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by

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CENTER FOR TRANSPORTATION RESEARCH

BUREAU OF ENGINEERING RESEARCH

THE UNIVERSITY OF TEXAS AT AUSTIN

November 1986

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

There was no invention or discovery conceived or first actually reduced to practice in the course of or under this contract, including any art, method, process, machine, manufacture, design or composition of matter, or any new and useful improvement thereof, or any variety of plant which is or may be patentable under the patent laws of the United States of America or any foreign country.

PREFACE

This is the second and final report in a series of reports dealing with field compaction of asphalt mixtures in Texas. This report summarizes the density data which were obtained from 17 construction projects in Texas.

The effort required to assemble the data for this project was provided by many people. Special appreciation is extended to Richard W. Floyd (Dist. 1), Franklin S. Craig (Dist. 3), Michael K. Ho (Dist. 12), Franklin J. Shenkir and Nick Turnham, Jr. (Dist. 17), Donald Williamson (Dist. 20), and Billy R. Russell (Dist. 23). The support of Texas State Department of Highways and Public Transportation and of the Federal Highway Administration, Department of Transportation, is acknowledged. Appreciation is also extended to the Center for Transportation Research staff who assisted in the preparation of the manuscript.

Thomas W. Kennedy
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November 1986

LIST OF REPORTS

Report No. 317-1, "Compaction of Asphalt Mixtures and the Use of Vibratory Rollers," by Thomas W. Kennedy, Freddy L. Roberts, Robert B. McGennis, and James N. Anagnos, summarizes a literature review concerned with compaction of asphalt mixtures and vibratory compaction, and presents suggested methods of operation of vibratory rollers.

Report No. 317-2F, "A Summary of the Field Compaction of Asphalt Mixtures in Texas," by Thomas W. Kennedy, Maghsoud Tahmoressi, and James N. Anagnos, summarizes the density data from 17 construction projects in Texas. A comparison is made between relative laboratory and field densities. Relative densities based on Rice maximum theoretical specific gravity and calculated maximum theoretical specific gravity are compared.

KEY WORDS: compaction, density, relative density, cores, asphalt content

ABSTRACT

This report summarizes the density data which were obtained from 17 construction projects in Texas. The data were analyzed to determine the level of density and variations being achieved. In addition, an evaluation of the adequacy of various density determination techniques was conducted. Also included is a limited evaluation of nuclear density measurements.

SUMMARY

This report summarizes the density data which were obtained during the 1983 construction season from 17 construction projects in the State of Texas. The data were analyzed to determine the level of density and variation being achieved. Asphalt content data were obtained for each project to study variations in asphalt content during the construction process and determine the magnitude of deviation of extracted asphalt content from the design value. An evaluation of the adequacy of various density determination techniques was conducted. Some Districts provided nuclear density data; an attempt was made to study the correlation between core and nuclear densities.

IMPLEMENTATION STATEMENT

A summary of typical densities which are currently being achieved in Texas is presented in this report. This summary may provide a basis for realistic density specifications; however, more density data are needed from projects which have attempted to control the density with a wide range of aggregates, in order to establish realistic density specifications.

TABLE OF CONTENTS

DEFINITIONS

G_C	specific gravity of the asphalt mixture determined from a field compacted core
G_L	specific gravity of the asphalt mixture determined from a laboratory compacted specimen
G_R	specific gravity of the asphalt mixture determined by a Theoretical Rice Specific Gravity Test (Tex - 227-F)
$G_{R\ day}$	based on G_R measured daily on plant mixed mixtures
$G_{R\ job}$	G_R measured when a design or mix change occurred or G_R day on the first day of a design
G_T	theoretical specific gravity of the asphalt mixture determined from the bulk specific gravities of the total materials in the mixture

$$G_T = \frac{100}{\frac{\%AGG}{G_{AGG}} + \frac{\%ASP}{G_{ASP}}}$$

where

%ASP = percent asphalt, based on total weight of mixture

%AGG = percent aggregate, based on total weight of mixture

G_{ASP} = bulk specific gravity of the asphalt

G_{AGG} = bulk specific gravity of the aggregate

$G_{T\ day}$	specific gravity based on average percent asphalt for the day determined from extractions
$G_{T\ design}$	specific gravity based on the percent asphalt in the design mixture
$G_{T\ extra.}$	specific gravity based on percent asphalt from the extraction used to determine laboratory density

CHAPTER 1. INTRODUCTION

Adequate compaction of asphalt mixtures is one of the more important factors affecting the performance of asphalt mixtures in pavements. To ensure adequate compaction, in-place densities are often specified in terms of a percentage of a standard laboratory compacted density or a percentage of a maximum theoretical density. The maximum theoretical densities can be calculated on the basis of the specific gravity of the aggregates and asphalt cement, with or without a correction for absorption, or the Rice specific gravity which accounts for absorption of asphalt by the aggregate.

In 1982, the Texas Department of Highways and Public Transportation adopted specifications requiring an end result density of 92 to 97 percent of Rice maximum theoretical density. Previous studies (Refs 1 and 2) had reported densities with air voids as high as 13 percent. Thus, there was a need in Texas to evaluate the relative densities, or air void contents, being achieved on projects and to establish procedures, guidelines, and specifications to assure satisfactory compaction, density, and air voids.

Densities obtained from 17 projects were analyzed to determine the level of density and variation being achieved. In addition, an evaluation of the adequacy of various density determination techniques was conducted. Also included is a limited evaluation of nuclear density measurements.

Field densities were obtained by coring and by nuclear testing equipment. Laboratory densities were obtained by making specimens from the field mixtures and compacting them in the laboratory. Relative densities were calculated as a percentage of (1) the maximum theoretical values based on the bulk specific gravities of the aggregate and asphalt, (2) the Rice maximum theoretical values, and, (3) the laboratory density.

The importance of the asphalt mixture density to pavement performance and the statistical concepts of density and variation are discussed in Chapter 2. Chapter 3 summarizes the experimental approach and density parameters evaluated. The data is summarized in Chapter 4 and discussed in Chapter 5. Chapter 6 contains the recommendations.

CHAPTER 2. IMPORTANCE OF DENSITY AND STATISTICAL CONCEPTS

This chapter discusses the importance of density to pavement performance and the significance of statistical concepts related to density and variation.

IMPORTANCE OF DENSITY

Long-term satisfactory performance of asphalt pavements is highly dependent on the void content or density of the asphalt mixtures. The three basic types of distress which, directly or indirectly, result in reduced pavement performance and increased pavement maintenance and rehabilitation are thermal or shrinkage cracking, fatigue cracking, and permanent deformation, or rutting.

Closely related are moisture damage and asphalt aging or hardening. Moisture damage, such as stripping and softening, can weaken the pavement and lead to increased fatigue cracking, rutting, and possibly flushing. Asphalt aging, or hardening due to oxidation, can also cause a brittle mixture resulting in fatigue and thermal cracking.

While a number of factors involving the actual structure of the pavement, mixture characteristics, and construction variables can affect the magnitude of these distresses and the severity of moisture damage and oxidation, the air void content (density) is one of the more important. Generally, reduced air void content or increased density achieved through compaction will significantly reduce fatigue cracking, rutting and permanent deformation, moisture damage, and age hardening.

Fatigue Cracking

A number of laboratory studies (Refs 2, 3, 4) have been conducted which illustrate the effect of air void content on fatigue life, i.e., the number of load repetitions required to fail the specimen. The results indicate that mixtures containing high void contents have relatively short fatigue lives. As shown in Figures 2.1 through 2.3, a decrease in air void content from 10 to 3 percent increased fatigue life by approximately a factor of 10. It can also

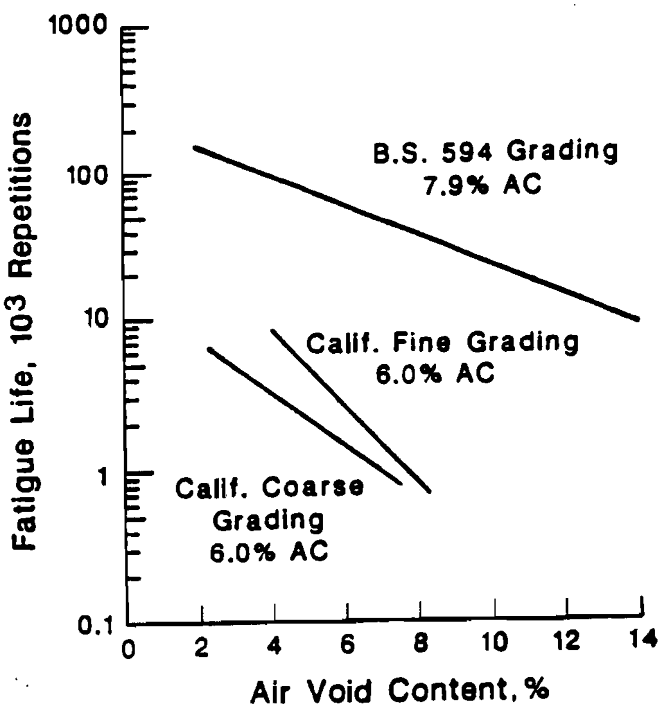


Figure 2.1. Effects of void content on fatigue life (Ref. 4)

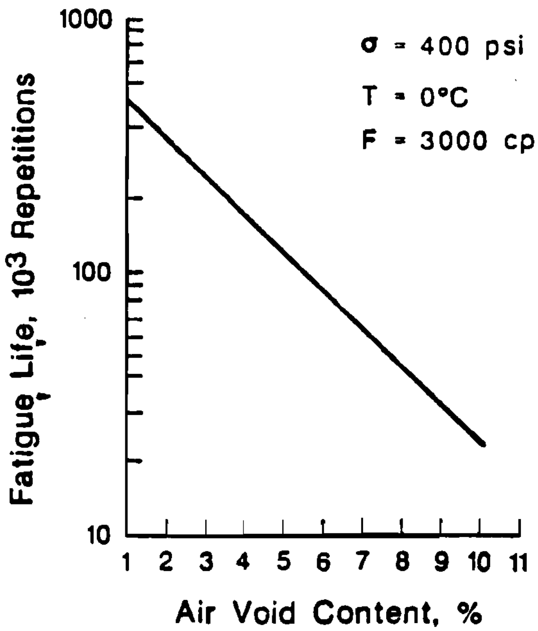


Figure 2.2. Effects of void content on fatigue life (Ref. 2)

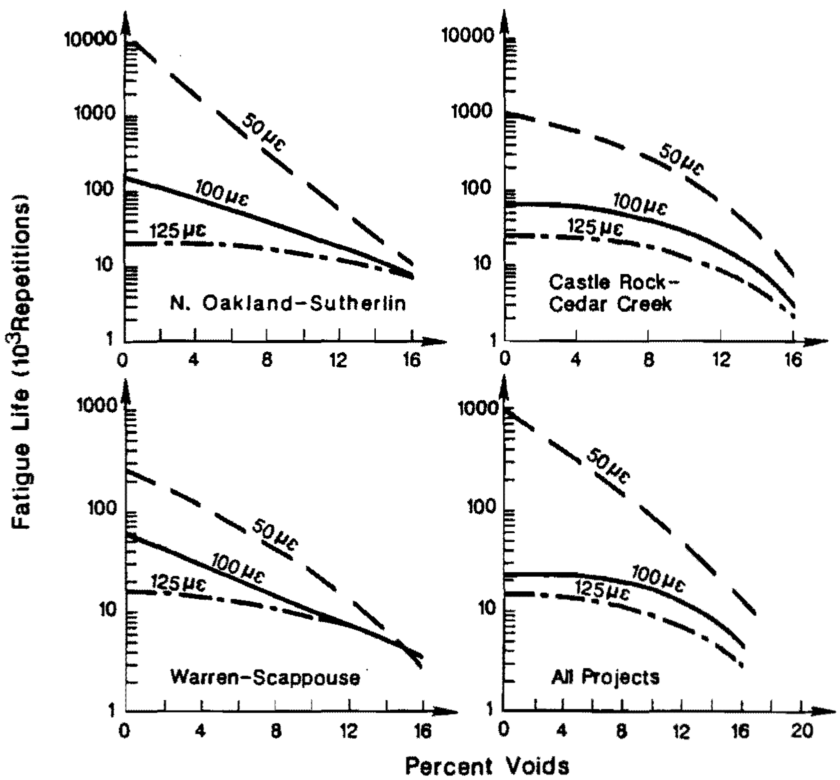


Figure 2.3. Effects of air void content on fatigue life at three different strain levels (Ref. 5)

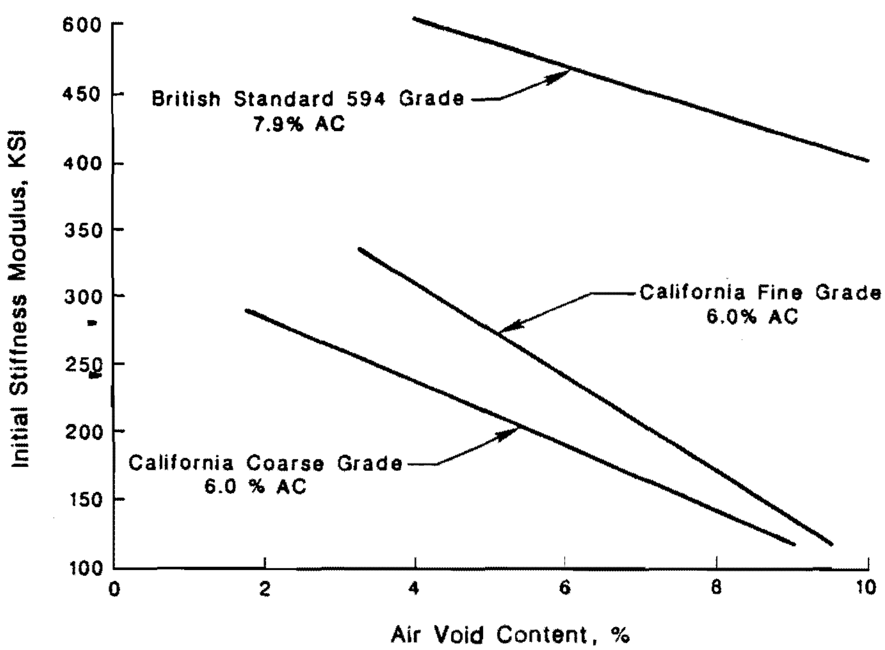


Figure 2.4. Effects of air void content on initial stiffness modulus (Ref. 4)

be seen in Figure 2.3 that at low strain levels, fatigue life decreased sharply with increased void contents. Decreased voids also increased the stiffness of the asphalt mixture (Fig 2.4) which in turn improves the load carrying ability of thick pavement sections and reduces the stresses transmitted to the underlying layers. In addition, stiffness is closely related to fatigue resistance. In general, for a repeated constant stress (thick pavements) fatigue life will increase with increased stiffness, while for a repeated constant strain (thin pavements) fatigue life will decrease with increased stiffness (Table 1.1). The exception is the effect of air void content. As shown in Table 1.1, a decrease in void content produced an increase in stiffness and an increase in fatigue life for both constant stress and constant strain.

Permanent Deformation

Similarly, it was shown by Hicks et al (Ref 5) that an increasing air void content resulted in a significant loss of pavement life in terms of rutting or permanent deformation. As shown in Figure 2.5, a decrease in void content increased the number of loads required to produce failure by a factor of 10.

Asphalt Aging

Pauls and Halstead (Ref 6) employed a hardness index which ranged from zero for no hardening to 100 which corresponded to a penetration value of approximately 10. As shown in Figure 2.6, the hardness index increased significantly with an increase in void content indicating a significant increase of aging or hardening of the asphalt. In addition, the Oregon study (Ref 5) reported significant increases in hardening (reduced penetration) for increased void contents (Fig 2.7).

Moisture Damage

High void contents have consistently been shown to be related to high levels of moisture damage such as stripping (Refs 7 and 8). In many cases, highly moisture susceptible mixtures have performed satisfactorily when compacted to relatively high density. For example, an analysis (Refs 9, 10)

TABLE 1.1. Factors Affecting the Stiffness and Fatigue Behavior of Asphalt Concrete Mixtures (Ref 5)

Factor	Change in Factor	Effect of Change in Factor: On Stiffness	On Fatigue Life: In Controlled Stress Mode	On Fatigue Life: In Controlled Strain Mode
Asphalt Penetration	Decrease	Increase	Increase	Decrease
Asphalt Content	Increase	Increase[1]	Increase[1]	Increase[2]
Aggregate Type	Increase Roughness and Angularity	Increase	Increase	Decrease
Aggregate Gradation	Open to Dense Gradation	Increase	Increase	Decrease[4]
Air Void Content	Decrease	Increase	Increase	Increase[4]
Temperature	Decrease	Increase[3]	Increase	Decrease

[1] Reaches optimum at level above that required by stability considerations.

[2] No significant amount of data; conflicting conditions of increase in stiffness and reduction of strain in asphalt make this speculative.

[3] Approaches upper limit at temperature below freezing.

[4] No significant amount of data.

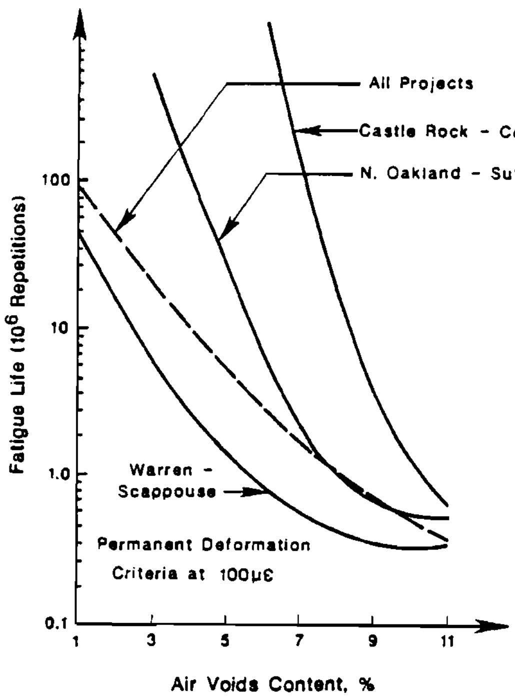
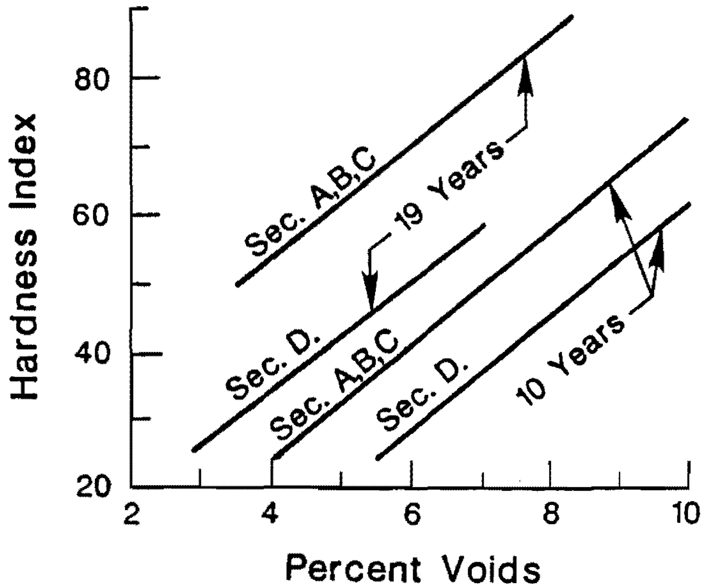


Figure 2.5. Effects of air voids content on fatigue life (data from Ref. 5)



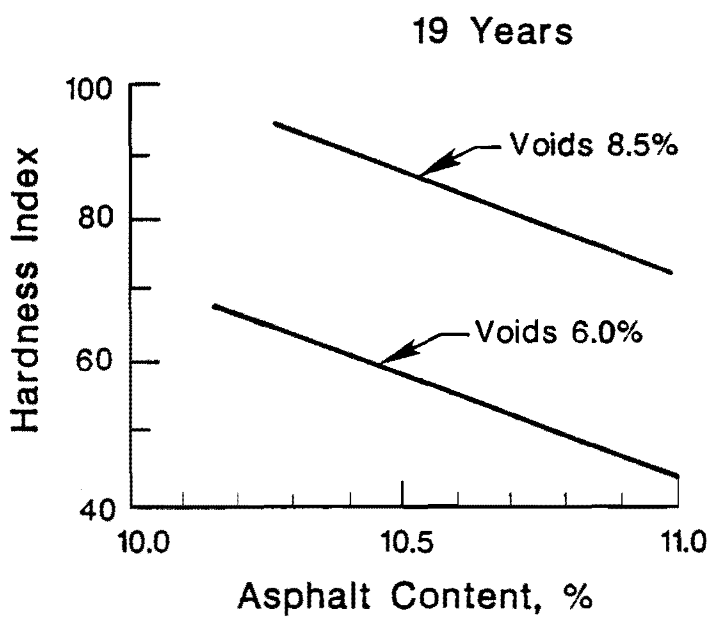


Figure 2.6. Effects of air void content on hardness index. (Ref. 6)

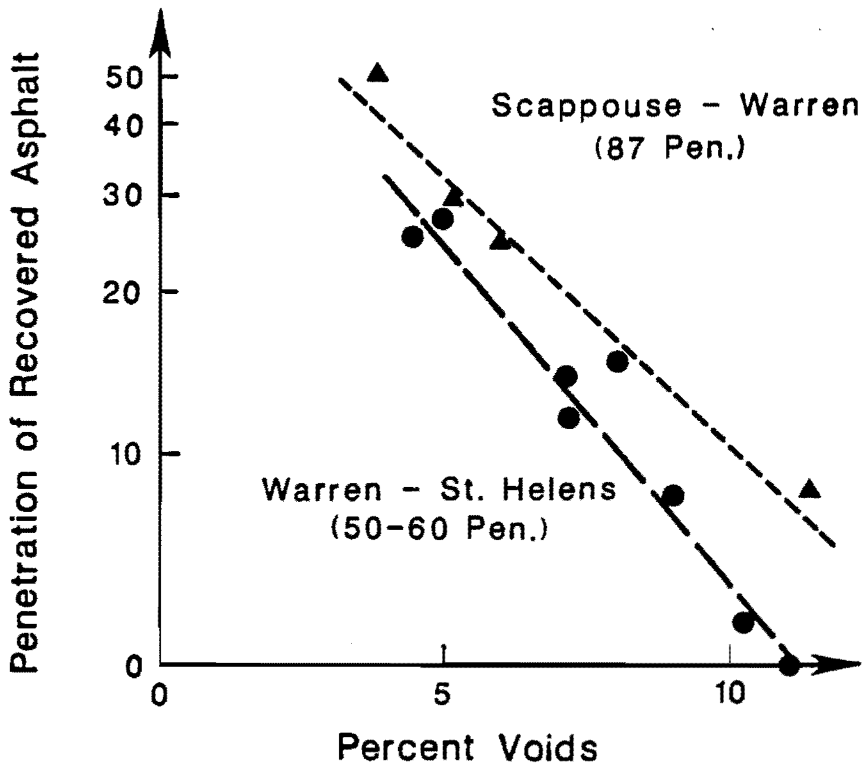


Figure 2.7. Effects of air voids content on penetration of recovered asphalt. (Ref. 5)

of a pavement failure in Texas found that one section of the roadway failed by rutting while another section performed extremely well with no signs of rutting. The evaluation of these failures indicated that the primary cause of the rutting was stripping with associated high moisture contents. Both sections contained essentially the same aggregates and asphalts; however, a high density was achieved in the section which performed satisfactorily which apparently prevented moisture penetration and thus moisture damage. Test samples taken from the roadway also indicated lower moisture contents for the satisfactory pavement sections.

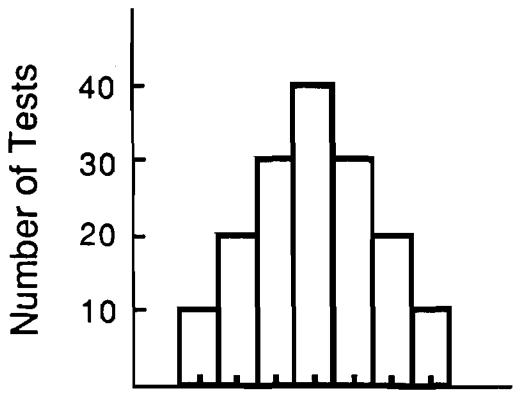
STATISTICAL CONCEPTS

Due to the nature of the materials utilized in asphalt pavements and the procedures involved in construction, density will vary within a given project. In order to provide adequate quality control and to establish realistic specifications, it is necessary to establish the amount or extent of this variation, i.e., the distribution and the nature of the density values.

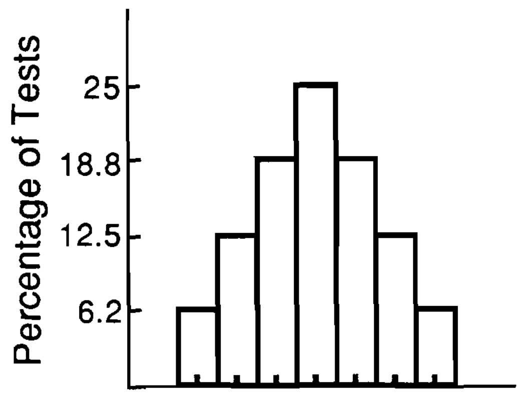
Distribution or Frequency Relationship

Assuming that the density at every possible location on a roadway is known or that a large number of density measurements are made by random sampling, it is possible to determine the number of densities which fall within a given range of relative densities, e.g., the number of densities within the range of 90.0 to 90.5 percent, 90.5 to 91.0 percent, 91.0 to 91.5 percent, etc. The resulting information can then be summarized in a bar graph in which the density range is shown on the horizontal x-axis and the number of density measurements within the range is on the vertical y-axis. The height of the bar graph therefore represents the number of densities which are within a given range of densities (Fig 2.8a).

Another method of illustrating the same information involves converting the actual number of densities in a given range to a percentage of the total number of density values being considered (Fig 2.8b). Thus the height of the bar represents the percentage of values in the given density range and the summation of all the bars represents 100 percent of the density values.

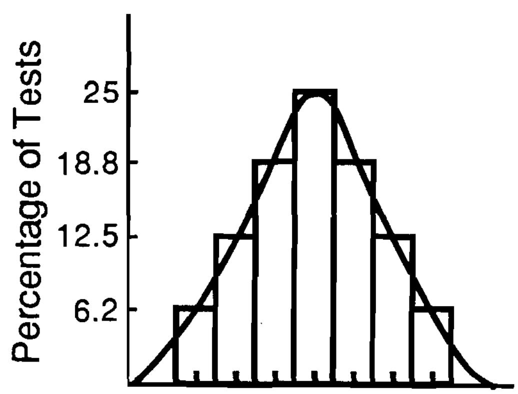


a. Number of tests

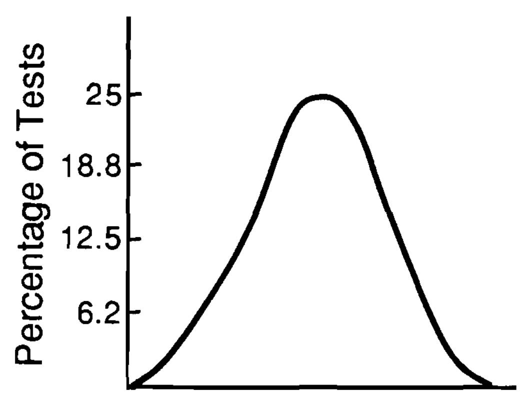


b. Percentage of tests

Figure 2.8. Bar chart presentations of density data



a. Connecting the mid points



b. Smooth curves

Figure 2.9. Bell shaped curve approximation of density data

The bars can be replaced by a smooth curve by connecting the midpoints of the bar as shown in Figure 2.9a. This produces a smooth distribution curve (Fig. 2.9b) and the area under this curve represents 100 percent of all of the density measurements. Thus by comparing areas it is possible to determine the percentage of densities which have greater or lesser values than a specified relative density or the percentage which have densities between two specified relative densities.

Normal Distribution

The bell-shaped frequency distribution represented in Figures 2.8 and 2.9 is referred to as a normal distribution. While other distributions (Fig 2.10) exist, the variation of most engineering properties of pavement materials can be represented by a normal distribution.

A normally distributed set of densities will produce an S-shaped curve (Fig 2.11a) if plotted on ordinary graph paper with the horizontal x-axis showing relative density and the vertical y-axis showing the number or percentage of densities which are smaller. If special graph paper, called normal probability graph paper, is used and the same data are plotted, the relationship will be a straight line (Fig 2.11b).

The two basic characteristics which describe the normal distribution are the mean, or average, and the standard deviation which is a measure of variation or dispersion of the data.

Mean or Average Value. The mean or average value is calculated as

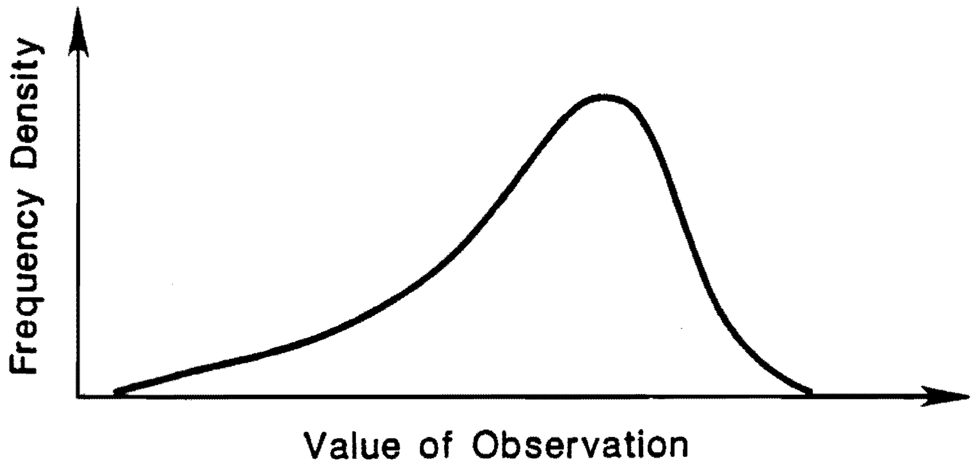
$$\text{Mean (average)}, \ \bar{X} = \frac{\Sigma y}{N} = \frac{\text{Sum of all measurements}}{\text{Number of measurements}}$$

where $\bar{X}$ = the mean or average for the sample,

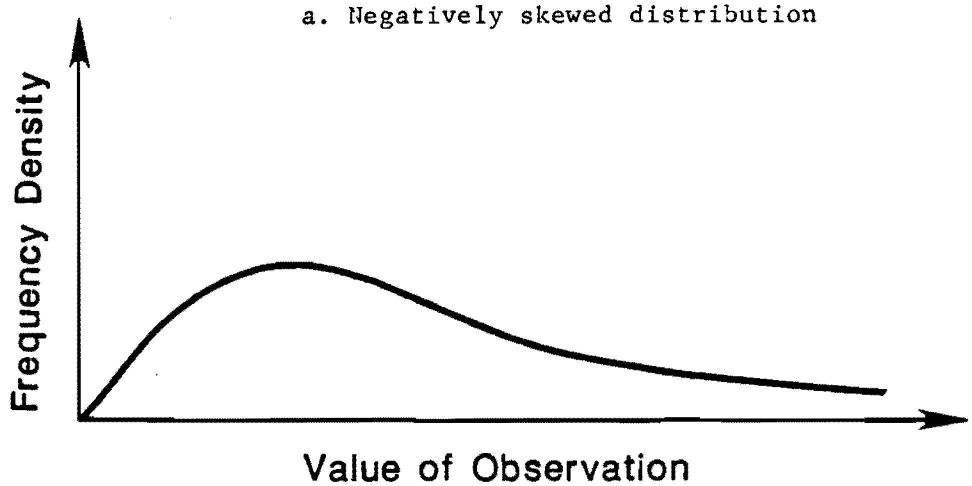
y = the individual measurements, and

N = the number of measurements in the sample.

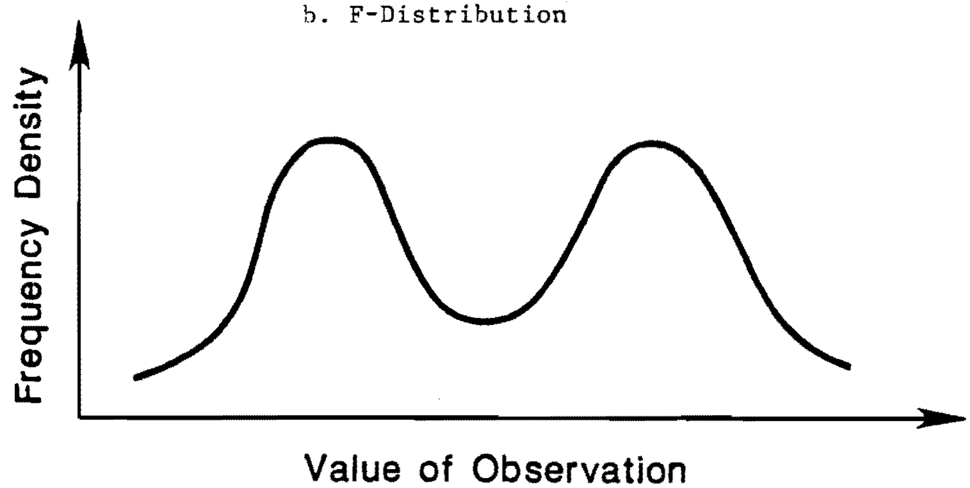
For a normal distribution, it is also the value (median) for which 50 percent of the values are greater and 50 percent are less, and the (mode) value which occurs most often, as shown in Figure 2.9.



a. Negatively skewed distribution

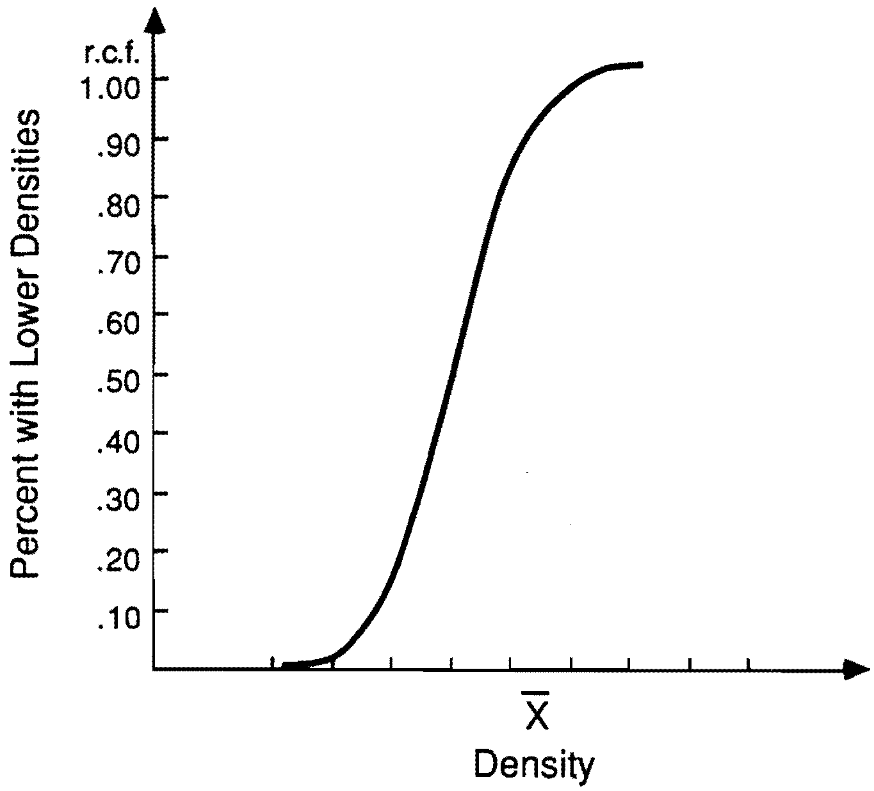


b. F-Distribution

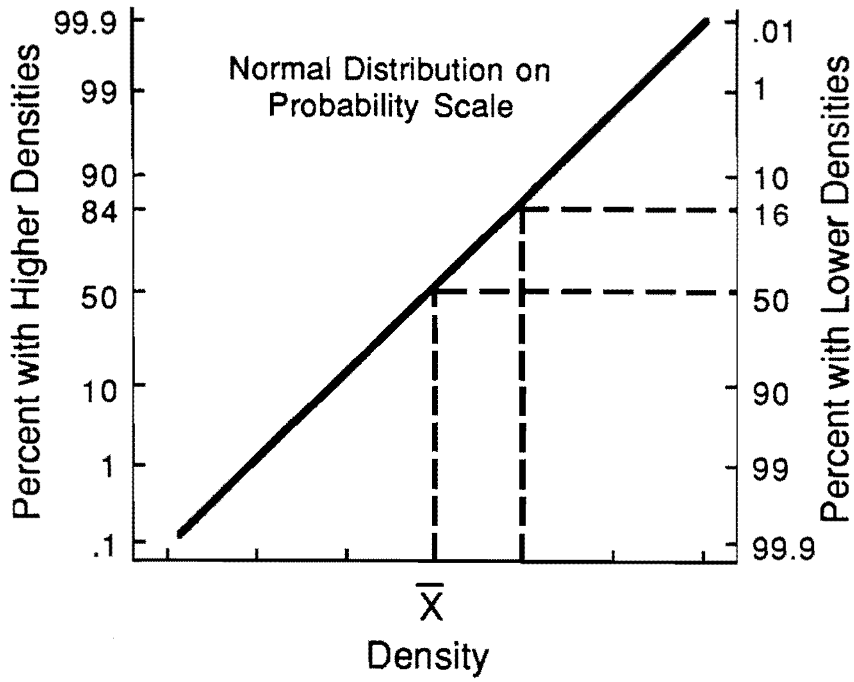


c. Bimodal distribution

Figure 2.10. Examples of non-normal distributions



a. Arithmetic cumulative distribution



b. Probability scale

Figure 2.11. Normal density distribution

Standard Deviation. The standard deviation is a measure of the amount of variation for a specific property and is calculated as

$$\text{Standard deviation, } S = \sqrt{\frac{\Sigma(y-\overline{X})^2}{N-1}}$$

where S = the standard deviation of the sample

The calculations can be easily performed on most hand calculators used by engineers.

Physically the standard deviation is the absolute value of the difference between the average value and the value at the inflection points of the normal distribution relationship as shown in Figure 2.12a. The area under the curve and thus the percentage of the values between plus and minus one standard deviation is approximately 68 percent, two standard deviations is 95 percent, and three standard deviations is 99 percent (Fig 2.12). Likewise the percentage of values within any given density range can also be calculated (Fig 2.13).

Figure 2.14a illustrates two samples with the same average value but different variations, while Figure 2.14b illustrates two samples with the same variation but different average values. Figures 2.14c and 2.14d illustrate samples with differing average values and differing amounts of variations.

Thus it is important to determine and consider both the average value and the standard deviation of the sample population.

Sampling

Roadway samples (cores) or laboratory samples (specimens) should be randomly obtained and tested. If a low value of density is obtained and as a result additional samples are taken to verify accuracy of the low value, the values for these additional samples should not be included in the determination of the mean and standard deviation since, in general, these values will tend to be low, producing an abnormally high number of failing values.

Samples can be taken at specified intervals of time or distance along the roadway or can be taken by selecting a random sampling plan. The sampling plan should be restricted in such a manner as to ensure that the samples statistically represent the entire section of the roadway.

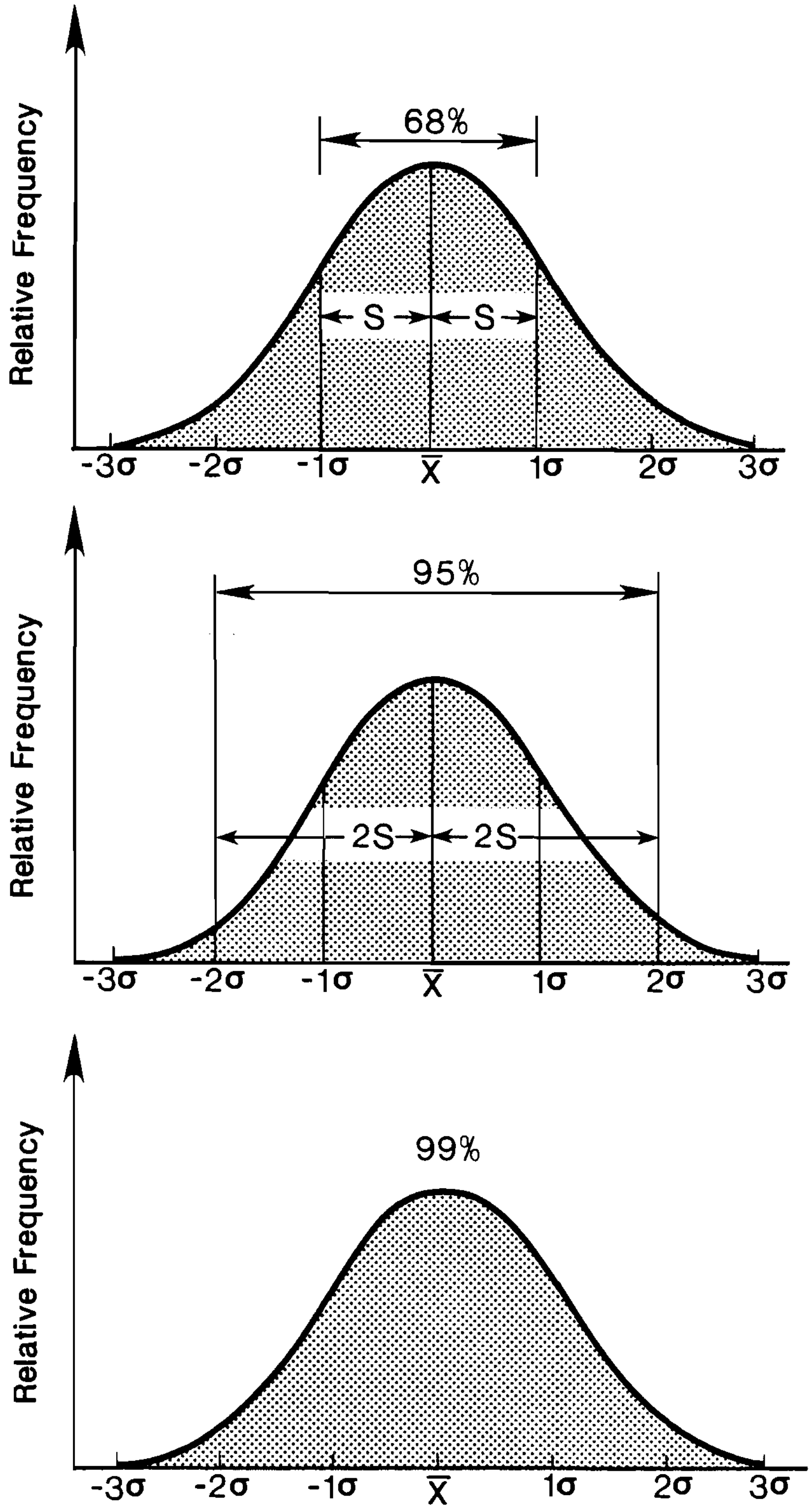


Figure 2.12. Definitions of standard deviation as related to the area under the normal curve

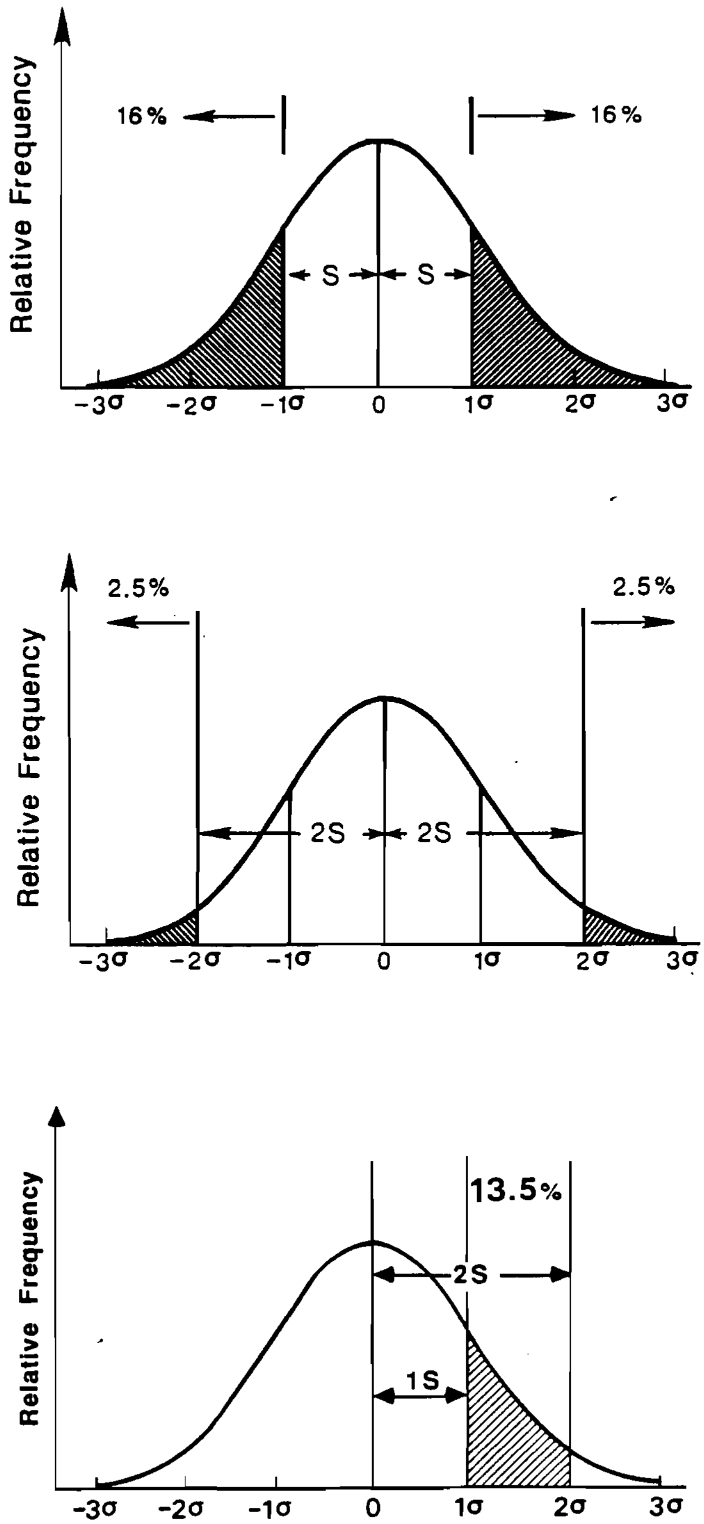


Figure 2.13. Percentage of test results within a specified range

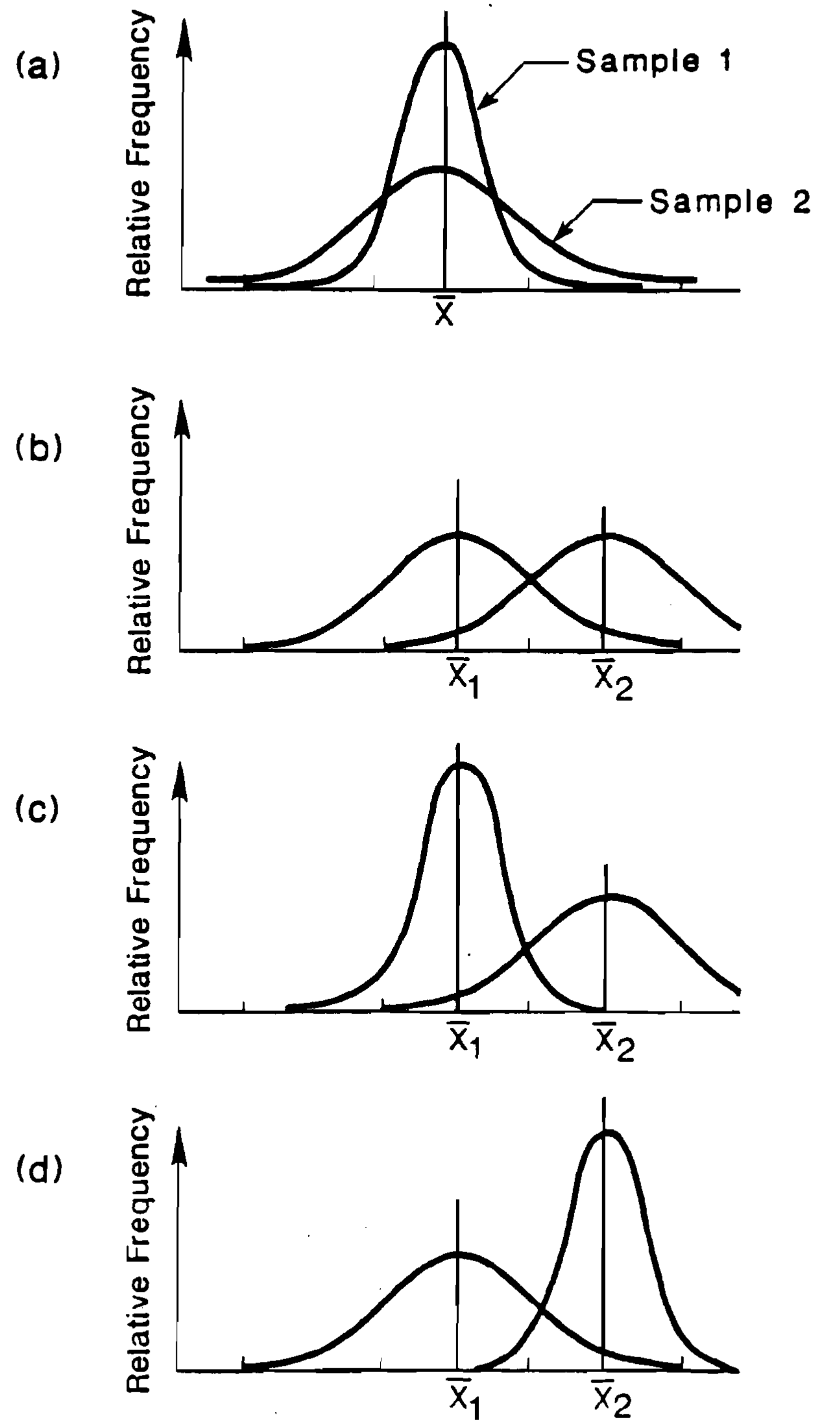


Figure 2.14. Effects of mean and standard deviation on shape of the normal curve.

CHAPTER 3. EXPERIMENTAL PROGRAM

The primary objectives of this study were to synthesize field information related to in-place density of asphalt mixtures to (1) determine the densities being achieved on Texas construction projects and (2) begin to establish realistic density requirements and specifications.

To accomplish these objectives, density data were collected from 17 highway construction projects in six different highway districts (Fig 3.1). The data included asphalt mixture designs, materials characteristics, extracted asphalt contents, laboratory densities, Rice and theoretical maximum densities, core densities, and field nuclear densities. It was not possible to obtain all of the above data for all the projects. For some projects, research personnel participated in the collection of the data; however, generally the raw data were supplied by district personnel.

DESCRIPTION OF PROJECTS TESTED

An attempt was made to evaluate a variety of mixtures containing different aggregates and asphalts in different regions of the state. All projects were attempting to obtain satisfactory density although the projects were not necessarily operating under a density specification. The actual range of mixtures and pavement types selected was dependent on the availability of projects and the ability of district personnel to participate.

Seventeen overlay projects using four types of asphalt mixtures in six districts were analyzed (Fig 3.1). Summary information relating to the projects is shown in Table 3.1. As shown in Figure 3.1, the projects primarily were distributed throughout the Northeastern quarter of the state with the majority of the data obtained from District 12 (Houston) and District 17 (Bryan).

All asphalt mixtures were hot mixed asphalt concrete mixtures, under the Texas State Department of Highway and Public Transportation Specification Item 340, "Hot Mix Asphaltic Concrete Pavement" (Ref. 11). Aggregate gradations were designated as either Type B, C, D or G, denoting the maximum aggregate size ranging from coarse to fine. Mixtures contained AC-20 asphalt cements except for two projects which used AC-10.

