

**Demonstration Project No. 59**

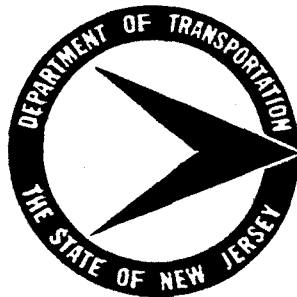
**EXPERIMENTAL LIME FLY ASH BASE COURSE,  
ROUTE I-295, MERCER COUNTY, NEW JERSEY**

**A Construction Report**

**APRIL, 1986**

**BY**

**VICTOR E. MOTTOLA  
PROJECT ENGINEER**



Prepared By  
New Jersey Department of Transportation  
Division of Research and Demonstration  
In Cooperation With  
U.S. Department of Transportation  
Federal Highway Administration

### DISCLAIMER STATEMENT

"The contents of this report reflect the views of the author(s) who is (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 New Jersey Department of Transportation or the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

1. Report No. FHWA/NJ-86-012-4712		2. Government Accession No.		3. Recipient's Catalog No.	
4. Title and Subtitle Demonstration Project No. 59, "Experimental Lime Fly Ash Base Course, Route I-295, Mercer Co., NJ" - A Construction Report				5. Report Date April, 1986	
				6. Performing Organization Code N.A.	
7. Author(s) Victor E. Mottola Project Engineer				8. Performing Organization Report No. 86-012-4712	
9. Performing Organization Name and Address New Jersey Department of Transportation Division of Research and Demonstration 1035 Parkway Avenue Trenton, NJ 08625				10. Work Unit No. (TRAIS) N.A.	
				11. Contract or Grant No. FHWA Grant Study 4712	
12. Sponsoring Agency Name and Address New Jersey Department of Transportation 1035 Parkway Avenue Trenton, NJ 08625				13. Type of Report and Period Covered Construction Report	
				14. Sponsoring Agency Code	
15. Supplementary Notes Prepared in cooperation with the Federal Highway Administration, U.S. Department of Transportation, Washington, D.C.					
16. Abstract  This report documents the design and construction phases of a demonstration project which utilized a plant-mixed lime-fly ash aggregate (LFA) material as a base course on Route I-295. Also described is the construction of a pavement of conventional design which will be used for performance comparisons over the next five years. Economic and energy utilization requirements for each of the pavement sections are provided. The specified four-hour time limit between mixing the LFA material and final compaction was found to be unnecessary. In addition, spreading the material with an asphalt paver instead of a jersey stone box was found to provide much better grade and segregation control. As a result, a revised specification allowing up to 24 hours before final compaction and requiring an asphalt paver for placing the LFA base has been issued. Coring results indicate that the material has exceeded the design strength and should perform as intended.					
17. Key Words  Fly Ash, Lime, Base Course, Construction			18. Distribution Statement  Copies available on request.		
19. Security Classif. (of this report) Unclassified		20. Security Classif. (of this page) Unclassified		21. No. of Pages	22. Price

## ACKNOWLEDGMENTS

In presenting this report, an expression of appreciation goes to the organizations and individuals who have given assistance and advice needed to complete this work.

The Federal Highway Administration has provided the financial means for performance of the research and has patiently awaited results. The FHWA's continued support and cooperation is gratefully acknowledged.

Thanks go to Mr. Frank Palise, Region III Materials Engineer for his interest and cooperation, and to Mr. David Boles of his staff who assisted in performing much of the testing in the field. In addition, the assistance of Mr. Kenneth Crosly, the Resident Engineer on the project and his inspection staff, is acknowledged.

Appreciation is expressed to Messrs. Hap Snover and Alan Van Gelder of the Limestone Products Corporation for their interest, help, and technical expertise during the research.

The author would also like to express special thanks to Research's secretarial staff and in particular, Ms. Jayne Karney, whose assistance in formatting and preparing this report was invaluable.

## Table of Contents

	<u>Page</u>
INDEX OF FIGURES .....	v
INDEX OF TABLES .....	vi
PART ONE: INTRODUCTION	
1.1 Objective .....	1
1.2 Background .....	1
1.3 Project Description .....	3
PART TWO: PAVEMENT DESIGN	
2.1 Climate .....	6
2.2 Design Traffic Data .....	6
2.3 Roadway Geometry .....	6
2.4 Pavement Section .....	8
PART THREE: LFA BASE COURSE MATERIALS	
3.1 Fly Ash .....	9
3.2 Lime .....	10
3.3 Aggregate .....	10
PART FOUR: LFA BASE COURSE MIX DESIGN AND PRODUCTION	
4.1 General .....	12
4.2 Design Verification Test Results .....	12
4.3 Production .....	13
PART FIVE: CONSTRUCTION	
5.1 Subgrade .....	17
5.2 Subbase .....	17
5.3 LFA Base Course .....	18

Table of Contents (continued)

	<u>Page</u>	
<b>PART SIX: FIELD AND LABORATORY TESTS</b>		
6.1 Unconfined Compression Tests .....	25	
6.2 Coring Results .....	25	
6.3 Nuclear Moisture Density Measurements.....	27	
<b>PART SEVEN: ENERGY REQUIREMENT ANALYSIS .....</b>		<b>28</b>
<b>PART EIGHT: COST OF ALTERNATE MATERIALS.....</b>		<b>31</b>
<b>PART NINE: CONCLUSIONS AND RECOMMENDATIONS</b>		
9.1 Conclusions .....	33	
9.2 Recommendations .....	34	
<b>PART TEN: REFERENCES.....</b>		<b>35</b>
<b>APPENDICES</b>		
A. Pavement Design Calculations .....	36	
B. Soil Aggregate and Bituminous Concrete Specification and Description.....	47	
C. LFA Specifications .....	50	
D. Laboratory and Field Test Results .....	71	
E. Calculations for Energy Consumption.....	85	

## Index of Figures

<u>Figure No.</u>		<u>Page</u>
1	Project Location .....	4
2	Plan View of Project.....	5
3	Typical Cross Section .....	7
4	LFA Plant at Sparta, New Jersey .....	14
5	Storage Silos for Fly Ash and Lime.....	14
6	Weigh Belt Feeder for Metering Lime .....	15
7	Pugmill for Mixing LFA .....	15
8	Portion of Computerized Controls on Mixing Plant.....	16
9	Discharge Shoot on Plant .....	16
10	Subbase Preparation Prior to Placing LFA Material .....	20
11	Constructing the Control Strip Using a Jersey Spreader Box.....	20
12	Close up of the Jersey Spreader Box .....	21
13	Compacting the Control Strip.....	21
14	Close up View of the LFA Material .....	22
15	Checking Density with a Troxler Nuclear Density Gauge .....	22
16	Keeping the LFA Moist Prior to Application of Cure Coat.....	23
17	Application of RC-30 Cure Coat.....	23
18	Completed LFA Material with Cure Coat .....	24
19	Overview of Roadway .....	24
20	Unconfined Compressive Strength Curves.....	26

Index of Tables

<u>Table No.</u>		<u>Page</u>
1	Pavement Sections .....	8
2	Fly Ash Test Results .....	10
3	LFA Base Course Aggregate Gradation .....	11
4	Mix Design Proportions.....	12
5	Compressive Strength Results .....	25
6	LFA Core Strengths .....	27
7	Energy Requirements .....	29
8	Bid Prices for Pavement Materials.....	31
9	Material Costs/Yd <sup>2</sup> .....	32
 <u>Appendix B</u>		
B1	Soil Aggregate Gradations .....	48
B2	Grading Requirements for Bituminous Concrete .....	49
 <u>Appendix D</u>		
D1	Soil Gradations from Experimental Sections.....	72

## PART ONE: INTRODUCTION

### 1.1 OBJECTIVE

This report documents the construction phase of a study designed to evaluate the design, construction and performance of a roadbase material utilizing fly ash and hydrated lime as stabilizing agents. The study is intended to provide a basis for a critical evaluation of New Jersey's existing specification for Aggregate Lime-Pozzolan Stabilized Base, as well as, a determination of needed improvements in the design methods and construction techniques for lime fly ash (LFA) bases. Overall performance, under traffic, of a section of roadway incorporating the LFA base will be compared to a control section of conventional construction for a period of five years.

### 1.2 BACKGROUND

In recent years there has been an increased awareness of the need to conserve resources and energy. As one step toward this end, in 1976, Congress passed the Resource Conservation and Recovery Act (RCRA) which directed public officials to make a sincere effort to utilize waste products as construction materials whenever possible.

Numerous waste and/or by-products from various industrial processes have been proposed for use as construction materials. Environmental Protection Agency consultants, hired under the provisions of the RCRA to investigate the potential use of various waste products, targeted fly ash as one of the most promising materials to recycle and to demonstrate in applications of highway construction. They concluded that in the highway construction area, not only can large quantities of fly ash be used, but also that the use of the materials can result in significant cost and energy savings.<sup>(1)</sup>

To promote the use of fly ash on federally participating transportation projects, the Federal Highway Administration organized Demonstration Project No. 59. The intent of this demonstration project is to provide funding both for the purchasing of fly ash and for the evaluation of the performance of highway materials containing fly ash.

Fly ash is a material recovered from the flue gases of the coal combustion processes. The majority of fly ash is obtained from coal-fired electric generation stations. Nationwide, some 51 million tons of this material is collected and must be disposed of each year.

The property of fly ash which makes it attractive for highway applications is its pozzolanic nature, which means that in the presence of lime and moisture, cementitious compounds are produced. The ability to form these cementitious products encourages the use of fly ash as a stabilizing agent in soil stabilization techniques and as a partial replacement for portland cement in concrete.

The use of fly ash as a stabilizing agent in New Jersey is not new. As far back as the early 1950s, stabilization of soil bases was attempted with lime-fly ash materials. These early attempts at field mixing stabilization products yielded mixed results, often times due to poor quality materials and/or construction techniques. Furthermore, since little testing or documentation was performed, it was often impossible to obtain satisfactory reasons for the problems. This demonstration study, however, is designed as a controlled experiment on an interstate roadway with adequate testing, documentation, and performance monitoring scheduled.

In conjunction with this study on the use of fly ash in a base course, New Jersey is currently conducting a broad-based research project funded with FHWA-HPR monies titled "Pavement Stabilization Methods". This research will utilize results of both field installation and extensive laboratory testing, to

provide more definitive answers to questions in materials, construction techniques, optimum mix design procedures, construction cut-off dates, and economic and performance potentials for various forms of stabilization. A Phase I report<sup>(2)</sup> of this study has already indicated that in addition to utilizing waste products, substantial cost savings over conventional designs can be realized when constructing pavements incorporating lime-fly ash bases.

In addition to these two studies, New Jersey is also conducting additional research, under Demonstration Project No. 59, on the use of fly ash in portland cement concrete. The sum of this research demonstrates New Jersey's commitment to both environmental issues, as well as, to providing the most cost-effective transportation facilities possible.

### 1.3 PROJECT DESCRIPTION

A portion of Route I-295, Section 7C (new construction) was redesigned to include a plant-mixed LFA base as a complete replacement for the dense graded aggregate base and partial replacement for the bituminous-stabilized base course used elsewhere on the project.

The Section 7C project is 1.3 miles in length and is located in Mercer County, Hamilton Township, New Jersey, from north of Kuser Road to south of Arena Drive. Mercer County is located on the Delaware River in Central New Jersey (see Figure 1). Originally slated for construction in August of 1983, various delays forced postponement of the completion of the LFA base until the fall of 1984.

As shown in Figure 2, the experimental LFA base test section is located on the southbound lanes between Stations 609 and 628 + 36 (1936'). The adjacent northbound lane will be used as a control in subsequent performance evaluations.

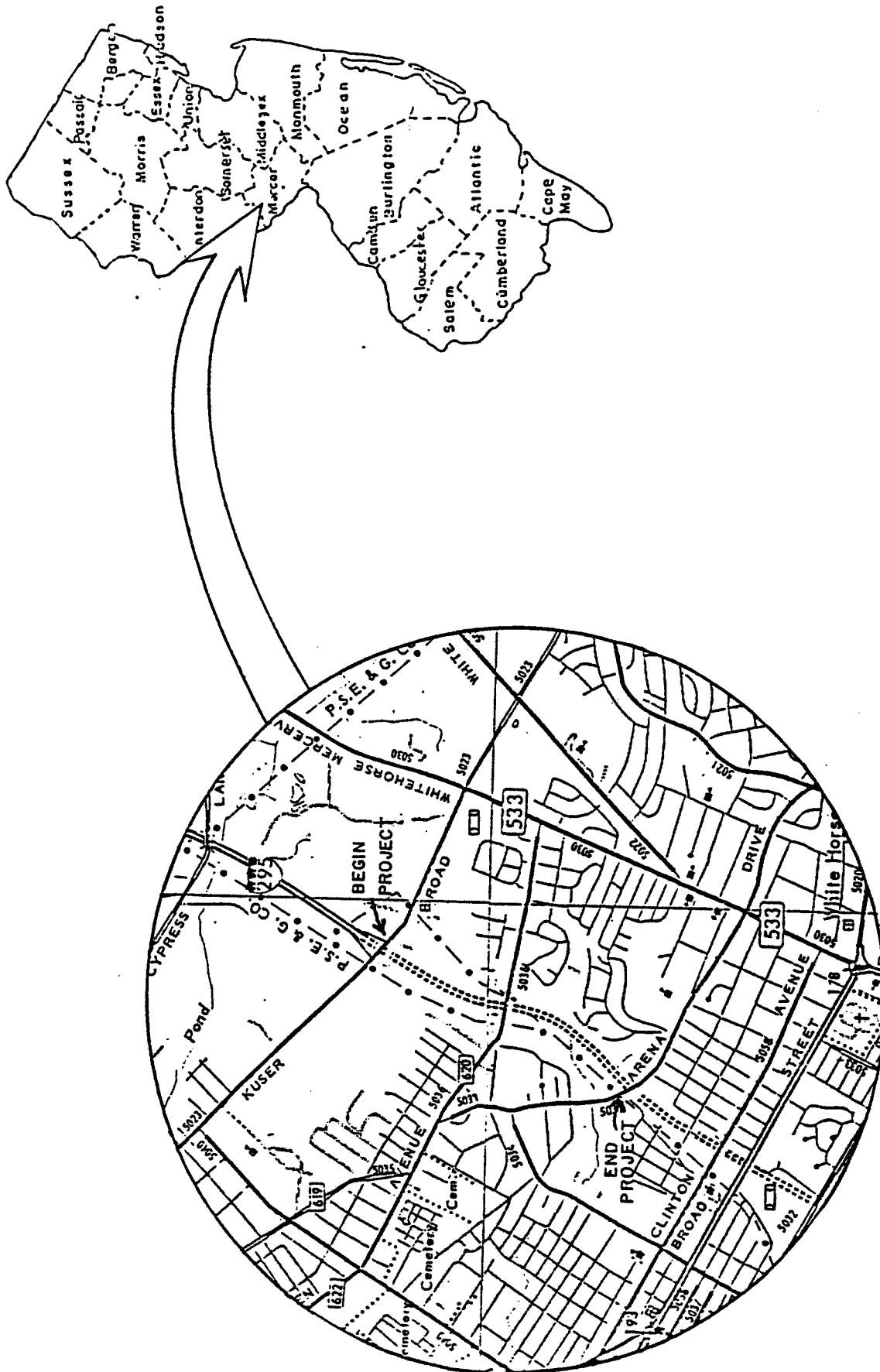


FIGURE 1 - PROJECT LOCATION

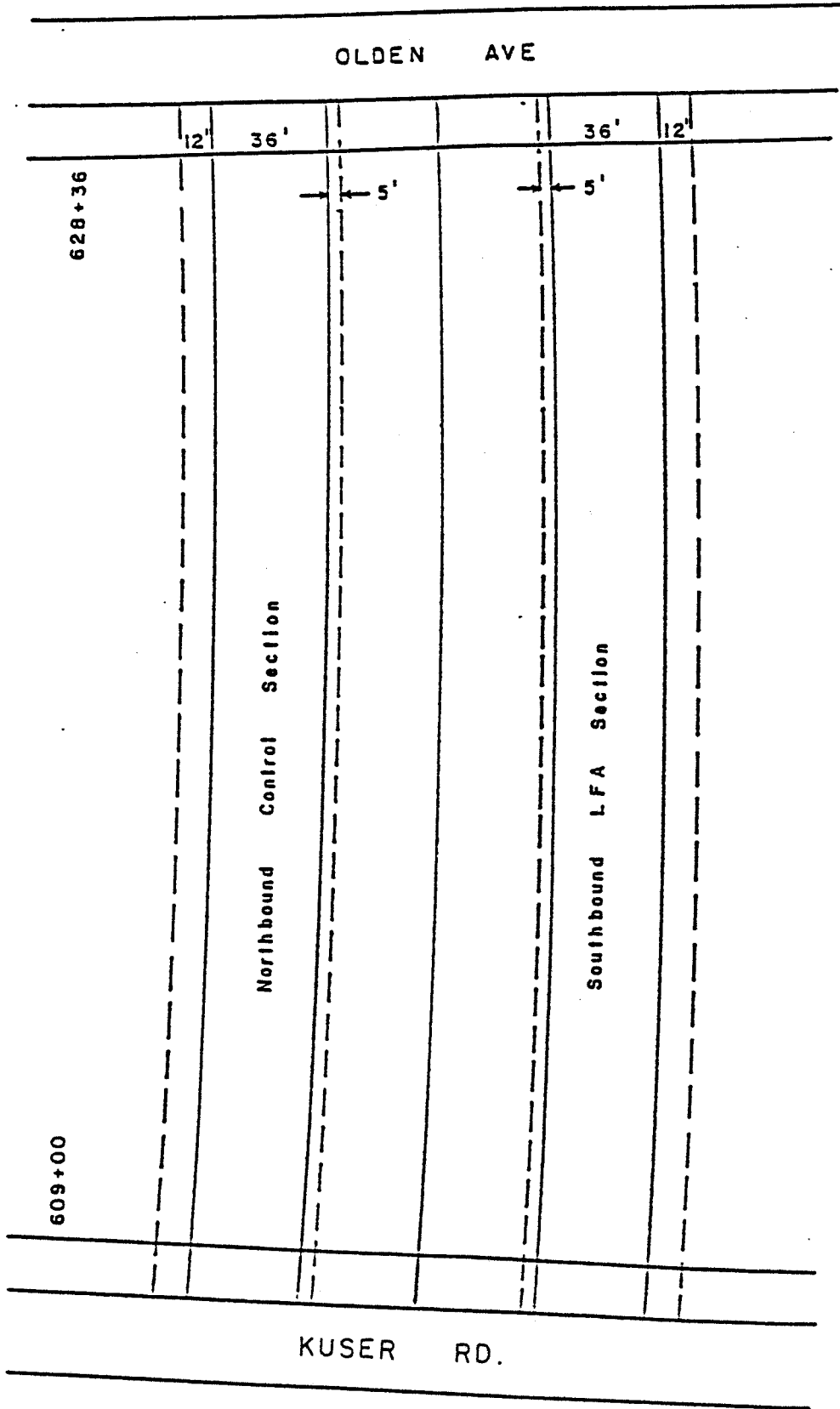


Figure 2  
PLAN VIEW OF PROJECT

## PART TWO: PAVEMENT DESIGN

### 2.1 CLIMATE

The climate in the vicinity of the test project is relatively mild, being moderated by the Appalachian Mountains to the west and the Atlantic Ocean to the east. Temperatures below 0 and above 100°F are relatively rare. The average January temperature is 32.2°F; the July temperature averages 71.8°F. The yearly average ambient temperature is 51.8°F. Maximum frost penetration ranges from 26 to 28 inches.

Precipitation is fairly evenly distributed throughout the year, with the maximum amounts occurring during the late summer months. Most of the summer precipitation is in connection with localized thunderstorms. Snowfall occurs infrequently, with single storms of 10 inches or more occurring about every five years. Total average annual precipitation is 39 inches.<sup>(3)</sup>

### 2.2 DESIGN TRAFFIC DATA

The average daily traffic (one-way ADT) used for the pavement design is as follows:

<u>Year</u>	<u>Volume (VPD)</u>
1984	11,770
2000	35,000

The anticipated truck volume is 18% and design speed is 70 mph.

### 2.3. ROADWAY GEOMETRY

The roadway consists of three 12' lanes in each direction with 12' outside shoulders and 5' inside shoulders, as shown in Figure 3. The control and experimental sections of the project are located on a 1.25% vertical upgrade

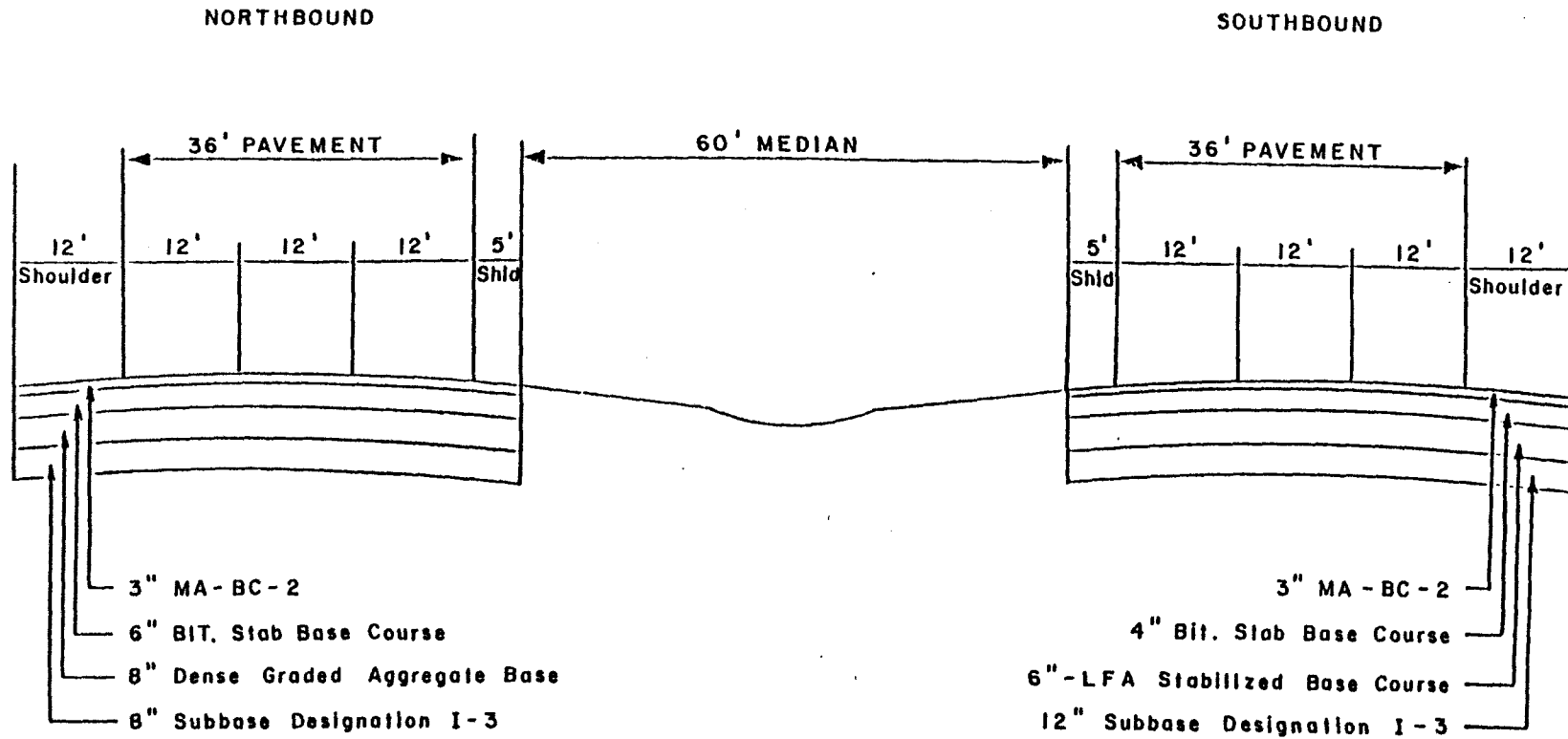


Figure 3  
TYPICAL CROSS SECTION

beginning in an 8' cut at Station 609 + 00 and rising to a 25' fill at Station 628 + 36.

