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Demonstration Project No. 59

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

Final Report

JULY 1997

BY

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

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16. Abstract

This report documents the design, construction, and performance summary 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 was used for performance comparisons over following 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 indicated that the material has exceeded the design strength and should perform as intended. In 1989, after five years of monitoring, the demonstration section on I-295 performed flawlessly. Deflection measurements indicated that the experimental sections performed better than the standard control sections. Neither section exhibited any appreciable rutting or cracking. Rideability of both sections was excellent. Several major interstate reconstruction projects were scheduled to use LFA bases because of their lower costs. While cost savings for LFA composite pavement sections over equivalent flexible pavement designs were significant ($4 to $5 per square yard in 1989), constructability is a major concern with any material, and LFA, can be handled, placed, and compacted as easily as a stone base. In New jersey, LFA may be placed with an asphalt paver before it is compacted. Besides requiring relatively little energy, this material also provides an envoronmentally safe means of disposing of large quantities of fly ash which would otherwise be landfilled (one lane mile of LFA base uses over 500 tons of fly ash).

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PERFORMANCE SUMMARY

Through a cooperative effort between research and maintenance staff, numerous small installations of LFA (parking lots, roadway widenings) were placed and evaluated for overall performance. Based on the extremely favorable results obtained, the Department's maintenance forces began to routinely use LFA in many highway rehabilitation projects. In a typical installation, LFA was used as a base course which replaced the unbound aggregate base and a portion of the bituminous concrete surface. The LFA base eventually hardened into a concrete-like material with compressive strengths up to 2000 psi. Maintenance found the material to be ideally suited for many of their projects because it costs about 1/3 less than bituminous concrete and can be stockpiled for several days before use. These maintenance projects provided an excellent data base for the development of comprehensive specifications for high quality, high strength, plant mixed LFA. The specifications cover materials, construction, design techniques and quality assurance. Using these specifications, our maintenance forces continue to place over 50,000 tons of plant-mixed LFA per year.

In the early 1980s, the Federal government began promoting the use of waste products such as fly ash in highway construction, and offered bonus payments for using fly ash. New Jersey was prepared and was able to take advantage of the incentives offered. Under FHWA Demonstration Project 59, a portion of I-295 was constructed with an LFA base in 1984.

The construction and five year performance of the plant-mixed lime-fly ash aggregate (LFA) material as a base course on Route I-295 in relation a pavement of conventional design which was built at the same time in the same section of road on the opposite side was studied. 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. Coring results indicated that the material has exceeded the design strength and should perform as intended. In 1989, after five years of monitoring, the demonstration section on I-295 performed flawlessly. Deflection measurements indicated that the experimental sections performed better than the standard control sections. Neither section exhibited any appreciable rutting or cracking. Rideability of both sections was excellent.

A revised specification allowing up to 24 hours before final compaction and requiring an asphalt paver for placing the LFA base has been issued. Several major interstate reconstruction projects were scheduled to use LFA bases because of their lower costs. While cost savings for LFA composite pavement sections over equivalent flexible pavement designs were significant ($4 to $5 per square yard in 1989), constructability is a major concern with any material, and LFA, can be handled, placed, and compacted as easily as a stone base. In New Jersey, LFA is placed with an asphalt paver before it is compacted. Besides requiring relatively little energy, this material also provides an environmentally safe means of disposing of large quantities of fly ash which would otherwise be landfilled (one lane mile of LFA base uses over 500 tons of fly ash).

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.(1)

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(2) 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 Demonstsration 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.

