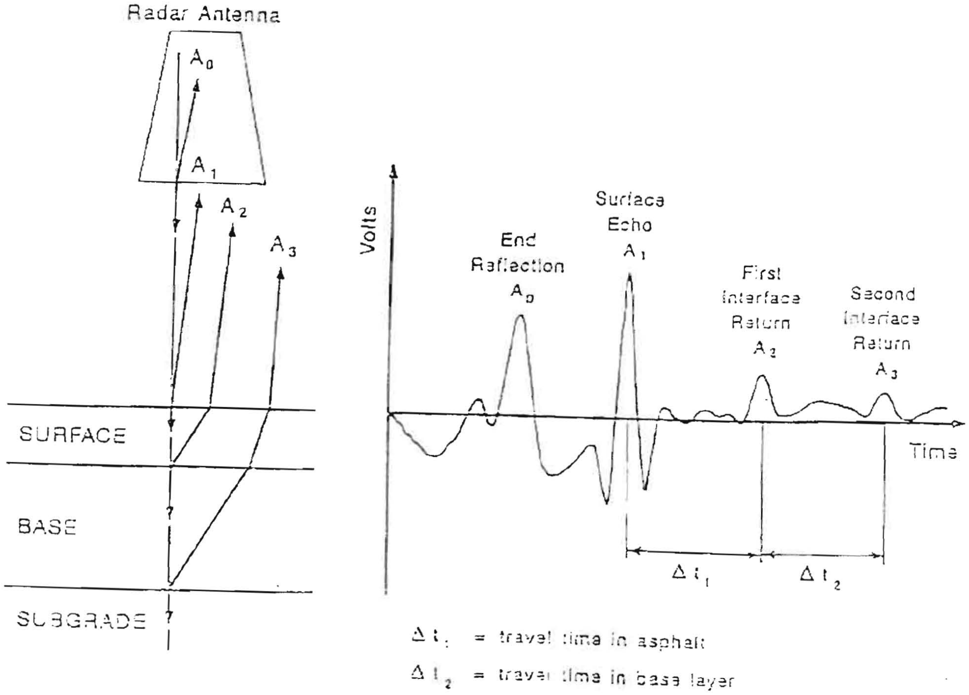
The Texas Transportation Institute s Ground Penetrating Radar (GPR) unit is shown in Figure 1a. This system sends discrete pulses of radar energy into the pavement system and captures the reflections from each layer interface within the structure. This particular GPR unit operates at highway speed (60 mph), transmits and receives 50 pulses per second, and can effectively penetrate to a depth of 2 feet. A typical plot of captured reflected energy versus arrival time for one pulse is shown in Figure 1b, as a graph of volts versus time in nanoseconds.

In Figure 1b, the reflection A_1 is the energy reflected from the surface of the pavement and A_2 and A_3 are from the top of the base and subgrade respectively. As described in Section 1.3, these amplitudes of reflection and the time delays between reflections are used to calculate both layer dielectrics and thickness. The dielectric constant of a material is an electrical property which is most influenced by moisture content and density. If the moisture content for a layer increases, then the dielectric of the layer will increase which will result in an increase in the energy reflected from the top of the layer. An increase in air voids would have the opposite effect if the amount of air in a layer increases the energy reflected and the resulting dielectric would decrease.

TTI has established a range of typical dielectrics for most paving materials. For example HMA layers normally have a dielectric value between 4.5 and 6.5, depending on the coarse aggregate type. Measured values significantly higher than this would indicate the presence of excessive moisture. Lower values could indicate a density problem or indicate that an unusual aggregate, such as lightweight, had been used.

In this study plots of surface dielectric are produced for each of the Material Transfer Devices (MTD s) used in the El Paso study. It is proposed that variations in surface dielectric are indicators of variations in the air void content of the top layer. For a homogeneous well compacted surface layer the dielectric plot versus distance should be a relatively flat horizontal line. Recent studies at the Texas Transportation Institute have found that sharp localized decreases in the surface dielectric are associated with areas of low density in the surface layer.

a. TTI GPR Equipment.

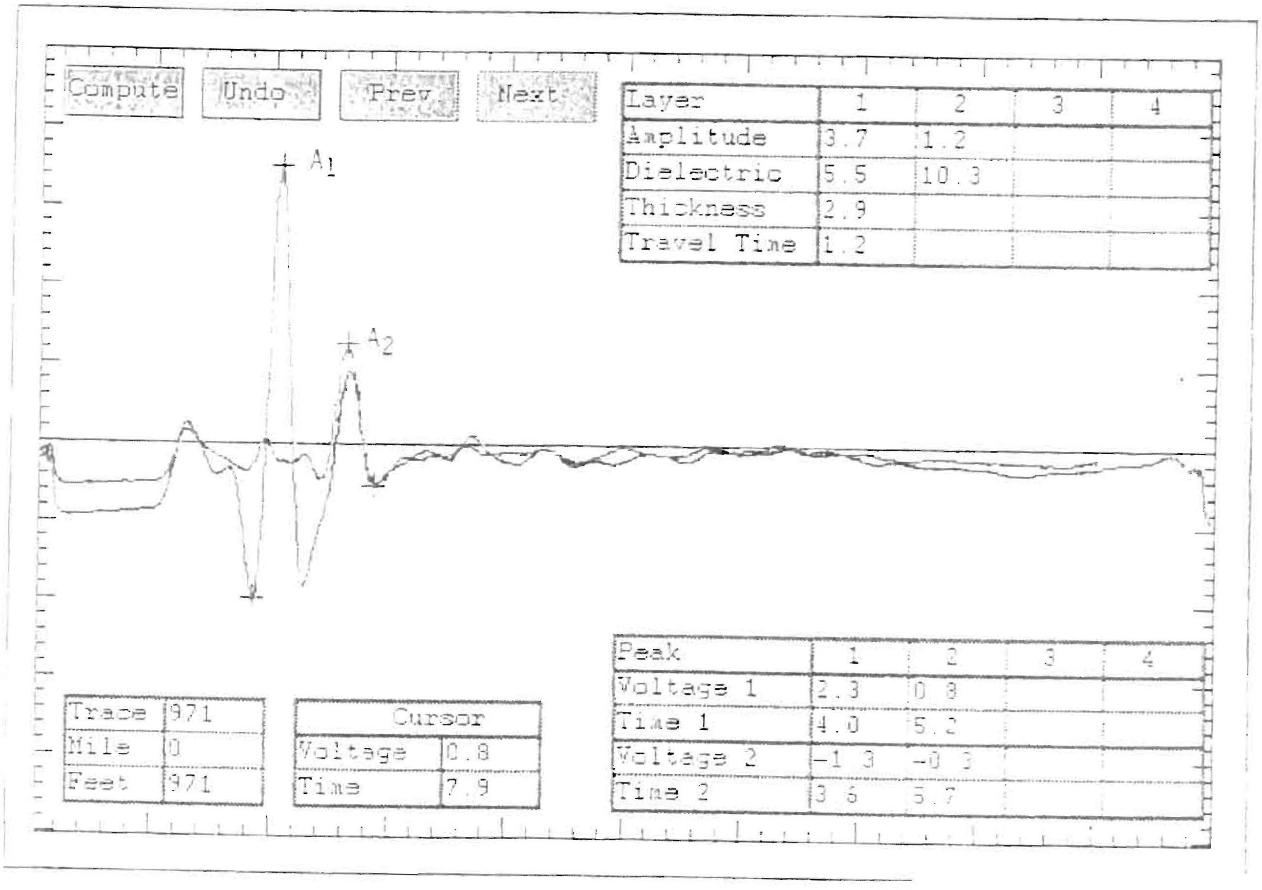


b. Principles of Ground Penetrating Radar. The Incident Wave is Reflected at Each Layer Interface and Plotted as Return Voltage Against Time of Arrival in Nanoseconds.

Figure 1. GPR Equipment and Principles of Operation.

1.2. GPR Reflections from a New HMA Surface

Figure 2 shows the reflection from a thin three inch thick HMA layer over a thick granular base. As the base typically has significantly more moisture than the HMA, there is often a large reflection from the top of the base. The amplitude of reflection from the top of the base is related to the moisture content of the base. However, with thin surface layers the reflections from both the surface and base reflections overlap. In order to measure the true amplitude of reflection from the top of the base, it is necessary to apply the surface removal technique developed in earlier studies at TTI. In figure 2 the blue line is the raw data and the red line represents the reflections remaining after the surface is removed.



Reflections A_1 and A_2 are from the Surface and top of Base Respectively. The Red Line is Obtained After Surface Removal.

Figure 2. Typical GPR Reflection from a Newly Constructed Pavement Consisting of a Thick Granular Base and Thin Surfacing.

1.3. Computation of Layer Thickness and Dielectrics

By automatically monitoring the amplitudes and time delays between peaks, it is possible to calculate layer dielectrics, layer thicknesses, and to estimate the moisture content of granular base material. The surface dielectric is used extensively in this study, it is calculated using Equation 1 shown below;

$$\sqrt{\epsilon_a} = \frac{A_m + A_1}{A_m - A_1} \qquad (1)$$

where

ε_a = the dielectric of the surface layer

A_1 = the amplitude of reflection from the HMA surface in volts

A_m = the amplitude of reflection from a large metal plate in volts (this represents the 100% reflection case)

The GPR trace can also be used to calculate surface and base thicknesses using the equations given below;

$$h_1 = \frac{c \times \Delta t_1}{\sqrt{\epsilon_a}} \qquad (2)$$

where

h_1 = the thickness of HMA layer

c = (normally 5.9 ins/ns) the speed of travel of a GPR wave in free space (ins/ns) as measured by the system. For two-way travel this value is 5.9 inches per nanosecond. The speed as measured by the GPR unit can be computed using a height calibration procedures

Δt_1 = the time delay between peaks A_1 and A_2 of Figure 2

$$\sqrt{\epsilon_b} = \sqrt{\epsilon_a}\left[\frac{1 - \left[\frac{A_1}{A_m}\right]^2 - \left[\frac{A_2}{A_m}\right]}{1 - \left[\frac{A_1}{A_m}\right]^2 - \left[\frac{A_2}{A_m}\right]}\right] \qquad (3)$$

where

ε_b = the dielectric of the base layer

A_2 = the amplitude of reflection from the top of the base layer in volts

Using the amplitude and time delay data presented in Figure 2, $A_1 = 3.7$ volts , $A_2 = 1.3$ volts, $\Delta t_1 = 1.2$ nanoseconds, and given $A_m = 9.14$ volts. Calculate the following dielectrics and layer thicknesses:

Using Equation 1,

$$\sqrt{\epsilon_a} = \frac{A_m + A_o}{A_m - A_o} = \frac{9.14 + 3.7}{9.14 - 3.7} = 2.36$$

$$\epsilon_a = 5.5$$

Using Equation 2,

$$h_a = \frac{5.9 \ x \ \Delta t_1}{\sqrt{\epsilon_a}} = \frac{5.9 \ x \ 1.2}{2.36} = 3.0 \ ins$$

Using Equation 3,

$$\sqrt{\epsilon_b} = 2.36 \left[\frac{1 - \left(\frac{3.7}{9.14}\right)^2 + \left(\frac{1.2}{9.14}\right)}{1 - \left(\frac{3.7}{9.14}\right)^2 + \left(\frac{1.2}{9.14}\right)} \right]$$

$$= 3.23$$

$$\epsilon_b = 10.4$$

The computed layer dielectrics and thickness are shown in the box in the upper right hand corner of Figure 2. The slight differences with those values calculated above is attributed to rounding errors.

1.4. Relating the Computed Dielectrics to Engineering Properties

The engineering properties of most interest to highway engineers are the air void content of the HMA layer and the moisture content of the granular base. Both of these impact the computed layer dielectrics. The computed dielectric for any layer is a function of the volumetric ratios of the components and their individual dielectric values. For example, the major components of a dry HMA layer are aggregate, asphalt, and air. For a granular base the components are aggregate, air, and water. The typical component dielectrics are tabulated below:

Material	Dielectric
Air	1.0
Water	81.0
Aggregate	5.5 (range 4 to 8 depending on rock type)

Asphalt 2.2

Therefore, the addition of more air to a HMA surface layer will cause a significant reduction in its dielectric value. Consequently, the addition of moisture to a granular base layer will cause a significant increase in its dielectric value. Continuous surface and base dielectric plots can be computed from a GPR survey as the vehicle passes over the newly constructed HMA layer. A typical surface dielectric plot from a newly placed Type B material which contained visual segregation is shown in Figure 3. The sharp decreases in the surface dielectric were correlated to segregated areas in the new mat.

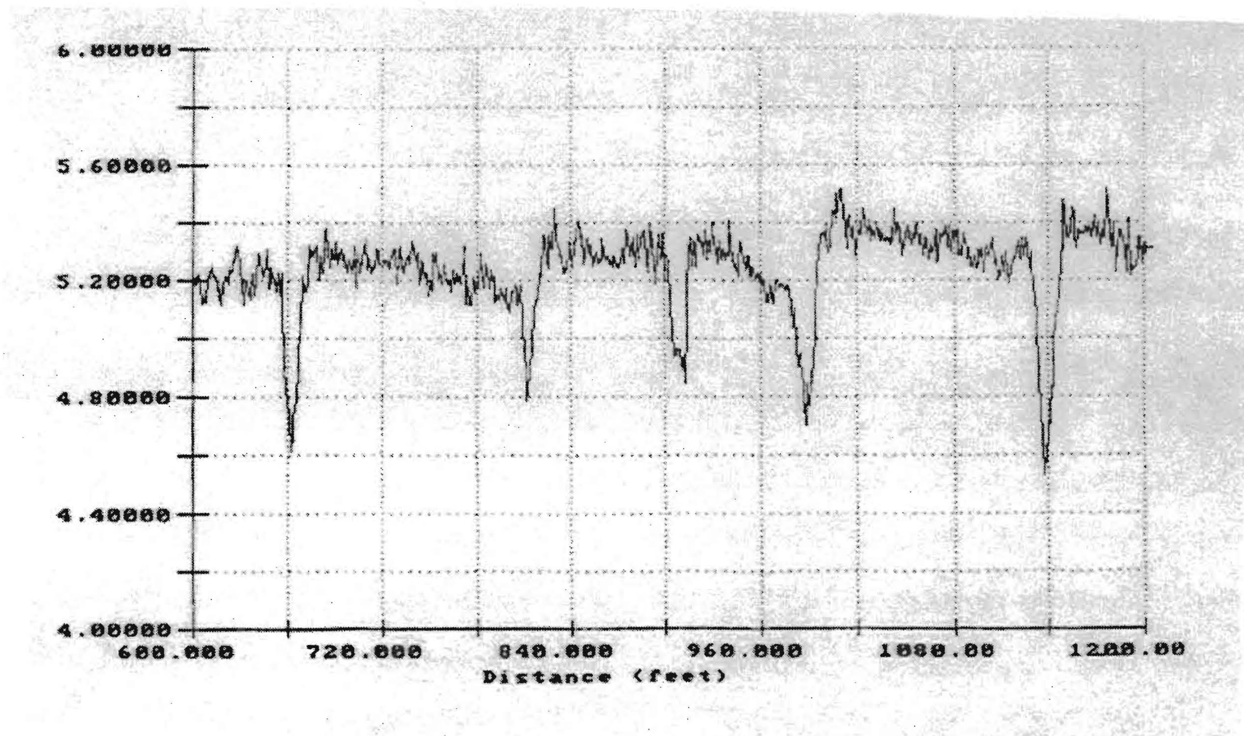


Figure 3. Surface Dielectric Plot Obtained on a HMA Layer which Contained Truck-End Segregation(Type B Material, IH 20 Odessa).

The relationship between surface dielectric and HMA air voids was studied extensively in Finland in the early 1990s by Timo Saarenketo of the Finnish National Roads Administration. As part of these studies, a laboratory test was performed to relate the surface dielectric measured with a probe to the air void content of the material. The researchers performed tests on both laboratory molded and field samples. Figure 4 shows a typical set of results from the laboratory samples. There is scatter in the data but it is noted that the results are for a range of mixes with different aggregate types. The work of the Finnish researchers found that the exponential relationship shown in Figure 4 is reasonable for both field and lab samples.

The conclusion from the earlier studies in Texas and Finland is that the air void content of a HMA layer is directly related to that layers surface dielectric value. This will be evaluated further in the section 3 and 4 of this report.

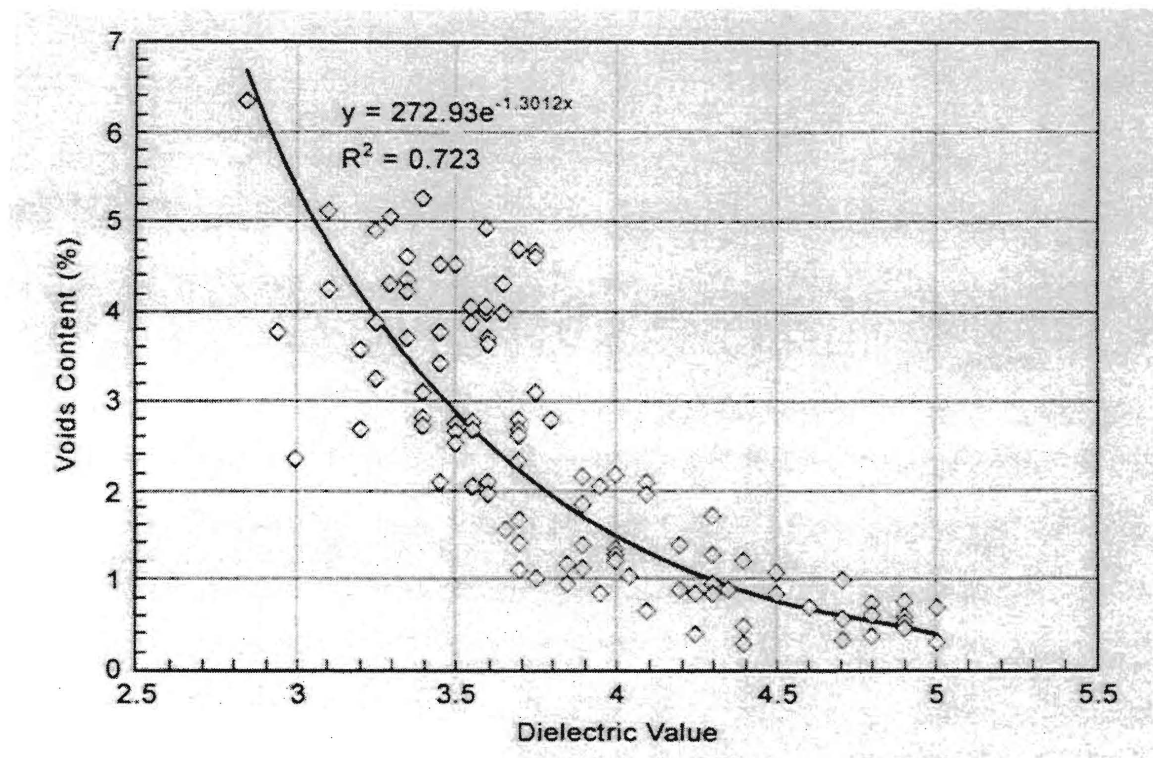


Figure 4. Laboratory Test Results Relating Air Void Content of HMA Samples to Measured Dielectric Values. (Saarenketo 1996)

2. DATA COLLECTION PLAN IN EL PASO

Photographs of the GPR equipment used in the El Paso study and the test site layout are shown in Figure 5. The aluminum foil shown in the top photograph was used to ensure that the same starting location was used while performing multiple passes over the section. The lower photo shows the start location of the lane paved with the Lincoln MTD, the center lane was paved with the RoadTec device and the inside lane used the Barber-Greene MTD.

Figure 6 presents a single GPR trace from one location from the Lincoln section. The pavement structure originally consisted of several inches of HMA over a flexible base. Prior to placing the new material the section was milled leaving a variable thickness layer of old HMA. The nominal thickness of the new HMA layer was 3 ins. From Figure 6 the reflection marked as A_1 is from the surface of the pavement, the two peaks to the right of the surface reflection are reflections from the top of the old HMA layer and the top of the flexible base. The box in the upper right corner shows the measured amplitudes and time delays between peaks as well as the computed layer dielectrics and thicknesses. In evaluating the uniformity of the HMA surfacings it is the variation in the amplitude of surface reflection which is of prime interest in this study.