#### 2.4 PAVEMENT SECTION

The pavement section was designed using the AASHTO Interim Guide with a regional factor of 1.5 and a terminal serviceability index of 2.5.

Based on the calculations shown in Appendix A, a structural number (SN) of 5.8 was selected as the target for the thickness design.

Table 1 shows the design sections selected for the 25" thick experimental and control sections of the project. (The mainline section was carried through the shoulder.)

Table 1: Pavement Sections

<u>Test Section</u>	<u>SN</u>	<u>Control Section</u>	<u>SN</u>
3" MABC*	1.32	3" MABC	1.32
4" Bit. Stab. Base Course	1.76	6" Bit. Stab. Base Course	2.64
6" LFA	1.98	8" Dense Graded Agg. Base	1.12
12" Subbase (I-3)	.96	8" Subbase (I-3)	.64
SN =	<u>6.02</u>	SN =	<u>5.72</u>

\*See Appendix B for a description and specification for each of the materials listed.

## PART THREE: LFA BASE COURSE MATERIALS

### 3.1 FLY ASH

Fly ash for the project was obtained from the Metropolitan Edison Company's electric generating station in Portland, Pennsylvania. Fly ash used for stabilization in New Jersey must conform to ASTM C-593 with the following modifications:

Loss on ignition less than 10%

Combined Silica ( $\text{SiO}_2$ ) and Aluminum Oxide ( $\text{Al}_2\text{O}_3$ ) greater than 60%

Moisture content less than .5%

The last requirement insures that only dry powdered fly ash will be used for stabilization purposes. The use of dry fly ash allows for more precise metering of the material into the mix than is normally obtainable with conditioned (wet) fly ashes and it keeps the fly ash in a reactive state until it is used in the mix. In addition, dry fly ash allows a more intimate blending with the hydrated lime, which appears at this time to yield better strength results than those obtained with conditioned fly ash. Table 2 provides the results of the chemical and physical tests on the fly ash used on the project.

Table 2: Fly Ash Test Results

Physical Analysis

Source - Portland Pennsylvania

Moisture Content	.10%
Loss on Ignition	3.6%
Specific Gravity	2.23%
Fineness	17.4% retained on #325 sieve

Chemical Analysis

Silica Dioxide	45.1%	
Aluminum Oxide	24.4%	92.1%
Iron Oxide	20.6%	
Sulfur Trioxide	1.0%	

3.2 LIME

Hydrated lime used in the LFA mix was a di-hydrate lime supplied by the Warner Company of Devault, Pennsylvania. The lime conformed to ASTM C-207 Type N. The combined calcium oxide (CaO) + magnesium oxide (MgO) was 93%. The moisture content was .4%.

3.3 AGGREGATE

The aggregate used in the mix was obtained from Limestone Products Corporation and was a high calcium crushed limestone. In order to meet the aggregate specification requirements for the LFA, #57 (3/4" stone) and #10 (screenings) were mixed together in a 1 to 1 ratio. The gradation of the individual constituents and the final product are shown in Table 3.

Table 3: LFA Base Course Aggregate Gradation

<u>Sieve Size</u>	<u>Percent Passing</u>			<u>Specification Limits</u>
	<u>#57 Stone</u>	<u>#10 Stone</u>	<u>Job Mix Formula</u>	
1½"	100	100	100	100
¾"	64.6	100	82.3	55 - 90
#4	4.5	75.3	40.0	25 - 60
#8	3.0	53.4	28.2	---
#50	---	17.7	8.9	5 - 25
#200	---	8.0	4.0	3 - 12

PART FOUR: LFA BASE COURSE MIX DESIGN AND PRODUCTION

4.1 GENERAL

The mixture design criteria for percentages of lime and fly ash in the mix was established in accordance with the New Jersey Department of Transportation specification for Aggregate-Lime-Pozzolan Stabilized Base Course. The mix design procedures, along with the test results submitted by the supplier, are included with the specifications for the project in Appendix C.

4.2 DESIGN VERIFICATION TEST RESULTS

Specifications required a minimum average design strength of 950 psi for LFA samples prepared in accordance with ASTM C-593 Part 8 and cured for 28 days at 100°F. Table 4 shows the actual mix design as submitted by the contractor. Verification tests performed by the New Jersey Department of Transportation laboratory yielded unconfined compressive strengths averaging 1125 psi and vacuum saturation test results of 1179 psi.

Table 4: Mix Design Proportions

<u>Material</u>	<u>Percent of Total Dry Mix</u>
Lime	2%
Fly Ash	6%
Fine Aggregate (#10 stone)	46%
Coarse Aggregate (#57 stone)	46%
Optimum Moisture Content	6.6%

#### 4.3 PRODUCTION

The LFA base course was produced by Limestone Products Corporation at their Sparta, New Jersey plant. This facility is a continuous mix pugmill plant with a capacity of 350 tons per hour. The plant consists of two aggregate bins, two fly ash silos, and a lime silo. Automated weigh scales are located on the aggregate and lime feed belts. Fly ash is weigh batched in small quantities, then metered with a Synco flow screw onto the feed belts. The system includes an interlock with the main feed belt to the mixer assuring accurate proportioning of each ingredient. Water is added to the material at the pugmill during the mixing operation. (See Figures 4 thru 9.)

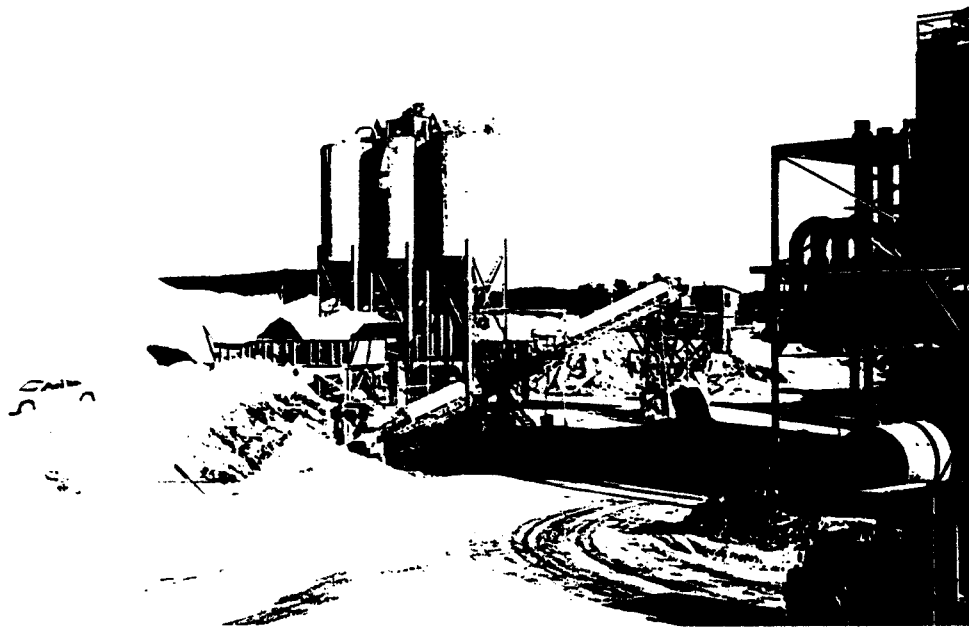


FIGURE 4. LFA Plant at Sparta, New Jersey



FIGURE 5. Storage Silos for Fly Ash and Lime

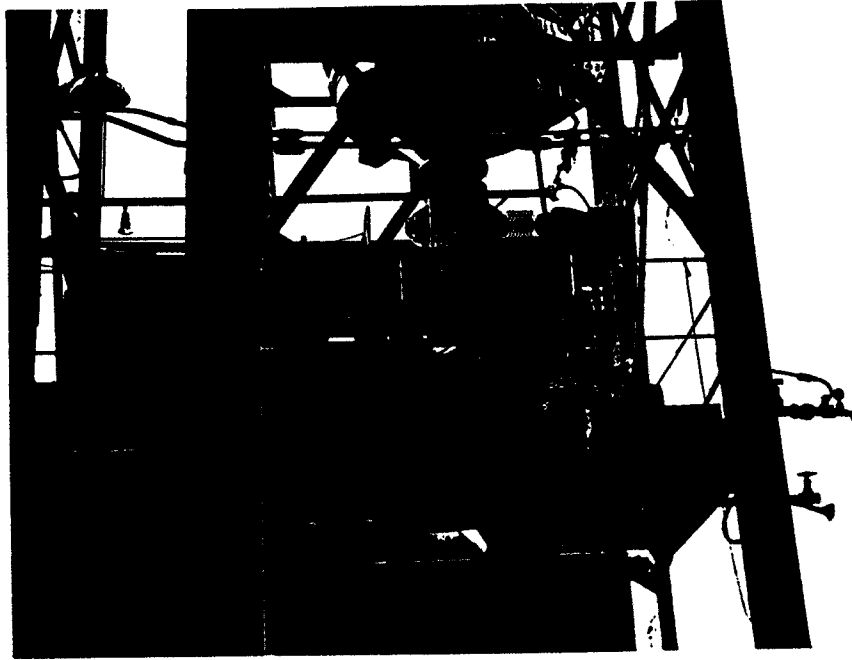


FIGURE 6. Weigh Belt Feeder for Metering Lime

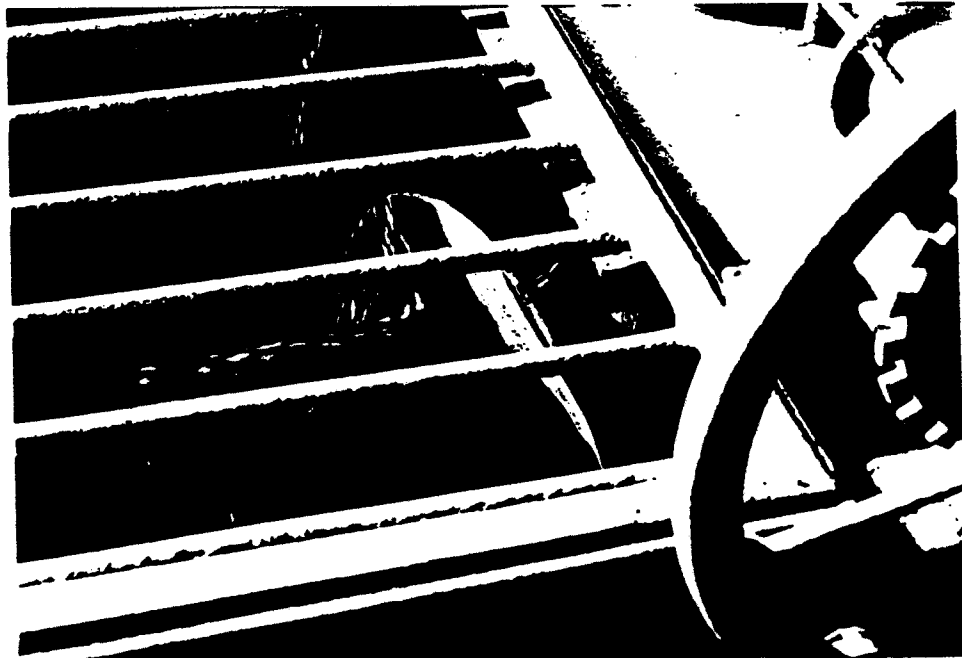


FIGURE 7. Pugmill for Mixing LFA

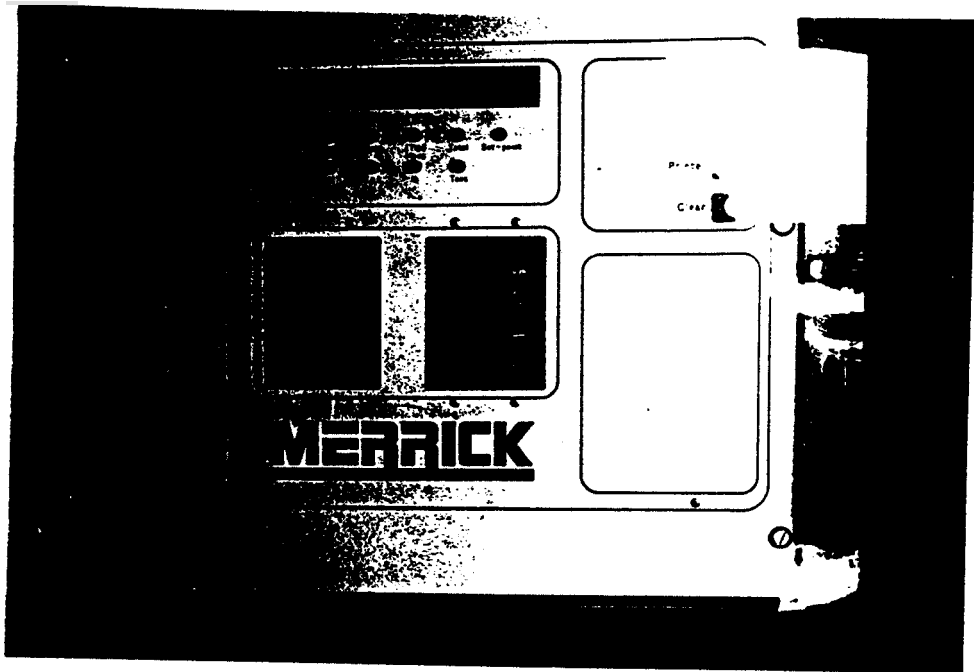


FIGURE 8. Portion of Computerized Controls on Mixing Plant

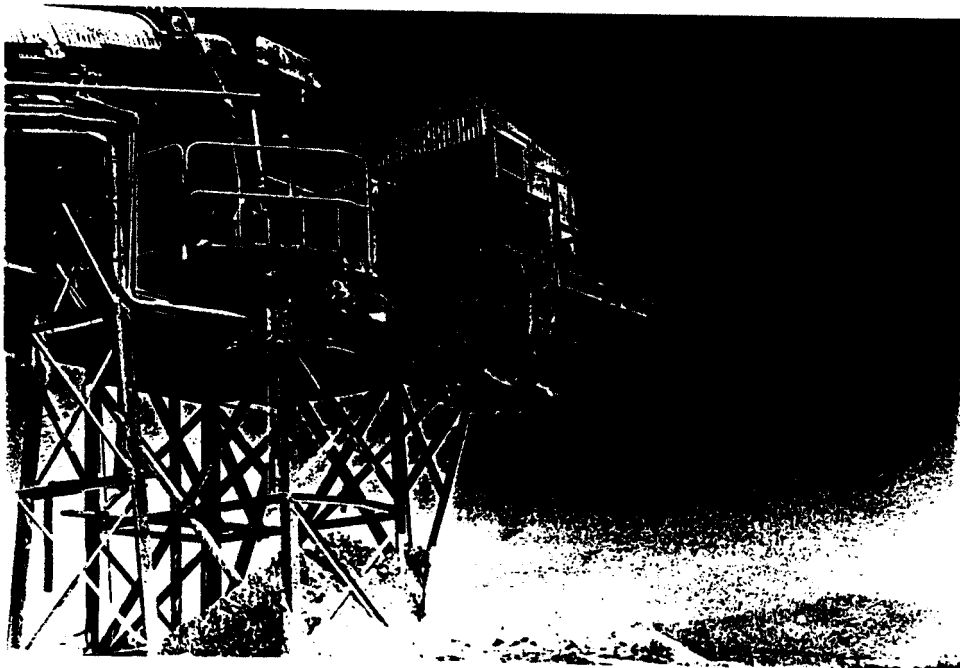


FIGURE 9. Discharge Chute on Plant

## PART FIVE: CONSTRUCTION

### 5.1 SUBGRADE

The construction contract was awarded to Hess Brothers Contractors of Parlin, New Jersey in February, 1983. Site preparation began in the early spring of that year. Construction in the area of the control and experimental sections between Station 609 to Station 619 was delayed until the unsuitable material in this area was excavated. This portion of the roadway was located through an abandoned landfill and required excavation to a depth of between 20 to 30 feet below the original ground surface. Backfill of the excavation was with a Zone II (I-11) select fill material (see Appendix B for specifications). The material was a clean, well-graded sand (AASHTO designation A-1-6). Soil analysis results on the fill material are provided in Appendix D. This material was the subgrade between Station 609 and Station 619.

Subgrade for the remainder of the control and experimental sections consisted of a clean bank run gravelly sand (AASHTO designation A-1-b). Results of the soil analysis performed on this material are provided in Appendix D.

All subgrade material was placed in 6" thick compacted lifts.

### 5.2 SUBBASE

Subbase was placed in late July, 1984. The material was subbase designation NJDOT I-3 (see Appendix B) placed 12" thick in the experimental area and 8" thick on the control section. The subbase had a proctor density of 112 PCF and an optimum moisture content of 11.5%. Gradations and additional test results are provided in Appendix D. Density control of the subbase was accomplished through the use of a Troxler 3400-B nuclear surface density-moisture meter. In-place density averaged 109 PCF or about 97% of the proctor density. The LFA base was placed directly on the subbase.

On the northbound (standard control section), Dense Graded Aggregate Base (D.G.A.B.) was used as the base course beneath the asphalt pavement. The material was a blast furnace slag from Warner Concrete, Morrisville, Pennsylvania (see Appendix D for test results). The D.G.A.B. had a proctor density of 111.6 PCF at an optimum moisture content of 5.9%.

### 5.3 LFA BASE COURSE

The first LFA material arrived on the job site on August 15, 1985. A jersey stone box powered by a D-5 caterpillar dozer was set up to spread the LFA material. Because the first semi-trailer which attempted to dump into the spreader box nearly upset, the remainder of the loads were dumped on the asphalt pavement on the northbound roadway. A front-end loader was then used to load tandem dump trucks which then fed the stone box.

Some trial-and-error adjustments on the stone box were made in order to place an 8" layer of uncompacted material which yielded the 6" required compacted thickness.

A density control strip was established and monitored with a Troxler Model 3400 B nuclear gauge. A Tambo Model R-166A, dual steel-wheeled vibratory roller was used for compaction. Analysis of the control strip data indicated that 95% of proctor density was achieved after four passes of the roller. The four passes were then used to compact the remainder of the LFA base.

Weather during this construction remained hot and dry, with daytime high temperatures averaging 85<sup>o</sup>F. Several passes of a water truck were made each morning and evening to prevent the completed LFA base from drying out. Construction continued without problems with 3691 tons of material placed in six working days. This is not representative of the achievable rate of production since spreading and compaction equipment often set idle while waiting for

material to arrive on the job site. The low rate of delivery to the project was caused first by a shortage of trucks during the exceptionally busy construction season, and secondly, by the fact that the trucks could only make two round trips per day. The LFA base course was produced at a plant about 75 miles from the I-295 jobsite, which resulted in a haul time of about two hours.

The use of a jersey stone box to place the LFA base permitted the material to be placed rapidly and accurately so that fine grading was not required. However, the large aggregate had a tendency to segregate and fall out at the edge of the spreader box with each pass. While the segregation was not excessive or problematic on this project, New Jersey has since revised its construction specifications to require asphalt laydown machines for future LFA projects. A subsequent project (Route 55, Section 13B) demonstrated the effective use of an asphalt paver for placing LFA.

After completion of the LFA base, an application of RC-30 prime coat, at the rate of .15 gallons per square yard, was applied to seal in the moisture. The area was blocked off to all traffic until the base was paved with asphalt during the first week of September, 1983. Construction of the bituminous base and binder course on the test section was completed in two days.

Since this was a Research demonstration project, density and moisture measurements were taken at 100 foot intervals on each lane of the construction. Normally, only lot densities, consisting of moisture and density measurements on every 5000 square yards of material would be taken. These lot densities, as noted in the specification in Appendix C, are used to calculate the quantities of lime and fly ash used on the project for payment under separate items. Figures 10 through 19 show the construction sequence beginning with the control strip construction to the final roadway.