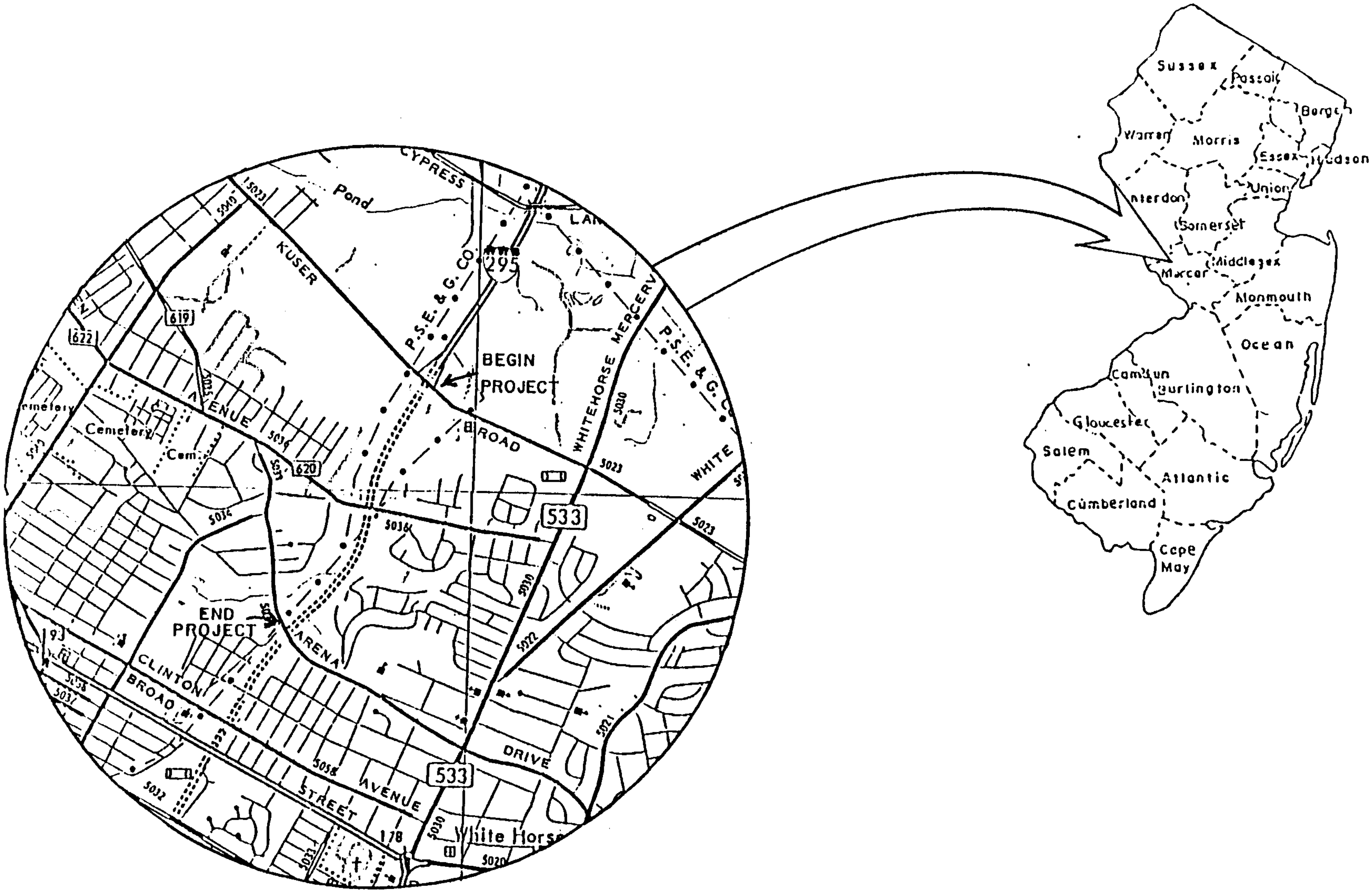


FIGURE 1 - PROJECT LOCATION

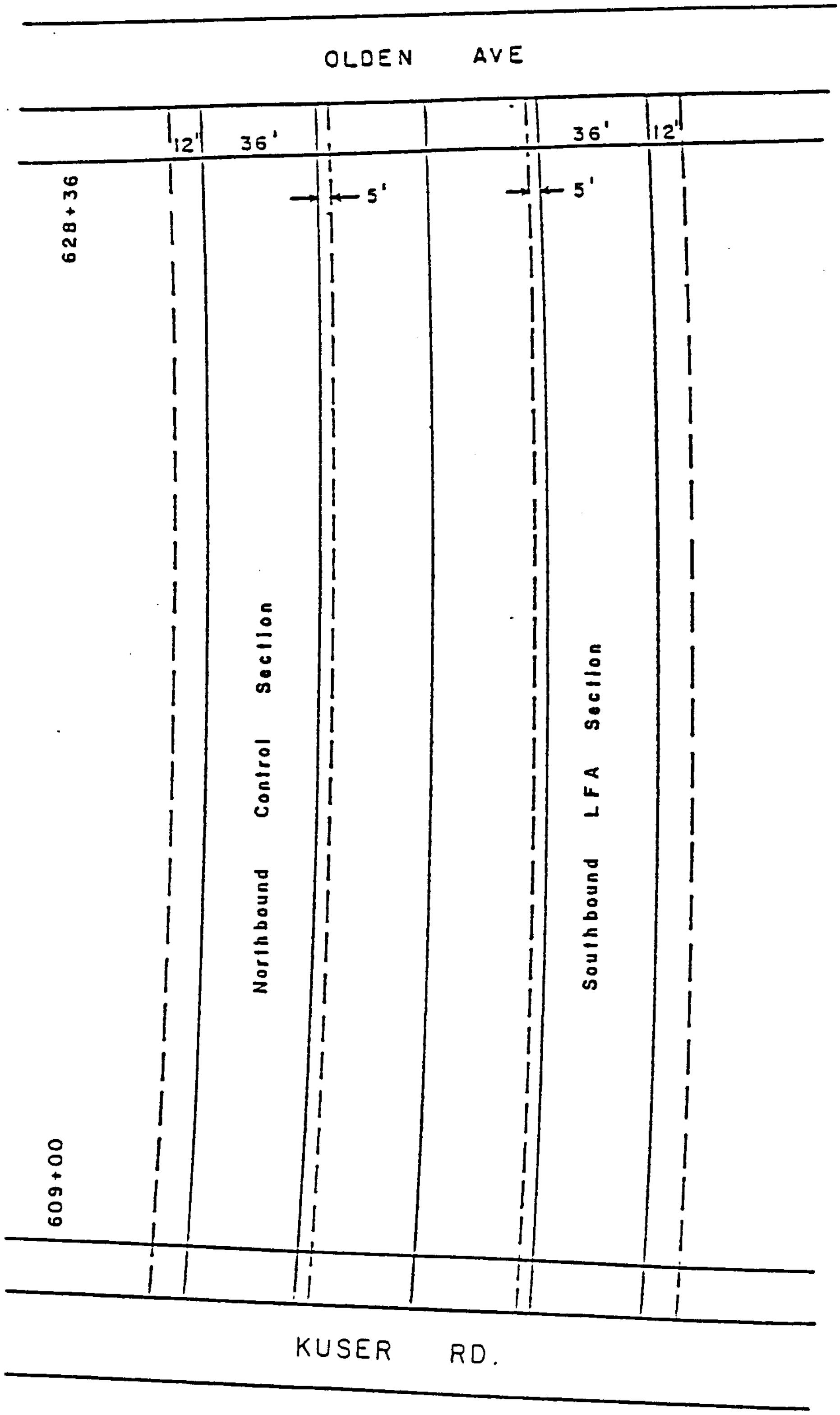


Figure 2
PLAN VIEW OF PROJECT

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.(3)

2.2 DESIGN TRAFFIC DATA

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

Year	Volume (VPD)
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

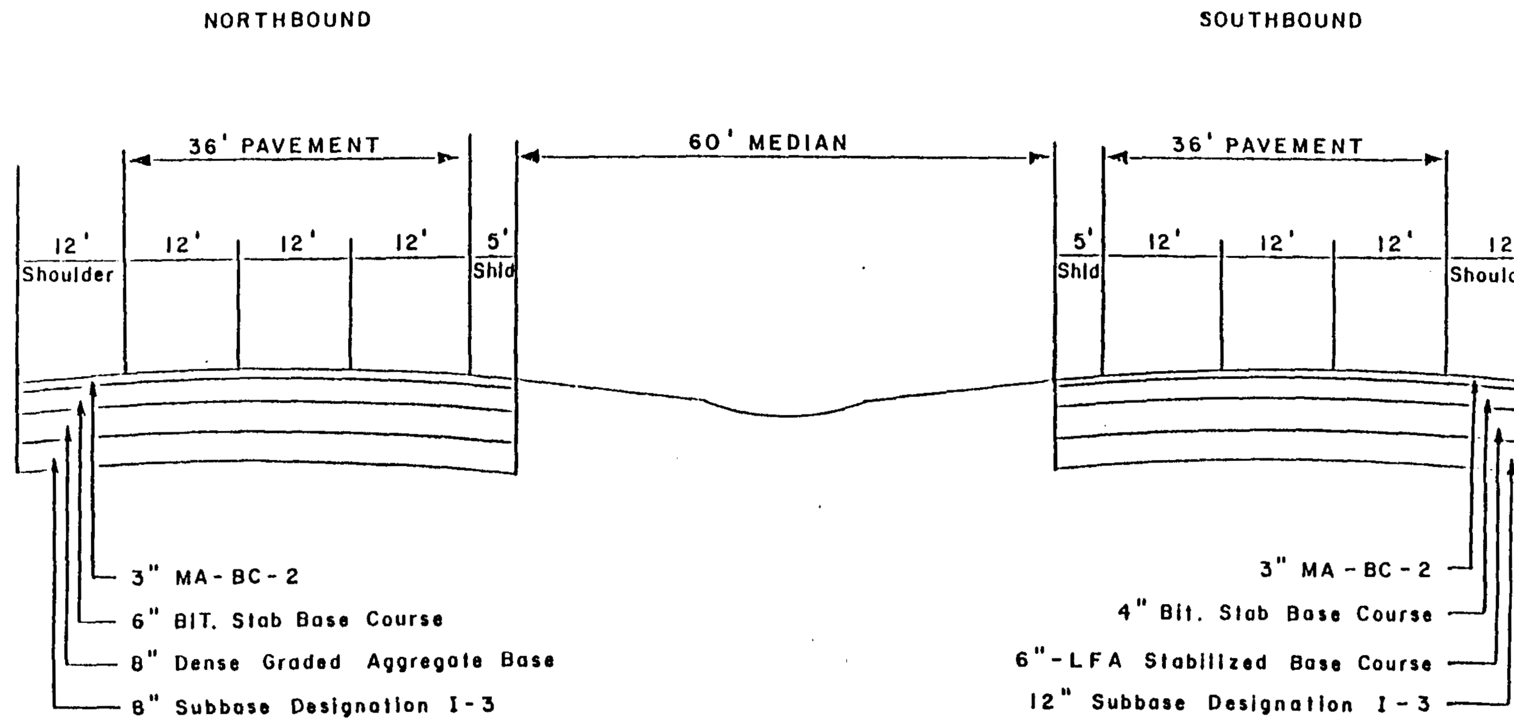


Figure 3

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

Test Section	SN	Control Section	SN
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 =	6.02	SN =	5.72