GPR testing of the experimental sections was conducted in two phases as described below;

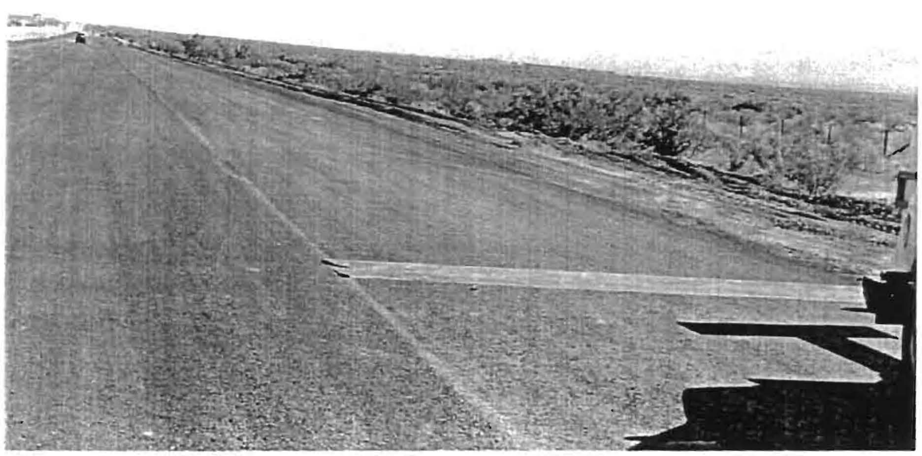
1) <u>Density Control Locations</u>

For each MTD the Texas DOT selected 6 locations to performed field density measurements and to take validation cores. These were locations where either the paver stopped or where segregated areas were visually apparent in the mat. At each location a series of nuclear density measurements were performed over a distance of approximately 60 ft and three cores were taken for lab testing. At each of these sites a GPR survey was conducted while traveling at 10 mph over the site with a GPR trace collected at 1 foot intervals. Markers were placed in the GPR data file to denote the beginning and ending of these test areas. A comparison of the GPR and lab densities is given in Section 3 of this report.

2) <u>Multiple Passes of representative sections</u>

The GPR provides subsurface information from a longitudinal strip of pavement which is about 8 inches wide. To gain information on the variability of these mats in the transverse direction multiple passes were made over representative section placed with each MTD device. Sections approximately 1490 ft long were selected. GPR data was collected at 5 transverse locations (outer edge, outer wheel path, middle, inside wheel path and inside edge). The results obtained are presented in Section 4 and in the Appendix to this report.

A. GPR Equipment



B. Start of Lincoln Test Site (Outside Lane)

Figure 5. El Paso Test Site.

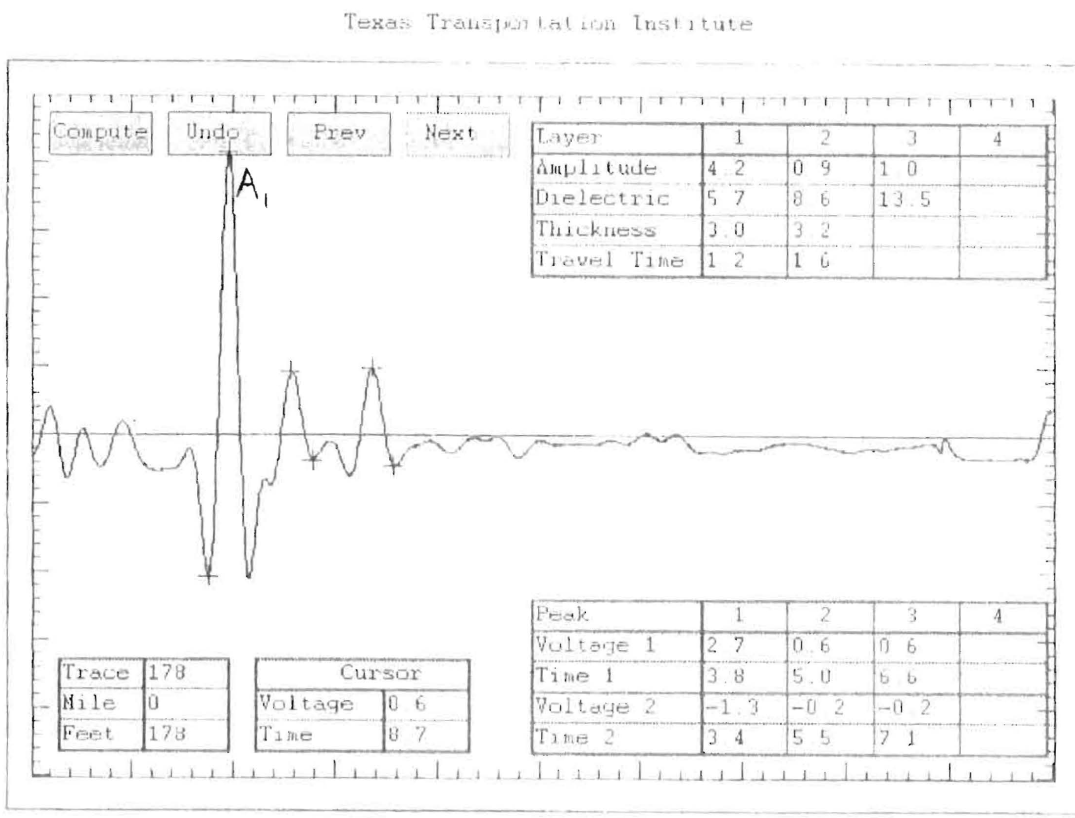


Figure 6. Typical GPR Trace from the Test Section Placed with the Lincoln MTD.

3. CORRELATING GPR SURFACE DIELECTRICS WITH MEASURED LAB DENSITIES

Figure 7 shows the computed surface dielectrics from one of the 60 ft long test areas selected by TxDOT for nuclear density measurements and coring. This is from location #5 (Sta. 185) for the section paved with the Lincoln MTD. The 3 coring locations are marked in figure 7. At each core location the computed surface dielectric and measured lab density (lbs/cuft) are given. The trend is that as the HMA density decreases the computed surface dielectric decreases. This is consistent with the discussion presented earlier in this report.

Figure 8 presents the correlation between the computed surface dielectric and the laboratory determined densities for the Lincoln MTD section. Again the trend is promising as the surface dielectric increases the lab density increases. The shape of the curve is reasonable, the relationship appears curvilinear heading towards an asymptote on the density scale.

The results shown in Figures 7 and 8 are the best documentation available evaluating the relationship between the computed surface dielectric and measured lab density. More work is needed in this area. There is some scatter in the data which may be partially attributed to the manner in which the data was collected. The GPR data was collected while traveling over the section at 10 mph, and placing marks in the data file noting the start and end of each section. The core locations were estimated from the offset distance provided by TxDOT. Therefore there may be some inaccuracies in exactly matching GPR data to the core locations.

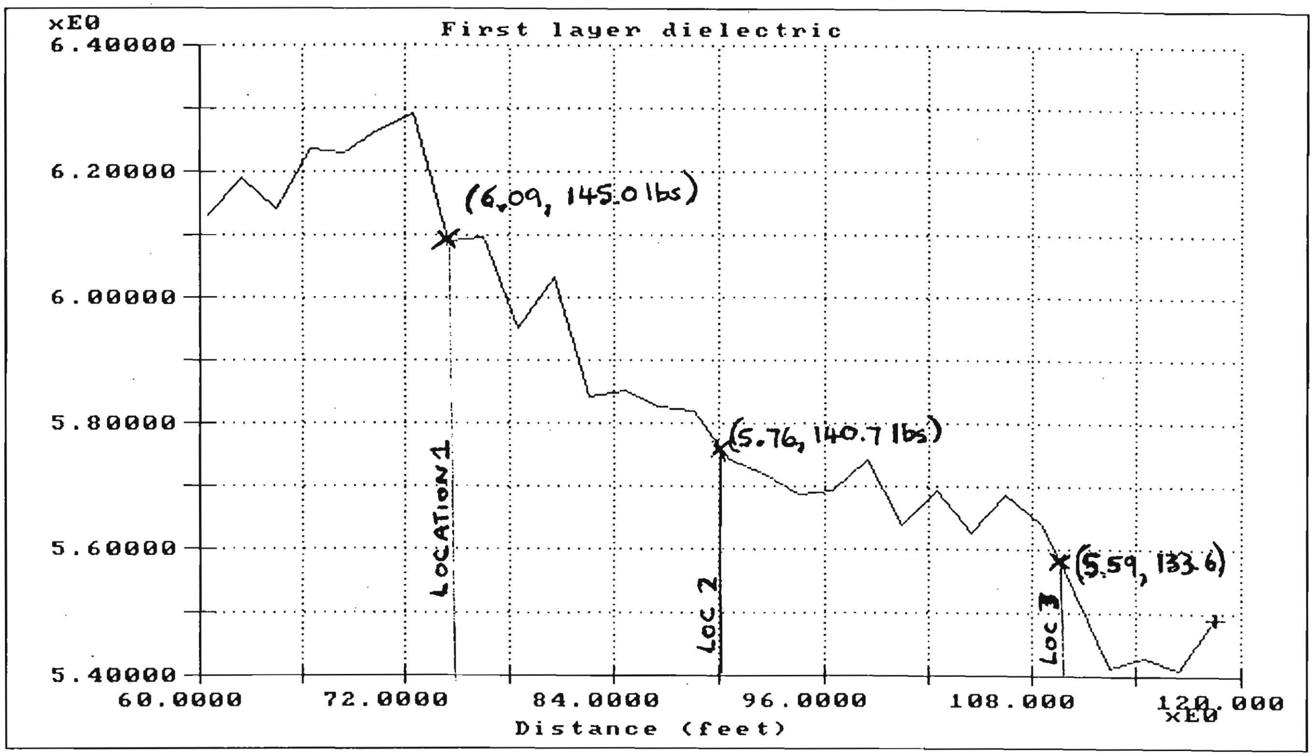


Figure 7. **Surface Dielectric Plot for Lab Validation Test Area 5 (Sta 185 + 00) from Lincoln Section. At Each of the 3 Coring Locations the Computed Surface Dielectric and Measured Laboratory Density is Shown.**

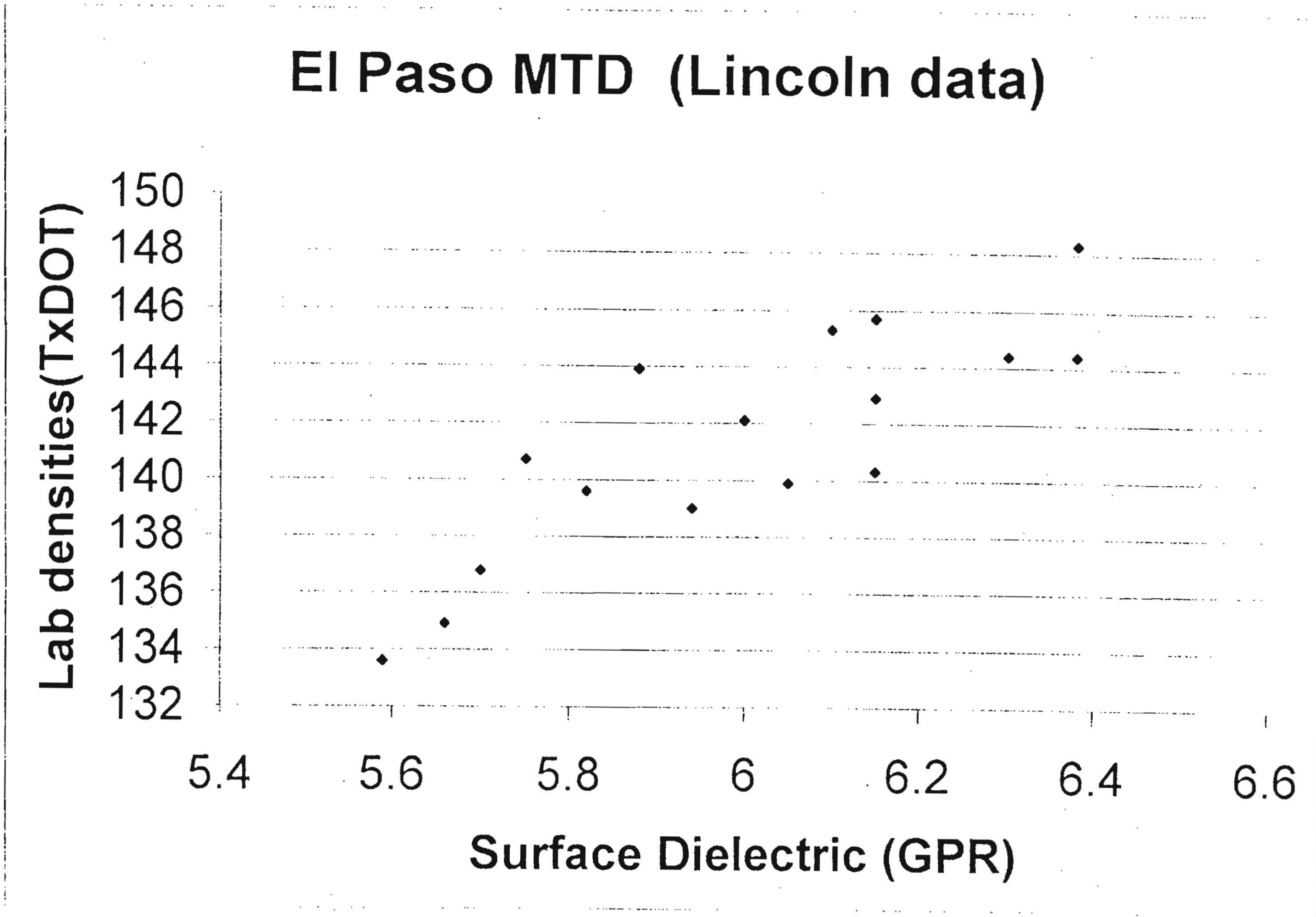


Figure 8. Summary Data from the Lincoln Section.

4. SURFACE DIELECTRIC PLOTS FROM DIFFERENT MTD'S

Representative surface dielectric plots from each of the 5 MTD's are shown in Figures 9 thru 14. Note two different Barber-Greene sections (Figure 10 and 11) were established and tested. Each section was approximately 1490 ft long and the distance scale is shown as the x-axis in each figure. As discussed earlier, sudden localized dips in the surface dielectric have been found to correlate with areas of segregation. Therefore the quality of the mat is judged in terms of both the overall variations in the surface dielectric and the absence of sudden dips.

Based on this criteria the best performer was the RoadTec MTD shown in Figure 12. The plot shows some variation in dielectric but no major localized dips. The high dielectric measured in the middle of the section should be ignored, it was attributed to a thin piece of metallic foil placed on the surface of the pavement for the profile measuring equipment. The next best performer was Barber-Greene 1 shown in Figure 10, which had a major problem area at one end of the section but this was a transition point between MTD devices. A few minor dips are marked on Figure 10. The performance of the other 3 devices (Lincoln, Cedar Rapids and Blaw Knox) was judged as inferior to the RoadTec MTD. The surface dielectric plots shown in Figures 9, 13 and 14, all show major periodic dips in the surface dielectric plots.

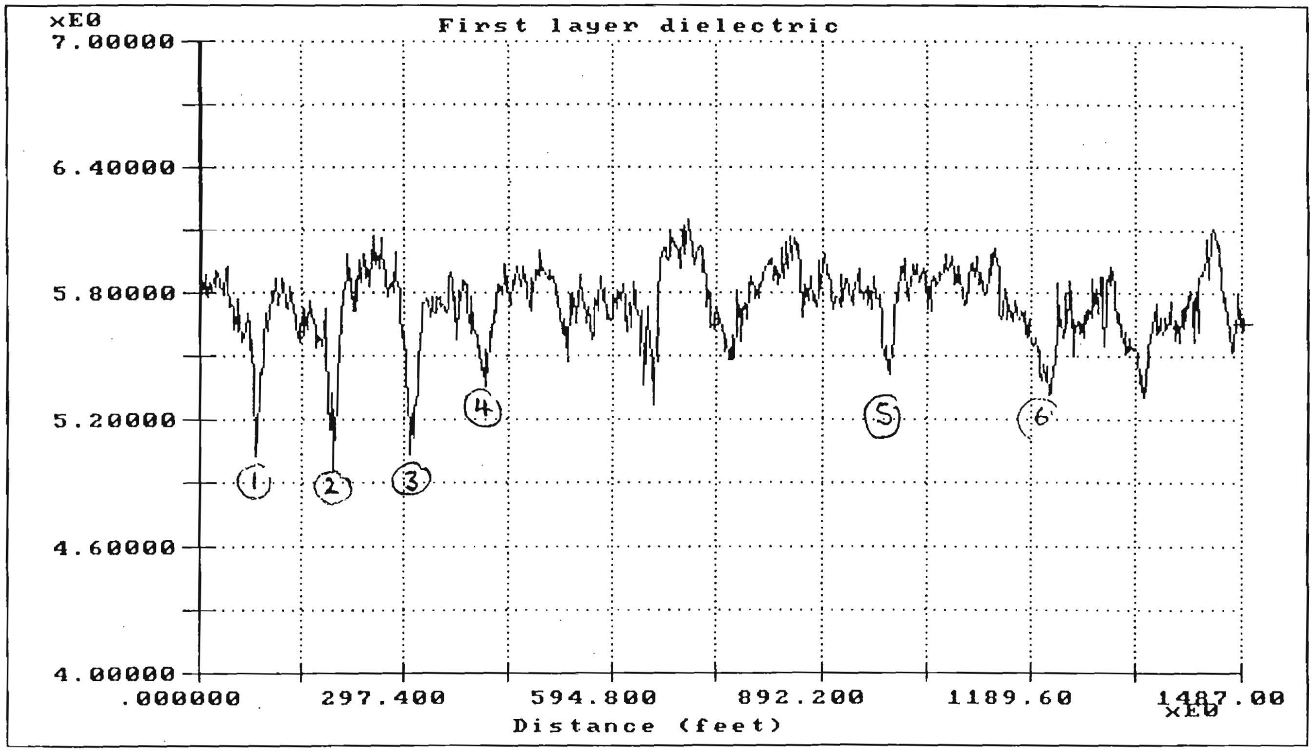


Figure 9. **Surface Dielectric Plot for LINCOLN MTD.**
(Note: Regular dips in plot, marked 1, 2, etc.)

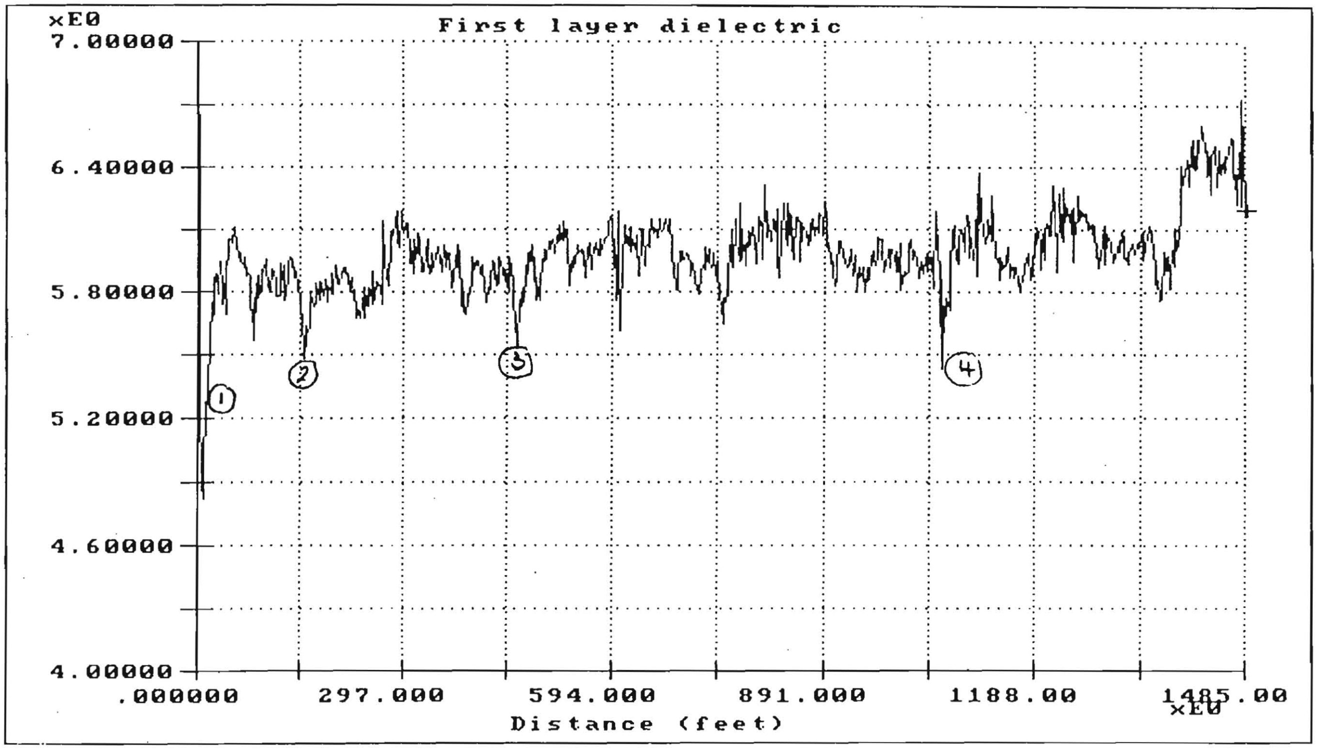


Figure 10. Surface Dielectric Plot of BARBER-GREENE 1 MTD.
(Note: Very low values at start of section, this was a transition area. Dips marked throughout section).