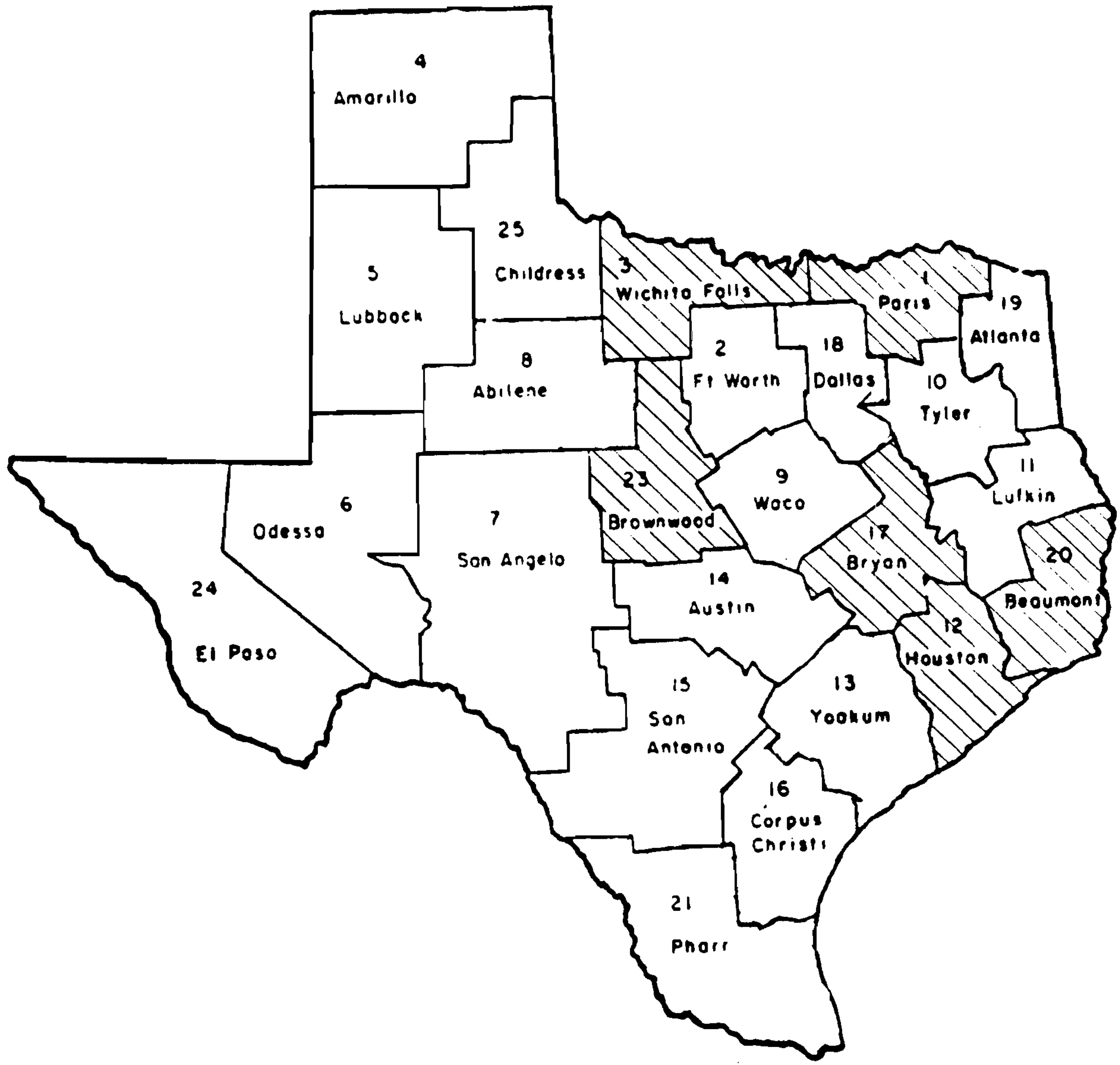


Figure 3.1. State Department of Highways and Public Transportation Districts from which density information was obtained

TABLE 3.1. DESCRIPTION OF PAVEMENT PROJECTS

Dist/Hwy/County	Aggregate/Asphalt	Placed On	Design Thickness	Design #	Design % AC	# of Days
	Item 340 Type D Mixture	PCC	2"			
Dist 1	Crushed Limestone			1	6.0	17
	Limestone Screenings			2	6.6	1
IH 30	Field Sand			3	6.6	33
Hunt Co.	AC-20 Dorchester					
	Item 340 Type D Mixture	15" Flexible Base	2"			
Dist 3	3/8" Chips			1	4.6	1
	#4 Screenings			2	4.8	2
US 287	Peacock Field Sand			3	4.6	3
				4	4.4	5
Wilbarger Co.	AC-10 Cosden			5	4.4	5
	Item 340 Type D Mixture	Flexible Base or PCC	1-1/4"			
Dist 12 Project A	Type D Limestone			1	4.7	3
	Type F Limestone			2	4.9	6
IH 45	Limestone Screenings			3	4.9	7
	Field Sand			4	4.9	1
D Level Up				5	5.1	1
	AC-20 Trumbull			6	5.0	3
Harris Co.				7	5.0	1
				8	5.1	1
				9	5.0	2
				10	5.1	7
				11	5.1	23
				12	5.1	10
				13	4.8	1

TABLE 3.1. (Continued)

Dist/Hwy/County	Aggregate/Asphalt	Placed On	Design Thickness	Design #	Design % AC	# of Days
	Item 340 Type D Mixture	Flexible Base or PCC	1-1/4"			
Dist 12 Project A	Type D Limestone			1	4.9	2
	Type F Limestone			2	4.8	12
IH 45	Limestone Screenings			3	4.5	2
	Iron Ore Field Sand			4	4.4	4
D Surface				5	4.5	9
	AC-20 Trumbull			6	4.6	2
Harris Co.				7	4.7	7
				8	4.7	4
				9	4.8	5
				10	4.8	3
	Item 340 Type D Mixture	Flexible Base	1-1/4"			
Dist 12 Project A	Type D Limestone			1	4.9	1
	Type F Limestone			2	4.6	7
FM 2920	Limestone Screenings			3	4.6	3
	Field Sand			4	4.6	3
D Level Up				5	4.7	6
	AC-20 Trumbull			6	4.9	1
Harris Co.				7	4.9	4
				8	4.9	1
				9	5.1	1
				10	5.1	1
				11	5.0	1
				12	5.1	5
				13	5.1	29
				14	5.5	1
				15	5.3	1
				16	5.1	2
				17	5.0	1

TABLE 3.1. (Continued)

Dist/Hwy/County	Aggregate/Asphalt	Placed On	Design Thickness	Design #	Design % AC	# of Days
	Item 340 Type D Mixture	Flexible Base	1-1/4"			
Dist 12 Project A	Type D Limestone			1	4.8	3
	Type F Limestone			2	4.8	2
FM 2920	Limestone Screenings			3	4.9	1
	Iron Ore Field Sand			4	4.8	4
D Surface				5	4.5	7
	AC-20 Trumbull			6	4.6	1
Harris Co.				7	4.7	13
	Item 340 Type D Mixture	PCC	2-1/2"			
Dist 12	Type D Limestone			1	5.1	3
	Type F Limestone			2	5.1	1
US 90A	Limestone Screenings			3	4.6	1
	Field Sand			4	4.6	1
Harris Co.				5	4.6	4
	AC-20 Trumbull			6	4.6	2
				7	4.6	5
	Item 340 Type D Mixture	--	--			
Dist 12	Pea Gravel			1	5.0	11
	Limestone Screenings			2	4.9	7
SH 105	Iron Ore					
Montgomery Co.	AC-20 Texaco					

TABLE 3.1. (Continued)

Dist/Hwy/County	Aggregate/Asphalt	Placed On	Design Thickness	Design #	Design % AC	# of Days
	Item 340 Type D Mixture	Flexible Base	2-1/2"			
Dist 12	Pea Gravel			1	4.8	3
	Type D Limestone			2	4.6	1
FM 149	Limestone Screenings			3	4.6	2
	Field Sand			4	4.6	16
Harris Co.				5	4.6	1
	AC-20 Gulf States					
	Item 340 Type D Mixture	Flexible Base	2-1/2"			
Dist 12	Pea Gravel			1	5.0	1
	Limestone Screenings			2	5.3	3
FM 1097	Iron Ore			3	5.4	3
				4	5.3	2
Montgomery Co.	AC-20 Texaco					
	Item 340 Type D Mixture	Flexible Base	2-1/2"			
Dist 12 Project B	Type D-F Blend Limestone			1	5.5	6
	Limestone Screenings			2	5.0	8
FM 2920	Iron Ore					
Harris County	AC-20 Exxon					

TABLE 3.1. (Continued)

Dist/Hwy/County	Aggregate/Asphalt	Placed On	Design Thickness	Design #	Design % AC	# of Days
	Item 340 Type B Mixture	PCC	3 - 6"			
Dist 17 Project A	Type B Rock			1	5.2	39
	Type D Rock			2	5.2	20
IH 45	Crusher Fines					
	Gresham Field Sand					
Leon/Madison Co.						
	AC-20 Exxon					
	Item 340 Type C Mixture	PCC	3 - 6"			
Dist 17 Project B	Type B Rock			1	5.2	4
	Type D Rock			2	4.9	30
IH 45	Screenings			3	4.2	4
	Harris Field Sand			4	4.4	1
Freestone Co.				5	4.6	9
	AC-20 Exxon			6	4.6	1
				7	4.8	25
				8	4.6	6
				9	4.6	24
	Item 340 Type D Mixture	PCC	1"			
Dist 17 Project B	Type D Rock			1	5.2	1
	Screenings			2	5.4	1
IH 45	Harris Field Sand			3	5.8	4
				4	6.0	14
Freestone Co.	AC-20 Exxon			5	5.8	1
				6	5.5	4
				7	5.7	1

TABLE 3.1. (Continued)

Dist/Hwy/County	Aggregate/Asphalt	Placed On	Design Thickness	Design #	Design % AC	# of Days
	Item 340 Type D Mixture	PCC	1-1/2"			
Dist 20	Coarse Aggregate			1	5.3	30
	Crushed Intermediate					
IH 10	Limestone Aggregate					
	Sandstone Screenings					
Jefferson Co.	Sand					
	AC-20 Texaco					
	Item 340 Type G Mixture	PCC	3-1/2"			
Dist 20	Type B Crushed Limestone			1	5.5	3
	Intermediate D-F Blend			2	5.3	25
IH 10	Limestone					
	Sandstone Screenings					
Jefferson Co.	Sand					
	AC-20 Texaco					
	Item 340 Type D Mixture	Flexible Base	2"			
Dist 23	Coarse Aggregate			1	5.0	33
	Screening					
US 190	Sand					
Lampasas Co.	AC-10 Gulf					

Seven producers supplied the asphalts. The aggregates were limestones, river sands and gravels, and iron ores in various combinations (Table 3.1).

SAMPLING PROGRAM

The mixture design, materials used, extracted asphalt contents, and laboratory densities were obtained from the daily construction reports supplied by the districts. In addition, some districts supplied Rice maximum theoretical densities, core densities, nuclear densities, and, in a few cases, cores were provided to project personnel for the determination of bulk density and Rice maximum theoretical density. A summary of the data obtained for each project can be found in Appendix A. Of the 17 construction projects, eight did not supply nuclear densities and five did not provide information concerning Rice maximum theoretical density.

PARAMETERS ANALYZED

The resulting asphalt content and density information was analyzed in terms of the following properties.

Asphalt Content

1. Design asphalt content
   The asphalt content of the mixture placed in the field. This value is either the asphalt content obtained during the design of the mixture or the asphalt content selected during construction.
2. Average extracted asphalt content
   The average asphalt content obtained by extracting field samples obtained from a section of highway containing a given mixture.
3. Average deviation from the design asphalt content
   The difference between the average extracted asphalt content and the design asphalt content for a given mixture.

Relative Laboratory Density

Laboratory densities were analyzed in terms of the relative density based on

1. <u>The maximum theoretical density</u> G_T

   The maximum theoretical density calculated from the bulk specific gravities of the aggregate and asphalt cement as specified in Test Method Tex-201-F.

2. <u>The Rice theoretical density</u> G_R

   The maximum theoretical density calculated using ASTM D2041-78 or Tex-227-F.

Relative Field Density

Field core densities were analyzed in terms of the relative density based on

1. <u>The maximum theoretical density</u> G_T

   The maximum theoretical density calculated from the bulk specific gravities of the aggregate and asphalt content as specified in Test Method Tex-201-F.

2. <u>The Rice theoretical density</u> G_R

   The maximum theoretical density calculated using ASTM D 2041-78 or Tex-227-F.

The maximum theoretical specific gravity, G_T, was calculated using the following equation

$$G_T = \frac{100}{\frac{\%AGG}{G_{AGG}} + \frac{\%ASP}{G_{ASP}}}$$

where

$\%ASP$ is the amount of asphalt in the mixture by weight

$\%AGG$ is the amount of aggregate in the mixture by weight

$\%ASP + \%AGG = 100\%$

G_{ASP} is the specific gravity of the asphalt

G_{AGG} is the specific gravity of the aggregate

Both the maximum theoretical specific gravities (G_T and G_R) were calculated by the following methods:

1. based on the mixture design asphalt content, $G_{T\ design}$ or $G_{R\ design}$
2. based on the daily average extracted asphalt content, $G_{T\ day}$ or $G_{R\ day}$
3. based on the asphalt content of the specimen for which the laboratory density was obtained, $G_{T\ extra}$ or $G_{R\ extra}$.

These maximum theoretical specific gravities for the 17 projects are summarized in Appendix A. The Rice maximum theoretical specific gravities were either obtained daily, $G_{R\ day}$, or when a design change occurred or the mixture changed, $G_{R\ job}$. Rice theoretical densities can also be found in Appendix A.

Relative densities were calculated for both field cores and laboratory compacted specimens. Relative field density was obtained by comparing core density with laboratory density, $G_{T\ design}$, $G_{T\ extra}$, and $G_{T\ job}$. The density of laboratory compacted specimens was compared to $G_{T\ design}$, $G_{T\ extra}$, and $G_{T\ job}$ to obtain relative laboratory density. The relative laboratory and field densities are shown as a percentage of maximum theoretical density in Appendix B. The core density compared with the laboratory density plotted versus working day for each project is shown in Appendix C.

To evaluate accuracy of nuclear density measurements, core densities were compared to nuclear densities. In one instance, the variation of core density over time was investigated.

Asphalt content data, such as extracted asphalt content and design asphalt content were obtained to enable better interpretation of density data. Variations in asphalt content during the construction period are shown in Appendix D.

CHAPTER 4. SUMMARY OF RESULTS

The primary objective of this study was to synthesize information related to the field density of asphalt mixtures achieved on selected Texas highway construction projects. Specific densities were required on some projects and only a recommended targeted range on others; nevertheless, all projects were attempting to obtain satisfactory densities.

The individual densities and extracted asphalt contents for each working day for the 17 projects are contained in Tables A-1 through A-17 and summarized in Table A, Appendix A. Design changes involving either a change in gradation, aggregate, or asphalt content are indicated.

The remainder of this chapter summarizes the asphalt contents and densities for the mixtures with 5 or more measurements. Discussion of the data is contained in Chapter 5.

ASPHALT CONTENTS

The variation of extracted asphalt contents with time is graphically illustrated in Figures B-1 through B-17, Appendix B. The specified (design) asphalt contents, average extracted asphalt contents, the standard deviations, and the average deviation from the specified asphalt content are summarized in Table C, Appendix C.

The average extracted asphalt contents for a majority of the mixtures on the 17 projects were within 0.1 percentage point of the design values (Table 4.1). The standard deviation for designs with 5 or more values varied from

TABLE 4.1. SUMMARY OF EXTRACTED ASPHALT CONTENTS

Deviation of Average from Design Value, percentage points		Standard Deviation, percentage points		
Total	Typical	Range	Typical	Average
-0.4 to +0.3	-0.1 to +0.1	0.05 to 0.39	0.12 to 0.26	0.18

0.05 to 0.39 percent with the majority ranging from 0.12 to 0.26. The average standard deviation was 0.18 percent which means that approximately 95 percent of asphalt contents would be expected to be within plus or minus 0.36 percentage points (2 x 0.18) of the average and 99 percent would be within plus or minus 0.54 percentage points (3 x 0.18). This corresponds well with the current tolerance of plus or minus 0.5 percentage points assuming that the average value was approximately equal to the specified asphalt content.

DENSITY

Densities obtained for laboratory compacted specimens and field cores from the constructed pavement are summarized in Appendix A. These densities involved 17 projects and 35 mixtures.

Relative Laboratory Density

The relative laboratory densities were analyzed in terms of

a. Relative density based on maximum theoretical density for

(1) the design mixture, $G_L/G_{T\ design}$, and

(2) the mixture corrected for actual extracted asphalt content, $G_L/G_{T\ extra}$;

b. Relative density based on Rice maximum theoretical density, $G_L/G_{R\ job}$.

See pages xv or 27 for a definition of terms.

The variations of the relative laboratory densities with time are illustrated in Figures D-1 through D-17, Appendix D. The average relative density and standard deviation of all density measurements for all projects are summarized in Table A, Appendix A. Average values and the standard deviations for the individual projects regardless of the number of mixtures utilized are contained in Table D, Appendix D and summary of relative density information for all mixtures is contained in Table 4.2.

G_L/G_T Design. The average relative densities for 35 mixtures from 17 projects varied from 94.8 to 99.9 percent (5.2 to 0.1 percent air voids) and averaged 97.9 (2.1 percent air voids). The standard deviations varied from

0.25 to 1.24 percentage points with an average value of 0.56. Typical values of standard deviation ranged from 0.33 to 0.79 with an average value of 0.52.

G_L/G_T Extracted. The average relative densities for 35 mixtures from 17 projects varied from 95.1 to 99.8 percent (4.9 to 0.2 percent air voids) with an average of 97.8 (2.2 percent air voids). The standard deviation varied from 0.2 to 1.34 and averaged 0.65. Typical values ranged from 0.38 to 1.00 with an average of 0.63.

G_L/G_R Job. The average relative densities for 30 mixtures from 12 projects varied from 93.8 to 98.6 percent (6.2 to 1.4 percent air voids) and averaged 97.1 (2.9 percent air voids). The standard deviation varied from 0.28 to 1.21 percentage points with an average value of 0.58. Typical values of standard deviation ranged from 0.28 to 0.95 and averaged 0.56.

TABLE 4.2. SUMMARY OF RELATIVE LABORATORY DENSITIES OF MIXTURES *

	Number (Projects) Mixtures		Relative Density, %		Standard Deviation, %			
					Range		Average	
			Range	$\bar{X}$	Total	Typical	Total	Typical
G_L/G_T Design	(17)	35	94.8 - 99.9	97.9	0.25 - 1.24	0.33 - 0.79	0.56	0.52
G_L/G_T Extra	(17)	35	95.1 - 99.8	97.8	0.20 - 1.34	0.38 - 1.00	0.65	0.63
G_L/G_R Job	(12)	30	93.8 - 98.6	97.1	0.28 - 1.21	0.28 - 0.95	0.58	0.56

* Mixtures with 5 or more density measurements

Relative Field Density

The relative field densities as obtained from cores were analyzed in terms of

a. Relative density based on laboratory density, G_C/G_L,

b. Relative density based on maximum theoretical density for

    (1) the design mixture, $G_C/G_{T\ design}$, and

    (2) the mixture corrected for the extracted asphalt content, $G_C/G_{T\ extracted}$

c. Relative density based on the Rice maximum theoretical density, G_C/G_R.

The variation of these relative field densities with time is illustrated in Figures E-1 through E-17, Appendix E. The average relative densities and standard deviations of all field density measurements for all projects are summarized in Table A, Appendix A. Average values and the standard deviations for the individual projects regardless of the number of mixtures utilized are contained in Table E, Appendix E and a summary of relative density information for all mixtures in contined in Table 4.3

TABLE 4.3. SUMMARY OF RELATIVE FIELD DENSITY OF MIXTURES *

	Number (Projects) Mixtures	Relative Density, %		Standard Deviation, %			
				Range		Average	
		Range	$\bar{X}$	Total	Typical	Total	Typical
G_C/G_L	(17) 32	91.3 - 99.6	95.1	0.75 - 5.47	0.93 - 2.63	1.89	1.71
G_C/G_T design	(17) 32	90.0 - 96.4	93.2	0.71 - 5.25	1.06 - 2.64	1.83	1.75
G_C/G_T extra	(17) 32	90.0 - 96.4	93.1	0.90 - 5.18	1.17 - 2.71	1.87	1.87
G_C/G_R job	(13) 25	88.5 - 96.4	92.5	0.70 - 5.22	1.03 - 2.60	1.78	1.69
G_C/G_R core	(1) 2	90.5 - 99.2	96.1	0.16	0.16	0.16	0.16

* Mixtures with 5 or more density measurements

G_C/G_L. The mean relative densities based on the laboratory compacted specimens for 32 mixtures from 17 projects ranged from 91.3 to 99.6 percent and averaged 95.1 percent. The standard deviations ranged from 0.75 to 5.47 percentage points with an average standard deviation of 1.89. Typical standard deviations ranged from 0.93 to 2.63 percentage points with an average of 1.71.

The average densities of the 17 projects shown in Table A, Appendix A, ranged from 91.8 to 99.6 percent with an average density of 95.3. The standard deviations ranged from 0.98 to 3.88 percentage points and averaged 2.07.

G_C/G_T Design. The mean relative densities based on the maximum theoretical density of 32 mixtures from 17 projects using the design asphalt content ranged from 90.0 to 96.4 percent (10.0 to 3.6 percent air) with an average of 93.2 percent (6.8 percent air). The standard deviation ranged from 0.71 to 5.25 percentage points with an average of 1.83. Typical values ranged from 1.06 to 2.64 with an average of 1.75.

The average density of the 17 projects (Table A, Appendix A) ranged from 90.3 to 96.4 percent (9.7 to 3.6 percent air) with an average of 93.3 percent (6.7 percent air). The standard deviations ranged from 1.08 to 3.87 percentage points with average standard deviation of 2.12.

G_C/G_T Extracted. The average of the relative densities based on the maximum theoretical density calculated using the extracted asphalt content for 32 mixtures from 17 projects ranged from 90.0 to 96.4 percent (10.0 to 3.6 percent air) with an average of 93.1 (6.9 percent air). Standard deviations ranged from 0.90 to 5.18 percentage points with an average of 1.87. Typical values ranged from 1.17 to 2.71 with an average of 1.87.

The average densities of the 17 projects (Table A, Appendix A) ranged from 90.4 to 96.4 percent (9.6 to 3.4 percent air) with an average of 93.7 (6.3 percent air). The standard deviations ranged from 1.14 to 3.84 percentage points with an average of 1.96.

G_C/G_R Job. The average of the relative densities based on the Rice maximum theoretical density for 25 mixtures from 13 projects ranged from 88.5 to 96.4 percent (11.5 to 3.6 percent air) with an average of 92.5 percent (7.5 percent air). The standard deviations ranged from 0.70 to 5.22 percentage points with an average of 1.78 while typical values ranged from 1.03 to 2.60 percentage points and averaged 1.69.

The average density of the 13 projects (Table A, Appendix A) ranged from 89.7 to 95.9 percent (11.3 to 4.1 percent air) with an average of 92.7 (7.3 percent air). The standard deviation ranged from 1.09 to 3.76 percentage with an average of 2.30

G_C/G_R Cores. Only one project directly measured the Rice maximum theoretical densities of the mixture corresponding to the roadway cores.

The relative densities for this project ranged from 93.2 to 98.6 (6.8 to 1.4 percent air) with an average of 96.4 (3.6 percent air) and a standard deviation of 1.23 percentage points.

Nuclear Densities

Nuclear densities were available for eight projects in five districts. The individual measurements ranging from 132.2 to 150.8 pcf are contained in Appendix A. The standard deviation ranged from 1.65 to 5.84, and the standard deviation for all data points was 2.57. Values are summarized by project in Table 4.4.

These individual and project summaries provide minimal information but the data is discussed with respect to estimating density using nuclear measurements.

TABLE 4.4. SUMMARY OF NUCLEAR DENSITIES

Project	Number of Data Points	Range, pcf	Average, pcf	Standard Deviation, pcf
Dist. 3, US 287	15	137.1 - 145.6	143.2	2.34
Dist. 12, US 90(A)	31	134.2 - 145.8	140.4	3.08
Dist. 12, IH 45(A) Type B	51	142.5 - 150.3	147.7	1.65
Dist. 17, IH 45(B) Type D	9	134.0 - 150.0	141.2	5.84
Dist. 17, IH 45(B) Type C	20	141.5 - 150.8	146.5	1.74
Dist. 20, IH 20	9	132.2 - 140.4	137.4	2.49
Dist. 23, US 190	12	141.0 - 149.1	146.2	2.14
All projects	147	132.2 - 150.8	143.2	2.57

CHAPTER 5. DISCUSSION OF RESULTS

EXTRACTED ASPHALT CONTENTS

Figures B-1 through B-17, Appendix B, show the extracted asphalt content during the construction period. As mentioned in the previous chapter, the asphalt contents achieved during construction were well within the current specification limit of ±0.5 percent of the design value.

DISTRIBUTION OF DENSITIES

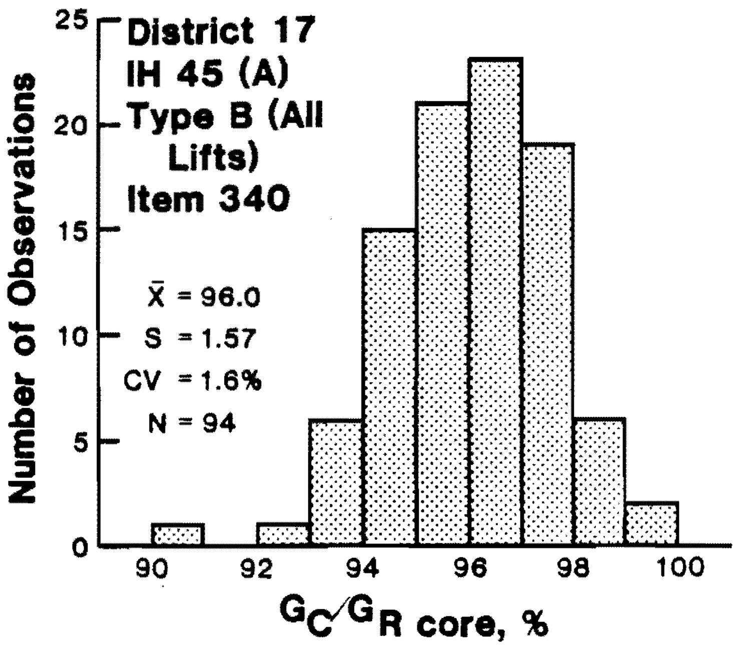
The distribution of the relative core densities based on Rice theoretical density for District 17, IH45(A) project involving 94 observations, is shown in Figure 5.1a and the cumulative frequency distributions on a probability scale are shown in Figure 5.1b. This distribution, along with density distributions for some other projects indicate that the densities were normally distributed except at possibly the high and low values. Thus, the average (mean) and standard deviation should satisfactorily describe the densities and the density variation for the various projects.

LABORATORY DENSITIES

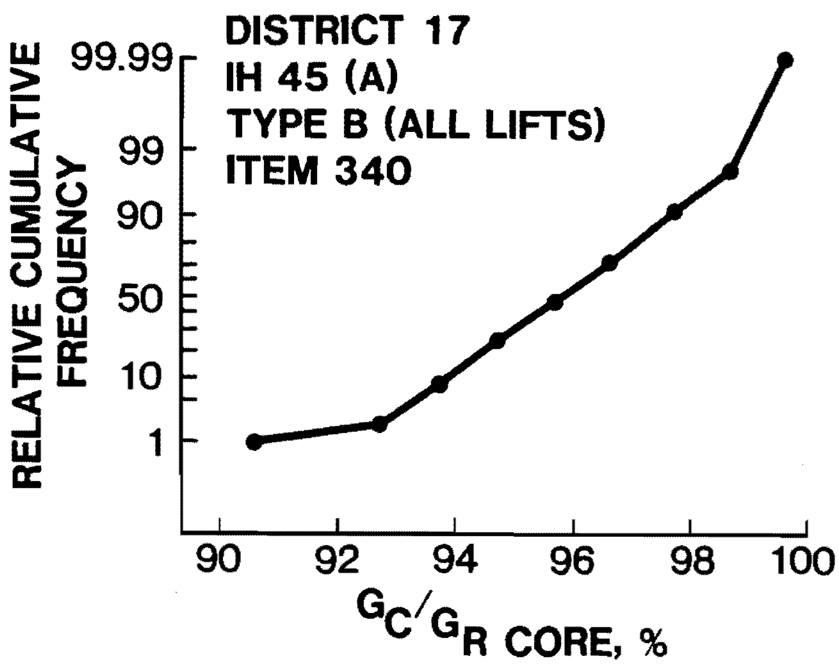
The required field densities often are specified as a percentage of a laboratory density, e.g., 95 percent of laboratory density. Such a specification assumes that the relative laboratory density for all mixtures is constant or that it represents a high density which is acceptable and can be achieved. As previously noted (Tables 4.2 and 4.3), the average relative densities of the laboratory compacted specimens varied significantly.

Rice Relative Densities

The Rice relative densities of the laboratory specimens, arranged in descending order of magnitude by project in Figure 5.2A, varied from 94.8 to 98.6 which means that the average air voids varied from 5.2 to 1.4. Thus, if the average density of the field mixture was equal to 95 percent of the

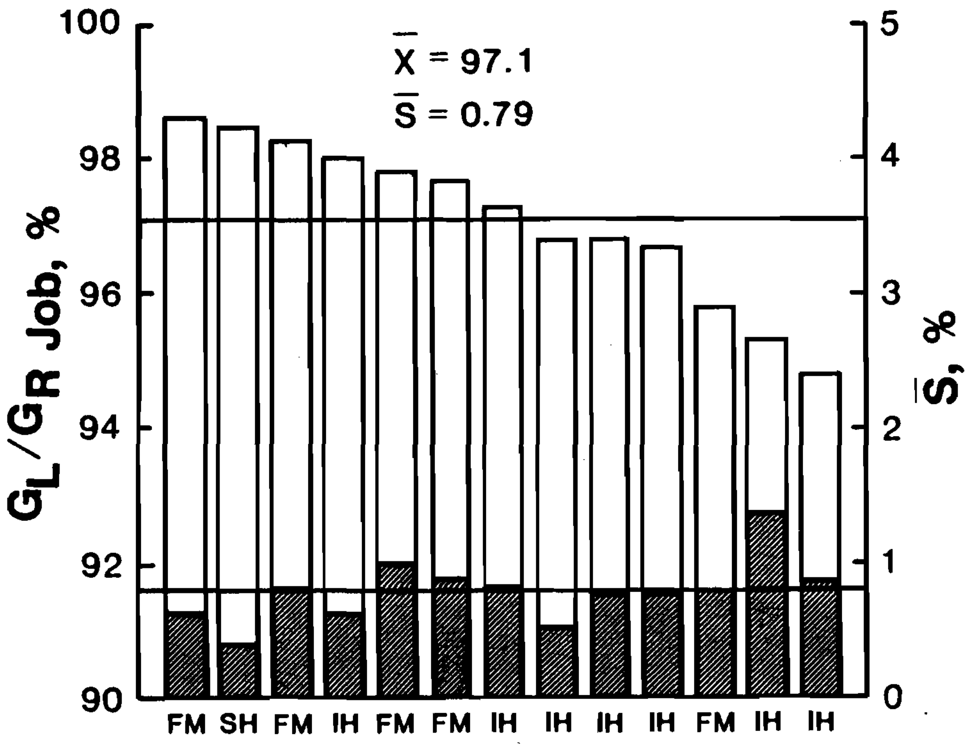


a. Histogram of field relative densities

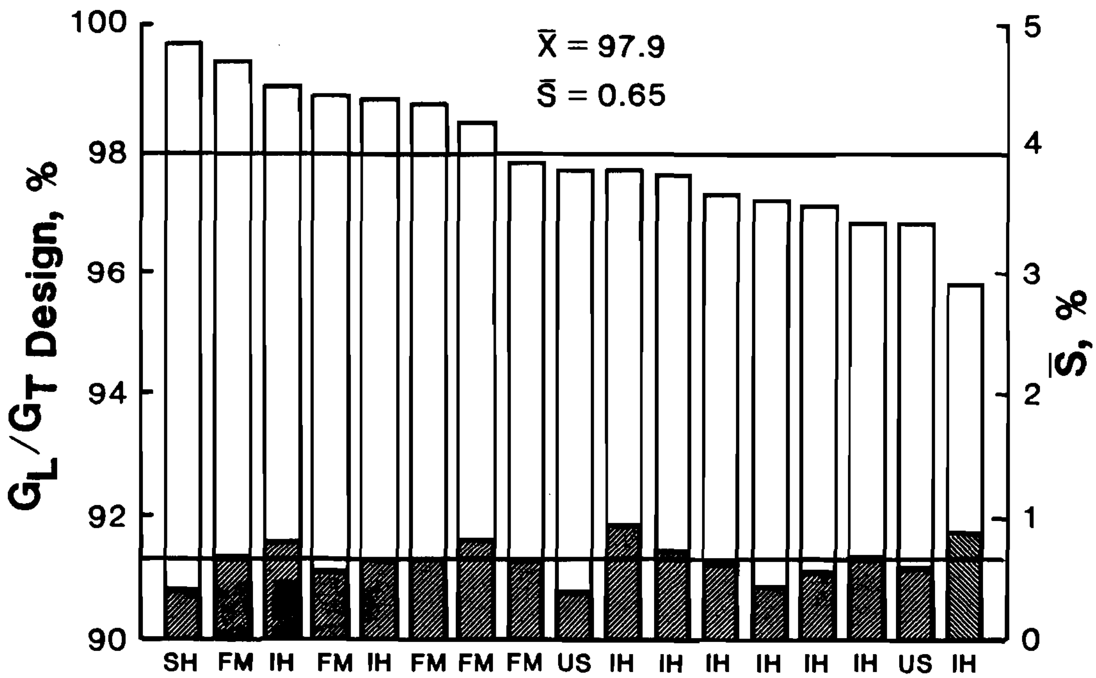


b. Relative cumulative frequency of densities

Figure 5.1. Distribution of field relative densities for project IH 45 (A), District 17, Type B



a. Rice theoretical density



b. Maximum theoretical density

Figure 5.2. Relative laboratory densities arranged in order of decreasing density by project

laboratory density, the average air voids on the various projects could range from 6.3 to 9.9.

In addition, it appears (Fig 5.2a) that the standard deviation, which averaged 0.74 and varied from 0.39 to 1.38 (Table 4.2), tended to increase as the average density decreased. These values, however, are for projects which often involved a number of mixture changes. Thus the relationship between the average Rice relative density and the standard deviation for each mixture was developed (Fig 5.3a). As shown, there was a definite tendency for the standard deviation to decrease with increased density; however, there was a great deal of scatter and it must be remembered that as relative density approaches 100 percent there is less possibility for large variations in density.

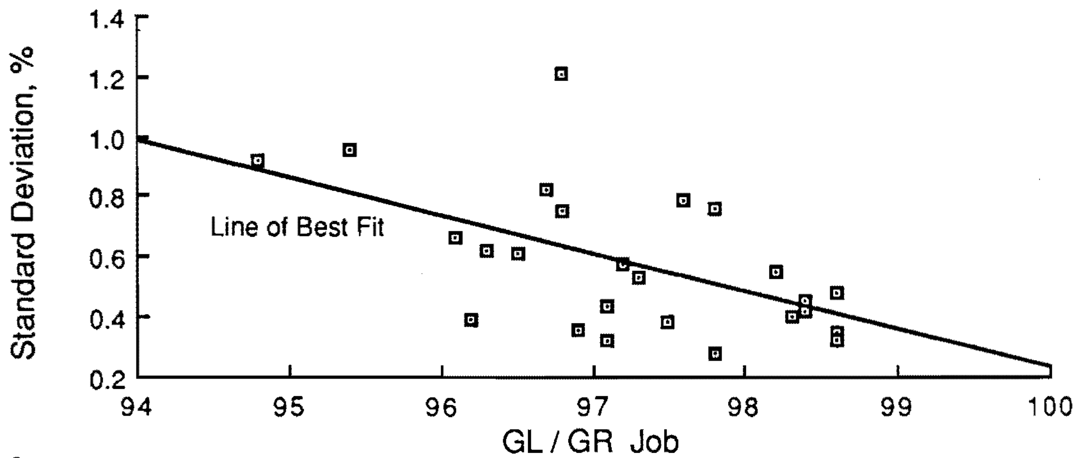
Maximum Theoretical Relative Densities

Similarly, the average relative densities, based on the maximum theoretical density, $G_{T\ design}$, varied significantly. Values varied from 95.8 to 99.7 (Fig 5.2b). This indicates that the air voids varied from 4.2 to 0.3, which is less than the average air voids calculated using the Rice theoretical density.

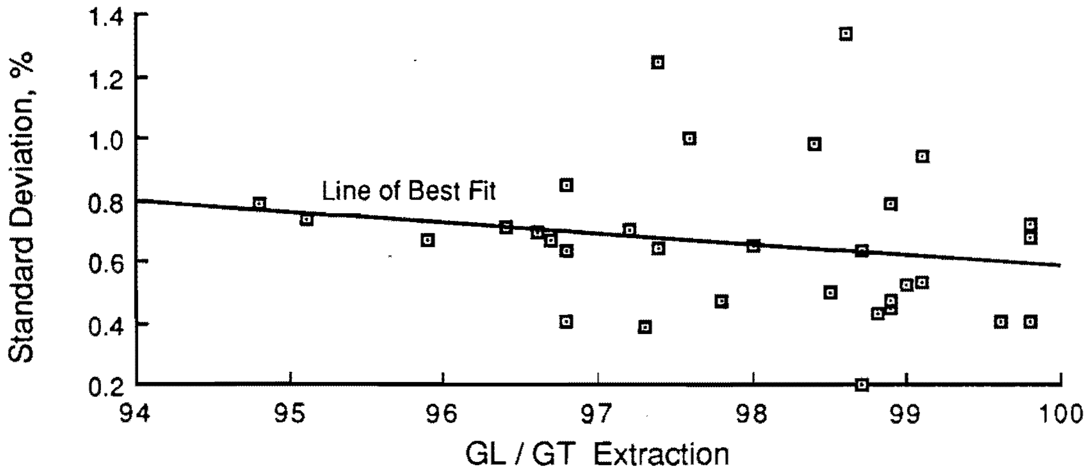
As with the Rice density evaluation, the standard deviation tended to increase with decreased density. Thus, the relationship between standard deviation and average maximum theoretical density for each mixture is shown in Figures 5.3b and 5.3c. The rate of decrease in standard deviation was less for the maximum theoretical relative densities than Rice relative densities.

Comparison of Relative Laboratory Densities

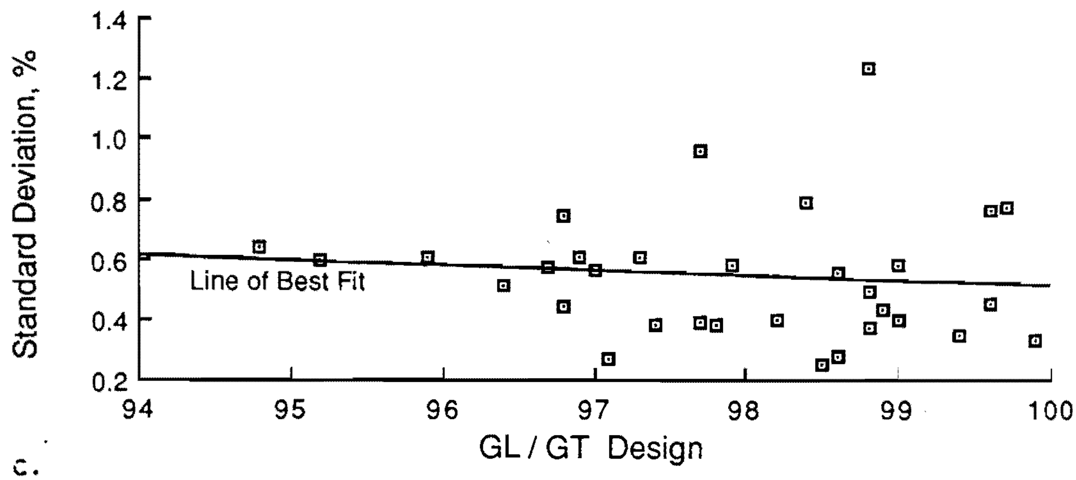
Figures D-1 through D-17 in Appendix D contain comparisons of the relative laboratory densities based on Rice maximum theoretical density with the relative density based on the theoretical maximum density. Except for one project, Figure D-13, the Rice relative densities were less and thus had



a.



b.



c.

Figure 5.3. Relationships between standard deviation and relative densities

higher void contents. A direct comparison is shown in Figure 5.4. The differences in the relative densities based on the Rice theoretical and the maximum theoretical densities were different for each project and ranged from approximately zero to 4 percent.

FIELD CORE DENSITIES

As previously noted (Tables 4.2 and 4.3), the average relative densities of field cores varied significantly.

The core densities were analyzed by mixture and by project and involved an analysis of relative density compared to (Table E, Appendix E)

1. the laboratory density
2. the theoretical density using
   a. the asphalt content specified in design, $G_{T\ design}$
   b. the extracted asphalt content $G_{T\ extra}$
3. the Rice maximum density using
   a. the design asphalt content, $G_{R\ job}$
   b. the extracted asphalt content for cores, $G_{R\ core}$

Laboratory Relative Densities

The average project relative densities, based on laboratory compacted specimens, varied from 91.8 to 99.6 percent (Fig 5.5a). This coupled with the wide variation in the actual laboratory densities used to calculate the laboratory relative densities makes it impossible to determine the actual air voids achieved in the pavement during compaction.

It is further complicated by the fact that the variation (standard deviation) within a given project or mixture is also different. As shown in Figure 5.5b, the standard deviation decreased as the relative density increased.

Rice Relative Densities

The relative densities, based on Rice maximum densities, varied from 89.8 to 96.3 percent (Fig 5.6a) which means that the average air void content for the 17 projects varied from 3.7 to 10.2 percent. The variation also

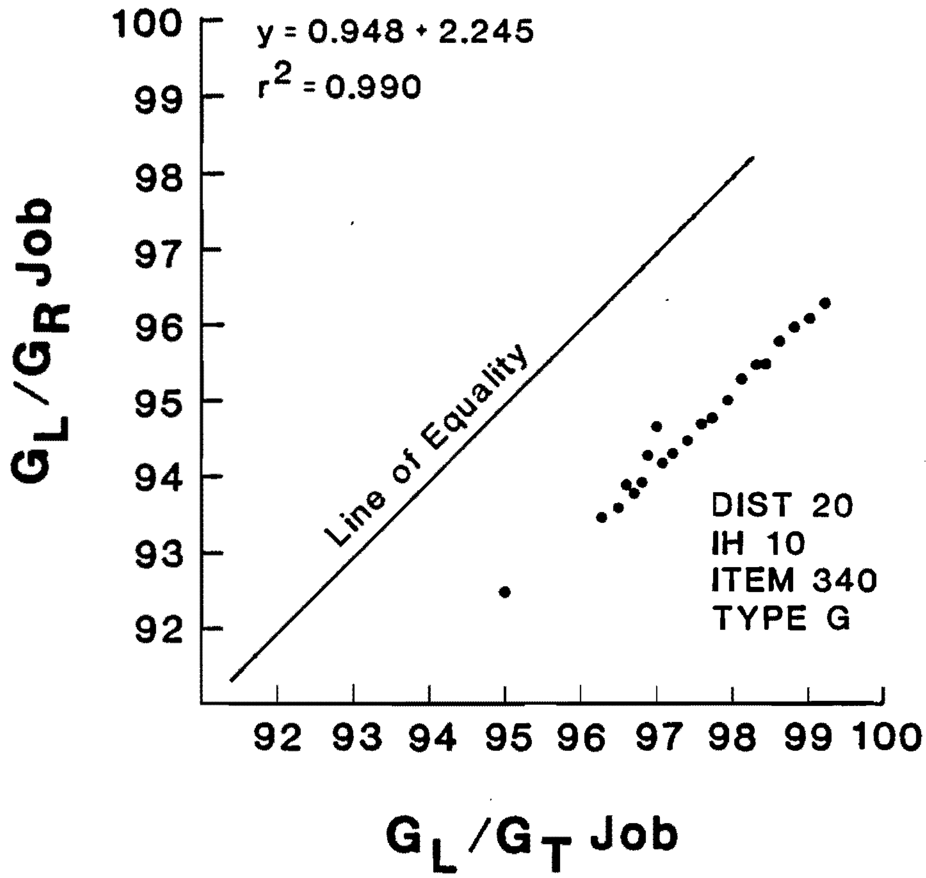


Figure 5.4. Comparison of Relative Laboratory Densities

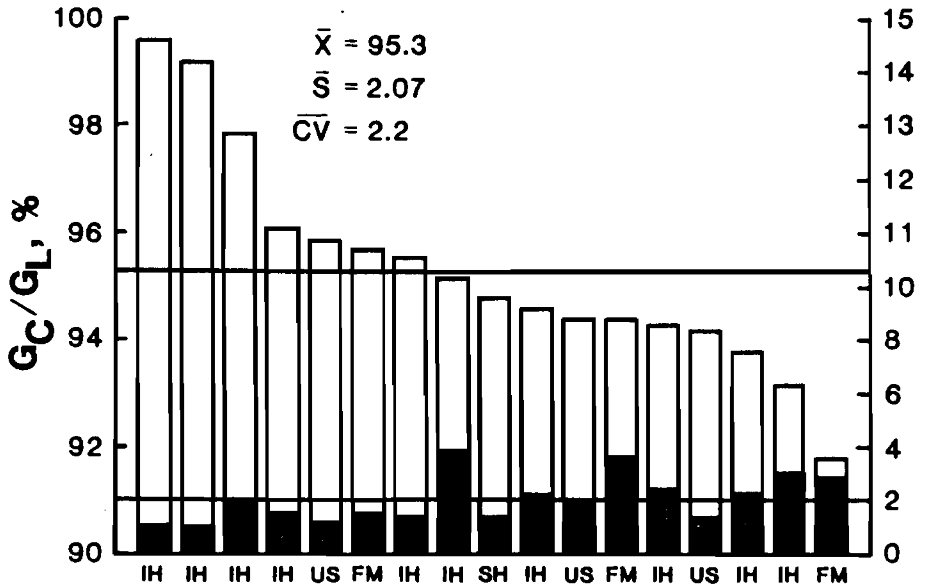


Figure 5.5a. Relative core densities based on laboratory compacted specimen density

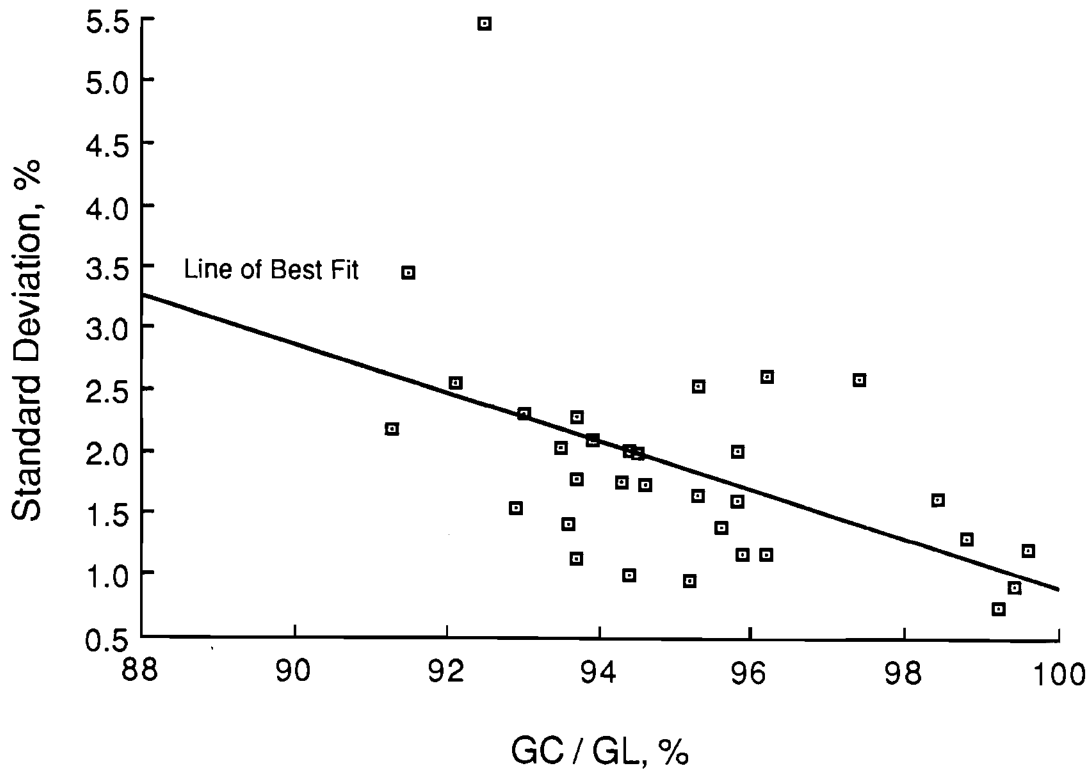


Figure 5.5b. Relationship between relative core density based on laboratory compacted specimen density and standard deviation

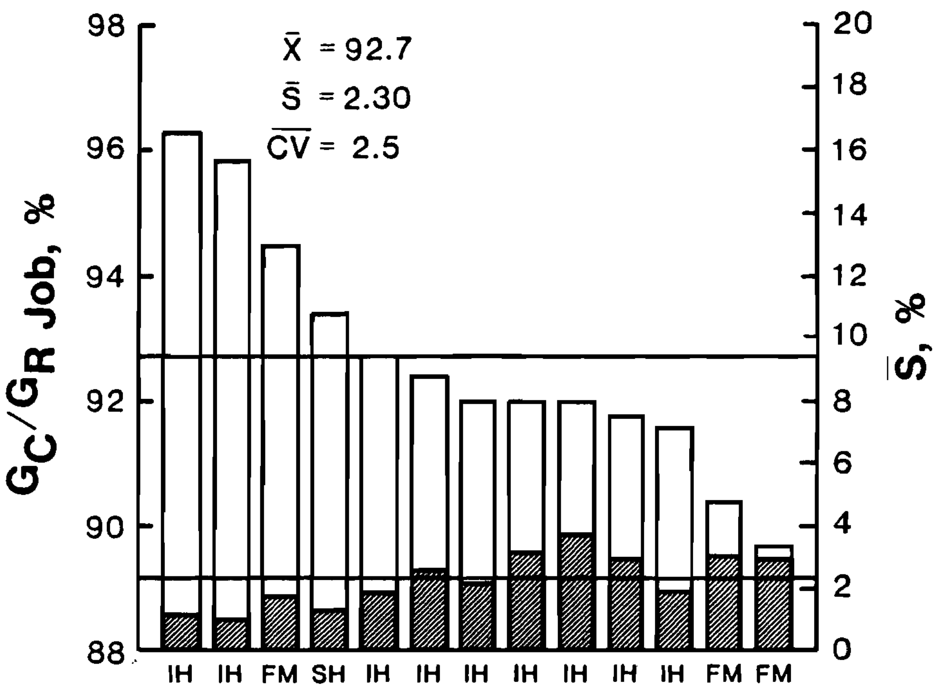


Figure 5.6a. Relative core densities based on Rice maximum specific gravity

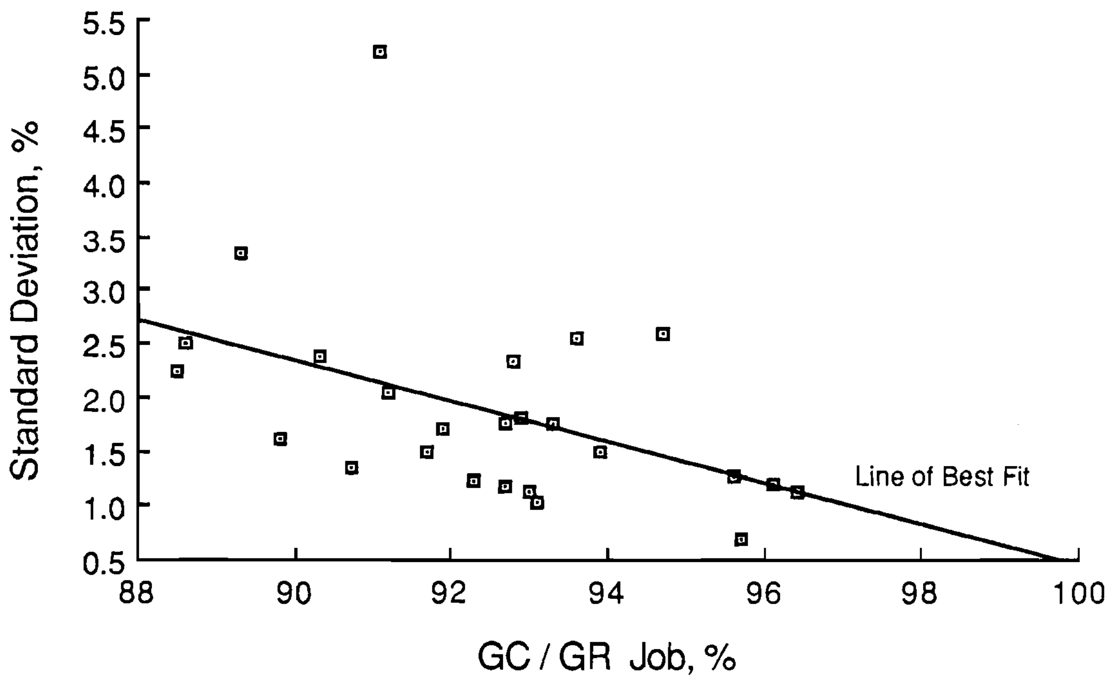


Figure 5.6b. Relationship between relative core density based on Rice maximum specific gravity and standard deviation

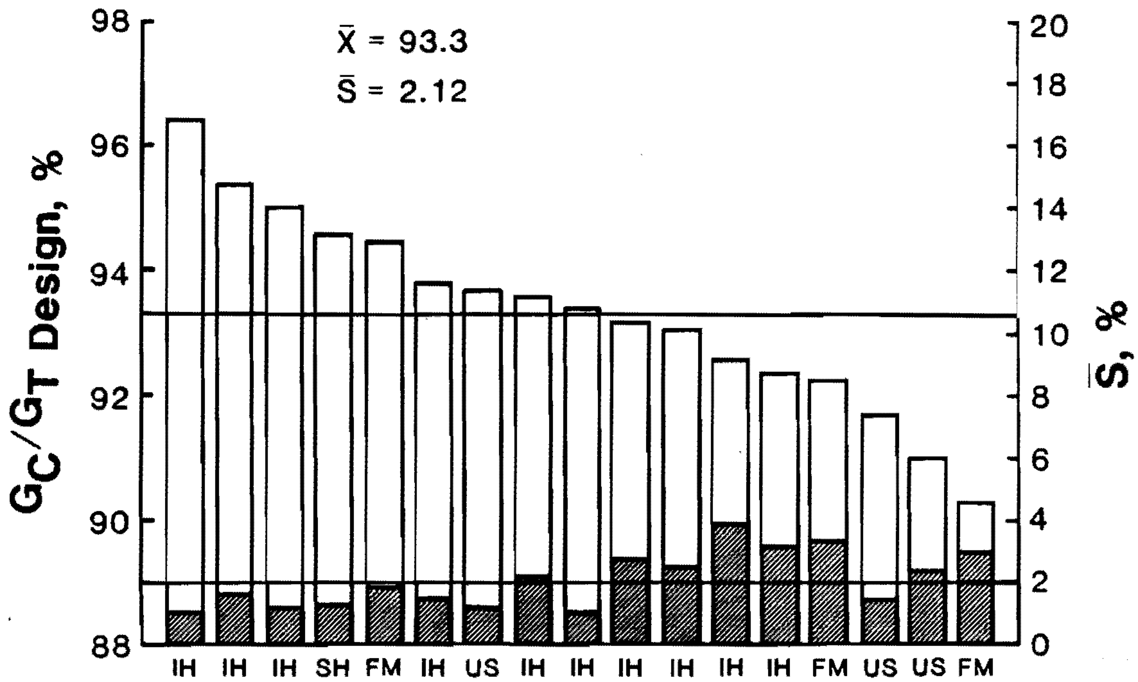


Figure 5.7a. Relative core densities based on G_T calculated from design asphalt contents

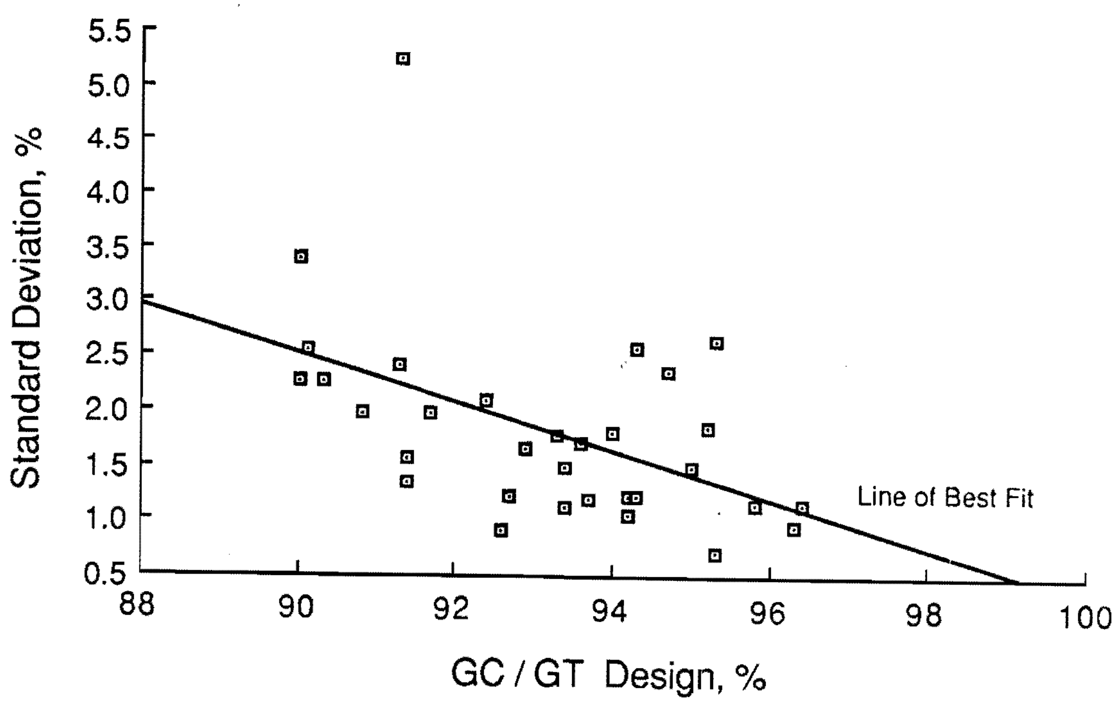


Figure 5.7b. Relationship between relative core density based on G_T calculated from design asphalt content and standard deviation.