*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 ($Si0_2$) and Aluminum Oxide (AI_2O_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

<u>Physical Analysis</u>		
Source - Portland Pennsylvania		
Moisture Content	.10%	
Loss on Ignition	3.6%	
Specific Gravity	2.23%	
Fineness	17.4% retained on #325 sieve	
<u>Chemical Analysis</u>		
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

Sieve Size	#57 Stone	#10 Stone	Job Mix Formula	Specification Limits
	Percent Passing			
1½"	100	100	100	100
3/4"	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^{o}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

Material	Percent of Total Dry Mix
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.)

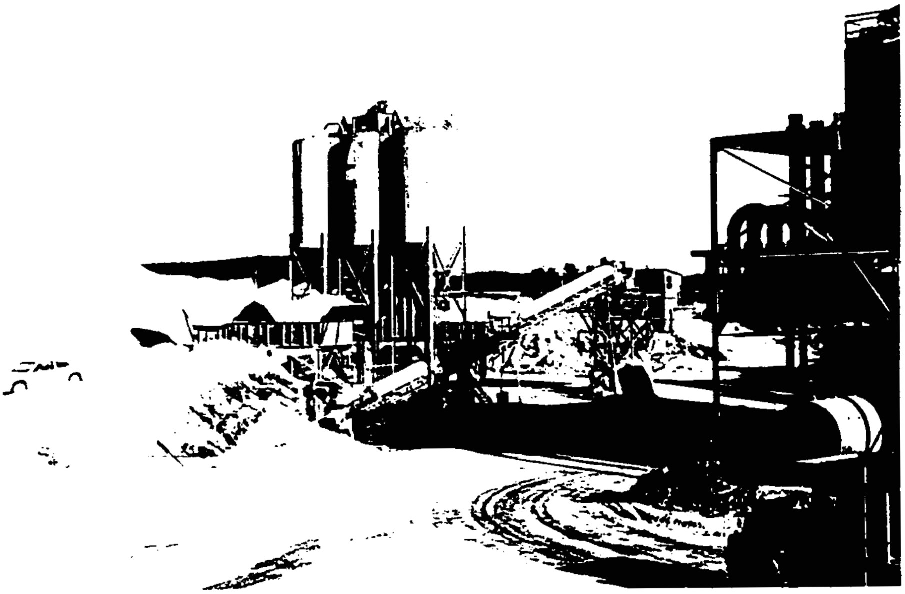


FIGURE 4. LFA Plant at Sparta, New Jersey

FIGURE 5. Storage Silos for Fly Ash and Lime

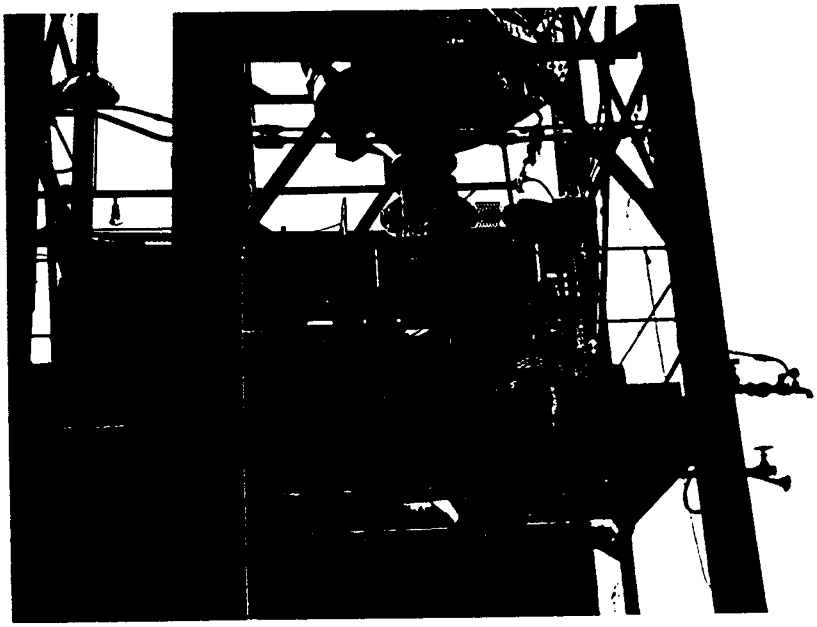


FIGURE 6. Weigh Belt Feeder for Metering Lime

FIGURE 7. Pugmill for Mixing LFA

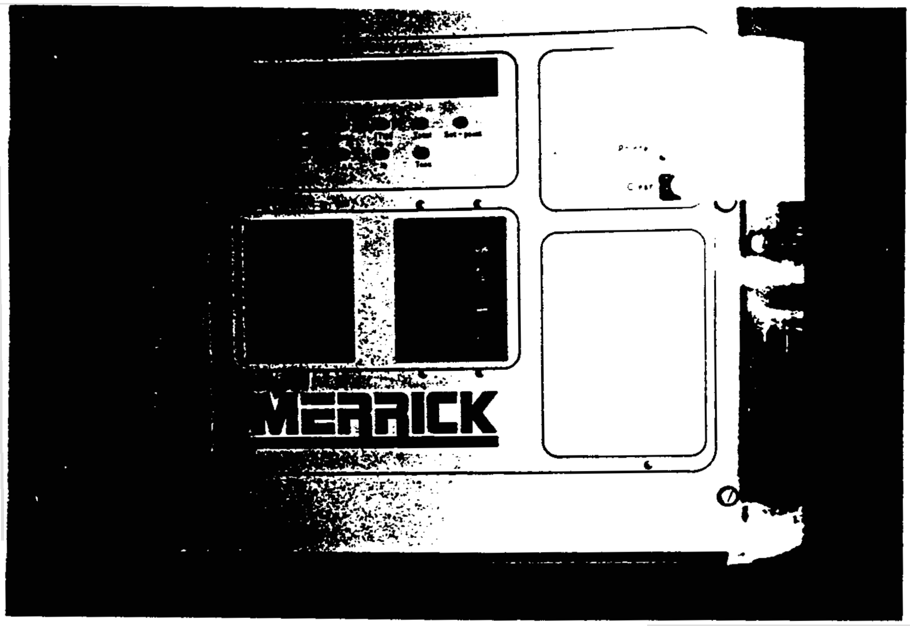


FIGURE 8. Portion of Computerized Controls on Mixing Plant

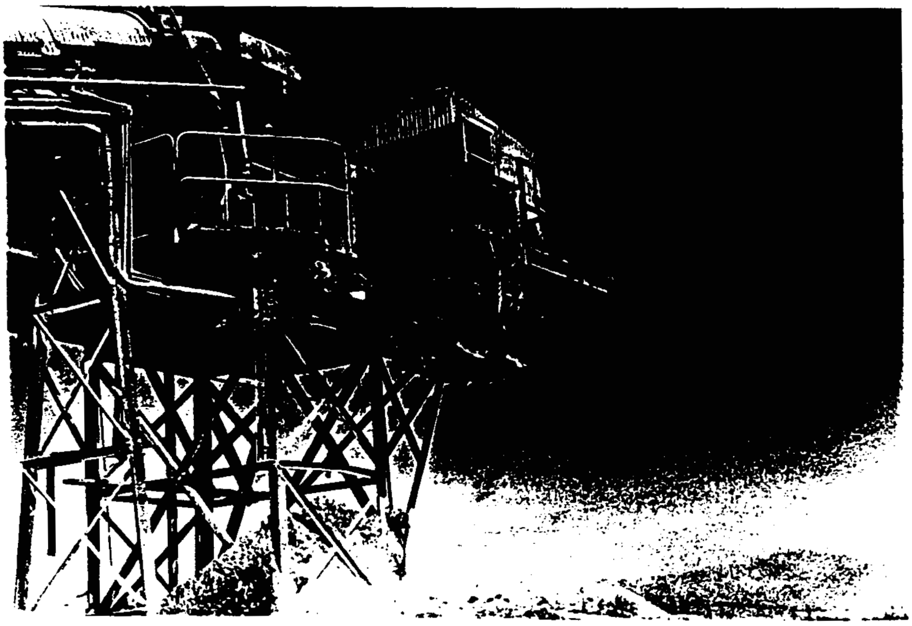


FIGURE 9. Discharge Chute on Plant

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 (AASHO 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 (AASHO 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 Tampo 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°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.