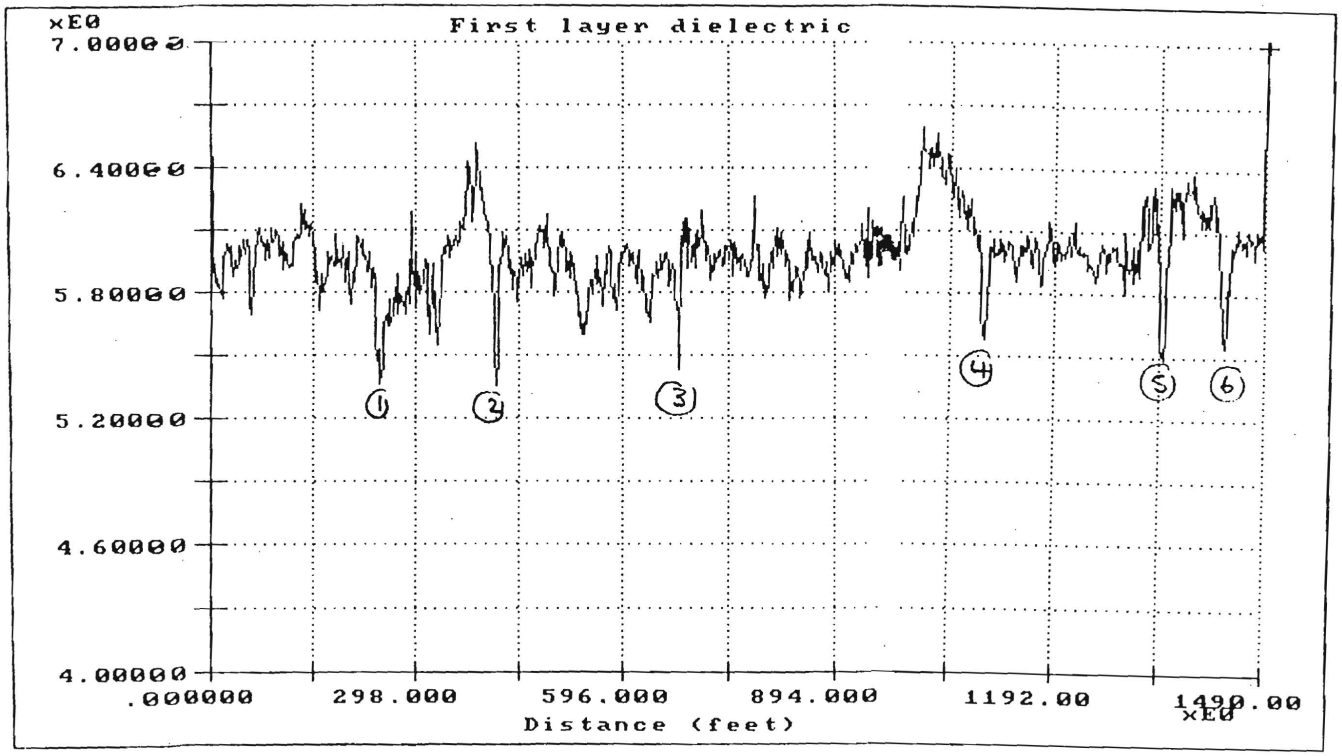


Figure 11. **Surface Dielectric Plot of BARBER-GREENE 2 MTD. (Note: Periodic dips marked, 1, 2, etc.)**

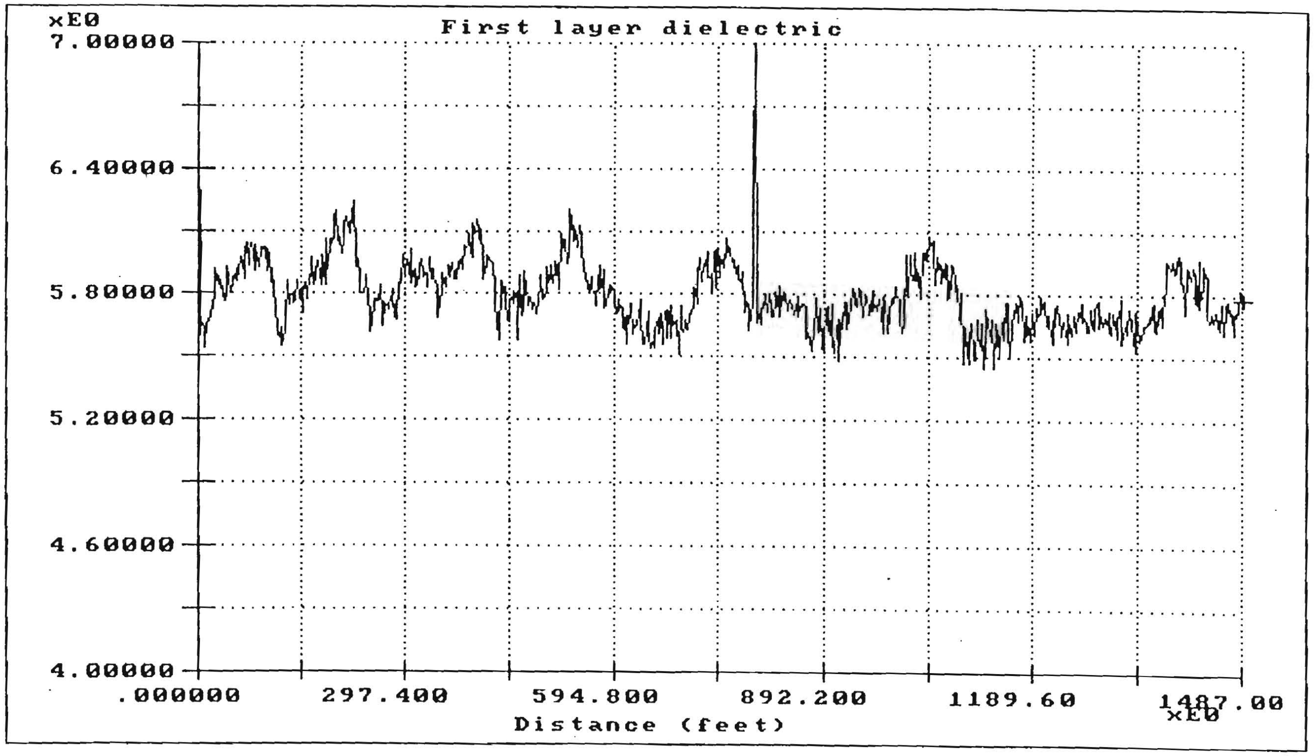


Figure 12. Surface Dielectric Plot of ROAD TECH MTD.

(Note: Absence of any localized dips indicating uniformity. High value in middle of run associated with metal foil strip on surface)

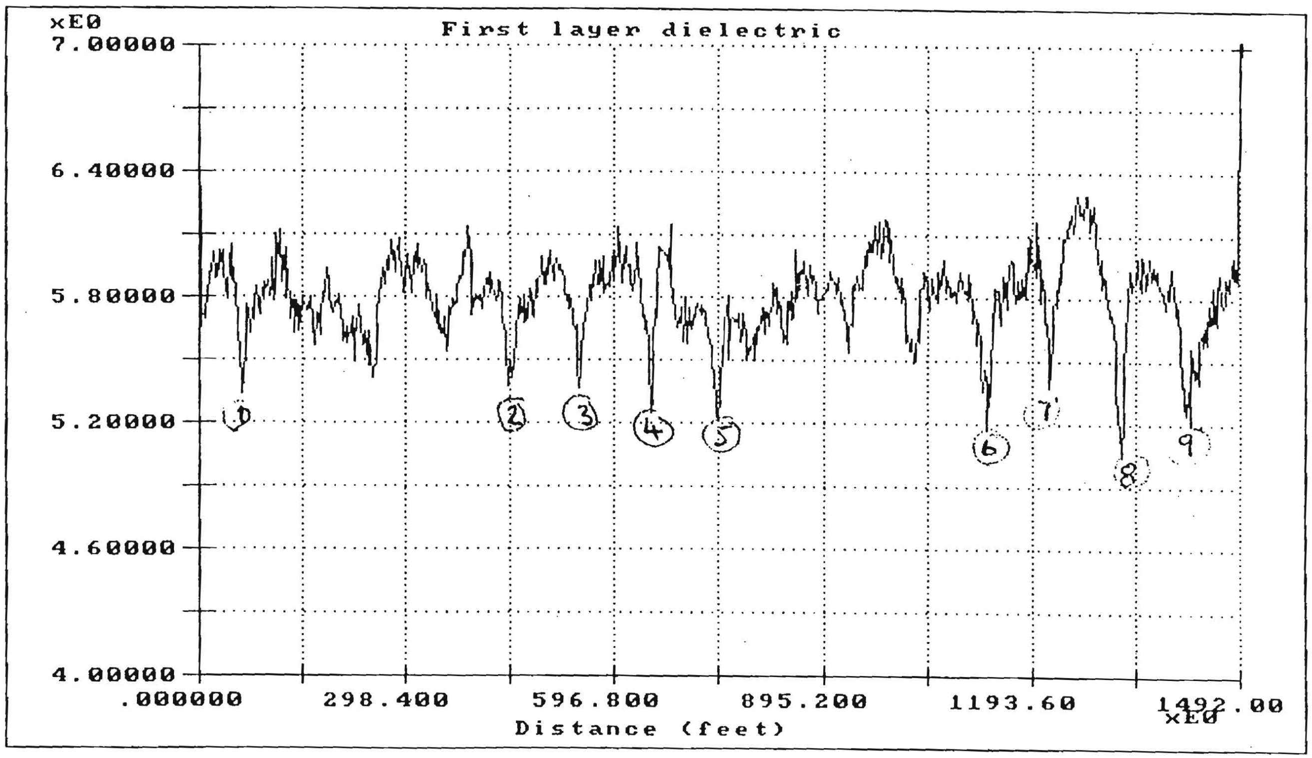


Figure 13. Surface Dielectric Plot of CEDAR RAPIDS MTD.
(Note: Regular dips in lot, marked 1, 2, etc.)

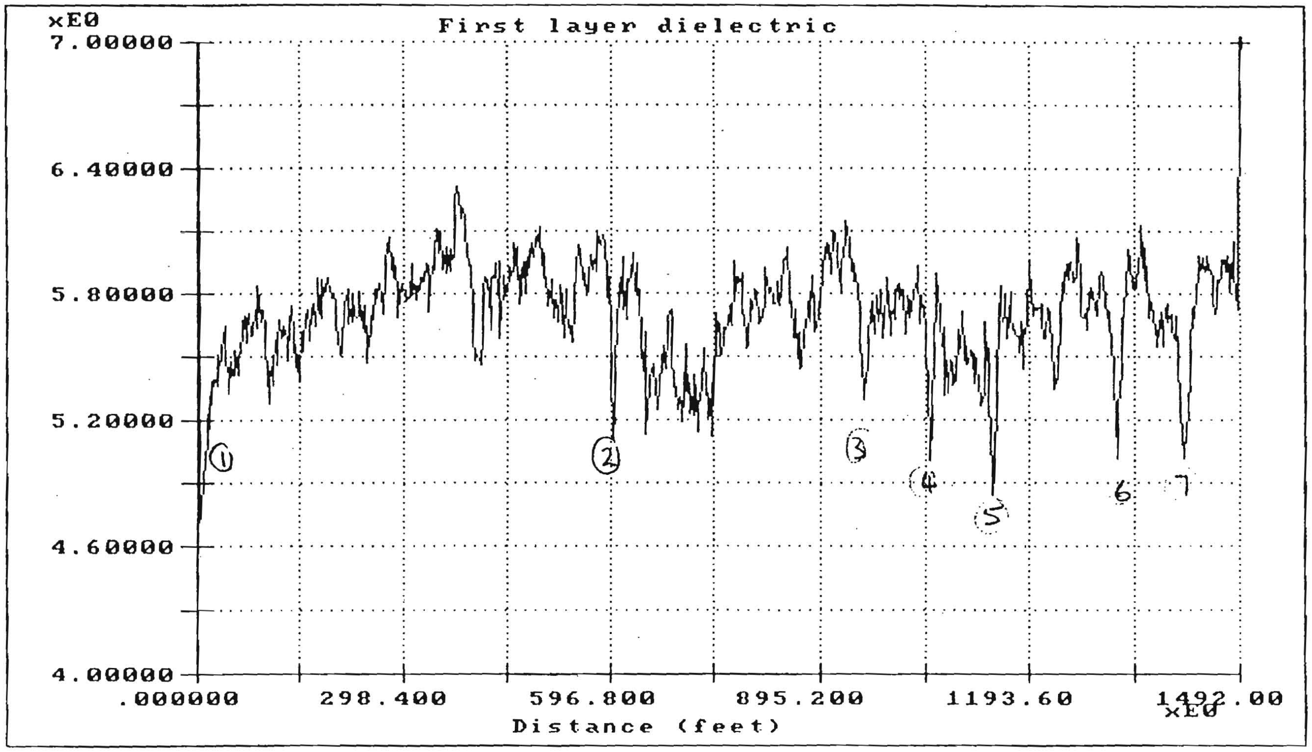


Figure 14. Surface Dielectric Plot of BLAW-KNOX 1 MTD.

5. CONCLUSIONS AND RECOMMENDATIONS

1. Based on the laboratory densities there appears to be a good correlation between surface dielectrics computed from the Ground Penetrating Radar reflections and the laboratory measured core densities. As expected from theory low surface dielectric correlate to low density.

2. GPR with its ability to rapidly scan an entire section and provide continuous results provides a very promising tool for quality control evaluations of new HMA surfaces.

3. The quality of the HMA mat can be related to the uniformity of the surface dielectric plot and the number of segregated areas can be estimated from the number of sudden localized dips in surface dielectric.

4. For the mix used in El Paso the RoadTec MTD is judged to provide the most uniform defect-free HMA layer.

5. The Barber-Greene MTD provided reasonable performance on the first test area (Figure 10) but poorer performance in the second area (Figure 11)

6. The other three MTD's (Lincoln, Blaw-Knox and Cedar-Rapids) were judged as inferior to the RoadTec device.

Appendix 1

SURFACE DIELECTRIC PLOTS FOR ENTIRE LANE

As discussed a total of 5 longitudinal passes were made over each 1500 ft by 12 ft test area. In order to present a"birds-eye" view of the potential problem areas a color coded plot was developed. These are shown in Figures 15 thru 19. Each figure shows a plan view of the test area. It is a composite of the information collected in each of the 5 passes (outer edge, outer wheel path, middle, inner wheel path and inner edge). In each Figure the red areas are locations of reasonable dielectric, the low dielectric areas have different colors. The lowest dielectric (lowest density) are the areas colored blue.

Each Figure is discussed below;

Figure 15 Lincoln MTD
The low dielectric (low density) areas line up across the mat. The low density area are at approximately 100 ft spacing. This appears to be the classical "truck-end" segregation pattern.

Figure 16 Barber-Greene MTD
This data was collected in the East to West direction. The major defect is at the beginning of the section, this is actually a transition areas. The other problem area was in the inside (free) edge of the mat.

Figure 17 RoadTec MTD
No major problems. Minor problems found in on one edge. This appears to be the most uniform section in the study.

Figure 18 Cedar Rapids MTD
Problems mostly on inside edge and in the last few hundred feet of the section. Towards the end the segregated areas cover the full width of the mat.

Figure 19 Blaw-Knox
Major problems in many areas, particularly in both wheel paths.

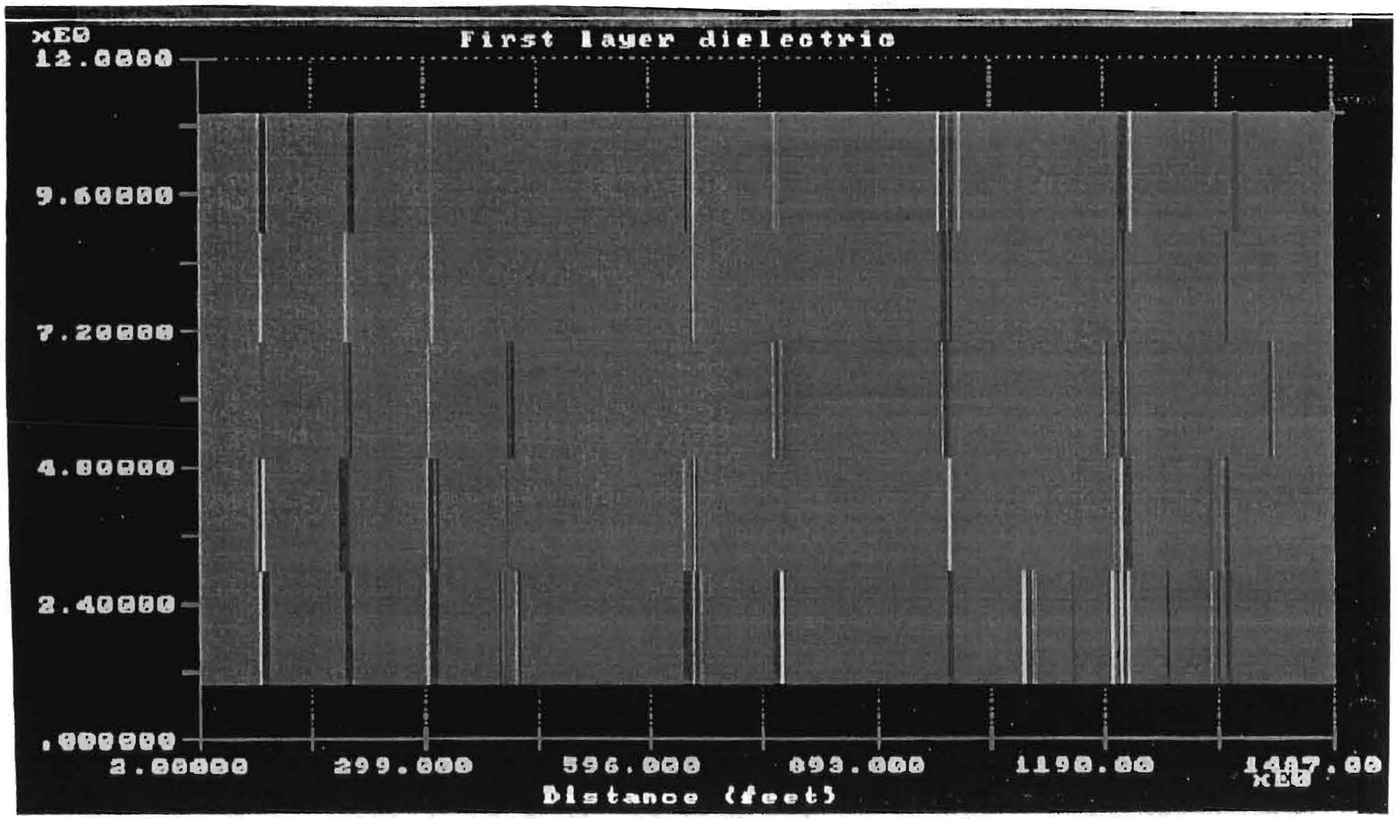


Figure 15. Plan View of Lincoln Section. (1490 ft by 12 ft). Blue Areas Indicate Low Dielectric.