FIGURE 10. Subbase Preparation Prior to Placing LFA Material

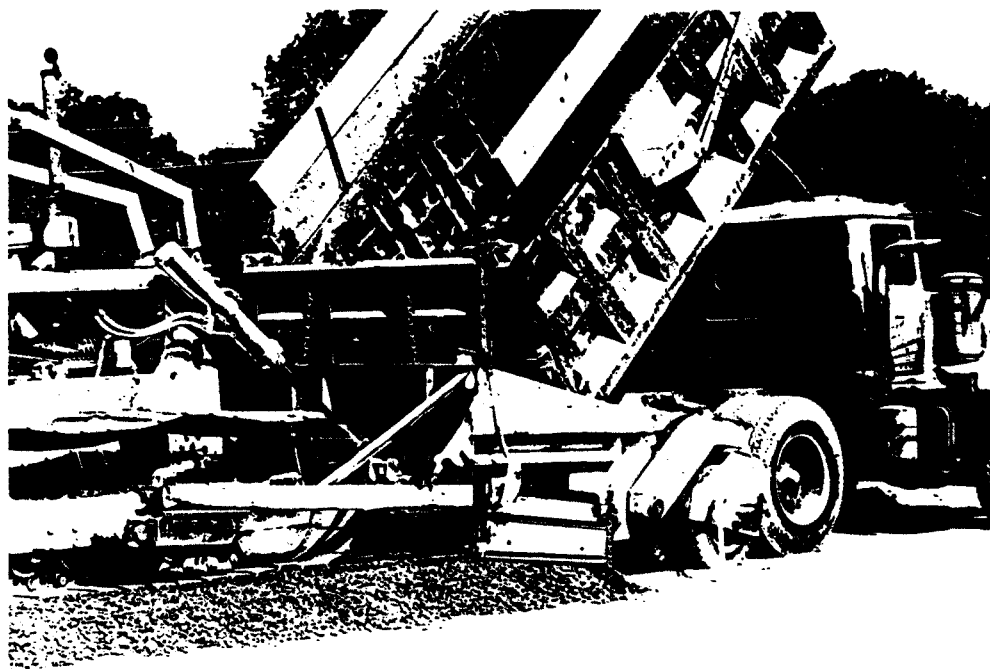


FIGURE 11. Constructing the Control Strip Using a Jersey Spreader Box

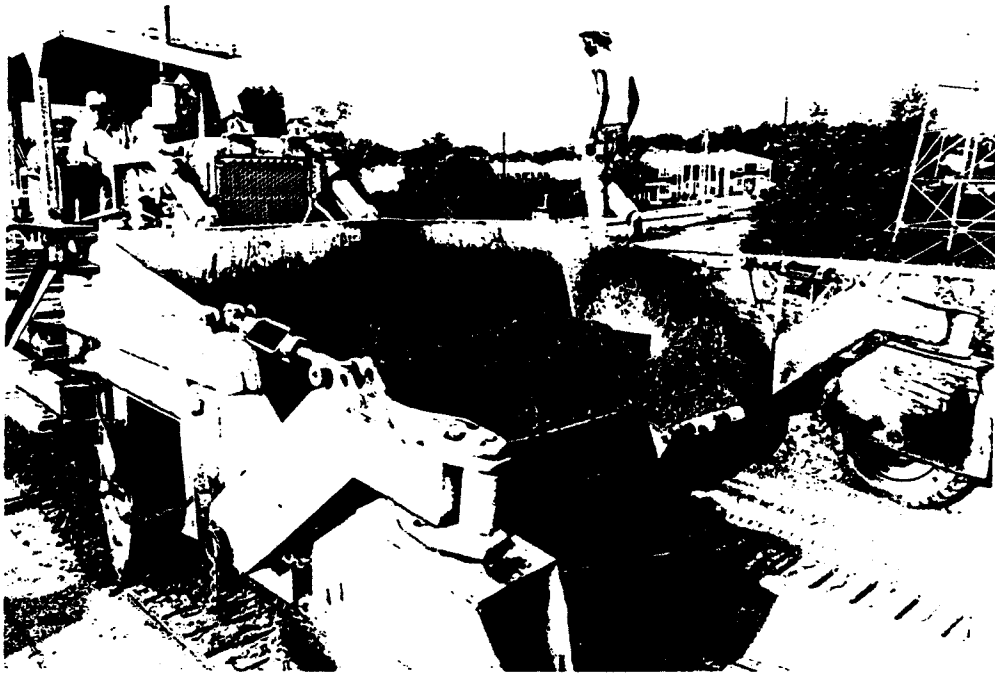


FIGURE 12. Close up of the Jersey Spreader Box

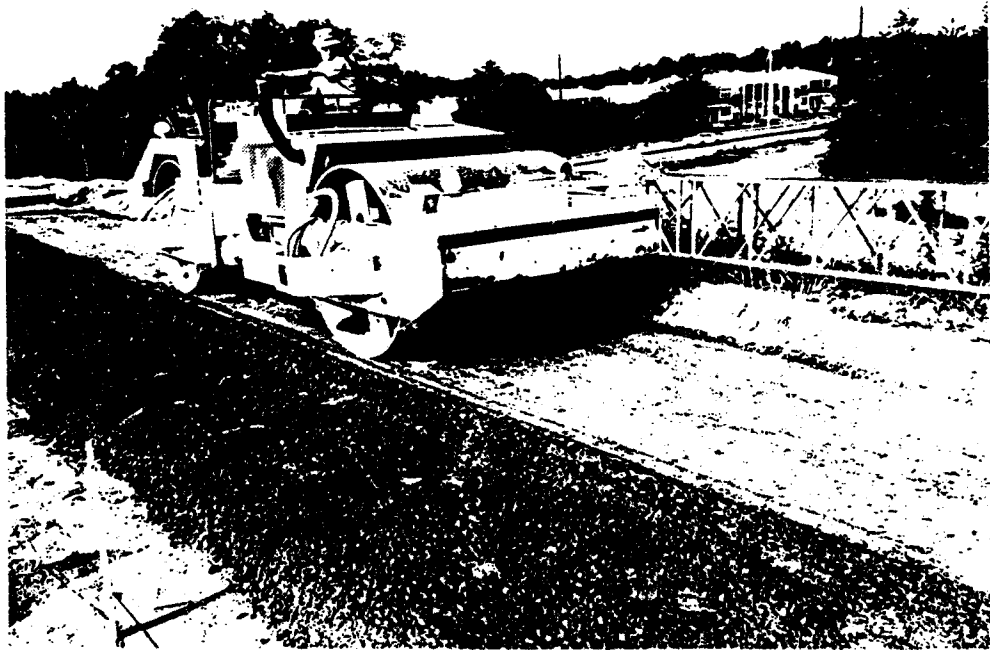


FIGURE 13. Compacting the Control Strip



FIGURE 14. Close up View of the LFA Material

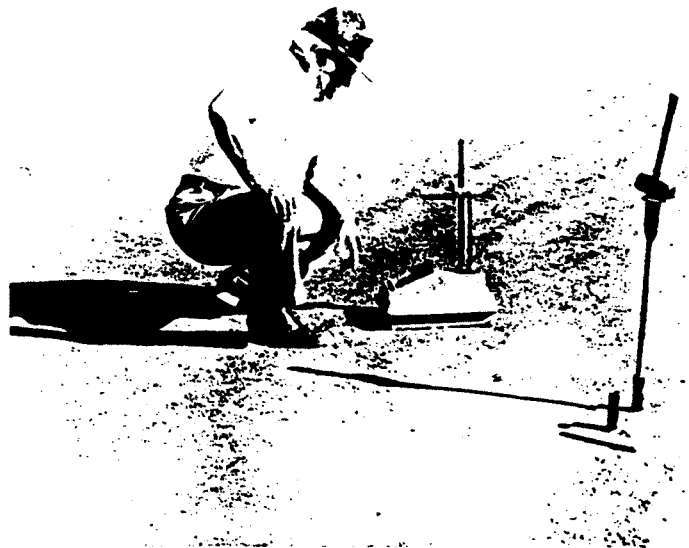


FIGURE 15. Checking Density with a Troxler Nuclear Density Gauge

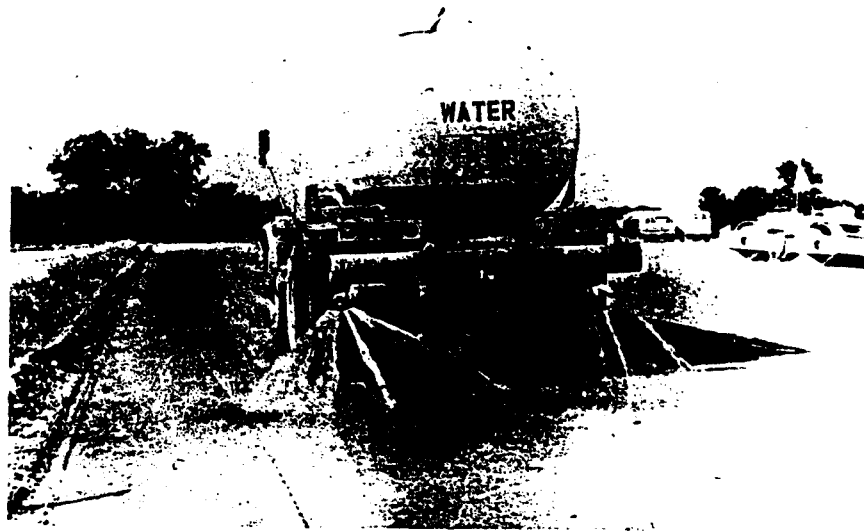


FIGURE 16. Keeping the LFA Moist Prior to Application of Cure Coat

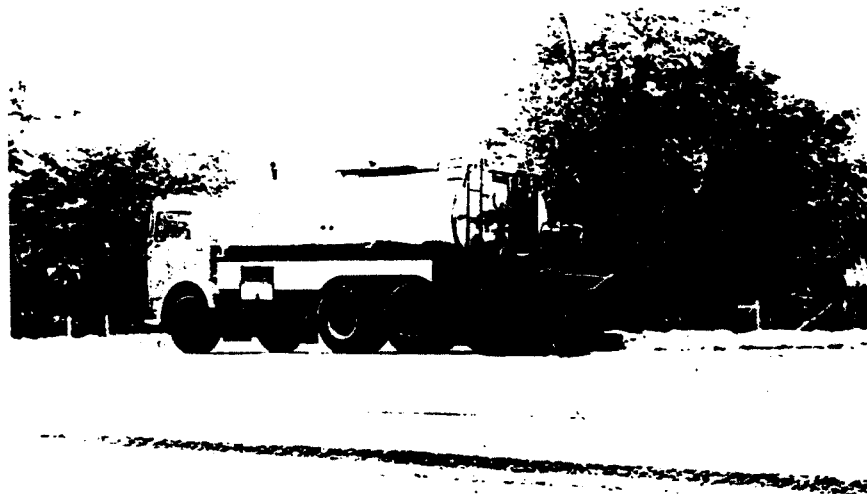


FIGURE 17. Application of RC-30 Cure Coat

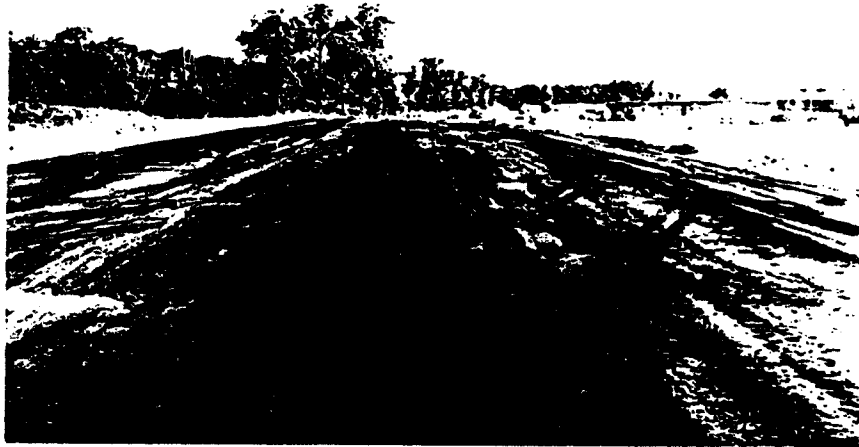


FIGURE 18. Completed LFA Material with Cure Coat

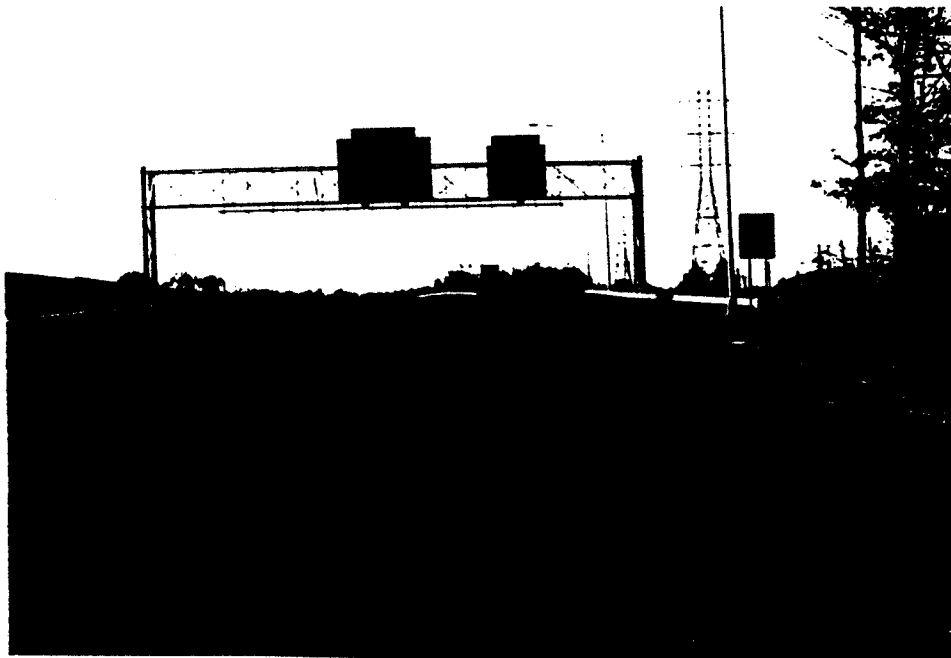


FIGURE 19. Overview of Roadway

PART SIX: FIELD AND LABORATORY TESTS

6.1 UNCONFINED COMPRESSION TESTS

Throughout the construction of the LFA base, samples of the material were removed from the spreader box and molded into cylinders according to AASHTO T99, Method C. Samples were molded at field moisture contents and tested for compression strengths according to ASTM C-593 after 28, 45, and 90 days of curing at 100°F. In addition, vacuum saturation tests were performed on samples from the first day's production. Table 5 shows the results of these unconfined compression tests.

Table 5: Compressive Strength Results

	<u>28 Days</u>	<u>45 Days</u>	<u>90 Days</u>
Unconfined Compressive (Average of 15 Tests)	1455	1574	1723
Vacuum Saturation (Average of 3 Tests)	1773	1603	2370

6.2 CORING RESULTS

Cores were taken at 28, 45, 90, 270, and 420 days after construction in an attempt to correlate field and laboratory strength development. The rate of strength development for an LFA mix utilizing Type F fly ash is extremely slow at room temperatures, and in fact, almost non-existent below 40°F. Therefore, long-term coring efforts are needed if the ultimate strength of the field material is to be obtained. In addition, freeze-thaw cycles can have an adverse effect on low-strength stabilized materials. Therefore, cores were taken after the base material had endured its first winter and again after a summer of curing. The results of the core strengths are shown in Table 6. Figure 20 shows a plot of both core and laboratory strength versus time. The results indicate the effects

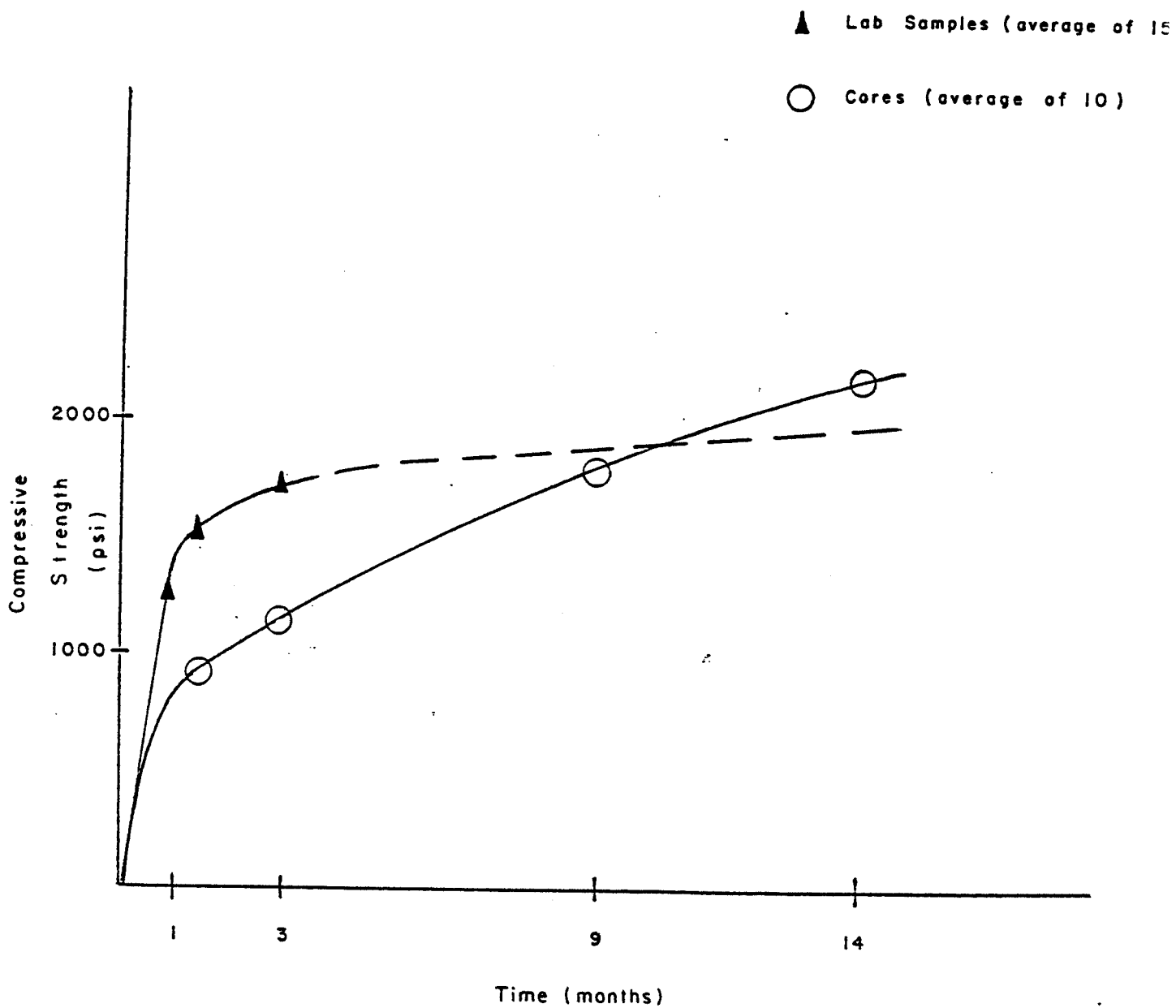


Figure #20

UNCONFINED COMPRESSIVE STRENGTH CURVES

of temperature on the cure rate of LFA mixes. Samples returned to the laboratory and cured at 100°F in the oven gained strength rapidly while material cured at ambient field temperatures developed strength at a much slower rate. It should be noted, however, that the ultimate strength of the field material was greater than that of the laboratory samples.

Table 6: LFA Core Strengths

<u>Strength (Avg. of 10 Cores)</u>	<u>28 Days</u>	<u>45 Days</u>	<u>90 Days</u>	<u>270 Days</u>	<u>420 Days</u>
psi	851	879	1149	1796	2210

### 6.3 NUCLEAR MOISTURE DENSITY MEASUREMENTS

The importance of adequate compaction and proper moisture content of an LFA material cannot be overstressed. Correct moisture contents are essential in achieving good density, and density is required if design strengths are to be obtained in the field. Moisture content was checked on the project by both the nuclear gauge and by taking samples of material each morning and afternoon and checking for moisture content in the lab. The average moisture content ( $\bar{X}$ ) as determined from 180 nuclear moisture tests was 6.33%, with a standard deviation ( $\sigma$ ) of .922%. The 10 oven dried moisture content tests averaged 6.35%. This indicates good correlation between the nuclear moisture measurements and the standard oven dried moisture tests.

Nuclear density measurements were taken at 142 locations and the results showed that the average in-place dry density was 136.8 pcf or 98% of standard Proctor density for this material. The standard deviation on the density tests ( $\sigma$ ) was 2.22 pcf. Based on nuclear density gauge results on similar base course materials, these tests indicate that the LFA material was uniformly and adequately compacted.

## PART SEVEN: ENERGY REQUIREMENT ANALYSIS

To determine the relative amount of energy consumed for the construction of the LFA base, a comparison was made between the energy required for the LFA base and that required for the structurally equivalent control section. The control section is typical of the design used since 1970 for Interstate pavements in New Jersey. As shown previously in Table 1, the experimental and control sections have basically identical structural numbers.

The calculations for the energy consumption for each pavement section is shown in Appendix E. Production and construction energy inputs for each material are based upon values presented in a report published by the Asphalt Institute<sup>(4)</sup>. Transportation energy inputs are based upon diesel fuel required to transport the material from the actual sources of materials used for the project. The diesel trucks were assumed to have a fuel economy of 4.5 mpg.

Table 7 presents the results of the energy comparison. The energy required for each section was converted to gallons of gasoline at 125,000 BTU/gallon.

Table 7: Energy Requirements

LFA Pavement Section

<u>Material</u>	<u>Thick- ness</u>	<u>Total Tons</u>	<u>Energy Req./Ton for Production, Hauling, and Const. (BTU)</u>	<u>Total Energy (BTU)</u>
Bit. Surface	3"	1915.2	528,210	$1.01 \times 10^9$
Bit. Stab. Base	4"	2553.6	528,210	$1.35 \times 10^9$
LFA Base	6"	3796	552,250	$2.10 \times 10^9$
Subbase (I-)	12"	5745.6	90,800	$5.22 \times 10^8$
MC30 Curing Compound	4"	(1026 gal.)	18,360,660	$7.34 \times 10^7$
				<hr/> $5.06 \times 10^9$ BTU or 40,480 gallons of gasoline

Control Pavement Section

<u>Material</u>	<u>Thick- ness</u>	<u>Total Tons</u>	<u>Energy Req./Ton for Production, Hauling, and Const. (BTU)</u>	<u>Total Energy (BTU)</u>
Bit. Surface	3"	1915.2	528,210	$101 \times 10^9$
Bit. Stab. Base	6"	3830.4	528,210	$2.02 \times 10^9$
Dense Graded Aggregate Base	8"	4035.6	102,560	$4.14 \times 10^8$
Subbase (I-3)	8"	3835.6	90,800	$3.48 \times 10^8$
MC Prime	—	(1026 gal.) 4 tons	18,360,660	$7.34 \times 10^7$
				<hr/> $3.87 \times 10^9$ BTU or 30,960 gallons of gasoline

As shown in Table 7, the LFA section on this project required an additional energy equivalent of approximately 9,500 gallons of gasoline as compared to the control section. While LFA material generally is not an energy intensive material, the 75-mile haul distance from the plant to the job site resulted in the LFA material requiring more total energy per ton than even hot mix bituminous base. In addition to the extra energy needed for hauling LFA, the control section utilized a blast furnace slag as a base course which required no energy for production. This material is not typical of material used for a base in New Jersey pavements. These two factors resulted in the LFA section requiring additional energy when compared to the energy needed to construct the control pavement.

PART EIGHT: COST OF ALTERNATE MATERIALS

Since the LFA section was constructed to be structurally equivalent to the control section, a cost comparison between each will be made for a square yard of the pavement sections. The bid prices for each item are shown in Table 8.

Table 8: Bid Prices for Pavement Materials

<u>Material</u>	<u>Cost</u>
Bituminous Concrete Surface	\$17.25/Ton
Bituminous Stabilized Base	\$17.25/Ton
Dense Graded Aggregate Base	\$18.50/Yd. <sup>3</sup>
Subbase (I-3)	\$11.00/Yd. <sup>3</sup>
LFA Base (6" Thick)	\$ 6.75/Yd. <sup>2</sup>
Lime	\$70.00/Ton
Fly Ash	\$15.00/Ton
MC-30 (Prime)	\$ 1.35/Gal.

These prices were converted to square yard costs for each item in the pavement section. Table 9 provides the breakdown of the actual cost per square yard per item and the total cost per square yard of the LFA and control pavements.

Table 9: Material Costs/YD<sup>2</sup>

LFA Section		Control Section	
<u>Material</u>	<u>Cost/yd<sup>2</sup></u>	<u>Material</u>	<u>Cost/yd<sup>2</sup></u>
3" Bit. Conc. Surface	\$2.91	3" Bit. Conc. Surf.	\$2.91
4" Bit. Stab. Base	\$3.88	6" Bit. Stab. Base	\$5.82
6" LFA	\$6.75	8" D.G.A.B.	\$4.11
12" Subbase (I-3)	\$3.67	8" Subbase (I-3)	\$2.44
Lime	\$0.096 (.10)	Prime Coat (MC-30)	\$0.14
Fly Ash	\$ .012 (.06)		
Curing Comp. (MC-30)	\$0.14		
	\$17.51		\$15.42
TOTAL COST			

From the above tabulation it can be seen that the LFA section for this roadway costs approximately an additional \$2.00 per square yard when compared to the conventional pavement construction. There are two reasons for the increase in cost of the LFA section over the standard pavement. The first (and most obvious) was the distance which the LFA material had to be hauled to the construction site (75 miles). The second (and not so obvious) was the fact that the D.G.A.B. used on this project was a blast furnace slag. This is not typical of New Jersey projects. D.G.A.B. is usually a crusher run material produced at a quarry, however, the contractor was able to locate near the project a source of less expensive blast furnace slag which met specifications. These two reasons helped reduce the cost of the standard control section.

## PART NINE: CONCLUSIONS AND RECOMMENDATIONS

### 9.1 CONCLUSIONS

While the ultimate benefits of the use of LFA base courses must await the outcome performance evaluation, the practicality of constructing an LFA stabilized base has been demonstrated. The following conclusions are offered:

1. No significant problems were encountered in constructing the LFA base. The LFA material proved to be very forgiving to construction techniques, with handling characteristics similar to dense graded aggregate base.
2. There were no problems in transporting the material to the job site, despite the long haul distance. Both laboratory dried and nuclear gauge measurements proved that the moisture content was maintained during the haul. Field densities averaged 98% of the Proctor density.
3. Laboratory compacted samples and core strengths exceeded the mix design strength. Core strengths after nine months were equal to the 90-day laboratory cured specimens. This demonstrates the slow curing of the material at normal (ambient field) temperatures. After 14 months, the core strengths exceeded the 90-day lab samples.
4. The facts that both the cost and energy consumption for the LFA section were greater than that for the control can be attributed to the haul distance between the job site and the LFA plant. The cost at the plant for this LFA material is approximately one-half that of hot mixed asphalt and the energy required to produce and construct an LFA base is less than 58% of the energy required to produce a hot mix asphalt base of equivalent thickness.

## 9.2 RECOMMENDATIONS

In view of the experience gained on this project, the following recommendations are made:

1. While spreading the LFA base with a spreader box resulted in less segregation than that which would occur if the material had been "bladed" to grade, an asphalt paver provides much better grade and segregation control. This was evidenced by the final products of several other LFA base projects where a paver was used. It is, therefore, recommended that where possible, asphalt pavers be used to place the material.
2. The original specifications for the project allowed only four hours between mixing the LFA material and final compaction. This restraint is too burdensome and, in fact, unnecessary as the data on the project demonstrated. Because of the long haul distance involved on this project, the specifications were relaxed to allow 24 hours between mixing at the plant and final compaction. Based on the excellent strength results obtained from this project, the material does not seem to be harmed by the 24-hour requirement and it should be permitted on all future jobs.
3. Other projects, perhaps nearer the source of the supply, should be designed with an LFA base as an alternate in that additional performance data can be assembled.