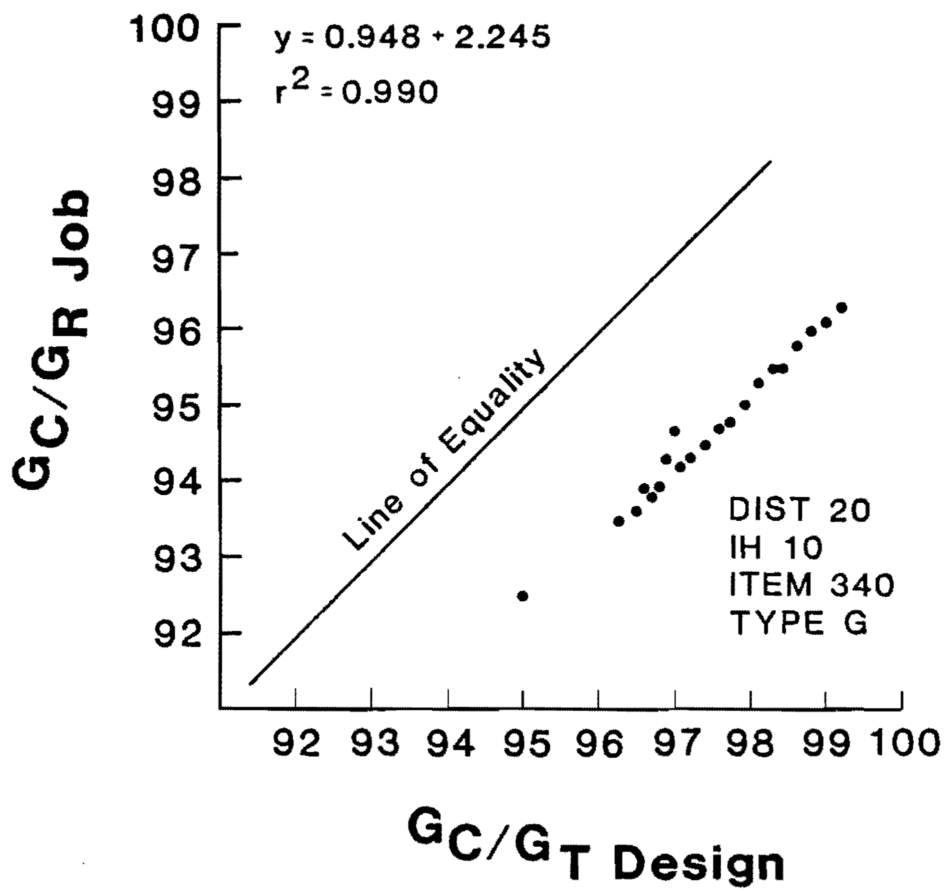


Figure 5.8. Example relationship between G_C/G_T and G_C/G_R

decreased with increased density. Standard deviations varied from 1.09 to 3.76. The relationship between the mean and standard deviation for 31 mixtures is shown in Figure 5.6b.

The worst combination had an average relative density of 89.8 percent and a standard deviation of 2.93. Thus 50 percent of the roadway had a void content of more than 10.2 percent, 16 percent had a void content of more than 13.1 percent (10.2 + 2.9), and 2.5 percent had voids exceeding 14.1 percent (10.2 + 2 x 1.93).

In contrast, the project with the highest density had an average value of 96.3 percent and a standard deviation of 1.16. Thus, only 2.5 percent of the roadway would be expected to have a void content in excess of 6.0 percent (3.7 + 2 x 1.16).

Maximum Theoretical Relative Densities

As shown in Figure 5.7a, values for the 17 projects varied from 90.3 to 96.4 percent (3.6 to 9.7 percent air voids). Standard deviations varied from 1.08 to 3.87 percentage points which was slightly higher than the values for the relative densities based on the Rice maximum density. An analysis of the means and standard deviations of the 31 mixtures is shown in Figure 5.7b. As in previous cases, the projects with higher relative densities tended to have lower standard deviations.

Comparison of Relative Field Densities

G_C/G_R Job vs. G_C/G_T Design. An example relationship is shown in Figure 5.8. The differences in the relative densities varied from 0 to 4 percent with the relative densities based on the maximum theoretical density being higher. In both the laboratory and field compacted specimens, the relative densities based on the Rice maximum density are normally less than the relative densities based on the maximum theoretical densities. This is probably due to the fact that all voids cannot be filled when determining the maximum theoretical densities.

Nuclear Densities

For projects which nuclear density data was available, an attempt was made to study the relationships between nuclear and core densities (Fig 5.9). As shown, core densities were generally higher than nuclear densities for almost all cases and satisfactory correlation could not be obtained for any given project. As mentioned in previous sections, the nuclear density data was provided to research personnel by the districts; therefore, information related to techniques used in measurement and the type of equipment used is not known. Previous experience with nuclear density gauges indicate that density readings could easily be affected by the type of equipment and the measurement procedure.

Figure 5.10 shows the relationship between core densities and nuclear densities for all projects. This figure supports the finding that nuclear densities obtained in the field are generally lower than core densities over a range of materials and climates.

Changes in Relative Density with Time

A limited amount of data was available for one of the projects to show the changes in relative densities over a 10-month period. Relationships between relative density and time after initial placement are shown in Figure 5.11. As shown in this figure, relative density increases by approximately 2 percent during the first four months; however, between 4 and 6 months after placement, relative density increases by as much as four percent and remains approximately constant after 6 months.

Relationships between relative densities based on Rice specific gravity, specific gravity of laboratory compacted specimens, and maximum theoretical specific gravity is also shown in Figure 5.11. As is evident from the figure, the Rice specific gravity yields lower relative densities than the other two techniques. Highest relative densities are obtained based on the specific gravity of laboratory compacted specimen.

The degree of compaction imposed by traffic shown in Figure 5.11 indicates the difference in relative densities between wheel paths and in the wheel path. Generally after six months, relative density in the wheel path was approximately 2 percent higher than the relative density between wheel paths.

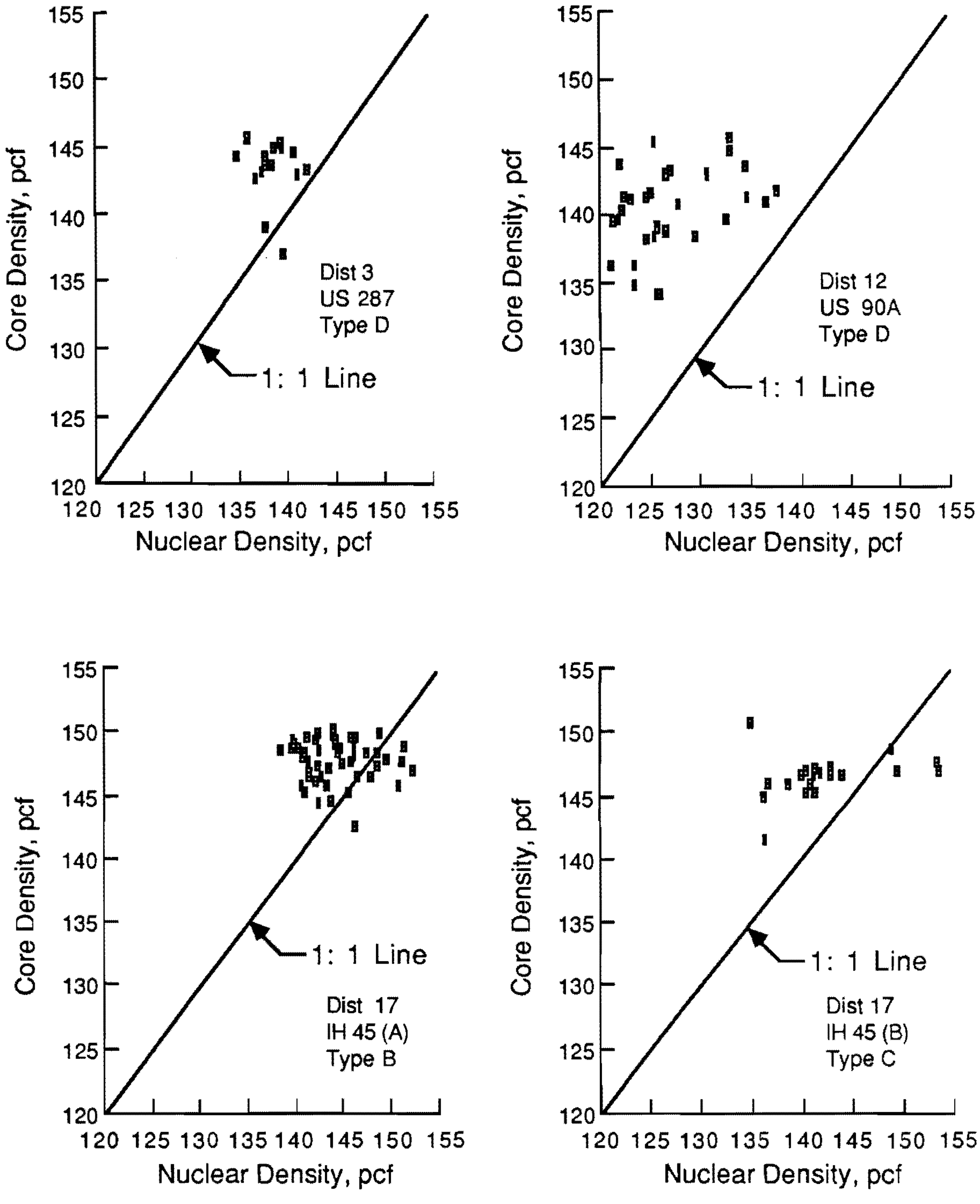


Figure 5.9. Relationships between core and nuclear densities

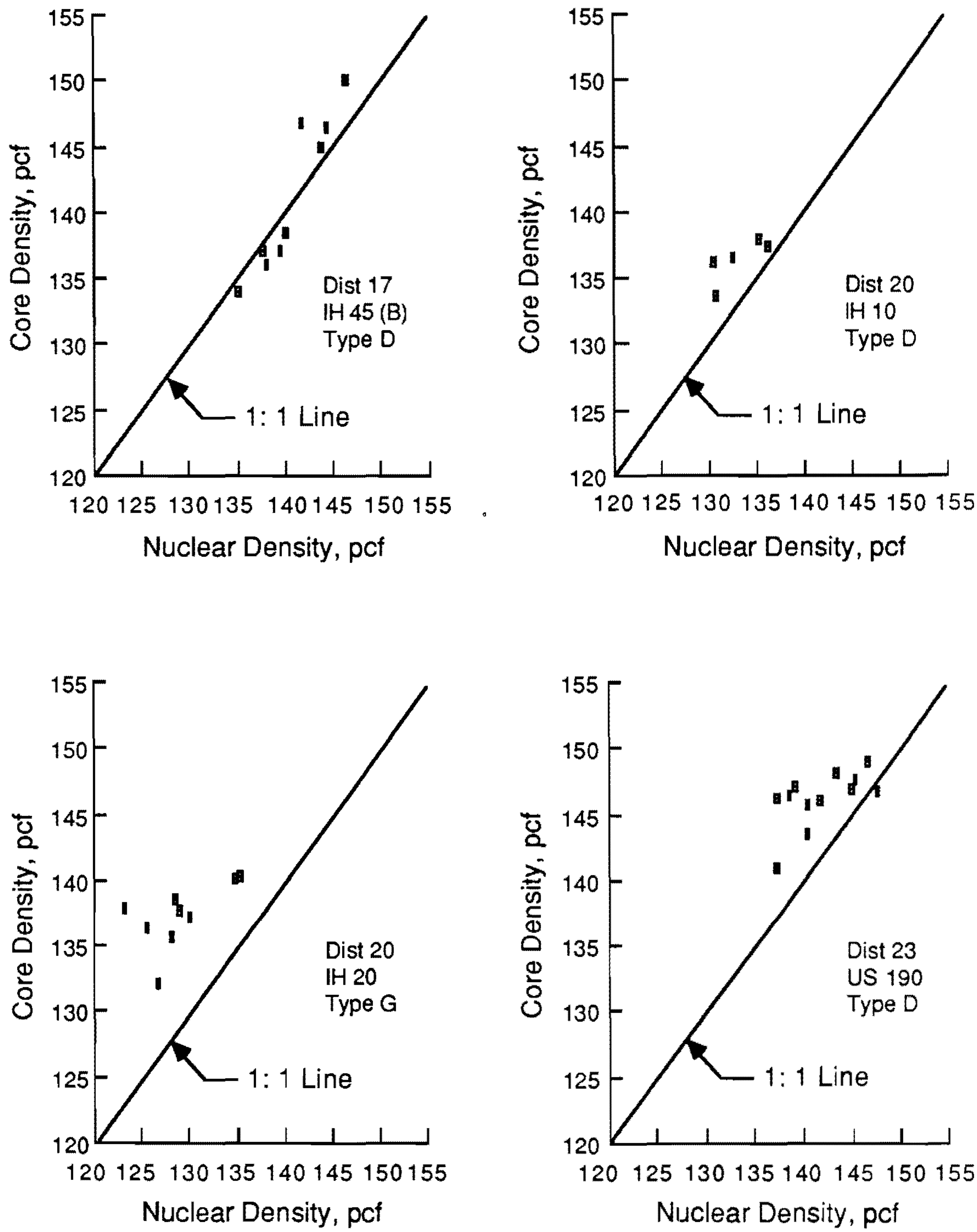


Figure 5.9. (cont.) Relationships between core and nuclear densities

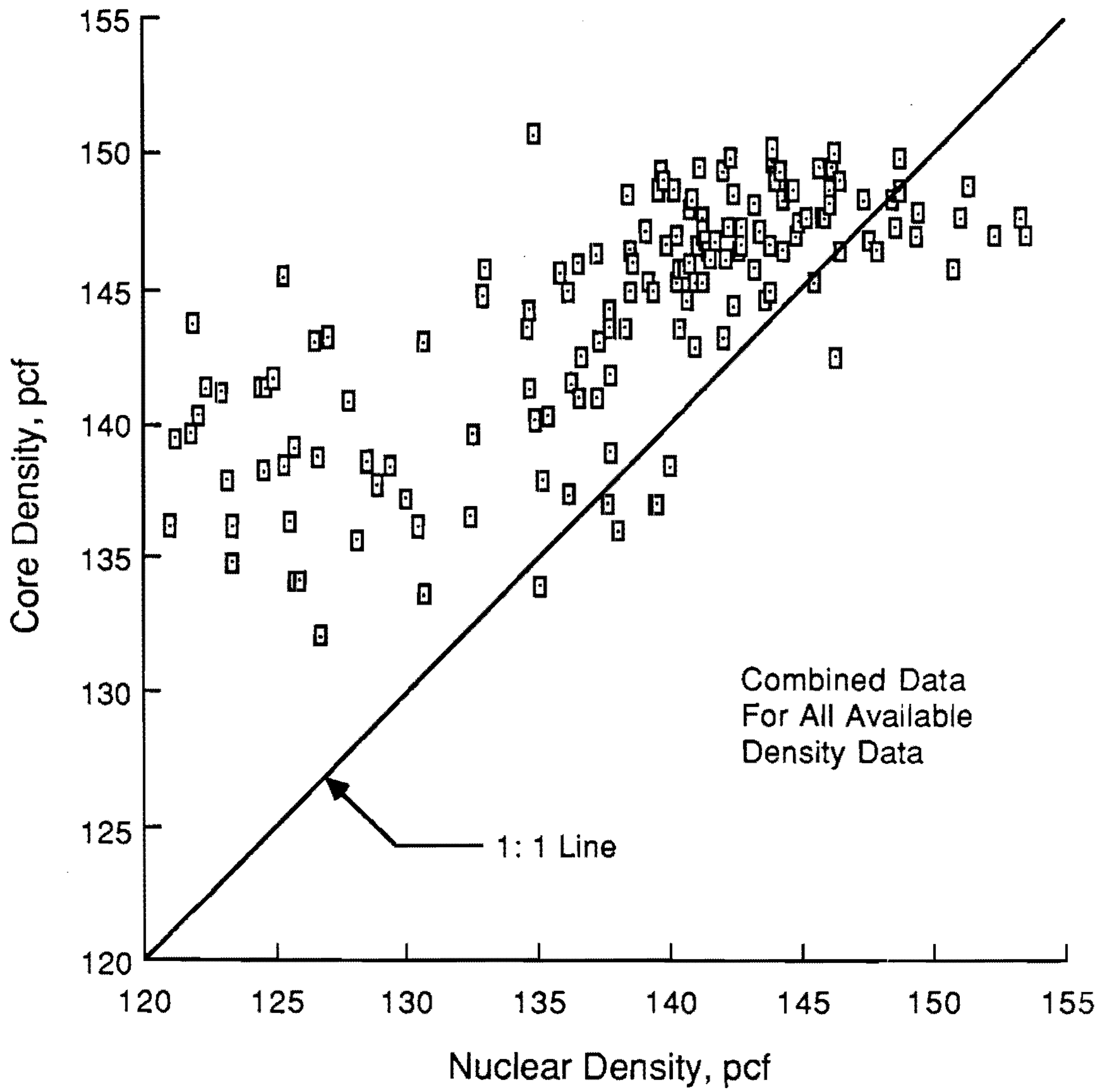


Figure 5.10. Relationships between core and nuclear densities for all projects

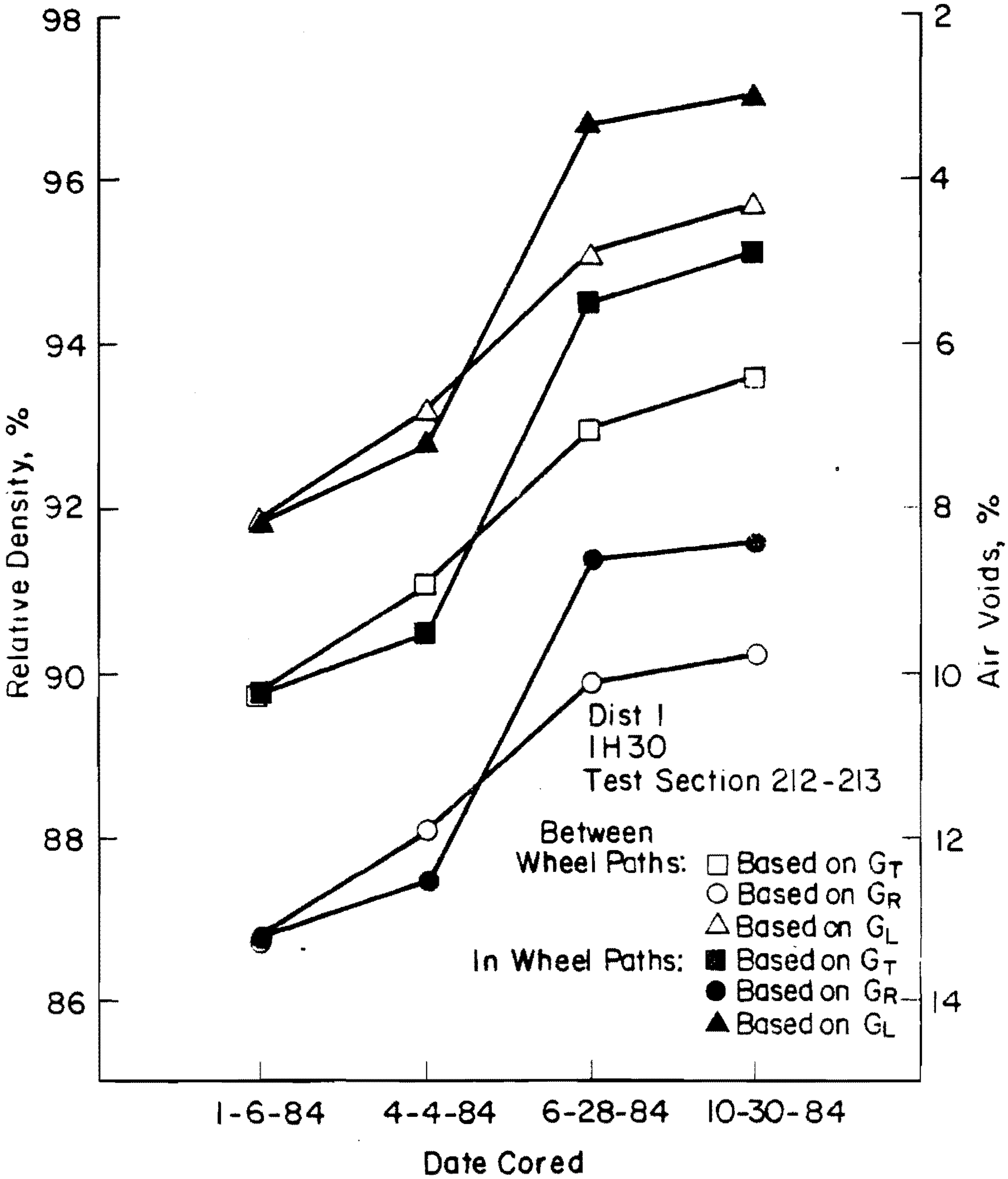


Figure 5.11. Changes in relative density with time

CHAPTER 6. CONCLUSIONS

Based on the data analyzed during this study, the following conclusions with regard to density and asphalt content of Texas pavement may be made.

Relative Density

1. Relative laboratory densities are generally more uniform than relative core densities.
2. Relative densities based on Rice maximum specific gravity were lower than relative densities based on theoretical maximum densities. Assuming that Rice specific gravity is a true measure of effective specific gravity, this finding implies that in projects for which theoretical maximum specific gravity is used for control, the true level of density accomplished is always lower than what is indicated by theoretical maximum specific gravity.
3. Relative density based on the density of laboratory compacted specimens indicated a range of 0.4 to 8.2 percent air voids for the data analyzed. The true air void content range for these data is 0.5 to 12.8 percent based on Rice specific gravity if 95 percent of laboratory density is achieved.
4. Standard deviations decreased as the mean relative density increased for all projects.

Nuclear Density

1. For the data analyzed in this study, nuclear density measurements were lower than core densities in almost all cases.
2. None of the nuclear density data showed a satisfactory correlation with core density data.

Asphalt Content

For projects studied, the asphalt contents achieved are well within the current specification limit of ±0.5 percent of the design value.

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APPENDIX A

ASPHALT CONTENTS AND INDIVIDUAL RELATIVE DENSITIES

TABLE A. SUMMARY OF INDIVIDUAL TEST RESULTS *

	No. of Projects	Range	$\bar{X}$	Standard Deviation, % Range Total	Standard Deviation, % Range Typical	Standard Deviation, % Average Total	Standard Deviation, % Average Typical
G_L/G_T Design	17	95.8 - 99.7	97.9	0.39 - 0.94	0.33 - 0.79	0.65	0.55
G_L/G_T Extra	17	95.7 - 99.7	97.8	0.40 - 1.00	0.40 - 0.98	0.72	0.66
G_L/G_R	13	94.8 - 98.6	97.1	0.39 - 1.38	0.35 - 0.92	0.79	0.58

	No. of Projects	Range	$\bar{X}$	Standard Deviation, % Range Total	Standard Deviation, % Range Typical	Standard Deviation, % Average Total	Standard Deviation, % Average Typical
G_C/G_L	17	91.8 - 99.6	95.3	0.98 - 3.88	1.00 - 2.63	2.07	1.97
G_C/G_T design	17	90.3 - 96.4	93.3	1.08 - 3.87	1.13 - 2.64	2.12	1.90
G_C/G_T extra	17	90.4 - 96.4	93.7	1.14 - 3.84	0.96 - 2.71	1.96	1.90
G_C/G_R job	13	89.7 - 95.9	92.7	1.09 - 3.76	1.03 - 2.60	2.30	1.92
G_C/G_R core	1	93.2 - 98.6	96.4	1.23	1.23	1.23	1.23

* Contained in Appendix Tables A-1 through A-17.

TABLE A-1. INDIVIDUAL ASPHALT CONTENTS AND DENSITIES FOR IH 30, DISTRICT 1

DIST 1, IH 30, TYPE D MIXTURE, ITEM 340

Design No.	Working Day	Design Asphalt Content,* %	Extracted Asphalt Content,* %	G_T Design	G_T Extra.	G_R Job	Lab, pcf	Core, pcf	Core Average, pcf
1	1	6.0	5.5	2.350	2.366	2.431	140.5	138.3	
								138.8	
								139.2	138.8
	2	6.0	-		-		142.5	133.2	
								136.2	
								133.4	134.3
	3	6.0	5.6		2.363		142.1	137.0	
								137.8	
								137.0	137.3
	4	6.0	6.0		2.350		143.4	137.2	
								140.0	
								140.1	139.0
	5	6.0	5.5		2.366		142.2	137.8	
								138.6	
								135.6	137.3
	6	6.0	6.0		2.350		143.0	134.5	
								138.5	136.5
	7	6.0	5.8		2.357		143.4	134.0	
								134.8	
								134.5	134.5
	8	6.0	5.5		2.366		142.6	132.2	
								129.2	130.7
	9	6.0	5.8		2.357		142.0	136.2	
								131.5	133.9
	10	6.0	-		-		-	-	-
	11	6.0	5.5		2.366		142.6	136.2	
								134.2	135.2
	12	6.0	5.7		2.360		141.1	140.8	
								134.8	137.8
	13	6.0	5.6		2.363		142.3	138.9	
								137.9	
								138.2	138.3

TABLE A-1. (Continued)

DIST 1, IH 30, TYPE D MIXTURE, ITEM 340

Design No.	Working Day	Design Asphalt Content,* %	Extracted Asphalt Content,* %	G_T Design	G_T Extra.	G_R Job	Lab, pcf	Core, pcf	Core Average, pcf
1	14	6.0	5.8	2.350	2.357	2.431	142.5	135.3	
								136.2	
								135.5	135.6
	15	6.0	5.5		2.366		142.4	134.2	
								134.7	
								135.2	134.7
	16	6.0	5.9		2.353		141.1	139.9	
								140.4	
								139.0	139.8
	17	6.0	-		-		-	-	-
2	18	6.6	6.3	2.331	2.340	-	141.6	135.9	
								140.7	
								140.7	139.1
3	19	6.6	6.2	2.331	2.344	2.370	144.3	136.0	
								137.0	
								138.2	137.1
	20	6.6	6.1		2.347		143.0	138.1	
								137.3	
								138.2	137.9
	21	6.6	6.1		2.347		143.0	128.2	
								140.2	134.2
	22	6.6	6.4		2.337		143.0	136.8	
								137.9	
								137.2	137.3
	23	6.6	6.1		2.347		142.6	138.0	
								141.0	
								141.7	140.2
	24	6.6	6.3		2.340		142.6	137.5	
								138.6	
								138.3	138.1
	25	6.6	-		-		-	-	-

TABLE A-1. (Continued)

DIST 1, IH 30, TYPE D MIXTURE, ITEM 340

Design No.	Working Day	Design Asphalt Content,* %	Extracted Asphalt Content,* %	G_T Design	G_T Extra.	G_R Job	Lab, pcf	Core, pcf	Core Average, pcf
3	26	6.6	6.3	2.331	2.340	2.370	142.6	136.8	
								138.1	
								136.1	137.0
	27	6.6	6.5		2.334		142.9	136.5	
								137.2	
								135.7	136.4
	28	6.6	6.1		2.347		143.3	139.0	
								137.3	138.1
	29	6.6	6.3		2.340		142.0	137.3	
								138.0	
								137.2	137.5
	30	6.6	6.2		2.344		142.5	138.3	
								141.0	
								141.8	140.4
	31	6.6	6.6		2.331		141.6	138.0	
								137.5	
								136.5	137.3
	32	6.6	6.4		2.337		143.8	139.8	
								139.6	
								139.8	139.7
	33	6.6	6.1		2.347		142.6	136.3	
								137.6	
								138.6	137.5
	34	6.6	6.1		2.347		142.2	135.1	
								136.0	
								135.7	135.6
	35	6.6	6.3		2.340		142.5	138.2	
								135.3	136.8
	36	6.6	6.2		2.344		140.4	137.8	
								138.0	
								139.6	138.5

TABLE A-1. (Continued)

DIST 1, IH 30, TYPE D MIXTURE, ITEM 340

Design No.	Working Day	Design Asphalt Content,* %	Extracted Asphalt Content,* %	G_T Design	G_T Extra.	G_R Job	Lab, pcf	Core, pcf	Core Average, pcf
3	37	6.6	-	2.331	-	2.370	-	-	-
	38	6.6	6.2		2.344		141.8	136.7	
								137.8	
								136.3	136.9
	39	6.6	6.1		2.347		142.1	134.7	
								136.0	
								136.2	135.6
	40	6.6	6.1		2.347		141.2	135.8	
								130.1	
								134.7	133.5
	41	6.6	6.2		2.344		142.2	135.4	
								136.9	
								135.8	136.0
	42	6.6	6.1		2.347		141.6	134.7	
								136.8	
								135.3	135.6
	43	6.6	6.2		2.344		143.3	138.0	
								139.3	
								137.5	138.3
	44	6.6	6.1		2.347		141.5	135.2	
								133.7	134.4
	45	6.6	-		-		-	-	-
	46	6.6	-		-		-	-	-
	47	6.6	-		-		-	-	-
	48	6.6	-		-		-	-	-
	49	6.6	-		-		-	-	-
	50	6.6	-		-		-	-	-
	51	6.6	-		-		-	-	-

TABLE A-2. INDIVIDUAL ASPHALT CONTENTS AND DENSITIES FOR US 287, DISTRICT 3

DIST 3, US 287, TYPE D MIXTURE, ITEM 340

Design No.	Working Day	Design Asphalt Content, %	Extracted Asphalt Content, %	G_T Design	G_T Day	G_T Extra.	Lab Density, pcf	Core Density, pcf	Nuclear Density, pcf
1	1	4.6	4.4,4.5,4.6	2.504	2.508	2.510	151.9	143.8	
								145.0	138.5
								143.6	138.3
2	2	4.8	5.0,4.8,4.5	2.497	2.497	2.490	151.5	144.3	137.7
			4.8,5.1			2.497	151.5	142.6	136.7
	3	4.8	5.1		2.492	2.486	152.7	144.9	139.4
3		4.6	4.8	2.504		2.497	151.7		
	4	4.6	4.7,4.9		2.500	2.500	153.0	145.6	135.9
			4.7			2.500	152.3		
	5	4.6	4.8,4.9,4.2		2.504	2.497	153.1	143.6	137.7
	6	4.6	4.6,4.8,4.3		2.500	2.504	152.2	142.8	141.0
								138.9	137.7
								143.0	137.4
4	7	4.4	4.5,4.5,4.6	2.510	2.508	2.508	151.5	145.3	139.2
	8	4.4	4.3,4.1		2.515	2.515	152.9		
			4.4			2.510	151.0		
	9	4.4	4.1,4.6,4.4		2.510	2.522	151.8		
	10	4.4	4.7,4.3		2.508	2.500	151.6		
	11	4.4	4.6,4.5		2.506	2.504	151.0		
5	12	4.4	4.5,4.8,4.5	2.510	2.504	2.508	152.6	144.5	140.7
	13	4.4	4.5,4.6,4.4		2.508	2.508	152.4	144.3	134.7
								143.2	142.1
	14	4.4	4.2,4.2,4.2		2.518	2.518	150.8		
	15	4.4	4.5,4.2,4.3		2.510	2.508	150.7	137.1	139.5
	16	4.4	4.4		2.510	2.510	151.1		

TABLE A-3. INDIVIDUAL ASPHALT CONTENTS AND DENSITIES FOR IH 45, DISTRICT 12, PROJECT A

DIST 12, IH 45, D LEVEL UP, ITEM 340, PROJECT A

Design No.	Working Day	Design Asphalt Content, %	Extracted Asphalt Content, %	G_T Design	G_T Extra.	G_R Job	G_R Day	Lab Density, pcf	Core Density, pcf
1	1	4.7	4.6	2.414	2.417	2.426	2.426	145.8	134.9
	2	4.7	4.2		2.431		2.442	148.6	138.2
	3	4.7	4.5		2.421		2.432	147.5	139.6
2	4	4.9	4.7	2.407	2.414	2.425	2.425	147.8	136.5
	5	4.9	4.9,4.7,5.2		2.407		2.425	148.0	137.6
	6	4.9	4.9,4.8		2.407		2.418	148.3	
	7	4.9	5.0,5.5,4.9		2.404		2.414	147.3	140.7
	8	4.9	5.3		2.393		2.427	148.4	136.1
	9	4.9	4.7,5.0		2.414		2.421	147.8	135.8
3	10	4.9	4.3		2.427	2.435	2.435	147.0	134.3
	11	4.9	4.6,5.0		2.417		2.426	148.3	137.3
	12	4.9	4.6		2.417		2.426	147.7	134.3
	13	4.9	4.9,5.0		2.407		2.417	148.3	144.0
	14	4.9	4.5		2.421		2.429	146.7	136.3
	15	4.9	5.1,5.0		2.400		2.411	147.6	134.5
	16	4.9	5.0,4.6		2.404		2.414	147.0	139.8
4	17	4.9	5.0		2.404	2.414	2.414	146.3	140.2
5	18	5.1	5.1,4.9,5.1	2.400	2.400	2.417	2.417	147.8	138.6
6	19	5.0	4.9	2.404	2.407	2.417	2.417	147.0	138.6
	20	5.0	4.9,5.0		2.407		2.417	148.1	137.5
	21	5.0	5.0		2.404		2.417	148.8	138.9
7	22	5.0	4.9		2.407	2.417	2.417	147.3	132.1
8	23	5.1	4.8,4.9	2.400	2.410	2.420	2.420	147.4	140.9
9	24	5.0	5.0,5.0	2.404	2.404	2.414	2.414	147.5	133.5
	25	5.0	4.9,4.9		2.407		2.417	148.3	138.0
10	26	5.1	4.8,4.8	2.400	2.410	2.420	2.420	148.5	136.2
	27	5.1	4.7		2.414		2.425	148.0	142.2
	28	5.1	4.9,4.7		2.407		2.417	148.8	138.9
	29	5.1	5.0		2.404		2.408	149.0	142.0
	30	5.1	4.9		2.407		2.417	149.1	144.5
	31	5.1	4.9,4.9		2.407		2.417	149.1	140.6
	32	5.1	5.2,5.1		2.397		2.407	149.6	141.3
11	33	5.1	4.9,4.7		2.407	2.417	2.417	148.4	140.9
	34	5.1	4.8,4.9		2.410		2.421	149.6	140.8
	35	5.1	4.9		2.407		2.417	148.5	
	36	5.1	5.1		2.400		2.410	149.1	141.4
	37	5.1	5.0		2.404		2.414	147.9	
	38	5.1	4.9		2.407		2.417	147.0	
	39	5.1	5.1,5.0		2.400		2.410	147.6	
	40	5.1	5.1		2.400		2.410	148.3	
	41	5.1	5.0		2.404		2.414	148.0	

TABLE A-3. (Continued)

DIST 12, IH 45, D LEVEL UP, ITEM 340, PROJECT A

Design No.	Working Day	Design Asphalt Content, %	Extracted Asphalt Content, %	G_T Design	G_T Extra.	G_R Job	G_R Day	Lab Density, pcf	Core Density, pcf
11	42	5.1	4.9	2.400	2.407	2.417	2.417	147.1	138.3
	43	5.1	4.9		2.407		2.417	148.6	145.2
	44	5.1	5.2		2.397		2.407	148.4	146.9
	45	5.1	5.0		2.404		2.414	147.8	147.2
	46	5.1	5.0		2.404		2.414	148.3	
	47	5.1	5.0		2.404		2.414	148.3	
	48	5.1	5.0		2.404		2.414	148.1	133.6
	49	5.1	5.3		2.393				
	50	5.1	5.3,5.1		2.393		2.404	148.8	146.1
	51	5.1	5.2		2.397		2.407	148.3	142.5
	52	5.1	5.2		2.397		2.407	148.5	145.5
	53	5.1	5.2		2.397		2.407	148.1	145.7
	54	5.1	5.2		2.397		2.407	147.5	
	55	5.1	5.2,5.0		2.397		2.414	148.2	141.4
12	56	5.1	4.9		2.407	2.417	2.417	147.9	
	57	5.1	5.5,5.2		2.387		2.398	148.8	144.7
	58	5.1	5.1		2.400		2.411	148.0	140.7
	59	5.1	5.1		2.400		2.417	148.9	138.0
	60	5.1	5.4		2.390		2.401	149.1	140.1
	61	5.1	5.0,4.8		2.404		2.414	146.6	139.3
	62	5.1	5.2		2.397		2.408	148.1	136.0
	63	5.1	4.7		2.414		2.425	147.1	
	64	5.1	5.0		2.404		2.472	148.1	139.8
	65	5.1	4.9		2.407		2.475	148.9	
13	66	4.8	4.6,4.7	2.410	2.417	2.472	2.472	151.4	

TABLE A-4. INDIVIDUAL ASPHALT CONTENTS AND DENSITIES FOR IH 45, DISTRICT 12, PROJECT A

DIST 12, IH 45, D SURFACE, ITEM 340, PROJECT A

Design No.	Working Day	Design Asphalt Content, %	Extracted Asphalt Content, %	G_T Design	G_T Extra.	G_R Job	G_R Day	Lab Density, pcf	Core Density, pcf
1	1	4.9	4.8	2.417	2.420	2.465	2.465	150.0	143.8
	2	4.9	5.0,5.0		2.413		2.458	150.0	140.6
2	3	4.8	4.8	2.420	2.420	2.465	2.465	149.4	147.0
	4	4.8	4.3,4.55		2.438		2.482	147.5	141.6
	5	4.8	4.7,4.8		2.424		2.470	148.9	139.2
	6	4.8	4.9		2.417		2.463	149.3	140.6
	7	4.8	4.8		2.420		2.465	150.4	142.0
	8	4.8	4.6,4.3		2.427		2.472	149.3	143.3
	9	4.8	4.5,4.6		2.431		2.475	149.6	139.5
	10	4.8	4.8,4.6		2.420		2.465	150.3	138.9
	11	4.8	5.5,4.5		2.396		2.476	150.1	141.7
	12	4.8	5.3		2.403		2.447	150.1	139.6
	13	4.8	5.1		2.410		2.447	150.7	138.0
	14	4.8	5.2		2.407		2.451	148.8	144.4
3	15	4.5	4.9,4.4	2.431	2.417	2.461	2.461	150.8	148.2
	16	4.5	4.9,4.5		2.417		2.461	150.9	143.3
4	17	4.4	4.7	2.434	2.424	2.468	2.468	148.8	143.2
	18	4.4	4.5,4.7		2.431		2.476	150.1	144.0
	19	4.4	4.5,4.3		2.431		2.475	150.8	144.7
5	20	4.4	4.6,4.4	2.434	2.427	2.471	2.471	151.3	139.7
6	21	4.5	4.75	2.431	2.422	2.463	2.463	150.1	144.5
	22	4.5	4.7,4.6		2.424		2.466	151.0	141.3
	23	4.5	4.4,4.5		2.434		2.478	150.2	143.5
	24	4.5	4.35		2.436		2.474	149.9	142.8
	25	4.5	4.7,4.5		2.424		2.467	149.0	141.3
	26	4.5	4.5,4.7		2.431		2.474	150.2	137.4
	27	4.5	4.4		2.434		2.478	149.3	137.2
	28	4.5	4.55		2.429		2.471	149.8	136.0
	29	4.5	4.35		2.436		2.475	149.7	137.5
7	30	4.6	4.2	2.427	2.441	2.486	2.486	148.9	148.6
	31	4.6	4.5		2.431		2.474	150.9	137.4
8	32	4.7	4.85	2.424	2.419	2.470	2.470	151.8	140.7
	33	4.7	4.65		2.425		2.463	152.3	
	34	4.7	4.9		2.417		2.459	149.4	
	35	4.7	4.9		2.417		2.459	150.5	
	36	4.7	4.9		2.417		2.459	149.4	
	37	4.7	4.8		2.420		2.463	151.3	143.9
	38	4.7	4.7		2.424		2.465	150.1	143.7

TABLE A-4. (Continued)

DIST 12, IH 45, D SURFACE, ITEM 340, PROJECT A

Design No.	Working Day	Design Asphalt Content, %	Extracted Asphalt Content, %	G_T Design	G_T Extra.	G_R Job	G_R Day	Lab Density, pcf	Core Density, pcf
9	39	4.7	5.0,4.6	2.424	2.413	2.454	2.454	150.3	139.7
	40	4.7	4.6		2.427		2.470	149.6	142.0
	41	4.7	4.4		2.434		2.477	149.9	143.3
	42	4.7	4.7		2.424		2.466	150.4	143.3
10	43	4.8	4.6	2.420	2.427	2.470	2.470	150.6	144.9
	44	4.8	4.7		2.424		2.466	150.6	145.9
	45	4.8	4.9		2.417		2.459	150.4	145.2
	46	4.8	4.5		2.431		2.474	147.7	137.4
	47	4.8	4.6		2.427		2.471	146.7	141.5
11	48	4.8	4.9	2.420	2.417	2.462	2.462	146.5	142.3
	49	4.8	4.7		2.424		2.469	146.8	134.7
	50	4.8	4.8		2.420		2.465	147.5	133.2

TABLE A-5. INDIVIDUAL ASPHALT CONTENTS AND DENSITIES FOR IH 45, DISTRICT 12, PROJECT B

DIST 12, FM 2920, D LEVEL UP, ITEM 340, PROJECT A

Design No.	Working Day	Design Asphalt Content, %	Extracted Asphalt Content, %	G_T Design	G_T Extra.	G_R Job	G_R Day	Lab Density, pcf	Core Density, pcf
1	Feb 1	4.9	5.1,5.0	2.407	2.400	2.411	2.411	147.6	138.7
2	Jul 2	4.6	4.3	2.417	2.427	2.423			
	Sep 3	4.6	4.4		2.424		2.423	149.4	136.5
	4	4.6	4.5		2.421		2.420	149.8	128.8
	5	4.6	4.4		2.424		2.423	148.9	152.0
	6	4.6	4.4		2.424		2.423	147.6	137.6
	7	4.6	4.7		2.414		2.414	149.1	132.6
	8	4.6	4.8,4.4		2.410		2.423	149.3	139.1
3	9	4.6	4.5		2.421	2.420	2.420	149.9	137.4
	10	4.6	4.5		2.421		2.420	148.1	134.5
	11	4.6	4.7		2.414		2.414	150.1	129.4
4	12		4.5		2.421	2.423	2.420	149.1	133.6
	13	4.6	4.6		2.417	2.428	2.428	147.9	137.1
	14	4.6	4.5		2.421		2.431	149.1	142.3
5	15	4.7	4.7	2.414	2.414	2.425	2.425	149.1	138.6
	16	4.7	4.7		2.414		2.425	149.8	143.3
	17	4.7	4.6		2.417		2.428	149.1	138.6
	18	4.7	4.6		2.417		2.428	149.0	138.6
	19	4.7	4.6		2.417		2.425	148.9	138.8
	20	4.7	4.7		2.414		2.425	147.8	139.7
6	21	4.9	4.7,4.8	2.407	2.414	2.423	2.423	149.1	136.1
7	22	4.9	5.1		2.400	2.411	2.411	148.9	141.9
	23	4.9	4.8		2.410		2.426	148.8	137.5
	24	4.9	5.1		2.400		2.411	148.5	141.0
	25	4.9	5.1,5.0		2.400				
8	26	4.9	5.0		2.404	2.414	2.414	146.3	133.8
9	27	5.1	4.9,5.1,5.1	2.400	2.407	2.417	2.417	147.8	139.8
10	28	5.1	4.8		2.410	2.420	2.420	147.4	135.3
11	29	5.0	5.0,5.0	2.404	2.404	2.414	2.414	147.5	136.5
12	30	5.1	4.8,4.8	2.400	2.410	2.417			
	31	5.1	4.9		2.407		2.417	148.8	142.7
	32	5.1	4.9		2.407		2.417	149.1	
	33	5.1	4.9,4.9		2.407		2.417	149.1	132.4
	34	5.1	5.2,5.1		2.397		2.407	149.6	140.6
13	35	5.1	4.9,4.7		2.407	2.417	2.417	148.4	
	36	5.1	4.8,4.9		2.410		2.421	149.6	139.1
	37	5.1	4.9		2.407		2.417	148.5	140.9
	38	5.1	5.1		2.400		2.417	148.5	
	39	5.1	5.0		2.404		2.414	147.9	
	40	5.1	4.9		2.407		2.417	147.0	139.5
	41	5.1	5.1		2.400		2.410	147.6	139.9

TABLE A-5. (Continued)

DIST 12, FM 2920, D LEVEL UP, ITEM 340, PROJECT A

Design No.	Working Day	Design Asphalt Content, %	Extracted Asphalt Content, %	C_T Design	C_T Extra.	C_R Job	C_R Day	Lab Density, pcf	Core Density, pcf
13	42	5.1	5.1	2.400	2.400	2.417	2.410	148.3	142.7
	43	5.1	5.0		2.404		2.414	148.0	
	44	5.1	5.1		2.400		2.410	147.7	143.0
	45	5.1	5.1		2.400		2.410	148.5	136.5
	46	5.1	5.2,5.0		2.397		2.407	149.1	145.5
	47	5.1	5.2		2.397		2.407	148.9	138.6
	48	5.1	4.9		2.407		2.417	147.1	131.5
	49	5.1	4.9		2.407		2.417	148.6	145.1
	50	5.1	5.2		2.397		2.407	148.4	
	51	5.1	5.0		2.404		2.414	147.8	
	52	5.1	5.8		2.377		2.414	148.3	
	53	5.1	5.0		2.404		2.414	148.1	144.8
	54	5.1	5.3		2.393		2.404	149.0	
	55	5.1	5.3,5.1		2.393		2.404	148.8	144.8
	56	5.1	5.2		2.397		2.407	148.3	
	57	5.1	5.1		2.400		2.411	148.5	
	58	5.1	5.2		2.397		2.407	148.5	
	59	5.1	5.2		2.397		2.407	148.1	
	60	5.1	5.2,5.0		2.397		2.414	148.2	137.2
	61	5.1	5.3		2.393		2.406	147.1	142.8
	62	5.1	4.9		2.407		2.417	147.8	144.2
	63	5.1	5.0		2.404		2.416	148.0	144.7
14	64	5.5	5.6	2.387	2.383	2.428	2.400	144.8	128.3
15	65	5.3	5.4	2.393	2.390	2.420	2.417	147.9	
16	66	5.1	4.7	2.400	2.414	2.425	2.425	147.1	
	67	5.1	5.0	2.400	2.404		2.472	148.1	
17	68	5.0	4.6	2.404	2.417	2.486	2.486	146.3	

TABLE A-6. INDIVIDUAL ASPHALT CONTENTS AND DENSITIES FOR IH 45, DISTRICT 12, PROJECT B

DIST 12, FM 2920, D SURFACE, ITEM 340, PROJECT A

Design No.	Working Day	Design Asphalt Content, %	Extracted Asphalt Content, %	G_T Design	G_T Extra.	G_R Job	G_R Day	Lab Density, pcf	Core Density, pcf
1	1	4.8	5.1,4.9	2.420	2.410	2.420	2.420	150.8	149.3
	2	4.8	5.1		2.410		2.411	150.6	144.7
	3	4.8	4.5,5.0		2.431		2.433	149.9	145.1
2	4	4.8	4.8		2.420	2.423	2.423	150.1	138.3
	5	4.8	4.7		2.424		2.469	150.8	143.9
3	6	4.9	5.0,5.0	2.417	2.413	2.458	2.458	150.0	143.6
4	7	4.8	4.2,4.8	2.420	2.422	2.470	2.470	148.9	142.7
	8	4.8	4.9		2.417		2.463	149.3	141.7
	9	4.8	4.8		2.420		2.465	150.4	142.4
	8/25 10	4.8	4.6,4.3		2.427		2.472	149.3	147.8
5	10/5 11	4.5	4.5,4.2	2.431	2.431	2.474	2.474	149.9	133.2
	12	4.5	4.7,4.5		2.424		2.467	149.0	131.3
	13	4.5	4.5,4.8		2.431		2.474	150.2	137.9
	14	4.5	4.55		2.429				
	15	4.5	4.35		2.436		2.475	149.7	138.7
	16	4.5	4.7		2.424		2.461	149.4	139.9
	17	4.5	4.6		2.427		2.461	149.4	138.4
6		4.6	4.9	2.427	2.417	2.472	2.472	150.5	-
	18	4.6	4.5		2.431		2.474	150.9	134.5
7	19	4.7	4.85	2.424	2.419	2.470	2.470	151.8	138.1
	20	4.7	4.8		2.420		2.460	151.5	144.8
	21	4.7	4.4		2.434		2.474	151.4	139.7
	22	4.7	4.9		2.417		2.460	151.6	142.8
	23	4.7	4.9		2.417				
	24	4.7	4.65		2.425		2.463	152.3	141.6
	25	4.7	4.9		2.417		2.459	149.4	140.2
	26	4.7	4.9		2.417		2.459	150.5	140.1
	27	4.7	4.6		2.427		2.470	149.3	142.9
	28	4.7	5.0		2.413		2.456	148.5	142.5
	29	4.7	4.8		2.420		2.463	150.4	141.4
	30	4.7	4.8		2.420		2.463	151.3	137.2
	31	4.7	4.8		2.420		2.463	151.1	143.7