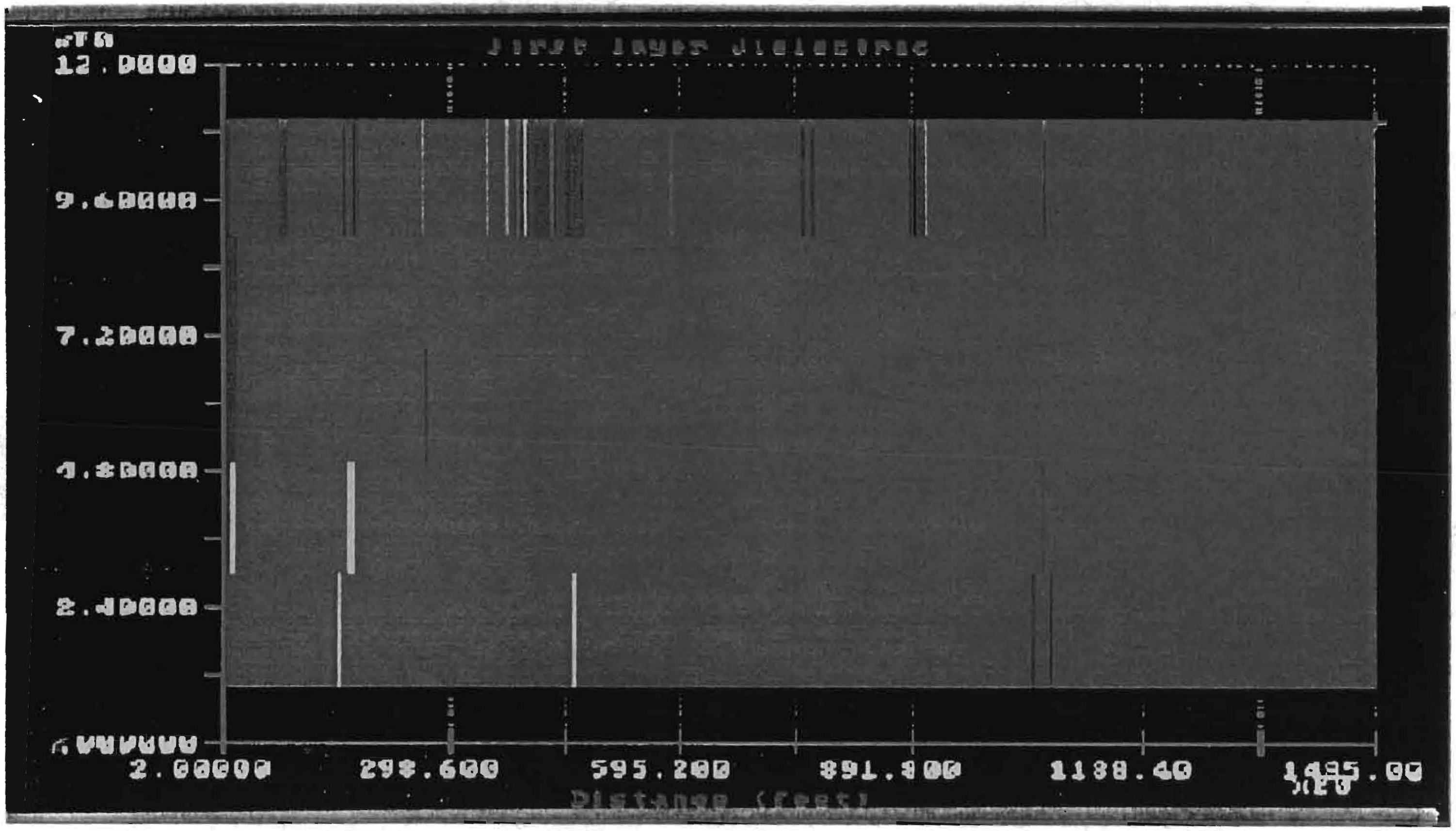


Figure 16. Plan View of Barber Greene Section. (1485 ft by 12 ft). Blue Areas Indicate Low Dielectric.

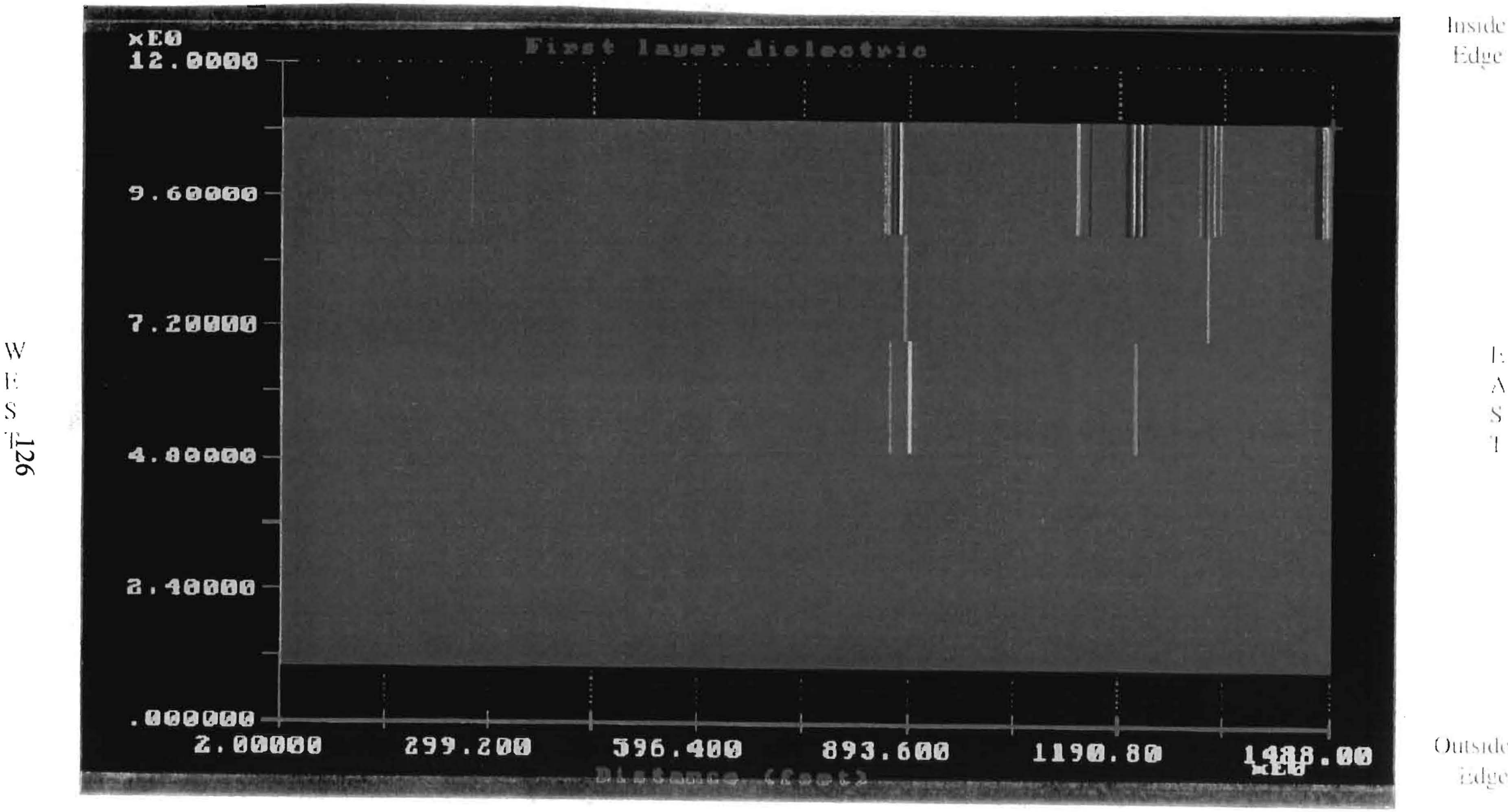


Figure 17. Plan View of Road Tee Section. (1488 ft by 12 ft). Blue Areas Indicate Low Dielectric.

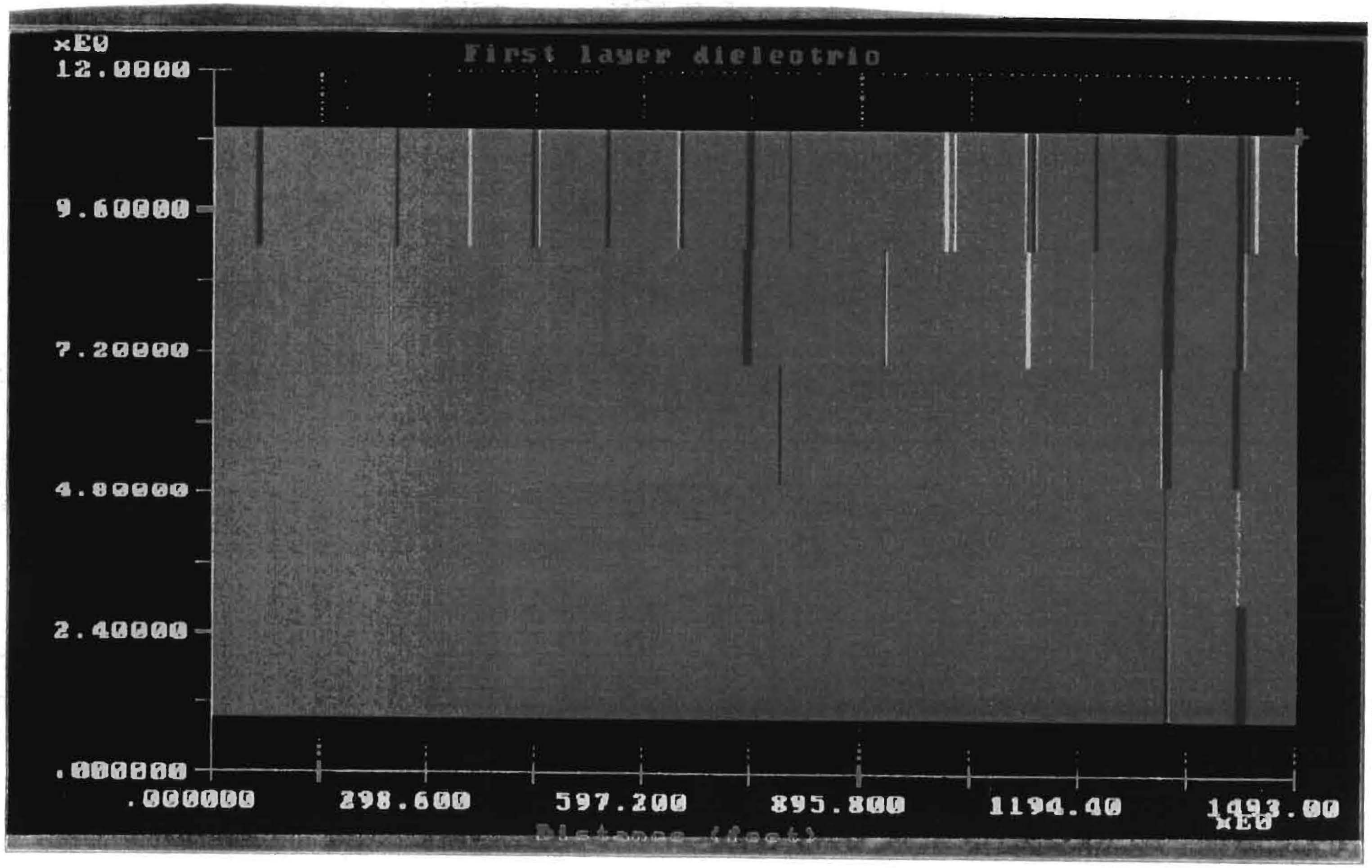
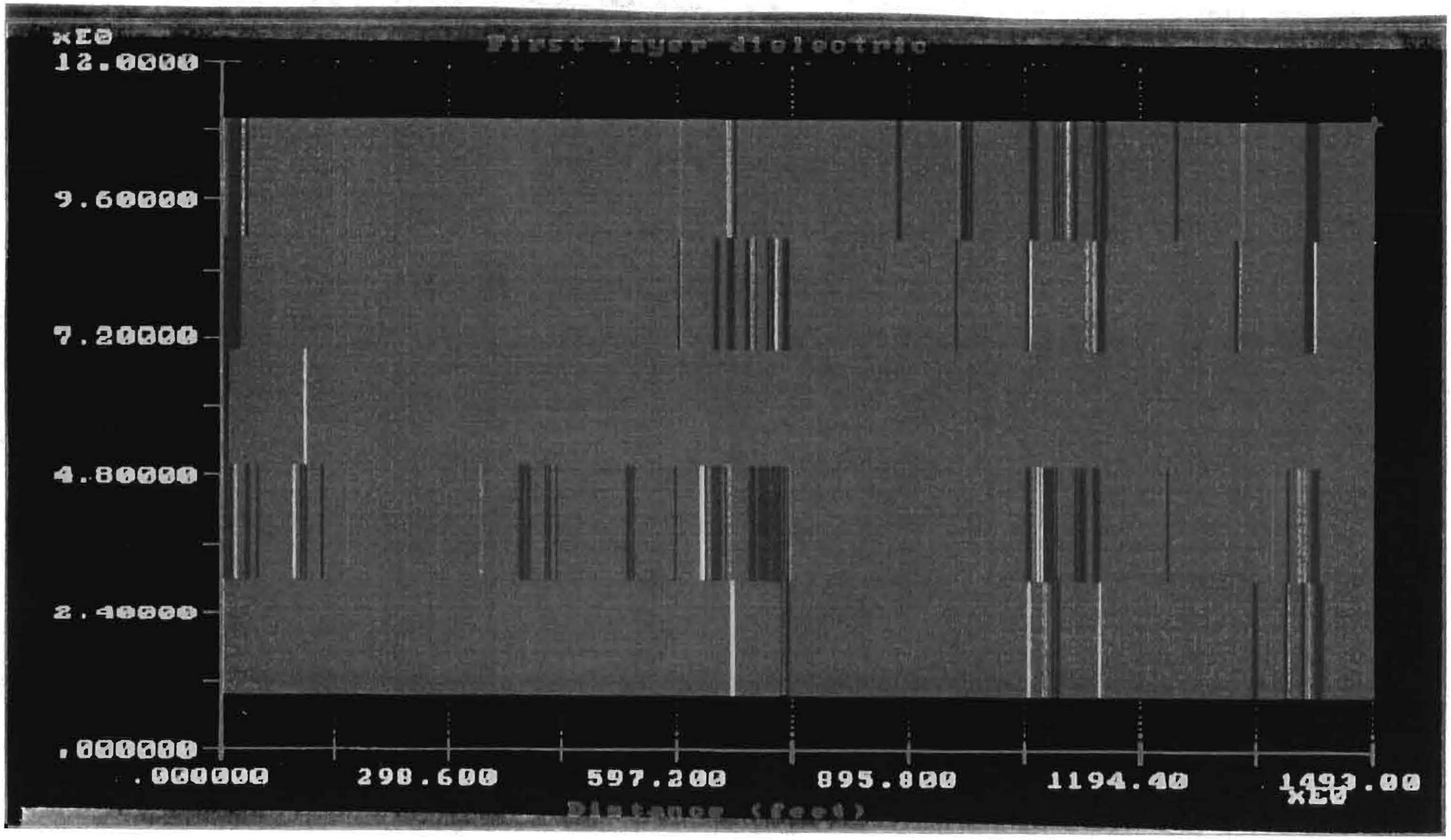


Figure 18. Plan View of Cedar Rapids Section. (1493 ft by 12 ft). Blue Areas Indicate Low Dielectric.



Inside Edge

WEST

EAST

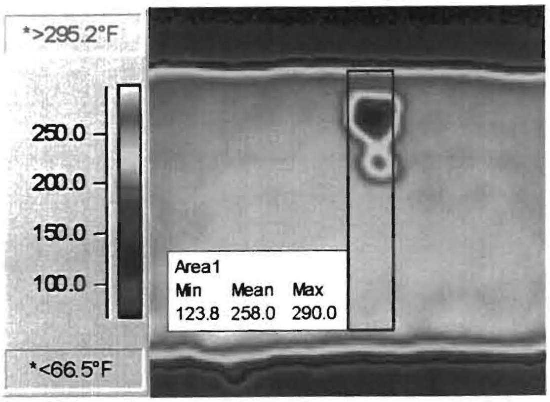
Outside Edge

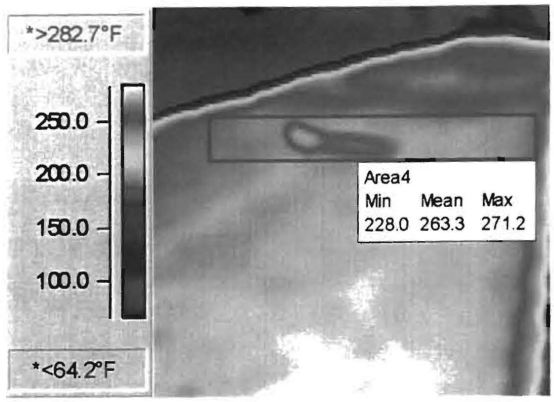
Figure 19. Plan View of Blaw-Knox Section. (1493 ft by 12 ft). Blue Areas Indicate Low Dielectric.

APPENDIX – D

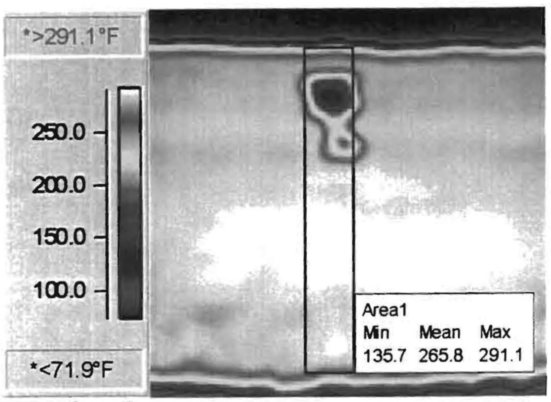
IMAGES FOR EVALUATING THERMAL CAMERAS

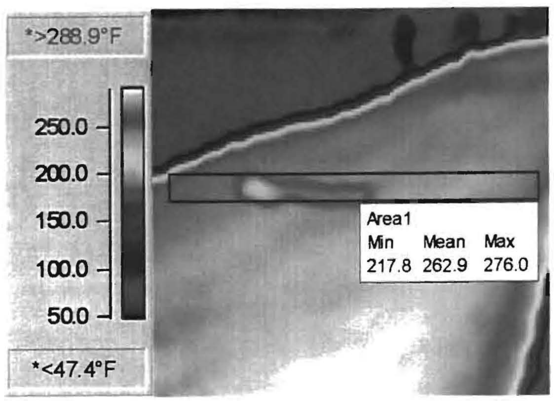
IMAGES BY INFRAMETRICS THERMASNAP



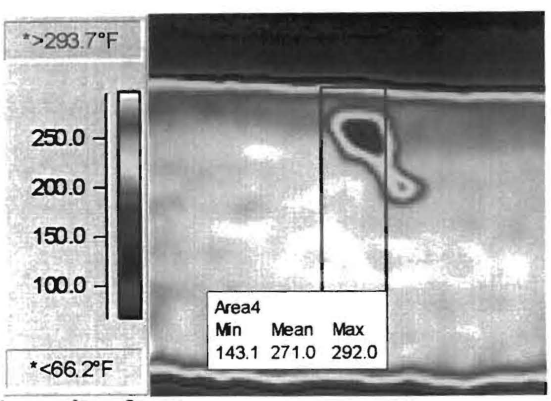


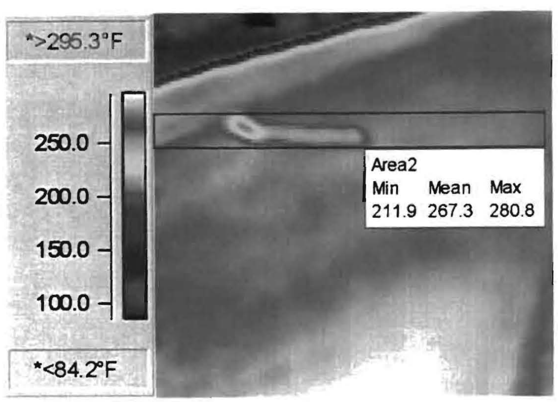
Location 1





Location 2



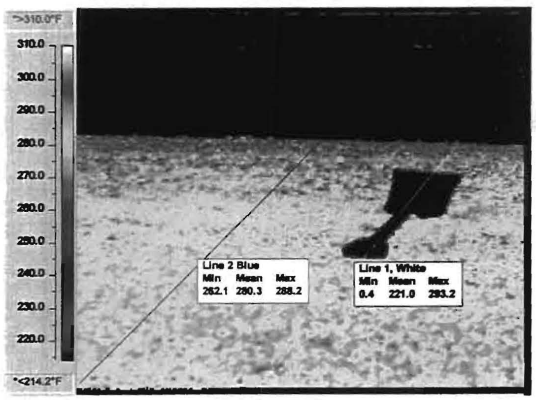


Location 3

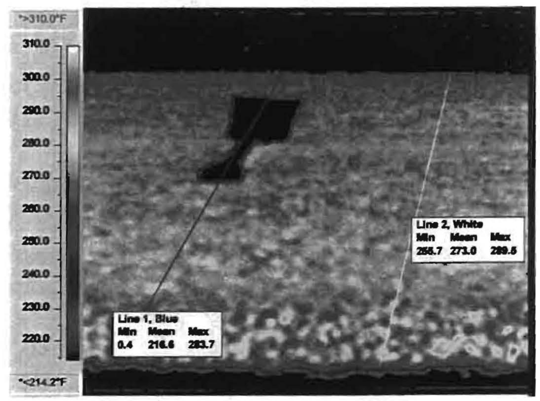
IMAGES BY INFRAMETRICS THERMACAM MODEL PM-280

Location: I-10, Exit 55 East Bound, El Paso Texas
Paver: Barber Greene 260C, 10B Extendable Screed
MTD: Blaw-Knox MC 330 with Mixing Hopper Insert
Mix: Type 1 Binder, 1 ¼" Stone
Paving Width: 15' Paving Depth: 3"
Haul Distance: 30 Miles, 45 Minutes
Date: October 22, 1999