PART TEN: REFERENCES

1. Hunt, Robert G., et al, "Development of Guidelines for Procurement of Highway Construction Products Containing Recovered Materials", Final Report, EPA Contract N. 68-01-6014, Washington, D.C., 1981.
2. Mottola, Victor E., "Feasibility of Pavement Stabilization in New Jersey", NJDOT Research Report, September, 1982.
3. Local Climatological Data (Annual Survey) NOAA, Asheville, N.C., 1983.
4. "Energy Requirements for Roadway Pavements", The Asphalt Institute, MISC-75-3, April, 1975.

**APPENDIX A**  
**PAVEMENT DESIGN CALCULATIONS**

PAVEMENT RECOMMENDATION  
REPORT

I-295, Section 7C  
Kuser Road to Arena Drive

November 1981

PAVEMENT RECOMMENDATION REPORT

1. INTRODUCTION

This report represents a revision of the recommended pavement structure, for I-295 Section 7, from Kuser Road to Arena Drive, based on updated 1981 traffic and pavement design data furnished by the NJ DOT.

The original pavement design report, dated 1968 (copy of which is enclosed in the Appendix to this report) had determined that flexible pavement was a more economical solution as compared with the rigid pavement. The new 1981 traffic and design data, as well as unit costs, do not change this fact. This report includes calculations for both the flexible and the rigid pavement to substantiate that flexible pavement is still the most economical solution.

2. RECOMMENDED PAVEMENT DESIGN

Based on the new data and calculations of this report the recommended pavement structure is as follows:

- 3" MA-BC-2 Surface Course, consisting of 1.5" top course and 1.5" bottom course,
- 6" Bituminous stabilized base course, constructed in 3-2" courses, <sup>3 1/2"</sup>
- 8" Subbase, dense aggregate <sup>1</sup>course,
- 8" Subbase, I-3.

3. DESIGN DATA

(Ref. NJ DOT letter dated September 18, 1981)

Traffic Design Data

1984 ADT (2-way)	23,540
2000 ADT (2-way)	70,000
2000 DHV (2-way)	5,615
2000 D	60%
2000 Heavy Trucks Pk. Hr.	6%

Pavement Design Data

1984 ADT (1-way)	11,770
2000 ADT (1-way)	35,000
Total Trucks 24 Hr.	18%
Heavy Trucks 24 Hr.	12%

18 KIP Equivalency Factor

Flexible Pavement	0.356
Rigid Pavement	0.498
Total Truck percent	18%

4. DESIGN CRITERIA

Reference: AASHTO Interim Guide for Design of Pavement Structures, 1972.

Frost Considerations: Frost susceptible soil with frost penetration up to a depth of 28 inches.

Regional Factor: 1.5

Serviceability Index: 2.5

Subgrade Soils: Generally AASHTO Designation A-7-6, A-7-5

<u>Soil Support Value:</u>	<u>SSV</u>	<u>CBR</u>
	3.75	3
	4.75	5
	5.25	7

Modulus of Subgrade Reaction: K = 150

Number of Lanes: 3 in each direction

Lane Distribution Factor: 0.90

5. FLEXIBLE PAVEMENT DESIGN

a. Design AADT:  $\frac{(11,770 + 35,000) \times 0.9}{2} = 21,047$

b. Design AAD Equivalent 18 Kip Loads  
 $\frac{(21,047) \times (0.356) \times (0.18)}{1} = 1,349$

c. Minimum Pavement Thickness  
 $0.75 \times 28" = 21 \text{ inches}$

d. Required S.N.: From AASHTO Chart (Fig.II-1) for serviceability index of 2.5 (Regional Factor = 1.5)

CBR = 3, SSV = 3.75:	S.N. = 5.4
CBR = 5, SSV = 4.75:	S.N. = 4.7
CBR = 7, SSV = 5.25:	S.N. = 4.5

e. Trial Pavement Sections

		<u>S.N.</u>	<u>1982 Cost/S.Y.</u>
(1) 1968 design: (Trial Section #1)	3" MA-BC-2	1.32	\$ 5.90
	6" Bit.Stab.Base	2.64	11.40
	8" Subbase, I-1	1.12	3.40
	8" Subbase, I-3	0.64	4.50
	25"	5.72	\$25.20
(2) 1981 design: (Trial Section #2)	3" MA-BC-2	1.32	5.90
	6" Bit.Stab.Base	2.64	11.40
	6" Subbase, I-1	0.84	2.80
	8" Subbase, I-3	0.64	4.50
	23"	5.44	\$24.60
(3) 1981 design: (Trial Section #3)	3" MA-BC-2	1.32	\$ 5.90
	4" Bit.Stab.Base	1.76	8.40
	8" Subbase, I-1	1.12	3.40
	8" Subbase, I-3	0.64	4.50
	23"	4.84	\$22.20

6. RIGID PAVEMENT DESIGN

Design AAD Equivalent 18 Kip Loads:

$$(21,047) \times (0.498) \times (0.18) = 1887$$

Using concrete working stress of 600 p.s.i. and modulus of subgrade reaction  $k=150$ , one obtains from AASHO Chart (Fig.III-1) for serviceability index of 2.5:

Slab thickness = 9 inches

Total required thickness for frost penetration: 21"

(21-9) = 12"; use 12" subbase (min.)

<u>Pavement</u>	<u>1982 Cost/S.Y.</u>
R.C. Pavement (9" thick)	\$33.00
Subbase, I-1 (8" thick)	3.40
Subbase, I-3 (6" thick)	3.60
	\$40.00

7. RECOMMENDATIONS

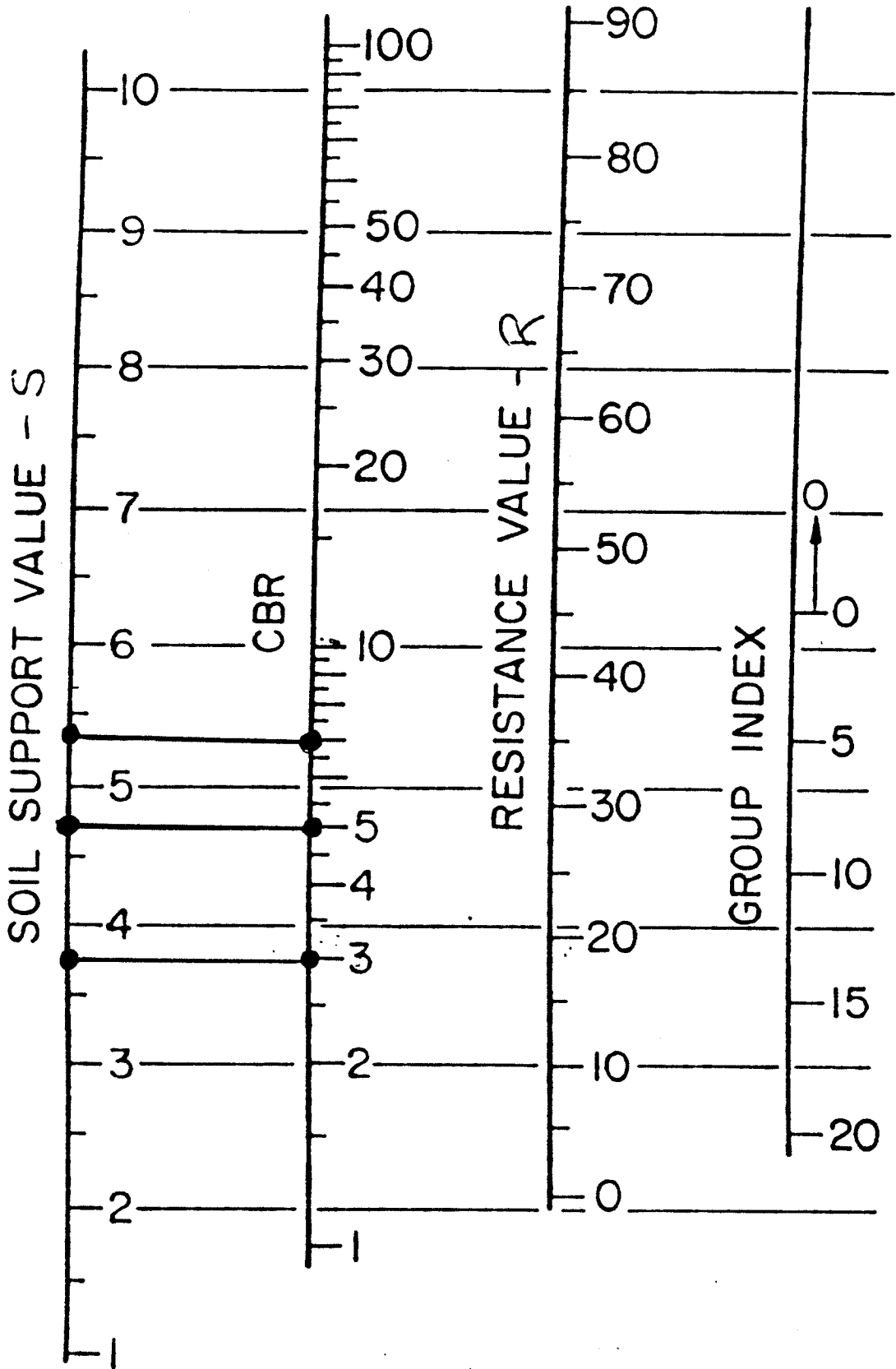
It is recommended that flexible pavement be adopted, since it is considerably less expensive than rigid pavement.

The prevailing existing subgrade CBR conditions are as follows:

<u>Station to Station</u>	<u>CBR</u>
604+00 to 609+70	5 or better
609+70 to 618+80	less than 3
618+80 to 664+00	5 or better

The unsuitable subgrade soils, between station 609 and 619, will be excavated and replaced with acceptable borrow materials. An improved CBR should therefore result in this portion of the project. The pavement structure of I-295 constructed up to Kuser Road, however, is same as Trial Section #1.

Although Trial Section #3 satisfies the structural and frost requirements and could result in a saving in construction cost, nevertheless, for consistency with the preceding sections of I-295 which have performed well to date, it is recommended that Trial Section #1 be retained for the project. A stronger pavement structure will provide a safety margin for unexpected increases in traffic as well as should result in less maintenance problems.



SOIL SUPPORT VALUE

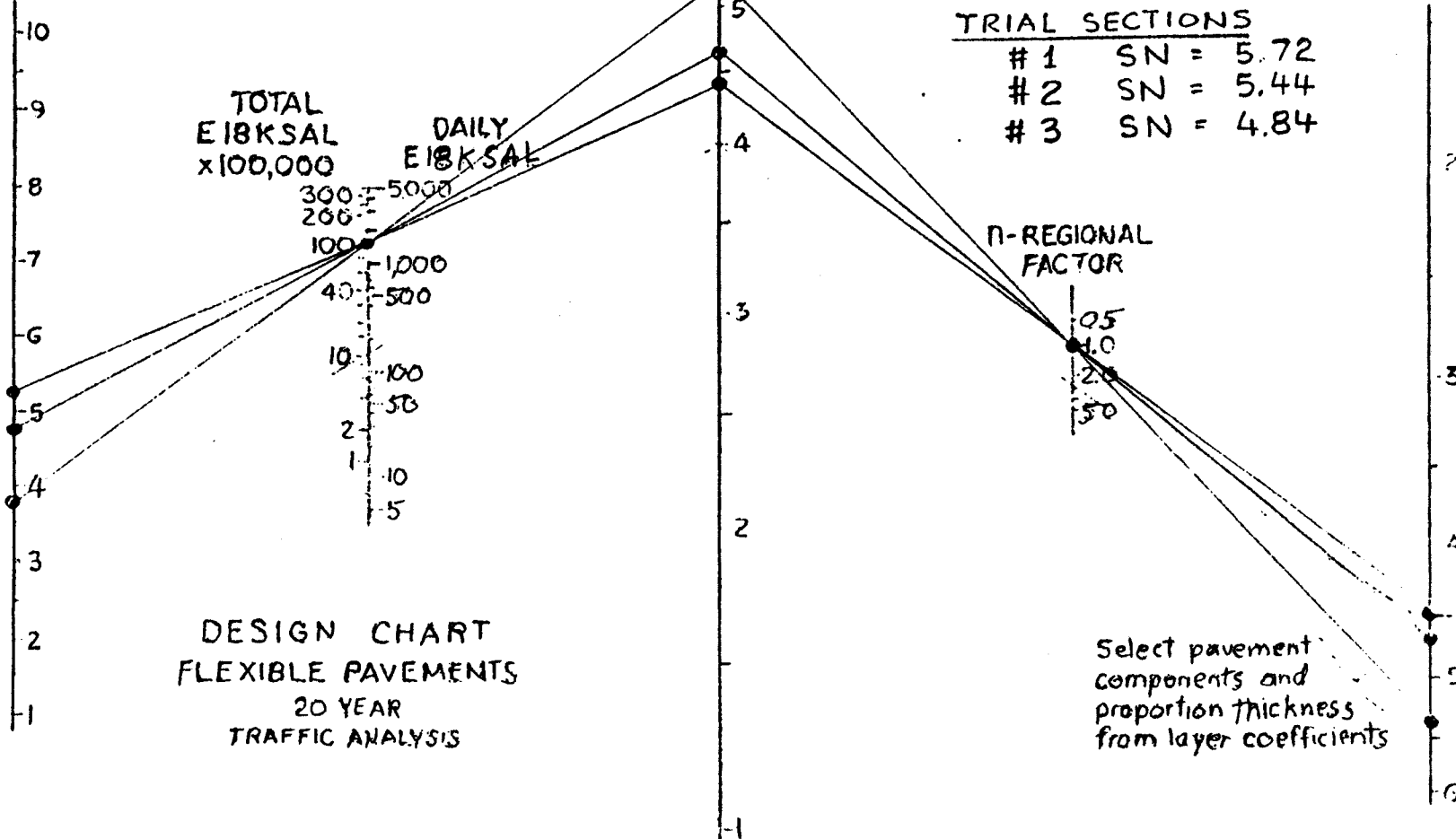
# AASHO INTERIM GUIDE

S - SOIL  
SUPPORT  
VALUE

SN -  
STRUCTURAL  
NO.

WEIGHTED  
STRUCTURAL  
NO.

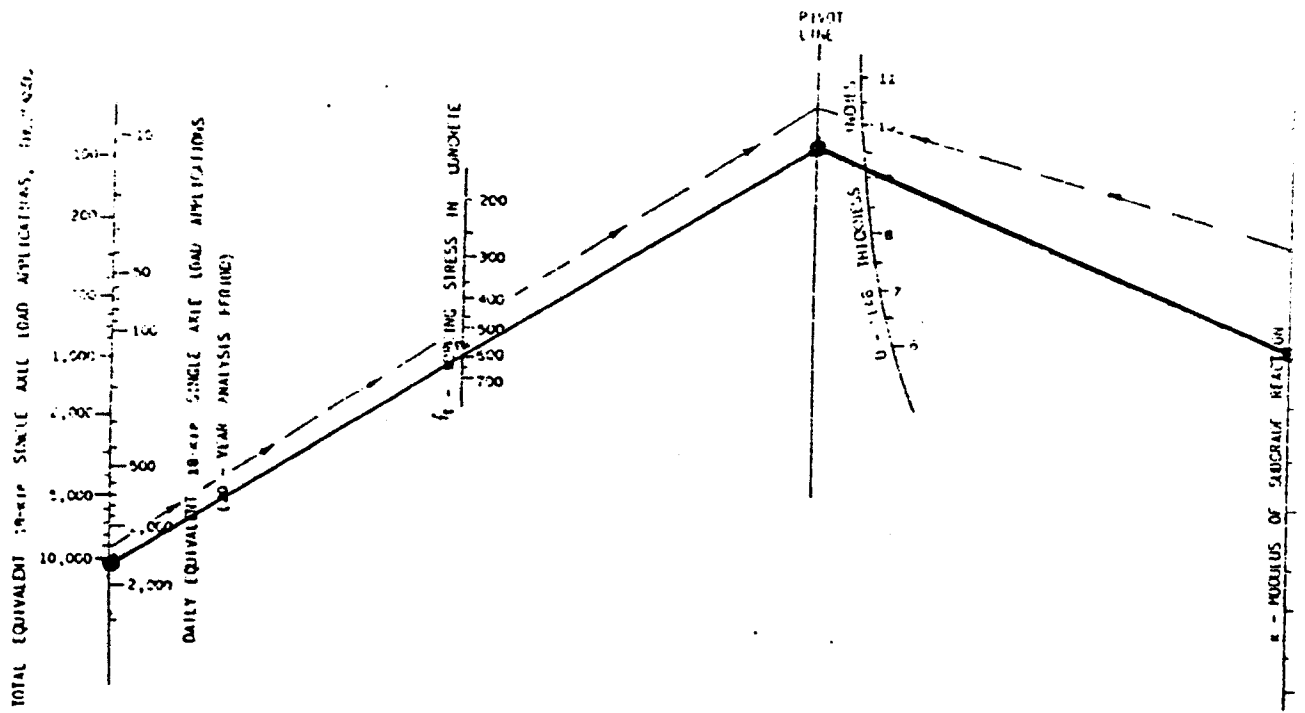
TRIAL SECTIONS	
# 1	SN = 5.72
# 2	SN = 5.44
# 3	SN = 4.84



DESIGN CHART  
FLEXIBLE PAVEMENTS  
20 YEAR  
TRAFFIC ANALYSIS

Select pavement  
components and  
proportion thickness  
from layer coefficients

DESIGN FOR PSI = 2.5 | N 20 YRS.





State of New Jersey  
DEPARTMENT OF TRANSPORTATION  
1035 PARKWAY AVENUE  
P.O. BOX 101  
TRENTON, NEW JERSEY 08625

IN REPLY PLEASE REFER TO  
Route 295, Sec. 7C  
Kuser Road to Arena  
Hamilton Township  
Mercer County  
Supplemental Pavement  
Recommendation

Anne P. Canby  
COMMISSIONER

March 9, 1982

Mr. Jack Freidenrich

This Supplemental Pavement Design is recommended to provide the Bureau of Transportation Structures Research with an experimental pavement section of equivalent strength and thickness as the previously recommended bituminous section. This change will affect the three southbound lanes of Route 295 from Station 609+00 southbound to Station 628+36.

This recommendation has been discussed and agreed upon by Messrs. K. Afferton, DOT Research, and R. A. Tompkins, FHWA.

We recommend the following.

Route 295 Southbound, Station 609+00 to Station 628+36

Mainline

- 3" MABC-2
- 4" Bituminous Stabilized Base Course
- 6" Aggregate-Lime Pozzolan Stabilized Base Course
- 12" Subbase, Designation I-3

Shoulders

- 1½" Bituminous Concrete Shoulder
- 1½" MABC Bottom Course
- 10" Dense Graded Aggregate Base Course
- 12" Subbase, Designation I-3

Nicolai D. Nicu

NDN:WD:cc

cc: Messrs. Freidenrich, Parker, Reilly, Bogdan, Dayton, Sunderland, Takacs, Afferton, Louis Berger Assoc., file(3)

MEMORANDUM

TO Mr. Charles Takacs

FROM Nicolai D. Nicu

Chief, Bureau of Roadway Plan  
Quality Review and  
Specifications Development

Chief, Bureau of  
Geotechnical Engineering

SUBJECT Rt. 295, Sec. 7C DATE 11/23/82 TELEPHONE NO. 4-5003  
Deletion of Top Course MABC

If there is a delay in opening this project to traffic after completion of construction, this office recommends that the 1½" top course MABC layer be deleted from all areas to remain unused.

  
\_\_\_\_\_  
Nicolai D. Nicu

NDN:WD:cc  
cc: K. Afferton  
W. Sunderland  
F. Bogdan  
file (3) ✓

APPENDIX B  
SOIL AGGREGATE AND BITUMINOUS CONCRETE  
SPECIFICATIONS AND DESCRIPTIONS

SOIL AGGREGATES

<u>TYPE</u>	<u>DESCRIPTION</u>
I-3	A subbase material generally used as a bottom course subbase beneath subbase I-1 or beneath a dense graded aggregate base course and primarily used in the same area of New Jersey as mentioned in I-1. It can be found in soil deposits in most areas of New Jersey.
I-11	Used as a general underwater backfill for areas which have been wet excavated. Also used for filling in depressions or channels in swamp or marsh areas prior to placing a sand blanket, and for a working table on top of the sand blanket in the "Sand Drain" or "Sand Blanket" types of construction.
Dense Graded Aggregate Base (D.G.A.B.)	Used as a base course material directly under bituminous concrete. While D.G.A.B. can consist of broken stone or blast furnace slag, it is generally a crusher run product. The portion of material passing the No. 40 is non plastic.

TABLE B-1

SOIL AGGREGATE GRADATIONS

GRADATION DESIGNATIONS—Percentage by weight passing square mesh sieves														
SIEVE SIZE	I-1	I-2	I-3	I-4	I-5	I-6	I-7	I-8	I-9	I-10	I-11	I-12	I-13	D.G.A.B.
4"	100		100						100	100	100	100	100	
2"	70-100	100		100	100				80-100	80-100	80-100			100
1"				60-100		100	100							
3/4"	50-95	65-100	60-100		70-100				60-100	60-100	60-100	70-100		55 - 90
1/2"				40-100		80-100	80-100	100						
No. 4	30-60	40-75	30-100	25-100	30-80			95-100	40-100	40-100	40-100		30-100	25 - 60
No. 8				20-100		45-100	35-100							
No. 16				15-85		30-90	25-90	45-70	20-70	20-70				
No. 50	5-25	5-30	5-35	8-45	10-35	0-20	5-60	5-25	5-35	5-40	0-75	0-75		5 - 25
No. 100						0-3	0-8		0-20	0-30				
No. 200	0-7	0-7	0-5	5-10	5-12		0-2	0-5	0-8	0-20	0-9	0-5	0-12	3 - 12

BITUMINOUS CONCRETE

- MABC - Medium Aggregate Bituminous Concrete - used as surface course on pavements.
- BSBC - Bituminous Stabilized Base Course - used as a stabilized base under MABC.

TABLE B-2  
GRADING REQUIREMENTS FOR BITUMINOUS CONCRETE

<u>Sieve Size</u>	<u>Percent Passing</u>	
	<u>MABC</u>	<u>BSBC</u>
2"	—	100
1½"	—	90 - 100
1"	100	80 - 100
¾"	95 - 100	—
½"	75 - 95	50 - 85
3/8"	65 - 85	—
#4	35 - 65	25 - 60
#8	25 - 50	20 - 50
#50	10 - 25	8 - 30
#200	3 - 10	4 - 12
Asphalt Cement % (by weight of mix)	4.5 - 9.5	3.5 - 8

APPENDIX C  
LFA SPECIFICATIONS

SECTION 4  
-----  
BORROW EXCAVATION  
-----

2.4.4. QUANTITY AND PAYMENT.  
-----

THE PAYMENT QUANTITY OF BORROW EXCAVATION, ZONE 2 WILL BE DETERMINED AS SPECIFIED IN ARTICLE 2.4.4 OF THE STANDARD SPECIFICATIONS UNDER METHOD B.2.

THE PAYMENT QUANTITY OF BORROW EXCAVATION, ZONE 3 WILL BE DETERMINED AS SPECIFIED IN ARTICLE 2.4.4 OF THE STANDARD SPECIFICATIONS UNDER METHOD A.2.

THE FOLLOWING IS ADDED TO THIS SECTION OF THE STANDARD SPECIFICATIONS:

SECTION 4A  
-----  
BORROW EXCAVATION, BRIDGE FOUNDATION  
-----

2.4A.3. METHOD OF CONSTRUCTION.  
-----

THE LAST SENTENCE OF THE FIRST PARAGRAPH ON PAGE NO. 58 OF THE SUPPLEMENT TO THE STANDARD SPECIFICATIONS IS CHANGED TO READ AS FOLLOWS:

DENSITY CONTROL IN THE FIELD WILL BE BASED ON THE SAND-CONE METHOD, RUBBER BALLOON METHOD OR THE NUCLEAR METHOD IN ACCORDANCE WITH THE REQUIREMENTS OF A.A.S.H.T.O. DESIGNATION T 191, DESIGNATION T 205 OR WITH A.A.S.H.T.O. DESIGNATION T 238 METHOD B AND DESIGNATION T 239.