TABLE A-7. INDIVIDUAL ASPHALT CONTENTS AND DENSITIES FOR US 90A, DISTRICT 12

DIST 12, US 90A, TYPE D MIXTURE, ITEM 340

Design No.	Working Day	Design Asphalt Content, %	Extracted Asphalt Content, %	G_T Design	G_T Day	G_T Extra.	Lab Density, pcf	Core Density, pcf	Nuclear Density, pcf
1	1	5.1	4.7,5.4	2.468	2.470	2.483	148.6	136.2	
								142.0	
								141.4	
	2	5.1	5.1		2.468	2.468	149.2	134.2	125.9
								141.3	124.4
								138.7	126.6
	3	5.1	5.4		2.457	2.457	148.9	143.8	121.9
								139.7	132.5
								141.2	123.0
2	4	5.1	5.2		2.465	2.465	149.1	141.3	124.6
								143.0	126.5
								145.5	125.3
3	5	4.6	4.9	2.470	2.459	2.459	149.4	139.4	121.2
								143.3	127.0
								139.7	121.8
4	6	4.6	4.5,4.3	2.470	2.477	2.473	148.3	138.3	124.5
								141.3	122.4
								140.8	127.8
5	7	4.6	4.6	2.470	2.470	2.470	149.7	136.3	123.4
								134.8	123.4
								136.2	121.0
	8	4.6	4.5		2.473	2.473	147.7	141.6	124.9
								140.4	122.1
								138.5	129.4
	9	4.6	4.4		2.477	2.477	146.6	138.5	125.3
								139.2	125.7
								134.2	125.7

TABLE A-7. (Continued)

DIST 12, US 90A, TYPE D MIXTURE, ITEM 340

Design No.	Working Day	Design Asphalt Content, %	Extracted Asphalt Content, %	G_T Design	G_T Day	G_T Extra.	Lab Density, pcf	Core Density, pcf	Nuclear Density, pcf
5	10	4.6	4.7	2.470	2.466	2.466	150.0	145.8	133.0
								143.0	130.6
								141.8	137.7
6	11	4.6	4.4,4.3	2.470	2.479	2.477	149.8	143.2	
								141.6	
								141.8	
	12	4.6	4.5,4.5,4.7		2.470	2.473	149.8	143.5	
								141.0	136.6
								144.8	
7	13	4.6	4.6,4.3,4.3	2.470	2.477	2.470	150.1	137.9	
								143.5	134.6
								142.9	
	14	4.6	4.4,4.6,4.3		2.477		150.0	142.3	
								142.3	
	15	4.6	4.7		2.466	2.466	149.2	137.3	
								141.3	134.7
								137.3	
	16	4.6	4.3,4.5		2.477	2.481	149.4	144.6	
								144.7	132.9
								144.3	
	17	4.6	4.5		2.473	2.473	149.4	137.0	

TABLE A-8. INDIVIDUAL ASPHALT CONTENTS AND DENSITIES FOR SH 105, DISTRICT 12

DIST 12, SH 105, TYPE D MIXTURE, ITEM 340

Design No.	Working Day	Design Asphalt Content, %	Extracted Asphalt Content, %	G_T Design	G_T Extra.	G_R Job	G_R Day	Lab Density, pcf	Core Density, pcf
1	1	5.0	5.0,5.0,5.0,5.0	2.395	2.395	2.425	2.425	148.3	139.5
	2	5.0	5.1		2.392		2.418	149.6	140.6
	3	5.0	4.8		2.402				
	4	5.0	5.2,4.9		2.389		2.418	148.8	139.7
	5	5.0	4.7		2.405		2.436	148.9	142.4
	6	5.0	4.95,5.0,5.0		2.397		2.422	149.5	143.6
	7	5.0	5.0		2.395		2.425	149.3	138.6
	8	5.0	4.8		2.402		2.431	149.6	141.5
	9	5.0	4.9		2.399		2.428	149.7	140.1
	10	5.0	4.8		2.402		2.431	148.9	141.4
	4/29 11	5.0	5.1		2.392		2.421	149.7	
2	5/26 12	4.9	4.9	2.399	2.399	2.428	2.428	148.2	145.0
	13	4.9	5.0,4.9		2.395		2.424	148.8	139.0
					-		2.428	148.6	
	14	4.9	5.0		2.395		2.424	149.0	143.5
	15	4.9	4.7		2.405		2.434	148.6	140.2
	16	4.9	4.9,4.9		2.399		2.430	149.7	143.9
	6/8 17	4.9	4.9,4.9,4.9		2.399		2.429	149.1	143.2
	8/1 18	4.9	4.7,4.6		2.405		2.438	150.5	140.7
							2.435	149.4	

TABLE A-9. INDIVIDUAL ASPHALT CONTENTS AND DENSITIES FOR FM 149, DISTRICT 12

DIST 12, FM 149, TYPE D MIXTURE, ITEM 340

Design No.	Working Day		Design Asphalt Content, %	Extracted Asphalt Content, %	G_T Design	G_T Extra.	G_R Job	G_R Day	Lab Density, pcf	Core Density, pcf
1		1	4.8	5.0,4.8	2.403	2.396	2.411	2.411	148.3	137.5
		2	4.8	4.75		2.405		2.421	146.2	135.8
	Apr	3	4.8	4.8		2.403		2.415	149.5	140.1
2		4	4.6	4.8,4.6	2.410	2.403	2.430	2.430	150.1	140.9
	Sep	5	4.6	4.4		2.416		2.433	146.8	134.8
		6	4.6	4.4,4.6		2.416		2.432	147.5	133.8
		7	4.6	4.4,4.6,4.6		2.416		2.433	147.3	136.3
		8	4.6	4.5,4.2,4.6,4.6		2.413		2.429	147.0	137.6
		9	4.6	4.4,4.2,4.7		2.416		2.443	147.2	134.0
		10	4.6	4.3		2.420		2.436	145.7	134.1
		11	4.6	4.8		2.403		2.415	149.8	135.0
		12	4.6	4.7		2.406		2.418	149.4	130.7
		13	4.6	4.9		2.400		2.416	149.9	135.2
		14	4.6	4.5		2.413		2.425	148.1	138.8
		15	4.6	4.6		2.410		2.426	147.1	130.6
		16	4.6	4.4,4.1		2.416		2.433	148.2	131.3
		17	4.6	4.7		2.406		2.422	148.5	149.8
		18	4.6	4.55		2.411		2.429	148.9	137.5
		19	4.6	4.8		2.403				
		20	4.6	4.7		2.406		2.422	147.9	127.6
		21	4.6	5.0		2.396		2.411	147.2	134.0
		22	4.6	4.4,4.9		2.416		2.432	147.0	137.8
3		23	4.6	4.7	2.410	2.406	2.422	2.422	148.1	134.8

TABLE A-10. INDIVIDUAL ASPHALT CONTENTS AND DENSITIES FOR FM 1097, DISTRICT 12

DIST 12, FM 1097, TYPE D MIXTURE, ITEM 340

Design No.	Working Day	Design Asphalt Content, %	Extracted Asphalt Content, %	G_T Design	G_T Extra.	G_R Job	G_R Day	Lab Density, pcf	Core Density, pcf
1	1	5.0	4.9,5.4	2.395	2.399	2.398	2.398	145.6	138.0
2	2	5.3	5.4	2.385	2.382	2.384	2.384	146.8	136.9
	3	5.3	5.3		2.385		2.386	146.8	139.8
	Apr 4	5.3	5.2		2.389		2.389	146.9	141.5
3	Jun 5	5.4	5.3	2.382	2.385	2.386	2.386	148.0	144.0
	6	5.4	5.4,5.5		2.382		2.382	148.0	141.8
	7	5.4	5.3,5.3		2.385		2.386	146.6	142.9
4	8	5.3	5.2	2.385	2.389	2.389	2.389	146.9	
	9	5.3	5.2		2.389		2.389	146.8	

TABLE A-11. INDIVIDUAL ASPHALT CONTENTS AND DENSITIES FOR FM 2920, DISTRICT 12

DIST 12, FM 2920, TYPE D MIXTURE, ITEM 340, PROJECT B

Design No.	Working Day	Design Asphalt Content, %	Extracted Asphalt Content, %	G_T Design	G_T Extra.	G_R Job	G_R Day	Lab Density, pcf	Core Density, pcf
1	1	5.5	5.4	2.348	2.351	2.406	2.406	144.3	134.8
	2	5.5	5.3		2.354		2.411	144.1	140.7
	3	5.5	5.4		2.351		2.408	144.8	138.1
	4	5.5	5.3		2.354		2.411	142.3	142.8
	5	5.5	4.8		2.371		2.428	141.2	140.3
	6	5.5	5.2,5.1		2.358		2.332	142.4	139.8
	7	5.5	4.7		2.374		2.411	144.1	135.1
2	8	5.0	4.9,5.0	2.364	2.367	2.404	2.404	143.5	136.8
	9	5.0	5.05,5.0,5.0,5.0		2.362		2.401	144.0	127.8
	10	5.0	5.05		2.362		2.397	145.0	130.6
	11	5.0	5.1,5.0		2.361		2.397	143.8	127.7
	12	5.0	4.95,5.0		2.366		2.401	144.0	133.0
	13	5.0	5.05		2.362		2.394	145.0	137.0
	14	5.0	5.0,5.0		2.364		2.401	144.7	134.8

TABLE A-12. INDIVIDUAL ASPHALT CONTENTS AND DENSITIES FOR IH 45 TYPE B, DISTRICT 17, PROJECT A

DIST 17, IH 45, TYPE B MIXTURE, ITEM 340, PROJECT A

Design No.	Working Day	Design Asphalt Content, %	Extracted Asphalt Content, %	G_T Design	G_T Day	G_T Extra.	G_R Job	G_R Day**	Lab Density, pcf	Core Density, pcf **	Nuclear Density, pcf
1	1	5.2	5.1	2.456	2.460	2.460	2.461	-	147.1	145.8	140.6
	2		5.0,5.2		2.460	2.463		2.467	148.4	147.7	145.9
	3		5.6,4.9		2.454	2.442		2.463	148.5	148.6	146.1
	4		5.7,5.6,5.6		2.442	2.438		2.458	148.5	148.5	138.4
	5		5.3,5.3,5.1		2.456	2.452	2.455	2.452	148.7	144.5	143.7
	6		4.7,5.3		2.463	2.474		2.465	146.5	145.3	145.5
	7		5.3,5.3		2.452	2.452		2.463	148.1	145.8	150.8
	8		5.3,5.3		2.452	2.452		2.461	147.7	148.4	148.5
	9		5.3,5.3,5.1		2.456	2.452		2.432	146.3	149.2	144.1
	10		5.0		2.463	2.463		2.450	148.1	-	143.2
	11		5.4		2.449	2.449		2.469	150.3	-	-
	12		4.9,5.0		2.465	2.467		2.477	149.1	-	145.4
	13		5.3,5.3		2.452	2.452		2.464	149.8	-	147.9
	14		5.2,5.0,5.1		2.460	2.456		2.451	148.4	142.5	146.3
	15		5.3,5.2		2.454	2.452		2.486	150.4	148.6	144.7
	16		5.1,5.0		2.461	2.460		2.464	149.2	149.9	148.8
	17		5.1,5.3,5.2,5.4		2.454	2.460		2.462	147.5	148.2	146.1
	18		5.1,5.1,5.5,5.2		2.456	2.460		2.469	148.1	147.0	152.3
	19		5.5,5.0,5.3		2.454	2.445		2.470	148.5	148.9	151.4
	20		5.0,5.0,5.2		2.461	2.463		2.500	148.0	147.4	148.6
	21		5.2,5.3,5.3		2.454	2.456		2.469	146.8	147.8	149.5
	22		5.1,5.1,5.1		2.460	2.460		2.455	146.3	147.6	151.1
	23		5.3,5.4		2.451	2.452		2.448	148.8	148.6	144.6
	24		5.4,5.1		2.454	2.449		-	148.9	149.6	145.7
	25		5.3,5.0		2.458	2.452	2.454	2.452	145.9	147.6	141.3
	26		5.3,5.2,5.3		2.454	2.452		2.470	147.6	145.3	141.0
	27		5.1,5.4		2.454	2.460		2.444	146.6	146.5	146.5
	28		5.4,5.2		2.452	2.449		2.458	148.3	-	147.9
	29		5.2,5.3,5.4		2.452	2.456		2.453	148.6	146.4	147.9
	30		5.0,5.0		2.463	2.463		2.491	148.3	-	142.4
	31		5.2,5.0,5.2		2.458	2.456		2.452	148.1	148.3	147.4
	32		5.1,5.3		2.456	2.460		2.467	148.5	149.6	146.2
2	33	5.2	5.0,5.0,5.2	2.460*	2.465	2.467		2.465	149.0	149.3	142.1
	34		5.1,5.0		2.465	2.463		2.470	149.3	146.8	141.4
	35		5.3,5.0,5.2		2.462	2.456		2.448	149.8	149.3	139.7
	36		5.1,5.3,5.2		2.460	2.463		2.447	148.2	148.4	140.9
	37		5.1,5.3		2.460	2.463		2.498	149.1	147.5	144.9
	38		5.3,5.1,5.0		2.462	2.456		2.476	149.4	-	141.0
	39		5.1,5.1,5.2		2.462	2.463		2.453	148.1	148.7	140.2

* change in asphalt ** calculated at Center for Transportation Research

TABLE A-12. (Continued)

DIST 17, IH 45, TYPE B MIXTURE, ITEM 340, PROJECT A

Design No.	Working Day	Design Asphalt Content, %	Extracted Asphalt Content, %	G_T Design	G_T Day	G_T Extra.	G_R Job	G_R Day**	Lab Density, pcf	Core Density, pcf **	Nuclear Density, pcf
2	40	5.2	5.2	2.460*	2.460	2.460	2.454	2.469	148.6	149.9	142.4
	41		5.1,5.0,5.2		2.463	2.463		2.464	148.7	147.7	145.8
	42		5.1		2.463	2.463		2.477	148.9	148.3	144.4
	43		5.1,5.0		2.465	2.463		2.462	148.9	-	142.0
1	44	5.2	5.0	2.456*	2.463	2.463		2.464	150.2	149.1	139.8
	45		5.3		2.452	2.452		2.440	149.3	149.7	144.0
	46		5.1,5.3,5.3		2.454	2.460		2.446	149.9	149.6	141.2
	47		5.0,5.2		2.460	2.463		2.446	149.1	147.3	142.3
	48		5.4,5.2		2.452	2.449		2.441	149.5	146.1	142.2
	49		5.4		2.449	2.449		2.442	149.1	149.0	144.1
	50		5.4,5.2,5.1		2.454	2.449	2.475	2.444	149.1	150.3	144.0
2	51	5.2	5.1,5.0,5.2	2.460*	2.463	2.463	2.475	-	150.1	149.3	144.3
	52		5.3		2.456	2.456		2.437	148.5	148.5	142.5
	53		5.3,5.0		2.462	2.456		2.441	149.2	147.1	143.5
	54		5.1,5.0,5.5		2.460	2.463		2.419	149.1	148.7	139.6
	55		5.1,5.1,5.0		2.465	2.463		2.463	148.1	148.0	140.8
											138.9
	56		5.2,5.2,5.1		2.462	2.460		2.463	147.5	144.4	142.5
	57		5.1,5.2,5.0		2.463	2.463		2.439	149.6	145.7	143.3
	58		5.3,5.5		2.453	2.456		2.433	148.1	146.4	142.7
	59		5.1,5.3		2.460	2.463		2.440	145.8	146.4	141.5

* change in asphalt ** calculated at Center for Transportation Research

TABLE A-13. INDIVIDUAL ASPHALT CONTENTS AND DENSITIES FOR IH 45 TYPE C, DISTRICT 17, PROJECT B

DIST 17, IH 45, TYPE C MIXTURE, ITEM 340, PROJECT B

Design No.	Working Day	Design Asphalt Content, %	Extracted Asphalt Content, %	G_T Design	G_T Day	G_T Extra.	G_R Job	Lab Density, pcf	Core Density, pcf	Nuclear Density, pcf
1	1	5.2	5.0,5.4,5.6	2.454	2.451	2.462	2.443	149.6		
	2	5.2	4.9,4.9,5.3		2.462	2.465		148.1	146.6	141.1
	3	5.2	4.9,4.8,5.4,5.1		2.460	2.465		148.6		
	4	5.2	5.1,4.9		2.462	2.458		149.9		
2	5	4.9	5.1,5.3,5.4	2.465	2.451	2.458	2.443	149.5		
	6	4.9								
	7	4.9	5.0,4.6,4.7		2.469	2.462		149.4	150.8	134.9
	8	4.9	4.7,5.0		2.467	2.473		148.9		
	9	4.9	4.7,4.9,4.6		2.473	2.473		148.5		
	10	4.9								
	11	4.9	4.8,4.6		2.473	2.469		148.6		
	12	4.9	4.7,4.6,4.9		2.473	2.473		148.9		
	13	4.9	4.7,5.1		2.465	2.473		148.8		
	14	4.9	4.6,4.4,5.2		2.473	2.476		148.2		
	15	4.9	4.6,4.7,4.7		2.473	2.476		148.2		
	16	4.9	4.6,4.2,4.5		2.484	2.476		147.9		
	17	4.9	4.8,4.8,4.5		2.473	2.469		148.6		
	18	4.9	4.6,4.9		2.471	2.476		148.8		
	19	4.9	4.9		2.465	2.465		147.6		
	20	4.9	5.0		2.462	2.462		147.9		
	21	4.9	5.0		2.462	2.462		147.6		
	22	4.9	4.9		2.465	2.465		147.4		
	23	4.9								
	24	4.9	5.5,4.6,4.6		2.465	2.443		149.7		
	25	4.9	5.2,4.6,4.7		2.469	2.454		148.8		
	26	4.9	5.0,5.0,4.6		2.465	2.462		148.8		
	27	4.9	5.0,4.9,4.9		2.465	2.462		147.9		
	28	4.9	5.0,4.8,4.9		2.465	2.462		148.8		
	29	4.9	4.9,4.7,5.4		2.462	2.465		147.9		
	30	4.9	5.0,5.0,4.9		2.462	2.462		147.8		
	31	4.9	4.9,4.8,5.1		2.465	2.465		148.4		
	32	4.9	4.6,4.7,4.8,4.9		2.471	2.476		145.6		
	33	4.9	4.8		2.469	2.469		148.2		
	34	4.9	5.0,4.9		2.463	2.462		148.4		
3	35	4.2	4.5,4.0,4.2	2.491	2.491	2.480	2.443	148.0		
	36	4.2	4.0,3.7,3.9		2.502	2.499		147.6	147.1	141.3
									146.7	142.8
	37	4.2	4.1,4.2		2.493	2.495		145.9		
	38	4.2	4.2,4.4		2.487	2.491		147.0		
4	39	4.4	4.7,4.6,4.9	2.484	2.473	2.473	2.459	148.6		

TABLE A-13. (Continued)

DIST 17, IH 45, TYPE C MIXTURE, ITEM 340, PROJECT B

Design No.	Working Day	Design Asphalt Content, %	Extracted Asphalt Content, %	G_T Design	G_T Day	G_T Extra.	G_R Job	Lab Density, pcf	Core Density, pcf	Nuclear Density, pcf
5	40	4.6	4.6,4.5	2.476	2.478	2.476	2.443	147.4		
	41	4.6	4.4,4.2,4.3		2.487	2.484		147.1		
	42	4.6							145.9	136.6
	43	4.6	5.0,4.9,4.9		2.465	2.462		147.5		
	44	4.6								
	45									
	46	4.6	4.6,4.7		2.474	2.476		145.4		
	47	4.6	4.5,4.1,4.5		2.484	2.480		145.5		
	48	4.6	4.6,4.5,4.6		2.476	2.476		145.9	144.9	136.2
6	49	4.6	4.4,4.2	2.476	2.487	2.484	2.459	146.7		
7	50	4.8	4.9,4.5,5.2	2.469	2.465	2.465	2.459	148.4		
	51	4.8	4.9,4.9,4.6		2.469	2.465		145.7		
	52	4.8	4.9,4.8,4.7		2.469	2.465		147.0		
	53	4.8	4.9,4.9		2.465	2.465		147.5	147.3	142.8
	54	4.8	4.5		2.480	2.480		147.0		
	55	4.8	4.6,4.8		2.473	2.476		149.6		
	56	4.8	4.8		2.469	2.469		148.1		
	57	4.8	4.6,4.7,4.7		2.473	2.476		148.4	145.3	141.3
	58	4.8	4.5,4.6		2.478	2.480		147.5	146.6	143.9
	59	4.8	4.8,5.1,4.6		2.469	2.469		148.0	146.9	140.3
	60	4.8	4.6		2.476	2.476		148.3		
	61	4.8	4.8,5.0		2.465	2.469		148.6		
	62	4.8	4.7,4.9,4.8		2.469	2.473		146.3		
	63	4.8	4.7,4.3,4.8		2.476	2.473		148.0		
	64	4.8	5.2		2.454	2.454		146.6		
	65	4.8	5.0,5.2		2.458	2.462		146.6		
	66	4.8	4.9,4.7		2.469	2.465		148.4		
	67	4.8	4.6,4.9		2.471	2.476		146.5		
	68	4.8								
	69	4.8	4.9,5.2,5.2		2.458	2.465		147.6	146.6	139.9
									147.7	153.3
	70	4.8	4.9,4.4,5.2		2.469	2.465		148.4		
	71	4.8	5.1,5.0		2.460	2.458		148.8	147.5	
									148.6	148.8
	72	4.8	4.6		2.476	2.476		147.0		
	73	4.8	4.9,5.3,4.7		2.462	2.465		148.6		
	74	4.8	4.9,5.1,4.7		2.465	2.465		148.0	145.3	140.3
8	75	4.6	4.8,4.8	2.476	2.469	2.469	2.443	147.5		
	76	4.6	4.8,4.2,4.4		2.480	2.469		146.8		
	77	4.6	4.6		2.476	2.476		147.0		
	78	4.6	4.6,4.5,4.6		2.476	2.476		145.0		

TABLE A-13. (Continued)

DIST 17, IH 45, TYPE C MIXTURE, ITEM 340, PROJECT B

Design No.	Working Day	Design Asphalt Content, %	Extracted Asphalt Content, %	G_T Design	G_T Day	G_T Extra.	G_R Job	Lab Density, pcf	Core Density, pcf	Nuclear Density, pcf
8	79	4.6	4.6,4.6,5.1	2.476	2.469	2.476	2.443	148.1		
	80	4.6	4.8,4.5		2.474	2.469		148.1		
9	81	4.6	4.9,4.9	2.476	2.465	2.465	2.443	147.2		
	82	4.6	4.5,4.6		2.478	2.480		148.1	147.0	153.5
	83	4.6	4.2,4.5		2.489	2.491		147.1	141.5	136.3
	84	4.6	4.7,4.4		2.478	2.473		148.1	145.9	140.8
									145.9	138.6
	85	4.6	4.7,4.8		2.471	2.473		147.5		
	86	4.6	4.9,4.5		2.473	2.465		145.8		
	87	4.6	5.1,4.6		2.467	2.458		148.6	146.9	149.4
	88	4.6	4.2,4.9		2.478	2.491		144.5		
	89	4.6	4.4,4.5		2.482	2.484		147.1		
	90	4.6	4.5,5.0,4.4		2.476	2.480		146.3	146.8	141.8
	91	4.6	4.6,4.2,4.2		2.487	2.476		146.9		
	92	4.6	4.5,4.4		2.482	2.480		147.5		
	93	4.6	4.7,4.2		2.482	2.473		146.5	145.9	
	94	4.6	4.3,4.2		2.489	2.487		147.1		
	95	4.6						-		
	96	4.6	4.4		2.484	2.484		146.9		
	97	4.6	4.6		2.476	2.476		147.6		
	98	4.6	4.3		2.487	2.487		148.3		
	99	4.6	4.8,4.7		2.471	2.469		146.9		
	100	4.6	4.5,4.5		2.480	2.480		146.1		
	101	4.6	4.9,4.2,4.6		2.476	2.465		146.3		
	102	4.6	4.6		2.476	2.476		146.9		
	103	4.6	4.8		2.469	2.469		147.0		
	104	4.6	4.6		2.476	2.476		-		

TABLE A-14. INDIVIDUAL ASPHALT CONTENTS AND DENSITIES FOR IH 45 TYPE D, DISTRICT 17, PROJECT B

DIST 17, IH 45, TYPE D MIXTURE, ITEM 340, PROJECT B

Design No.	Working Day	Design Asphalt Content, %	Extracted Asphalt Content, %	C_T Design	C_T Day	C_T Extra.	C_R Job	Lab Density, pcf	Core Density, pcf	Nuclear Density, pcf
1	1	5.2	5.4	2.456	2.449	2.449	2.459	-	-	-
2	2	5.4	5.7,5.7,5.2	2.449	2.445	2.438	2.459	147.9	137.0	137.6
3	3	5.8	5.8,5.7,5.6	2.434	2.438	2.434	2.459	147.5	145.0	143.9
									138.5	140.0
									146.5	144.4
	4	5.8								
	5	5.8	5.8		2.434	2.434		147.2		
	6	5.8	5.9		2.431	2.431		147.1		
4	7	6.0	5.7,5.8	2.427	2.436	2.438	2.439	147.2		
	8	6.0	6.0,5.9		2.429	2.427		147.1		
	9	6.0	5.9,6.0		2.429	2.431		147.6		
	10	6.0	5.8,5.9		2.432	2.434		146.6	134.0	135.1
	11	6.0	5.9,5.8		2.432	2.431		147.8	150.0	146.3
									137.0	139.4
	12	6.0	6.1,5.8		2.429	2.424		147.8	136.0	138.0
										152.7
	13	6.0	5.9,5.7		2.434	2.431		147.2		
	14	6.0	5.8,6.0,6.1		2.427	2.434		147.9		
	15	6.0	5.9		2.431	2.431		148.0		
	16	6.0	6.1,6.2		2.422	2.424		147.5		
	17	6.0	6.0,6.2,6.0		2.424	2.427		147.6		
	18	6.0	6.0,5.9		2.429	2.427		146.5		
	19	6.0	5.8,5.6,5.8		2.438	2.434		148.6		
	20	6.0	5.7,6.0,5.8		2.434	2.438		148.0		
5	21	5.8	5.8,6.0	2.434	2.431	2.434	2.439	148.3		
6	22	5.5	5.6,5.5	2.445	2.443	2.441	2.439	147.1		
	23	5.5	5.7		2.438	2.438		147.6		
	24	5.5	5.4,5.4		2.449	2.449		147.0		135.1
	25	5.5	5.6		2.441	2.441		148.4		
7	26	5.7	5.8	2.438	2.434	2.434	2.439	148.0		

TABLE A-15. INDIVIDUAL ASPHALT CONTENTS AND DENSITIES FOR IH-10 TYPE D, DISTRICT 20

DIST 20, IH-10, TYPE D MIXTURE, ITEM 340

Design No.	Working Day	Design Asphalt Content, %	Extracted Asphalt Content, %	G_T Design	G_T Day	G_T Extra.	Lab Density, pcf	Core Density, pcf	Nuclear Density, pcf
1	1	5.3	5.5,5.6	2.340	2.332	2.334	141.5	138.0	135.2
	2		5.4,6.0,5.3		2.331	2.337	141.8		
	3		5.4,5.4,5.5		2.337	2.337	142.9	136.6	132.4
	4		5.6,5.4,5.0		2.340	2.331	142.8		
	5		5.2,5.4,5.2		2.340	2.343	142.3		
	6		5.5,5.2,5.2		2.340	2.334	143.4	137.5	136.2
	7		5.2,5.4,5.0		2.343	2.343	142.8		
	8		5.5,5.1		2.340	2.334	142.0		
	9		5.3,5.3,5.4		2.340	2.340	143.0		
	10		5.2,6.1,5.3		1.334	2.343	142.7	136.2	130.5
	11		5.0,5.3,5.2		2.343	2.350	142.3		
	12		5.5,5.1,5.1		2.343	2.334	142.8	133.7	130.6
	13		5.1,5.2		2.345	2.347	141.7		
	14		5.2		2.343	2.343	142.2		
	15		5.2,5.0		2.347	2.343	142.3		
	16		5.0,5.1,5.2		2.347	2.350	143.3		
	17		5.1,5.0,4.9		2.350	2.347	142.5		
	18		4.9,4.9		2.353	2.353	141.9		
	19		5.1,5.0,5.1		2.347	2.347	143.3		

TABLE A-15. (Continued)

DIST 20, IH-10, TYPE D MIXTURE, ITEM 340

Design No.	Working Day	Design Asphalt Content, %	Extracted Asphalt Content, %	G_T Design	G_T Day	G_T Extra.	Lab Density, pcf	Core Density, pcf	Nuclear Density, pcf
1	20	5.3	5.0	2.340	2.350	2.350	142.1		
	21		5.0,5.1,5.3		2.347	2.350	141.5		
	22		5.4,5.1,5.1		2.343	2.337	142.2		
	23		4.9		2.353	2.353	140.3		
	24		5.1,5.1		2.347	2.347	141.5		
	25		5.1,5.0		2.348	2.347	141.9		
	26		5.5,5.2		2.339	2.334	142.6		
	27		5.2,5.2		2.343	2.343	140.8		
	28		5.3,5.4		2.339	2.340	140.5		
	29		5.1,5.0		2.348	2.347	140.5		
	30		5.7,5.2		2.335	2.328	140.3		

TABLE A-16. INDIVIDUAL ASPHALT CONTENTS AND DENSITIES FOR IH 10 TYPE G, DISTRICT 20

DIST 20, IH 10, TYPE G MIXTURE, ITEM 340

Design No.	Working Day	Design Asphalt Content,* %	Extracted Asphalt Content,* %	G_T Design	G_T Day	G_T Extra.	G_R Job	G_R Day	Lab Density, pcf	Core Density, pcf	Nuclear Density, pcf
1	1	5.5	5.6,5.7	2.303	2.298	2.300	2.369	2.369	140.0	132.2	126.7
						-	-			-	127.9
	2	5.5	5.0,5.3,5.8		2.306	2.318		-	138.8	-	127.9
					-	-	-	-	-	-	131.0
	3	5.5	5.7,5.3,5.6,6.2		2.297	2.297		-	141.2	-	-
2	4	5.3	4.6,4.9	2.312	2.329	2.334	2.379	-	142.5	-	129.5
	5	5.3	5.6,5.1,5.2		2.312	2.303		-	141.8	-	127.1
	6	5.3	5.3,4.8,5.9		2.312	2.312		2.379	142.2	135.7	128.1
					-	-		-	-	-	128.7
	7	5.3	4.7,5.7,5.7	2.309	2.306	2.327		2.379	141.0	138.6	128.5
						-				-	128.2
						-		2.378		140.4	135.4
	8	5.3	5.3,6.1,5.1		2.303	2.309		2.378	140.3	137.2	130.0
	9	5.3	4.8,4.9		2.323	2.324		2.381	139.0	140.2	134.9
						-		-		-	136.4
	10	5.3	5.4		2.306	2.306		-	141.0	-	125.3
	11	5.3	5.2,5.4,5.4		2.309	2.312		-	139.3	-	130.2
	12	5.3	5.0,5.1,5.3		2.315	2.318		-	138.8	-	131.5
	13	5.3	5.3,5.6,5.5		2.303	2.309		2.323	140.0	137.9	123.2
						-				-	125.6
						-		2.398		136.4	125.5
	14	5.3	5.3,5.2,5.4		2.309	2.309		2.398	139.4	137.8	128.9
						-				-	124.8
	15	5.3	5.8,4.7,5.8		2.306	2.294		-	140.7	-	-
	16	5.3	5.9,5.9,6.0		2.291	2.291		-	141.8	-	-
	17	5.3	5.4		2.306	2.306		-	141.7	-	-
	18	5.3	4.8,5.2,5.6,5.6		2.303	2.324		-	141.0	-	-
	19	5.3	4.8,5.0,4.9		2.321	2.324		-	140.6	-	-
	20	5.3	5.1,5.0,4.8		2.318	2.315		-	140.8	-	-
	21	5.3	5.2,6.3,5.2		2.300	2.312		-	141.8	-	-
	22	5.3	4.9		2.321	2.321		-	143.0	-	-
	23	5.3	4.6,6.0,5.1		2.312	2.330		-	141.8	-	-
	24	5.3	5.1,5.2,4.9		2.315	2.315		-	139.9	-	-
	25	5.3	5.0		2.318	2.318		-	142.6	-	-
	26	5.3	5.6,5.3,5.4		2.306	2.300		-	141.4	-	-
	27	5.3	5.6,5.1,5.2	2.316	2.316	2.307		-	140.0	-	-
	28	5.3	5.5	2.316	2.310	2.310		-	137.3	-	-

* Percent AC by weight of mixture

TABLE A-17. INDIVIDUAL ASPHALT CONTENTS AND DENSITIES FOR US 190, DISTRICT 23

DIST 23, US 190, TYPE D MIXTURE, ITEM 340

Design No.	Working Day	Design Asphalt Content, %	Extracted Asphalt Content, %	G_T Design	G_T Extra.	Lab Density, pcf	Core Density, pcf	Nuclear Density, pcf
1	1	5.0	4.8	2.497	2.505	152.0	143.5	140.4
							146.3	137.3
							141.0	137.3
	2	5.0	4.8		2.505	151.4	144.6	
							145.5	
	3	5.0	5.2		2.490	153.7	145.3	
	4	5.0	5.0		2.497	152.1	147.6	145.2
	5	5.0	5.1		2.493	152.6		
	6	5.0	5.1		2.493	152.7	147.2	139.1
							146.1	141.6
							146.5	138.5
							146.9	144.8
	7	5.0	5.0		2.497	152.1	145.7	140.4
							148.1	143.3
							146.8	147.6
	8	5.0	5.0		2.497	151.9		
	9	5.0	5.1		2.493	151.8		
	10	5.0	5.1		2.493	152.9	149.1	146.5
	11	5.0	5.0		2.497	152.4		
	12	5.0	5.1		2.493	152.1		
	13	5.0	5.2		2.490	152.4		
	14	5.0	5.0		2.497	152.5		
	15	5.0	5.1		2.493	152.9		
	16	5.0	5.2		2.490	152.1		
	17	5.0	5.1		2.493	151.7		
	18	5.0	5.0		2.497	151.9	146.1	
	19	5.0	5.1		2.493	152.8		
	20	5.0	5.1		2.493	151.6		

TABLE A-17. (Continued)

DIST 23, US 190, TYPE D MIXTURE, ITEM 340

Design No.	Working Day	Design Asphalt Content, %	Extracted Asphalt Content, %	G_T Design	G_T Extra.	Lab Density, pcf	Core Density, pcf	Nuclear Density, pcf
1	21	5.0	5.1	2.497	2.493	152.2		
	22	5.0	5.0		2.497	150.8		
	23	5.0	5.4		2.482	151.9		
	24	5.0	5.0		2.497	152.5		
	25	5.0	5.0		2.497	152.7		
	26	5.0	5.1		2.493	153.1		
	27	5.0	5.0		2.497	152.1		
	28	5.0	5.1		2.493	152.3		
	29	5.0	5.2		2.490	152.3		
	30	5.0	5.2		2.490	152.8		
	31	5.0	5.0		2.497	150.8		
	32	5.0	5.2		2.490	151.6		
	33	5.0	5.1		2.493	152.8		

APPENDIX B

VARIATIONS IN EXTRACTED ASPHALT CONTENTS

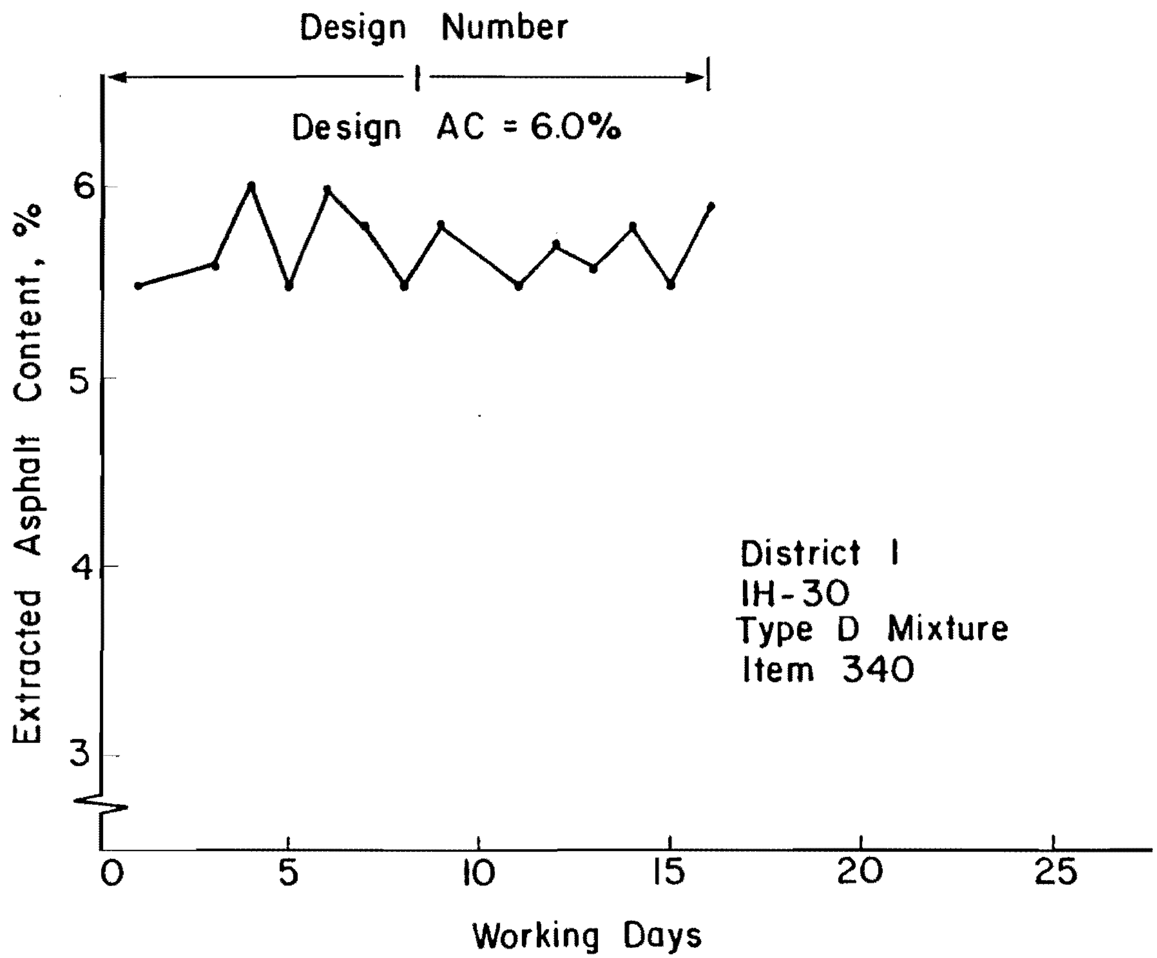


Figure B-1. Variation of extracted asphalt contents for project IH-30, District 1, Type D mixture

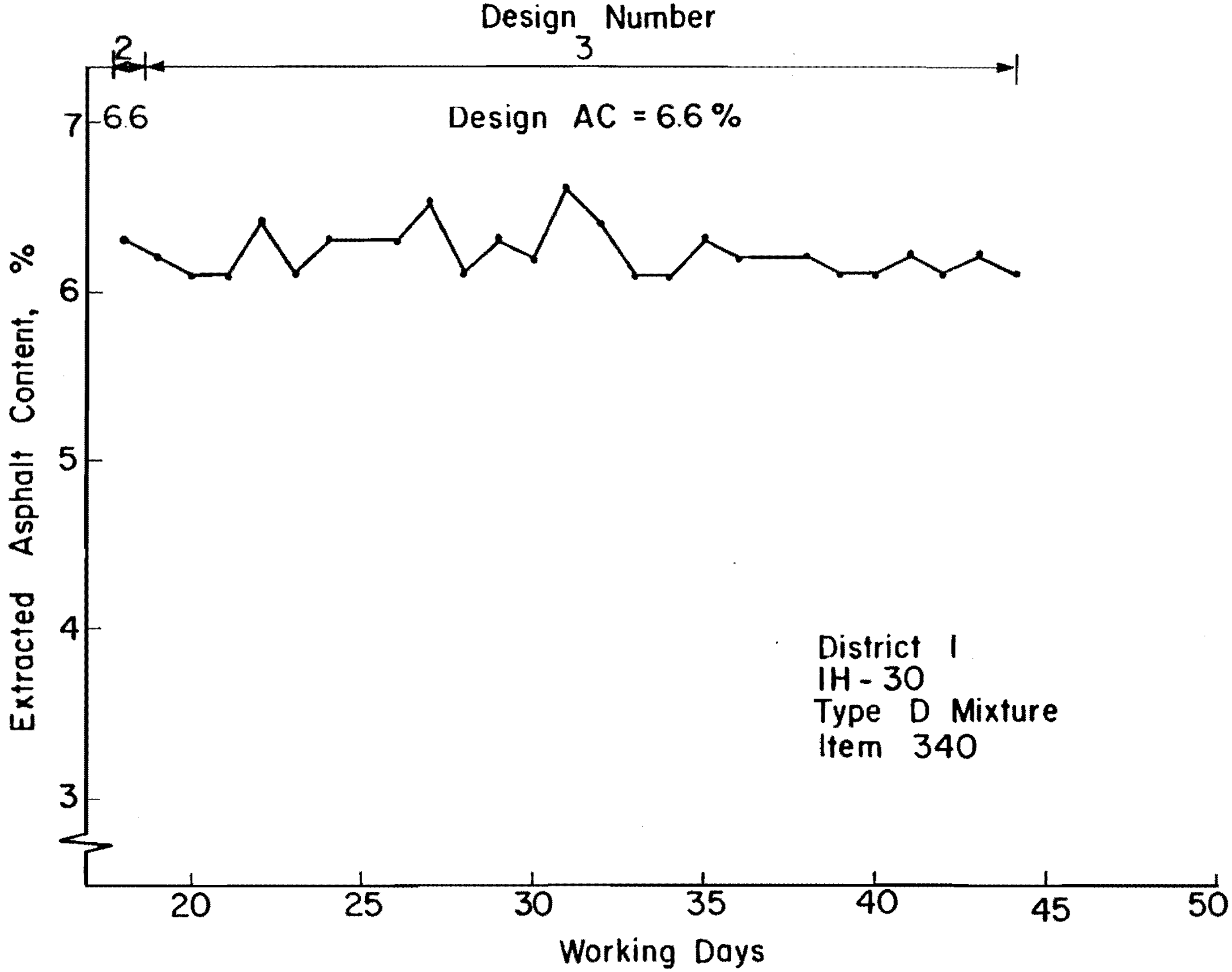


Figure B-1. (cont.) Variation of extracted asphalt contents for project IH-30, District 1, Type D mixture

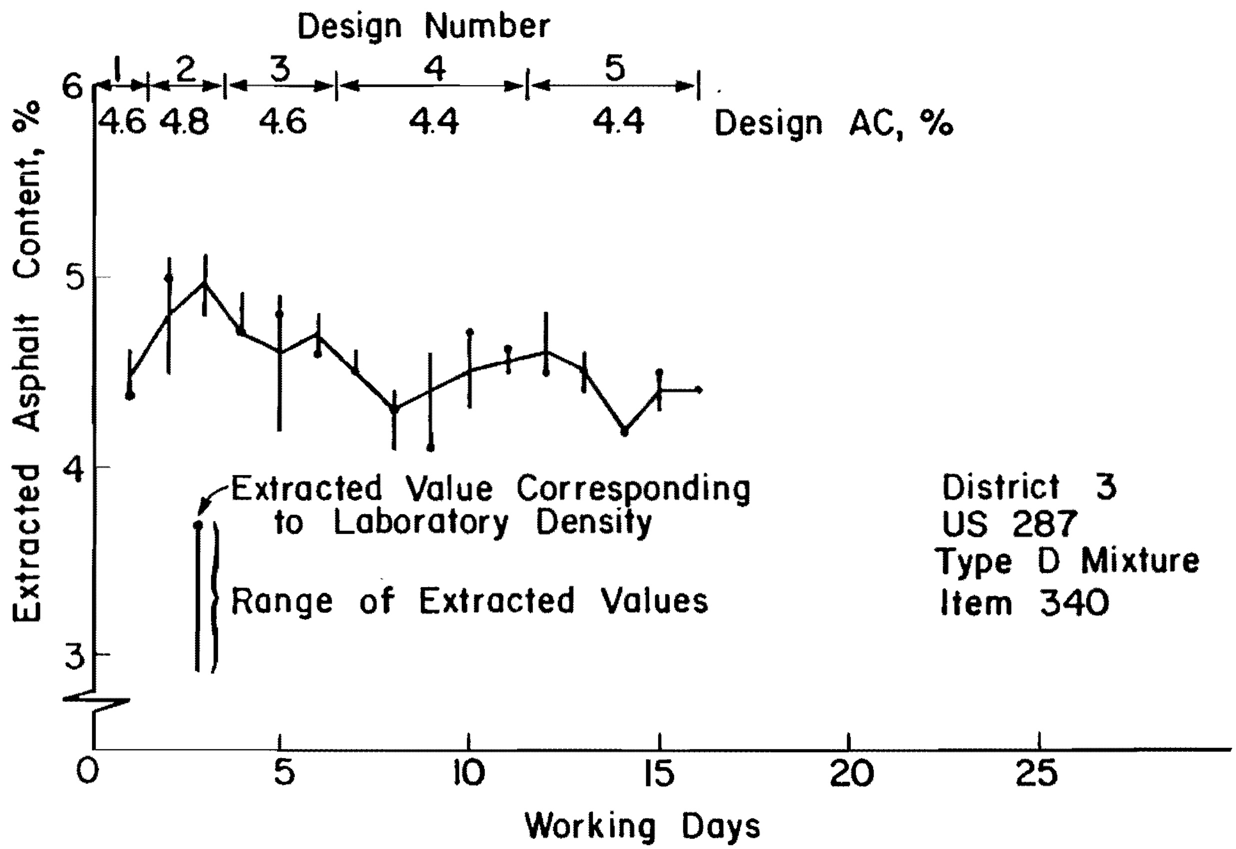


Figure B-2. Variation of extracted asphalt contents for project US 287, District 3, Type D mixture

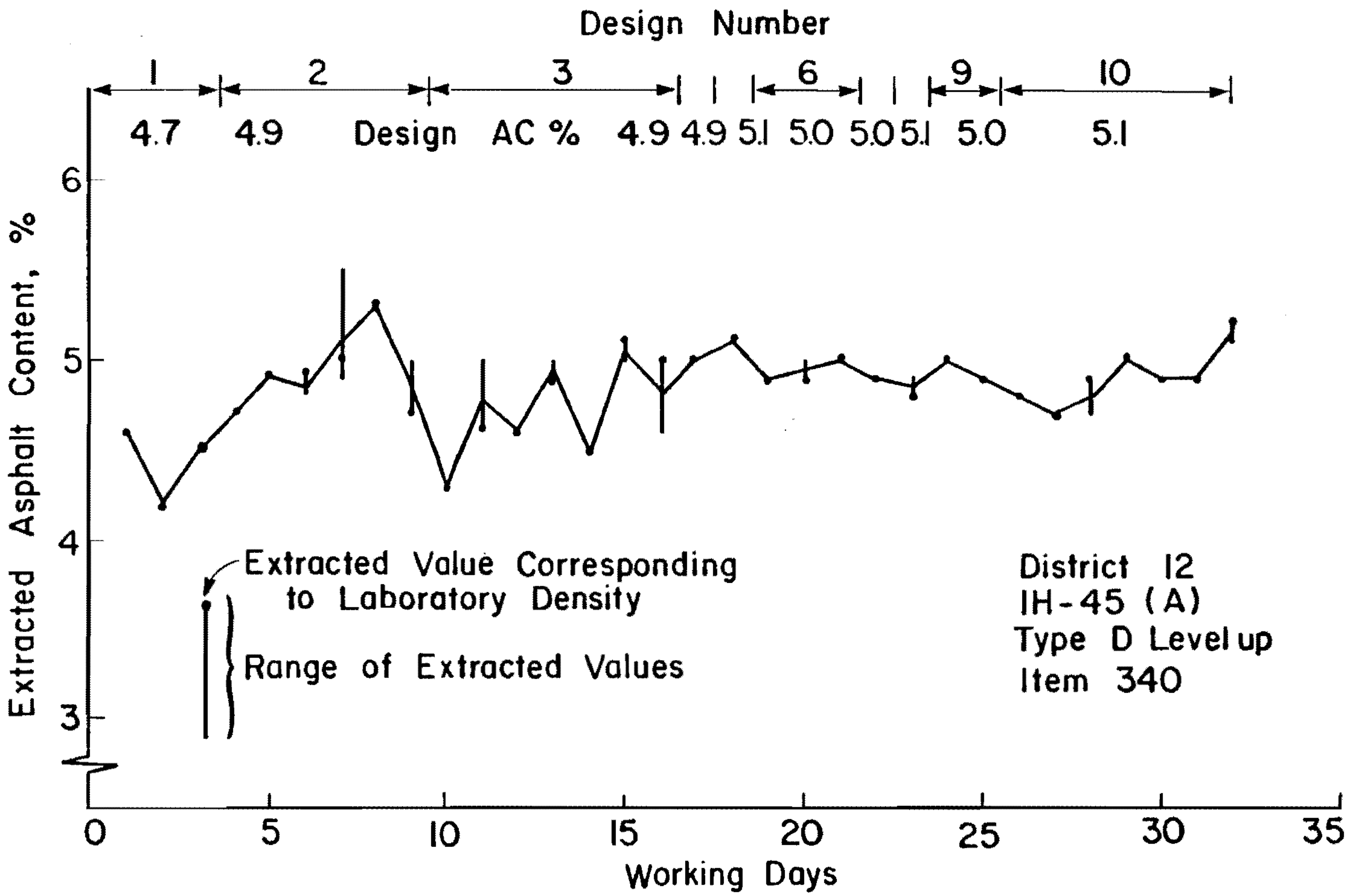


Figure B-3. Variation of extracted asphalt contents for project IH-45 (A), District 12, Type D Level up

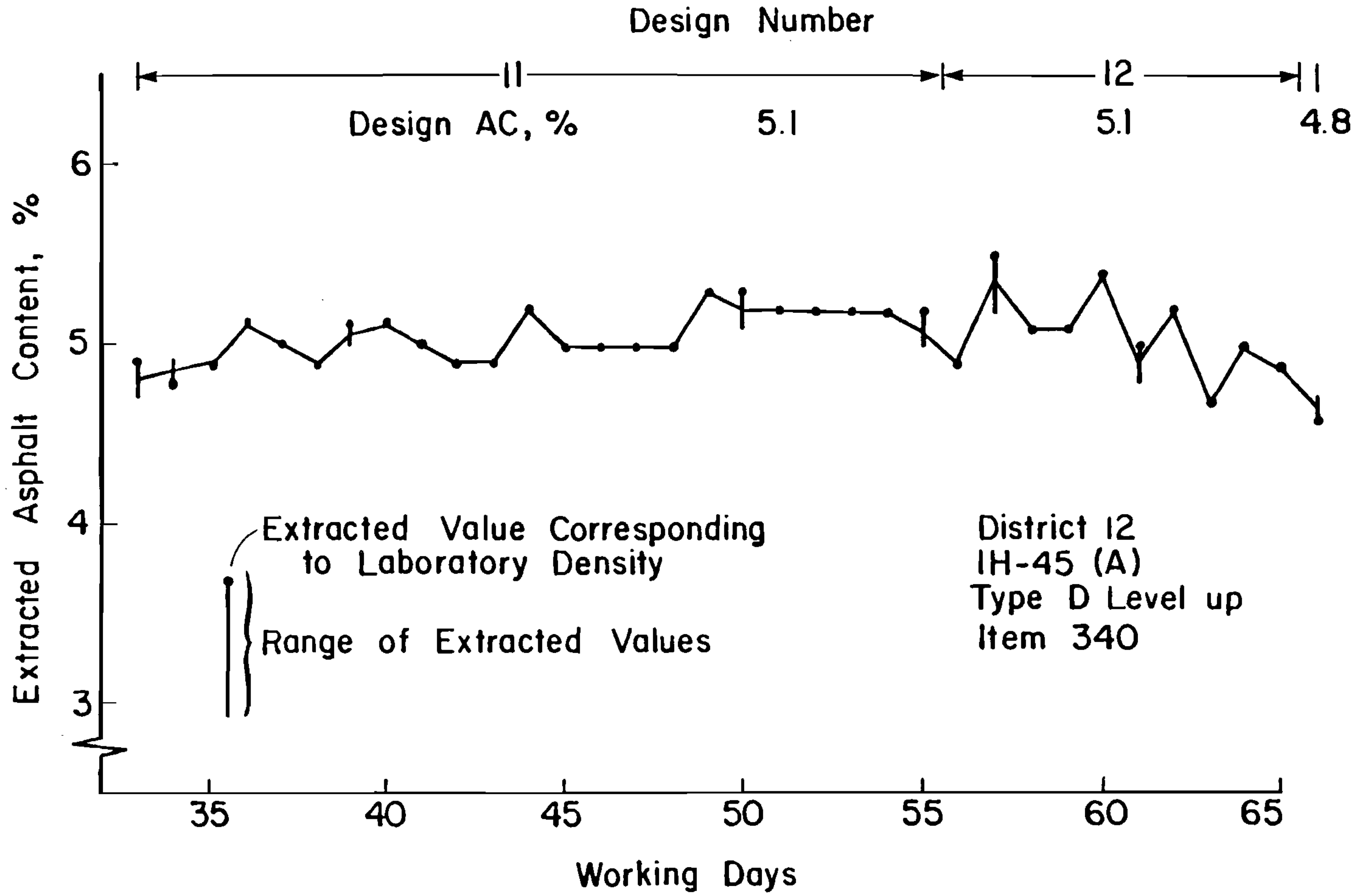


Figure B-3. (cont.) Variation of extracted asphalt contents for project IH-45 (A), District 12, Type D Level up