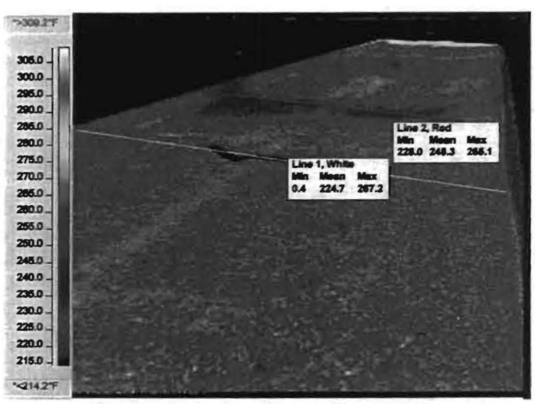
Location 1 - Test 1



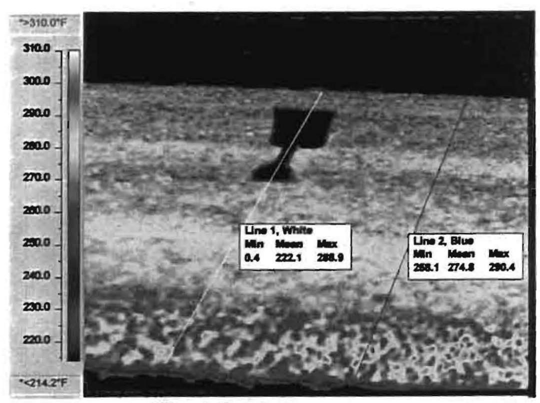
Test 2



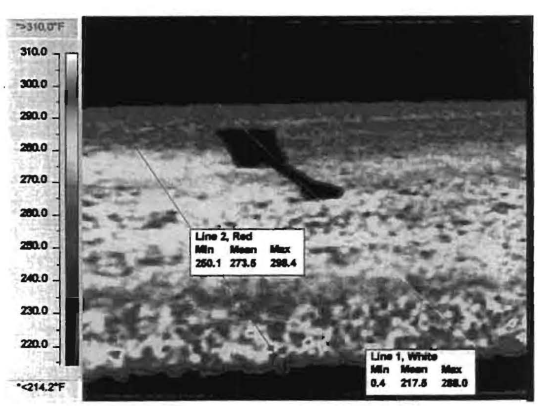
Location 2 - Test 1



Test 2



Location 3 - Test 1



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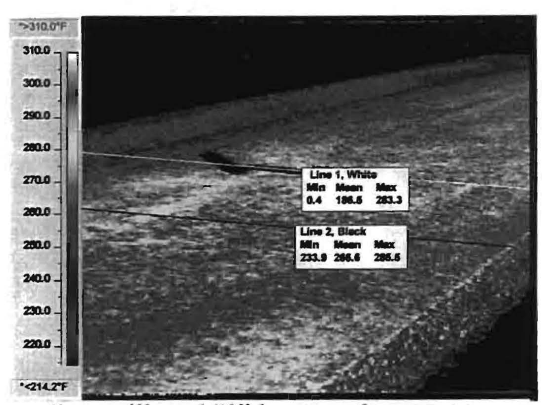
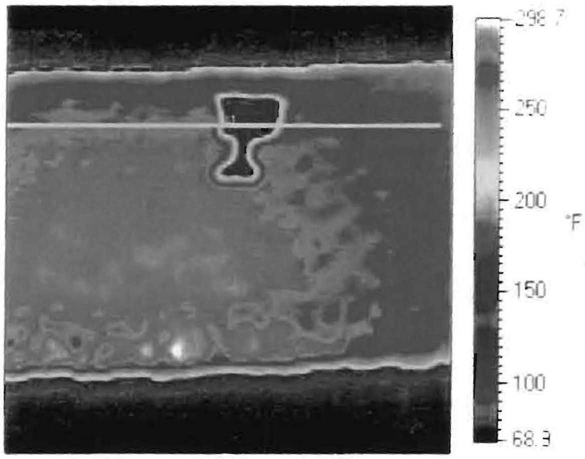


*Where line passes across the target shovel, temperature readings will read "0" because the target temperature is less than 210 degrees

IMAGES BY IR SNAPSHOT MODEL PM-525

Test 1



IR00202.ISI

Info:

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Image Date/Time	Friday, October 22, 1999 9:47:55 AM
Report Date/Time	Monday, October 25, 1999 8:53:09 AM
Temp Unit	Fahrenheit
User	Rick James
Location	El Paso I-10
Target	

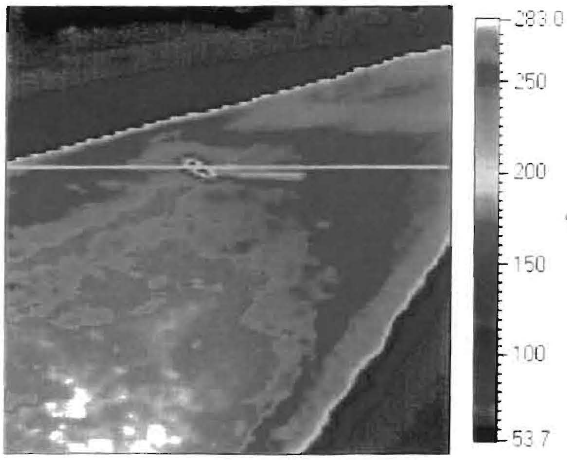
Data:

Label	Emissivity	Background	Average	Std Dev	Max	Min
L1	0.93	83.93	256.87	47.08	282.2	117.8

Comments:

Picture #:202	Paving Speed: 40FPM	Stopped ❑ Time Stopped ❑ Windrow Length	
Head of Material: ½ Auger			
Auger speed: Erratic ❑	Estimated Speed : 5-40 RPM	Auger height low	
Plant Output Temperature: 340		Temperature Input at Paver 320	
Visual Segregation:	Other: Open textured mat		
Ambient at 7:30 am 44 degrees F wind N 5 left to right across windrow			
Type A mix 3" depth 14' wide			

Test 2



IR00203.ISI

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Temp Unit	Fahrenheit
User	Rick James
Location	El Paso I-10
Target	

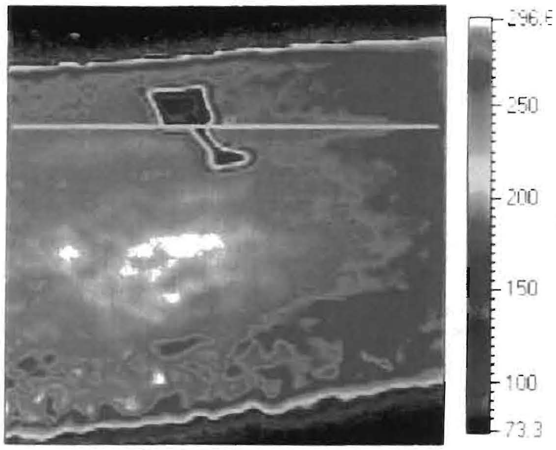
Data:

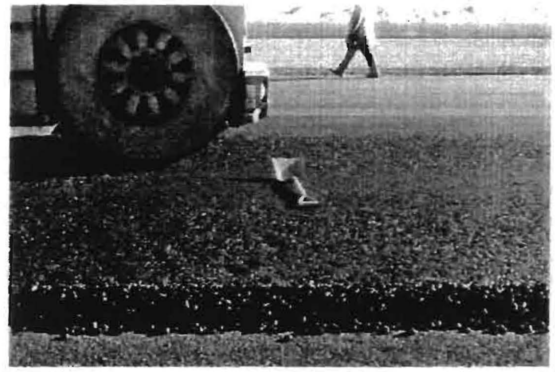
Label	Emissivity	Background	Average	Std Dev	Max	Min
L1	0.93	83.93	244.26	18.58	260.7	165.6

Comments:

Picture #:202	Paving Speed: 40FPM Stopped ❑ Time Stopped ❑ Windrow Length
Head of Material: ½ Auger	
Auger speed: Erratic ❑ Estimated Speed : 5-40 RPM Auger height low	
Plant Output Temperature: 340 Temperature Input at Paver 320	
Visual Segregation: Other: Open textured mat	
Ambient at 7:30 am 44 degrees F wind N 5 left to right across windrow	
Type A mix 3" depth 14' wide	

Test 3





IR00204.ISI

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Temp Unit	Fahrenheit
User	Rick James
Location	El Paso I-10
Target	

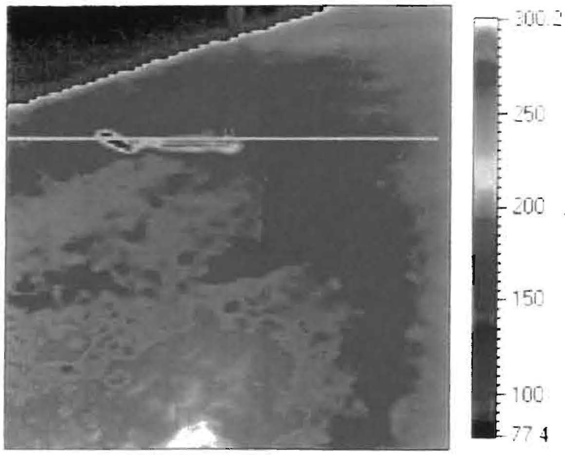
Data:

Label	Emissivity	Background	Average	Std Dev	Max	Min
L1	0.93	83.93	274.82	22.38	287.6	161.8

Comments:

Picture #:202	Paving Speed: 40FPM	Stopped ❑ Time Stopped ❑ Windrow Length
Head of Material: ½ Auger		
Auger speed: Erratic ❑	Estimated Speed : 5-40 RPM	Auger height low
Plant Output Temperature:	340	Temperature Input at Paver 320
Visual Segregation:	Other: Open textured mat	
Ambient at 7:30 am 44 degrees F wind N 5 left to right across windrow		
Type A mix 3" depth 14' wide		

Test 4



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User	Rick James
Location	El Paso I-10
Target	

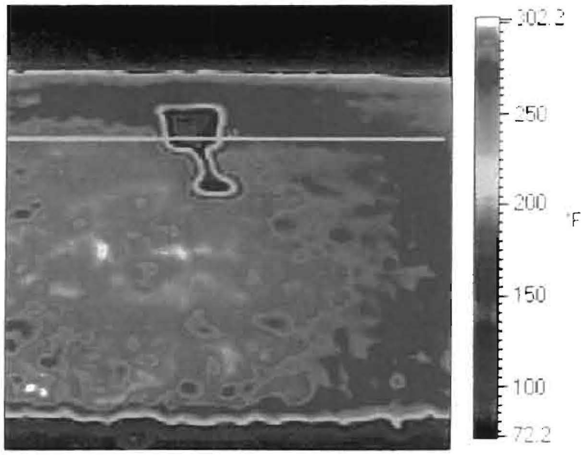
Data:

Label	Emissivity	Background	Average	Std Dev	Max	Min
L1	0.93	83.93	255.32	23.77	273.7	161.3

Comments:

Picture #:202	Paving Speed: 40FPM	Stopped ❑ Time Stopped ❑ Windrow Length
Head of Material: ½ Auger		
Auger speed: Erratic ❑	Estimated Speed : 5-40 RPM	Auger height low
Plant Output Temperature: 340		Temperature Input at Paver 320
Visual Segregation:	Other: Open textured mat	
Ambient at 7:30 am 44 degrees F wind N 5 left to right across windrow		
Type A mix 3" depth 14' wide		

Test 5



IR00206.ISI

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Temp Unit	Fahrenheit
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Location	El Paso I-10
Target	

Data:

Label	Emissivity	Background	Average	Std Dev	Max	Min
L1	0.93	83.93	266.42	41.26	295.6	135.4

Comments:

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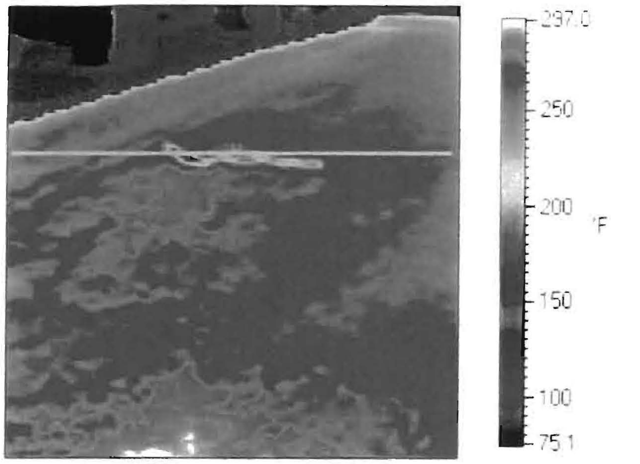
Head of Material: ½ Auger		
Auger speed: Erratic ❑	Estimated Speed : 5-40 RPM	Auger height low
Plant Output Temperature: 340		Temperature Input at Paver 320
Visual Segregation:	Other: Open textured mat	
Ambient at 7:30 am 44 degrees F wind N 5 left to right across windrow		
Type A mix 3" depth 14' wide		

R00206.ISI 10/25/99 9:03 AM 1 of 1

Test 6



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Temp Unit	Fahrenheit
User	Rick James
Location	El Paso I-10
Target	

Data:

Label	Emissivity	Background	Average	Std Dev	Max	Min
L1	0.93	83.93	251.49	20.78	271.1	175.6

Comments:

Picture #:202	Paving Speed: 40FPM	Stopped ❑ Time Stopped ❑ Windrow Length

Head of Material: ½ Auger

Auger speed: Erratic ❑ Estimated Speed : 5-40 RPM Auger height low

Plant Output Temperature: 340 Temperature Input at Paver 320

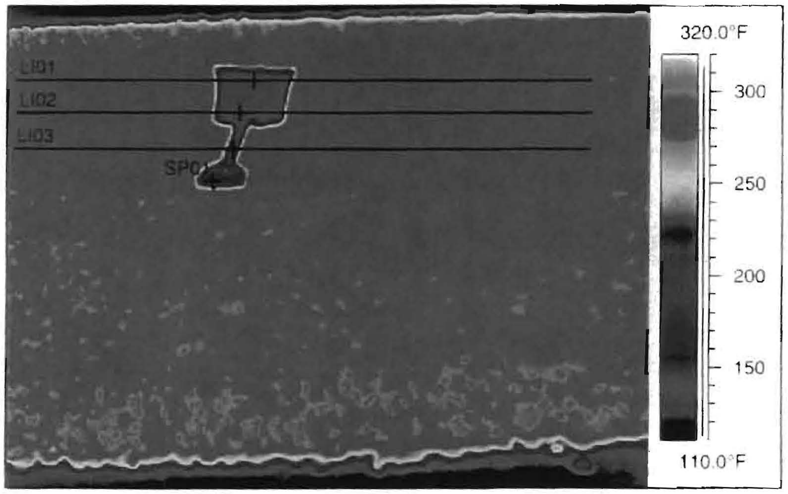
Visual Segregation: Other: Open textured mat

Ambient at 7:30 am 44 degrees F wind N 5 left to right across windrow

Type A mix 3" depth 14' wide

IMAGES BY FLIR AGEMA MODEL PM-550

El Paso, TX: Barber-Greene 260C Using an MC-330 with BG-650 Pick Up and BK Twin Pug Mill Hopper Insert

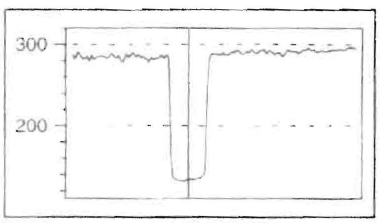


INGERSOLL-RAND
CONSTRUCTION & MINING

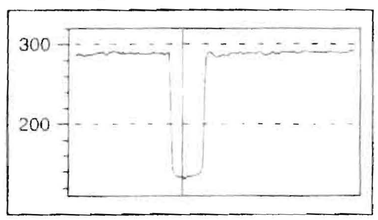
Image Number:
Shovel Front 1

10/22/99

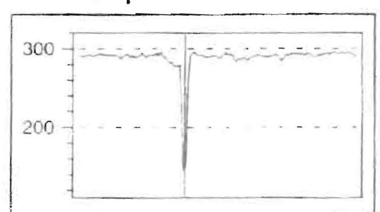
Temp Profile of LI01



Temp Profile of LI02



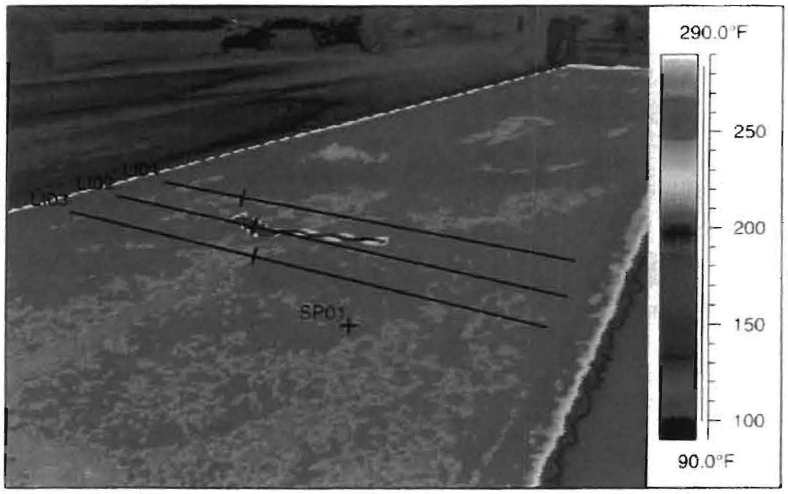
Temp Profile of LI03



	Cursor Temp	Max Temp	Min Temp	Avg Temp
LI01	133.6°F	296.5°F	131.5°F	269.0°F
LI02	133.3°F	293.2°F	131.5°F	271.0°F
LI03	144.8°F	295.9°F	144.8°F	287.9°F
SP01	166.2°F	-	-	-

Summary:______________________________________

El Paso, TX: Barber-Greene 260C Using an MC-330 with BG-650 Pick Up and BK Twin Pug Mill Hopper Insert



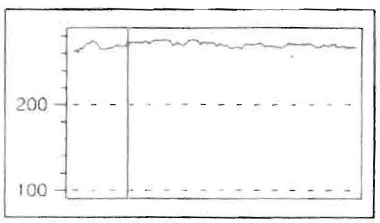
BLAW-KNOX

INGERSOLL-RAND
CONSTRUCTION & MINING

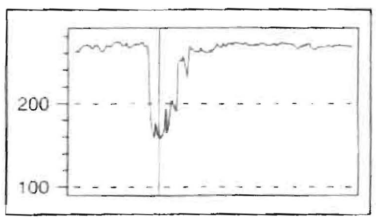
Image Number:
ShovelSide 1

10/22/99

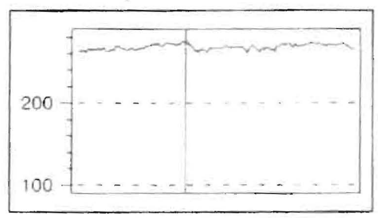
Temp Profile of LI01



Temp Profile of LI02



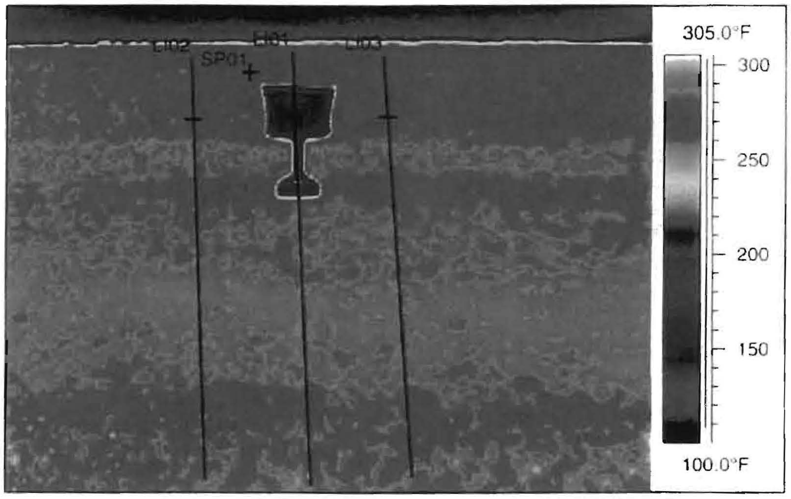
Temp Profile of LI03



	Cursor Temp	Max Temp	Min Temp	Avg Temp
LI01	273.8°F	277.5°F	260.1°F	270.4°F
LI02	159.6°F	273.3°F	158.7°F	258.2°F
LI03	274.4°F	274.4°F	260.0°F	268.0°F
SP01	265.6°F	-	-	-

Summary: ______________________________

El Paso, TX: Barber-Greene 260C Using an MC-330 with BG-650 Pick Up and BK Twin Pug Mill Hopper Insert



