EVALUATION OF THE TROXLER MODEL 4640 THIN LAYER DENSITY GAUGE

DHT-2

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AND
PUBLIC TRANSPORTATION

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EVALUATION OF THE
TROXLER MODEL 4640 THIN LAYER
DENSITY GAUGE

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ABSTRACT

The Troxler Model 4640 Thin Layer Density Gauge was evaluated for its capability to determine the in-place density of bituminous pavements in comparison to the values measured by Test Method Tex-207-F Part I. Density determinations were made on four independent projects by both test methods. The following observations were made: First, the Troxler demonstrates less repeatability than cores tested by Test Method Tex-207. Secondly, a correlation must be made between the two test methods on each project. Finally, the Troxler indicates a wide range of air voids with respect to Test Method Tex-207-F. There is an obvious correlation between the two methods for determining the in-place density of bituminous mixtures; however, the correlation may not be close enough to permit their interchangeable use.

DISCLAIMER STATEMENT

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INTRODUCTION

The in-place density is one of the most significant physical properties of bituminous pavements. It is a contributing factor to stability, permeability, and durability. The 1982 SDHPT Standard Specifications allow in-place density control by "cores or sections of asphaltic pavements tested in accordance to Test Method Tex-207-F" or by any method which correlates satisfactorily with this method (refer to Appendix C). Density control by Test Method Tex-207-F is labor intensive and time consuming. Since the results are typically not available until the next day, density control for the pavement being tested is difficult. A method capable of measuring the in-place density with the mix in a workable state would enable the inspector to correct the density problem of the mix being tested. The Troxler Model 4640 Thin Layer Density Gauge would provide the inspector with this capability, and therefore, if it can produce reliable results, the Troxler would be beneficial.

DEFINITIONS

* Density will refer to the in-place density of a bituminous pavement expressed in pcf unless otherwise stated.

* Density difference will refer to the algebraic difference between the density measured by the Troxler Model 4640 Thin Layer Density Gauge and the density measured by Test Method Tex-207-F Part I.

* Four inch core will refer to a four inch diameter core of a bituminous mixture taken from the roadway.

* Pcf will refer to pounds per cubic feet as the unit for density.

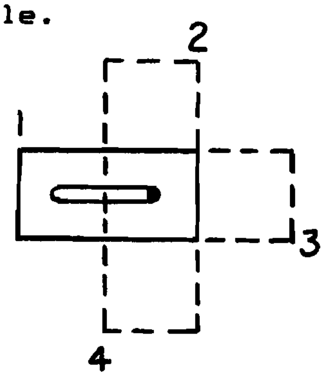
* Six inch core will refer to a six inch diameter core of a bituminous mixture taken from the roadway.

* Test Method Tex-207-F will refer to Test Method Tex-207-F Part I unless otherwise stated.

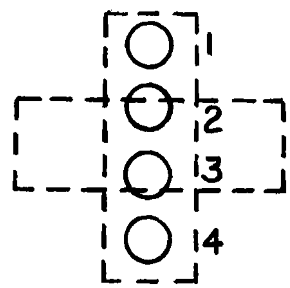
* Troxler will refer to the Troxler Model 4640 Thin Layer Density Gauge.

RESEARCH PROCEDURE

On four independent projects the in-place densities were determined for several locations by both test methods. Figure 1 illustrates the testing methods for each location. First, the density was measured for a section of pavement at four orientations of the Troxler. Then, the pavement was cored as close to the section tested by the Troxler as possible.



Troxler Positions



Core Positions

Figure 1

The average of the four Troxler readings, using a four minute count for each reading, defined the in-place density at each location. When four inch cores were used, the average of four values obtained from Test Method Tex-207-F defined the density. When six inch cores were used, the average of two values defined the density. Each test method occasionally demonstrated a value inconsistent with the other values at that location. The inconsistent values, when determined to be unrepresentative, were deleted from the research.

The four projects demonstrated the properties of each test method under different roadway conditions. The pavement depth remained approximately two inches for all four projects. While most nuclear density gauges measure depths greater than two inches, the data demonstrated that the depth variance control on the Troxler 4640 gauge operates properly. On two of the projects the surface material was the same as the underlying material. On one project the underlying material was a different bituminous mixture and on the other it was a lime treated subgrade. A more complete description may be found in Appendix A.

DATA AND DISCUSSION

REPEATABILITY

The density repeatabilities of the Troxler and Test Method Tex-207-F were determined from the research data. Since several density measurements were obtained at each location, the repeatabilities were defined using the following method. The difference between the individual value and the average of all the values at a single location defined the variation. Using this criteria, and assuming a normal distribution, the standard deviations of all the variations for each test method were computed. The repeatabilities were computed as the 90% confidence level of the variations using the following equation:

$$R = 1.645 \times s.d.$$

where R = repeatability in pcf

s.d. = standard deviation of the variation

Table 1 shows the total sample size used to calculate the repeatability for each test method.

TEST	SAMPLE SIZE
Test Method Tex-207-F 4 in cores	180
Test Method Tex-207-F 6 in cores	88
Troxler 4640	356

Table 1

The repeatabilities remained approximately constant on all the projects for each test method. Therefore, this consistency indicates that the repeatability was not affected significantly by any variable dependent on the individual projects.

Figure 2 illustrates the repeatabilities of the densities from Test Method Tex-207-F with four and six inch cores and the densities from the Troxler 4640 gauge.