2.8.1. ROAD MIXED STABILIZATION.  
-----

THE ENTIRE TEXT OF THIS ARTICLE IS CHANGED TO READ AS FOLLOWS:

AGGREGATE-LIME-POZZOLAN STABILIZED BASE COURSE  
-----

2.8.1. DESCRIPTION.  
-----

THIS ITEM SHALL CONSIST OF CONSTRUCTING A STABILIZED BASE COURSE COMPOSED OF AGGREGATE, HYDRATED LIME, FLY ASH AND

WATER MIXED IN A CONTINUOUS OR BATCH TYPE PUGMILL PLANT, TRANSPORTING THE MIXTURE TO THE SITE, SPREADING IT ON A PREPARED SUBBASE OR SUBGRADE TO A UNIFORM THICKNESS, GRADING AND COMPACTING TO THE CROSS-SECTION SHOWN ON THE PLANS AND IN ACCORDANCE WITH THESE SPECIFICATIONS.

MATERIALS.

2.8.2. AGGREGATE.

THE AGGREGATE USED IN THIS CONSTRUCTION SHALL CONFORM TO THE REQUIREMENTS OF ARTICLE 2.9.2 AND 8.5.5. IN ADDITION, THIS MATERIAL WHEN COMBINED WITH THE DESIGN PROPORTIONS OF LIME, FLY ASH AND WATER SHALL PRODUCE A MIXTURE WITH THE FOLLOWING LIMITATIONS:

<u>LIMITATION</u>	<u>METHOD OF TEST</u>
LIQUID LIMIT LESS THAN 25%	AASHTO T-89
PLASTIC INDEX LESS THAN 6%	AASHTO T-90

THESE TESTS WILL BE PERFORMED AND REPORTED AS PART OF THE MIX DESIGN.

2.8.3. STABILIZING AGENTS.

(A) HYDRATED LIME. THE LIME SHALL MEET THE REQUIREMENTS OF ARTICLE 8.5.33 WITH THE FOLLOWING MODIFICATIONS:

- (1) TOTAL CALCIUM AND MAGNESIUM OXIDES ON A NON-VOLATILE BASIS SHALL NOT BE LESS THAN 90 PERCENT BY WEIGHT.
- (2) MECHANICAL MOISTURE IN HYDRATED LIME (AS RECEIVED) SHALL BE LESS THAN 4% BY ASTM C25.

(B) FLY ASH. THE FLY ASH SHALL MEET THE REQUIREMENTS OF ARTICLE 8.5.30 AND AS FOLLOWS:

<u>REQUIREMENT</u>	<u>LIMITATION</u>	<u>METHOD OF TEST</u>
LOSS OF IGNITION	LESS THAN 10%	ASTM C311, SECTION 13
COMBINED SILICA (SI O2) AND ALUMINUM OXIDE (Al2 O3)	MORE THAN 60%	ASTM C311, SECTION 14

THE FLY ASH SHALL CONTAIN NO MORE THAN 1/2 PERCENT MOISTURE BY ASTM C311 SECTION 9 AND 10.

2.8.4. WATER AND BITUMINOUS CURING MATERIALS.

-----  
(A) WATER. WATER SHALL MEET THE REQUIREMENTS OF ARTICLE 8.5.38.

(B) BITUMINOUS CURING MATERIALS. THE BITUMINOUS CURING MATERIALS SHALL MEET THE REQUIREMENTS OF ARTICLE 8.1.7 FOR CUT-BACK ASPHALT-GRADE RC-70 OR 250 AND ARTICLE 8.1.5 FOR EMULSIFIED ASPHALT-GRADE RS-1 OR RS-2. THE USE OF BITUMINOUS MATERIALS SHALL CONFORM TO THE PROVISIONS OF THE NEW JERSEY ADMINISTRATIVE CODE, TITLE 7, CHAPTER 27, SUBSECTION 16, CONTROL AND PROHIBITION OF AIR POLLUTION BY VOLATILE ORGANIC SUBSTANCES.

2.8.5. EQUIPMENT.

-----  
EQUIPMENT SHALL CONFORM TO ALL REQUIREMENTS OF ARTICLE 1.4.8 AND TO THOSE THAT ARE CONTAINED IN THE FOLLOWING SUBSECTIONS.

THE TRAVELING PLANT SUCH AS A SPREADER BOX OR ASPHALT LAYDOWN MACHINE SHALL BE SELF-PROPELLED OR TRACTOR-DRAWN AND CAPABLE OF MAINTAINING A UNIFORM RATE OF TRAVEL WHILE SPREADING. IT SHALL BE MOUNTED ON WHEELS OR TRACK EQUIPMENT OF SUCH TYPE THAT WHEN LOADED TO CAPACITY IT WILL NOT RUT OR DAMAGE THE SUBGRADE OR SUBBASE COURSE, AND IT SHALL BE CAPABLE OF LAYING A LIFT OF UNIFORM CONSISTENCY AND THICKNESS WITH PROPER GRADE CONTROL. ROLLER SHALL CONFORM TO ARTICLE 3.10.3.

OTHER MACHINES WHICH ARE CAPABLE OF ACCOMPLISHING THE REQUIRED RESULTS, IN REGARD TO BOTH UNIFORMITY AND CONTROL, WILL BE ACCEPTABLE.

2.8.6. COMPOSITION OF MIXTURE.

-----  
THE LIME, FLY ASH AND AGGREGATE SHALL BE PROPORTIONED WITHIN THE FOLLOWING LIMITS ON A DRY WEIGHT BASIS:

MATERIAL	RANGE OF PERCENT BY WEIGHT
	OF TOTAL DRY MIX
LIME	2 TO 5
FLY ASH	6 TO 20
AGGREGATE	75 TO 92

THE LIME TO FLY ASH RATIO SHALL BE HELD BETWEEN 1:3 AND 1:4. THE MIXTURE WILL BE WITHIN PLUS OR MINUS 2 PERCENT OF THE OPTIMUM MOISTURE OF THE MIXTURE, AS DETERMINED FROM THE AASHTO T99, METHOD C (WITH REPLACEMENT) PROCEDURE.

THE MIX DESIGN FOR THE MIXTURE SHALL BE SUCH THAT WHEN COMPACTED INTO CYLINDERS, CURED FOR 28 DAYS AT 100 DEGREES F, AND TESTED IN ACCORDANCE WITH ASTM C593, PART 8 AND 9, THE CYLINDERS WILL HAVE A MINIMUM AVERAGE COMPRESSIVE STRENGTH OF 950 PSI AND NO INDIVIDUAL TEST LOWER THAN 800 PSI. THEY SHALL ALSO HAVE A MINIMUM AVERAGE RESIDUAL STRENGTH OF 600 PSI OR 85 PERCENT OF THE DESIGN COMPRESSIVE STRENGTH WHICHEVER IS HIGHER AS DETERMINED FROM THE VACUUM SATURATION PROCEDURE OUTLINED IN ASTM C593, PART 9. WHEN TESTING IN ACCORDANCE WITH ASTM C593, AASHTO T99, METHOD C (WITH REPLACEMENT) SHALL BE USED IN PLACE OF ASTM D-1557, METHOD D FOR COMPACTION AND DETERMINATION OF MOISTURE CONTENT.

THE MIX PROPORTIONS SHALL BE BASED ON EITHER OF THE DESIGN PROCEDURES IN SUBSECTION 2.8.22.

2.8.7. VERIFICATION OF THE MIX DESIGN.

AT LEAST 45 DAYS PRIOR TO THE PRODUCTION OF THE STABILIZED MIXTURE, THE CONTRACTOR SHALL SUBMIT FOR THE ENGINEER'S APPROVAL, A MIX DESIGN, A STATEMENT NAMING THE SOURCE OF EACH COMPONENT, AND A REPORT SHOWING THE RESULTS OF THE APPLICABLE TESTS. THE CONTRACTOR SHALL SUBMIT THE FOLLOWING QUANTITIES OF COMPONENTS FOR MATERIAL TESTING AND VERIFICATION OF THE MIX DESIGN:

HYDRATED LIME	25 POUNDS
FLY ASH	50 POUNDS
AGGREGATE	200 POUNDS

AT THE ENGINEER'S OPTION, VERIFICATION OF THE MIX DESIGN MAY BE DONE ON AN ANNUAL BASIS PROVIDED THE PROPERTIES AND PROPORTIONS OF THE MATERIAL DO NOT CHANGE APPRECIABLY. IF A JOB IS THE CONTINUATION OF WORK IN PROGRESS DURING THE PREVIOUS CONSTRUCTION SEASON USING APPROVED MIX DESIGNS, AND THE CONTRACTOR VERIFIED IN WRITING THAT THE SAME SOURCE AND CHARACTER OF MATERIALS ARE TO BE USED, THE ENGINEER MAY WAIVE THE REQUIREMENT FOR THE DESIGN AND VERIFICATION OF THE NEW MIXES. THE APPROVED PROPORTIONS OF MATERIAL WILL GOVERN DURING THE PROGRESS OF THE WORK EXCEPT THAT THE CONTRACTOR MAY SWITCH TO ANOTHER PREVIOUSLY APPROVED MIX DESIGN PROVIDED THAT THE ENGINEER IS NOTIFIED AT LEAST ONE WORKING DAY PRIOR TO THE CHANGE. NO CHANGE IN SOURCE OR CHARACTER OF ANY MATERIAL SHALL BE MADE UNTIL APPROVED. APPROVAL WILL BE BASED ON VERIFICATION OF THE NEW MIX DESIGN.

WHEN UNSATISFACTORY RESULTS FOR ANY SPECIFIED CHARACTERISTIC OF THE WORK MAKE IT NECESSARY, THE CONTRACTOR MAY ESTABLISH A NEW MIX DESIGN FOR APPROVAL.

FOR VERIFICATION OF THE MIX DESIGN, THE DEPARTMENT PERSONNEL SHALL PREPARE 6 COMPRESSION TEST CYLINDERS AND 6 VACUUM SATURATION TEST CYLINDERS IN ACCORDANCE WITH ASTM C593 EXCEPT FOR THE MODIFICATIONS NOTED IN ARTICLE 2.8.6.

MIX DESIGNS COMPLYING WITH THE REQUIREMENTS OF ARTICLE 2.8.6 AND YIELDING ACCEPTABLE VERIFICATION RESULTS WILL BE APPROVED.

2.8.8. MIXING.

-----  
THE AGGREGATE SHALL BE MIXED WITH THE PROPER AMOUNTS OF LIME, FLY ASH AND WATER AS SPECIFIED IN THE MIX DESIGN IN A STATIONARY OR PORTABLE BATCH OR CONTINUOUS TYPE MIXER EQUIPPED WITH BATCHING OR METERING DEVICES FOR PROPORTIONING THE COMPONENTS EITHER BY WEIGHT OR VOLUME AND SHALL BE OF SUCH ACCURACY THAT THE AMOUNTS OF AGGREGATE, STABILIZING AGENTS AND WATER BASED ON THE TOTAL DRY WEIGHT WILL BE MAINTAINED WITHIN THE FOLLOWING TOLERANCES:

LIME	PLUS OR MINUS 0.5 PERCENT BY WEIGHT
POZZOLAN	PLUS OR MINUS 1.5 PERCENT BY WEIGHT
AGGREGATE	PLUS OR MINUS 2.0 PERCENT BY WEIGHT
WATER	PLUS OR MINUS 2.0 PERCENT OF OPTIMUM MOISTURE

A BITUMINOUS BATCH PLANT OR CONTINUOUS DRUM-MIX PLANT MEETING THE REQUIREMENTS OF ARTICLE 3.10.3 THESE SPECIFICATIONS CAN BE USED FOR THE PURPOSE OF MIXING THESE MATERIALS. THE CAPACITY OF THE PLANT SHALL NOT BE LESS THAN 50 TONS PER HOUR.

ALL AGGREGATE SIZES SHALL BE KEPT SEPARATED. SURGE HOPPERS SHALL BE USED TO SUPPLY AGGREGATE FOR BLENDING TO MEET THE REQUIRED GRADATION. THE BLEND WILL BE SAMPLED DAILY TO CHECK THE BLENDED GRADATION. THE AGGREGATE SHALL BE HANDLED IN SUCH A MANNER AS TO PREVENT CONTAMINATION, DEGRADATION AND SEGREGATION.

THE LIME AND FLY ASH WILL BE STORED IN VERTICAL WATERPROOF SILOS, AND DELIVERED TO THE PLANT OPERATION BY APPROVED MEANS. FLY ASH STORED IN OPEN STOCKPILES WILL NOT BE USED.

FOR A BATCH TYPE PLANT, PRIOR TO INTRODUCING THE WATER, THE LIME AND FLY ASH WILL BE BLENDED TOGETHER AND COMBINED WITH THE AGGREGATE UNTIL A UNIFORM MIXTURE IS PRODUCED, BUT NOT LESS THAN 15 SECONDS PER CUBIC YARD OR THREE REVOLUTIONS OF THE MIXING DRUM SHALL BE USED FOR BLENDING. THE MINIMUM MIXING TIME AFTER THE WATER HAS BEEN ADDED TO THE MIXTURE SHALL BE

DETERMINED FROM THREE TRIAL RUNS AS DIRECTED BY THE ENGINEER. THE PLANT WILL BE CAPABLE OF DISCHARGING THE MIXTURE WITHOUT UNDUE SEGREGATION.

FOR CONTINUOUS TYPE PLANT, THE PUGMILL SHALL BE EQUIPPED WITH ADJUSTABLE PADDLES OR AN ADJUSTABLE BAFFLE WHICH CAN BE LOCKED IN POSITION AT THE DISCHARGE END OF THE PUGMILL. EITHER DEVICE WILL BE USED TO ADVANCE OR RETARD THE MIXTURE FLOW THROUGH THE PUGMILL IN ORDER TO ACHIEVE ADEQUATE MIXING. THE PLANT SHALL HAVE A MANUFACTURER'S PLATE GIVING THE NET VOLUMETRIC CONTENT OF THE MIXER AT SEVERAL HEIGHTS INSCRIBED ON A PERMANENT GAUGE. THE MIXING TIME WILL BE DETERMINED FROM AASHTO M156 AS:

$$\text{MIXING TIME IN SECOND} = \frac{\text{PUGMILL CAPACITY IN POUNDS}}{\text{OUTPUT IN POUNDS/SECONDS}}$$

THE MINIMUM MIXING TIME FOR A CONTINUOUS PLANT (PUGMILL OR DRUM TYPE) WILL BE DETERMINED BASED ON A VISUAL INSPECTION OF THE OUTPUT OF THE DRY MATERIALS.

#### 2.8.9. QUALITY CONTROL TESTING.

(A) FIELD LABORATORY. THE AGGREGATE-LIME-POZZOLAN MATERIAL SHALL BE SUPPLIED BY A PLANT WHICH HAS BEEN APPROVED AS MEETING ALL REQUIREMENTS OF THESE SPECIFICATIONS AND AS HAVING THE FACILITIES NECESSARY TO ASCERTAIN AND CONTROL THE QUALITY OF THE PRODUCT.

A TESTING FACILITY OR LABORATORY, AS DESCRIBED BELOW, SHALL BE PROVIDED WITHIN CLOSE PROXIMITY TO THE PLANT. IN ADDITION, THE LABORATORY SHALL BE LOCATED IN CLOSE PROXIMITY TO APPROVED SANITARY FACILITIES.

THE LABORATORY SHALL MEET THE SAME REQUIREMENTS AS THAT FOR THE CONCRETE LABORATORY CITED IN ARTICLE 3.12.3 WITH THE FOLLOWING EXCEPTIONS:

- (1) THE SLUMP CONE AND ROCK UNIT WEIGHT CONTAINER OF 1/2 CUBIC FOOT AND EQUIPMENT FOR DETERMINING SPECIFIC GRAVITY OF SAND ARE NOT REQUIRED.
- (2) THERE SHALL BE PRESENT IN THE LABORATORY, PROCTOR MOLDS, 5.5 POUND AND 10 POUND DROP HAMMERS, SEALABLE CANS WITH LIDS, TAPE, SAMPLE EXTRACTOR, GRADUATED CYLINDERS, ASSORTED GLASSWARE, AND A CURING OVEN OR CABINET CAPABLE OF ATTAINING AND MAINTAINING THE REQUIRED CURING TEMPERATURES FOR THE REQUIRED TIME AND CAPABLE OF HOLDING 250 SAMPLES AT ONE TIME, AND APPROVED COMPRESSION

LOADING MACHINE, AND A VACUUM CHAMBER, AND ANY OTHER ADDITIONAL EQUIPMENT NECESSARY TO PERFORM THE MOISTURE-DENSITY TESTS, COMPRESSION TESTS, VACUUM SATURATION TESTS AND LIME CONTENT DETERMINATION TESTS.

THE PLANT WILL BE EQUIPPED WITH PLATFORM TRUCK SCALES COMPLYING WITH THE APPROPRIATE REQUIREMENTS FOR SCALES AT MANUAL BATCH PLANTS.

(B) CONSISTENCY AND COMPLIANCE TESTING. QUALITY CONTROL OF THE STABILIZED MATERIAL IS THE RESPONSIBILITY OF THE CONTRACTOR. AT LEAST ONE QUALIFIED TECHNICIAN AND NECESSARY EQUIPMENT SHALL BE PROVIDED TO PERFORM ALL SAMPLING AND TESTING NECESSARY TO MAINTAIN THE PROPERTIES GOVERNED BY THE SPECIFICATION WITHIN THE SPECIFIED LIMITS.

THREE RANDOM SAMPLES FOR COMPRESSION TESTS AND THREE RANDOM SAMPLES FOR VACUUM SATURATION TESTS WILL BE TAKEN EACH DAY OF PRODUCTION.

THE LIME CONTENT OF THE UNCURED MIXTURE WILL BE MONITORED AT THE SAME SAMPLING RATE OF THREE PER DAY USING THE PROCEDURE OUTLINED IN ASTM D3155. THE COMPRESSION TESTS AND VACUUM SATURATION TESTS WILL BE PERFORMED IN ACCORDANCE WITH THE REQUIREMENTS OF ARTICLE 2.8.6.

TEST RESULTS SHALL BE NOTED AND TABULATED ON FORMS FURNISHED BY THE DEPARTMENT, TO WHICH THE CONTRACTOR'S QUALITY CONTROL TECHNICIAN SHALL AFFIX HIS SIGNATURE. THESE FORMS SHALL BE FORWARDED TO THE ENGINEER AS DIRECTED.

CONSTRUCTION REQUIREMENTS.

-----  
2.8.10. LIMITATIONS.  
-----

STABILIZATION WILL NOT BE PERMITTED WHEN THE AGGREGATE OR THE SURFACE ON WHICH THE BASE COURSE IS TO BE LAID IS WET OR FROZEN OR WHEN IT IS RAINING OR SNOWING. PROCESSING OPERATIONS FOR THIS STABILIZED BASE COURSE SHALL NOT BE STARTED UNTIL SURFACE TEMPERATURE IS AT LEAST 40 DEGREES F AND RISING. THE CONSTRUCTION OF THE AGGREGATE-LIME-POZZOLAN STABILIZED BASE COURSE SHALL NOT BE ALLOWED BETWEEN SEPTEMBER 30 AND APRIL 1.

2.8.11. TRANSPORTATION.  
-----

THE MIXTURE SHALL BE TRANSPORTED FROM THE CENTRAL PLANT IN VEHICLES THAT WILL MAINTAIN THE MOISTURE CONTENT AND PREVENT THE LOSS OF THE FINE MATERIALS OR SEGREGATION.

2.8.12. PREPARATION OF SUBBASE OR SUBGRADE.

-----  
PREPARATION OF SUBBASE, SUBGRADE OR SURFACE SHALL BE PERFORMED IN ACCORDANCE WITH THE APPLICABLE PROVISIONS OF ARTICLE 2.9.3 OR ARTICLE 2.10.3.

2.8.13. SPREADING.

-----  
PLANT MIXED AGGREGATE AND STABILIZERS SHALL BE DELIVERED TO THE PREPARED SUBGRADE OR SUBBASE AND SPREAD UNIFORMLY WITH A MINIMUM OF MANIPULATION TO PREVENT SEGREGATION. SPREADER BOXES OR ASPHALT LAYDOWN MACHINES WITH AUTOMATIC GRADE CONTROL SHALL BE USED. OTHER EQUIPMENT MAY BE USED WITH APPROVAL.

THE MAXIMUM THICKNESS OF A COMPACTED LAYER SHALL BE 8 INCHES. WHEN THE COMPACTED BASE COURSE IS REQUIRED TO BE GREATER THAN 8 INCHES, IT SHALL BE CONSTRUCTED IN APPROXIMATELY EQUAL DEPTH LIFTS. THE TIME BETWEEN PLACEMENT OF SUBSEQUENT LIFTS SHOULD BE KEPT AS SHORT AS POSSIBLE TO ENSURE THAT THE LOWER LAYER HAS NOT SET UP, AND TO PROMOTE KNITTING WITH THE UPPER LAYER. THE LOWER LAYER WILL BE KEPT FREE OF LOOSE MATERIAL, DIRT OR SAND. IF THESE CONDITIONS EXIST, THE LOWER LAYER WILL BE THIGHTLY SCARIFIED TO A DEPTH OF ONE INCH PRIOR TO PLACEMENT OF THE NEXT LAYER. THE LOWER LAYER WILL BE MOISTENED AS REQUIRED PRIOR TO PLACEMENT OF SUBSEQUENT LAYERS. PLACEMENT OF SUBSEQUENT LAYER SHALL BE WITHIN FOUR HOURS.

IF THE STABILIZED MATERIAL IS PLACED IN MULTIPLE-LANES, THE MAXIMUM TIME FOR PLACEMENT OF AN ADJACENT LANE WILL BE THE SAME AS THE TIME PERMITTED BETWEEN MULTIPLE-LIFTS.

2.8.14. COMPACTION, SHAPING AND FINISHING.

-----  
(A) COMPACTION. PNEUMATIC-TIRED ROLLERS OR VIBRATORY ROLLERS WILL BE USED TO PROVIDE INITIAL DENSIFICATION OF THE MIXTURE. COMPACTION OF THE STABILIZED MATERIAL SHALL CONFORM TO THE REQUIREMENTS OF THE FOLLOWING:

GENERAL. COMPACTION OF EACH LAYER SHALL CONTINUE UNTIL A SUBSTANTIAL PORTION (80 PERCENT OR MORE) OF THE LAYER HAS A DRY DENSITY OF NOT LESS THAN 95 PERCENT OF THE REFERENCE MAXIMUM DENSITY ESTABLISHED IN A CONTROL STRIP. THE IN-PLACE DRY DENSITY OF EACH COMPACTED COURSE WILL BE DETERMINED BY THE ENGINEER IN ACCORDANCE WITH THE CURRENT PROVISIONS OF AASHTO T191 OR AASHTO T238.

THE SURFACE OF EACH LAYER SHALL BE MAINTAINED DURING THE COMPACTION OPERATIONS IN SUCH A MANNER THAT A UNIFORM TEXTURE IS PRODUCED AND THE AGGREGATE FIRMLY KEYED. WATER SHALL BE UNIFORMLY APPLIED OVER THE MATERIALS DURING COMPACTION IN THE AMOUNT

NECESSARY FOR REQUIRED DENSITY.

CONTROL STRIPS. ONE OR MORE CONTROL STRIPS SHALL BE CONSTRUCTED FOR THE PURPOSE OF DETERMINING PROJECT COMPACTION REQUIREMENTS. ONE CONTROL STRIP SHALL BE CONSTRUCTED AT THE BEGINNING OF WORK. AN ADDITIONAL CONTROL STRIP SHALL BE CONSTRUCTED WHEN A CHANGE IS MADE IN THE TYPE OF SOURCE OF MATERIAL, WHENEVER A SIGNIFICANT CHANGE OCCURS IN THE COMPOSITION OF THE MATERIAL FROM THE SAME COURSE, OR AS DIRECTED. EACH CONTROL STRIP SHALL CONSIST OF AN AREA OF AT LEAST 400 SQUARE YARDS, AND THE THICKNESS SHALL BE THE SAME AS FOR COMPLETED COURSES IN THE ROADWAY SECTION. EACH CONTROL STRIP IS TO REMAIN IN PLACE AND BECOME A PORTION OF THE COMPLETED COURSE.