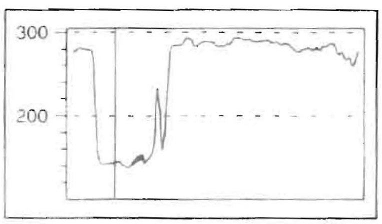
BLAW•KNOX

INGERSOLL-RAND
CONSTRUCTION & MINING

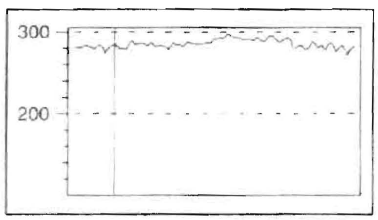
Image Number:
Shovel Front 2

10/22/99

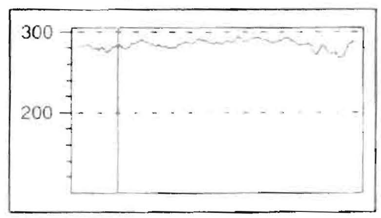
Temp Profile of LI01



Temp Profile of LI02



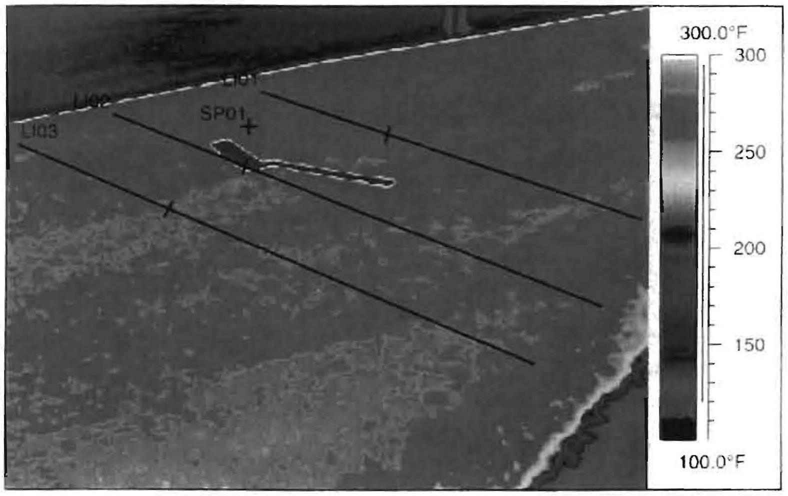
Temp Profile of LI03



	Cursor Temp	Max Temp	Min Temp	Avg Temp
LI01	144.6°F	294.0°F	138.1°F	251.1°F
LI02	284.9°F	297.8°F	270.8°F	285.1°F
LI03	283.9°F	294.9°F	268.2°F	284.5°F
SP01	280.5°F	-	-	-

Summary:

El Paso, TX: Barber-Greene 260C Using an MC-330 with BG-650 Pick Up and BK Twin Pug Mill Hopper Insert



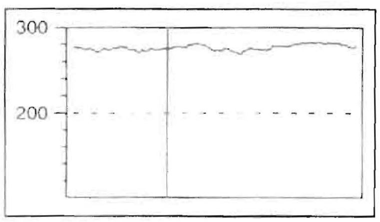
BLAW-KNOX

INGERSOLL-RAND
CONSTRUCTION & MINING

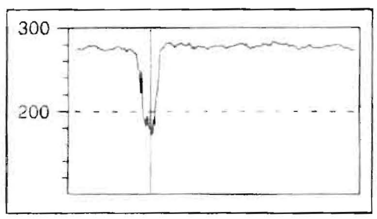
Image Number:
ShovelSide 2

10/22/99

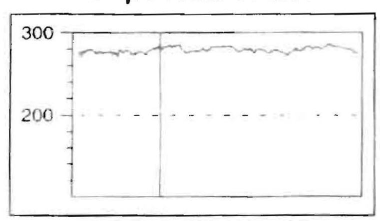
Temp Profile of LI01



Temp Profile of LI02



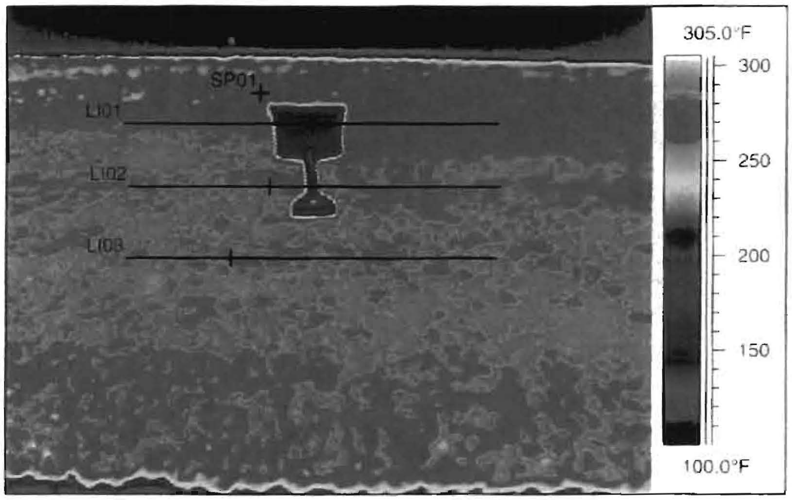
Temp Profile of LI03



	Cursor Temp	Max Temp	Min Temp	Avg Temp
LI01	274.7°F	283.4°F	268.5°F	276.7°F
LI02	181.5°F	283.8°F	172.8°F	271.9°F
LI03	283.0°F	286.2°F	270.8°F	279.4°F
SP01	276.8°F	-	-	-

Summary:____________________________________

El Paso, TX: Barber-Greene 260C Using an MC-330 with BG-650 Pick Up and BK Twin Pug Mill Hopper Insert



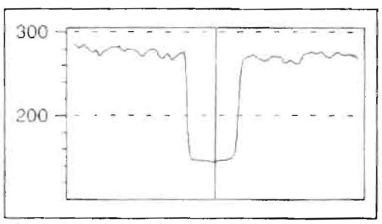
BLAW•KNOX

INGERSOLL-RAND
CONSTRUCTION & MINING

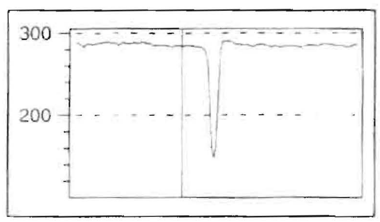
Image Number:
Shovel Front 3

10/22/99

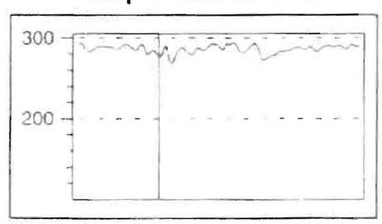
Temp Profile of LI01



Temp Profile of LI02



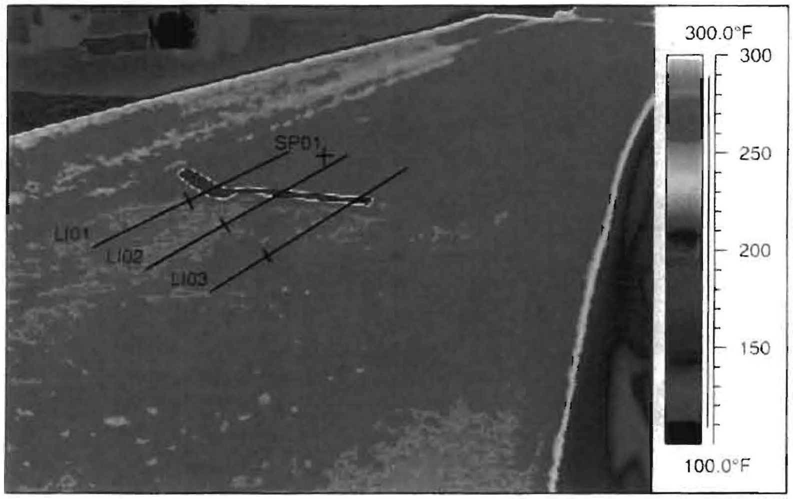
Temp Profile of LI03



	Cursor Temp	Max Temp	Min Temp	Avg Temp
LI01	145.6°F	285.7°F	145.1°F	251.0°F
LI02	283.8°F	291.0°F	148.3°F	281.6°F
LI03	276.6°F	294.7°F	268.1°F	286.2°F
SP01	278.5°F	-	-	-

Summary: ______________________________

El Paso, TX: Barber-Greene 260C Using an MC-330 with BG-650 Pick Up and BK Twin Pug Mill Hopper Insert



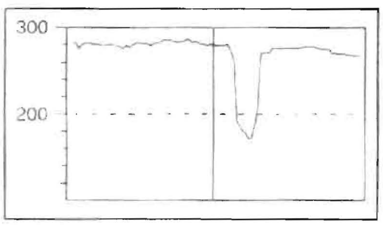
BLAW•KNOX

INGERSOLL-RAND
CONSTRUCTION & MINING

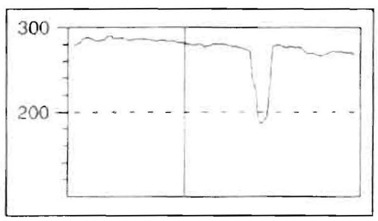
Image Number:
Shovel Side 3

10/22/99

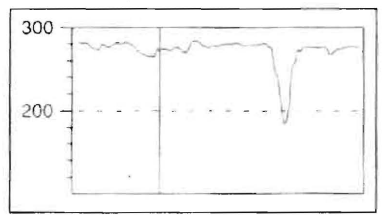
Temp Profile of LI01



Temp Profile of LI02



Temp Profile of LI03



	Cursor Temp	Max Temp	Min Temp	Avg Temp
LI01	280.3°F	286.5°F	170.8°F	270.1°F
LI02	281.3°F	290.8°F	186.0°F	274.3°F
LI03	273.0°F	284.1°F	184.0°F	272.0°F
SP01	269.7°F	-	-	-

Summary: ______________________________

APPENDIX – E

BARBER-GREENE EQUIPMENT

BARBER-GREENE®
A Division of Caterpillar Paving Products Inc.

Page 7105
Release 102

BG-650

WIDE THROAT WINDROW ELEVATOR

■ STANDARD FEATURES AND BENEFITS

Swing out front support wheels with hydraulic height adjustment to control pickup head height.

Foot shaft mounted combining augers (737 mm/**29 in.** diameter) provide a wide throat (2997 mm/**118 in.**) for pick up of off-center and extra wide windrows.

High capacity slat conveyor, with 1473 mm/**58 in.** wide by 178 mm/**7 in.** deep slats mounted to roller flight chain, provide long life and low maintenance.

A clean wheel path for the paver is maintained by, height adjustable, scrapers mounted behind the combining augers.

Swing up towing frame with pintle hook.

Three point suspension allows machine to closely follow road contours.

Break-away scrapers protect machine against accidental damage from obstructions in roadway.

Front idler design provides a high, rearward directed slat entry into windrow to help propel the unit into the windrow and to minimize vibration.

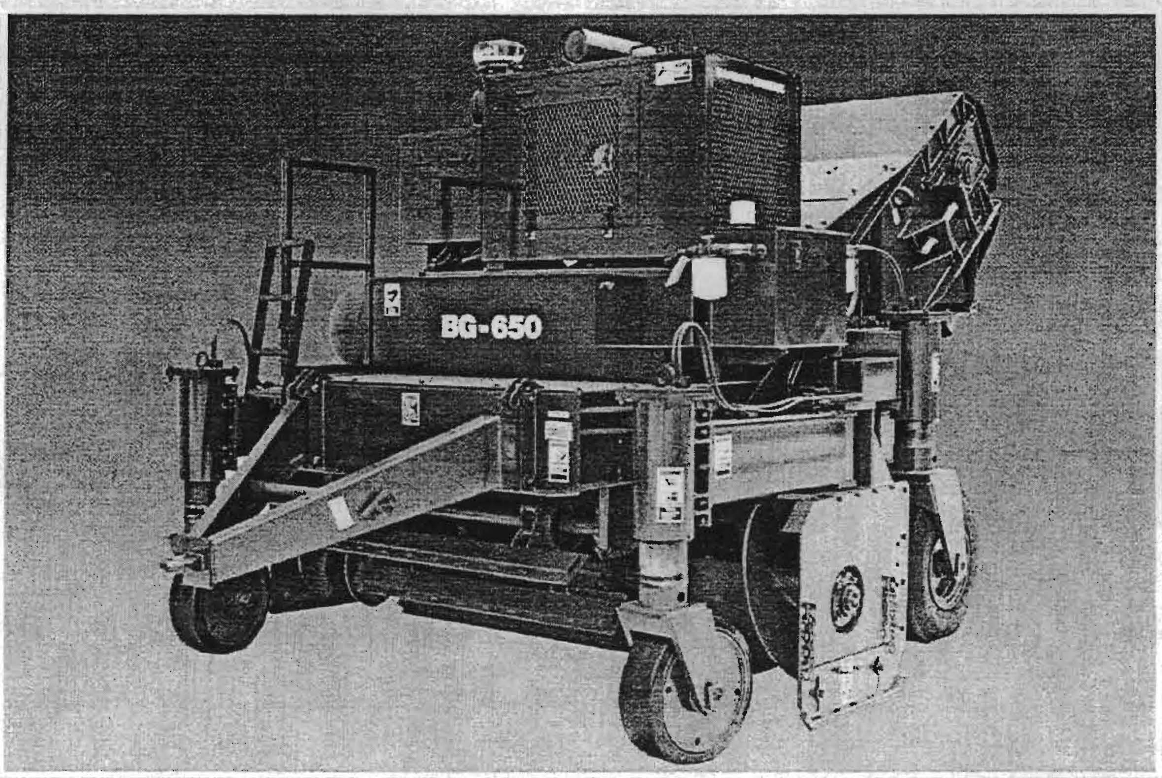
- **Cat® 3054DIT Turbo-charged Diesel Engine** .... 80 kw/107 hp
- **Overall Length** .... 4267 mm/14 ft. 0 in.
- **Overall Height (with exhaust)** ...... 2946 mm/9 ft. 8 in.
- **Travel Width** .... 3099 mm/10 ft. 2 in.
- **Operating Width** .... 3150 mm/10 ft. 4 in.
- **Weight** .... 7 983 kg/17,600 lbs.

Machines shown may have optional equipment.

Dual operating stations allow full control, at ground level, from either side of machine.

1905 mm/**75 in.** conveyor discharge height for full paver hopper loading.

Easy attachment to paver without removing push roller or truck hitch.



FEATURES

The Model BG-650 Windrow Elevator is a new generation of windrow elevator that provides greater productivity and flexibility than previously available designs. This machine has the capability to handle off-center or wide windrows with no loss of productivity. It can handle windrows laid by conventional end dump trucks as well as those laid by belly dumps. Steering and tracking is accurate, and it can easily and quickly be re-positioned on the job site.

■ Engine

Caterpillar® 3054DIT turbo-charged, four stroke/cycle diesel engine with four cylinders, 100 mm/**3.94 in.** bore, 127 mm/**5.00 in.** stroke and 4,0 liter/**243 cu. in.** displacement. Gross horsepower @ 2200 rpm: 80 kw/**107 hp**. 12 volt electric starting system with 115 amp alternator and one 12 volt battery. 176 l/**40 gallon** fuel tank.

■ Elevating Conveyor

Inlet opening is 2997 mm/**118 in.** wide. Conveyor slats are 1473 mm/**58 in.** wide by 179 mm/**7 in.** deep. Discharge height is 1905 mm/**75 in.** Front idler design provides a high, rearward-directed slat entry into the windrow to help propel the unit into the windrow and minimize vibration. Flight chain is heavy-duty roller bushed. Replaceable abrasion resistant liner. Heavy-duty head and tail shafts with heavy-duty anti-friction bearings.

■ Suspension

Two 559 mm/**22 in.** x 179 mm/**7 in.** solid rubber tires on front casters. Two 8:25 x 15 tires on rear casters. All wheels have heavy-duty caster assemblies. Caster wheels pinned for towing. Front casters mounted to swing arms, allow unit to be loaded on 2438 mm/**8 ft.** trailer, or spread to 4318 mm/**170 in.** (track) to clear wide windrows.

■ Hydraulic Drive System

Variable displacement pump is direct connected to the engine and drives a fixed displacement hydraulic motor directly connected to conveyor head shaft. Gear-type pump provides hydraulic pressure to suspension system.

■ Controls

Control panels on both sides of unit include: Emergency stop, engine throttle, conveyor on/off, hydraulic raise/lower front and rear wheels. Engine instrument panel includes: Oil pressure gauge, water temperature gauge, voltmeter, fuel gauge, and hour meter.

■ Hydraulic lift system

Hydraulic cylinders raise and lower rear caster assemblies together and front caster assemblies individually.

■ Swing up towing frame

■ Attaching Adaptor

Designed to fit most pavers, without removing the push roller or truck hitch.

BARBER-GREENE®
A Division of Caterpillar Paving Products Inc.

QEHQ9362

APPENDIX – F

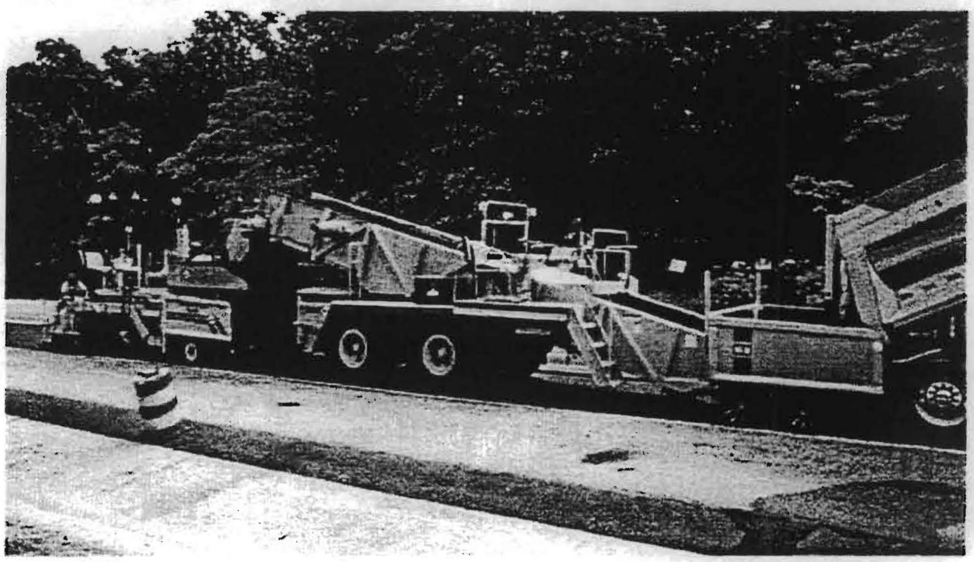
BLAW-KNOX EQUIPMENT

BLAW•KNOX™ Specifications MC-30

The MC-30 Mobile Conveyor is a self-propelled, wheel mounted, bulk material handling/delivery system with a built-in surge storage capacity of approximately 30 tons (27.2 T). A proven economical alternative to current methods and equipment, the MC-30's application potential includes in-line or offset paving, road widening and milling operations with either bituminous, aggregate or concrete materials.

Functioning as a material tender for hot mix asphalt paving operations, the MC-30 has proven to reduce material hauling cost and increase paver laydown production, all while improving the overall quality and smoothness of the new asphalt pavement.

Standard end-dump haul units deposit material into the front receiving hopper of the MC-30. This material is then transported, undisturbed, rearward via a high capacity, live bottom, belt conveyor to be discharged as required for smooth, continuous, undisturbed operation of the paver performing the laydown operation. Material discharge is direct from the rear or, with the addition of the optional rear swing conveyor, at any point up to a 90° angle on either side of the unit.



Width–Overall (hopper sides up)	10'1⅜" (3.08 m)
Width—Overall (hopper sides down)	10'6⅜" (3.20 m)
Gage Width (center to center of drive wheels)	95" (2413 mm)
Wheelbase	256" (6502 mm)
Turning Radius (inside)	34'4" (9.85 m)
Loading Ramp Angle	12°
Length–Overall (standard machine)	40'0" (12.19 m)
Length–Overall (w/optional swing conveyor retracted)	48'6" (14.78 m)
Length–Overall (w/optional swing conveyor extended)	56'10" (17.32 m
Height–Overall (upper conveyor sides removed)	10'9" (3.28 m
Height–Overall (upper conveyor sides installed)	12'4" (3.76 m
Ground Clearance–Main Conveyor	7'6" (2.29 m
Ground Clearance–Optional Swing Conveyor (max.)	10'1" (3.07 m
(min.)	8'0" (2.44 m
Weight–Total (standard machine)	43,000# (19,545 kg
Weight–Total (w/optional swing conveyor)	54,100# (24,590 kg

KEY FEATURE COMPARISON

Improves the Quality and Smoothness of Hot Mix Asphalt Pavements........

- Eliminates truck contact/bumping of the paver.
- Non-stop operation produces a more consistent flow of material for smoother, more uniform pavements.
- The undisturbed transfer of material from the haul unit to the paver helps eliminate mix segregation.
- Optional Mixer/Agitator re-mixes paving material to minimize end-of-load segregation.
- Optional Twin Pug Tub virtually eliminates all material segregation.
- Protects new or tack coated bases by receiving and delivering paving material from the adjacent lane.