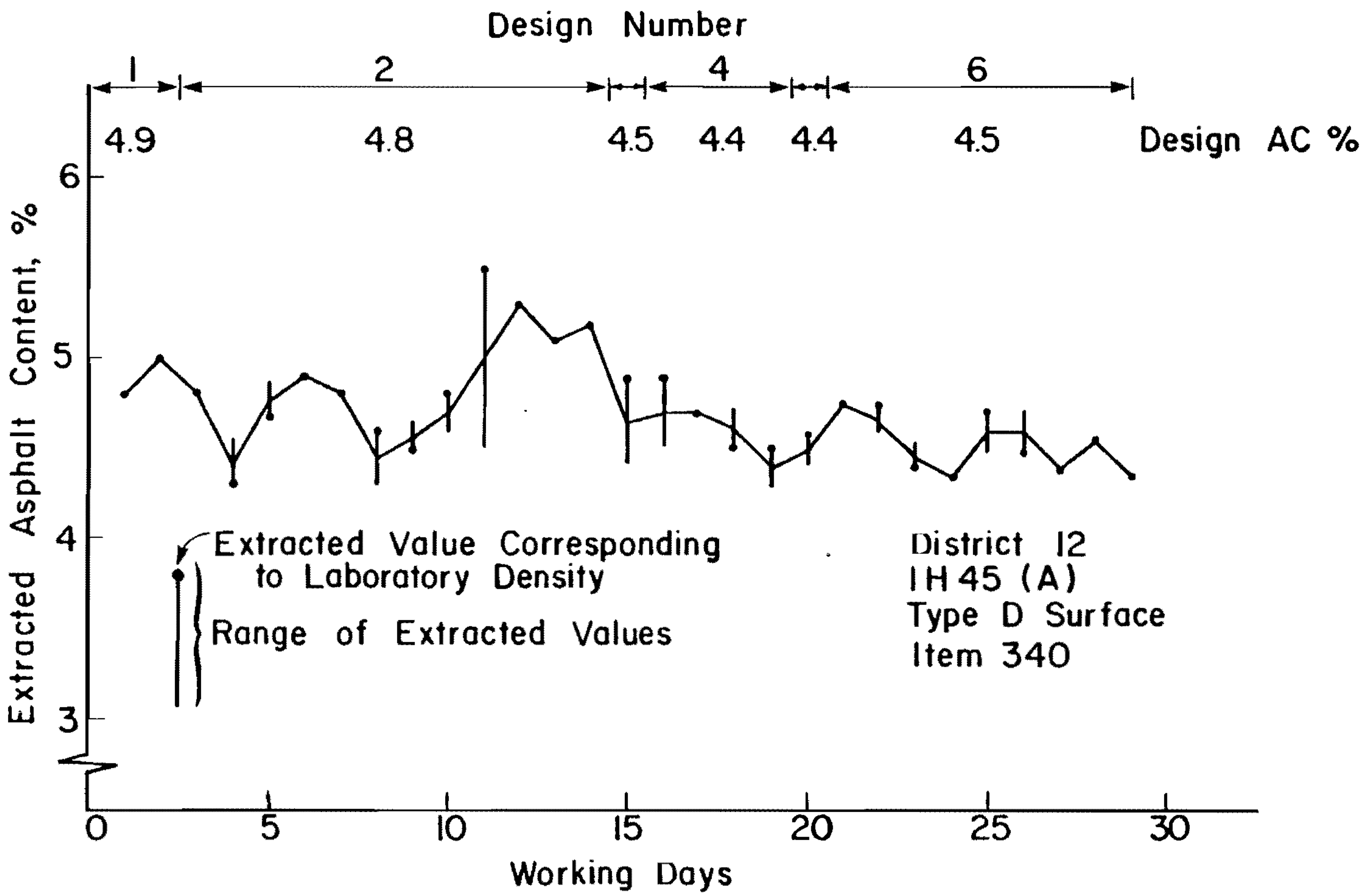


Figure B-4. Variation of extracted asphalt contents for project IH-45 (A), District 12, Type D Surface

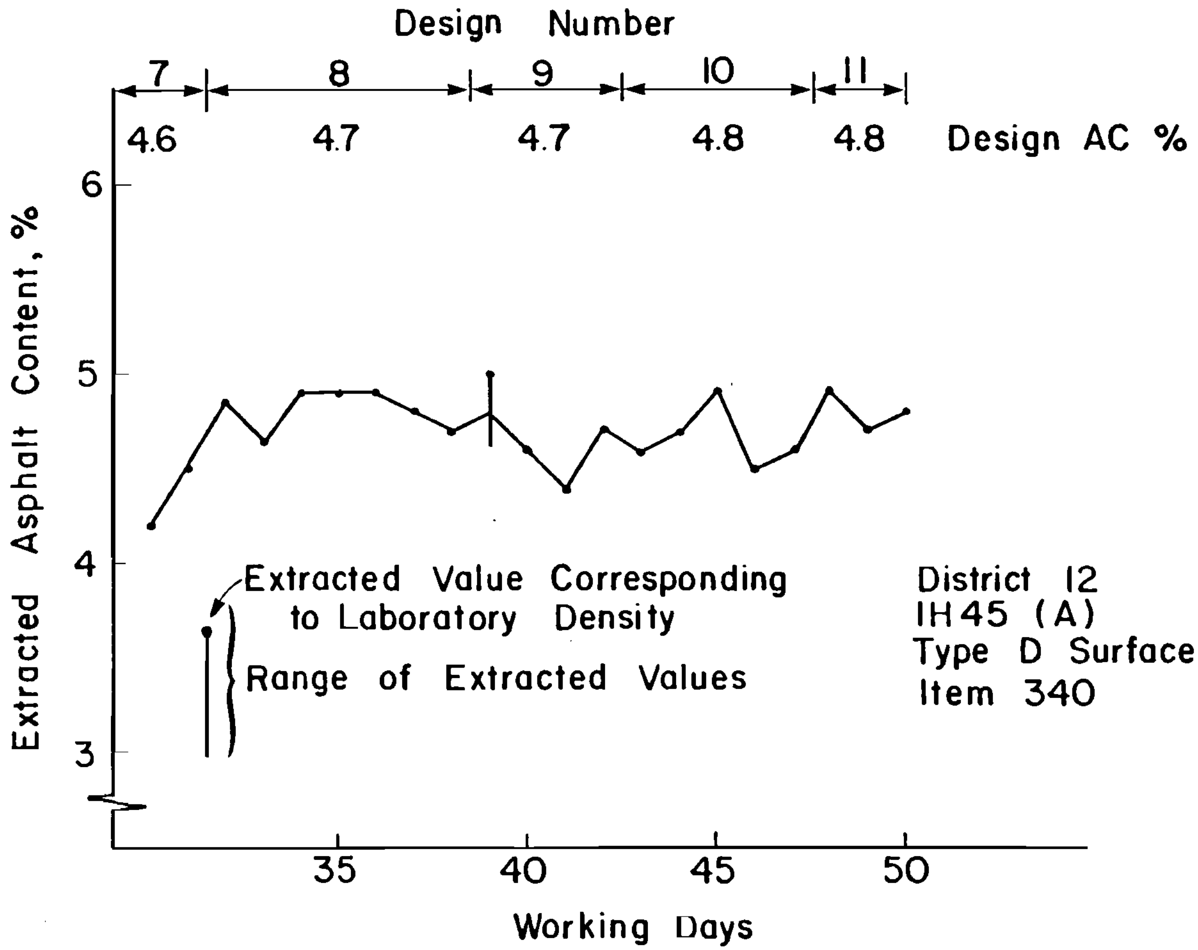


Figure B-4. (cont.) Variation of extracted asphalt contents for project IH-45 (A), District 12, Type D Surface

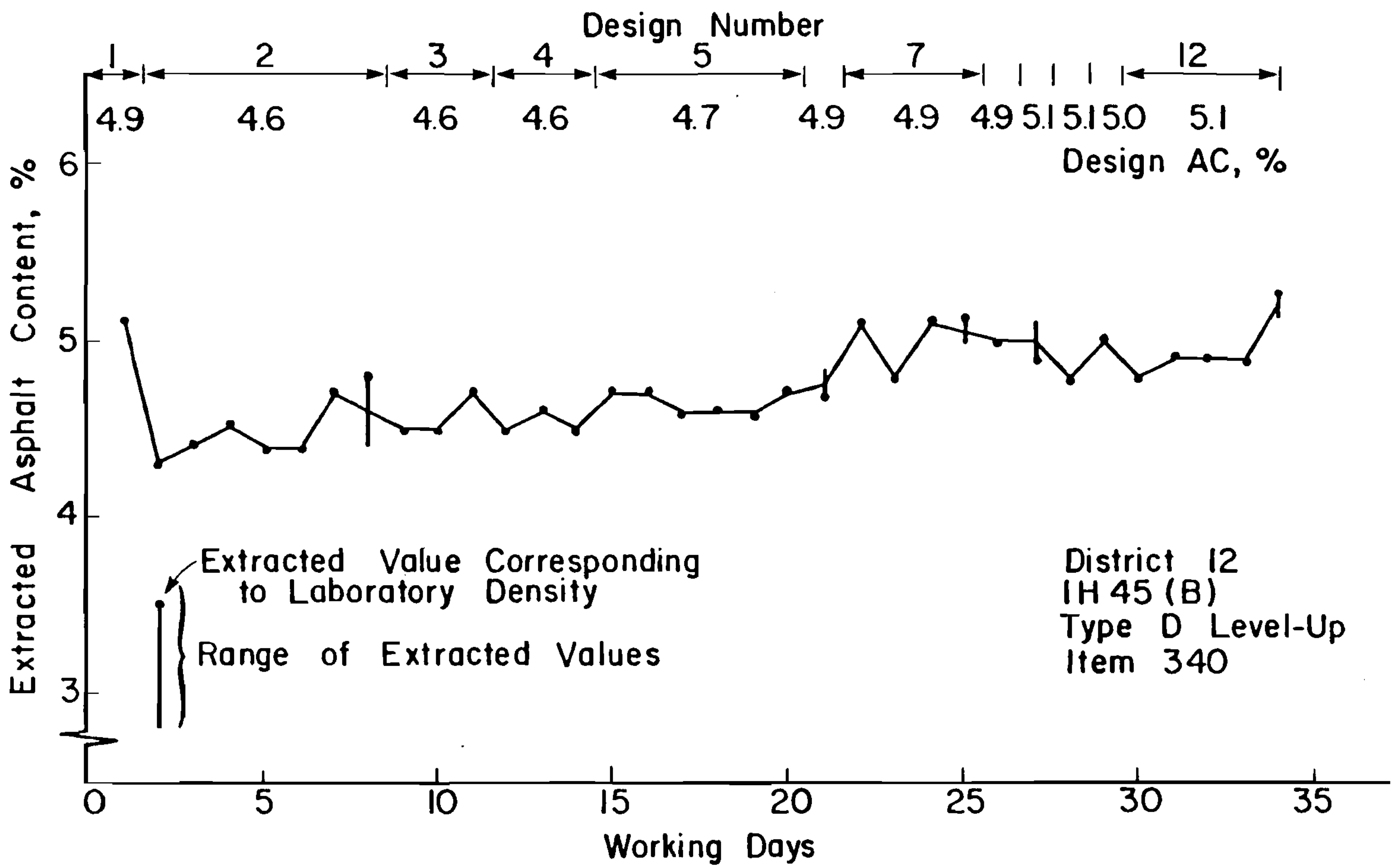


Figure B-5. Variation of extracted asphalt contents for project FM 290 (A), District 12, Type D Level-up

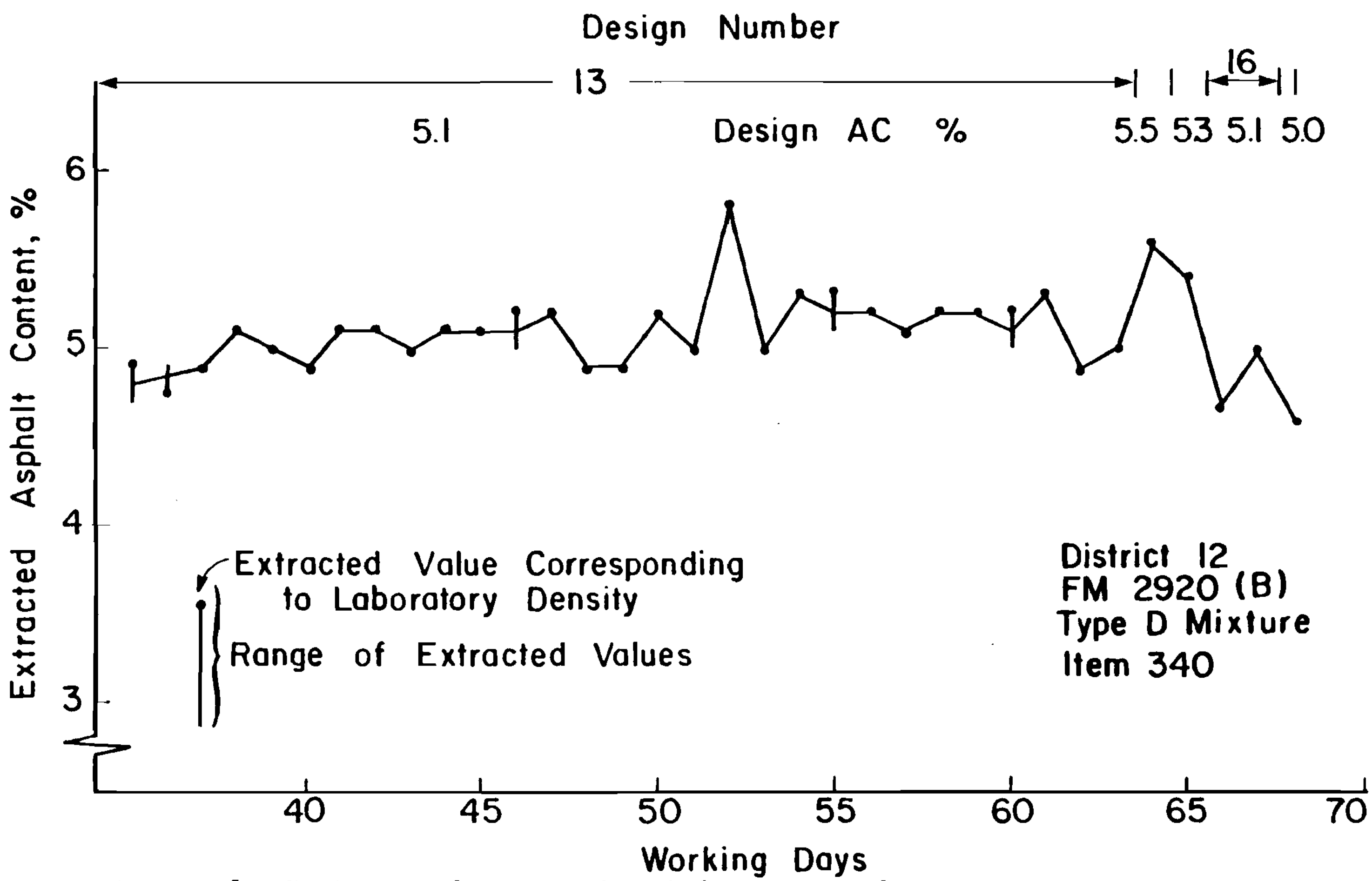


Figure B-5. (cont.) Variation of extracted asphalt contents for project FM 2920 (A), District 12, Type D Level-up

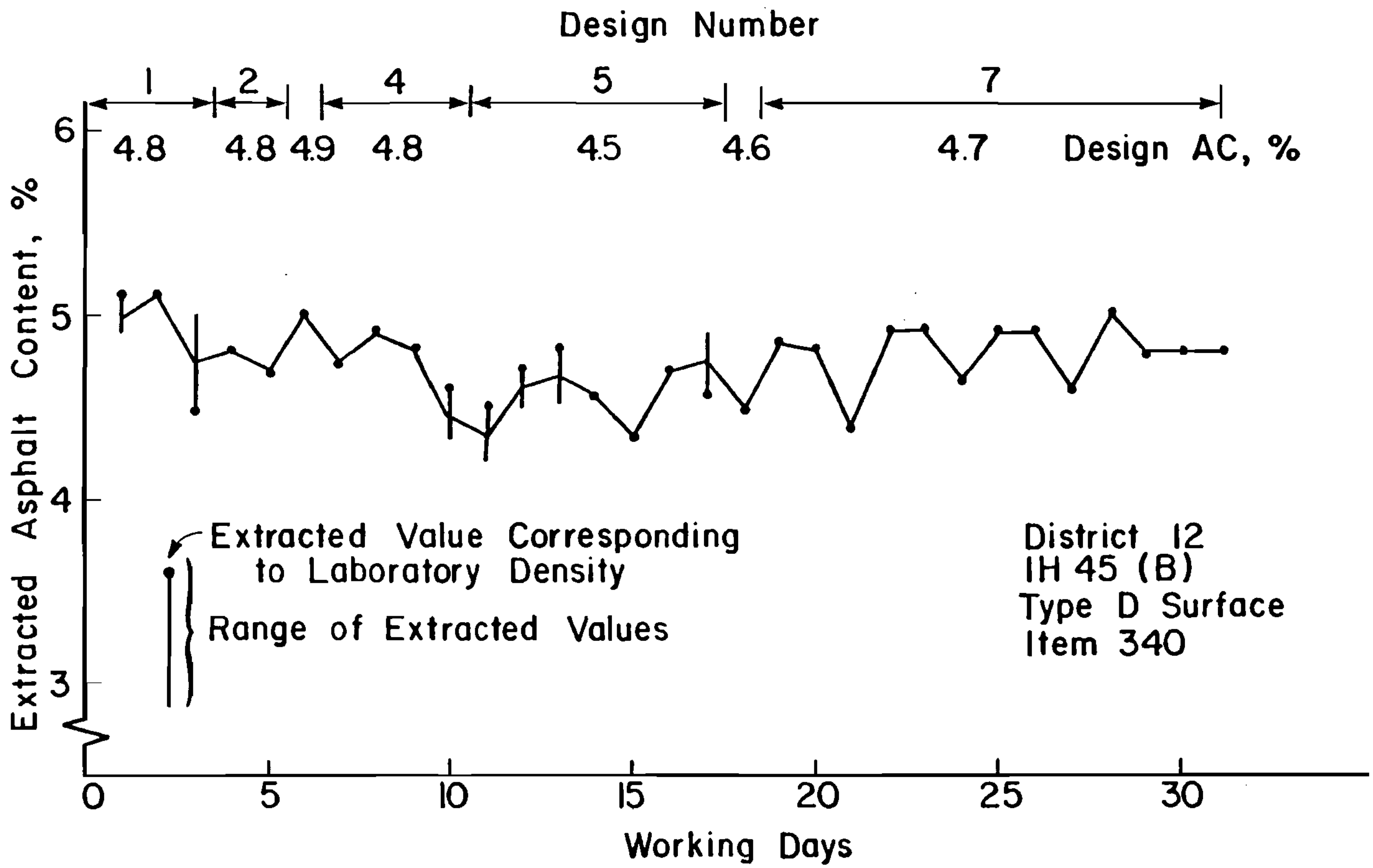


Figure B-6. Variation of extracted asphalt contents for project IH 45 (B), District 12, Type D surface

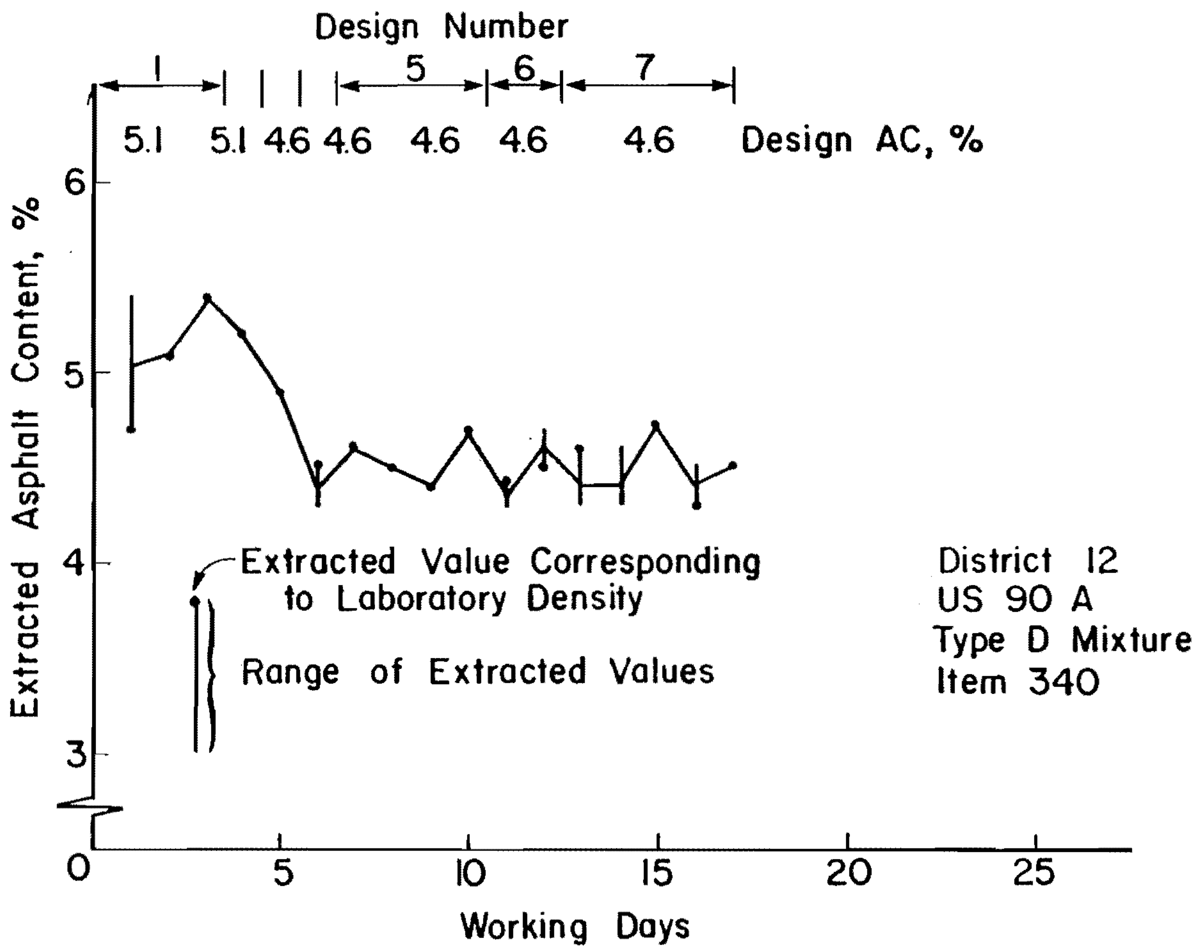


Figure B-7. Variation of extracted asphalt contents for project US 90 A, District 12, Type D mixture

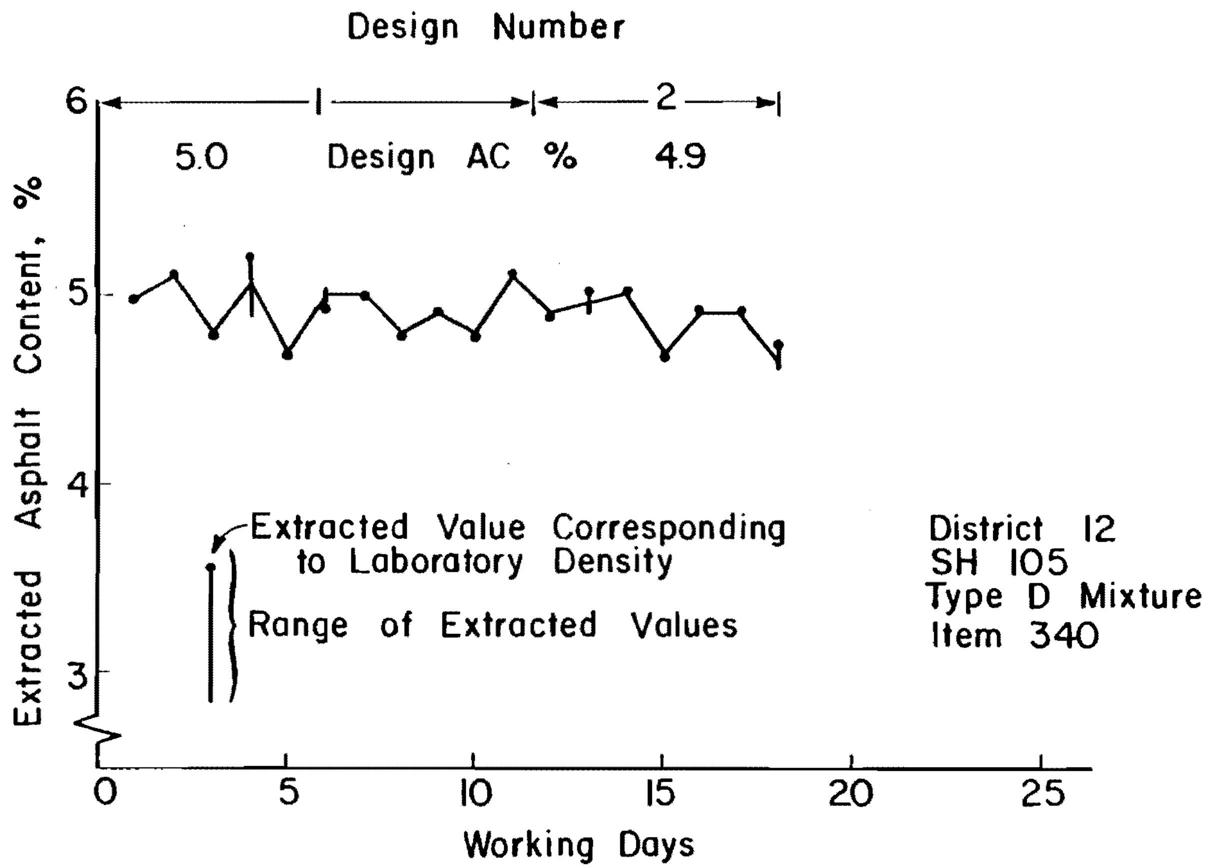


Figure B-8. Variation of extracted asphalt contents for project SH 105, District 12, Type D mixture

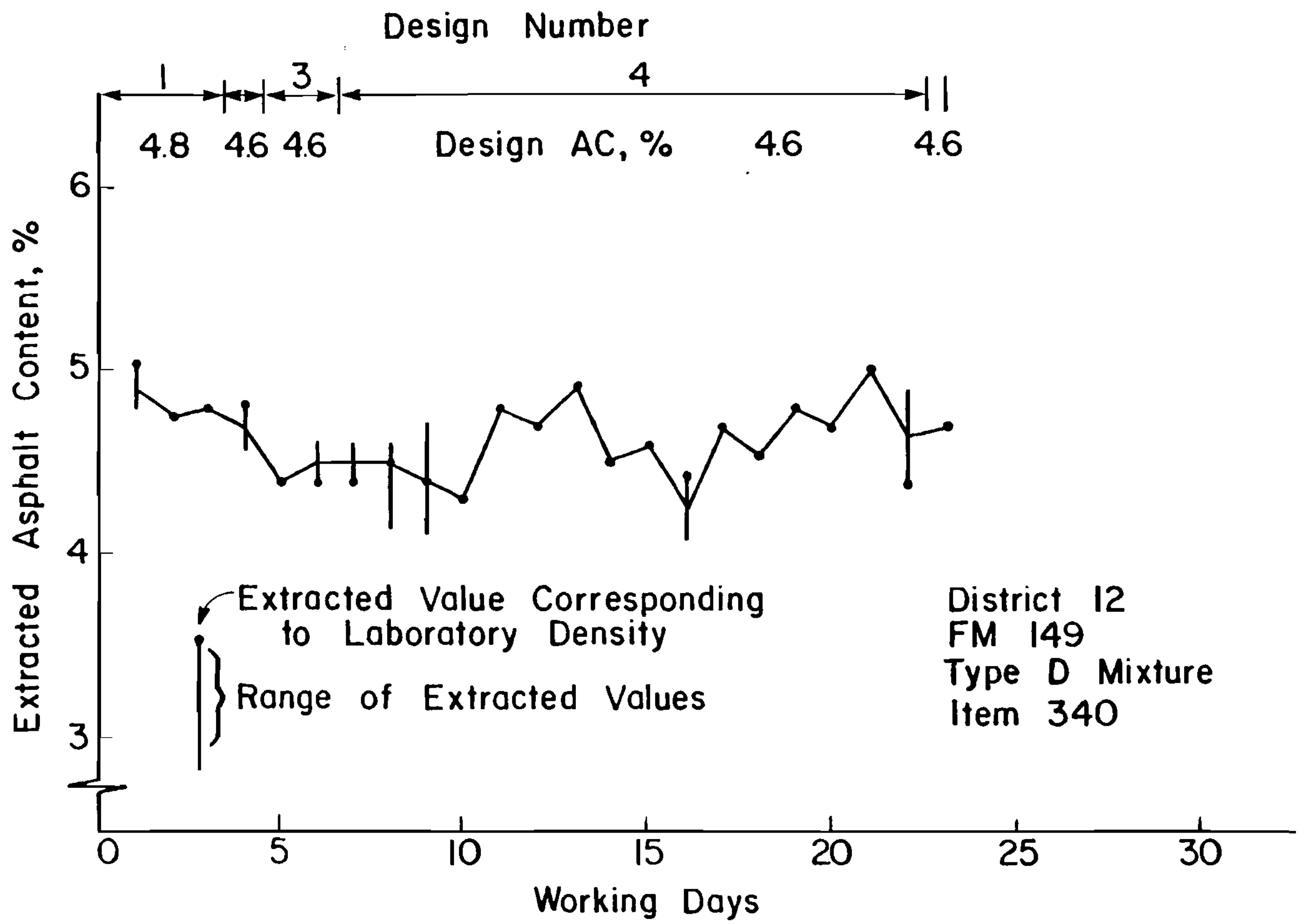


Figure B-9. Variation of extracted asphalt contents for project FM 149, District 12, Type D mixture

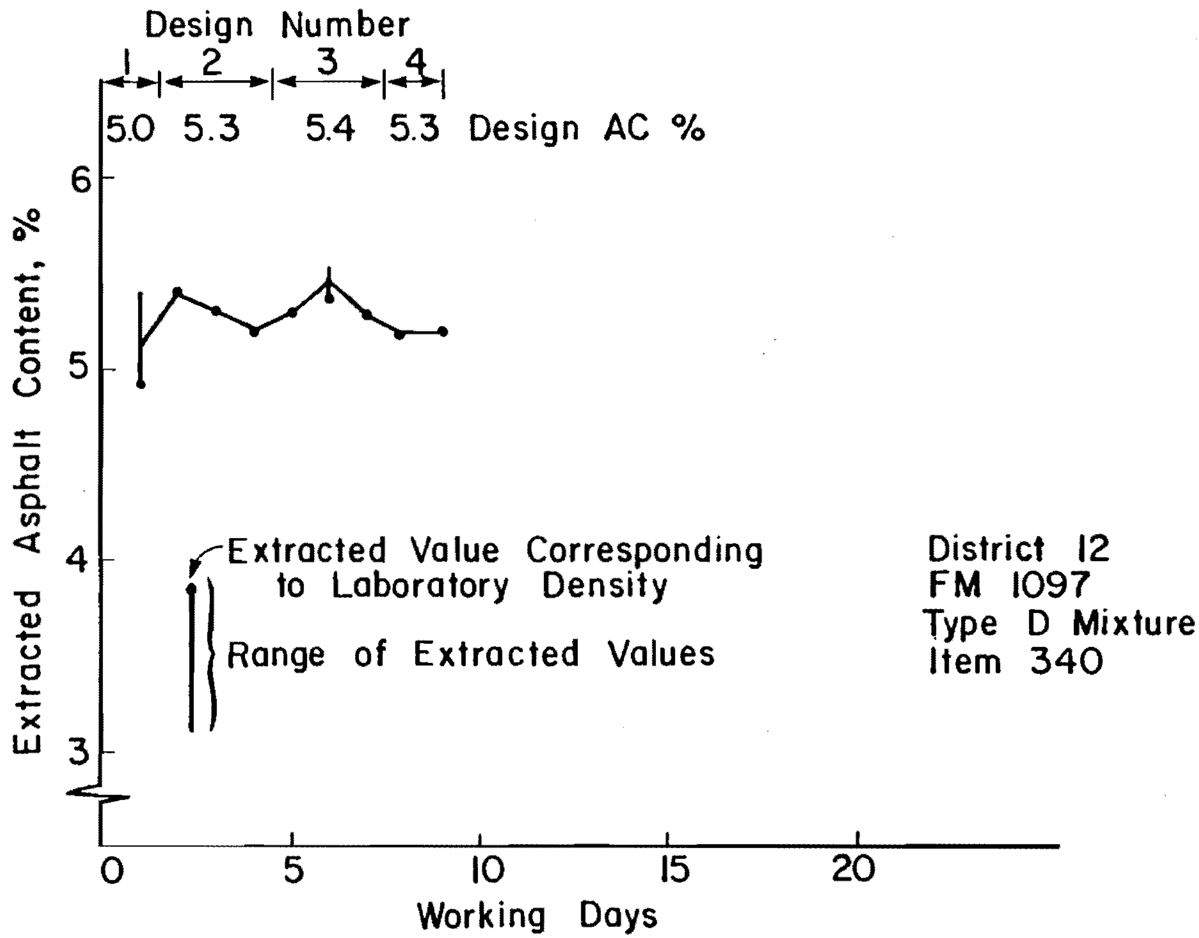


Figure B-10. Variation of extracted asphalt contents for project FM 1097, District 12, Type D mixture

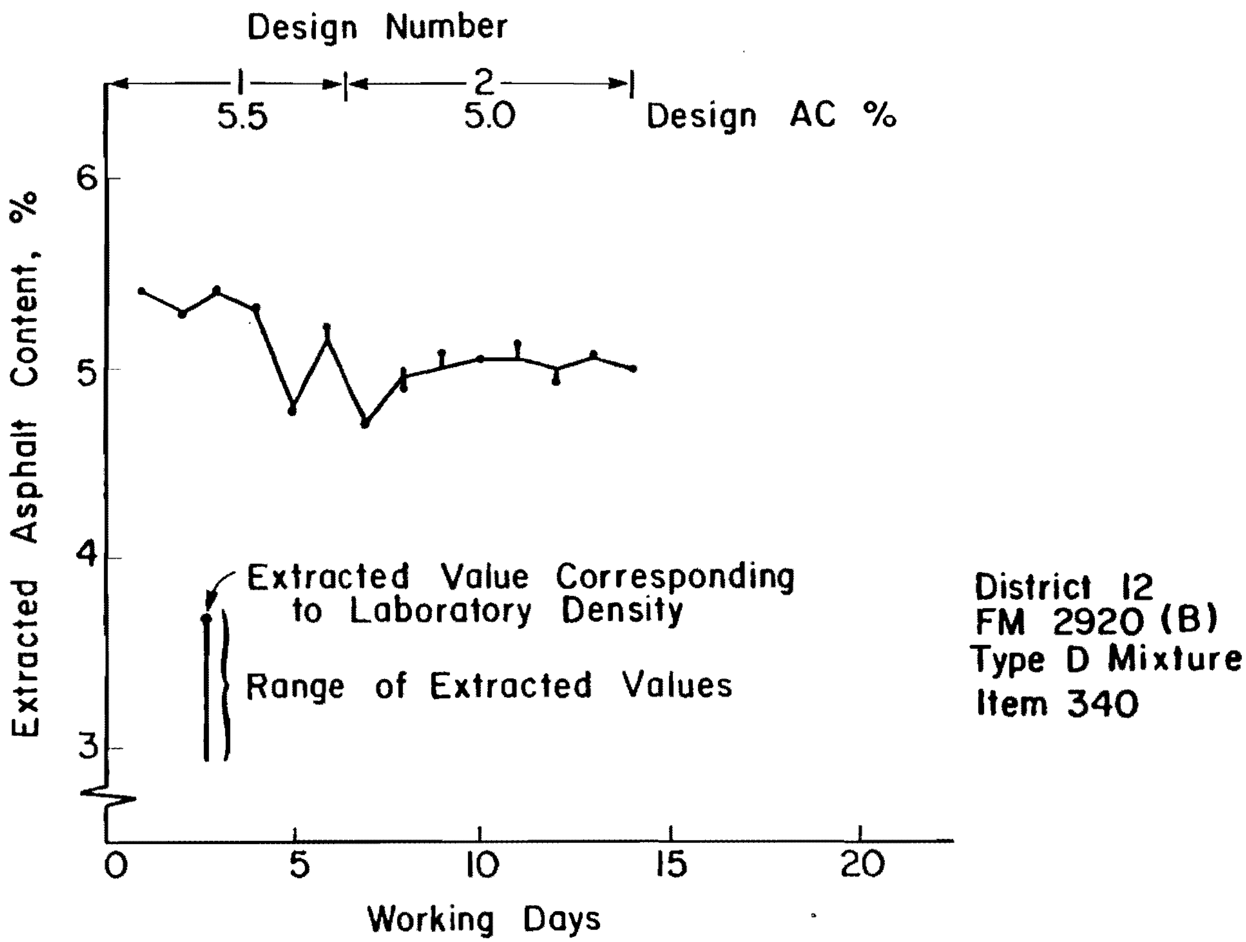


Figure B-11. Variation of extracted asphalt contents for project FM 2920 (B), District 12, Type D mixture

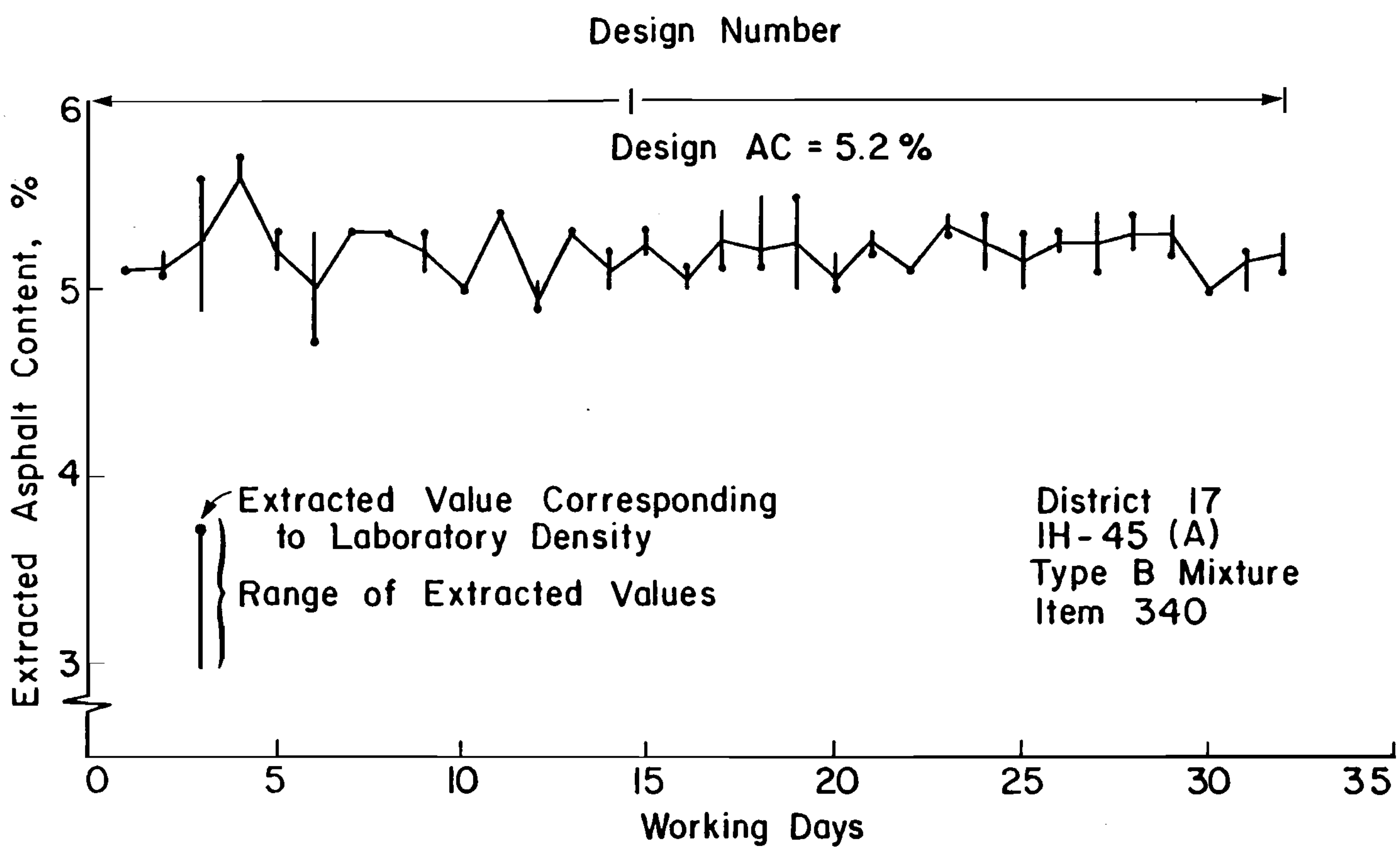


Figure B-12. Variation of extracted asphalt contents for project IH-45 (A), District 17, Type B mixture

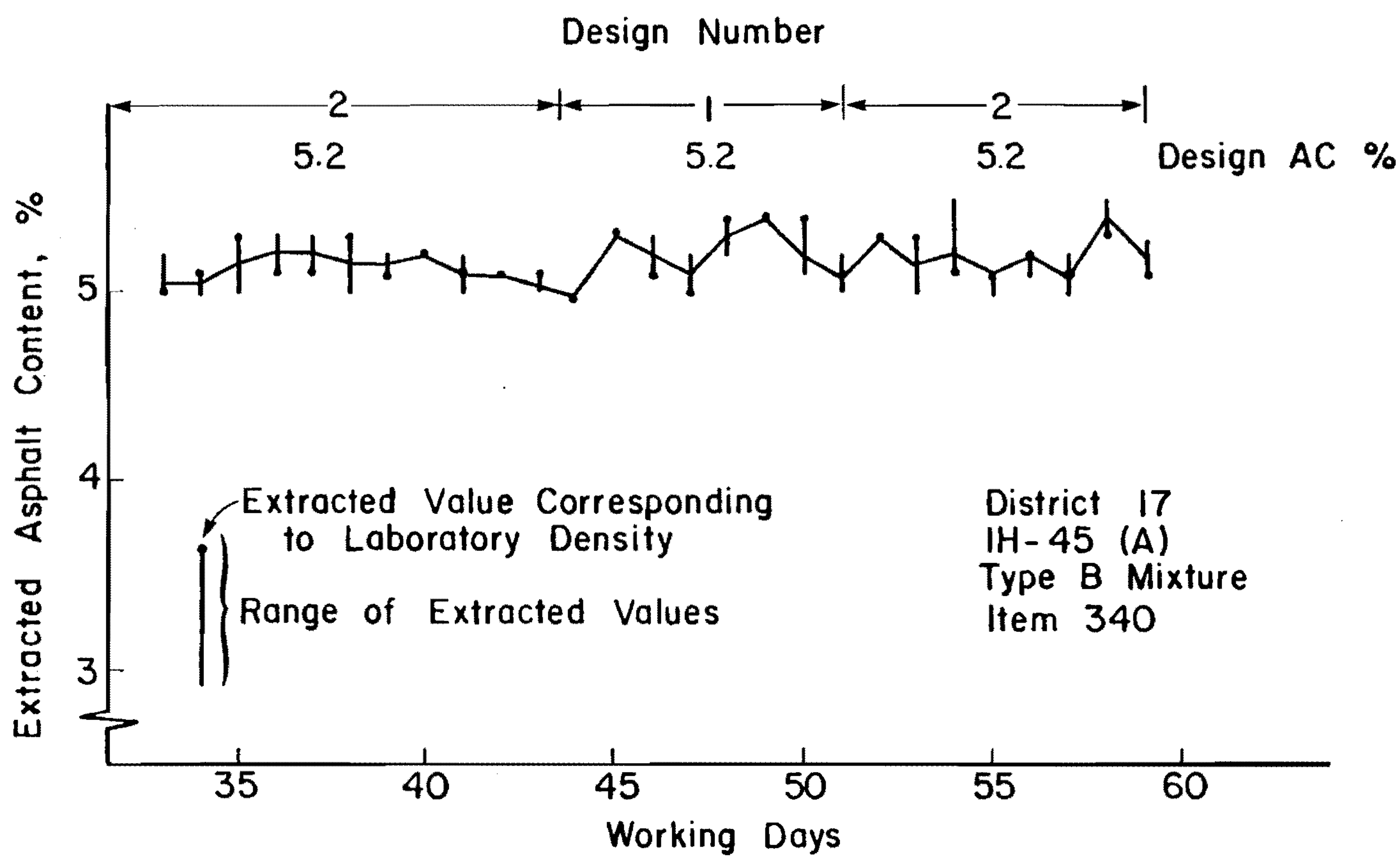


Figure B-12. Variation of extracted asphalt contents for project
(cont.) IH-45 (A), District 17, Type B mixture

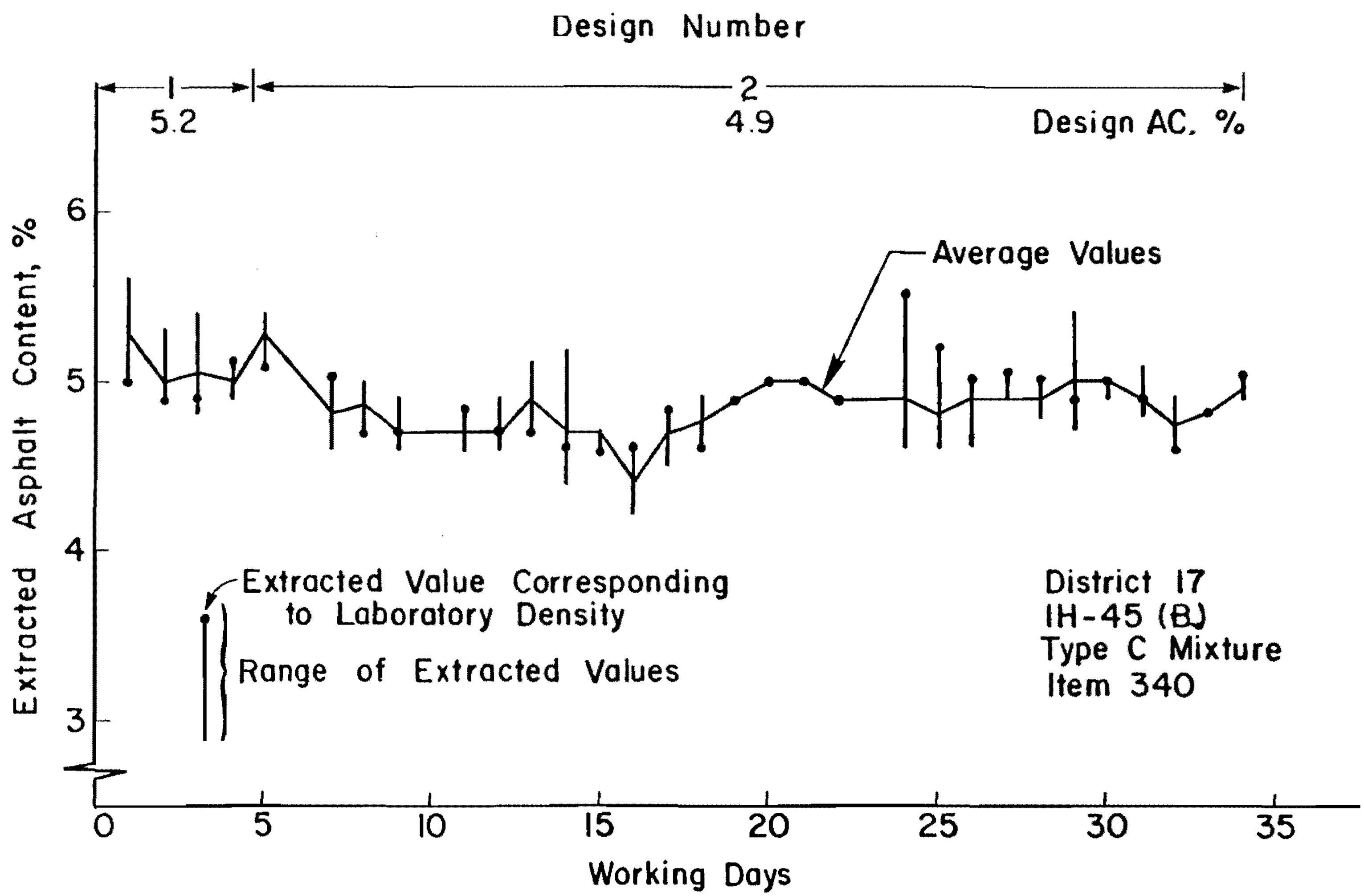


Figure B-13. Variation of extracted asphalt contents for project IH-45 (B), District 17, Type C mixture

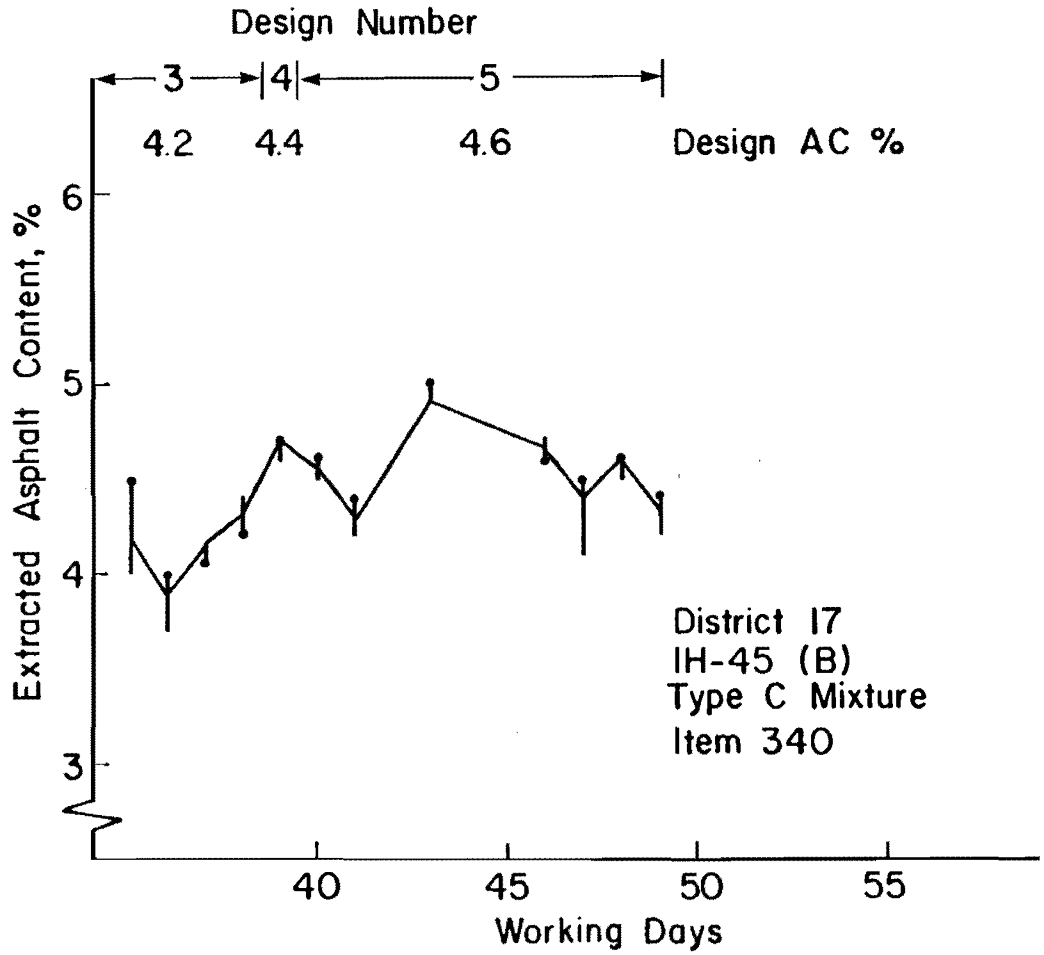


Figure B-13. Variation of extracted asphalt contents for project
(cont.) IH-45 (B), District 17, Type C mixture