THE MATERIAL USED IN EACH CONTROL STRIP SHALL BE FURNISHED FROM THE SAME SOURCE AND SHALL BE OF THE SAME TYPE AS THE MATERIAL USED IN THE AGGREGATE SURFACE COURSE WHOSE COMPACTION REQUIREMENTS ARE ESTABLISHED BY THAT CONTROL STRIP. UNLESS OTHERWISE APPROVED BY THE ENGINEER, MOISTURE CONTENT OF THE TEST STRIP MATERIAL SHALL BE WITHIN PLUS OR MINUS TWO PERCENT OF ITS OPTIMUM MOISTURE CONTENT AS DETERMINED FROM AASHTO T99, METHOD C. COMPACTION OF CONTROL STRIPS SHALL BE ACCOMPLISHED USING THE SAME TYPE AND WEIGHT OF EQUIPMENT THAT WILL BE USED ON THE REMAINDER OF THE PROJECT.

THE SUBGRADE OR COURSE UPON WHICH A CONTROL STRIP IS CONSTRUCTED SHALL BE APPROVED BY THE ENGINEER PRIOR TO THE CONSTRUCTION OF THE CONTROL STRIP.

THE CONTROL STRIP SHALL BE COMPACTED BY A MINIMUM OF TWO COMPLETE PASSES WITH THE COMPACTION EQUIPMENT. A PASS IS DEFINED AS ONE PASSAGE OF ANY ONE TIRE, COMPACTING WHEEL, OR VIBRATING UNIT OVER THE ENTIRE SURFACE OF THE LAYER. COMPACTION SHALL CONTINUE UNTIL NO APPRECIABLE INCREASE IN DENSITY IS OBTAINED BY ADDITIONAL PASSES. FOR THIS PURPOSE, BETWEEN SUCCESSIVE PASSES, DENSITY DETERMINATIONS WILL BE MADE BY THE ENGINEER USING THE SAME APPARATUS AS IS TO BE USED FOR ACCEPTANCE TESTING.

UPON COMPLETION OF COMPACTION, A MINIMUM OF TEN TESTS WILL BE MADE AT RANDOM LOCATIONS TO DETERMINE THE AVERAGE IN-PLACE DRY DENSITY OF THE CONTROL STRIP. IF THE AVERAGE DENSITY OF THE MATERIAL IN THE CONTROL STRIP IS EQUAL TO OR GREATER THAN 95 PERCENT OF ITS MAXIMUM DENSITY AS DETERMINED FROM AASHTO T99, METHOD C, THEN THE VALUE OF THIS AVERAGE SHALL BE THE REFERENCE MAXIMUM DENSITY FOR COURSES OF THE SAME MATERIALS AND THICKNESSES. A CONTROL STRIP SATISFYING THE 95 PERCENT OF AASHTO T99, METHOD C DENSITY REQUIREMENTS MUST BE ESTABLISHED BEFORE CONSTRUCTION OF ADDITIONAL AGGREGATE BASE COURSE ON THE PROJECT CAN PROCEED. FAILURE TO ACHIEVE THIS DENSITY LEVEL IN THE CONTROL STRIP SHALL

BE CAUSE FOR THE ENGINEER TO NOT APPROVE THE COMPACTION EQUIPMENT AND/OR ITS METHOD OF USE.

(B) SHAPING AND FINISHING. AFTER THE MIXTURE HAS BEEN COMPACTED, BUT PRIOR TO THE INITIAL SET, THE SURFACE SHALL BE SHAPED TO THE REQUIRED LINES, GRADES AND CROSS SECTION. WHEN NECESSARY THE CONTRACTOR WILL LIGHTLY SCARIFY THE SURFACE WITH A DRAG HARROW OR SIMILAR EQUIPMENT TO PRODUCE A SMOOTH AND UNIFORM SURFACE. THE FINAL SURFACE WILL BE ROLLED WITH A TANDEM ROLLER. THE MOISTURE CONTENT OF THE SURFACE MATERIAL SHALL BE MAINTAINED WITHIN PLUS OR MINUS 2 PERCENT OF THE SPECIFIED OPTIMUM DURING ALL FINISH OPERATIONS. COMPACTING AND FINISHING OPERATIONS SHALL BE COMPLETED WITHIN THE SPECIFIED TIMES AND SHALL BE CARRIED OUT IN SUCH A MANNER AS TO PRODUCE A SMOOTH, DENSE SURFACE. DURING THE FINAL FINISHING THE MATERIAL ACCUMULATED BY BLADING AND CLIPPING WITH A GRADER SHALL BE REMOVED.

THE NUMBER OF COMPACTION AND FINISHING UNITS SHALL BE SUFFICIENT TO INSURE THE INITIAL COMPACTION OF THE PROCESSED SECTION OF THE STABILIZED BASE COURSE WITHIN 4 HOURS FROM THE TIME THE WATER IS ADDED AT THE MIXER. THE FINAL FINISHING AND COMPACTION SHALL BE WITHIN 8 HOURS FROM THE TIME OF MIXING. THIS TIME MAY BE EXTENDED BY THE ENGINEER, IF THE MATERIAL HAS NOT REACHED AN INITIAL SET. IF FOR ANY REASON CONSTRUCTION OPERATIONS ARE DELAYED OR SUSPENDED AND THE ENGINEER ORDERS ANY LOOSE OR UNCOMPACTED MATERIAL REMOVED AND DISPOSED OF, THE CONTRACTOR SHALL PERFORM THIS WORK AT HIS OWN EXPENSE. NO POZZOLANIC BASE COURSE MAY BE SALVAGED.

#### 2.8.15. CONSTRUCTION JOINTS.

-----

AT THE BEGINNING OF EACH DAY'S CONSTRUCTION A STRAIGHT TRANSVERSE CONSTRUCTION JOINT SHALL BE FORMED BY CUTTING BACK INTO THE PREVIOUSLY COMPLETED WORK TO FORM A TRUE VERTICAL FACE FREE OF LOOSE AND SHATTERED MATERIAL. FOR MULTIPLE LANE AND MULTIPLE LAYER SECTIONS, THE CONSTRUCTION JOINTS SHALL BE OFFSET BY AT LEAST 5 FEET.

#### 2.8.16. DENSITY.

-----

FOR THE PURPOSE OF CHECKING CONFORMANCE TO THE COMPACTION REQUIREMENTS, THE AGGREGATE BASE COURSE CONSTRUCTED ON THE PROJECT SHALL BE DIVIDED BY THE ENGINEER INTO LOTS CONSISTING OF APPROXIMATELY 5000 SQUARE YARDS OR LESS OF AREA. EACH LOT OF COMPLETED AGGREGATE BASE COURSE WILL BE TESTED FOR ACCEPTANCE.

TO BE ACCEPTABLE, A LOT SHALL HAVE NOT MORE THAN 20 PERCENT OF THE LOT AREA, AS DETERMINED FROM TABLE 1, WITH A DRY DENSITY OF LESS THAN 95 PERCENT OF THE REFERENCE MAXIMUM DENSITY.

IF A LOT FAILS TO MEET THIS REQUIREMENT IT SHALL BE REWORKED AND RECOMPACTED BY THE CONTRACTOR AT HIS EXPENSE AND SHALL BE RESUBMITTED FOR ACCEPTANCE.

THE CONTRACTOR SHALL BE RESPONSIBLE FOR MAINTAINING THE SPECIFIED DENSITY OF ALL COMPLETED LOTS.

THE PERCENT OF LOT AREA WITH A DRY DENSITY LESS THAN 95 PERCENT OF THE REFERENCE MAXIMUM DENSITIES SHALL BE DETERMINED FROM THE CALCULATED VALUE OF THE TERM Q. THE TERM Q IS HERE DEFINED AS:

$$Q = \frac{\text{AVERAGE LOT DENSITY} - 0.95 \text{ OF THE REFERENCE MAXIMUM DENSITY}}{\text{RANGE OF LOT DENSITY}}$$

WHERE AVERAGE LOT DENSITY IS THE AVERAGE DRY DENSITY OF FIVE RANDOMLY SELECTED LOCATIONS IN THE LOT AND THE RANGE OF LOT DENSITY IS THE ABSOLUTE DIFFERENCE BETWEEN THE LOWEST AND HIGHEST DRY DENSITY VALUES RECORDED AT THESE SAME FIVE LOCATIONS. THE ENGINEER SHALL DETERMINE THE FIVE LOCATIONS FOR DENSITY TESTS IN A LOT BY THE USE OF A TABLE OF RANDOM NUMBERS. ONE DENSITY DETERMINATION WILL BE MADE BY THE ENGINEER AT EACH OF THE SELECTED LOCATIONS USING THE METHOD OF AASHTO T191 OR AASHTO T230.

TABLE 1

RELATION OF Q TO PERCENT OF LOT BELOW SPECIFIED DENSITY

Q	PERCENT OF LOT BELOW 95 PERCENT OF REFERENCE MAXIMUM DENSITY
0.36 OR GREATER	0-20
0.35 TO 0.29	21-25
0.28 TO 0.23	26-30
0.22 TO 0.17	31-35
0.16 TO 0.11	36-40
LESS THAN 0.11	GREATER THAN 40

2.8.17. SURFACE AND THICKNESS.

THE SURFACE WILL BE TESTED BY THE ENGINEER USING A 10 FOOT STRAIGHT EDGE AT A RANDOM LOCATION. THE VARIATION OF THE SURFACE FROM THE TESTING EDGE OF THE STRAIGHT - BETWEEN ANY 2 CONTACTS WITH THE SURFACE SHALL AT NO POINT EXCEED 3/4 INCH. ALL DEPRESSIONS EXCEEDING THE SPECIFIED TOLERANCE SHALL BE CORRECTED BY REMOVING THE ENTIRE LAYER AND REPLACING IT WITH NEW MATERIAL AS SPECIFIED. HUMPS MAY BE PLANED OFF BY ACCEPTABLE METHODS SHOULD THE ENGINEER DETERMINE THAT SUCH METHODS WILL

PROVIDE AN ACCEPTABLE SURFACE BY THE REQUIREMENTS OF THIS SPECIFICATION.

THE THICKNESS OF BASE WILL BE DETERMINED FROM THE MEASUREMENT OF TEST HOLES DUG AT RANDOM LOCATIONS AT INTERVALS NOT TO EXCEED 500 FEET. THE MEASURED THICKNESS SHALL NOT DEVIATE FROM THAT SHOWN ON THE PLANS BY PLUS 3/4 INCH OR MINUS 1/2 INCH.

WORK FOUND NOT TO BE IN CONFORMANCE WITH THE ABOVE SHALL BE RECONSTRUCTED OR REPLACED IN ACCORDANCE WITH APPLICABLE PROVISIONS OF THIS SECTION. THE CONTRACTOR SHALL FILL ALL TEST HOLES WITH AN APPROVED BASE COURSE MATERIAL AND ADEQUATELY RE-COMPACT THE MATERIAL THEREIN.

2.8.18. CURING AND PROTECTION.

---

AFTER FINAL SHAPING AND COMPACTION HAS BEEN COMPLETED, THE STABILIZED BASE SHALL BE CURED. THE CURING MATERIAL AS SPECIFIED IN ARTICLE 8.1.7 OR ARTICLE 8.1.5 SHALL BE APPLIED AT THE RATE OF 0.10 TO 0.25 GALLON PER SQUARE YARD AS SOON AS POSSIBLE AFTER COMPLETION OF THE BASE CONSTRUCTION, BUT IN NO CASE LATER THAN TWENTY-FOUR HOURS AFTER THE COMPLETION OF FINISHING OPERATIONS. THE FINISHED BASE COURSE SHALL BE KEPT CONTINUOUSLY MOIST UNTIL THE CURING MATERIAL IS PLACED.

THE CURING MATERIAL SHALL BE MAINTAINED BY THE CONTRACTOR DURING A SEVEN DAY PROTECTION PERIOD SO THAT ALL OF THE BASE COURSE WILL BE COVERED EFFECTIVELY DURING THIS PERIOD.

FINISHED PORTIONS OF THE LIME-FLY ASH BASE COURSE THAT ARE TRAVELED ON BY EQUIPMENT USED IN CONSTRUCTING AN ADJOINING SECTION SHALL BE PROTECTED IN SUCH A MANNER AS TO PREVENT EQUIPMENT FROM MARRING OR DAMAGING COMPLETED WORK.

2.8.19. MAINTENANCE UNDER TRAFFIC.

---

MAINTENANCE SHALL BE PERFORMED AS PROVIDED UNDER ARTICLE 1.4.3.

COMPENSATION.

---

2.8.20. METHOD OF MEASUREMENT.

---

AGGREGATE-LIME-POZZOLAN STABILIZED BASE COURSE OF THE THICKNESS SHOWN ON THE PLANS WILL BE MEASURED BY THE SQUARE YARD WITHOUT DEDUCTIONS OF AREAS OCCUPIED BY MANHOLES AND SIMILAR STRUCTURES.

STABILIZING AGENTS WILL BE MEASURED AS FOLLOWS:

LIME  
FLY ASH                      TON  
   TON

CURING MATERIALS WILL NOT BE MEASURED FOR PAYMENT.

2.8.21. BASIS OF PAYMENT.

-----  
THE ACCEPTED QUANTITY OF AGGREGATE-LIME-POZZOLAN STABILIZED BASE COURSE OF THE THICKNESS SHOWN ON THE PLANS WILL BE PAID FOR AT THE CONTRACT UNIT PRICE PER SQUARE YARD COMPLETE IN PLACE.

THE ACCEPTED QUANTITIES OF THE VARIOUS TYPE OF STABILIZING AGENTS WILL BE PAID FOR AT THE CONTRACT UNIT PRICE BASED ON THE UNIT OF MEASUREMENT SPECIFIED IN ARTICLE 2.8.20. THE QUANTITY OF STABILIZING AGENTS FOR WHICH PAYMENT WILL BE MADE WILL BE DETERMINED FROM THE TONNAGE ACTUALLY PLACED ON THE PROJECT BASED ON THE STABILIZING AGENT PROPORTIONS IN THE MIX DESIGN AND THE AVERAGE MOISTURE CONTENT OF THE MIXTURE AS FOLLOWS:

$$WS = \frac{WT}{W+1} = W \text{ LIME} + W \text{ FLY ASH} + W \text{ SOIL}$$

- WT = TOTAL WEIGHT (TON)
- WS = WEIGHT OF DRY SOLIDS = W LIME + W FLY ASH + W SOIL
- W = AVERAGE DAILY MOISTURE CONTENT OF THE MIXTURE (SEE NOTE 1)
- W LIME = WS X LIME PERCENT (IN MIX DESIGN)
- W FLY ASH = WS X FLY ASH PERCENT (IN MIX DESIGN)

NOTE 1: MOISTURE CONTENT WILL BE DETERMINED BY ASTM D2216 OR ASTM D3017.

PAYMENT WILL BE MADE UNDER:

PAY ITEM -----	PAY UNIT -----
AGGREGATE-LIME-POZZOLAN, STABILIZED BASE COURSE	SQUARE YARD
STABILIZING AGENT, LIME	TON
STABILIZING AGENT, FLY ASH	TON

2.8.22. METHOD OF TEST.

-----  
METHOD OF TESTS FOR DETERMINING THE DESIGN MIX PROPORTIONS FOR THE AGGREGATE-LIME-POZZOLAN STABILIZED BASE COURSE.

SCOPE.

1. THESE METHODS OF TESTS COVER THE PROCEDURES FOR DETERMINING THE DESIGN MIX PROPORTIONS FOR AN AGGREGATE-LIME-POZZOLAN STABILIZED BASE COURSE.

APPARATUS.

2. THE APPARATUS SHALL BE IN ACCORDANCE WITH THE CURRENT REQUIREMENTS OF ASTM C593 EXCEPT THAT THE EQUIPMENT USED IN AASHTO T99, METHOD C WILL BE USED FOR COMPACTION AND FOR DENSITY AND MOISTURE CONTENT DETERMINATIONS.

PREPARATION OF TEST SAMPLES.

3. THE COMPONENTS OF EACH CYLINDER WILL BE WEIGHED SEPARATELY AND THEN COMBINED TO ENSURE THE PROPER PROPORTIONING OF THE MIXTURES.

PROCEDURE.

METHOD 1:

4. (A) DEVELOP A CURVE OF FLY ASH CONTENT VERSUS DRY DENSITY OF THE MIXTURE CURVE FROM A SERIES OF MOISTURE-DENSITY TESTS AT VARYING FLY ASH CONTENTS USING THE MAXIMUM DRY DENSITY OF EACH TEST BY AASHTO T99, METHOD C (WITH REPLACEMENT). THE FLY ASH CONTENT IS THE PERCENTAGE OF THE DRY AGGREGATE BY WEIGHT. THE DESIGN MIX QUANTITY OF FLY ASH WILL BE THAT AMOUNT WHICH PRODUCES THE MAXIMUM DENSITY FROM THE FLY ASH VERSUS DRY DENSITY CURVE.

(B) THE DESIGN LIME TO FLY ASH RATION (BETWEEN 1:3 AND 1:4) SHALL BE DETERMINED FROM A SERIES OF 3 COMPRESSION CYLINDERS MADE WITH MIXTURES OF PROGRESSIVE LIME TO FLY ASH PROPORTIONS AT THE CONSTANT FLY ASH CONTENT DETERMINED IN 4 (A) PREVIOUSLY. THE CYLINDERS MADE AT EACH LIME TO FLY ASH RATIO WILL BE PREPARED IN ACCORDANCE WITH ASTM C593, PART 8, EXCEPT THAT AASHTO T99 COMPACTION WILL BE ACCOMPLISHED AT THE OPTIMUM MOISTURE CONTENT AS IN 2. ABOVE AND THAT THE CYLINDERS WILL BE CURED FOR 28 DAYS AT 100 DEGREES F. IN CONTAINERS WHICH WILL NOT LOOSE MORE THAN 0.25 PERCENT MOISTURE. THE PROPORTIONS PRODUCING THE GREATEST COMPRESSIVE STRENGTH SHALL BE USED IN THE MIX DESIGN, PROVIDED THAT THE RESULTING AVERAGE COMPRESSIVE STRENGTH FOR THOSE PROPORTIONS IS GREATER THAN THE MINIMUM REQUIRED IN ARTICLE 2.8.6. IF THIS REQUIREMENT IS NOT SATISFIED, THE PERCENTAGE OF MATERIAL PASSING THE 200 SIEVE WILL BE REDUCED TO ACCOMMODATE GREATER QUANTITIES OF LIME AND FLY ASH AND THEN REDESIGNED TO EVALUATE THE NEW PROPORTIONS.

METHOD 2:  
-----

5. (A) PREPARE 3 COMPRESSION CYLINDERS AT 2, 3, 4 AND 5 PERCENT LIME CONTENTS AT LIME TO FLY ASH RATIO OF 1:3 AND 1:4 FOR EACH LIME CONTENT. THE CYLINDERS WILL BE MADE IN ACCORDANCE WITH ASTM C593, PART 8, WITH THE EXCEPTIONS NOTED PREVIOUSLY IN 4. ABOVE.

(B) FROM THE TEST RESULTS IN 5 (A) CONSTRUCT TWO CURVES FOR THE AVERAGE UNCONFINED COMPRESSIVE STRENGTH VERSUS THE LIME CONTENT; ONE CURVE FOR THE 1:3 RATIO AND ONE CURVE FOR THE 1:4 RATIO.

(C) AT THE MINIMUM ALLOWABLE COMPRESSIVE STRENGTH VALUE REQUIRED IN ARTICLE 2.8.6 ON EACH CURVE, DRAW VERTICAL LINES TO THE RESPECTIVE LIME CONTENTS. (IF ALL AVERAGE COMPRESSIVE STRENGTHS ARE GREATER THAN THAT REQUIRED IN ARTICLE 2.8.6, USE 2 PERCENT LIME CONTENT.) USE THE HIGHER OF THE TWO AS THE LIME CONTENT OF THE MIX DESIGN WITH A LIME TO FLY ASH RATIO OF 1:3.5. THE RESULTING DESIGN SHOULD UPON VERIFICATION COMPLY WITH THE REQUIREMENTS IN ARTICLE 2.8.7, USE A SLIGHTLY HIGHER LIME CONTENT TO ACHIEVE VERIFICATION. A CHANGE IN THE PERCENTAGE OF MATERIAL PASSING THE 200 SIEVE MAY ALSO BE NECESSARY.

REPORT.  
-----

6. THE REPORT SHALL INDICATE THE PROPORTIONS OF THE LIME, FLY ASH AND AGGREGATE IN THE MIX DESIGN. THE AMOUNT OF LIME, FLY ASH AND AGGREGATE WILL BE EXPRESSED AS PERCENTAGES OF THE WEIGHT OF THE TOTAL DRY MIX TO ENSURE COMPLIANCE WITH THE LIMITS SET IN ARTICLE 2.8.6. THE REPORT SHALL ALSO CONTAIN THE MAXIMUM DRY DENSITY AND OPTIMUM MOISTURE CONTENT OF THE MIX DESIGN PROPORTION IN ACCORDANCE WITH AASHTO T99, METHOD C; (WITH REPLACEMENT). IF METHOD 2 IS USED, THE TWO CURVES AT THE 1:3 AND 1:4 LIME TO FLY ASH RATIOS SHALL BE INCLUDED IN THE REPORT.

 **LIMESTONE PRODUCTS CORPORATION**  
SUBSIDIARY OF PENN VIRGINIA CORPORATION

P. O. BOX 217 • SPARTA, NEW JERSEY 07871 • TELEPHONE (201) 383-2000

May 7, 1984

Mr. Thomas Corcoran  
Project Engineer, Materials  
New Jersey Department of Transportation  
Bureau of Plant and Project Inspection  
7 Route #22  
Clinton, NJ 08809

Dear Sir:

Enclosed are several copies of Limestone Products Corporation 1984 Mix Designs for Lime, Fly Ash, and Aggregate. When the design has been approved and signed by you, would you please send me a signed copy for our files.

There will be no reason to change this mix design next year. If there is any reason why a project cannot be completed this year, this same mix design will carry on through 1985.

If there are any problems with the mix design or with production, please notify me immediately because there will be very little time between approval and the start up of the Route 295 Section 7C project.

I am also submitting to you with this mix design about 150 LBS of coarse and fine limestone aggregate, 50 LBS of Fly Ash and 25 LBS of Hydrate Lime that will be used on all New Jersey D.O.T. Projects, for your laboratory verification.

Sincerely yours,

*Alan R. Van Gelder*

Alan R. VanGelder  
Laboratory Supervisor

AVG/djm



P. O. BOX 217 · SPARTA, NEW JERSEY 07871 · TELEPHONE (201) 383-2000

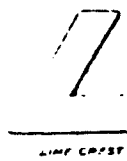
1984 MIX DESIGNS

NEW JERSEY DEPARTMENT OF TRANSPORTATION--HYDRATE LIME, FLY ASH, AND DENSE GRADED LIMESTONE AGGREGATE MIX DESIGNS

- 2.0 % Lime (Warners Dihydrate)
- 6.0 % Fly Ash ( Metropolitan Edison From Portland, Pennsylvania)
- 46.0 % Fine Aggregate (#10 Lime Crest Limestone)
- 46.0 % Coarse Aggregate (#57 Lime Crest Limestone)

AGGREGATE GRADATION

<u>SIEVE SIZES</u>	<u>COARSE AGGREGATE</u>		<u>FINE AGGREGATE</u>		<u>AGGREGATE COMBINATION</u>	<u>DENSE AGGREGATE</u>
	#57 = 50%		#10 = 50%			<u>SPECKS</u>
1 1/2 inch	100	50		50	100	100
1 inch	93.2	46.6		50	96.6	
3/4 inch	64.6	32.3		50	82.3	55-90
1/2 inch	29.2	14.6	100	50	64.6	
3/8 inch	10.5	5.3	97.1	48.6	53.9	
4 mesh	4.5	2.3	75.3	37.7	40.0	25-60
8 mesh	3.0	1.5	53.4	26.7	28.2	
16 mesh			36.6	18.3	18.3	
30 mesh			25.7	12.9	12.9	
50 mesh			17.7	8.9	8.9	5-25
100 mesh			11.1	5.6	5.6	
200 mesh			8.0	4.0	4.0	3-12



# LIMESTONE PRODUCTS CORPORATION

SUBSIDIARY OF PENN VIRGINIA CORPORATION

P. O. BOX 217 - SPARTA, NEW JERSEY 07871 - TELEPHONE (201) 363 2000

The following tables consists of data with various percentages of Lime, Fly Ash and Lime Crest Aggregates.