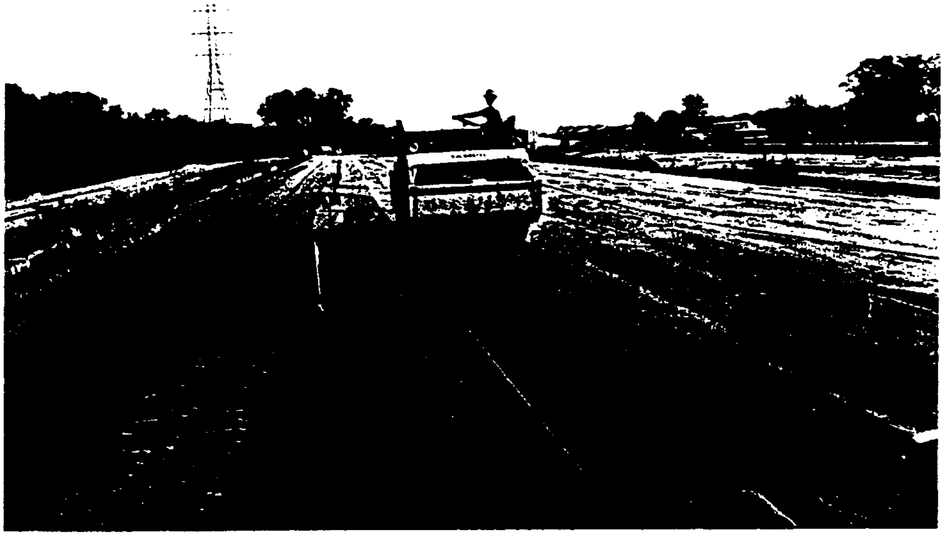


FIGURE 10. Subbase Preparation Prior to Placing LFA Material

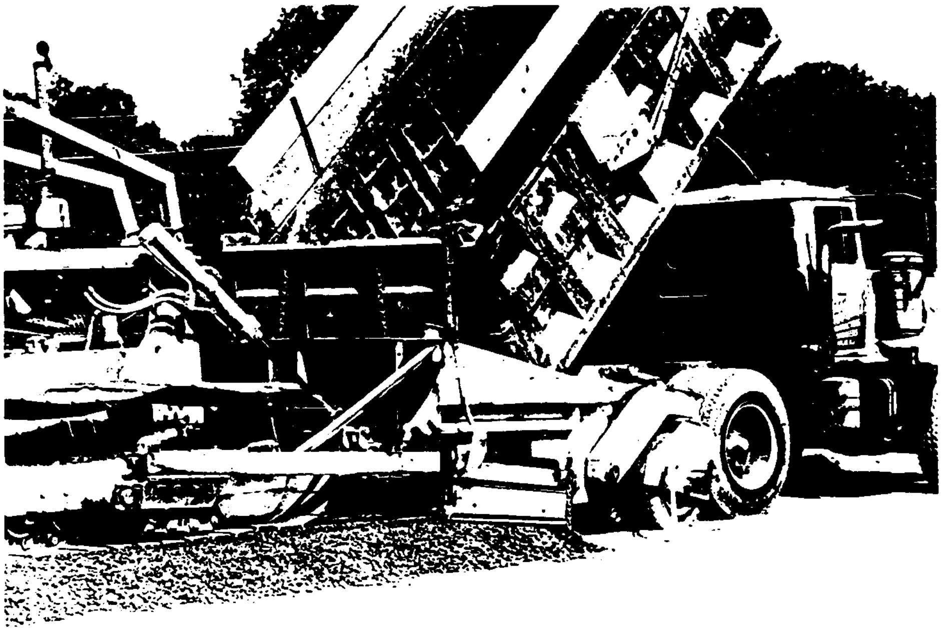


FIGURE 11. Constructing the Control Strip Using a Jersey Spreader Box

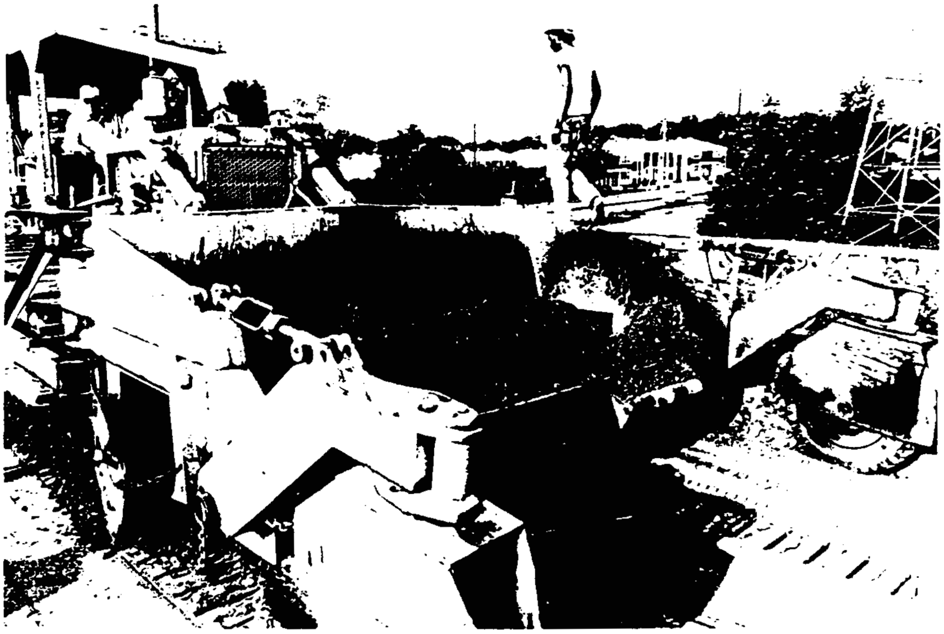


FIGURE 12. Close up of the Jersey Spreader Box

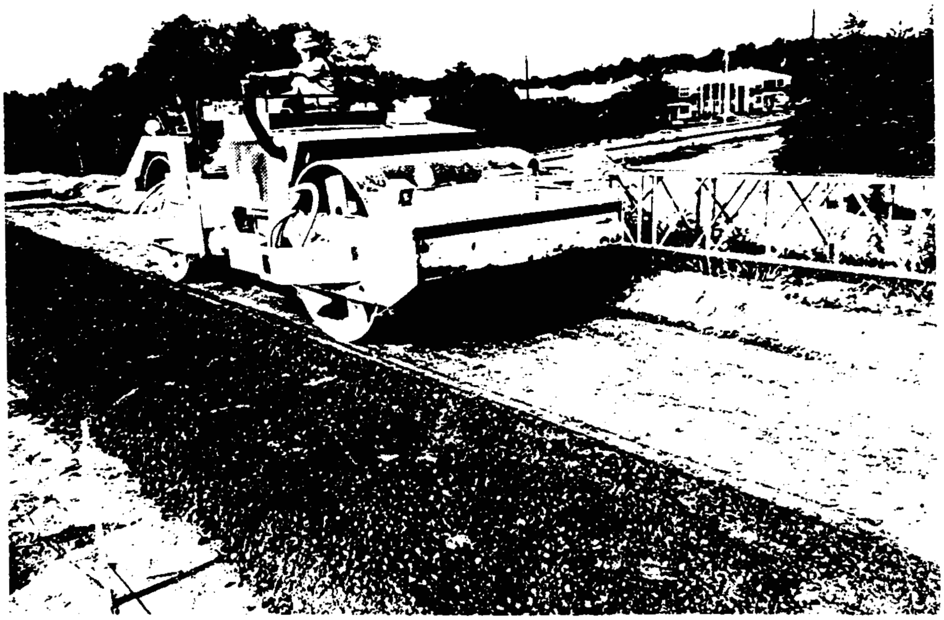


FIGURE 13. Compacting the Control Strip

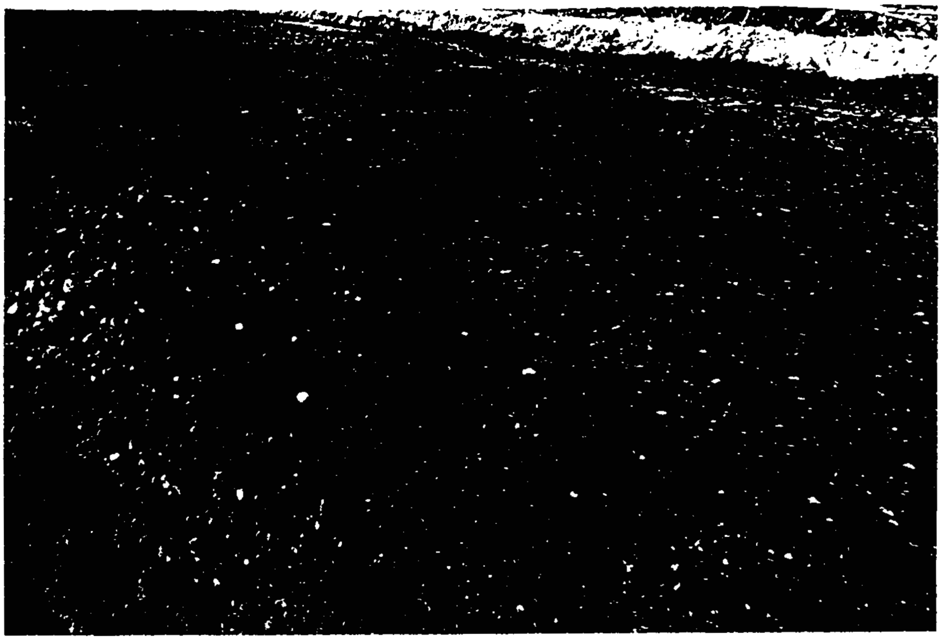


FIGURE 14. Close up View of the LFA Material