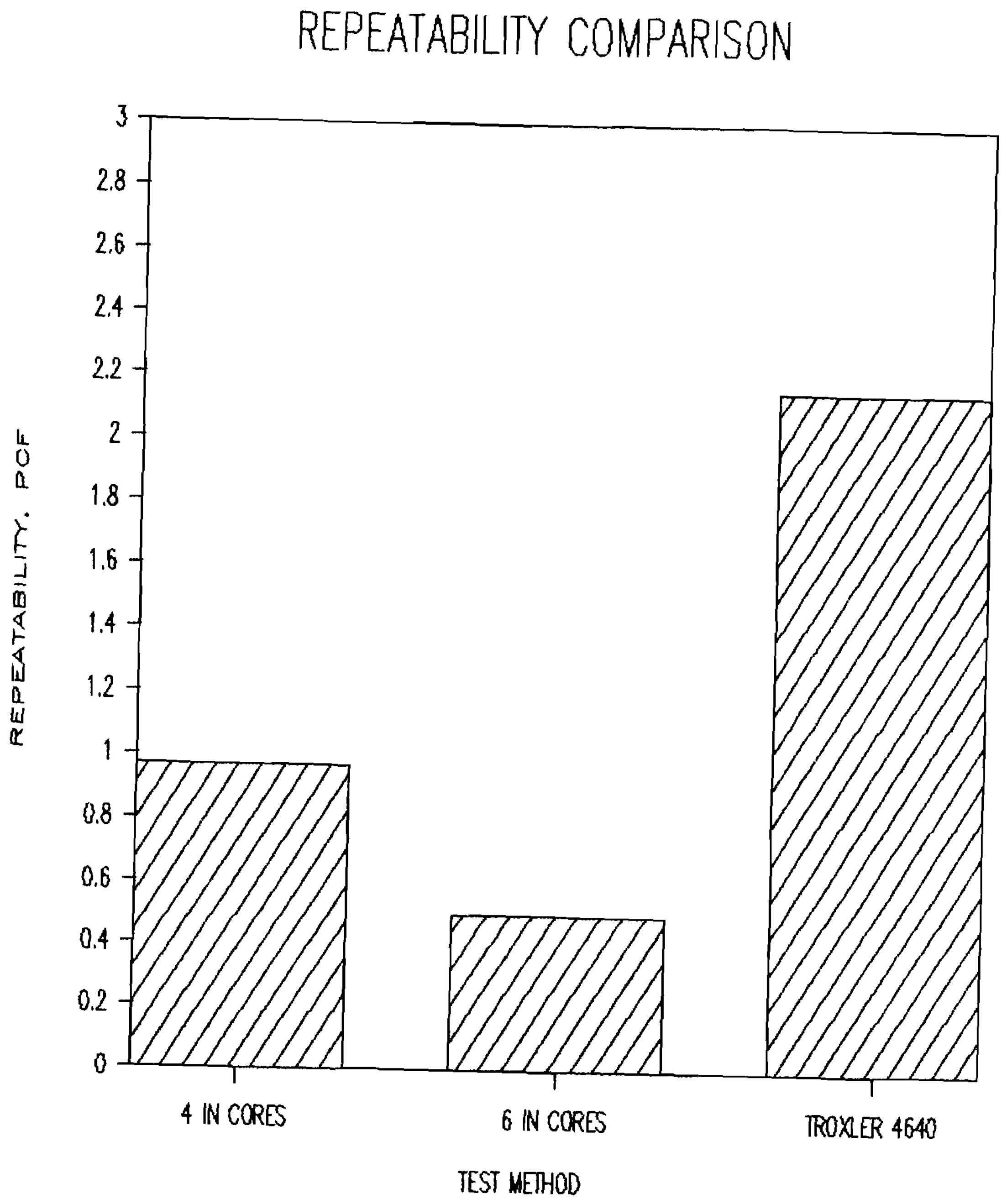

REPEATABILITY COMPARISON
REPEATABILITY, PCF
3
2.8
2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
4 IN CORES
6 IN CORES
TROXLER 4640
TEST METHOD

Figure 2

The data for the density measured by Test Method Tex-207-F with six inch cores demonstrates the best results with a repeatability of 0.50 pcf. The data for the four inch cores indicates a repeatability of 0.97 pcf and for the Troxler indicates a value of 2.16 pcf.

Based on the repeatability, six inch cores appear to be the better choice to use in comparison with the four inch cores. Samples with a larger cross sectional area are damaged less during the coring operation for most pavements. However, six inch cores are almost impossible to remove from thin layers of pavement without completely damaging the core. In these cases four inch cores may be more practical.

The individual densities measured by the Troxler gauge demonstrate greater variations than the individual densities from Test Method Tex-207-F (with both the four and six inch cores). This may be attributed to the effect of the heterogeneousness of bituminous mixtures. A large rock immediately beneath the source of the Troxler could indicate a greater density than actually exists. For this research three of the four projects demonstrated greater densities by the Troxler than by Test Method Tex-207-F.

Even though a large variation by the Troxler exists in comparison to Test Method Tex-207-F, the greater deviations may be deleted by using the average of more readings at each location.

CORRECTION FACTOR

As previously stated, the densities were measured on four projects with various field conditions (refer to Appendix A). The Troxler typically indicated a higher density than the cores tested by Test Method Tex-207-F. In addition, the differences by the two methods appear to be unique for each project. Therefore, the data indicates a need to establish a correlation or a correction factor for each project.

Figures 3, 4, 5 and 6 illustrate the correlation between the two methods for each project. The graphs show the frequency of occurrence for each difference in density by the two methods. For example, Figure 3 shows that there were six densities obtained by the Troxler that were 1.1 to 1.5 pcf greater than the corresponding densities by Test Method Tex-207-F. The frequency indicates a pattern of variation in the density difference.