The first table is unconfined compressive strength development, Part 8, as stated in ASTM C593.

<u>PERCENT LIME</u>	<u>PERCENT FLY ASH</u>	<u>PERCENT FINE AGG.</u>	<u>PERCENT COARSE AGG.</u>	<u>P.S.I. #1 PLUG</u>	<u>P.S.I. #2 PLUG</u>	<u>P.S.I. #3 PLUG</u>	<u>AVG.</u>	<u>PERCENT AVERAGE RESISTANCE</u>
2	6	46	46	1275	1050	1065	1130	---
3	9	44	44	1550	1530	1695	1590	---
4	12	42	42	1410	1340	1330	1360	---
5	15	40	40	1180	1320	1360	1285	---
2	8	45	45	960	775	1020	920	---
3	12	42.5	42.5	1020	865	1230	1040	---
4	16	40	40	1155	1050	1090	1100	---
5	20	37.5	37.5	1500	1450	1500	1485	---

This second table is vacuum strength testing procedure, Part 9, as stated in ASTM C593.

2	6	46	46	1160	1195	1225	1195	10
3	9	44	44	1770	1550	1460	1595	10
4	12	42	42	1360	1060	1600	1340	9
5	15	40	40	1515	1375	1660	1515	11
2	8	45	45	1300	1105	955	1120	10
3	12	42.5	42.5	1050	1360	1275	1230	11
4	16	40	40	1335	1360	995	1230	11
5	20	37.5	37.5	1195	1260	1210	1230	8



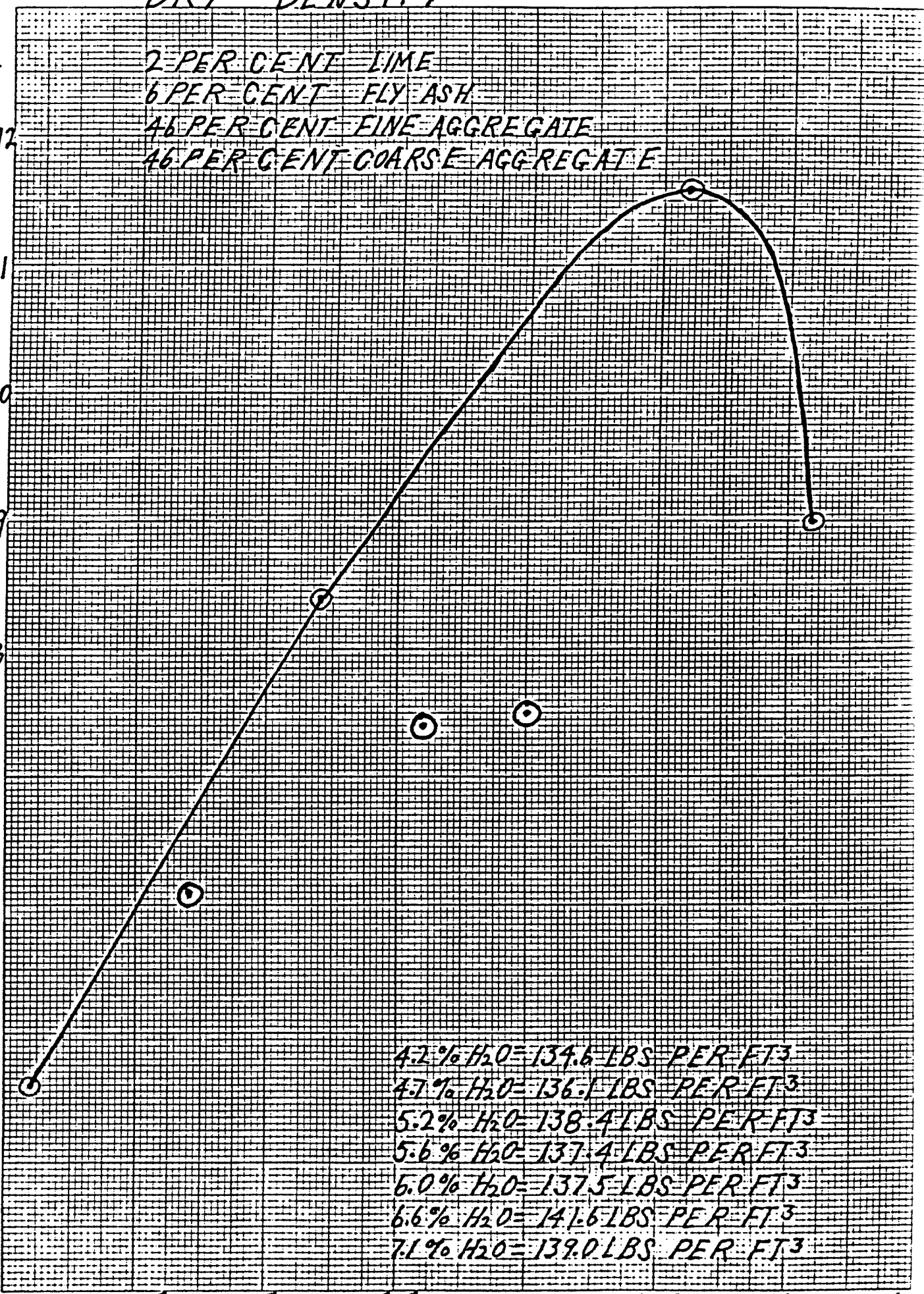
# DRY DENSITY

2 PER CENT LIME  
6 PER CENT FLY ASH  
46 PER CENT FINE AGGREGATE  
46 PER CENT COARSE AGGREGATE

WATER CONTENT

134  
135  
136  
137  
138  
139  
140  
141  
142

4 4.5 5 5.5 6 6.5 7 7.5



- 4.2% H<sub>2</sub>O = 134.6 LBS PER FT<sup>3</sup>
- 4.7% H<sub>2</sub>O = 136.1 LBS PER FT<sup>3</sup>
- 5.2% H<sub>2</sub>O = 138.4 LBS PER FT<sup>3</sup>
- 5.6% H<sub>2</sub>O = 137.4 LBS PER FT<sup>3</sup>
- 6.0% H<sub>2</sub>O = 137.5 LBS PER FT<sup>3</sup>
- 6.6% H<sub>2</sub>O = 141.6 LBS PER FT<sup>3</sup>
- 7.1% H<sub>2</sub>O = 139.0 LBS PER FT<sup>3</sup>

**APPENDIX D**  
**LABORATORY AND FIELD TEST RESULTS**

TABLE D-1  
SOILS GRADATIONS FROM EXPERIMENTAL SECTIONS

Percent Passing (Average of three tests)

<u>Sieve Size</u>	<u>Subgrade</u>	<u>I-11</u>	<u>I-3</u>	<u>D.G.A.B.</u>
2"	100	100	100	100
1½"	100	100	100	100
¾"	98.4	100	88.3	82.3
#4	93.0	99.0	85.3	39.2
#50	37.8	28.5	21.0	10.8
#200	19.1	4.5	5.6	5.7

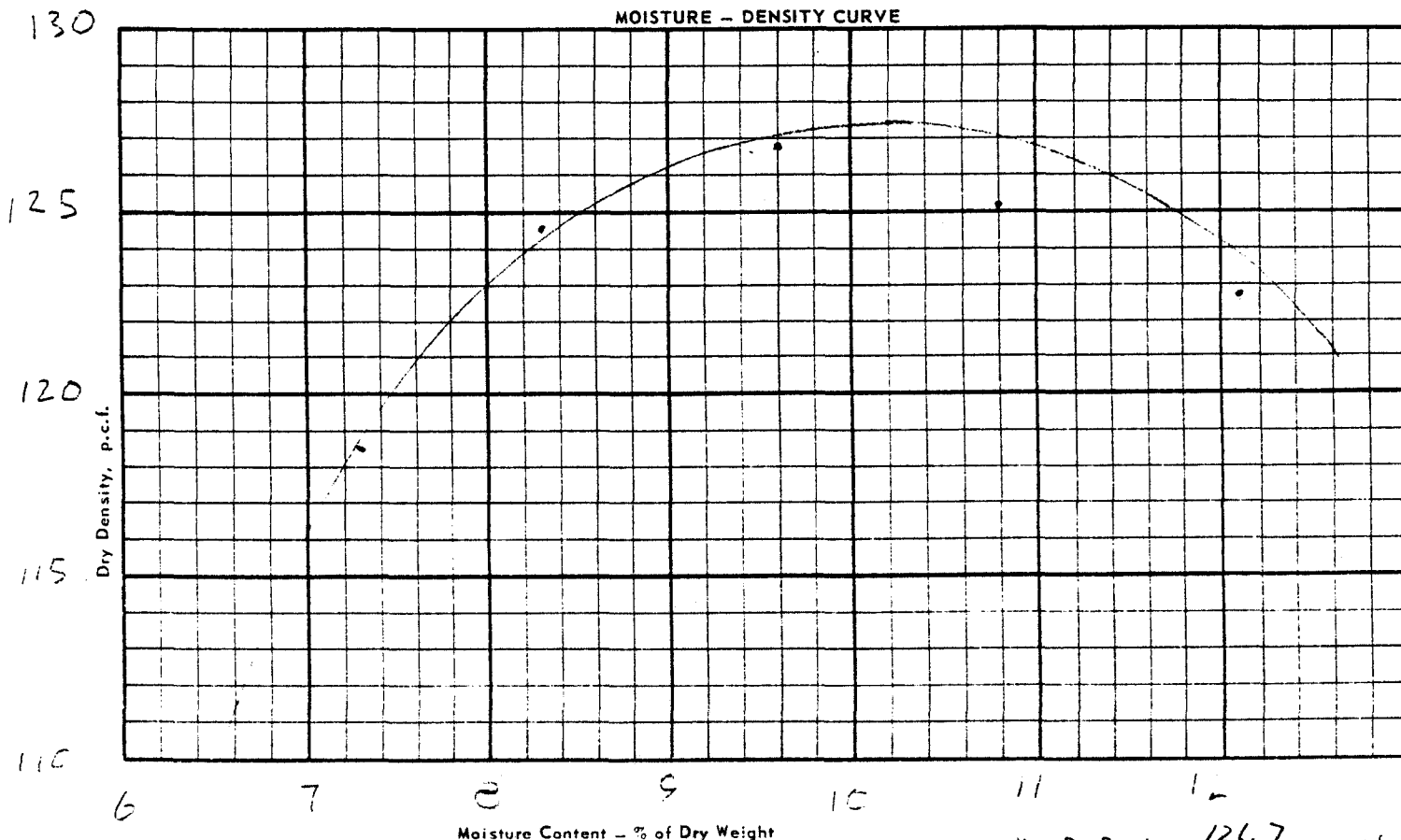
**LABORATORY SOIL ANALYSIS**

Form LB-200 (b) 6-72

MOISTURE - DENSITY RELATIONSHIP

Serial No. Subgrade Date Tested 10/19/83 Producer \_\_\_\_\_  
 Route J-295 \_\_\_\_\_ -  $\frac{3}{4}$ " #4 = \_\_\_\_\_  
 Section 7C Station 625 to 5.8. - #4 = \_\_\_\_\_  
 AASHTO or ASTM Designation D 698 Method D

REST RESULTS										
Trial No.		1	2	3	4	5	6	7	8	9
Water Added	%	6	7	8	9	10				
Weight of Cyl. & Soil	gms.	6230	6346	6407	6405	6386				
Weight of cyl.	gms.	4303	4303	4303	4303	4303				
Weight of Soil	gms.	1927	2043	2104	2102	2083				
Wet Density	p.c.f.	127.2	134.8	138.9	138.7	137.5				
Can Number		1	2	3	4	5				
Weight Wet Soil & Can	gms.	296.8	287.2	284.3	294.6	287.0				
Weight Dry Soil & Can	gms.	279.8	268.8	263.6	270.6	261.2				
Weight Loss	gms.	17.0	18.4	20.7	24.0	25.7				
Weight of Can	gms.	48.1	47.9	48.0	47.7	48.2				
Weight of Dry Soil	gms.	231.7	220.9	215.6	222.9	213.0				
Moisture %		7.3%	8.3%	9.6%	10.8%	12.1%				
Dry Density	p.c.f.	118.5	124.5	126.7	125.2	122.7				



Max. Dry Density 126.7 p.c.f.  
 Optimum Moisture 9.6 %

SIGNED \_\_\_\_\_

**LABORATORY SOIL ANALYSIS**

Form LB-200 (b) 6-72

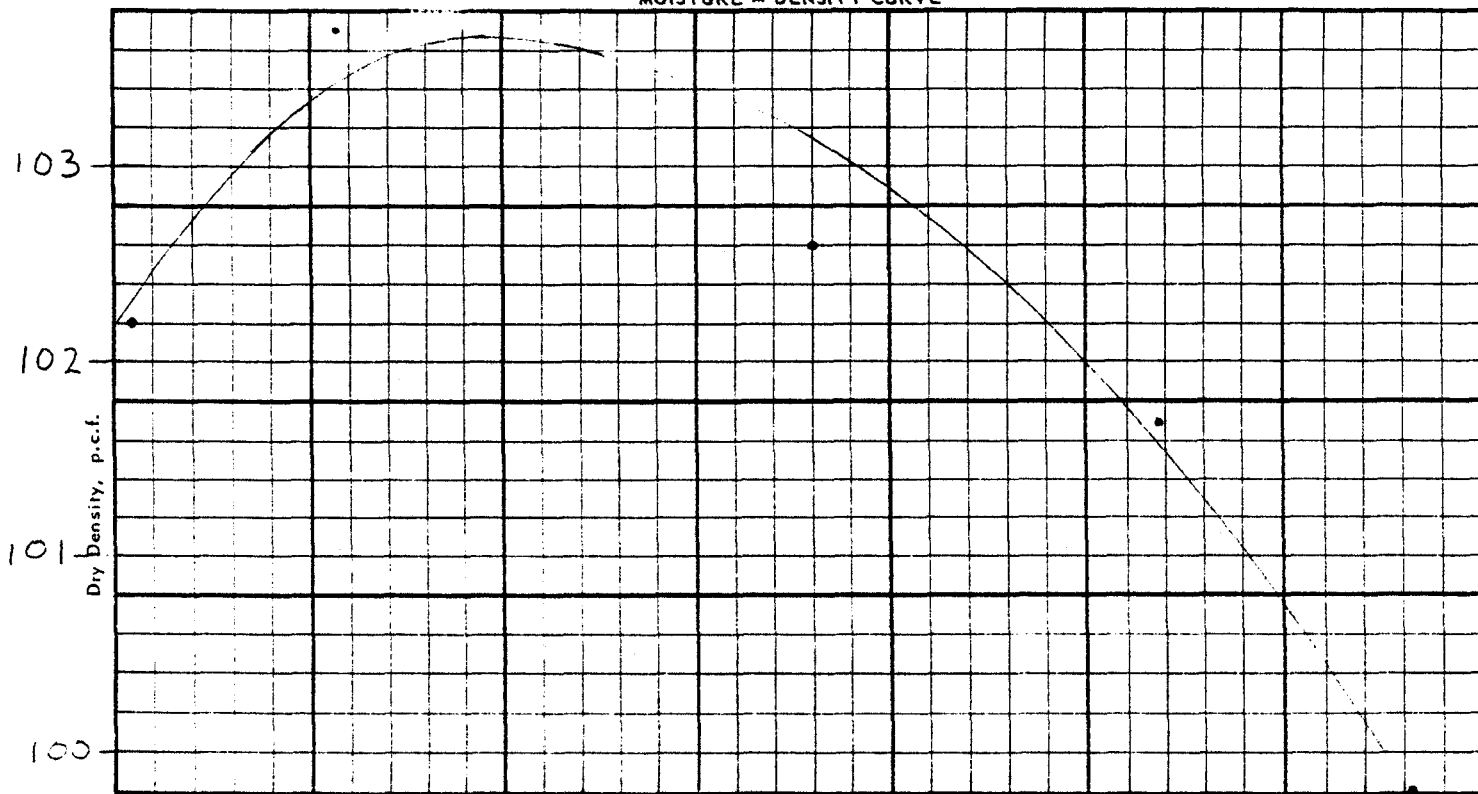
MOISTURE - DENSITY RELATIONSHIP

Serial No. I-11 (Zone II) Date Tested 10/2/83 Producer \_\_\_\_\_  
 Route I-295 Station 615+0 S.B. - 3/4" + 4" =  
 Section 7C Station 615+0 S.B. - 4" =  
 AASHTO or ASTM Designation D 698 Method D

**TEST RESULTS**

Trial No.	1	2	3	4	5	6	7	8	9
Water Added %	0	2	4	6	8				
Weight of Cyl. & Soil gms.	6054	6142	6194	6258	6239				
Weight of cyl. gms.	2307	2307	2307	2307	2307				
Weight of Soil gms.	3747	3845	3887	3951	3932				
Wet Density p.c.f.	112.5	115.5	116.8	118.7	118.1				
Can Number									
Weight Wet Soil & Can gms.	5	6	7	8	9				
Weight Dry Soil & Can gms.	130.5	118.8	126.0	173.8	144.5				
Weight Loss gms.	120.6	107.7	112.9	152.0	125.5				
Weight of Can gms.	22.8	21.5	22.5	21.5	21.8				
Weight of Dry Soil gms.	97.8	97.3	90.4	130.5	103.7				
Moisture %	10.1%	11.4%	14.5%	16.7%	18.3%				
Dry Density p.c.f.	102.7	103.7	102.6	101.7	99.8				

**MOISTURE - DENSITY CURVE**



Moisture Content - % of Dry Weight

Max. Dry Density 103.7 p.c.f.

Optimum Moisture 11.4 %

SIGNED \_\_\_\_\_

LABORATORY SOIL ANALYSIS

Form LB-200 (b) 6-72

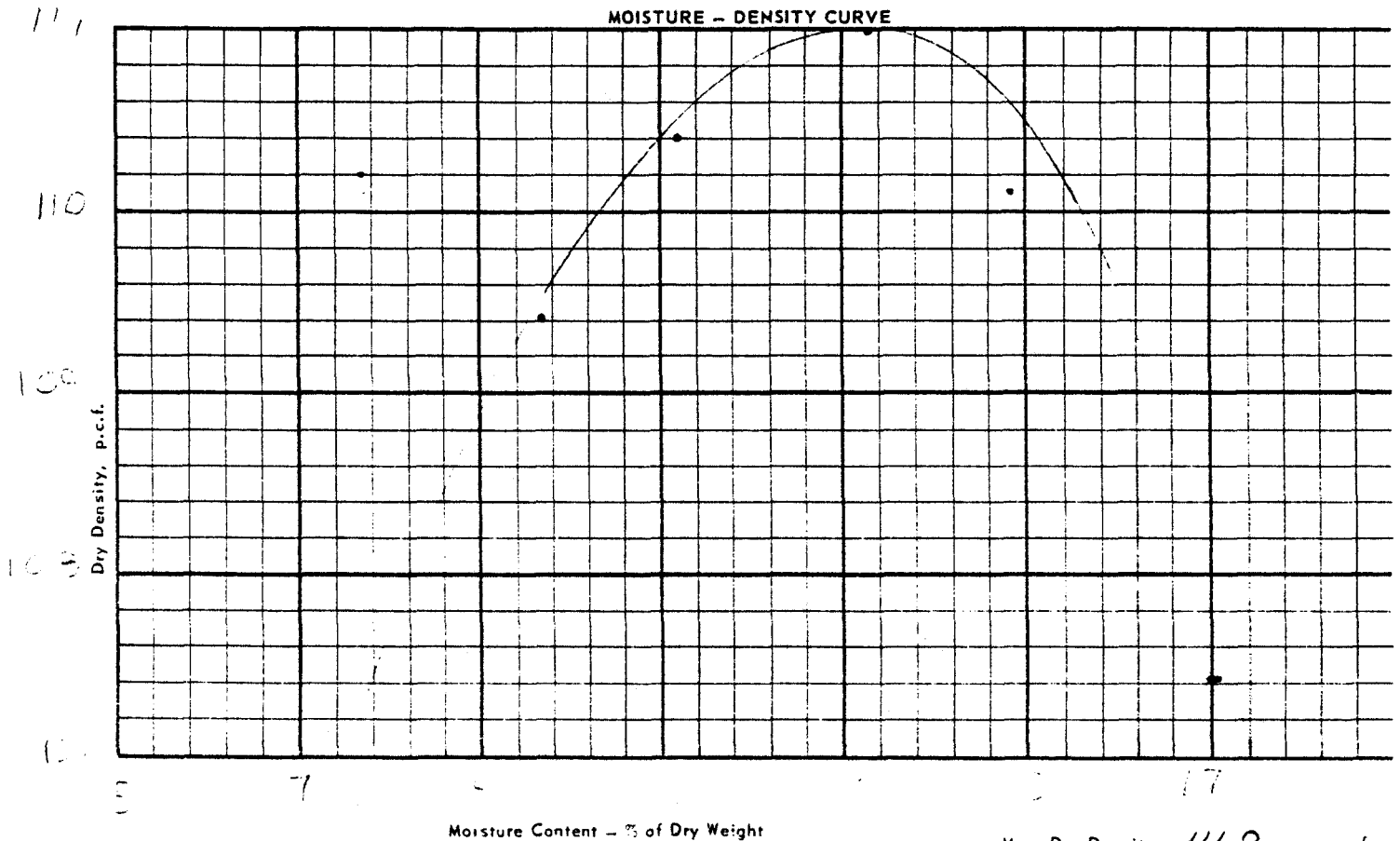
MOISTURE - DENSITY RELATIONSHIP

Serial No. Subbase (I-3) Date Tested 7/30/84 Producer \_\_\_\_\_  
 Route I-295 Station 617+50 S.B. - #4 = \_\_\_\_\_  
 Section 7C Station 617+50 S.B. - #4 = \_\_\_\_\_  
 AASHTO or ASTM Designation D698 Method D

TEST RESULTS

Trial No.	1	2	3	4	5	6	7	8	9
Water Added %	8	10	12	14	16	18			
Weight of Cyl. & Soil gms.	6099	6118	6163	6208	6218	6206			
Weight of cyl. gms.	4302	4302	4302	4302	4302	4302			
Weight of Soil gms.	1797	1816	1861	1906	1916	1904			
Wet Density p.c.f.	118.7	119.9	122.8	125.8	126.2	125.7			
Can Number	1	2	3	4	5	6			
Weight Wet Soil & Can gms.	195.1	197.4	176.9	202.9	217.3	212.2			
Weight Dry Soil & Can gms.	183.6	183.0	162.6	183.1	191.0	186.5			
Weight Loss gms.	11.5	14.4	14.3	19.8	23.3	25.7			
Weight of Can gms.	35.1	35.1	34.3	34.6	34.8	35.3			
Weight of Dry Soil gms.	148.5	147.9	127.7	148.5	156.2	151.2			
Moisture %	7.79	9.75	11.29	13.39	14.91	17.00			
Dry Density p.c.f.	107.2	109.3	110.4	111.0	111.0	107.4			

MOISTURE - DENSITY CURVE



Moisture Content - % of Dry Weight

Max. Dry Density 111.0 p.c.f.