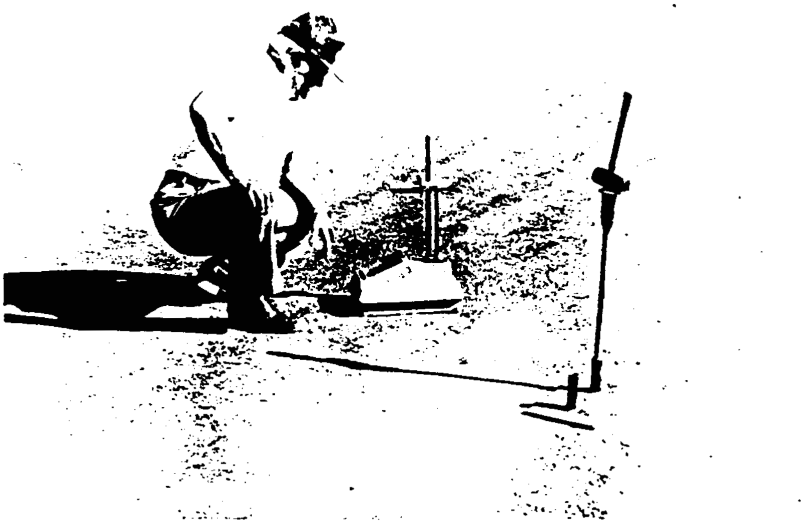


FIGURE 15. Checking Density with a Troxler Nuclear Density Gauge

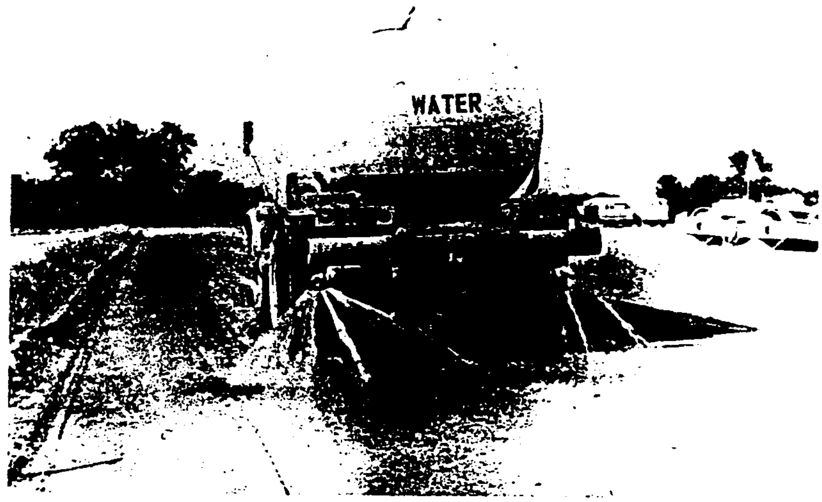


FIGURE 16. Keeping the LFA Moist Prior to Application of Cure Coat

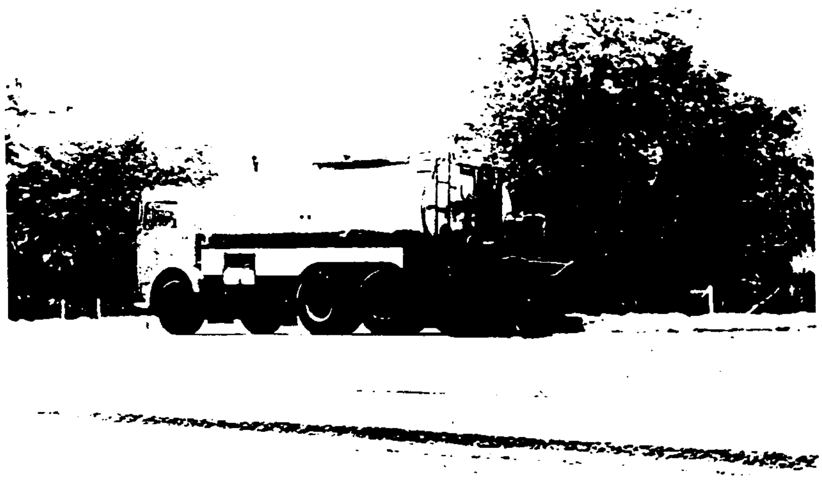


FIGURE 17. Application of RC-30 Cure Coat

FIGURE 18. Completed LFA Material with Cure Coat

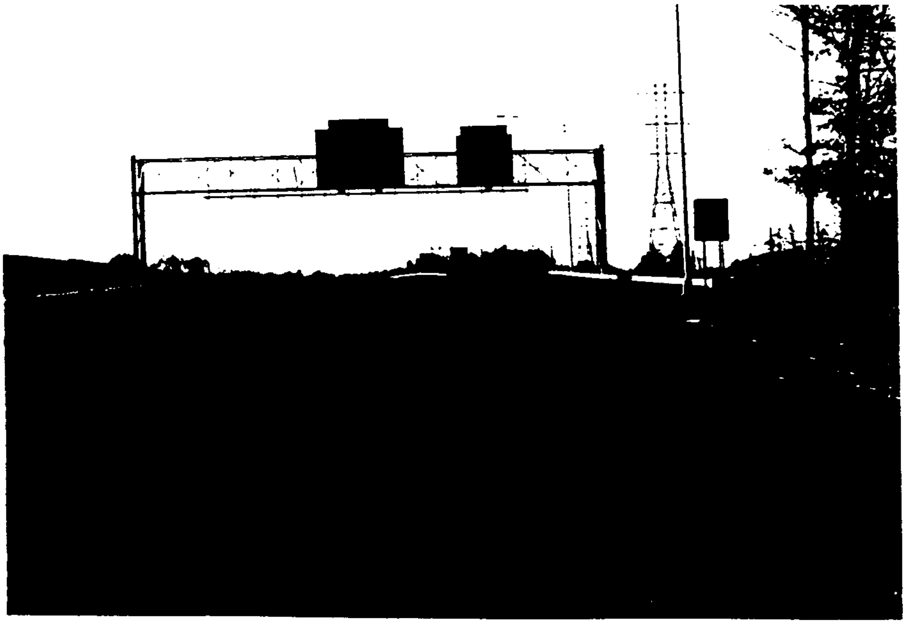


FIGURE 19. Overview of Roadway

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