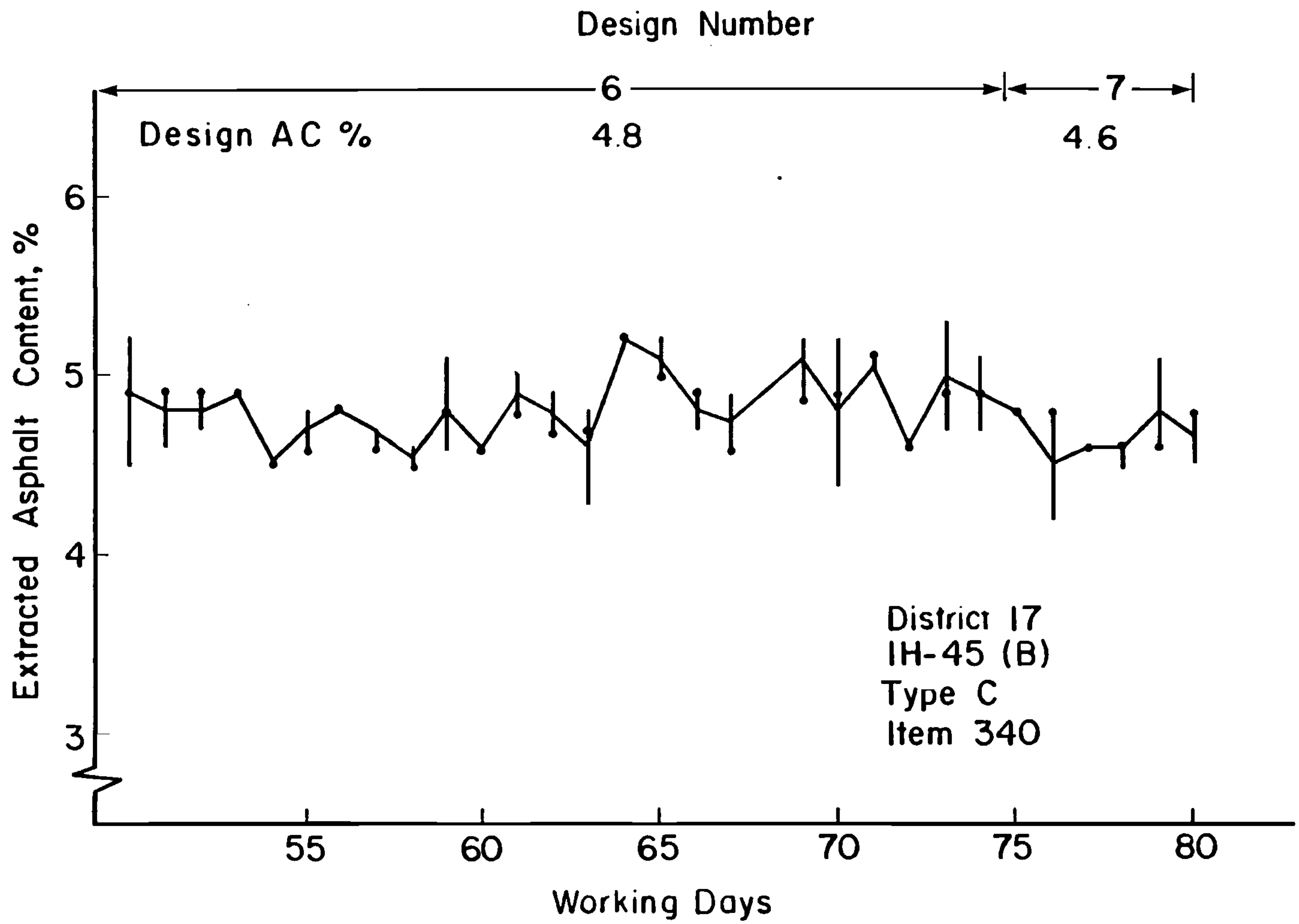


Figure B-13. Variation of extracted asphalt contents for project
(cont.) IH-45 (B), District 17, Type C

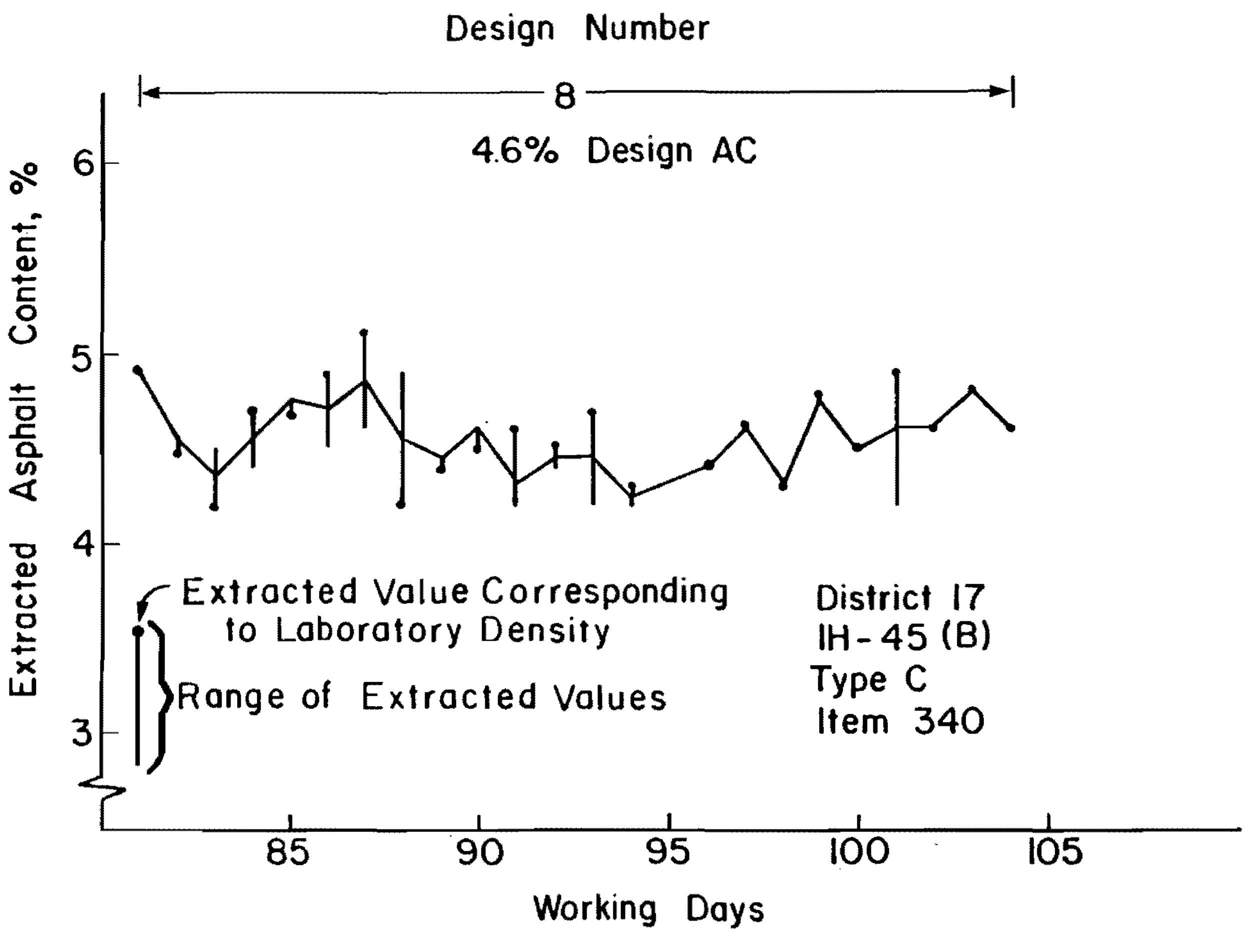


Figure B-13. Variation of extracted asphalt contents for project (cont.) IH-45 (B), District 17, Type C

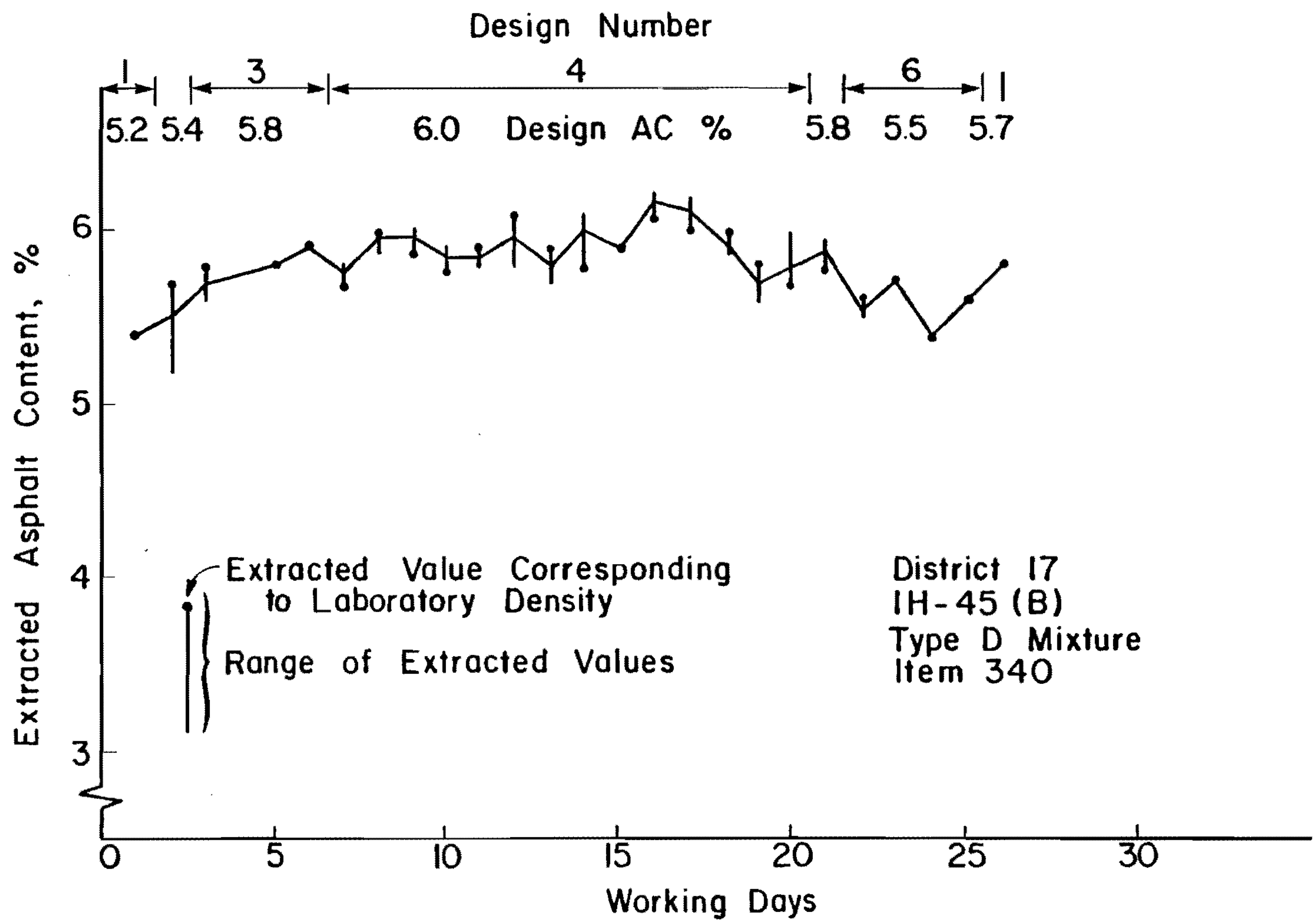
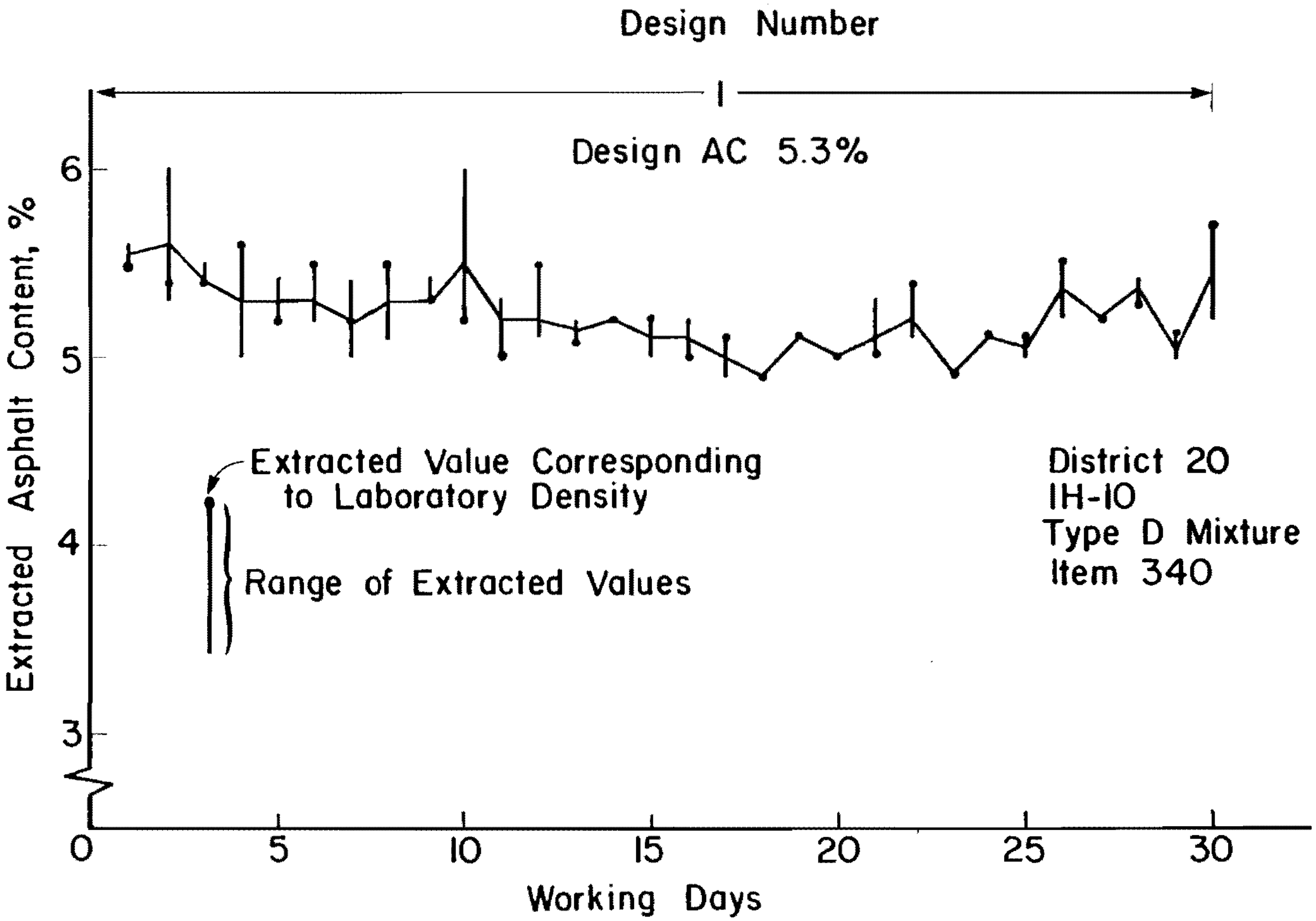


Figure B-14. Variation of extracted asphalt contents for project IH-45 (B), District 17, Type D mixture



Fiture B-15. Variation of extracted asphalt contents for project IH-10, District 20, Type D mixture

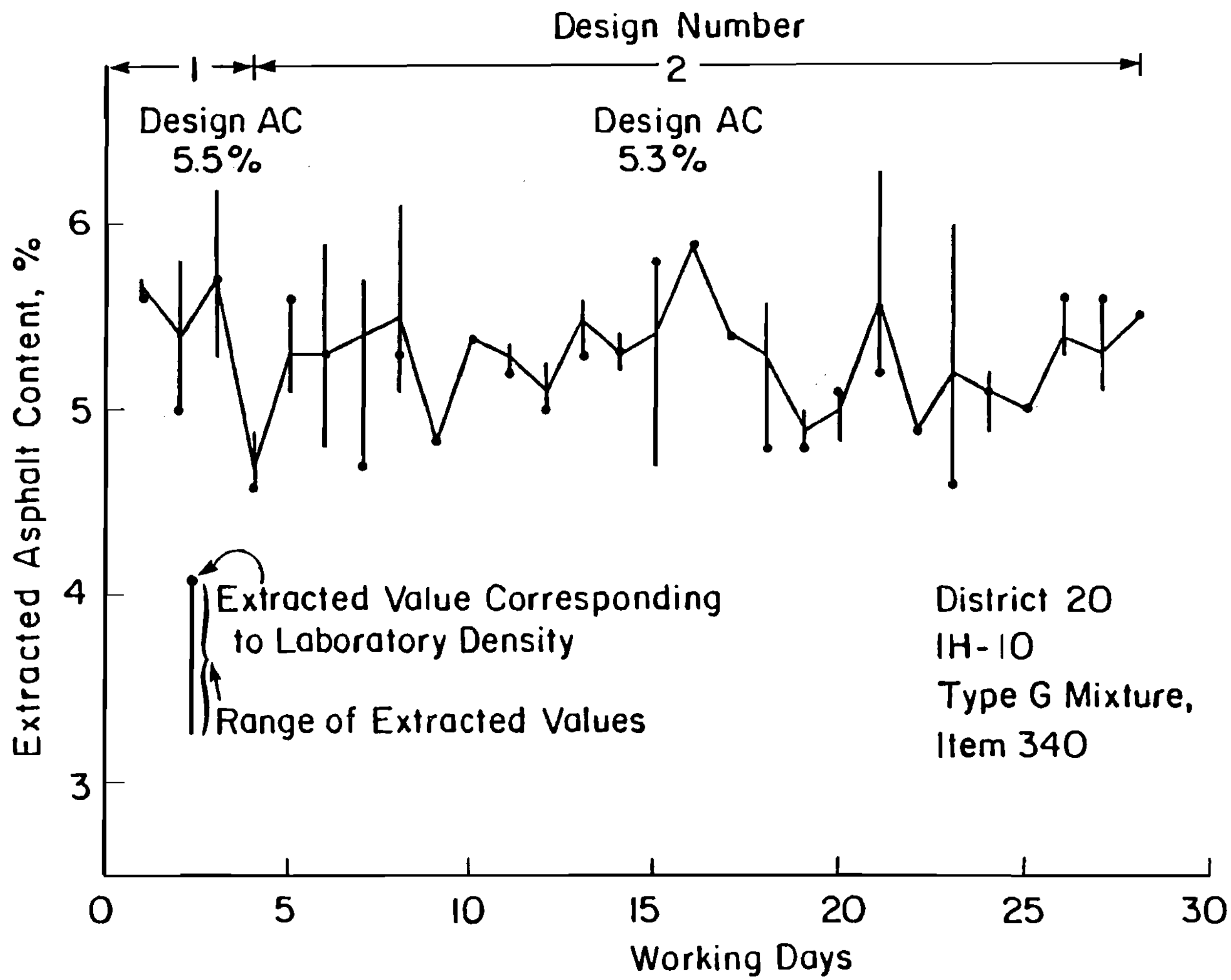


Figure B-16. Variation of extracted asphalt contents for project IH-10, District 20, Type G mixture

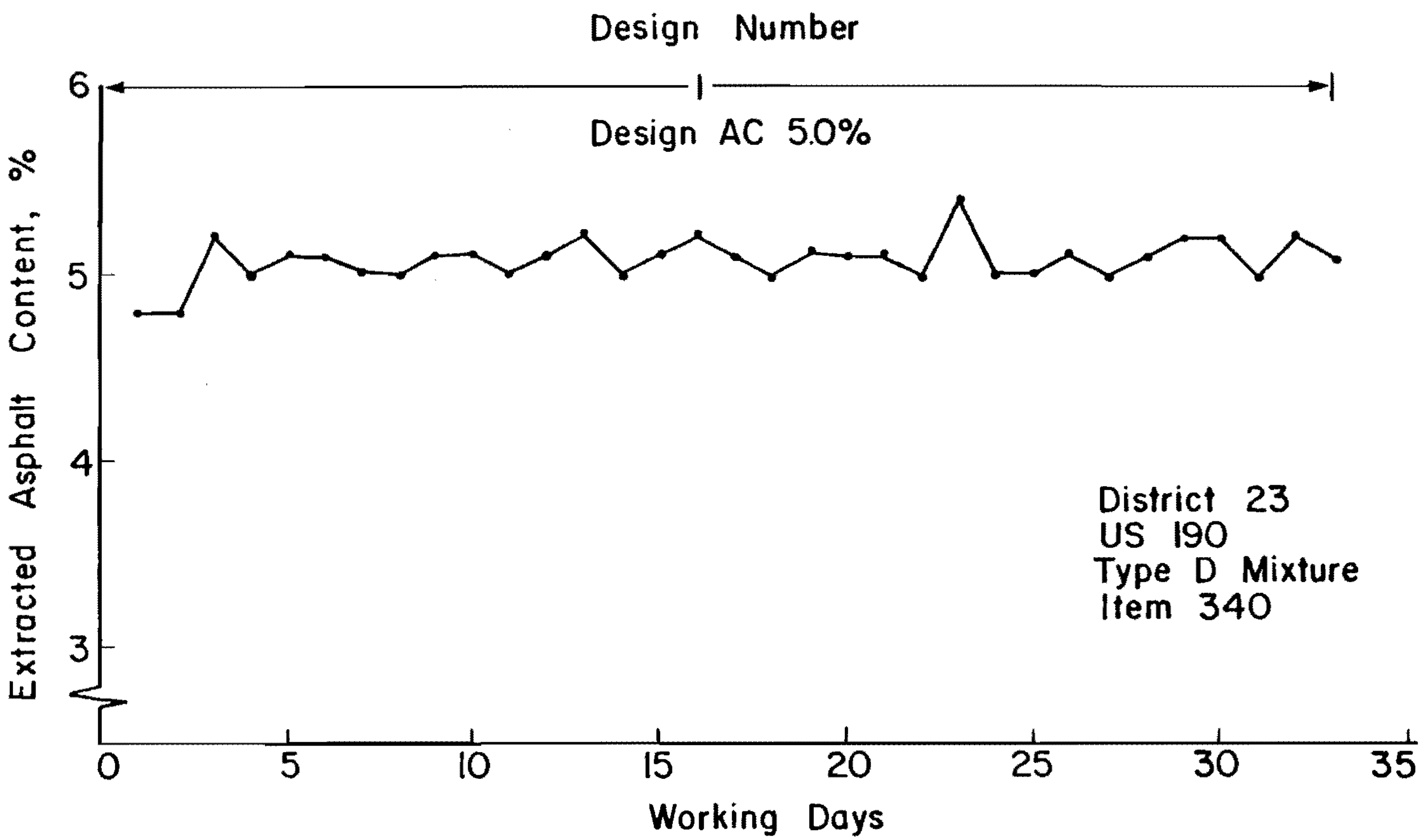


Figure B-17. Variation of extracted asphalt contents for project US 190, District 23, Type D mixture

APPENDIX C

SUMMARY OF DESIGN AND EXTRACTED ASPHALT CONTENTS

TABLE C. SUMMARY OF ASPHALT CONTENT DATA

Dist/Hwy	Design No.	Design % AC	% AC (Extracted) N	$\bar{X}$	S	Δ*
1 IH 30	1	6.0	14	5.7	.19	-.3
Type D	2	6.6	1	6.3	-	-.3
	3	6.6	24	6.2	.14	-.4
3 US 287	1	4.6	3	4.5	.10	-.1
Type D	2	4.8	7	4.9	.21	+.1
	3	4.6	9	4.7	.22	+.1
	4	4.4	13	4.4	.19	0
	5	4.4	13	4.4	.18	0
12 IH 45	1	4.7	3	4.4	.21	-.3
Project A	2	4.9	12	5.0	.25	+.1
D Level Up	3	4.9	11	4.8	.27	-.1
	4	4.9	1	5.0	-	+.1
	5	5.1	3	5.0	.12	-.1
	6	5.0	4	5.0	.06	0
	7	5.0	1	4.9	-	-.1
	8	5.1	2	4.9	.07	-.2
	9	5.0	4	5.0	.06	0
	10	5.1	11	4.9	.15	-.2
	11	5.1	28	5.0	.15	-.1
	12	5.1	12	5.1	.24	0
	13	4.8	2	4.7	.07	-.1
12 IH 45	1	4.9	3	4.9	.12	0
Project A	2	4.8	18	4.8	.33	0
D Surface	3	4.5	2	4.7	.35	+.2
	4	4.4	7	4.6	.20	+.2
	5	4.4	2	4.5	.14	+.1
	6	4.5	13	4.5	.14	0
	7	4.6	2	4.4	.21	-.2

* Δ = Deviation of extracted asphalt content from the design value

TABLE C. (Continued)

Dist/Hwy	Design No.	Design % AC	% AC (Extracted) N	$\bar{X}$	S	Δ
12 IH 45	8	4.7	7	4.8	.10	+.1
Project A	9	4.7	5	4.7	.22	0
D Surface	10	4.8	5	4.7	.15	-.1
(cont'd)	11	4.8	3	4.8	.10	0
12 FM 2920	1	4.9	2	5.1	.07	+.2
Project A	2	4.6	8	4.5	.17	-.1
D Level Up	3	4.6	3	4.6	.11	0
	4	4.6	3	4.5	.06	-.1
	5	4.7	6	4.7	.05	0
	6	4.9	2	4.8	.07	-.1
	7	4.9	5	5.0	.13	+.1
	8	4.9	1	5.0	-	+.1
	9	5.1	3	5.0	.12	-.1
	10	5.1	1	4.8	-	-.3
	11	5.0	2	5.0	.00	0
	12	5.1	8	4.9	.14	-.2
	13	5.1	34	5.1	.20	0
	14	5.5	1	5.6	-	+.1
	15	5.3	1	5.4	-	+.1
	16	5.1	2	4.9	.21	-.2
	17	5.0	1	4.6	-	-.4
12 FM 2920	1	4.8	5	4.9	.25	+.1
Project A	2	4.8	2	4.8	.07	0
D Surface	3	4.9	2	5.0	.00	+.1
	4	4.8	6	4.7	.21	+.1
	5	4.5	10	4.5	.18	0
	6	4.6	2	4.7	.28	+.1
	7	4.7	13	4.8	.16	+.1

TABLE C. (Continued)

Dist/Hwy	Design No.	Design % AC	% AC (Extracted) N	$\bar{X}$	S	Δ
12 US 90A	1	5.1	4	5.2	.33	+.1
Type D	2	5.1	1	5.2	-	+.1
	3	4.6	1	4.9	-	+.3
	4	4.6	2	4.4	.14	-.2
	5	4.6	4	4.6	.13	0
	6	4.6	5	4.5	.15	-.1
	7	4.6	10	4.5	.15	-.1
12 SH 105	1	5.0	17	5.0	.13	0
Type D	2	4.9	12	4.9	.12	0
12 FM 149	1	4.8	4	4.8	.11	0
Type D	2	4.6	2	4.7	.14	+.1
	3	4.6	3	4.5	.12	-.1
	4	4.6	25	4.6	.23	0
	5	4.6	1	4.7	-	+.1
12 FM 1097	1	5.0	2	5.2	.35	+.2
Type D	2	5.3	3	5.3	.10	0
	3	5.4	5	5.4	.09	0
	4	5.3	2	5.2	.00	-.1
12 FM 2920 Project B	1	5.5	7	5.2	.21	-.3
Type D	2	5.0	15	5.0	.09	0
17 IH 45 Project A	1	5.2	89	5.2	.17	0
Type B	2	5.2	48	5.1	.13	-.1
17 IH 45	1	5.2	12	5.1	.26	-.1
Project B	2	4.9	67	4.8	.24	-.1
Type C	3	4.2	10	4.1	.23	-.1
	4	4.4	3	4.7	.15	+.3

TABLE C. (Continued)

Dist/Hwy	Design No.	Design % AC	% AC (Extracted) N	$\bar{X}$	S	Δ
17 IH 45	5	4.6	16	4.6	.24	0
Project B	6	4.6	2	4.3	.14	-.3
Type C	7	4.8	54	4.8	.23	0
(cont'd)	8	4.6	14	4.6	.22	0
	9	4.6	43	4.6	.25	0
17 IH 45	1	5.2	1	5.4	-	+.2
Project B	2	5.4	3	5.5	.29	+.1
Type D Surface	3	5.8	5	5.8	.11	0
	4	6.0	31	5.9	.15	-.1
	5	5.8	2	5.9	.14	+.1
	6	5.5	6	5.5	.12	0
	7	5.7	1	5.8	-	+.1
20 IH 10	1	5.3	72	5.2	.23	-.1
Type D Surface						
20 IH 10	1	5.5	9	5.6	.35	+.3
Type G	2	5.3	64	5.3	.39	0
23 US 190	1	5.0	33	5.1	.12	+.1
Type D						

APPENDIX D

LABORATORY RELATIVE DENSITIES BY PROJECT

TABLE D. PROJECT SUMMARY OF RELATIVE LABORATORY DENSITIES

	G_L/G_T Design			G_L/G_R Job			G_L/G_T Extra.		
Dist/Hwy	N	$\bar{X}$	S	N	$\bar{X}$	S	N	$\bar{X}$	S
1 IH 30 Type D	40	97.6	0.72	39	95.3	1.38	39	97.1	0.76
3 US 287 Type D	20	97.1	0.56	-	-	-	20	97.2	0.66
12 IH 45 (A) Type D Level Up	65	98.8	0.64	65	98.0	0.62	65	98.7	0.72
12 IH 45 (A) Type D Surface	50	99.0	0.79	50	97.3	0.82	50	99.0	0.93
12 FM 2920 (A) Type D Level Up	65	98.9	0.55	65	98.3	0.80	65	98.8	0.63
12 FM 2920 (A) Type D Surface	30	99.4	0.67	30	97.8	1.01	30	99.4	0.71
12 US 90A Type D	17	96.8	0.59	-	-	-	17	96.7	0.68
12 SH 105 Type D	19	99.7	0.40	18	98.5	0.39	19	99.7	0.40
12 FM 149 Type D	22	98.4	0.82	22	97.7	0.87	22	98.5	1.00

TABLE D. (Continued)

Dist/Hwy	G_L/G_T Design			G_L/G_R Job			G_L/G_T Extra.		
	N	$\bar{X}$	S	N	$\bar{X}$	S	N	$\bar{X}$	S
12 FM 1097 Type D	9	98.7	0.65	9	98.6	0.61	9	98.6	0.65
12 FM 2920 (B) Type D	14	97.8	0.66	14	95.8	0.78	14	97.6	0.87
17 IH 45 (A) Type B	59	96.8	0.69	59	96.8	0.77	59	96.8	0.77
17 IH 45 (B) Type C	95	95.8	0.88	95	96.7	0.77	95	95.7	0.94
17 IH 45 (B) Type D	24	97.2	0.45	24	96.8	0.51	24	97.2	0.40
20 IH 10 Type D	30	97.3	0.61	-	-	-	30	97.2	0.70
20 IH 10 Type G	28	97.7	0.94	29	94.8	0.88	28	97.5	1.00
23 US 190 Type D	33	97.7	0.39	-	-	-	33	97.8	0.46

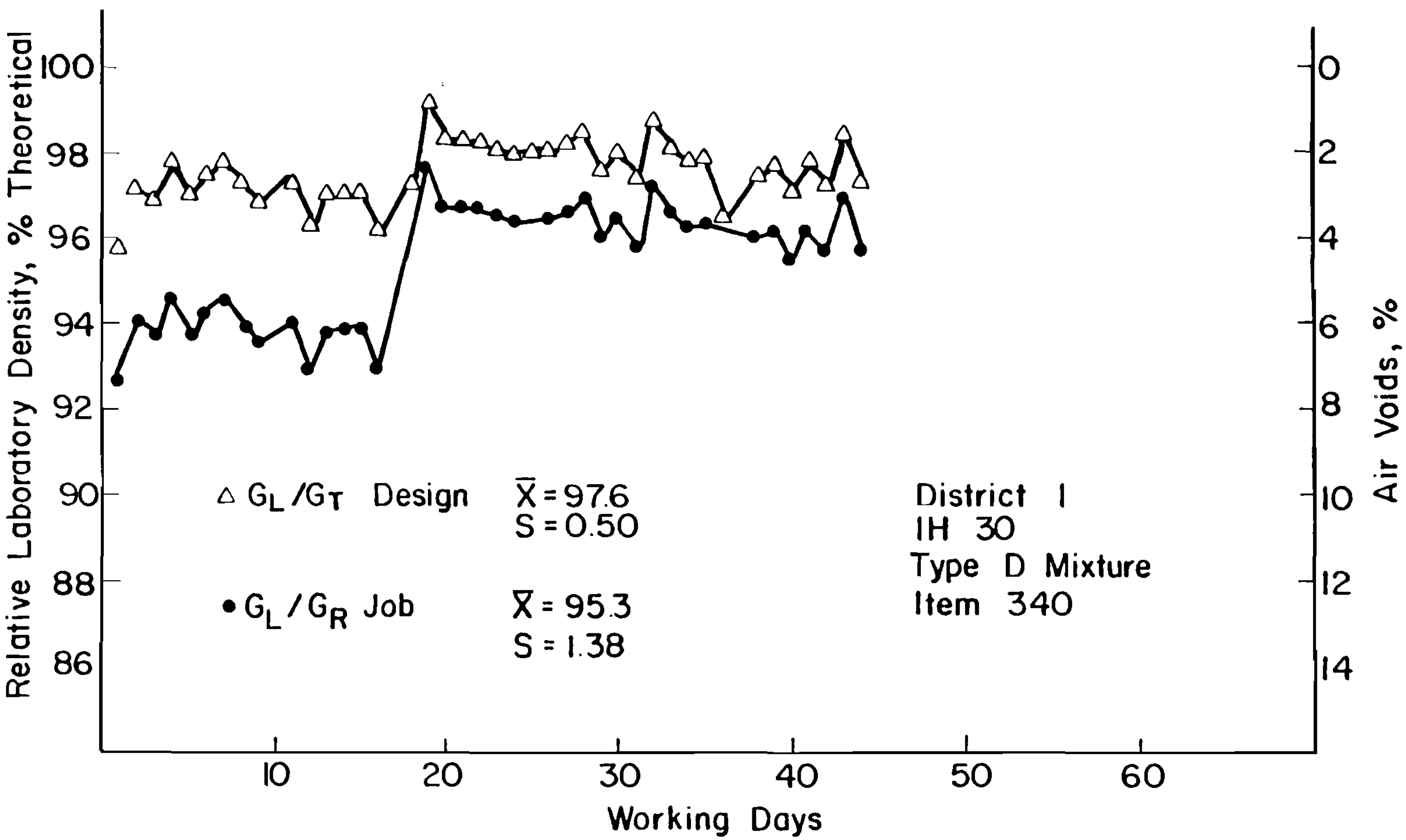


Figure D-1. Variations of relative laboratory densities for project IH-30, District 1, Type D mixture

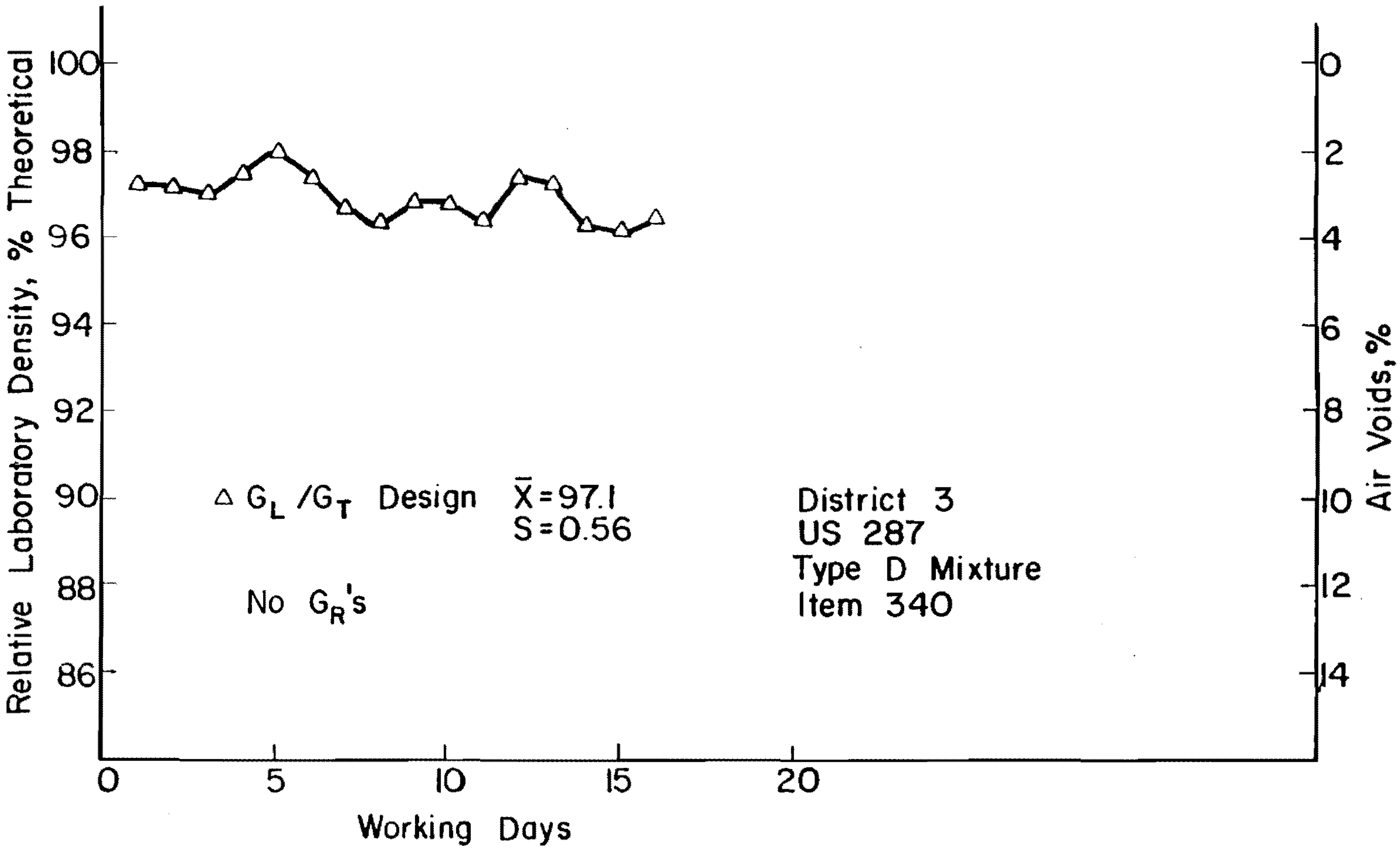


Figure D-2. Variations of relative laboratory densities for project US 287, District 3, Type D mixture

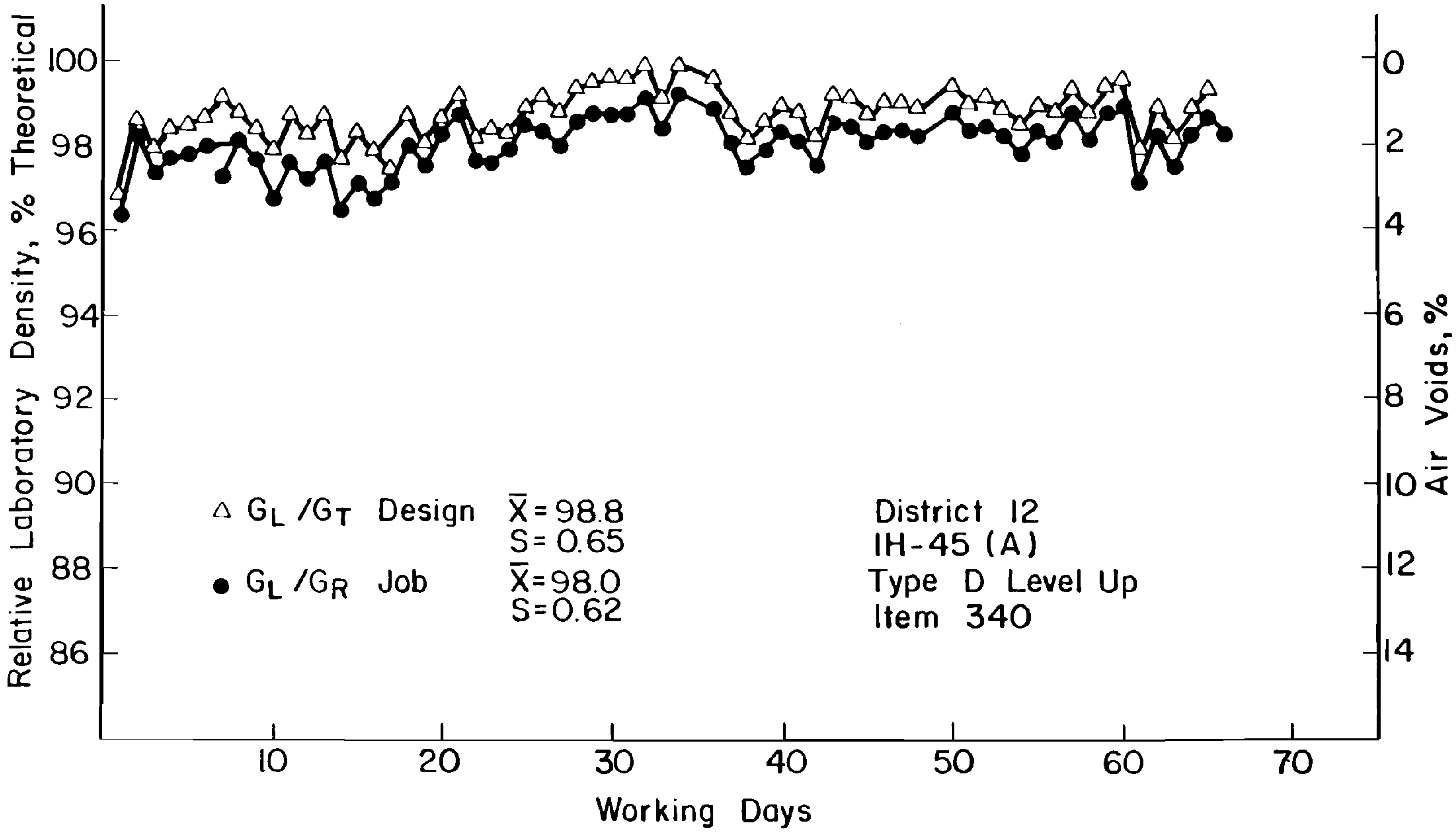


Figure D-3. Variations of relative laboratory densities for project IH-45 (A), District 12, Type D Level up

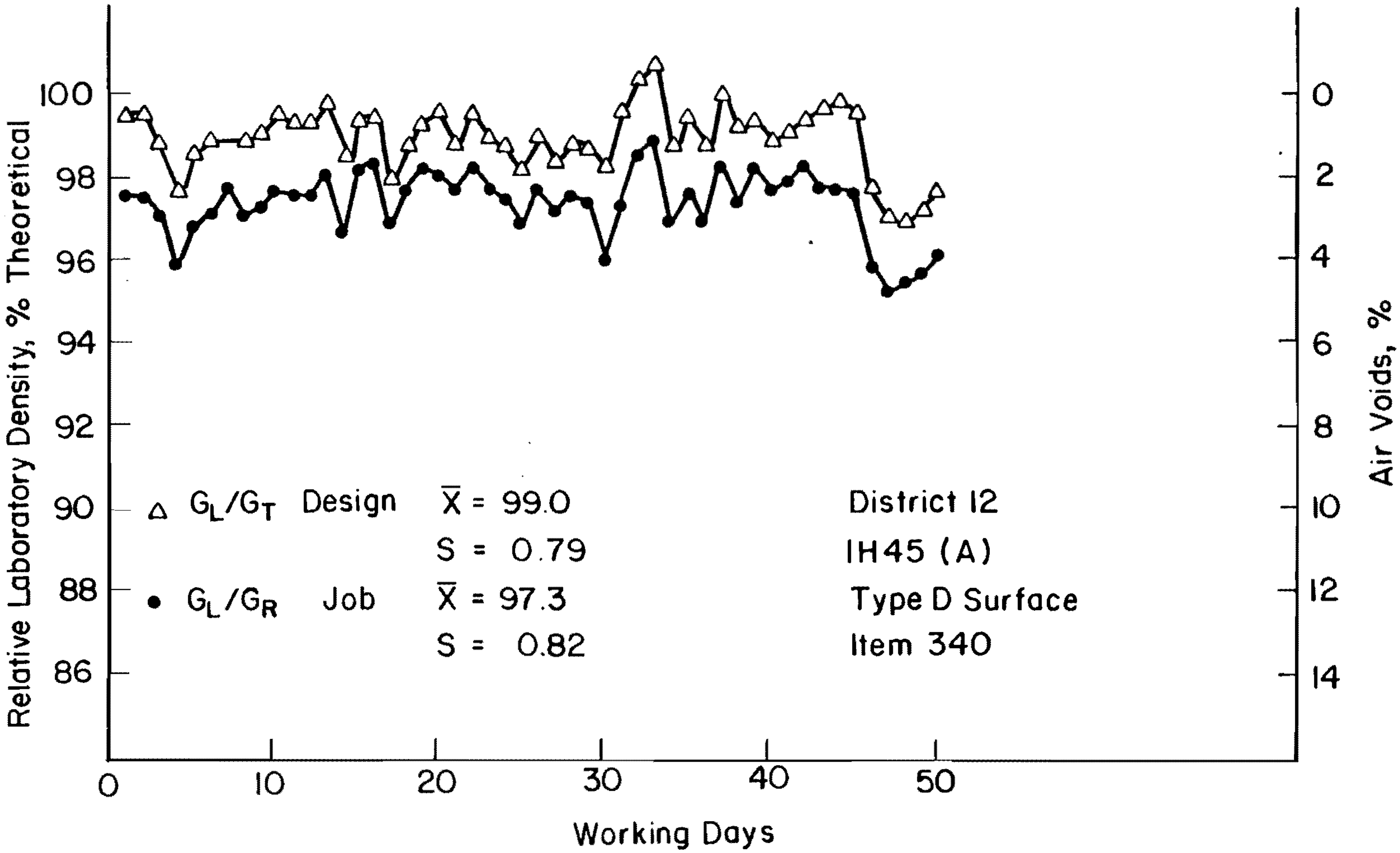


Figure D-4. Variations of relative laboratory densities for project IH-45 (A), District 12, Type D Surface

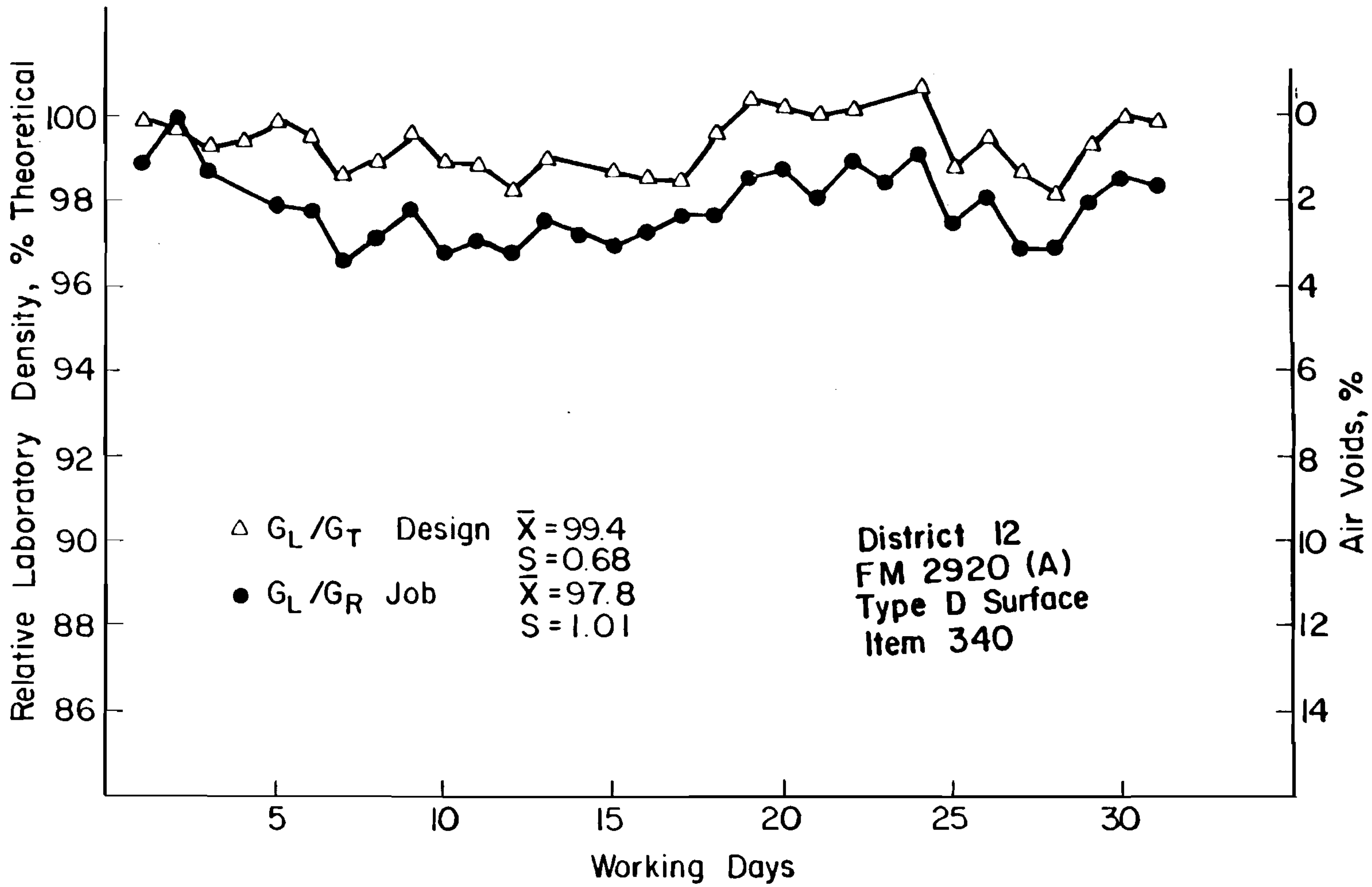


Figure D-5. Variations of relative laboratory densities for project FM 2920 (A), District 12, Type D Surface

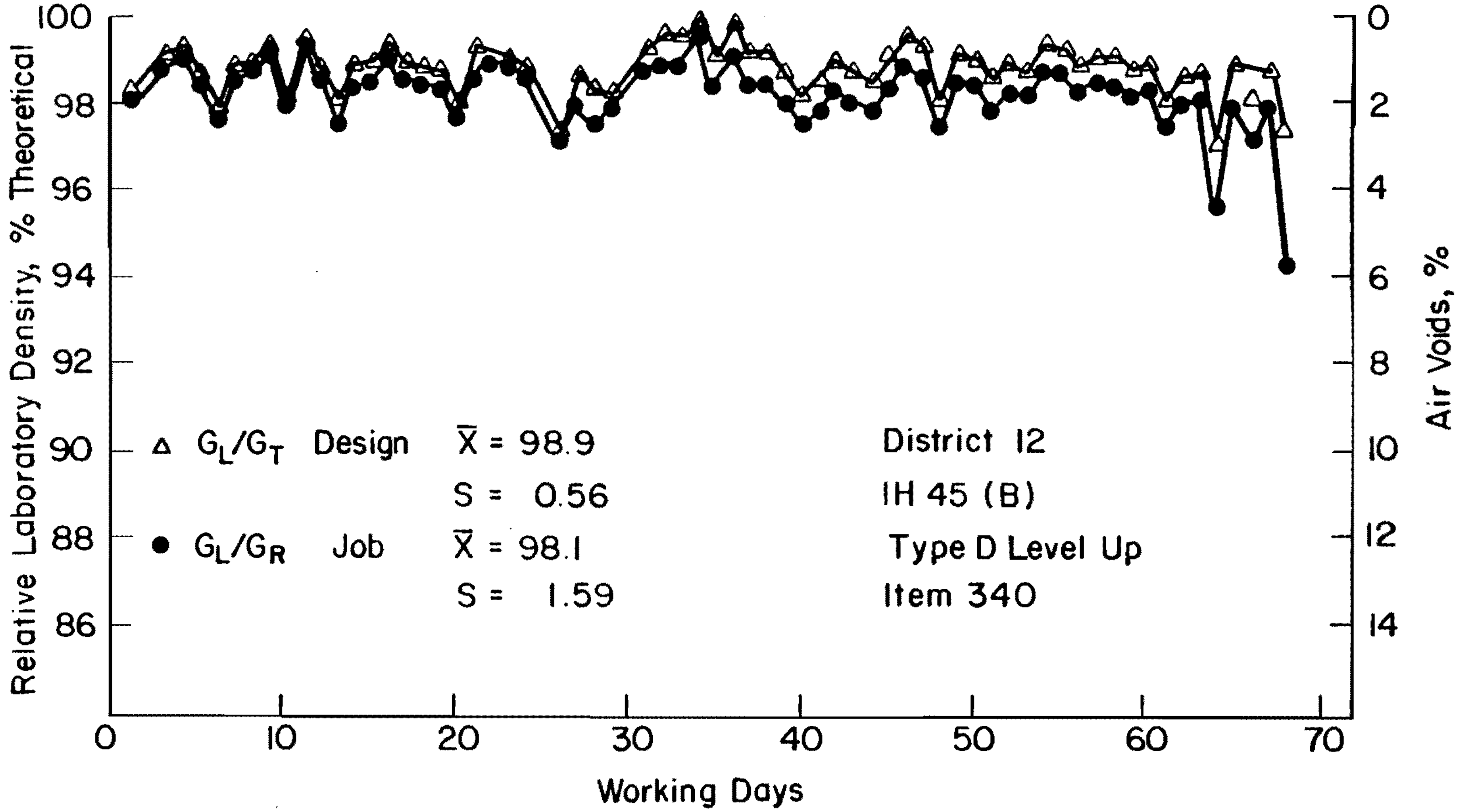


Figure D-6. Variations of relative laboratory densities for project IH 45 (B), District 12, Type D level up