Optimum Moisture 13.3 %

SIGNED \_\_\_\_\_

**LABORATORY SOIL ANALYSIS**

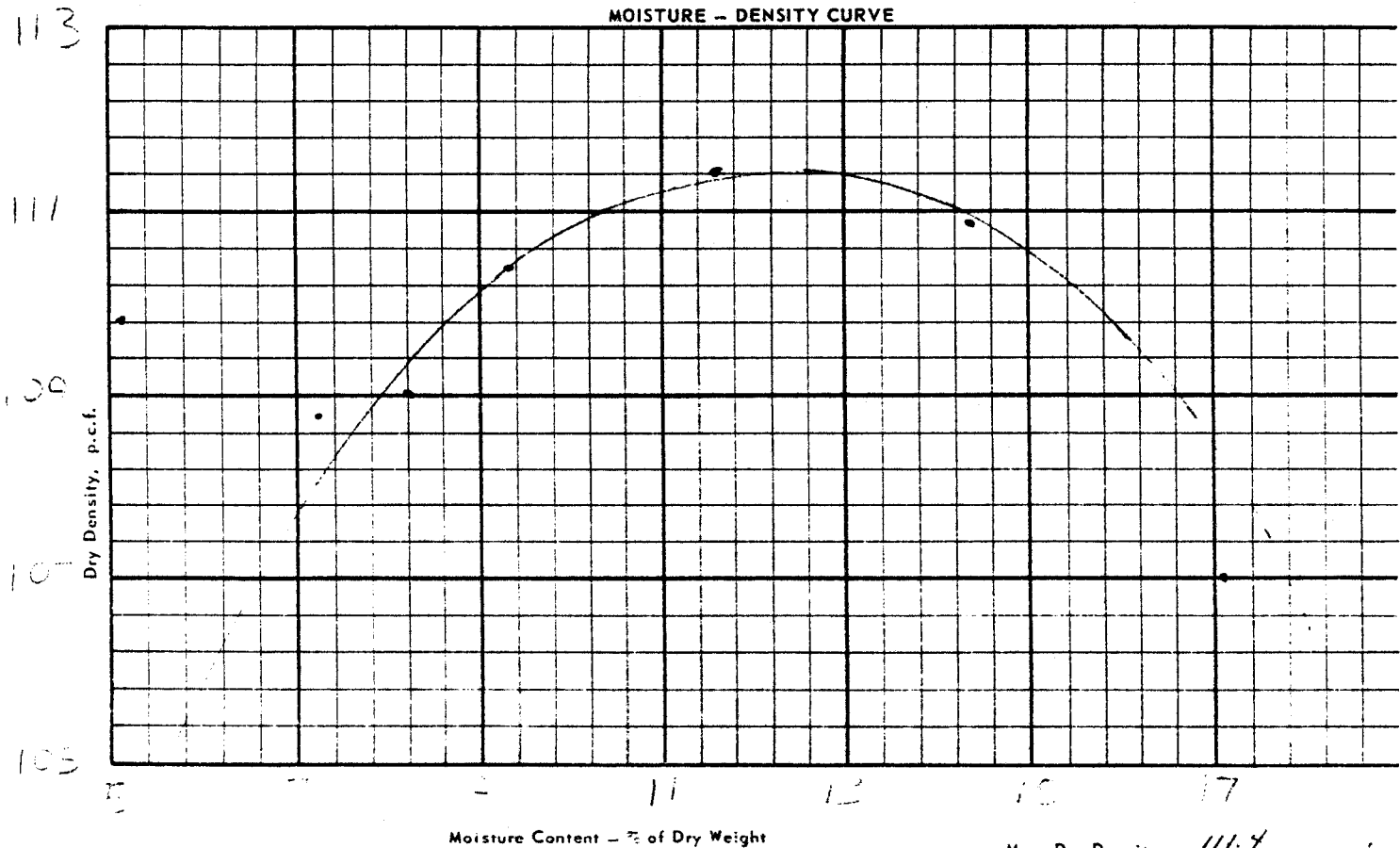
Form LB-200 (b) 6 72

MOISTURE - DENSITY RELATIONSHIP

Serial No. Subbase (I-3) Date Tested 7/27/84 Producer \_\_\_\_\_  
 Route RT. I-295 Station 616+0 N.B. - 3/4" #4 = \_\_\_\_\_  
 Section 7C Station 616+0 N.B. - #4 = \_\_\_\_\_  
 AASHO or ASTM Designation D698 Method 0

REST RESULTS										
Trial No.		1	2	3	4	5	6	7	8	9
Water Added	%	4	6	7	8	10	12	14		
Weight of Cyl. & Soil	gms.	6050	6069	6089	6133	6185	6225	6201		
Weight of cyl.	gms.	4302	4302	4302	4302	4302	4302	4302		
Weight of Soil	gms.	1748	1767	1787	1831	1883	1923	1899		
Wet Density	p.c.f.	115.4	116.6	117.9	120.8	124.3	126.9	125.3		
Can Number		1	2	3	4	5	6	7		
Weight Wet Soil & Can	gms.	277.2	314.6	304.1	380.7	331.1	433.2	322.8		
Weight Dry Soil & Can	gms.	265.5	295.8	283.7	351.2	300.3	383.1	279.7		
Weight Loss	gms.	11.7	18.8	20.4	29.5	30.8	50.1	43.1		
Weight of Can	gms.	35.1	35.4	35.3	34.7	34.7	34.9	27.8		
Weight of Dry Soil	gms.	230.4	260.4	248.4	316.5	265.6	348.2	251.9		
Moisture %		5.1%	7.2%	8.2%	9.3%	11.6%	14.4%	17.1%		
Dry Density	p.c.f.	109.3	109.3	109.3	110.5	111.4	110.9	107.0		

MOISTURE - DENSITY CURVE



Moisture Content - % of Dry Weight

Max. Dry Density 111.4 p.c.f.  
 Optimum Moisture 11.6 %

SIGNED \_\_\_\_\_

LABORATORY SOIL ANALYSIS

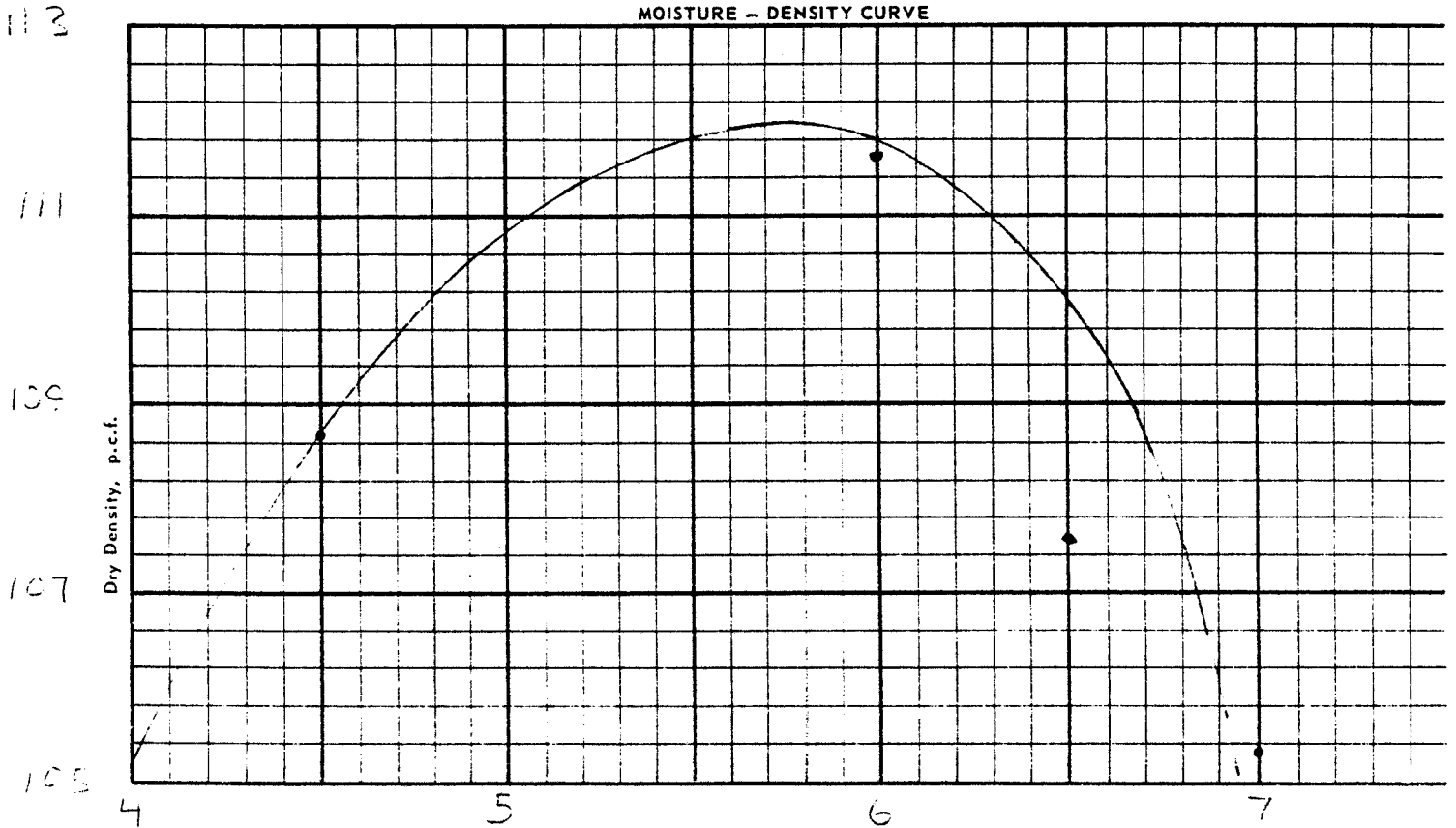
Form LB-200 (b) 6/72

MOISTURE - DENSITY RELATIONSHIP

Serial No. D.G. AB. Date Tested 10/11/84 Producer Blast Furnace Slag  
 Route I-295  $-\frac{3}{4}'' \pm 4 =$   
 Section 7C Station 62070 N.B. -#4=  
 AASHTO or ASTM Designation D 698 Method D

REST RESULTS										
Trial No.		1	2	3	4	5	6	7	8	9
Water Added	%	3	4	5	6					
Weight of Cyl. & Soil	gms.	6034	6104	6050	6020					
Weight of cyl.	gms.	4314	4317	4314	4314					
Weight of Soil	gms.	1720	1790	1736	1706					
Wet Density	p.c.f.	113.6	118.2	114.6	112.0					
Can Number		1	2	3	4					
Weight Wet Soil & Can	gms.	1897	1969	1804	1869					
Weight Dry Soil & Can	gms.	1821.7	1869	1760.1	1759.5					
Weight Loss	gms.	75.3	100	103.9	109.5					
Weight of Can	gms.	155.5	170.5	158.2	173.0					
Weight of Dry Soil	gms.	1666.2	1698.5	1601.9	1580.5					
Moisture %		4.5%	5.9%	6.5%	6.9%					
Dry Density	p.c.f.	108.7	111.6	107.6	105.3					

MOISTURE - DENSITY CURVE



Moisture Content - % of Dry Weight

Max. Dry Density 111.6 p.c.f.

Optimum Moisture 5.9 %

SIGNED \_\_\_\_\_

**REPORT OF ANALYSIS OF AGGREGATE**

354725

8-10-84

CHARGED TO: Limestone Products Corporation

PROPOSED USE Lime Flyash Stabilized Base

KIND OF MATERIAL SIZE TYPE CLASS

PRODUCER Limestone Products LOCATION Limecrest, N.J.

PLANT " " LOCATION " "

SAMPLE TAKEN FROM	Stockpile at Limestone Prods.
QUANTITY REPRESENTED	1000 Tons
MARKS ON SAMPLE	PM 1
SAMPLED BY	R. Magon
DATE TAKEN	5-10-84
DATE REC'D. AT LAB.	5-21-84
SEAL NO.	
LAB. SERIAL NO.	354725

REPORTED TO  
Limestone Prods.  
T. Corcoran  
C. Heckman  
P. Marchetti ✓  
M. Liao  
F. Stia

SIZE OF OPENING SQUARE	TOTAL PERCENT PASSING		REQUIRED	
			Min.	Max.
4"				
3 1/2"				
3"	Compressive strength psi			
2 1/2"	Cyl. #1	1237		
2"	2	1082		
1 1/2"	3	1057		
1"	Avg.	1125 (Design Strength)	950 psi	
3/4"				
1/2"	Vacuum Saturated (PST)			
3/8"	Cyl. #1	1240		
No. 4	5	1033		
No. 8	6	1261		
No. 16	Avg.	1179	961 psi	85% Design Strength
No. 30				
No. 50				
No. 100				
No. 200				

PLASTICITY INDEX	
ABSORPTION	
SODIUM SULFATE LOSS	

REMARKS: Mix Design proportions 2.0% Lime(Warner Dihydrate)  
6.0% Fly Ash(Metropolitan Edison, Port  
Complies. 46.0% Fine Aggr. (#10 Limecrest Limestone)  
5% Moisture.

PM:cam Original Signed P. Marchetti





AGCBTCED-2 11/15/85

NEW JERSEY DEPARTMENT OF TRANSPORTATION  
BUREAU OF QUALITY CONTROL  
BITUMINOUS CORE SUMMARY

THICKNESS LOT NO. 3

CORE NO.	LOCATION	STATION	LANE	OFF SET	THICKNESS - INCHES			VOIDS LOT NO.	AIR VOIDS - PERCENT	
					SURFACE	BINDER	BASE		SURFACE	BINDER
					SPECIFIED THICKNESS	1.50	6.00	7.50		
831	NB	0634+57	L3	5.0	1.51	6.31	7.82	3A	6.4	4.9
832	NB	0632+93	L0S	10.0	2.57	8.20	10.77	3A	6.5	3.1
833	NB	0627+52	L1S	5.0	2.18	7.24	9.42	3A	7.8	5.7
834	NB	0625+40	L1	1.0	1.60	7.30	8.90	3A	8.0	6.4
835	NB	0623+41	L2	7.0	1.52	8.13	9.65	3A	6.8	3.6
836	NB	0621+62	L3	5.0	1.83	6.96	8.79	3B	7.4	5.1
837	NB	0620+91	L0S	10.0	1.35	8.12	9.47	3B	12.8	5.0
838	NB	0618+59	L1S	3.0	1.60	6.77	8.37	3B	11.7	6.0
839	NB	0618+16	L1	7.0	1.48	8.00	9.48	3B	6.9	6.0
840	NB	0615+27	L2	3.0	1.45	6.25	7.70	3B	6.7	5.5
841	NB	0614+43	L3	10.0	2.00	6.83	8.83	3C	6.1	5.8
842	NB	0611+56	L0S	1.0	2.74	5.27	8.01	3C	8.0	11.4
843	NB	0611+19	L1S	8.0	1.78	6.72	8.50	3C	11.4	9.5
844	NB	0609+68	L1	4.0	1.67	7.29	8.96	3C	9.7	10.3
845	NB	0607+32	L2	11.0	1.54	6.41	7.95	3C	7.0	5.3

\*\*\* POSSIBLE ERROR IN INPUT VALUE(S) FOR:  
CORE 832 VALUE(S)  
CORE 842 VALUE(S)

2.57 } INFORMATION  
2.74 } CORRECT

ACC01CED-2 11/15/85

NEW JERSEY DEPARTMENT OF TRANSPORTATION  
BUREAU OF QUALITY CONTROL  
BITUMINOUS CORE SUMMARY

AIR VOIDS LOT NO.	COURSE	AIR VOIDS - PERCENT AVER. CONTROL	PERCENT DEV. ABOVE/ BELOW CONTROL	LOTSIZE (SQ YDS)	AVER. THICK (INCHES)	REDUCTIONS PERCENT	TONS
3A	BINDER	7.1	2-8	5767	1.88	0	0
3A	BASE	4.7	2-8	5767	7.44 > 9.32	0	0
3B	BINDER	9.1	2-8	5767	1.54	10	52
3B	BASE	5.7	2-8	5767	7.22 > 9.76	0	0
3C	BINDER	8.4	2-8	5767	1.95	5	33
3C	BASE	8.5	2-8	5767	6.50 > 8.45	5	112

AL = 6.80

$\frac{26.53}{3} = 8.84$  AVE LOT THICK

$\frac{R1}{2.95}$      $\frac{R2}{1.78}$      $\frac{R3}{1.01}$      $\frac{AVR}{1.91}$

$QL = \frac{8.84 - 6.80}{1.91}$

$QL = \frac{2.04}{1.91}$

QL = 1.07 = NO REDUCTION

AOCBTCED-2 11/15/85

NEW JERSEY DEPARTMENT OF TRANSPORTATION  
BUREAU OF QUALITY CONTROL  
BITUMINOUS CORE SUMMARY

CORE NO.	LOCATION	STATION	LANE	OFF SET	THICKNESS - INCHES		TOTAL THICK	VOIDS LOT NO.	AIR Voids - PERCENT	
					SURFACE BINDER	BASE			SURFACE BINDER	BASE

THICKNESS LOT NO. 4										
SPECIFIED THICKNESS 1.50 4.00 5.50										
B47	SB	0609+20	R1S	6.0	1.82	3.72	5.54	4A	9.8	6.2
B48	SB	0610+51	K1	5.0	2.21	5.12	7.35	4A	6.0	6.0
B49	SB	0612+44	R2	11.0	4.21	5.68	9.89	4A	6.0	4.0
B50	SB	0613+30	R3	0.0	2.26	5.50	5.87	4A	7.4	5.8
B51	SB	0614+41	R0S	0.0	1.65	5.09	6.74	4A	8.3	4.7
B52	SB	0615+93	R1S	5.0	3.17	4.39	7.56	4B	4.8	2.7
B53	SB	0617+44	R1	19.0	3.12	4.39	7.51	4B	5.7	4.3
B54	SB	0619+22	R2	7.0	3.35	4.24	7.59	4B	5.3	5.1
B55	SB	0619+76	K3	5.0	4.27	3.48	7.75	4B	4.8	5.7
B56	SB	0621+46	R0S	5.0	2.40	4.03	6.43	4B	7.9	7.4
B57	SB	0622+03	R1S	5.0	2.99	4.14	7.13	4C	5.1	4.0
B58	SB	0623+88	R1	3.0	3.63	4.22	6.85	4C	5.0	3.1
B59	SB	0624+45	R2	5.0	1.03	4.87	6.90	4C	5.0	3.9
B60	SB	0626+45	R3	9.0	1.61	3.89	5.50	4C	5.1	3.2
B60	SB	0627+61	R0S	9.0	1.61	3.89	5.50	4C	5.1	3.2

\*\*\* POSSIBLE ERROR IN INPUT VALUE(S) FOR:

- CORE B48
- CORE B51
- CORE B52
- CORE B53
- CORE B54
- CORE B56
- CORE B57

4.21  
3.17  
3.15  
3.35  
4.27  
2.63

INFORMATION  
CORRECT

AOCOTCED-2 11/15/85

NEW JERSEY DEPARTMENT OF TRANSPORTATION  
BUREAU OF QUALITY CONTROL  
BITUMINOUS COKE SUMMARY

AIR VOIDS LOT NO.	COURSE	AIR VOIDS - PERCENT		LUT SIZE (750 YDS)	AVER. THICK (INCHES)	REDUCTIONS TONS	
		AVER.	CONTROL			PERCENT	TONS
4A	BINDER BASE	7.9	2-8	4105	2.43	0	0
		5.4	2-8	4105	4.64	7.07	0
4B	BINDER BASE	5.7	2-8	4105	3.24	0	0
		4.4	2-8	4105	4.11	7.37	0
4C	BINDER BASE	5.6	2-8	4105	2.24	0	0
		4.0	2-8	4105	4.28	6.52	0
						20.96 = 6.99	

AL = 4.85

$\frac{R1}{435} = \frac{R2}{1.32} = \frac{R3}{1.63} = \frac{AV. \bar{R}}{2.43}$

QL =  $\frac{6.99 - 4.85}{2.43}$

QL =  $\frac{2.14}{2.43} = 0.88$

APPENDIX E  
CALCULATIONS FOR ENERGY CONSUMPTION

ENERGY CALCULATIONS FOR BITUMINOUS CONCRETE

Given

Mix Design: 60% crushed stone, 35% sand, 5% mineral filler, 5.5% asphalt cement.

Haul Distance: Crushed stone 15 miles  
 Sand 30 miles  
 Asphalt Cement 50 miles  
 Mix 12 miles

Temperatures: Ambient 70°F, mix 300°F.

Moisture: Avg. in sand and crushed stone 6%.

Truck Type: Assume all items hauled in 5 axle, diesel fueled trucks.  
 Mix hauled in 3 axle, diesel trucks.

MATERIALS

<u>Asphalt Cement</u>	<u>BTU/TON</u>
Refine asphalt cement	587,500
Haul 50 miles x 2 x 1960 BTU/Ton miles	196,000
Total for A.C.	<u>783,500</u>

Aggregates

Produce Crushed stone at 70,000 BTU/Ton, 60%	42,000
Produce sand at 15,000 BTU/Ton, 35%	5,250
Produce mineral filler at 70,000 BTU/Ton, 5%	3,500
Haul stone and mineral filler 15 miles x 2 at 1960 BTU/Ton, 65%	38,220
Haul sand 30 miles x 2 at 1980 BTU/Ton, 35%	41,160
	<u>130,130</u>

Asphalt Concrete Mix Composition

Asphalt concrete, 5.5% at 783,500 BTU/Ton	43,090
Coarse and fine aggregate, 94.5% at 130,130 BTU/Ton	122,970
	<u>166,060</u>

PLANT OPERATIONS

Dry aggregate, 6% moisture at 28,000 BTU/% x/945	132,300
Heat aggregate, 230°F at 470 FTU/°F/ton x /945	102,154
Other plant operations (mixing, etc.)	19,800
	<u>254,254</u>

HAUL AND PLACE AT JOB SITE

Haul mix, 12 miles x 2 at 3,800 BTU/Ton	91,200
Spread and compact	16,700
	<u>107,900</u>

TOTAL FOR ASPHALT CONCRETE

Mix Composition	166,060
Plant Operations	254,254
Haul and Place	<u>107,900</u>

TOTAL BTU/TON:	528,214
----------------	---------

ENERGY CALCULATIONS FOR LFA BASE

Given

Mix Design: 2% Lime, 6% Fly ash, 92% Aggregate, optimum moisture  
6.6%.

Haul Distance: Lime 80 miles  
Fly Ash 25 miles  
Aggregate 0 miles

MATERIALS

BTU/TON

Manufacture lime - 7,500,000 BTU/Ton x .02 tons	150,000
Process fly ash - negligible x .06 tons	0
Produce crushed stone at 70,000 BTU/Ton x .92	64,400
Mixing at 15,000 BTU/Ton	15,000
Haul lime, 80 mi. x 2 x 1960 BTU/Ton mi. x .02 tons	6,270
Haul fly ash, 25 mi. x 2 x 1960 BTU/Ton mi. x .06 tons	5,880
	<u>241,550</u>
Haul mix to job site, 75 mi. x 2 x 1960 BTU/Ton mi.	294,000
Spread and compact	16,700
	<u>310,700</u>

TOTAL FOR LFA

Mix Composition and Plant Operations	241,550
Haul and Place	<u>310,700</u>
TOTAL BTU/TON:	552,250

ENERGY CALCULATIONS FOR DENSE GRADED AGGREGATE BASE (D.G.A.B.)

The D.G.A.B. used on this project was a blast furnace slag which is a by-product of steel manufacturing. Therefore, no energy will be charged to this material for production.

<u>MATERIALS</u>	<u>BTU/TON</u>
Produce and handle blast furnace slag	15,000
 <u>HAUL AND PLACE</u>	
Haul 18 mi. x 2 x 1960 BTU/Ton	70,560
Spread and compact	<u>17,000</u>
TOTAL BTU/TON	102,560

ENERGY CALCULATIONS FOR SUBBASE (BANK RUN GRAVEL)

Given

Source located 15 miles from job site.

<u>MATERIALS</u>	<u>BTU/TON</u>
Digging and Hauling	15,000
<u>HAULING AND PLACING</u>	
Haul 15 mi. x 2 x 1960 BTU/Ton	58,800
Place and compact	<u>17,000</u>
TOTAL BTU/TON:	90,800

ENERGY CALCULATIONS FOR PRIME COAT (AND CURING COMPOUND)

Given

MC-30                      256 gallons/ton

<u>ENERGY TO REFINE AND ENERGY IN THE MATERIAL</u>	<u>BTU/TON</u>
70,000 BTU/gal. x 256 gallons	17,920,000

ENERGY TO HAUL AND DISTRIBUTE

Haul 5.0 mi. x 2 x 3270 BTU/Ton mi.	327,000
-------------------------------------	---------

Distribute 444 BTU/gal. x 256 gallons/ton	<u>113,664</u>
---	----------------

TOTAL BTU/TON:	18,360,660
----------------	------------