Increases Paving Productions...

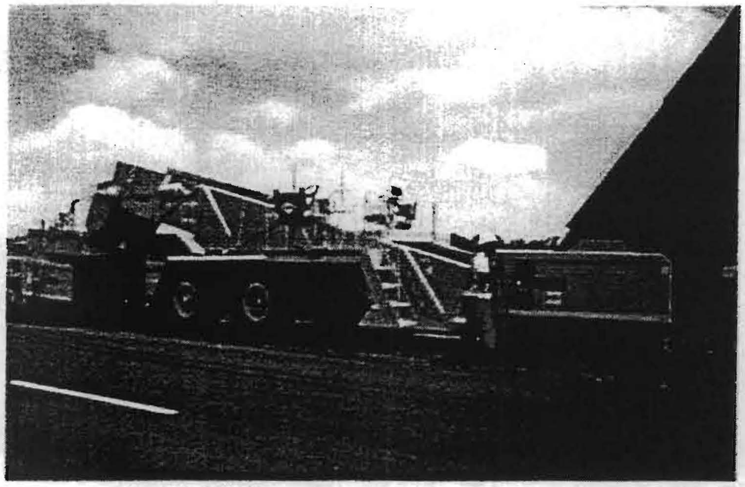
- Feeds mix to paver as required to produce a continuous, non-stop paving operation.
- Infinitely variable discharge rate up to a maximum of 32 tons (29 T) per minute.

Reduces Material Hauling Costs...

- Cycles trucks quicker...reduces total number of trucks required by up to 25%.
- Permits the efficient use of larger trucks.
- Eliminates truck waiting bottleneck at the paver.
- Provides an on-site material surge storage capability of 30 tons (27.2 T)...50 tons (45.4 T) using the optional paver hopper insert.

An Alternative to Current Methods and Equipment..............................

- Simplicity in design employs field proven componentry for greater reliability.
- Fewer moving parts reduce maintenance time & costs.
- Better operator visibility fore & aft.
- Compact width renders easier, safer operation in traffic.
- More flotation ... better maneuverability.
- Easy service access to all systems.
- New conveyor configuration reduces clean-up time to 30 minutes or less.



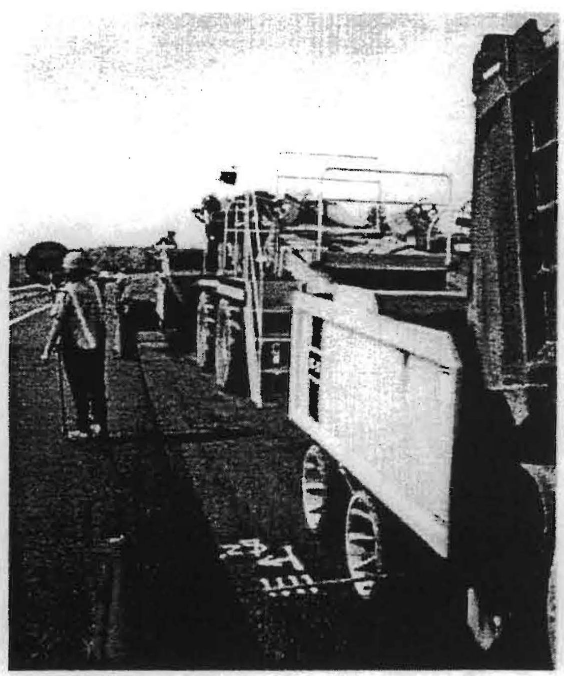
Engine: Cummins 6 cylinder, turbo-charged diesel model 6BT 5.9 .. 359 cubic inch (5.88 L) displacement, 150 hp (113 kW) @ 2200 rpm. Engine is equipped with an oil cooler, replaceable oil filter and replaceable air cleaner element.

Cooling System: 26 qts. (25 L)

Fuel System: 50 gal. (189.3 L) fuel tank with replaceable filter provides an onboard diesel fuel supply for the engine and pressurized washdown system. A 35' (10.67 m) washdown hose with spray valve/nozzle, mounted on a self-storing, spring retracting hose reel is standard.

Electrical System: 12 volt, negative ground with 105 amp alternator. Wiring is color coded, number impregnated and harness wrapped in polyethylene looms for maximum durability and easy servicing. All circuits tie to a central, easy access junction box equipped with automatic reset circuit breakers.

Hydraulic System: 42 gal. (159 L) reservoir capacity. Primary filtration is accomplished with 5.0 micron variable depth "Fiberglas" filters on the suction side of the traction and main conveyor drive pumps. Secondary filtration is accomplished with 100 mesh strainers on the suction side of the general purpose and auxiliary drive pump circuits.



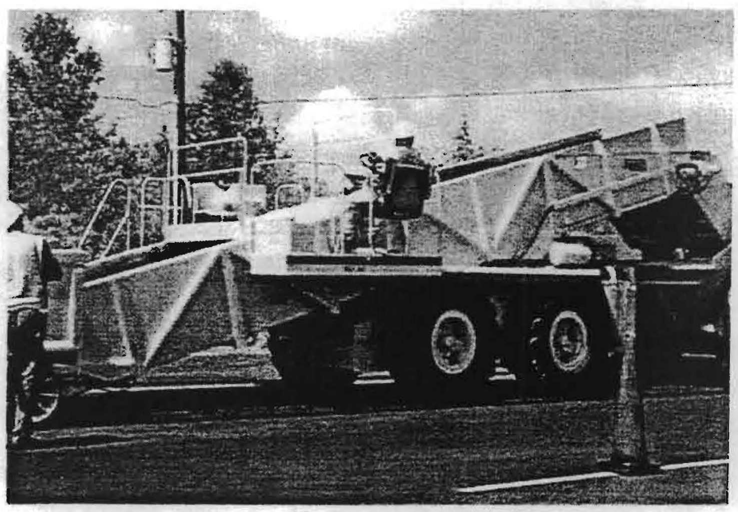
Traction Drive: An electrically controlled, variable displacement hydrostatic pump drives a fixed displacement hydrostatic motor which in turn drives an electric over hydraulic 3-speed reduction transmission connected to an electrically shifted 2-speed differential axle. There is no neutral position in the 3-speed reduction transmission since the electric/hydraulic shift arrangement has one ... ranges engaged at all times. High strength, oversized roller

Low Range/Lo Axle	0-141 fpm (43.0 m/min
Low Range/Hi Axle	0-196 fpm (59.8 m/min
Mid Range/Lo Axle	0-294 fpm (89.6 m/min
Mid Range/Hi Axle	0-409 fpm (124.7 m/min
High Range/Lo Axle	0-10.7 mph (17.1 km/hr
High Range/Hi Axle	0-14.7 mph (23.5 km/hr
Reverse	Full reverse in any of the six speed ranges. A back-up alarm is standard equipment.

Rear Suspension: Four 16.00 x 24 heavy-duty G2 grader tires inflates to 60-6 psi (448 Kpa).

Front Suspension: Four steerable, solid rubber tired wheels, [two 12" (30 mm) wide x 22" (559 mm) diameter front and two 14" (356 mm) wide x 22 (559 mm) diameter rear], mounted on an offset tandem bogie frame; fror machine weight is proportionally split 40-60% between the front and rear set of bogies for optimum weight distribution. Tie rod synchronized cylinders (on on each side) are mounted on the outside of the bogie frame for easy servic access.

Controls: Dual control stations, each with 90° rotation of the operator's se and console, provide the operator with optimum view and control in eithe operating or transport mode. Control functions provided on each operator console include main power switch, starter, throttle, steering direction/spee selection, electrical shifting of the 3-speed transmission and 2-speed axle; ma conveyor function, speed and direction; folding hopper, horn and parking brak Electric switch controls for the optional swing conveyor and truck hitch are als included if the unit is so equipped.



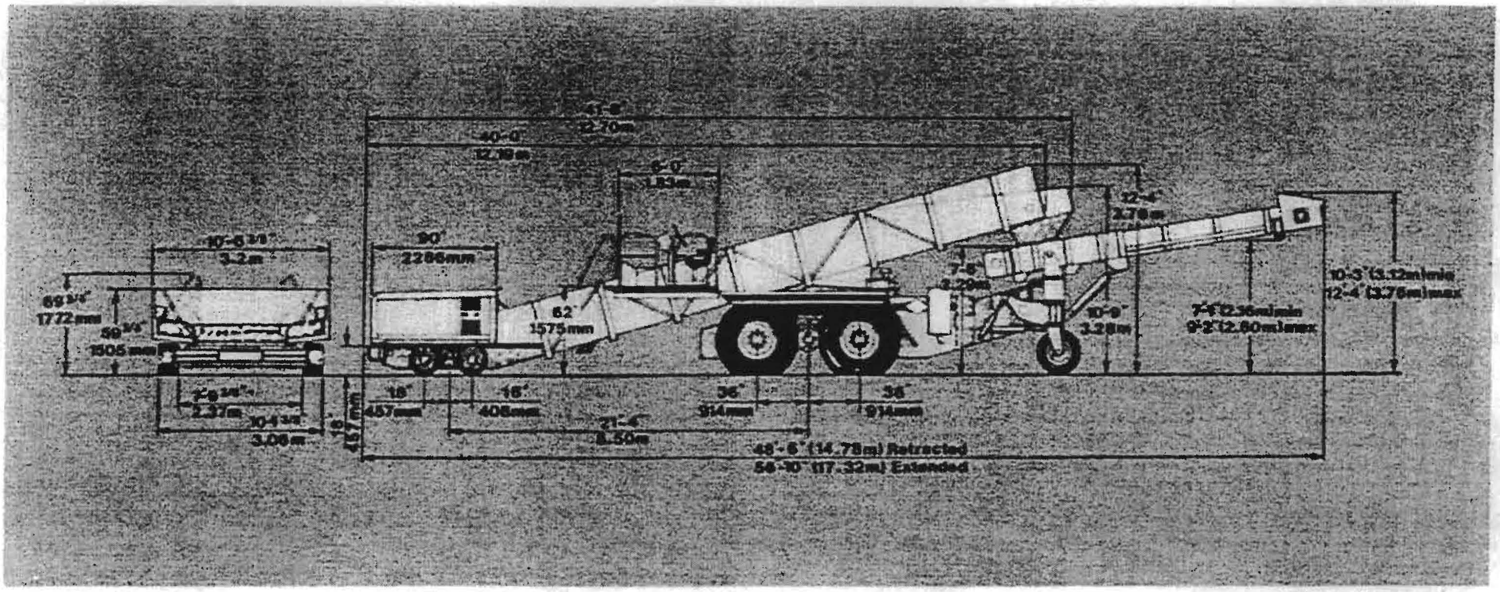
The main control console, located at the left side control station, serves as t main electrical junction box. Additionally, operator control/reference f left/right console selector switch, tachometer/hour meter, parking brake war ing light and LCD instrument readout with warning light for engine oil pressu and coolant temperature, hydraulic oil temperature and voltmeter are located this main console. On-off control of the optional generator set is also includ if the unit is so equipped.

Brakes: Primary braking is accomplished through the dynamics of the hydr static traction drive system. Foot actuated, hydraulic caliper/disc seconda brakes, mounted on the output ends of the axle, provide secondary/back- brake control. An independent, spring applied parking brake is automatica actuated when the ignition switch is turned off or electrical power is lost. T parking brake can also be manually applied via an electrical switch on eit operator's control console.

Front End: Choice of either Oscillating Push Rollers or Truck Hitch.

Oscillating Push Rollers: Two bearing equipped push rollers mounted on 111.75" (2839 mm) wide, oscillating frame; compensates for minor directio misalignment of the truck with the MC-30.

Truck Hitch: Two bearing equipped push rollers mounted on an oscillati frame with electric/hydraulic actuated roller equipped clamp arms; quickly gr and secures a truck in proper attitude for unloading material into the machin hopper; automatically compensates for both minor lateral and directio



Maximum Arm Opening	130" (3302 mm)
Minimum Arm Opening	72" (1829 mm)
Degree of Swivel	±8°
Drift from Center (right or left)	12" (305 mm)
Automatically Self-Centering	

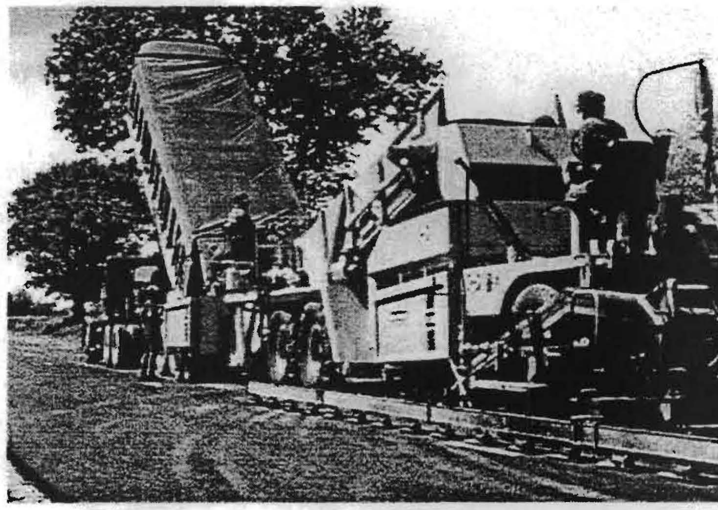
Hopper: 14 ton (12.5 T) [225 ft.^{3} (6.4 m^3) struck] capacity; hydraulically folding sides with Tivar® polymer retaining lip. Adjustable side extensions are provided to increase hopper capacity and prevent side spill over.

Truck Entry Width	120" (3048 mm)
Truck Dump Clearance	26" (660 mm)

Main Conveyor: Heat and oil resistant rubber belt attached to steel cross bars which in turn are welded to special, heat treated steel roller chain equipped with an automatic lube system.

Belt Width	60" (1524 mm)
Belt Thickness	⅜" (10 mm)
Side Height	19" (483 mm)
Angle of Incline	15°
Speeds (infinitely variable)	0-61 fpm (18.6 m/min)
Discharge Rate	up to a maximum of 32 tons (29 T) per minute

Neoprene flashing, along both sides of the conveyor belt, retards material migration into the interior of the conveyor structure. Two easily removable trays, located under the main conveyor, shield the engine and drive componentry from any material carry-over, and provide for quick, easy clean-out of any material



accumulation. Access doors, located along both sides of the conveyor structu facilitate quick easy inspection and servicing of the conveyor track and chains

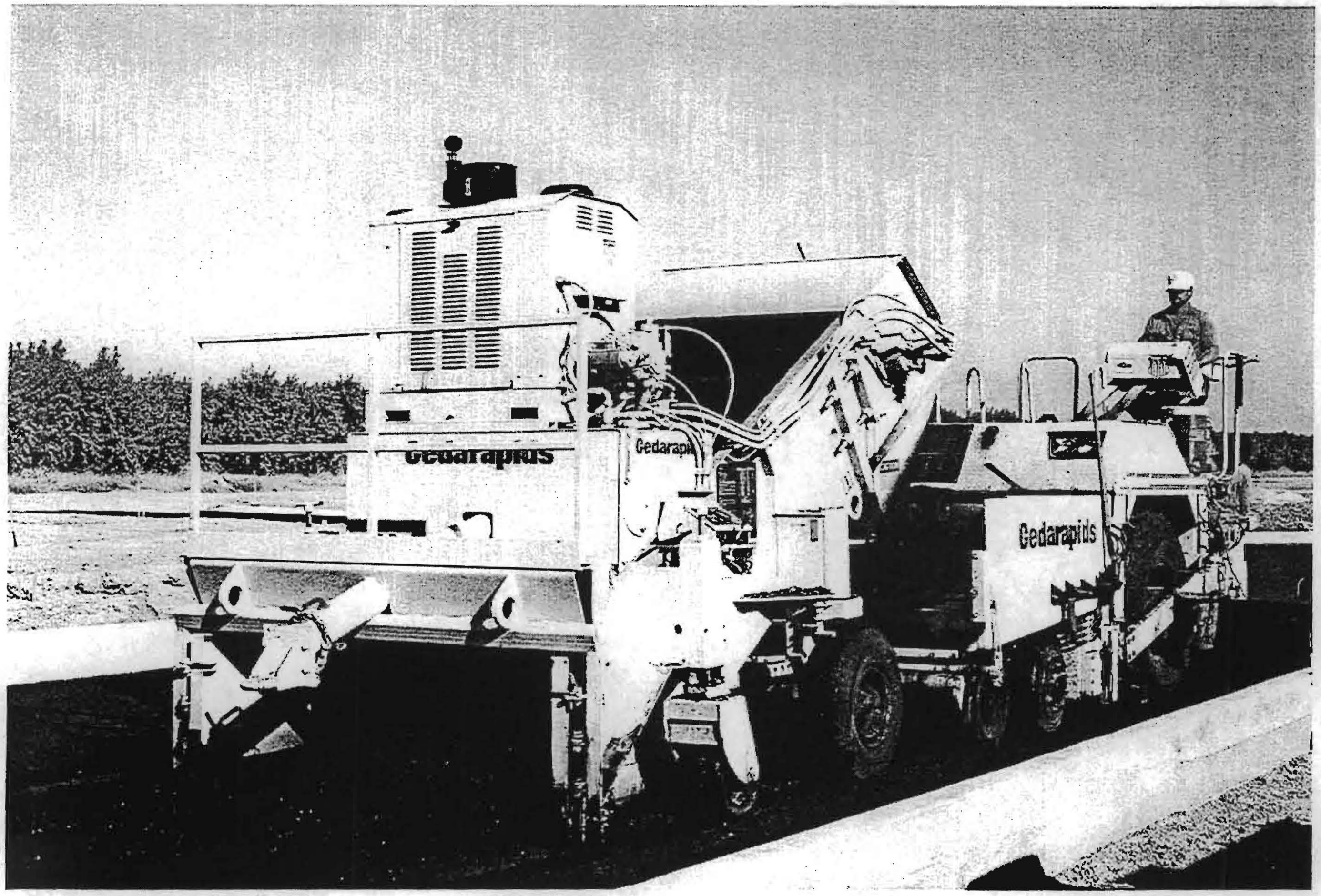
Main Conveyor Drive: independent, variable speed hydrostatic drive from electrically controlled, variable displacement pump through dual orbital motc and planetary final reduction drives on the upper conveyor shaft, powers the l bottom conveyor either forward or rearward. On-off operation, speed and dire tion are controlled from either operator's console.

APPENDIX – G

CEDERAPIDS EQUIPMENT

Cedarapids
CR MS-1 & CR MS-2 Pickup Machines

Form 18197 (12/91)



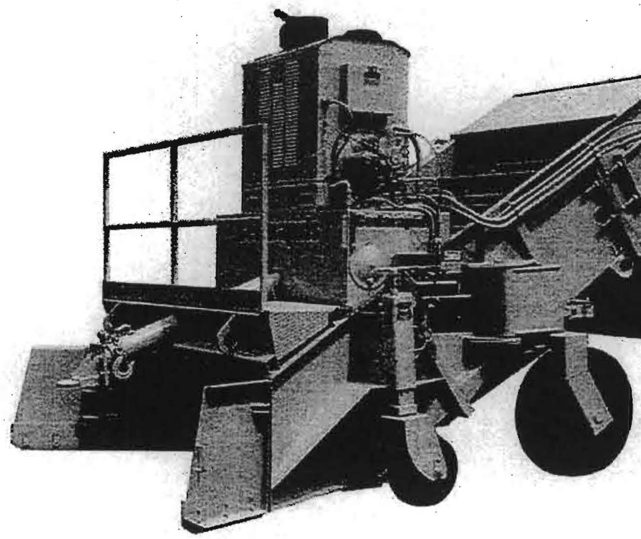
Cedarapids windrow pickup machine with John Deere 4039T engine, direct variable hydraulic elevator drive, hydraulic leveling, adjustable front scraper blade, rear wheel caster pin lock, telescoping pintle hitch, adjustable-length paver attachment and engine access platform.