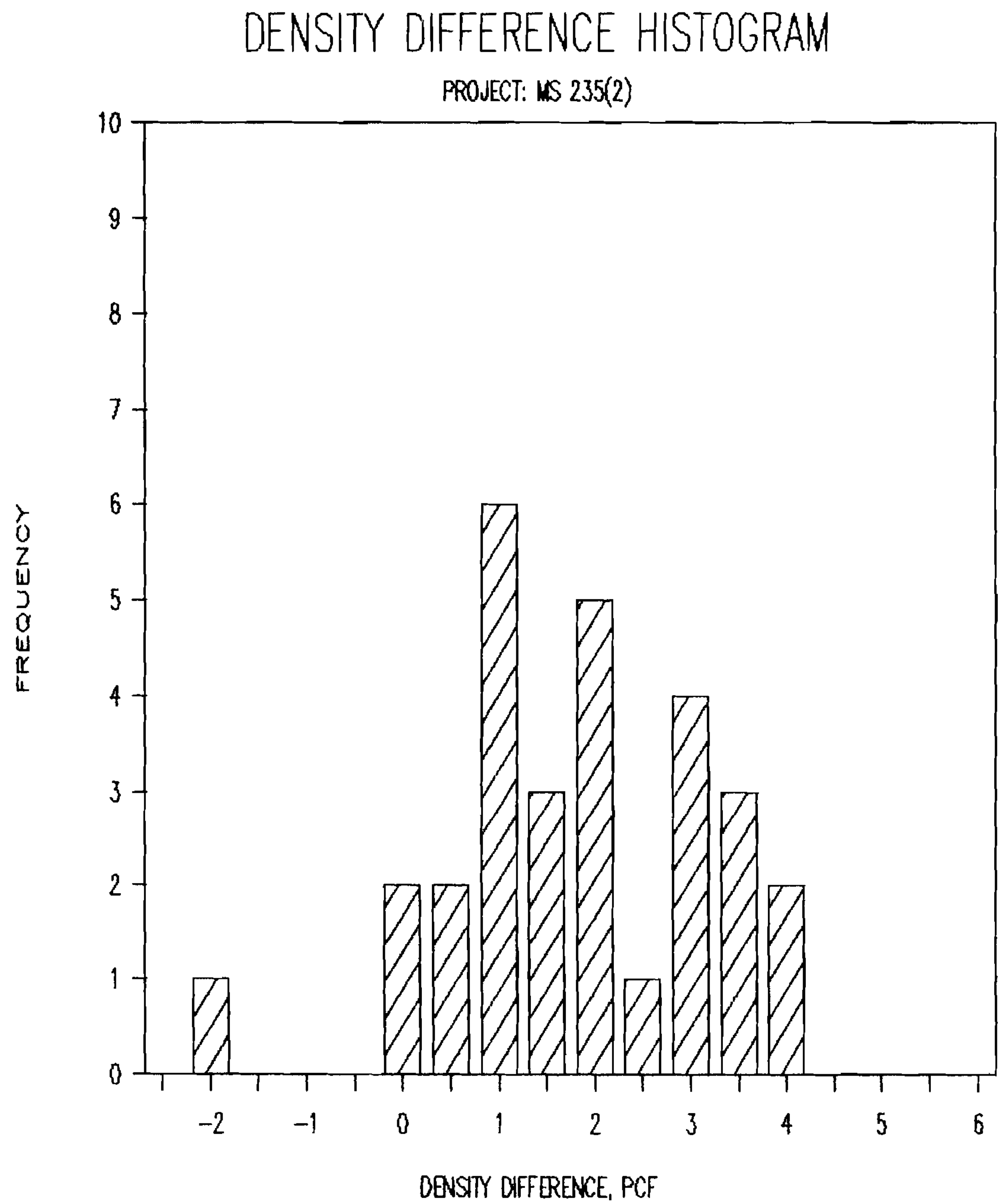

DENSITY DIFFERENCE HISTOGRAM
PROJECT: MS 235(2)
FREQUENCY
10
9
8
7
6
5
4
3
2
1
0
-2
-1
0
1
2
3
4
5
6
DENSITY DIFFERENCE, PCF