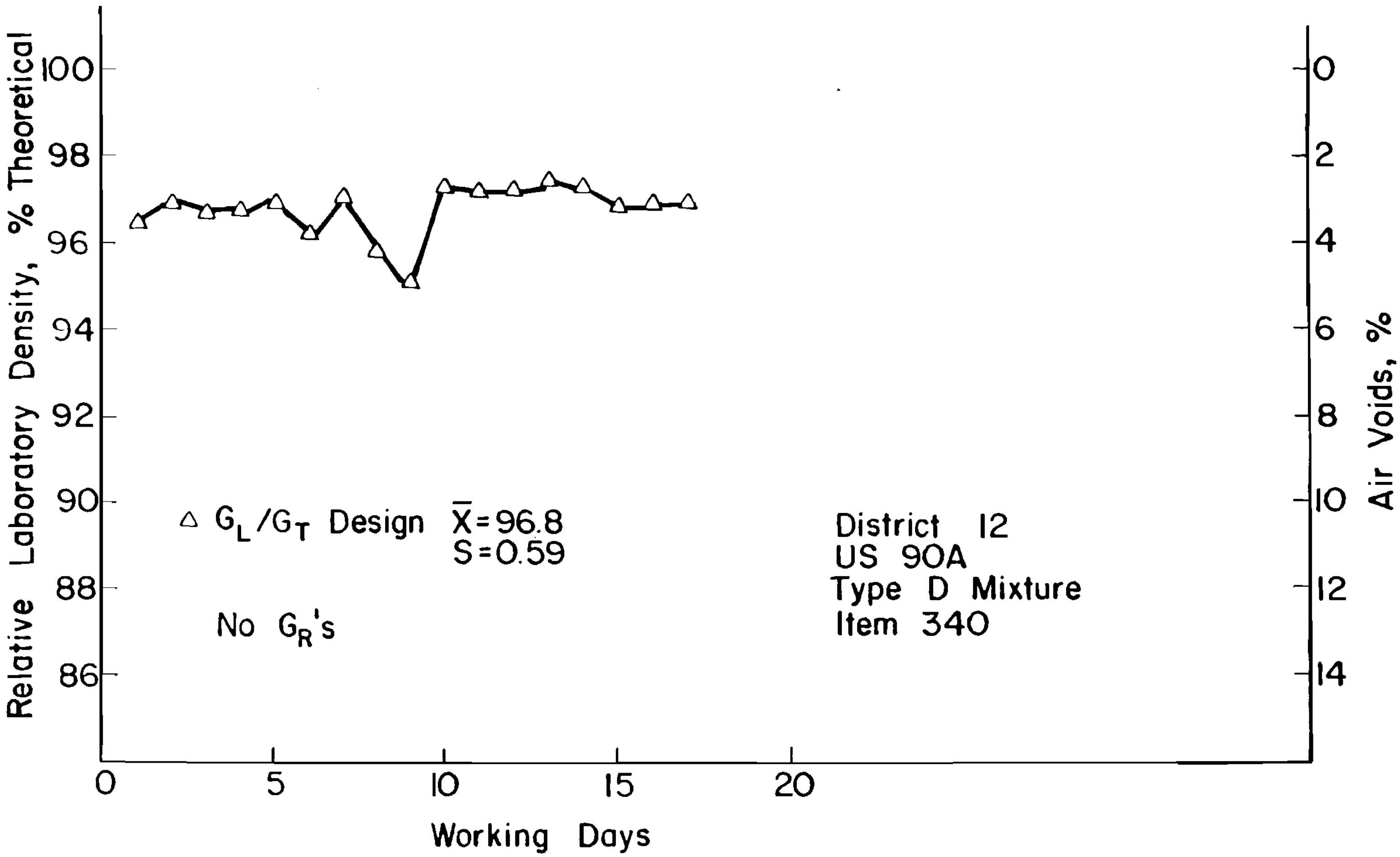


Figure D-7. Variations of relative laboratory densities for project US 90A, District 12, Type D mixture

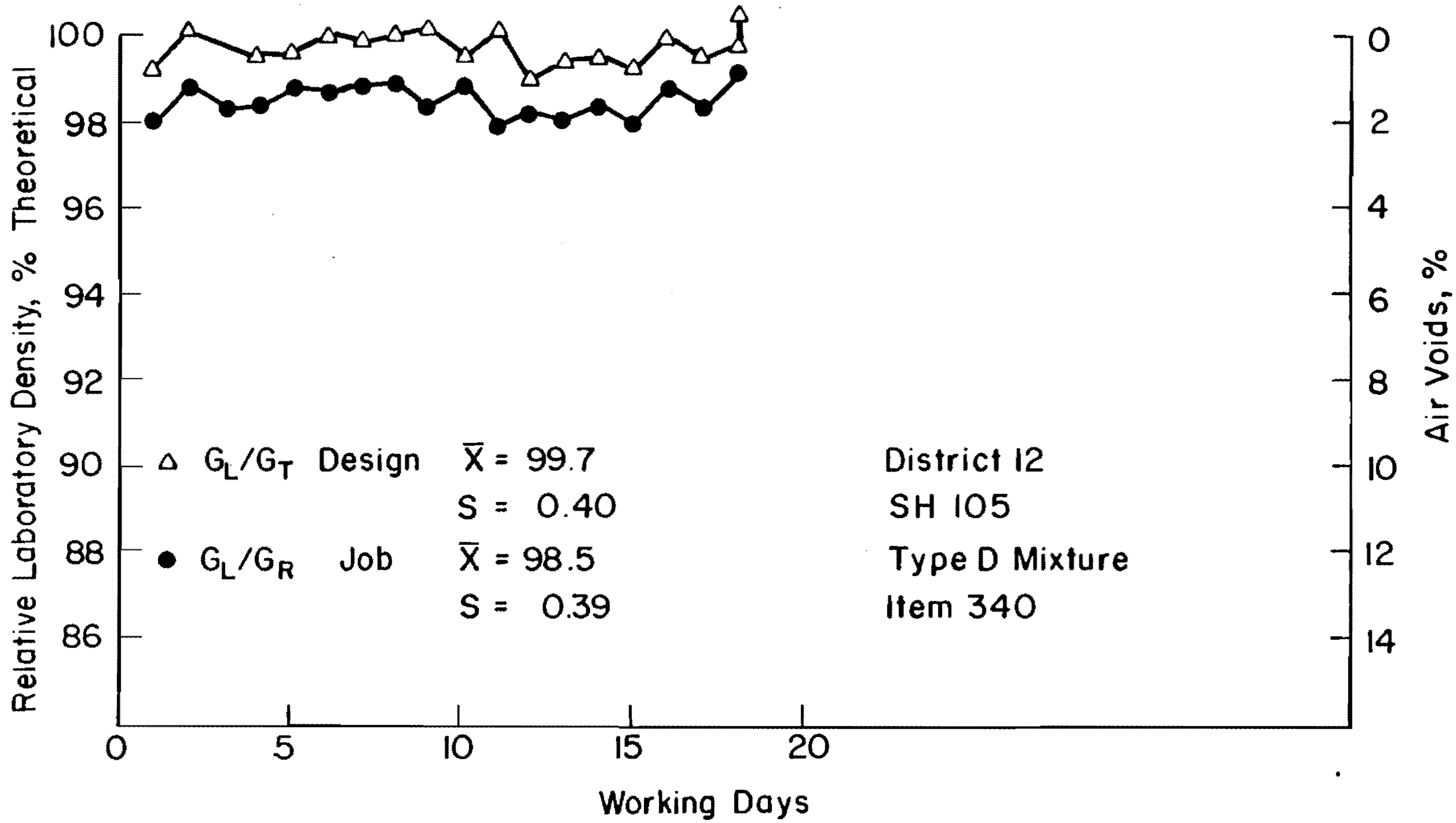


Figure D-8. Variations of relative laboratory densities for project SH 105, District 12, Type D mixture

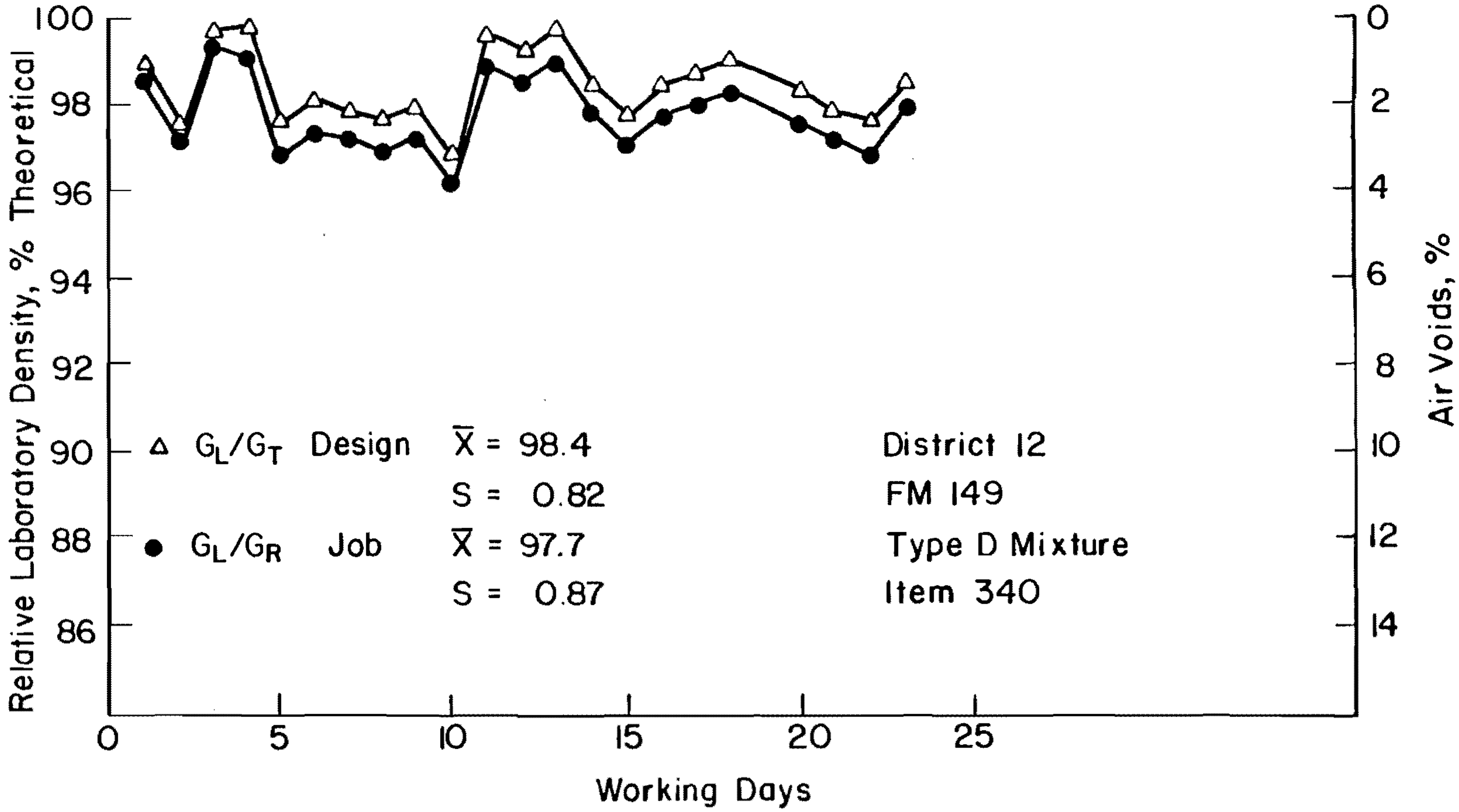


Figure D-9. Variations of relative laboratory densities for project FM 149, District 12, Type D mixture

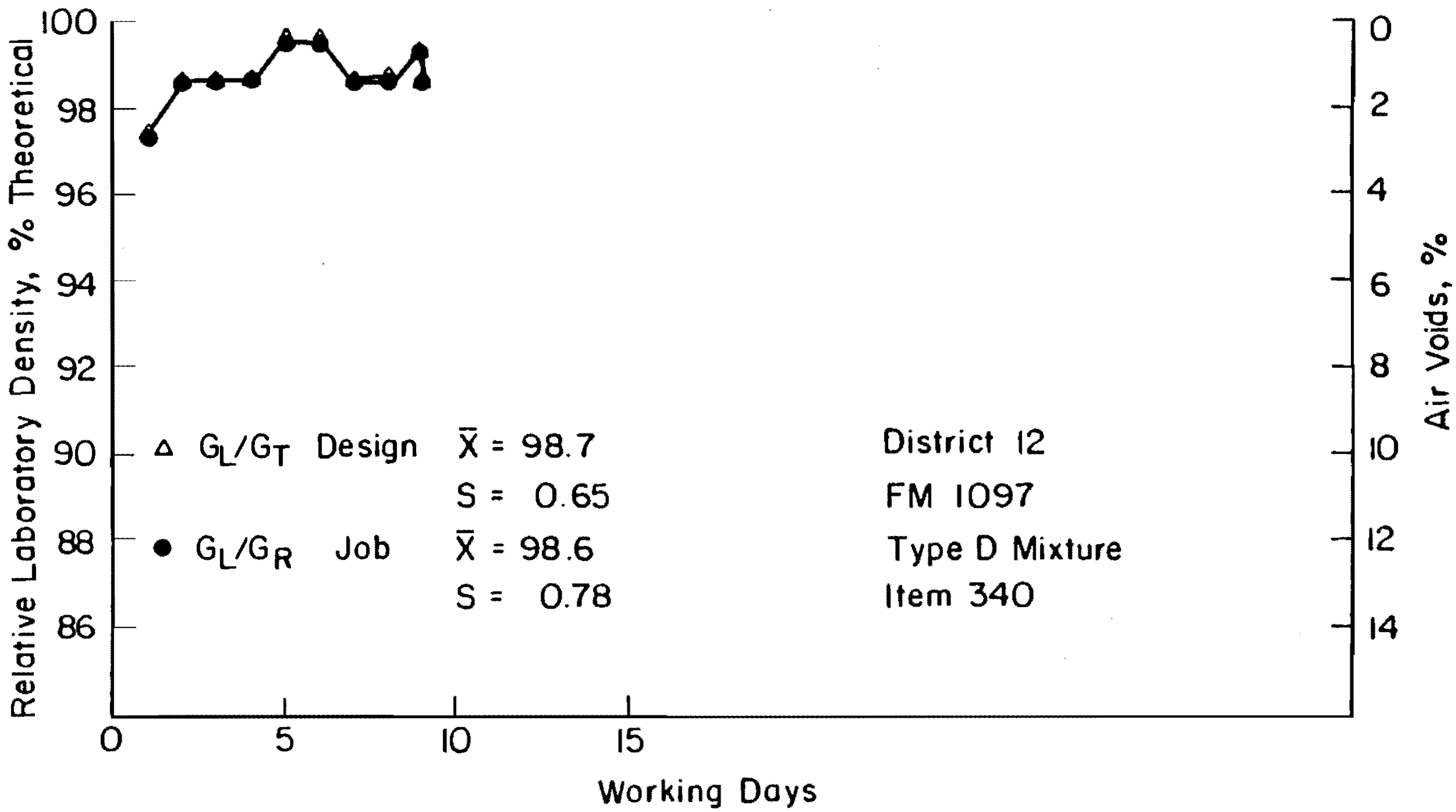


Figure D-10. Variations of relative laboratory densities for project FM 1097, District 12, Type D mixture

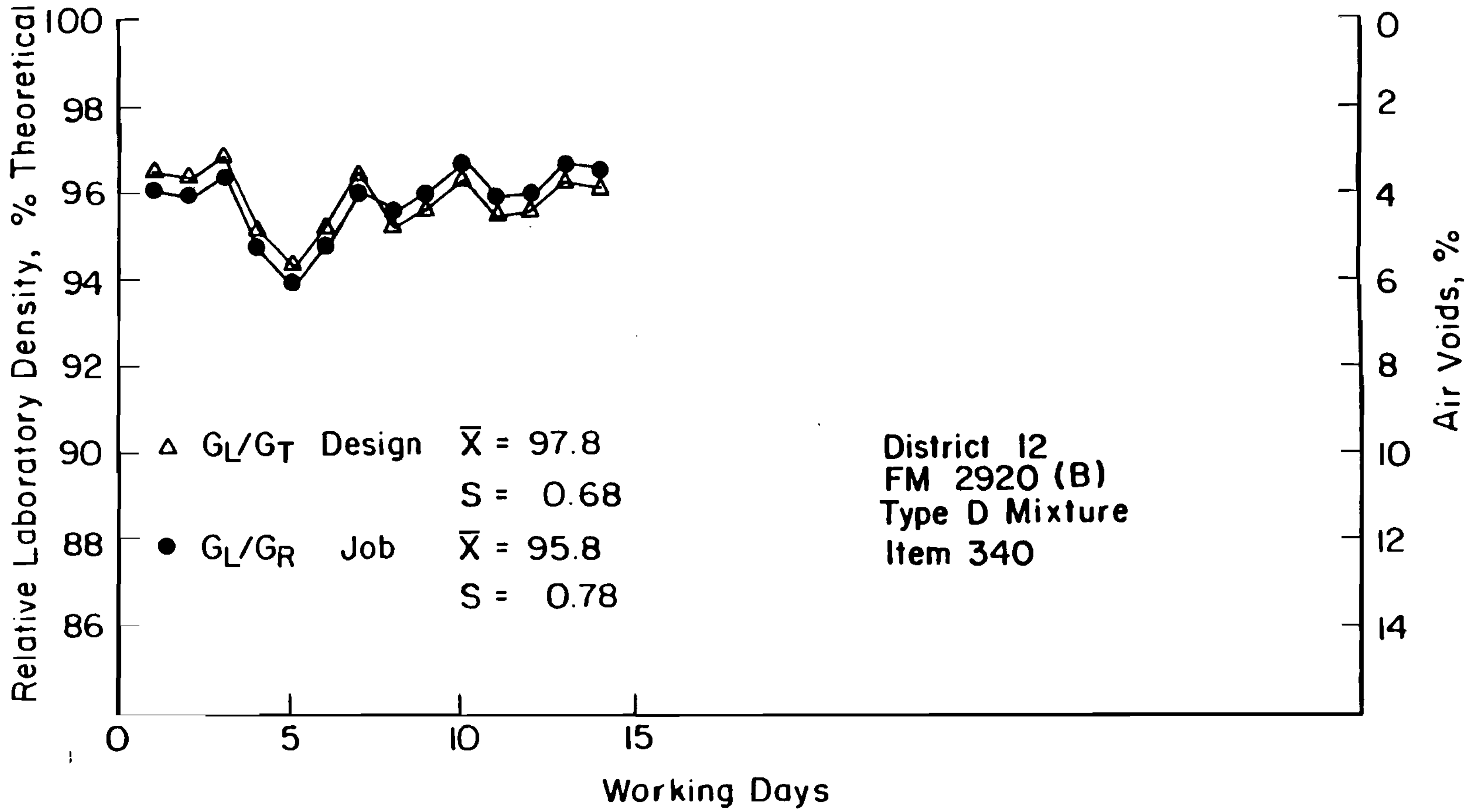


Figure D-11. Variations of relative laboratory densities for project FM 2920 (B), District 12, Type D mixture

Figure D-12. Variations of relative laboratory densities for project IH-45 (A), District 17, Type B mixture

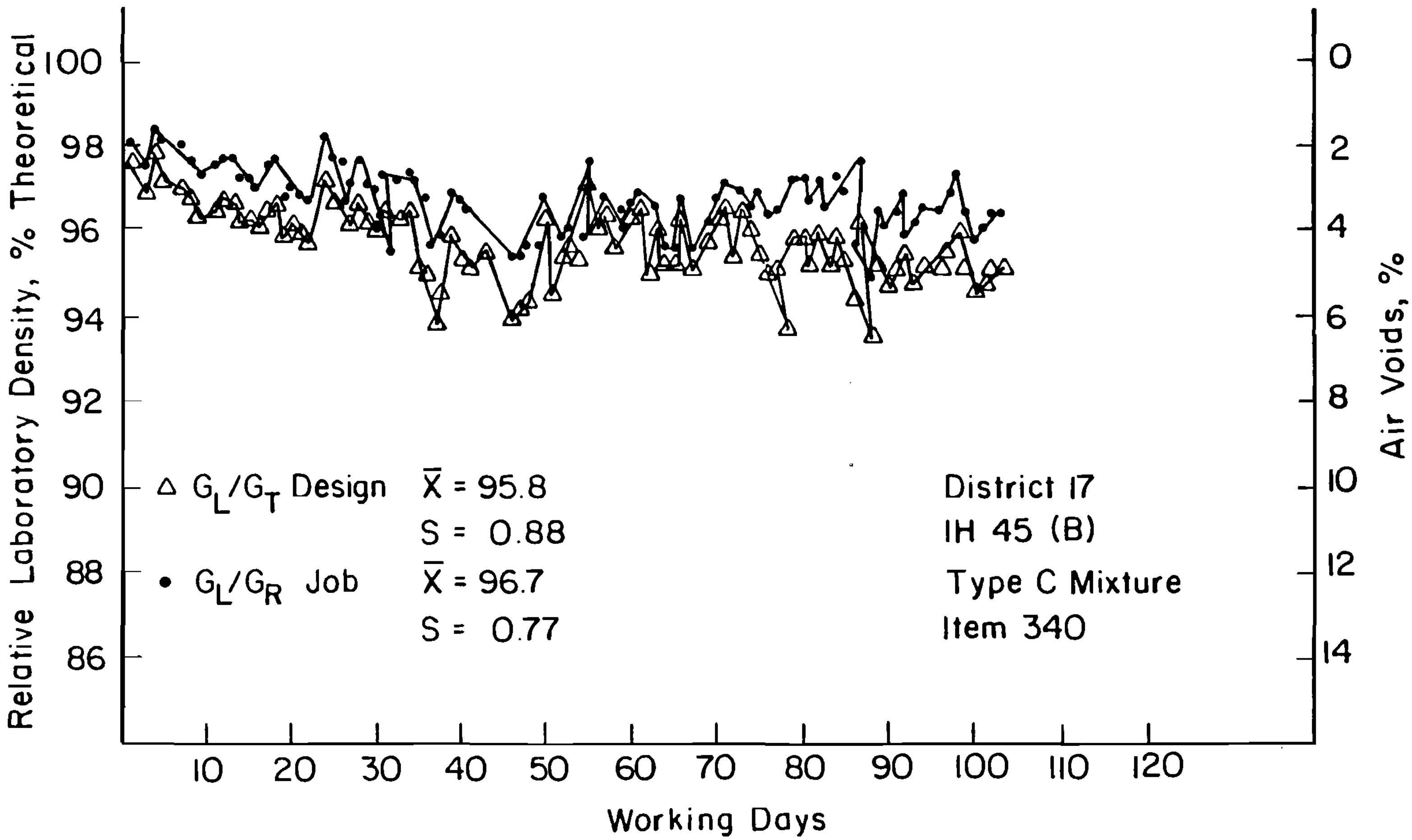


Figure D-13. Variations of relative laboratory densities for project IH-45 (B), District 17, Type C mixture

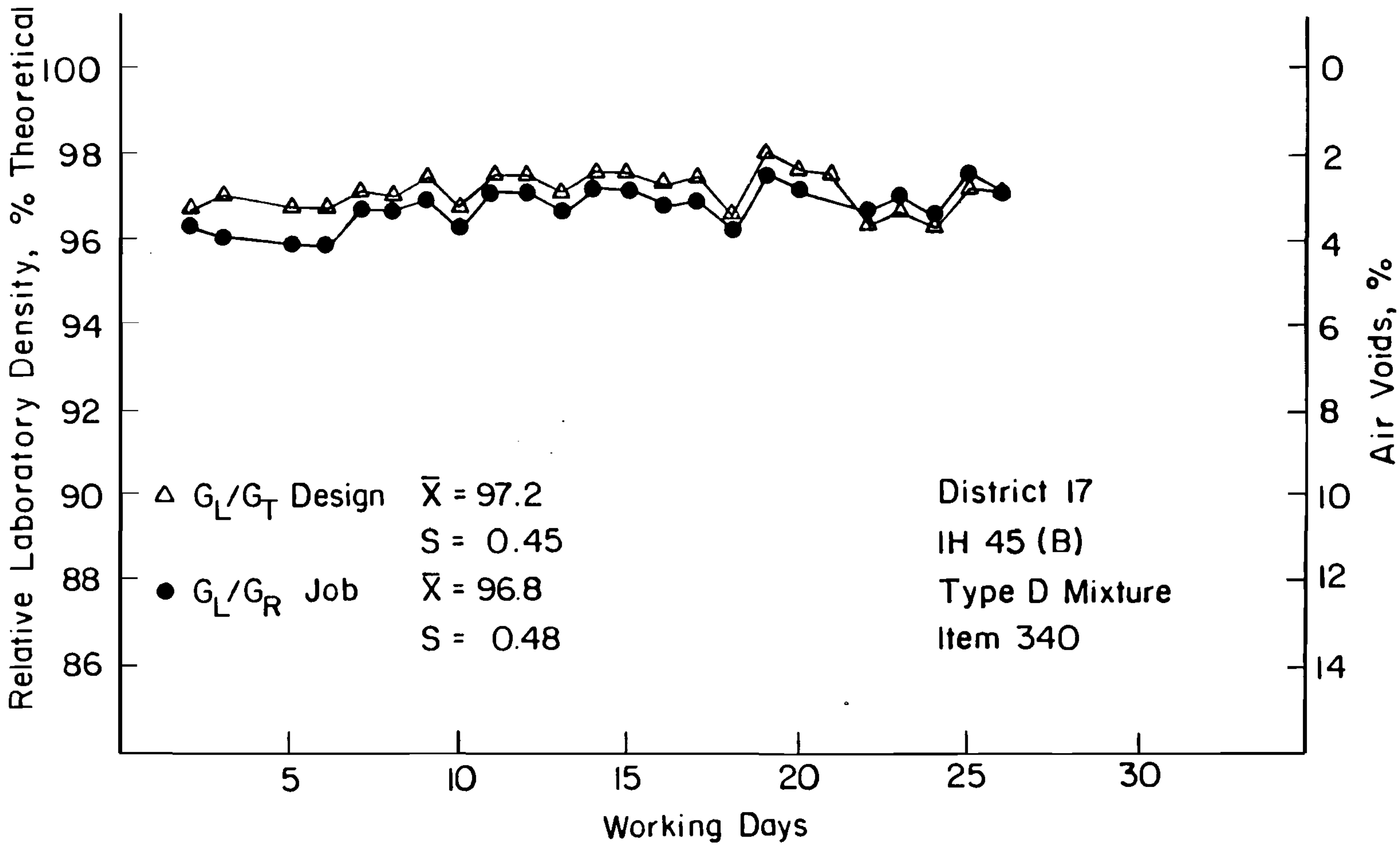


Figure D-14. Variations of relative laboratory densities for project IH-45 (B), District 17, Type D mixture

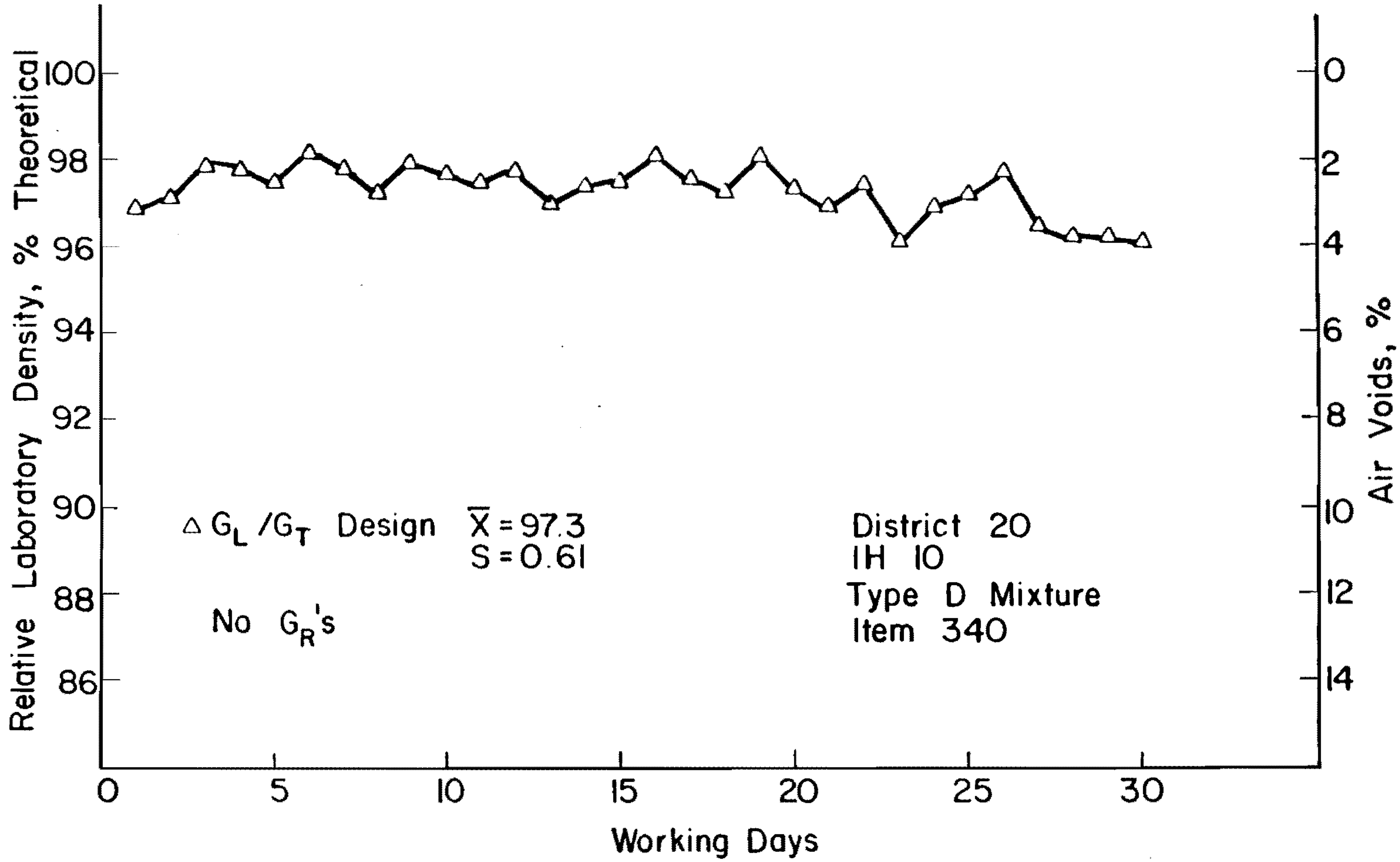


Figure D-15. Variations of relative laboratory densities for project IH-10, District 20, Type D mixture

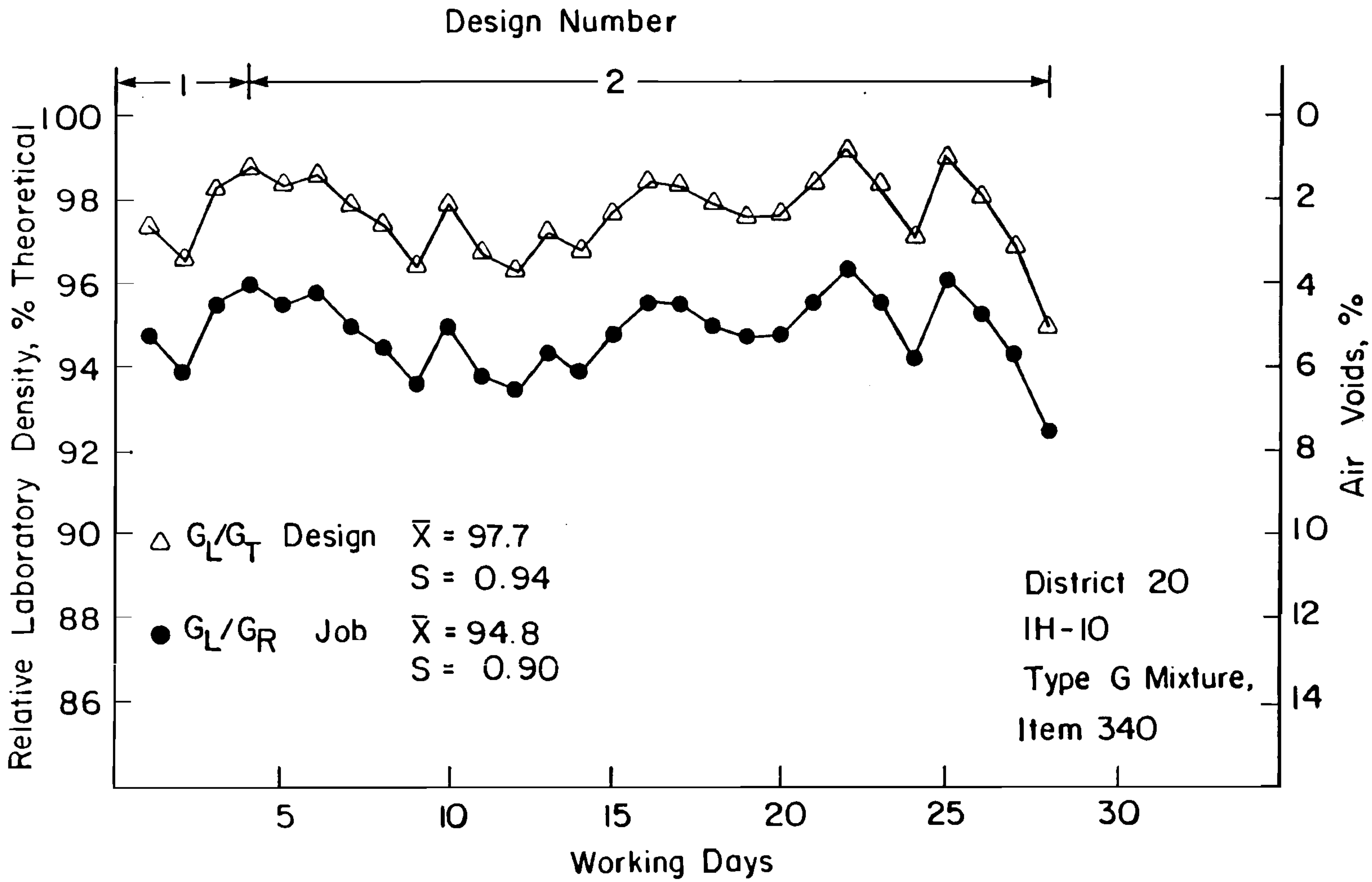


Figure D-16. Variations of relative laboratory densities for project IH-10, District 20, Type G mixture

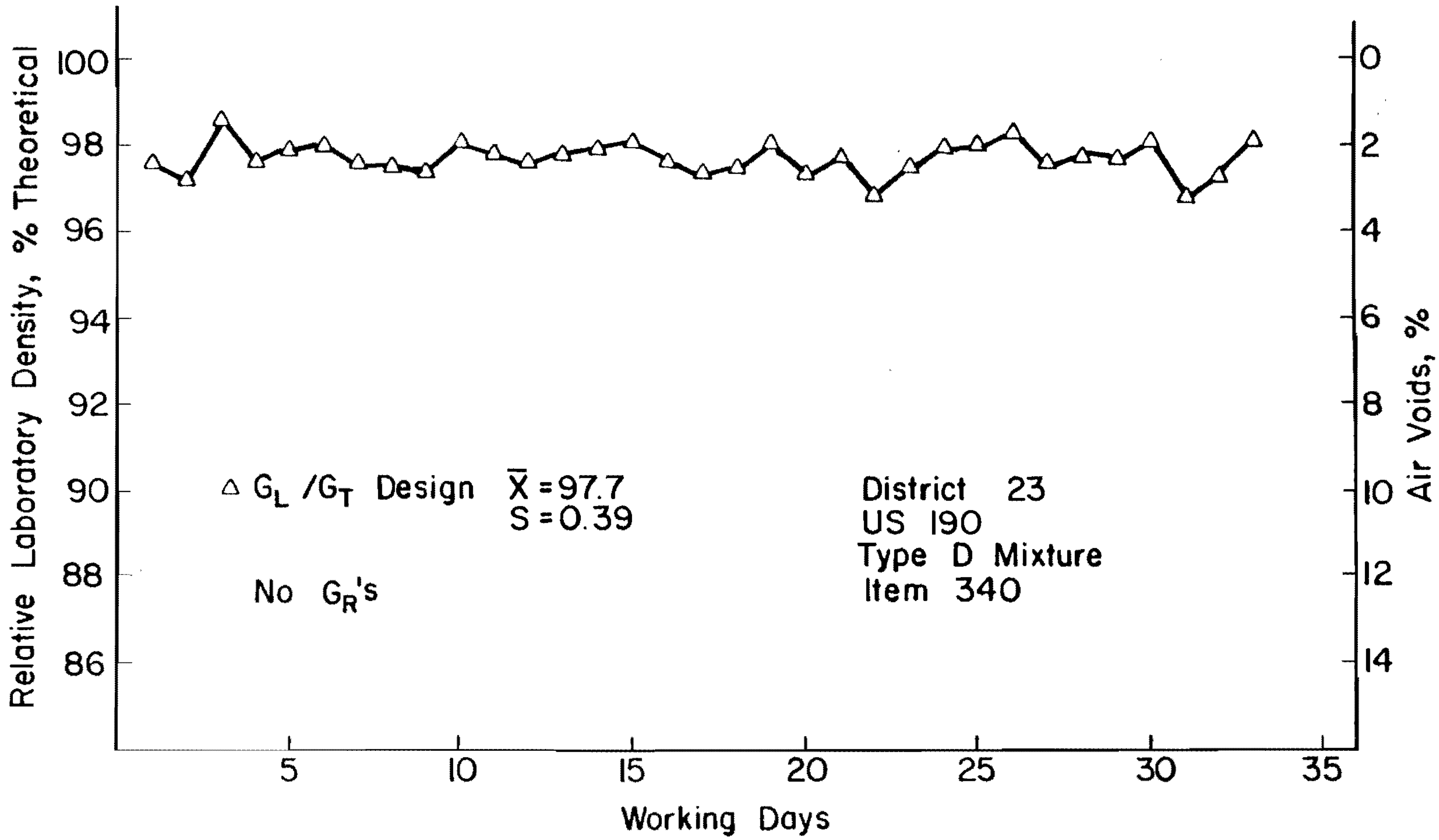


Figure D-17. Variations of relative laboratory densities for project US 190, District 23, Type D mixture

APPENDIX E

RELATIVE FIELD DENSITIES BY PROJECT

TABLE E. PROJECT SUMMARY OF RELATIVE FIELD DENSITIES

Dist/Hwy	G_C/G_L N	G_C/G_L $\bar{X}$	G_C/G_L S	G_C/G_T Design N	G_C/G_T Design $\bar{X}$	G_C/G_T Design S	G_C/G_R Job N	G_C/G_R Job $\bar{X}$	G_C/G_R Job S	G_C/G_T Extra. N	G_C/G_T Extra. $\bar{X}$	G_C/G_T Extra. S
1 IH 30 Type D	40	96.1	1.56	40	93.9	1.75	39	91.6	1.96	39	93.4	1.56
3 US 287 Type D	15	94.2	1.39	16	91.7	1.55	-	-	-	16	91.7	1.52
12 IH 45 (A) Type D Level Up	51	94.3	2.36	51	93.1	2.58	51	92.4	2.57	51	93.0	2.64
12 IH 45 (A) Type D Surface	46	94.6	2.18	46	93.6	2.22	46	91.9	2.19	46	93.6	2.26
12 FM 2920 (A) Type D Level Up	48	93.5	3.20	48	92.4	3.24	48	92.0	3.19	48	92.4	3.23
12 FM 2920 (A) Type D Surface	29	93.8	2.67	29	93.2	2.77	29	91.8	3.01	29	93.3	2.78
12 US 90A Type D	48	94.4	1.92	48	91.3	1.95	-	-	-	46	91.2	2.01
12 SH 105 Type D	16	94.8	1.36	16	94.6	1.29	16	93.2	1.38	16	94.5	1.28
12 FM 149 Type D	22	91.8	2.93	22	90.3	2.99	22	89.8	2.93	22	90.4	3.03

TABLE E. (Continued)

Dist/Hwy	G_C/G_L N	G_C/G_L $\bar{X}$	G_C/G_L S	G_C/G_T Design N	G_C/G_T Design $\bar{X}$	G_C/G_T Design S	G_C/G_R Job N	G_C/G_R Job $\bar{X}$	G_C/G_R Job S	G_C/G_T Extra. N	G_C/G_T Extra. $\bar{X}$	G_C/G_T Extra. S
12 FM 1097 Type D	7	95.7	1.47	7	94.5	1.87	7	94.4	1.82	7	94.5	1.82
12 FM 2920 (B) Type D	14	94.4	3.67	14	92.3	3.42	14	90.6	3.23	14	92.1	3.24
17 IH 45 (A) Type B	51	99.6	1.12	51	96.4	1.08	51	96.3	1.16	51	96.4	1.14
17 IH 45 (B) Type C	21	99.2	0.98	22	94.5	1.80	22	95.9	1.09	21	95.0	1.39
17 IH 45 (B) Type D	8	95.2	3.88	8	92.6	3.87	8	92.0	3.76	8	92.6	3.84
20 IH 10 Type D	5	95.6	1.39	5	93.4	1.13	-	-	-	5	93.6	1.17
20 IH 10 Type G	9	97.7	2.19	9	95.4	1.66	9	92.2	1.59	9	95.1	1.42
23 US 190 Type D	16	95.9	1.18	16	93.7	1.21	-	-	-	16	93.7	1.33

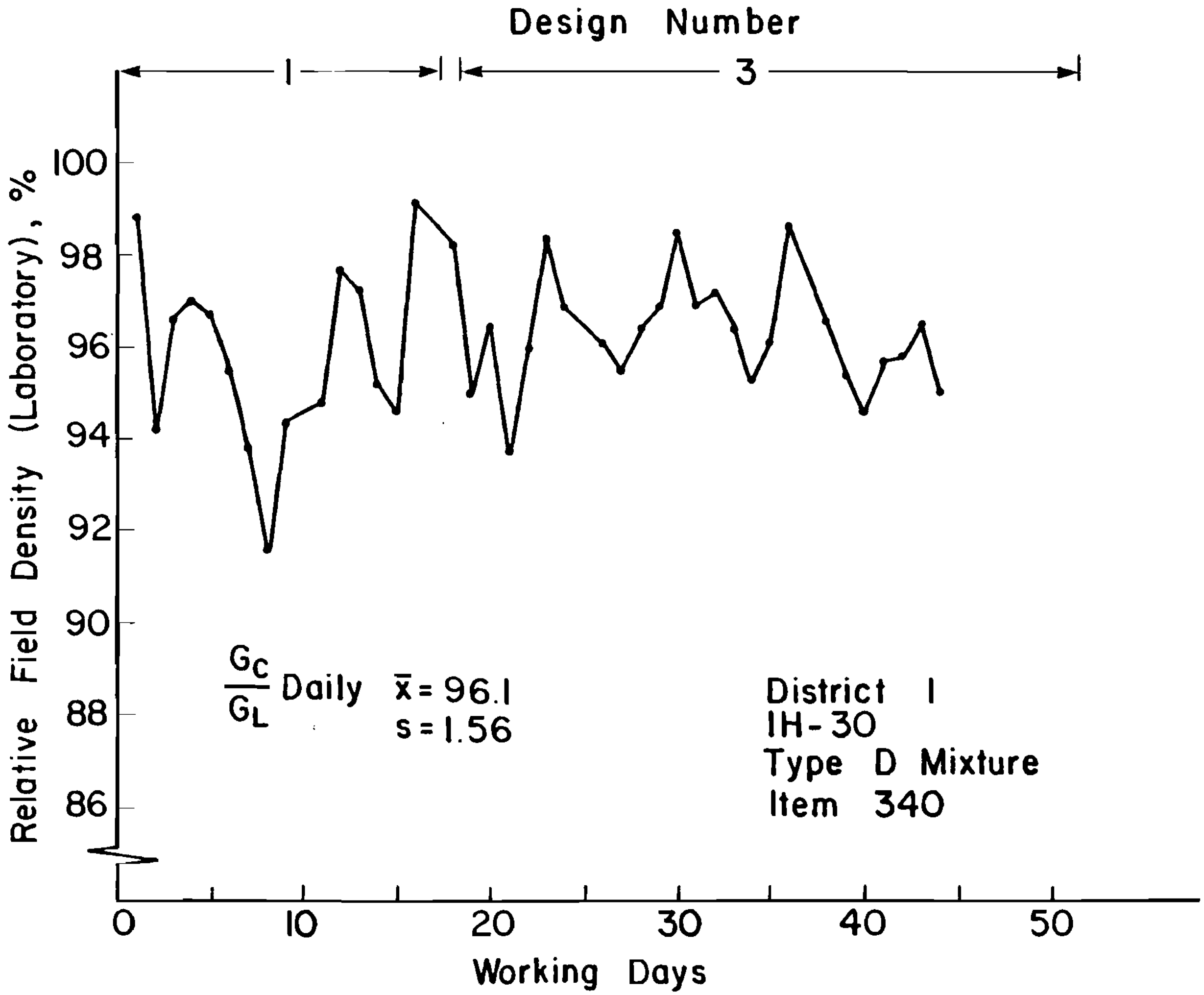


Figure E-1. Variation of relative field density (laboratory based) for project IH-30, District 1, Type D mixture

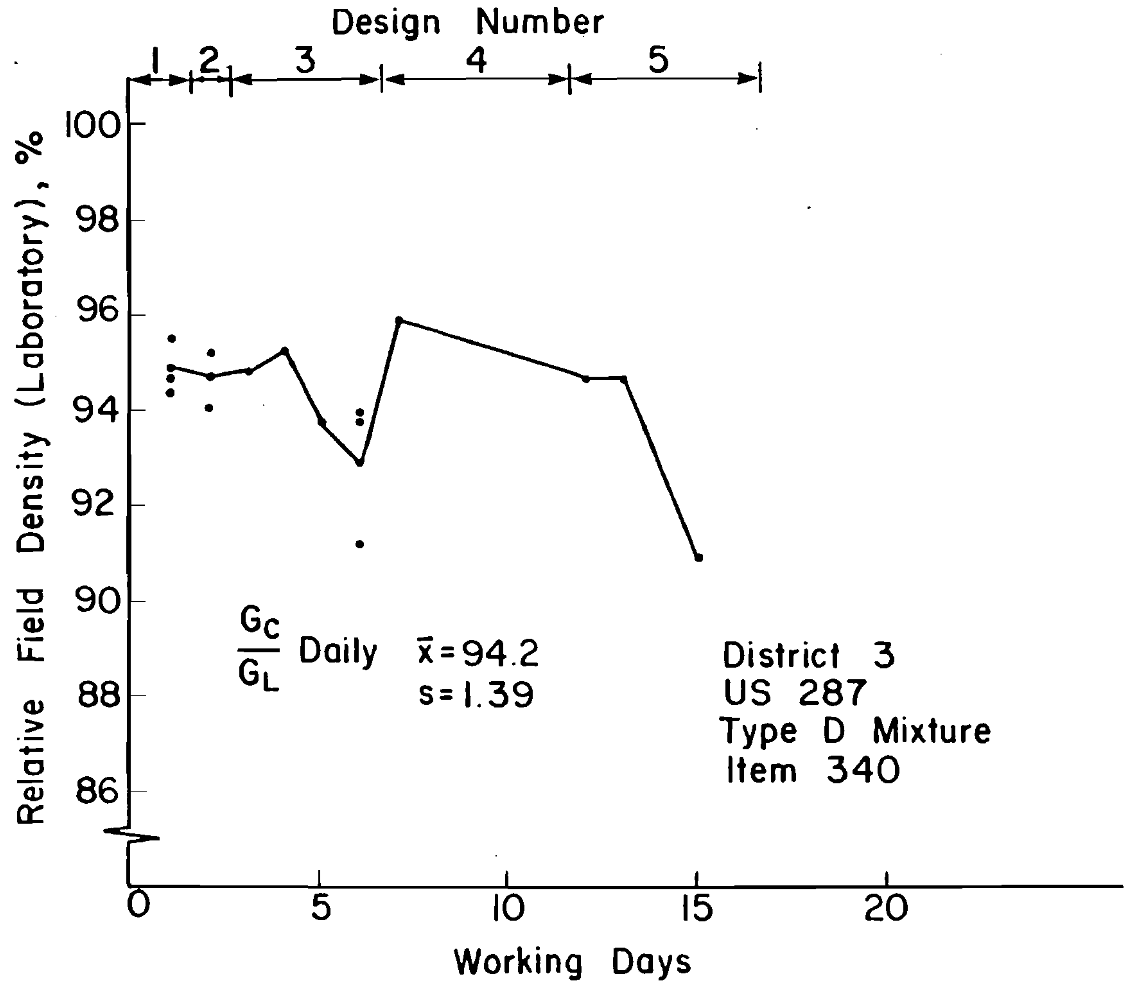


Figure E-2. Variation of relative field density (laboratory based) for project US 287, District 3, Type D mixture

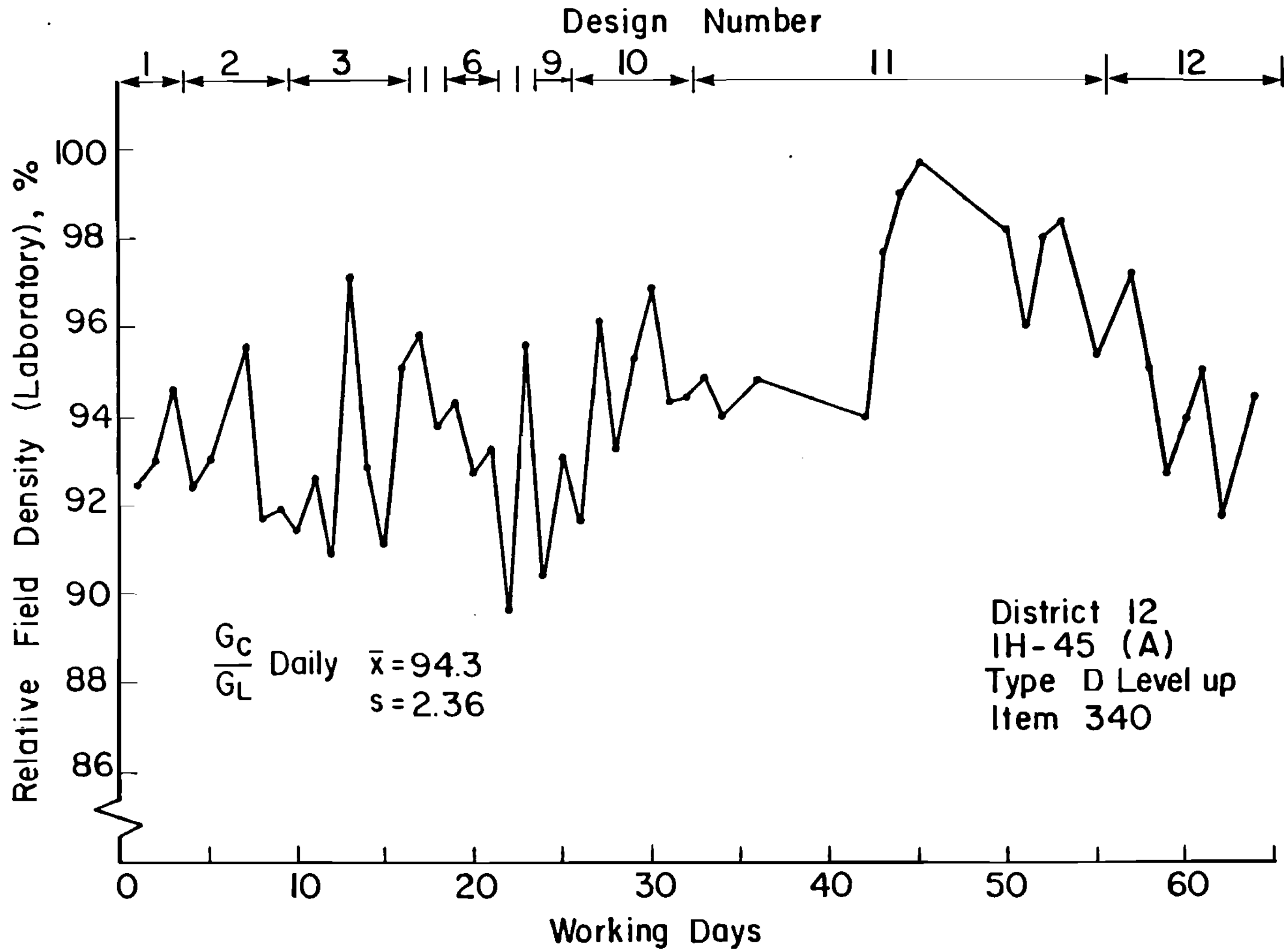


Figure E-3. Variation of relative field density (laboratory based) for project IH-45 (A), District 12, Type D level up