Standard Features

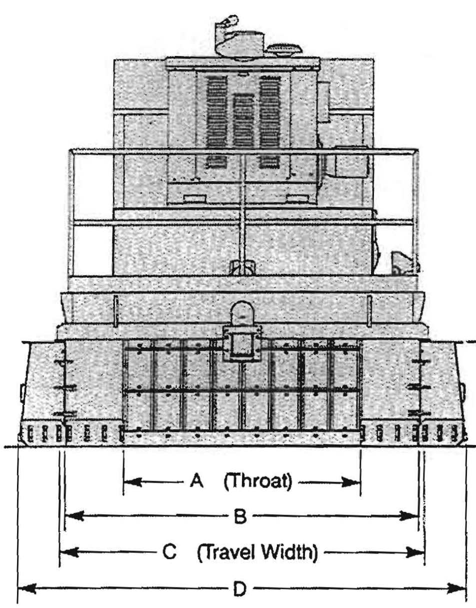
Dual elevator roller chains with bolt-on flights
Variable hydrostatic drive with two planetary gear boxes and drive motors on head shaft
John Deere engine
High alloy floor liners
Segmented head shaft sprockets and tail shaft idlers
Reversible elevator to clear obstructions
Double seal on head shaft gearbox
Adjustable front scraper blade
Rear wheel width allows loading on 8' trailer
3-point suspension with hydraulic front leveling
Super heavy-duty pivots, front and rear
Solid rubber front tires, pneumatic rear tires
Quick-tach, telescoping style, paver attachment
Pintle hook with telescoping pull hitch
Elevator rear discharge hood removable for easy maintenance and service
Engine instrumentation at ground level
Optional field kit diesel spray down system

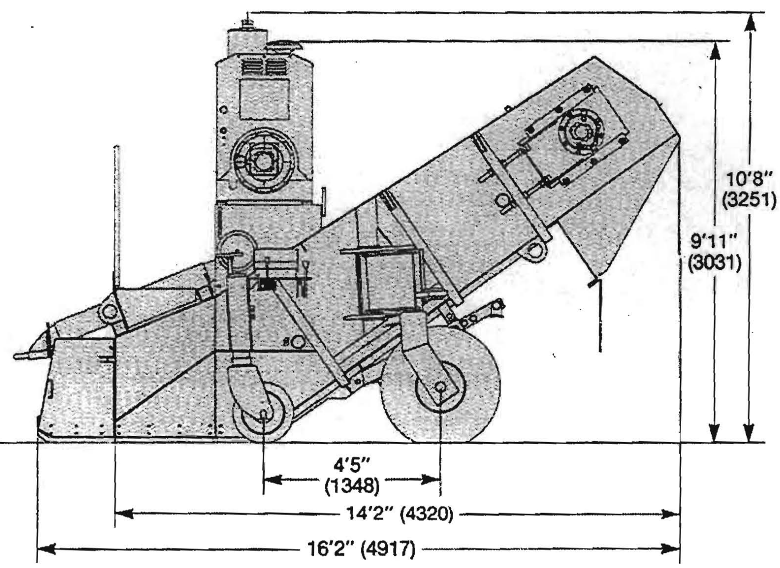
Cedarapids
CR MS-1 & CR MS-2 Pickup Machines

Cedarapids Inc • 916 Sixteenth St NE • Cedar Rapids IA 52402 USA • Telephone 319 363 3511 • Fax 319 399 4871



Rear wheel width allows loading on 8′ trailer, both models.





	A	B	C	D		A	B	C	D
CR MS-1	6′ (1829)	8′11″ (2718)	9′6″ (2896)	11′4″ (3454)	CR MS-2	5′ (1524)	7′11″ (2413)	8′6″ (2591)	10′4″ (3150)

CR MS-1 Specifications

Weight (approx) .... 16,000 lbs (7258 kg)
Capacity (max - theoretical) ...... 1586 tph (1440 tonnes/hr)
Elevator
  Width .... 72″ (1829 mm)
  Bolt-on flights .... 6″ × 4″ × ½″ (152 × 102 × 13 mm)
  B1 roller chain .... 5.51″ pitch
  High alloy liners .... ⅜″ (10 mm)
John Deere 4039T engine .... 100 hp @ 2000 rpm
Front tires .... 18″ × 9″ (457 × 229 mm) solid
Rear tires .... 10.00 × 15 18-ply

CR MS-2 Specifications

Weight (approx) .... 14,500 lbs (6577 kg)
Capacity (max - theoretical) ...... 1321 tph (1199 tonnes/hr)
Elevator
  Width .... 60″ (1524 mm)
  Bolt-on flights .... 6″ × 4″ × ⅜″ (152 × 102 × 10 mm)
  B1 roller chain .... 5.51″ pitch
  High alloy liners .... ⅜″ (10 mm)
John Deere 4039T engine .... 100 hp @ 2000 rpm
Front tires .... 18″ × 9″ (457 × 229 mm) solid
Rear tires .... 8.25 × 15 12-ply

APPENDIX – H

LINCOLN EQUIPMENT

LINCOLN

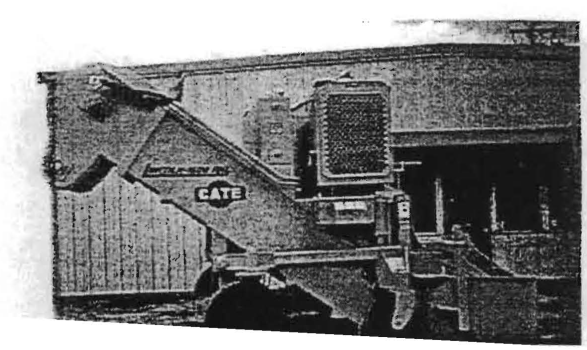
1600 AXL Windrow Elevator

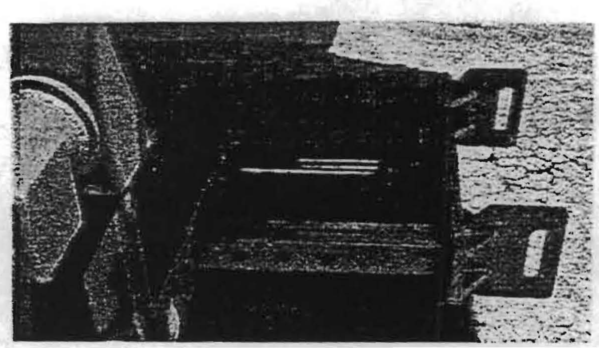
The Lincoln windrow elevator will provide a continuous flow of material to the paver resulting in increased production and improved material handling, continuous paver operation without stopping for truck exchanges, and reduced trucking costs. Continuous operation improves ride quality by eliminating stops and starts and problems associated with truck exchanges.

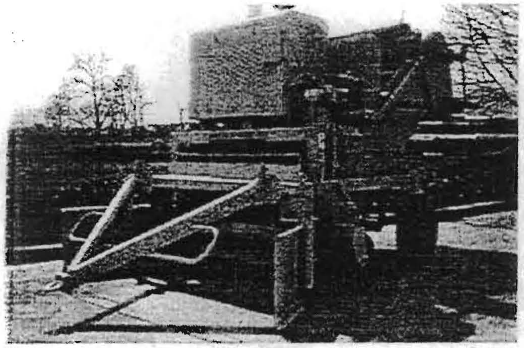
The unique remixing auger reblends asphalt materials just before they are delivered to the paver hopper eliminating segregation and ensuring a uniform mix temperature.

STANDARD FEATURES

- Proven reliable design
- Hydrostatic drive system
- 72" wide - high capacity slat conveyor
- Remixing auger to reblend asphalt materials to eliminate segregation
- 6'-2" discharge height for full hopper load
- High speed raise and lower to clear obstructions and speed setup
- Rear wheel width allows loading on trailer
- Hydraulic telescoping paver attachment for ease of hookup







Specifications
Lincoln 1600 AXL

ENGINE

John Deere PowerTech 6068 diesel engine
170 hp @ 2400 rpm
50 gallon fuel tank

ELEVATING CONVEYOR

72" wide throat (1829 mm)
6'-2" discharge height (1880 mm)
Heavy duty roller flight chain
Heat treated flight wear edges
Replaceable two-segment drive chain sprockets
Replaceable hardened floor liner
Heavy duty head and tail shafts with heavy duty bearings

REMIXING AUGER

14" diameter cast Ni-Hard Hemi segments
Left and right-hand segments feed to the center for remixing
Hydraulic motor coupled to auger shaft
Variable speed control for optimum remixing

PAVER ATTACHING ADAPTOR

Hydraulic telescoping paver attachment (Quickie Hook)
Adjustable up to 24" with hydraulic cylinder to position dump point
Fully extended to hook up paver then retract to operating position
Adapter fits most pavers

CONTROLS

Control panels on both sides of the machine include:
- Emergency Stop
- Engine increase/decrease
- Pump increase/decrease
- Cylinders up/down

SUSPENSION

Four wheels have heavy duty caster assemblies
Rear caster assemblies pin for towing or swivel inside for loading on trailer
Two 8.25 x 15 - 18 ply pneumatic rear tires
Two 6.90 x 9 - 10 ply foam filled front tires
Swing up towing frame with pintle ring

HYDROSTATIC DRIVE SYSTEM

Variable displacement pump is directly connected to the engine and drives two fixed displacement hydraulic motors with planetary gear boxes directly connected to conveyor head shaft.
Auxiliary mounted vane pump drives remixing auger and powers controls
60 gallon reservoir with large capacity heat exchanger

HYDRAULIC LIFT SYSTEM

High speed raise & lower up to 10" at the front cutting edge to clear obstructions
Left and right height locking screws

DIMENSIONS

Length (with wings folded in) 13' - 0" (3962 mm)
Height 10' - 2" (3099 mm)
Travel Width 9' - 6" (2896 mm)
Rear tires width outside / outside of tread in loading position 106"
Front tires stationary width outside to outside of tread 113"
Operating Width 11' - 0" (3352mm)
Weight 16,000 lbs. (7258 kg)

Clark's Welding & Machine Works
3030 Power Inn Road
Sacramento, CA 95826
Telephone 916-452-2487
Toll Free 877-762-5460
Fax 916-452-7862

Sold and serviced by:

Design and specifications subject to change without notice

APPENDIX – I

ROADTEC EQUIPMENT

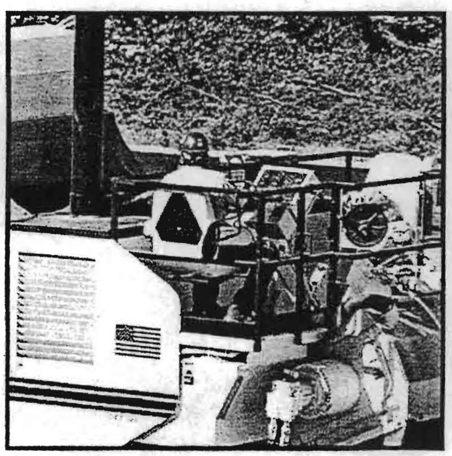
The Shuttle Buggy material transfer vehicle has revolutionized the asphalt laydown industry. If used properly it can eliminate three to four trucks from the job. Contractors who own the machines have found the greatest savings in smaller work. One contractor recently reported that he went from using seven trucks to using three trucks on intersection work, and did twice as many intersections. When trucks arrive at the job, they can immediately dump into the Shuttle Buggy which can then load the paver hopper. The paver is considerably more maneuverable because it never has to come into contact with the truck. This allows the mechanical placing of pavement that was previously done by hand. Anywhere the paver can be driven, mix can be laid. Not only does this eliminate handwork, but the quality of the mat is considerably enhanced in small areas such as intersections, parking lots, rest areas, etc.

Aside from the economics, perhaps the most important contribution made by the Shuttle Buggy is the ability to insure the highest quality and smoothest pavement with no segregation, even when placing difficult mixes. Most of all a quality mix can be produced without the extreme care now required in the operation of the plant, in trucking, and in the paving operation. The machine takes the sensitivity out of the entire operation while giving all involved needed relief in the terribly competitive environment that exists in our industry.

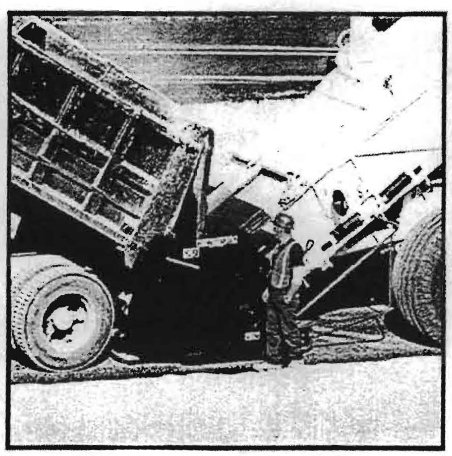
SB 2500

MATERIAL TRANSFER VEHICLE

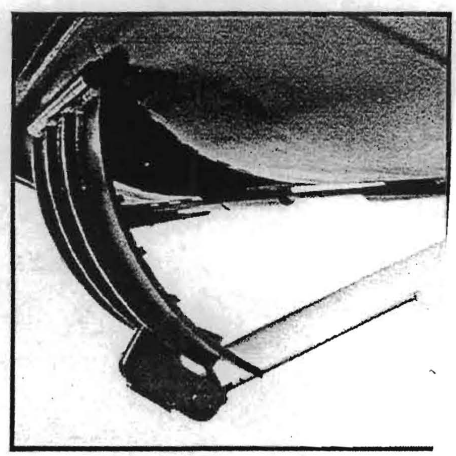
The SB-2500 Shuttle Buggy® material transfer vehicle can move great distances away from the paver, receive 25 tons of hot mix and then return and transfer the mix without interfering with the paver's continuous speed. A triple-pitch Ni-Hard segmented anti-segregation auger remixes the asphalt, eliminating temperature and aggregate segregation and cold truck ends. The continuous paving operation creates pavement smoothness levels previously unattainable.



The operator's station is equipped with operator positions on both sides of the machine. The control panel swivels for use from either station. This allows same lane or adjacent lane operation from either side.



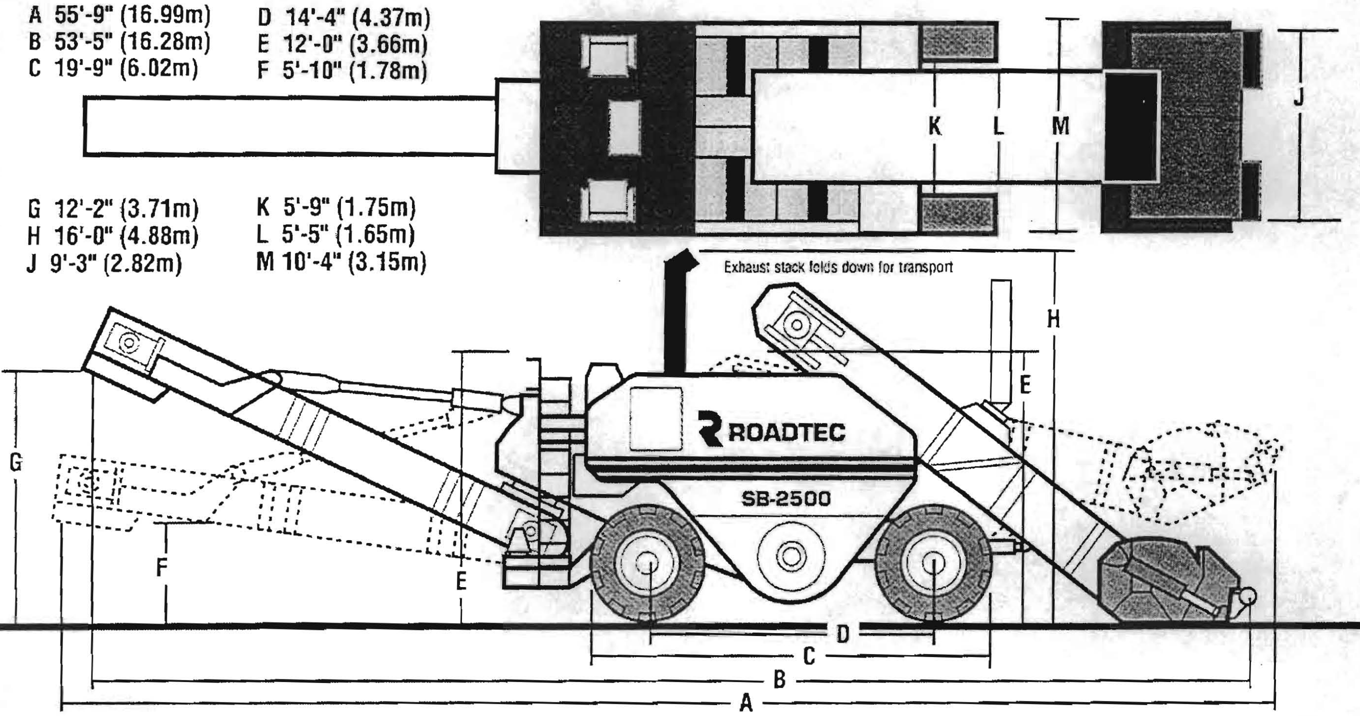
The truck unloads into a front dump hopper. Vibrators enhance the feed into a Ni-hard segmented converging auger which keeps material moving onto the conveyor. The conveyor capacity is rated at 1000 TPH (907 MTPH). A fixed push roller is standard



A clean-out door is located on the ur derside of the front dump hopper. It hydraulically actuated by a switch (the side of the dump hopper and co trolled by the ground operator.

US PATENT 4818139; 4944630; 5035534 CANADIAN PATENT 1303891; 1305736

A 55'-9" (16.99m)
B 53'-5" (16.28m)
C 19'-9" (6.02m)
D 14'-4" (4.37m)
E 12'-0" (3.66m)
F 5'-10" (1.78m)
G 12'-2" (3.71m)
H 16'-0" (4.88m)
J 9'-3" (2.82m)
K 5'-9" (1.75m)
L 5'-5" (1.65m)
M 10'-4" (3.15m)



SHIPPING WEIGHT: 76,000 Lbs. (34,473Kg)

ENGINE:
Cummins 6 CTA8.3 260 diesel, 505 cu in (8.28 l). 6-cylinder engine, 276 HP (206 kw) @ 1,900 rpm. Engine instrumentation includes tach/hour meter, oil pressure, voltage and emergency shutdown system.

OPERATOR'S STATION:
Operator positions on both sides. Control panel swivels for use from either station allowing for same-lane or adjacent-lane operation from either side. Inside turning radius 26'6" (8.1 m).

GROUND DRIVE:
All hydrostatic for continuously variable speed control with two speed ranges. Electric shift-on-the-go control between high and low. Hydraulic shift between working and transport ranges. Maximum speed (working range) 3.0 mph (4.8 kph). Maximum speed (travel range) 9 mph (14.5 kph).

TIRES:
Large, high-flotation - 21:00 x 25" (53.3 m x 635 mm).

ELECTRICAL SYSTEM:
Standard system includes heavy-duty alternator, battery, and circuit breaker protection of all systems.

FUME EXTRACTION SYSTEM:
Two blowers. Fold-down 10' (254 mm) exhaust pipes.

SLAT CONVEYORS

TRUCK UNLOADING (C-1):
High-capacity truck unloading system with low deck height, 9'2" (2.8 m) side truck opening and 29" (737 mm) o.d. x 7" (178 mm) deep Ni-Hard segmented converging auger for quick material flow. Conveyor has weld-on flights 5/8" (16 mm) thick, 7" (178 mm) wide x 58" (1,473 mm) long. Ni-Hard liner plates are removable. Power dump front hopper has a vibrator on the bottom that helps keep material moving. Fixed push roller is standard. Conveyor capacity is rated at 1,000 TPH (907 MTPH).

SURGE BIN (C-2):
Unloads the surge bin with a multi-pitch 29" (737 mm) o.d. x 7" (178 mm) deep Ni-Hard segmented anti-segregation auger in the hopper. Conveyor system has weld-on flights 5/8" (16 mm) thick, 7" (178 mm) wide x dual 16" (406 mm) long. Liner plates are Ni-Hard and removable. Conveyor capacity is 600 TPH (544 MTPH).

PAVER LOADING (C-3):
Conveyor swings 55 degrees to either side of center. Maximum conveyor discharge height is 12' 2' (3.7 m) from ground level. Conveyor flights welded to the chain are 5/8" (16 mm) thick, 3" (76.2 mm) wide and 30" (762 mm) long. Conveyor has bolted 1/2" (12.7 mm) T-1 replaceable floor plates and doors. C-2 and C-3 conveyors have on/off controls that are interlocked. Conveyor capacity is 600 TPH (544 MTPH).

HOPPER INSERT:
A mass-flow paver hopper insert is used to increase the hopper capacity of a conventional paver when used with the SB-2500.

CAPACITIES:
Fuel tank........150 gal (568 l)
Hopper........25 tons (22.7 MT)
material........120 lbs/cu ft (1,922 kg/cu m)

WEIGHTS:
Shipping weight........76,000 lbs (34,473 kg)

OPTIONS:
Spray down system
Hydraulic generator set
Windrow attachment
Road widener attachment

Performances may vary according to materials.

Specifications subject to change without notice.

an Astec company

2/98

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REO ↑

Texas Department of Transportation

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REO ↓

MATERIAL TRANSFER DEVICE SHOWCASE IN EL PASO, TEXAS

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DEMONSTRATION PROJECT CONDUCTED
In El Paso, Texas
October 18,1999 – October 22, 1999

CONDUCTED BY:
TEXAS DEPARTMENT OF TRANSPORTATION
El PASO DISTRICT

IN COOPERATION WITH
DAN WILLIAMS COMPANY
AND
JOBE CONCRETE PRODUCTS, INC.,

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