Figure 3

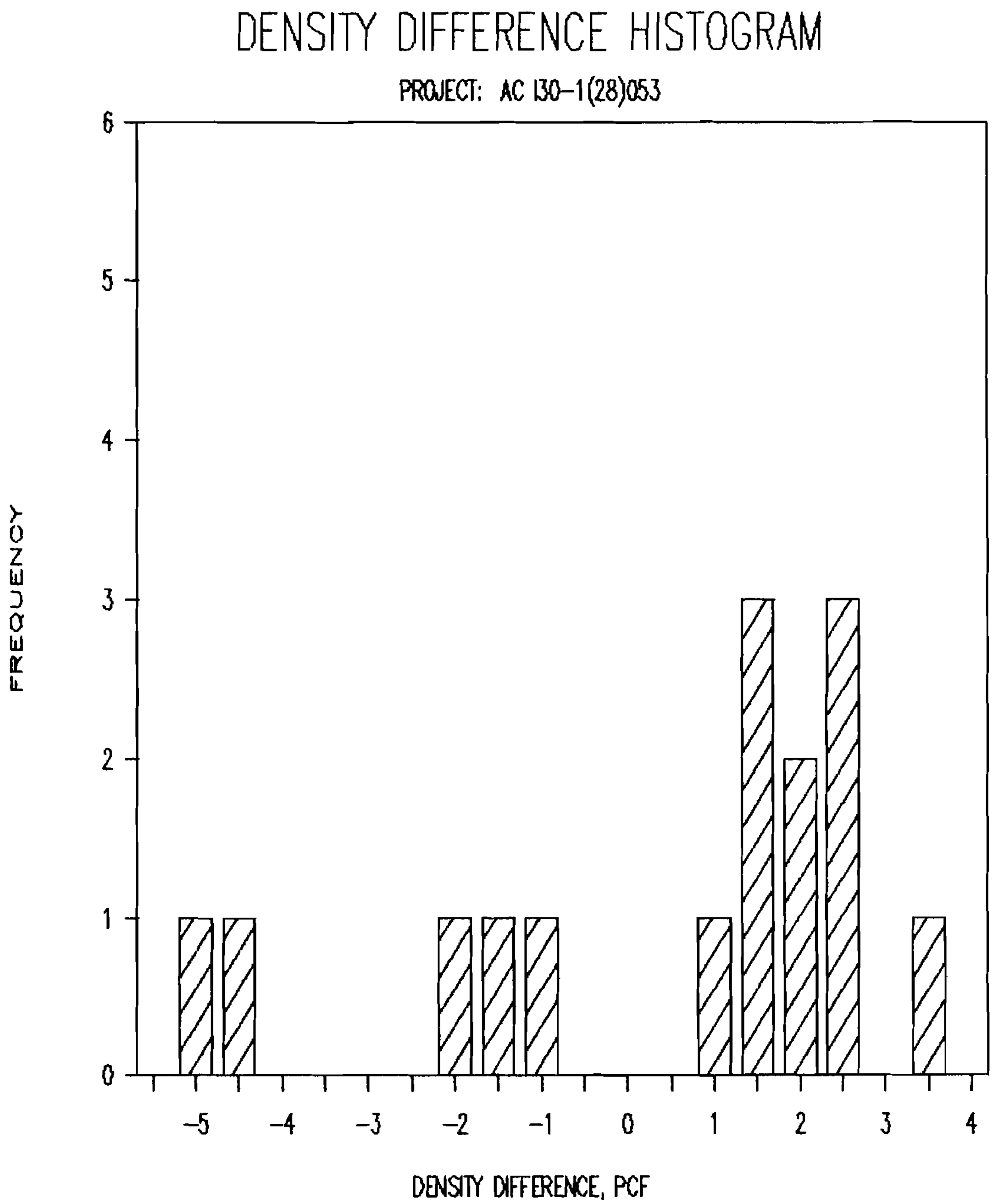

DENSITY DIFFERENCE HISTOGRAM
PROJECT: AC 130-1(28)053
FREQUENCY
0
1
2
3
4
5
6
-5
-4
-3
-2
-1
0
1
2
3
4
DENSITY DIFFERENCE, PCF