	28 Days	45 Days	90 Days
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

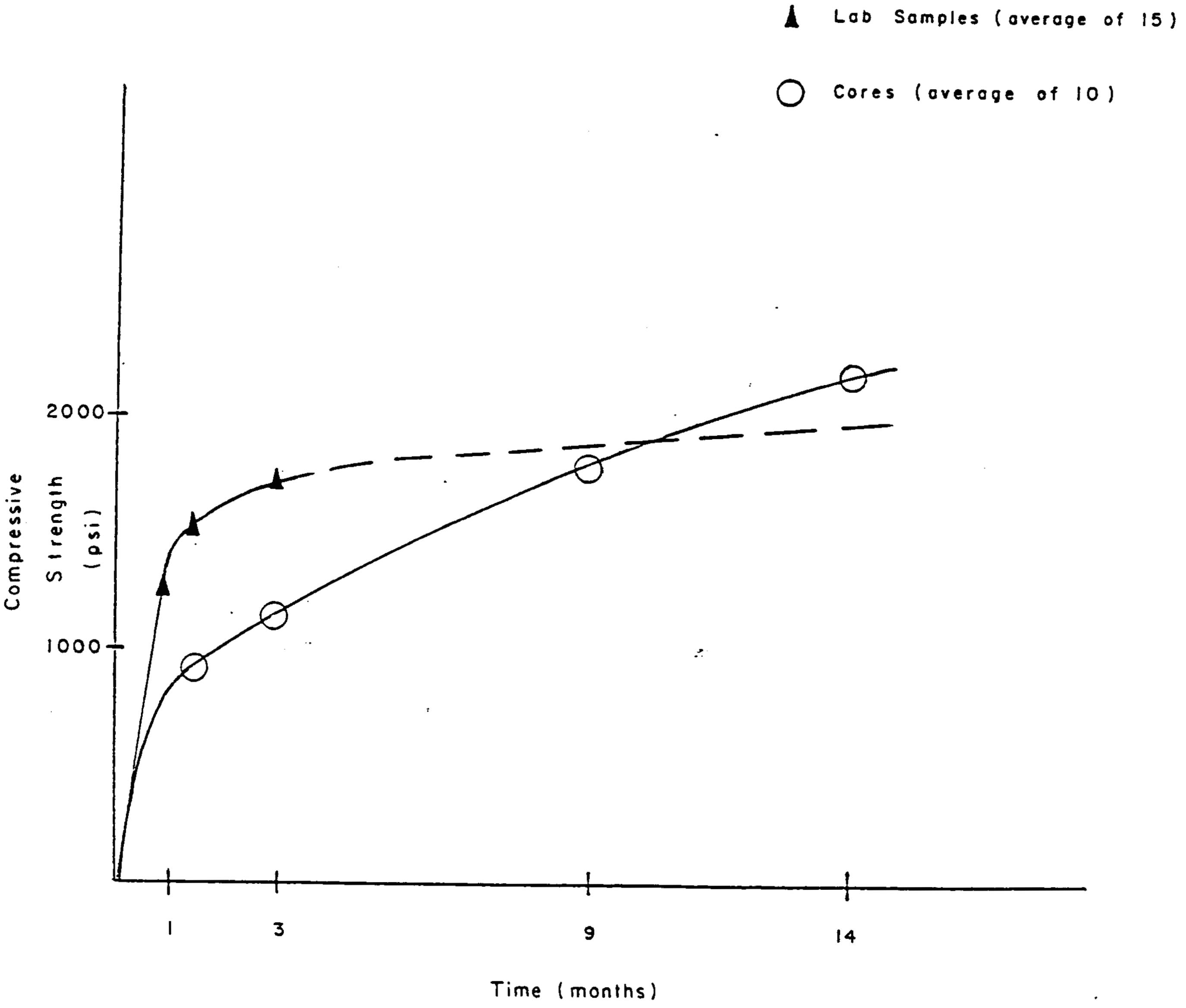


Figure #20

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

Strength (Avg. of 10 Cores)	28 Days	45 Days	90 Days	270 Days	420 Days
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 (σ) 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 (σ) 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[(4)]. 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 mph.