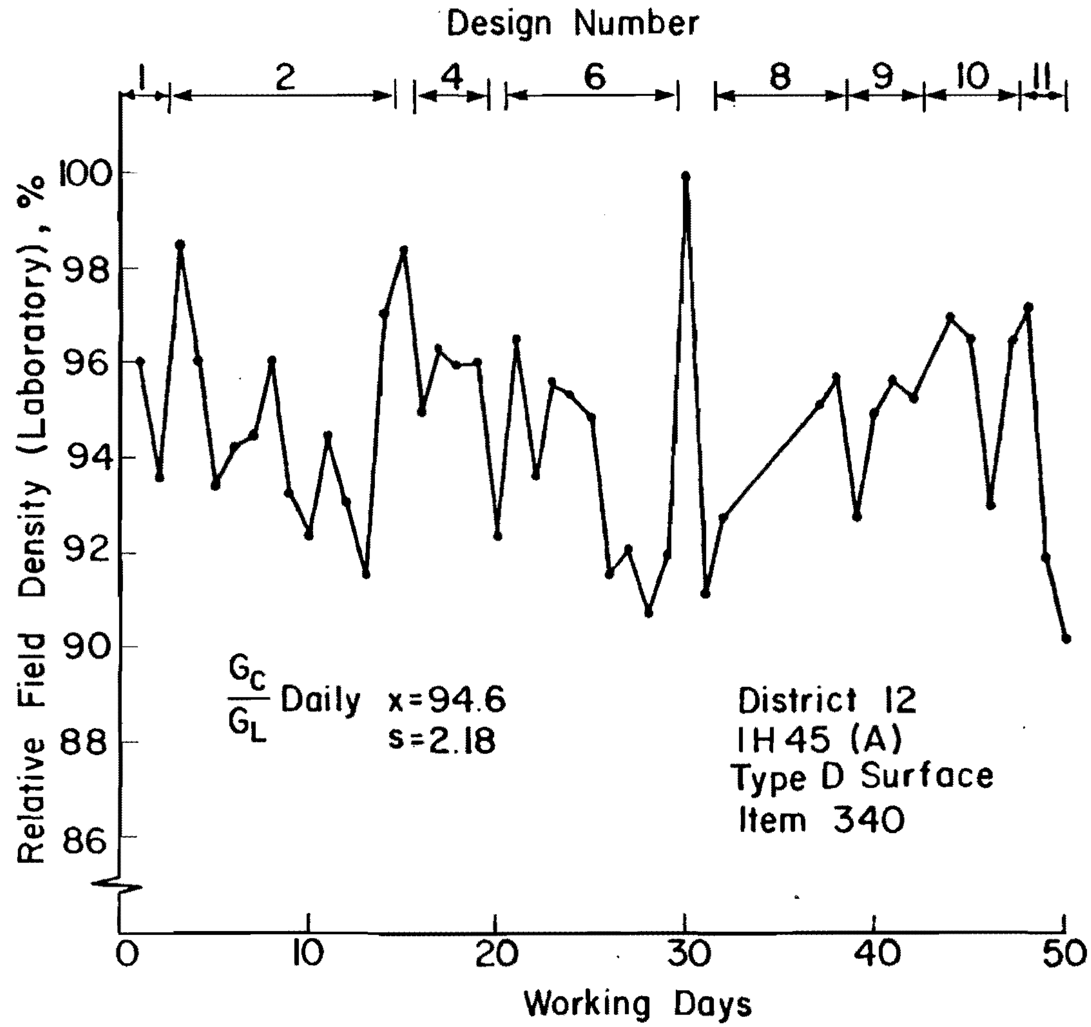


Figure E-4. Variation of relative field density (laboratory based) for project IH 45 (A), District 12, Type D surface

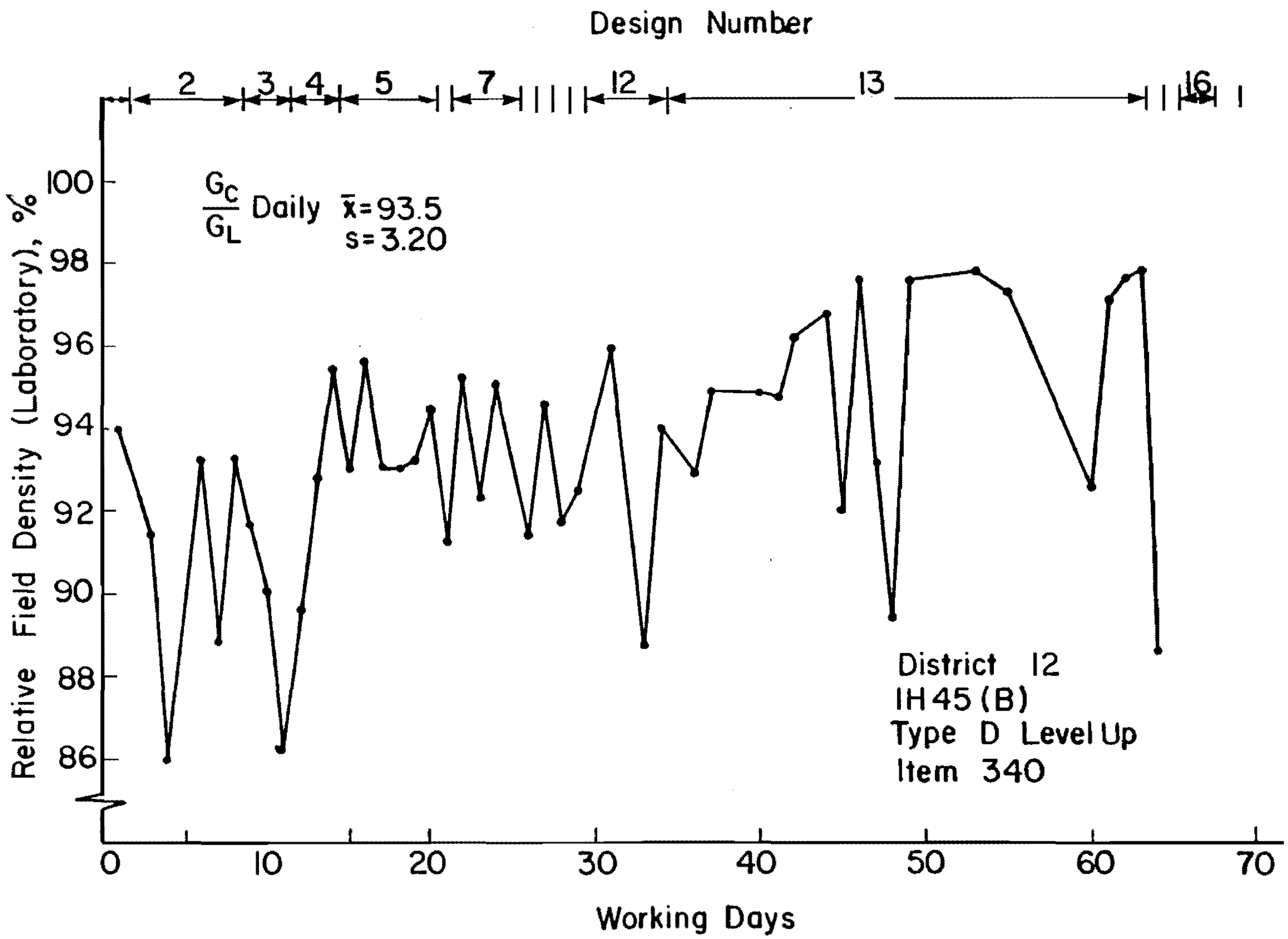


Figure E-5. Variation of relative field density (laboratory based) for project IH 45 (B), District 12, Type D level up

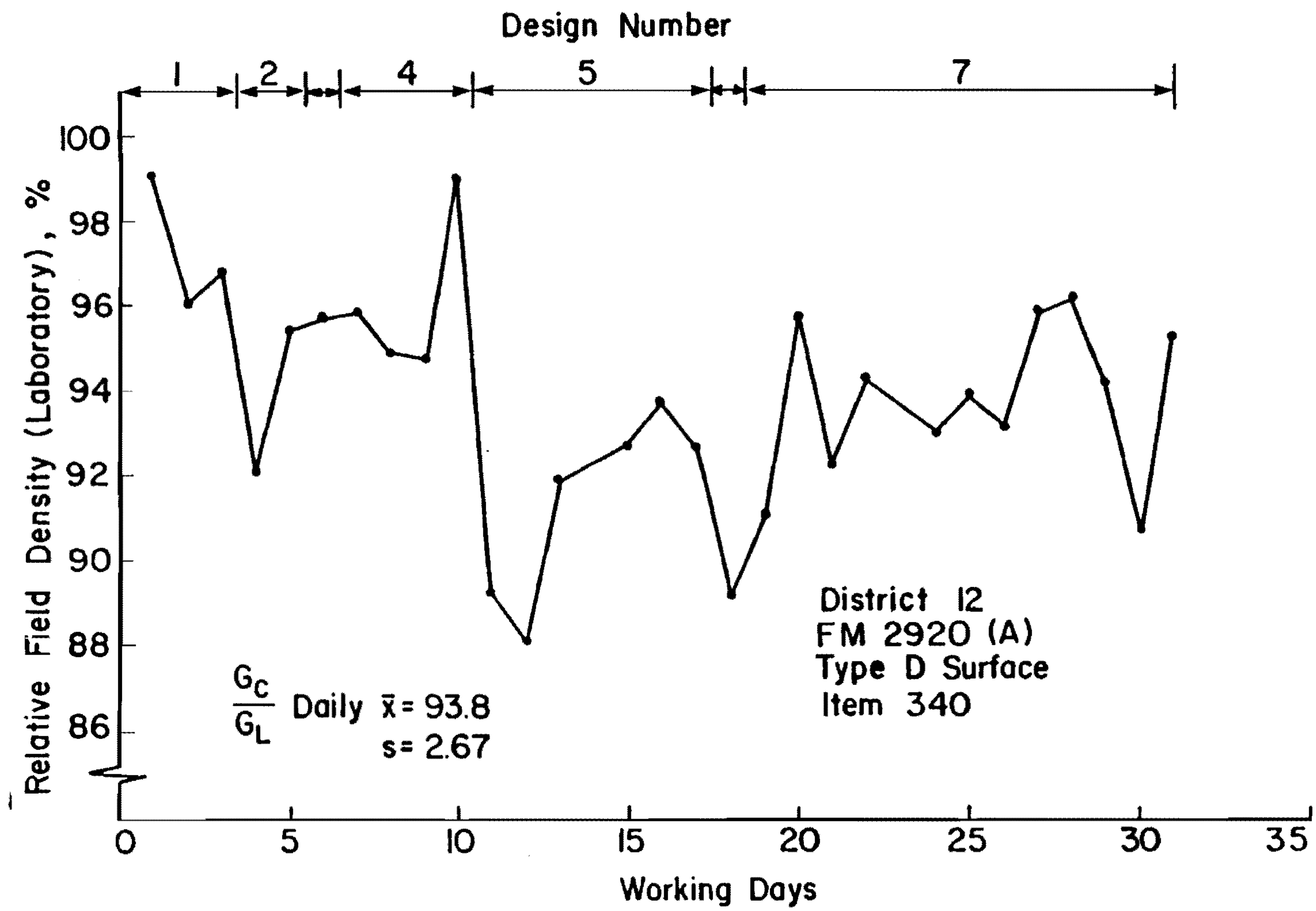


Figure E-6. Variation of relative field density (laboratory based) for project FM 2920 (A), District 12, Type D surface

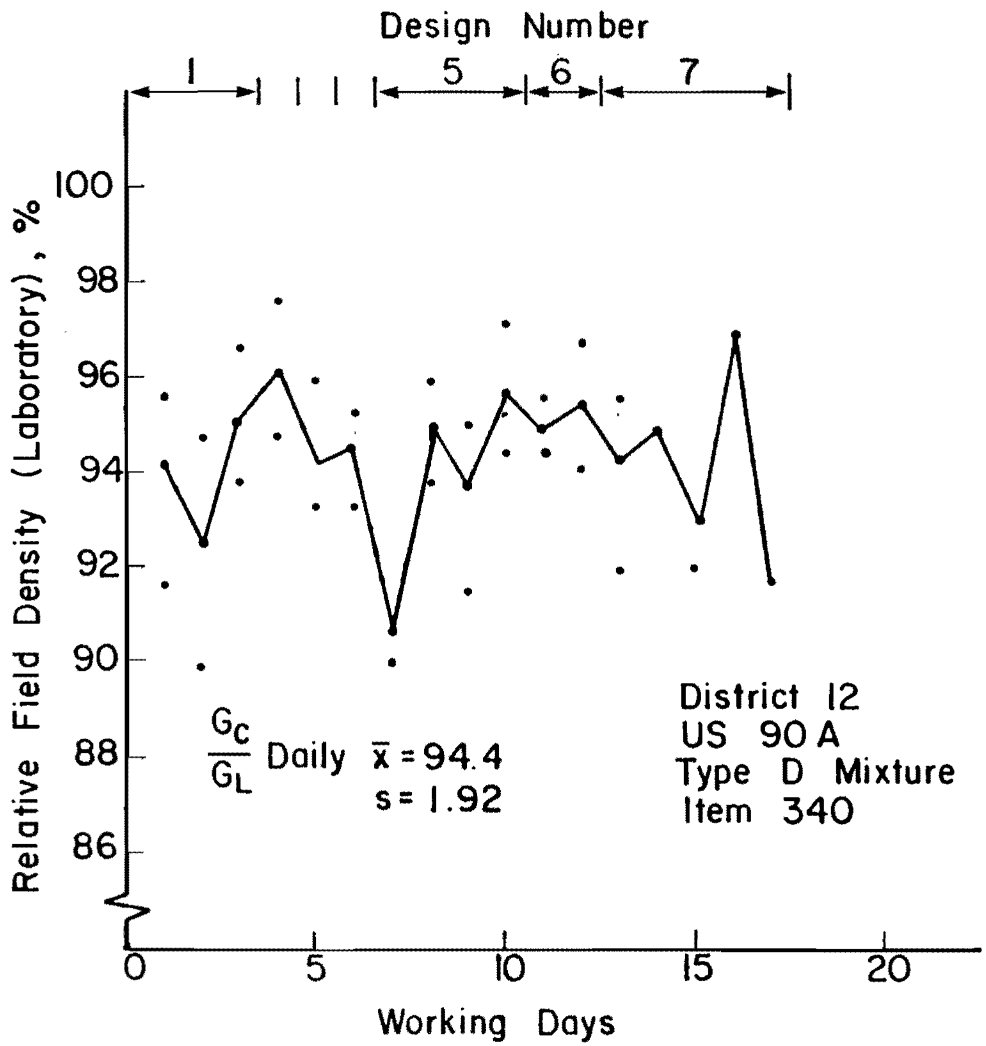


Figure E-7. Variation of relative field density (laboratory based) for project US 90A, District 12, Type D mixture

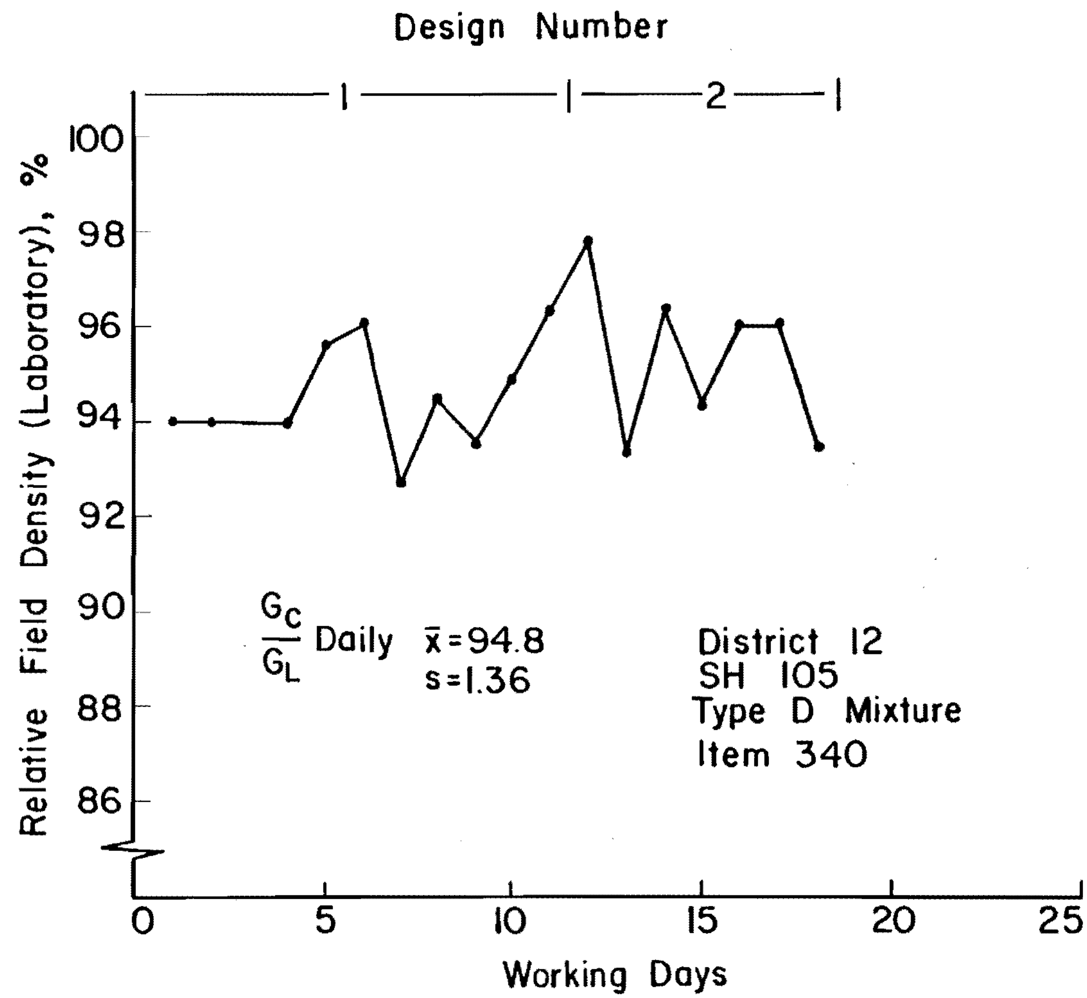


Figure E-8. Variation of relative field density (laboratory based) for project SH 105, District 12, Type D mixture

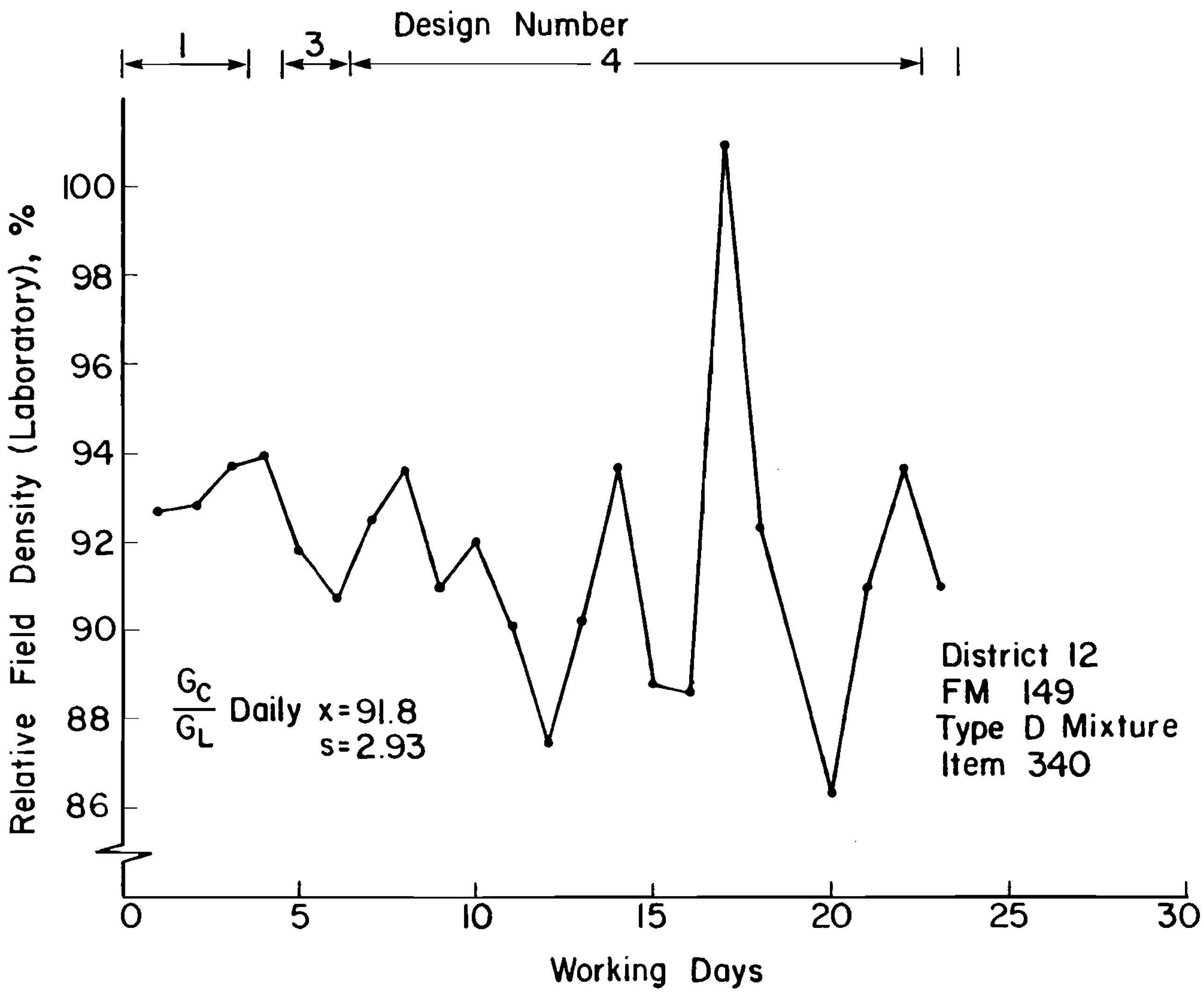


Figure E-9. Variation of relative field density (laboratory based) for project FM 149, District 12, Type D mixture

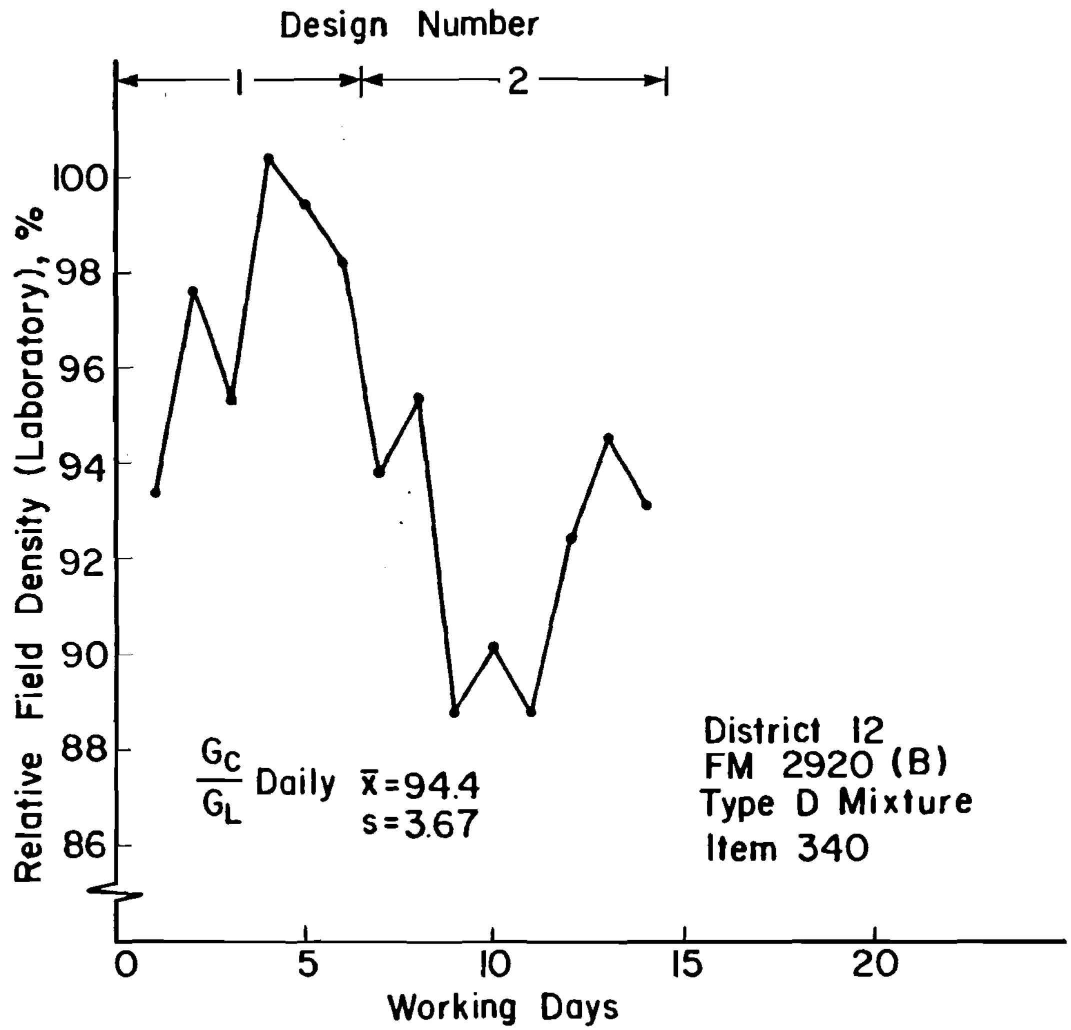


Figure E-11. Variation of relative field density (laboratory based) for project FM 2920 (B), District 12, Type D mixture

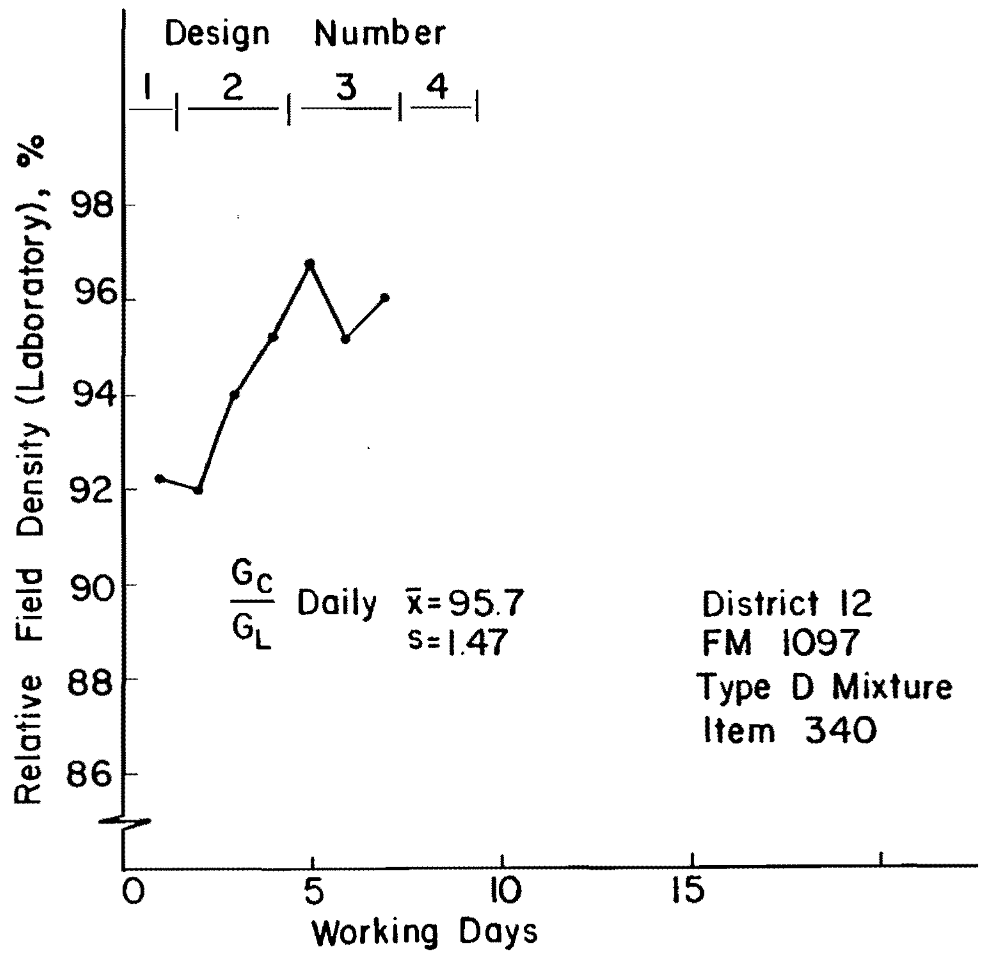


Figure E-10. Variation of relative field density (laboratory based) for project FM 1097, District 12, Type D mixture

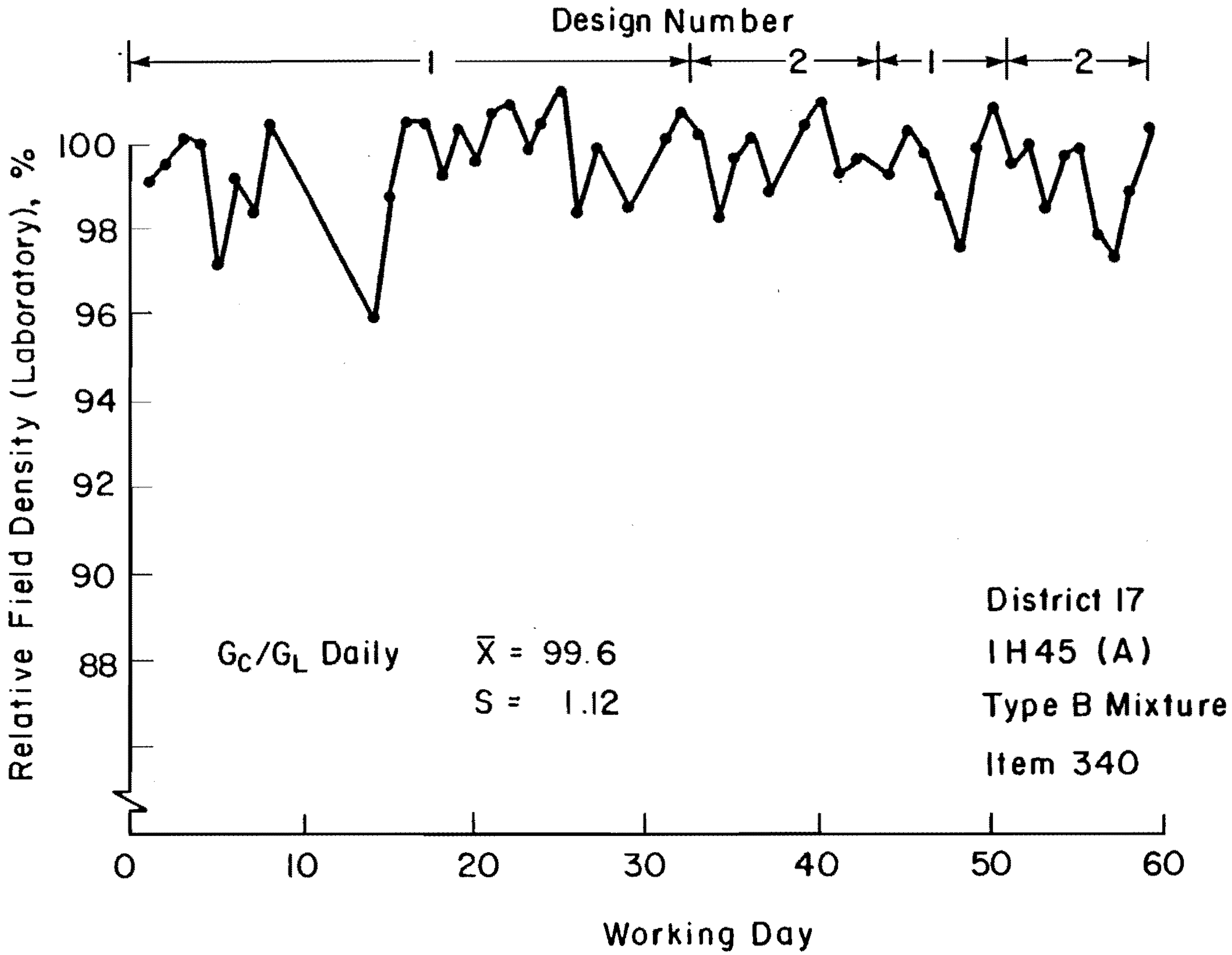


Figure E-12. Variation of relative field density (laboratory based) for project IH 45 (A), District 17, Type B mixture

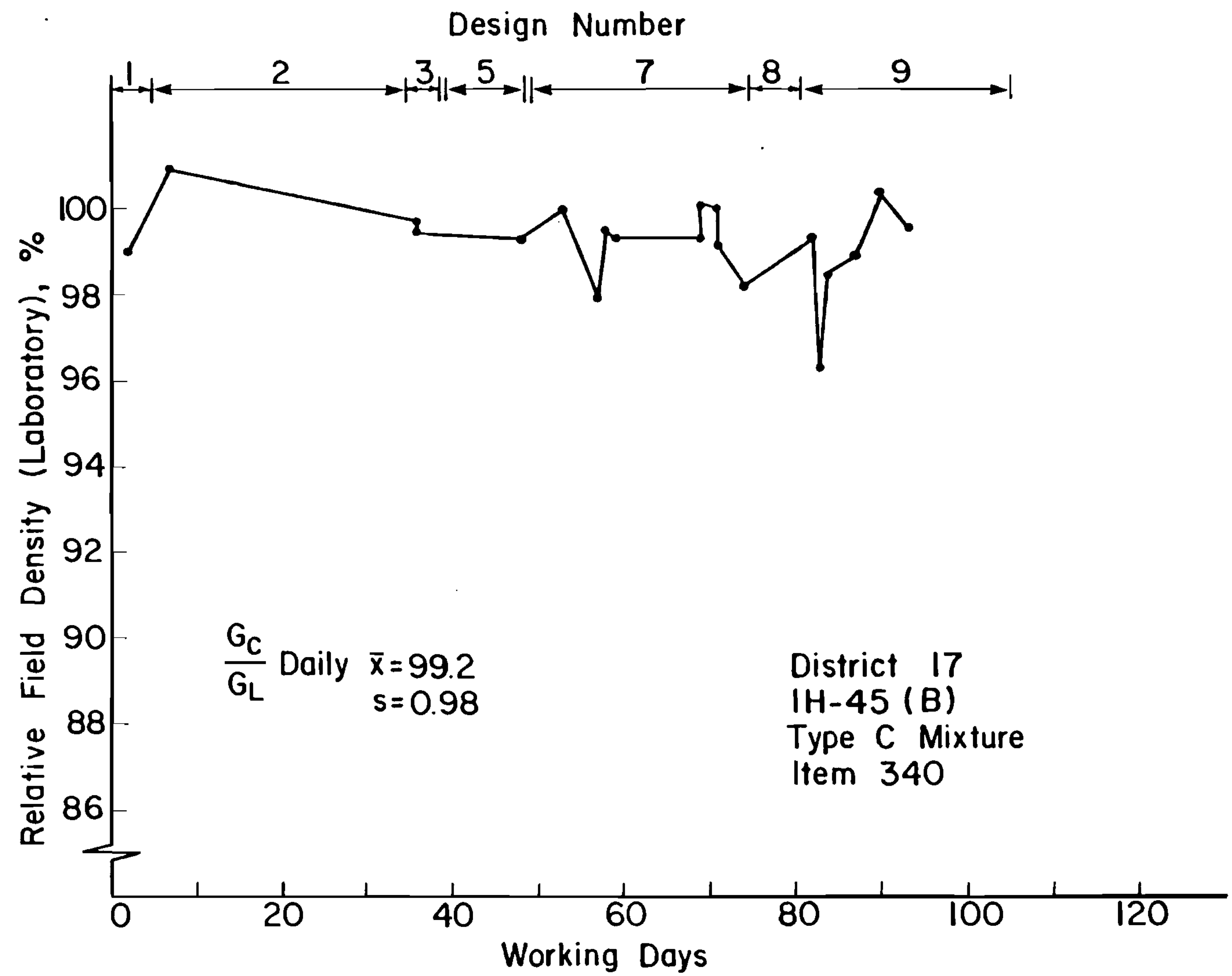


Figure E-13. Variation of relative field density (laboratory based) for project IH-45 (B), District 17, Type C mixture

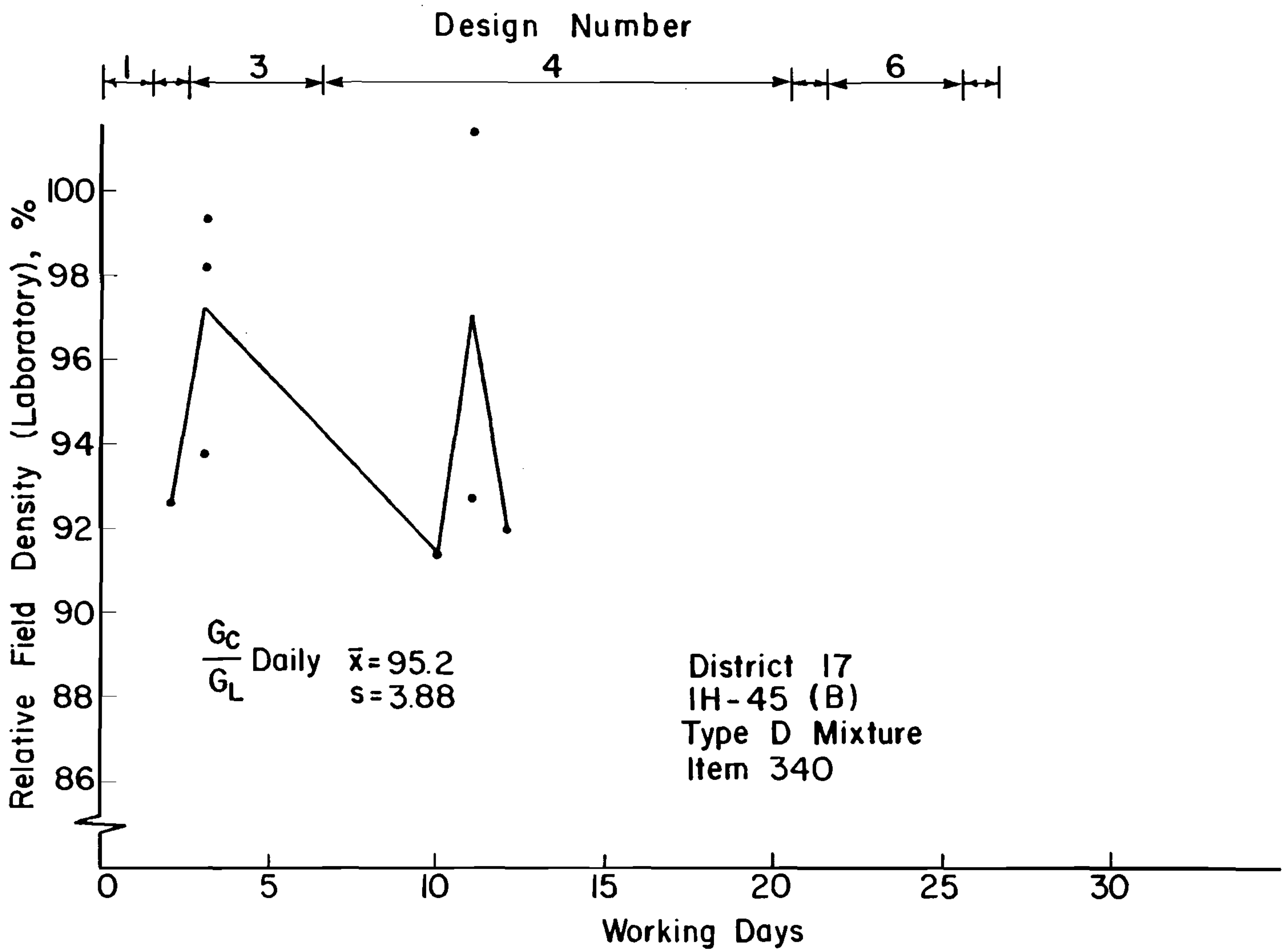


Figure E-14. Variation of relative field density (laboratoy based) for project IH-45 (B), District 17, Type D mixture

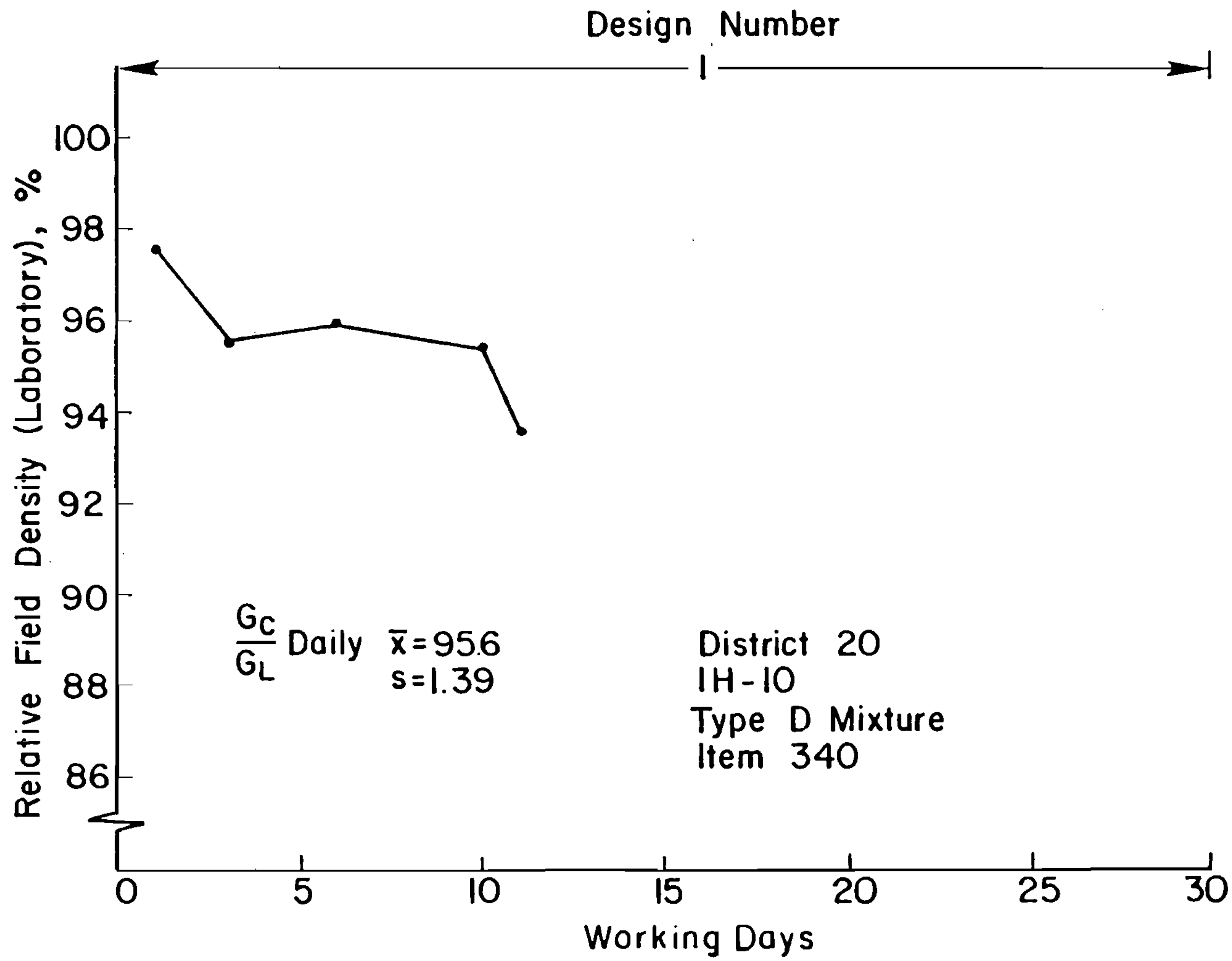


Figure E-15. Variation of relative field density (laboratory based) for project IH-10, District 20, Type D mixture

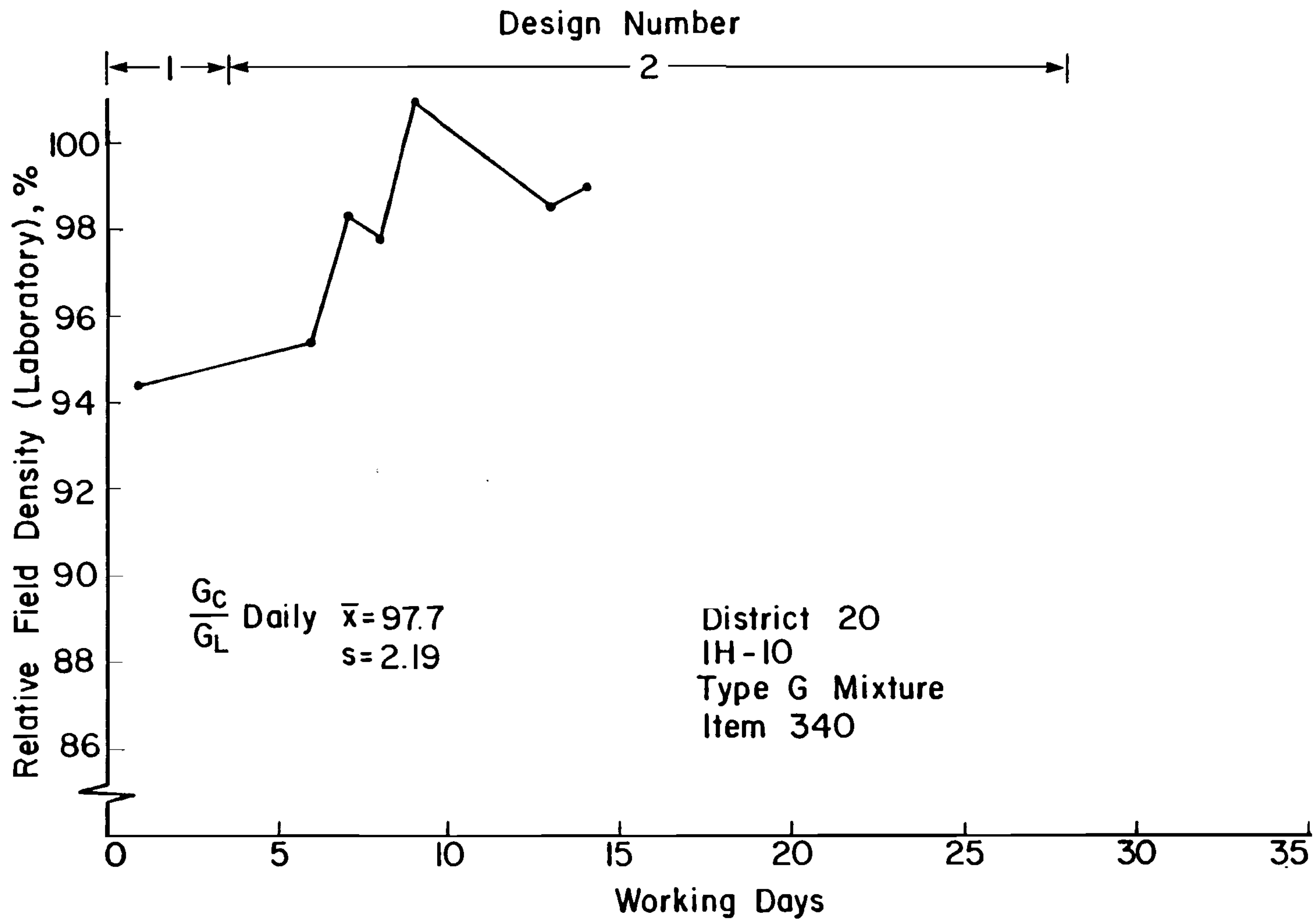


Figure E-16. Variation of relative field density (laboratory based) for project IH-10, District 20, Type G mixture

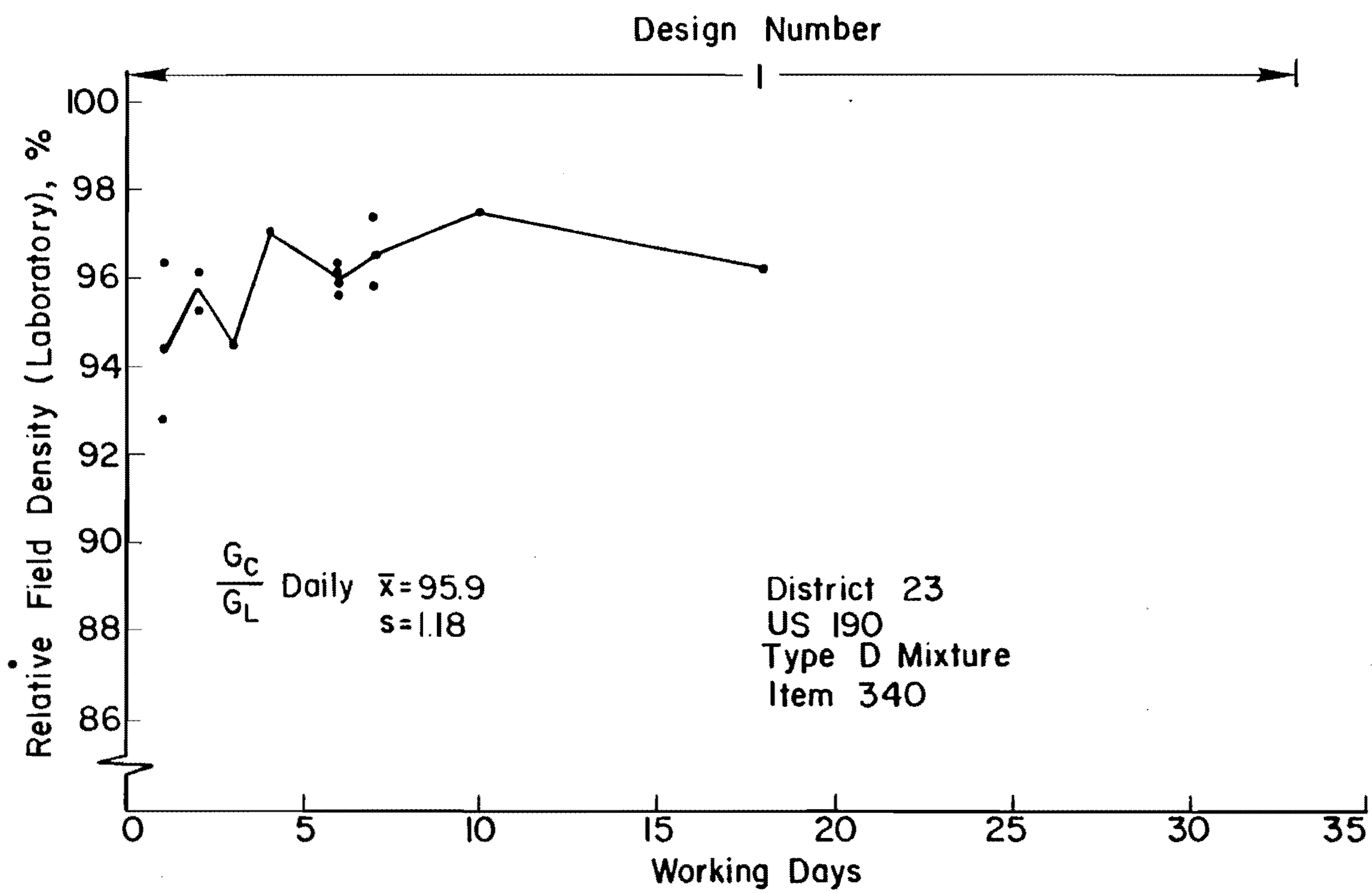


Figure E-17. Variation of relative field density (laboratory based) for project US 190, District 23, Type D mixture