Figure 4

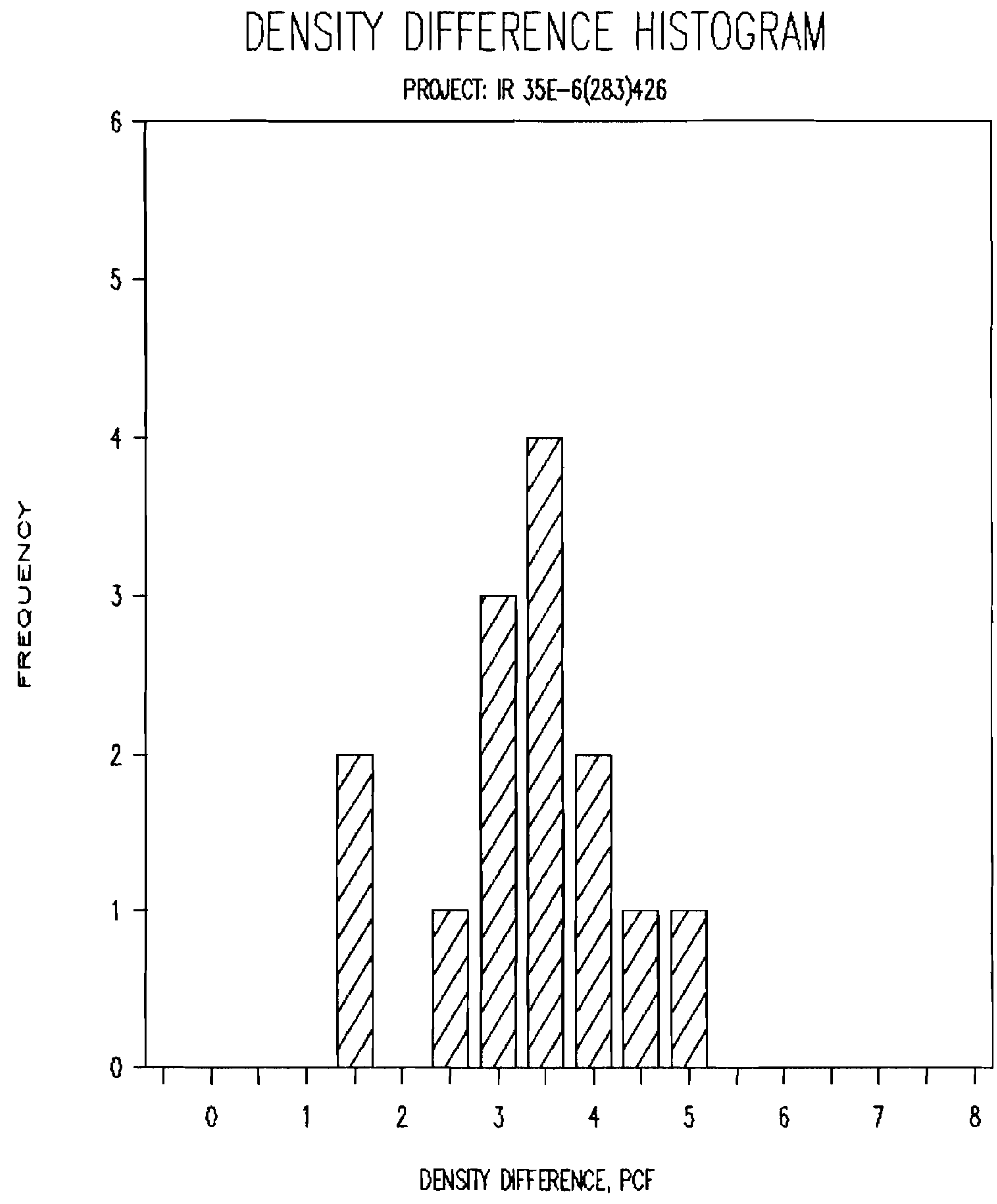

DENSITY DIFFERENCE HISTOGRAM
PROJECT: IR 35E-6(283)426
FREQUENCY
0
1
2
3
4
5
6
0
1
2
3
4
5
6
7
8
DENSITY DIFFERENCE, PCF

Figure 5

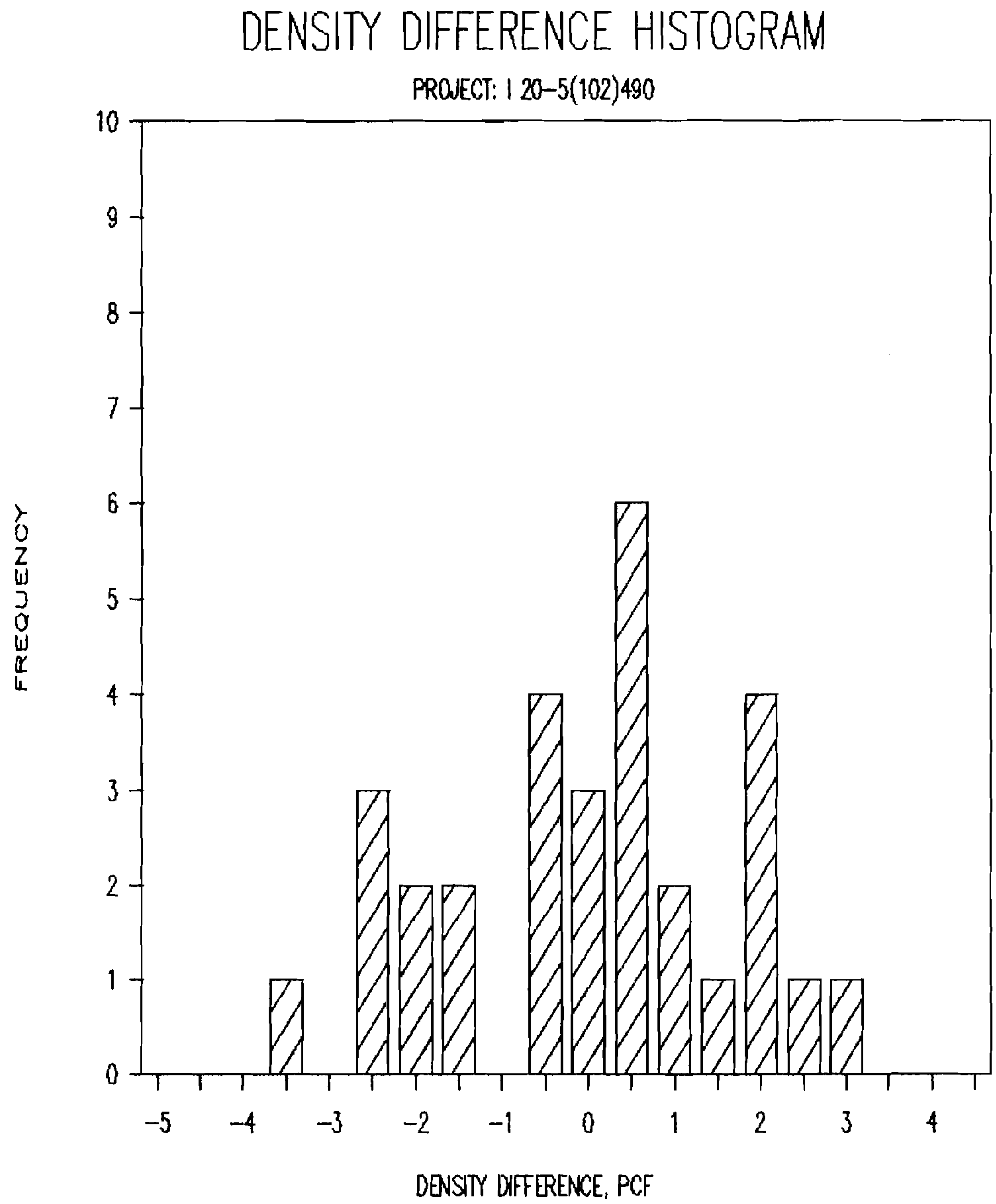

DENSITY DIFFERENCE HISTOGRAM
PROJECT: I 20-5(102)490
FREQUENCY
10
9
8
7
6
5
4
3
2
1
0
-5
-4
-3
-2
-1
0
1
2
3
4
DENSITY DIFFERENCE, PCF

Figure 6

A normal distribution was computed for the density difference on each project. The average difference defined the correlation factor and the standard deviation indicated the relative certainty of the correlation factor. For this research the correlation factors and standard deviations are presented in Table 2.

PROJECT NO	CORRELATION FACTOR	STANDARD DEVIATION
MS 235(2)	2.9 pcf	1.6 pcf
AC I30-1(28)053	2.4 pcf	2.5 pcf
I 20-5(102)490	- 0.2 pcf	1.6 pcf
IR 35E-6(283)426	3.6 pcf	1.0 pcf

TABLE 2

As shown from the data in Table 2, a correlation on each project between the two methods would be necessary in order to determine the correction factor. A correlation of 30 samples and a standard deviation of 1.6 pcf will result in a correction factor accurate to plus or minus 0.48 pcf (with a 90% confidence interval) as computed by the following equation.

$$\frac{L}{2} = 1.645 \times \frac{s.d.}{\sqrt{n}}$$

where L = interval length

s.d. = standard deviation = 1.6 pcf

n = sample size = 30

This correction factor may then be used to correlate the densities obtained by the Troxler with those from Test Method Tex-207-F. Since the correlation will require measuring the density of at least 30 locations by both test methods the process will be labor intensive and time consuming.

ACCURACY

Once the correction factors have been applied to the Troxler densities, the accuracy of the Troxler can be compared with respect to Test Method Tex-207-F. For this research, each individual Troxler density was corrected by the correlation factors listed in Table 2 in order to normalize the values with respect to the densities from Test Method Tex-207-F. The normalized densities indicate the accuracy of the Troxler may be unsatisfactory in comparison to the SDHPT Standard Specification requirements.

The percent air voids were calculated for the normalized Troxler densities and the Test Method Tex-207-F densities. The theoretical densities used in the calculations were determined by tests performed on the cores in accordance with Test Method Tex-227-F.

Figure 7 illustrates the comparison of air voids determined by the two test methods. The data indicates, using the following equation, that the 90 % confidence interval is approximately 3.6 % air voids.

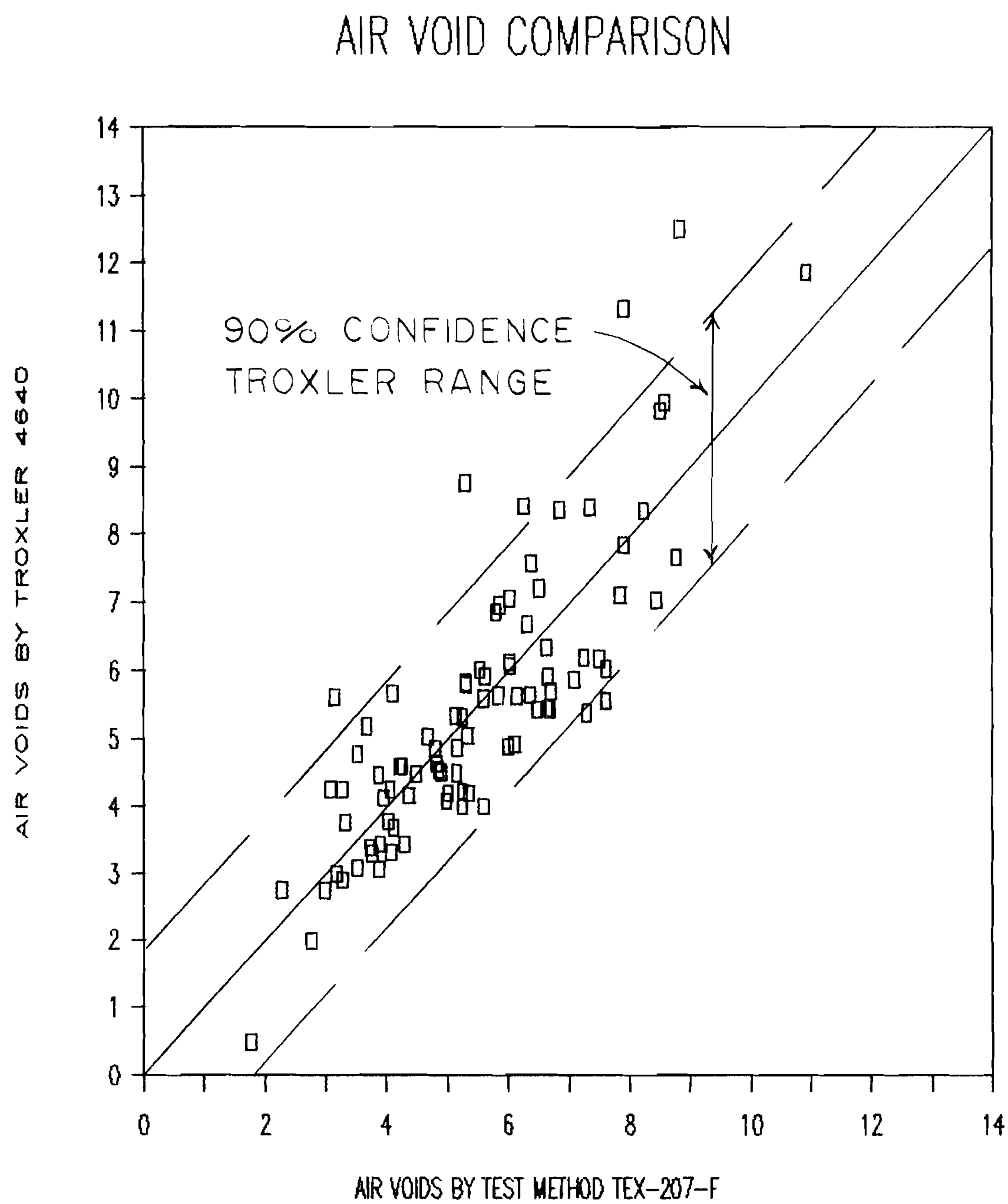
$$C.I. = 2 \times 1.645 \times s.d.$$

where C.I. = confidence interval

s.d. = standard deviation = 1.1

The relationship of the confidence interval to the SDHPT Specifications are illustrated in Figure 8. As shown in Figure 8, if the air voids content indicated by Test Method Tex-207-F is 5.5 %, ninety percent of the Troxler readings would indicate an air voids content between 3.7 % and 7.3 %.

The total range of air voids allowed by the SDHPT Standard Specifications is 3.0 % to 8.0 %. The data from this research indicates, in comparison to the allowable range of the SDHPT specification, the Troxler may not be accurate enough, with respect to Test Method Tex-207-F, to justify its use.



AIR VOID COMPARISON
90% CONFIDENCE
TROXLER RANGE
AIR VOIDS BY TROXLER 4640
AIR VOIDS BY TEST METHOD TEX-207-F
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14

Figure 7

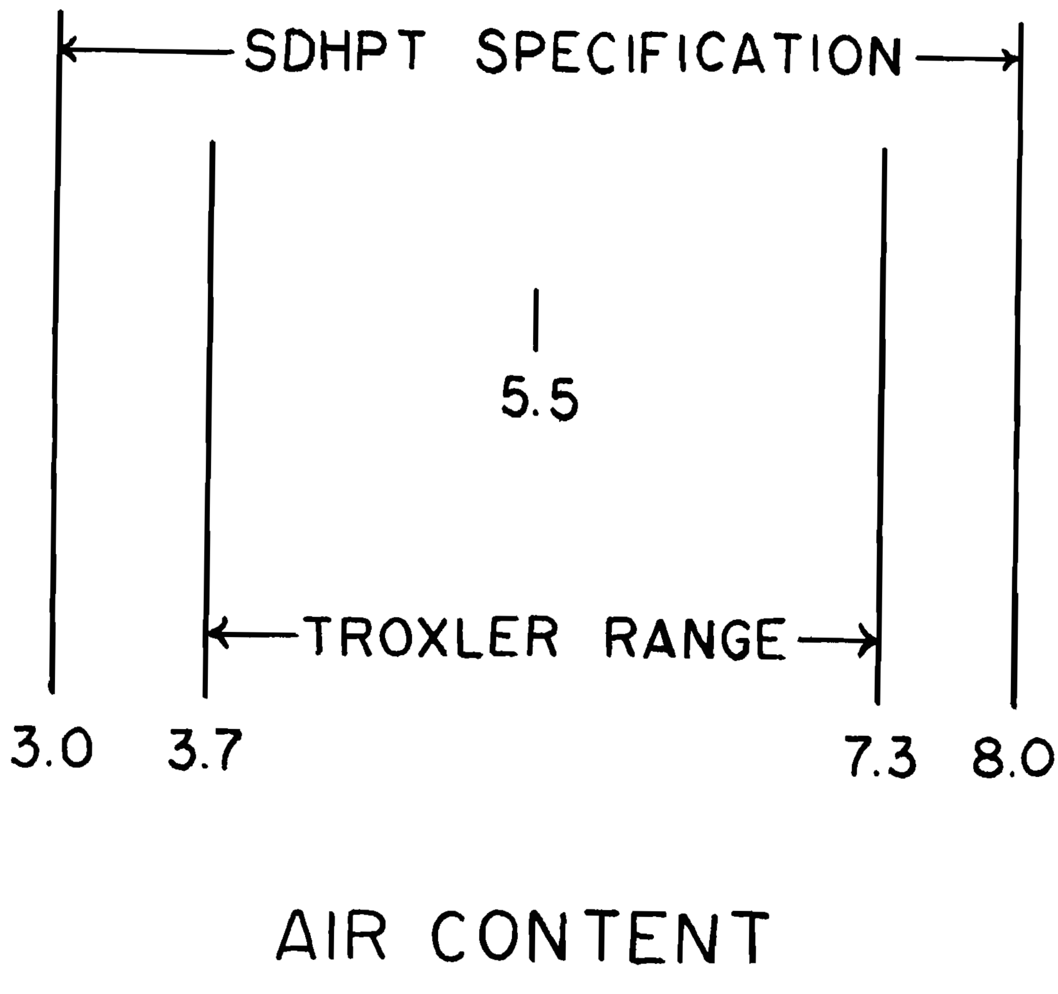

SDHPT SPECIFICATION
5.5
TROXLER RANGE
3.0
3.7
7.3
8.0
AIR CONTENT

Figure 8

CONCLUSION

The District 18 Laboratory evaluated the Troxler Model 4640 Thin Layer Density Gauge to determine its capability to measure the in-place density of bituminous pavements in comparison to Test Method Tex-207-F Part I. There are three primary conclusions from this research.

First, the repeatability of the Troxler is approximately 2.1 pcf, while the repeatabilities of the four and six inch cores are less than 1.0 pcf. This indicates that the densities determined by cores tested in accordance with Test Method Tex-207-F had a better repeatability, and therefore, a core removed from the roadway appears to be satisfactory as a representative sample. However, the densities from the Troxler do not indicate as good a repeatability, and therefore, may not be as capable of producing reliable results.

Secondly, a correction factor for each project should be established. The average density difference between the two test methods ranged from - 0.2 pcf to + 3.6 pcf. A correlation of thirty samples would produce a correction factor accurate to plus or minus 0.5 pcf.

Finally, once the correction factor has been applied, the Troxler could be expected to indicate an air voids content within plus or minus 1.8 % of the air voids content measured by Test Method Tex-207-F.

There are many variables which could affect the performance of each test and this research only investigated a few. The purpose of this research was to evaluate the two test methods under various roadway conditions. From the data and for the conditions examined, the cores tested in accordance with Test Method Tex-207-F appear to be more reliable than the Troxler. In addition, since a correlation would be necessary, Test Method Tex-207-F may often be more time efficient. There is an obvious correlation between the two test methods; however, the data indicates that the correlation may not be close enough to justify the interchangeable use of the Troxler Model 4640 Thin Layer Density Gauge with Test Method Tex-207-F Part I.

APPENDIX A

APPENDIX A

PROJECT NO	DESCRIPTION	NO OF SAMPLES		
		Test Method Tex-207-F		Troxler 4640
		4 in cores	6 in cores	
MS 235(2)	Asphalt stabilized base with lime subgrade for the underlying material	60	30	120
AC I30-1(28)053	Asphalt stabilized base with the same for the underlying material	60	0	60
I 20-5(102)490	Asphalt stabilized base with the same for the underlying material	60	30	120
IR 35E-6(283)426	Asphaltic concrete with a different asphaltic concrete for the underlying material	0	28	56

APPENDIX B

Project: MS 235(2)

Theoretical Density Tex-227	In-place Density Tex-207-F	In-place Density Troxler 4640
153.3	144.3	145.6
153.2	145.0	149.7
152.3	146.1	150.2
152.8	140.2	143.0
152.4	144.3	142.0
154.1	144.8	146.2
153.6	143.6	145.5
152.5	146.6	148.6
153.6	141.9	147.3
152.5	144.4	146.6
153.6	143.9	146.3
153.1	144.5	147.0
152.4	145.0	148.4
152.4	144.4	148.9
153.6	145.0	150.4
151.6	145.7	149.3
151.1	143.8	147.0
150.6	145.0	148.4
150.9	146.1	149.3
149.5	143.7	147.8
152.8	146.3	148.7
151.4	144.9	149.1
151.3	142.2	146.8
150.8	140.7	145.5
152.7	143.5	146.4
151.6	144.8	147.7
151.2	145.1	148.4
150.9	142.9	145.0
151.5	144.4	146.8
149.1	144.4	143.6

Project: I 20-5(102)490

Theoretical Density Tex-227	In-place Density Tex-207-F	In-place Density Troxler 4640
154.1	149.5	149.7
152.3	149.6	151.4
153.7	145.8	145.3
153.8	147.1	147.2
153.6	145.1	144.2
152.6	147.9	145.9
152.4	146.8	144.3
153.6	147.3	144.7
152.9	147.5	145.4
152.4	147.4	145.7
152.6	147.6	148.0
151.9	147.7	148.7
154.6	146.9	148.1
154.5	144.8	141.3
153.6	150.1	149.2
153.4	145.5	146.3
153.0	145.5	145.9
152.4	144.4	146.1
153.4	144.5	142.7
153.3	147.9	148.4
154.3	146.2	145.9
152.7	146.5	146.0
154.9	143.1	146.1
153.8	140.8	142.8
153.8	145.2	145.0
153.1	142.6	140.1
152.5	143.3	143.0
153.5	142.6	144.3
156.5	146.1	146.4
152.4	143.1	144.7

Project: AC I 30-1(28)053

Theoretical Density Tex-227	In-place Density Tex-207-F	In-place Density Troxler 4640
152.7	139.2	136.0
152.6	143.2	146.4
152.9	140.8	138.0
152.7	139.3	143.4
152.1	141.9	145.8
151.4	138.5	138.9
151.9	141.8	146.0
151.7	140.7	144.7
152.8	136.1	137.1
152.0	140.9	146.2
151.8	141.7	145.2
152.0	140.6	145.0
152.3	141.1	141.9
152.2	142.5	146.0
151.6	139.7	143.2

Project: IR 35E-6(283)426

Theoretical Density Tex-227	In-place Density Tex-207-F	In-place Density Troxler 4640
153.1	145.2	149.2
153.6	145.4	149.4
154.1	148.0	151.3
154.2	144.2	149.4
154.6	144.7	146.5
153.8	146.1	150.9
153.9	147.4	150.4
154.1	148.3	152.6
153.3	147.0	151.2
153.6	148.5	151.4
154.1	146.7	150.2
154.0	145.0	148.9
154.1	141.9	145.6
154.8	141.5	143.0

APPENDIX C

APPENDIX C

The following is the specification requirement for the first paragraph listed under Item 340.6 (c) of the SDHPT 1982 Standard Specifications:

(c) In-Place Density. In-place density control is required for all mixtures except thin irregular depth level-up courses. The material should be placed and compacted to either the percent of theoretical density or the percent of laboratory molded specimen density that is shown on the plans. Roadway specimens, which shall be either cores or sections of asphaltic pavement, will be tested according to Test Method Tex-207-F. When indicated on the plans, the Contractor shall be responsible for the required roadway specimens at his expense and in a manner and at a location satisfactory to the Engineer. Other methods of determining in-place density which correlate satisfactorily with results obtained from the project roadway specimens may be used when approved by the Engineer.