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

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

Control Pavement Section

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

Material	Cost
Bituminous Concrete Surface	\$17.25/Ton
Bituminous Stabilized Base	\$17.25/Ton
Dense Graded Aggregate Base	\$18.50/Yd.^{3}
Subbase (I-3)	\$11.00/Yd.^{3}
LFA Base (6" Thick)	\$ 6.75/Yd.^{2}
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^2

LFA Section		Control Section	
Material	Cost/yd^2	Material	Cost/yd^2
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		
TOTAL COST	$17.51		$15.42

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,

8" Subbase, dense aggregate BASE 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 AASHO Designation A-7-6, A-7-5

Soil Support Value:

SSV	CBR
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
(21,047)x(0.356)x(0.18) = 1,349

c. Minimum Pavement Thickness
0.75 x 28" = 21 inches

d. Required S.N.: From AASHO 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

			S.N.	1982 Cost/S.Y.
(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)x(0.498)x(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.)

Pavement		1982 Cost/S.Y.
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

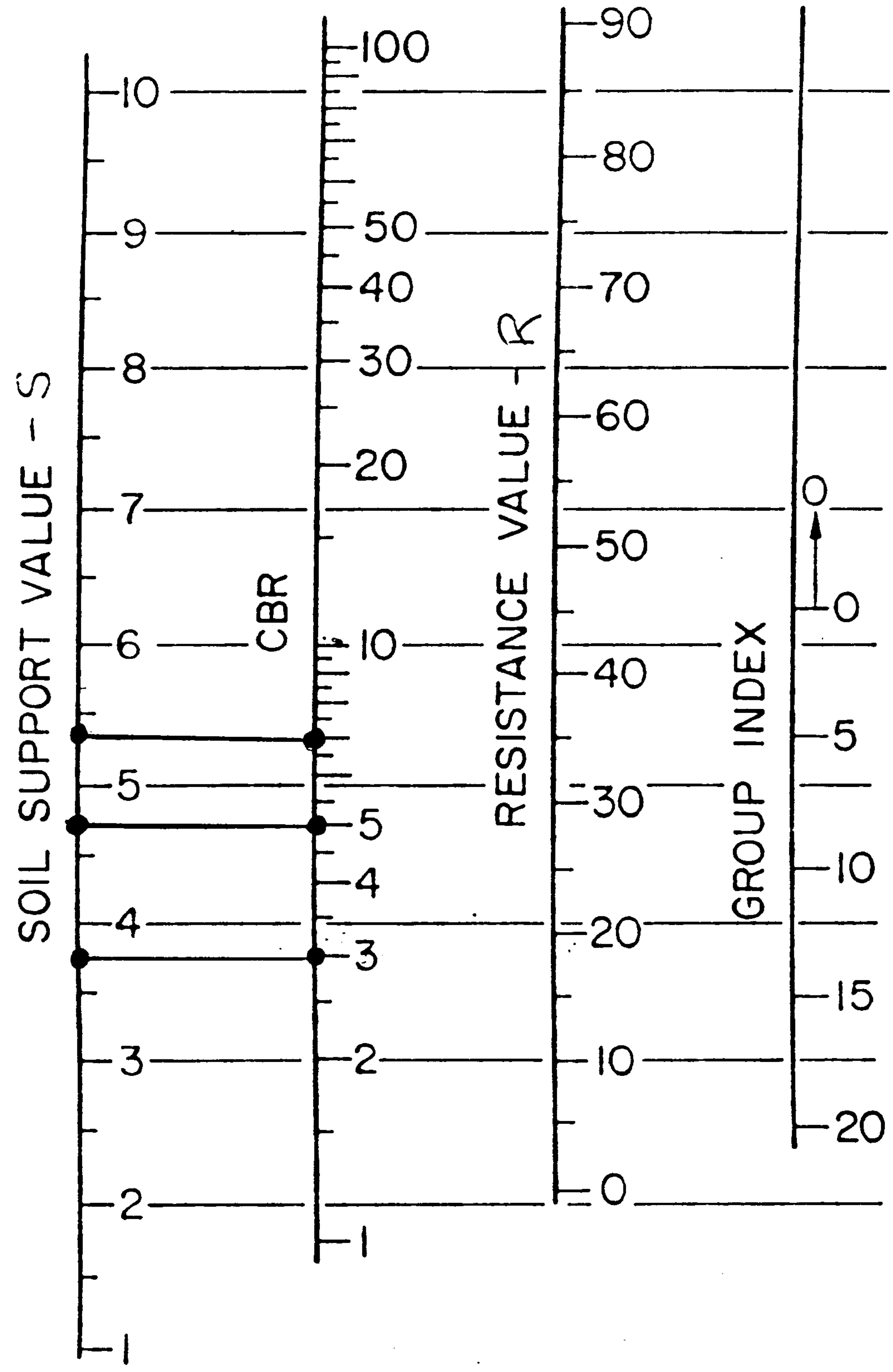
It is recommended that flexible pavement be adopted, since it is considerably less expensive than rigid pavement.

The prevailing existing subgrade CBR conditions are as follows:

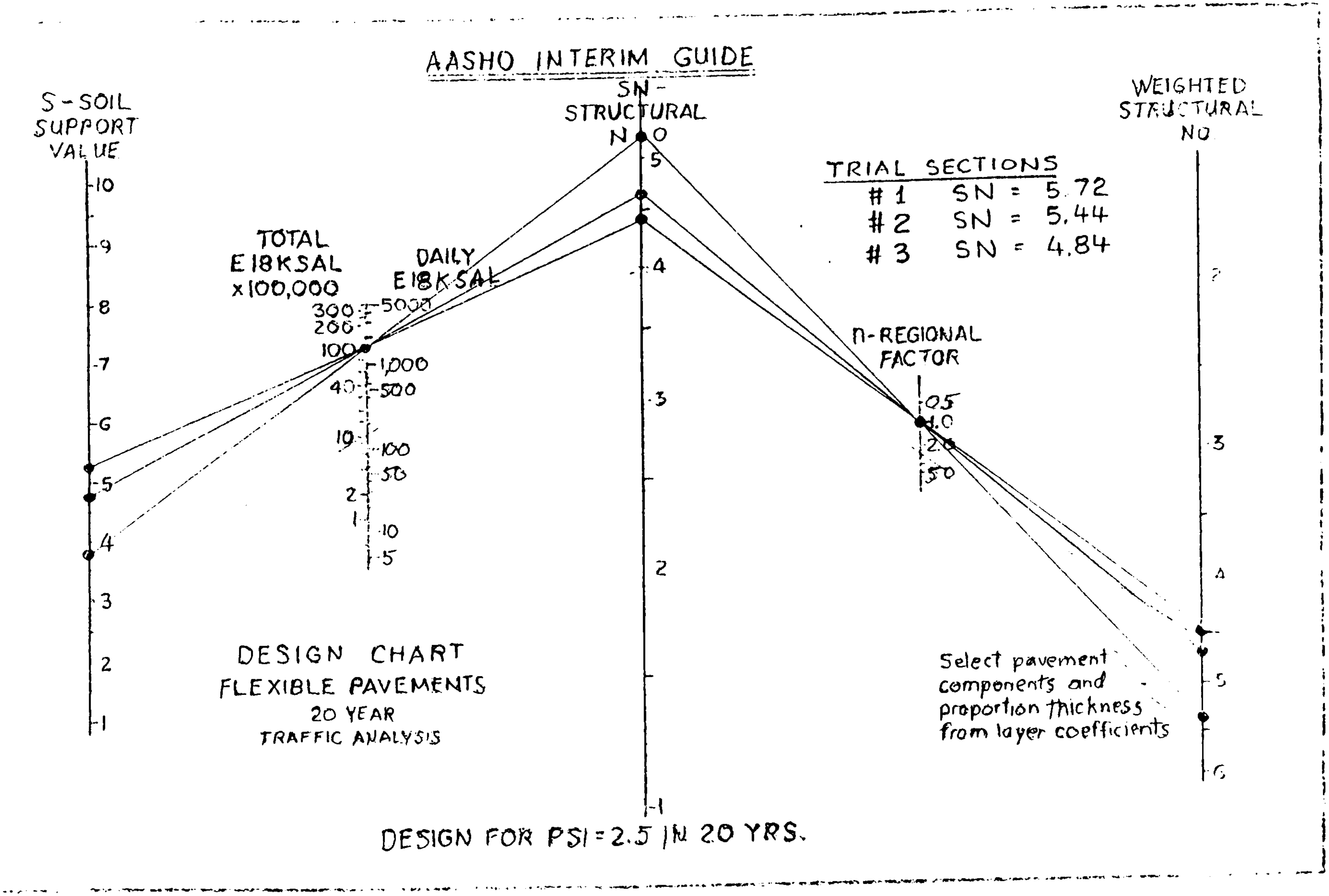
Station to Station	CBR
604+00 to 609+70	5 or better
609+70 to 618+80	less than 3
618+80 to 664+00	5 or better

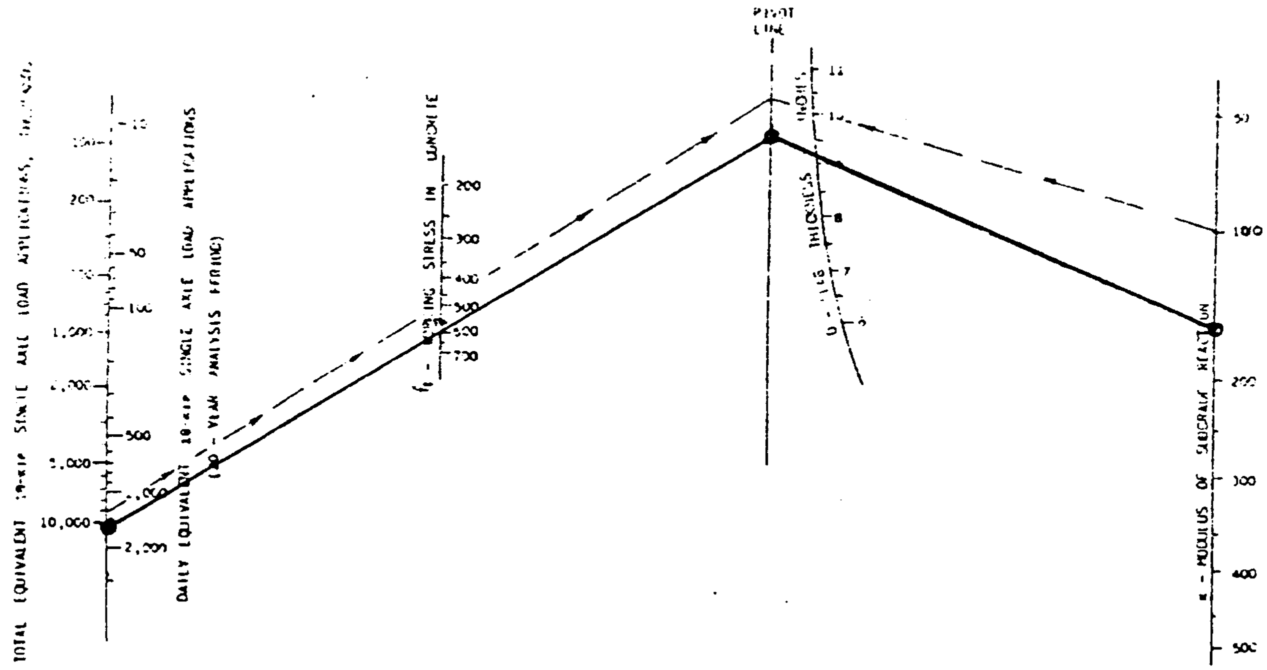
The unsuitable subgrade soils, between station 609 and 619, will be excavated and replaced with acceptable borrow materials. An improved CBR should therefore result in this portion of the project. The pavement structure of I-295 constructed up to Kuser Road, however, is same as Trial Section #1.

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
TOTAL E18KSAL x100,000
DAILY E18KSAL
SN - STRUCTURAL NO
TRIAL SECTIONS
1 SN = 5.72
2 SN = 5.44
3 SN = 4.84
n-REGIONAL FACTOR
WEIGHTED STRUCTURAL NO
DESIGN CHART
FLEXIBLE PAVEMENTS
20 YEAR
TRAFFIC ANALYSIS
Select pavement components and proportion thickness from layer coefficients
DESIGN FOR PSI = 2.5 IN 20 YRS.


PIVOT LINE
10,000
200
300
400
500
100
200
300
400
500

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

Anne P. Canby
COMMISSIONER

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

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(5)

Form AD 40 5 77

NEW JERSEY DEPARTMENT OF TRANSPORTATION

MEMORANDUM

TO Mr. Charles Takacs

Chief, Bureau of Roadway Plan
~~Quality Review and~~
Specifications Development

FROM Nicolai D. Nicu

Chief, Bureau of

Geotechnical Engineering

SUBJECT Rt. 295, Sec. 7C
Deletion of Top Course MABC

DATE 11/23/82 TELEPHONE NO. 4-5003

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

TYPE	DESCRIPTION
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							
¾"	50-95	65-100	60-100		70-100				60-100	60-100	60-100	70-100		55 - 90
½"				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

	Percent Passing	
Sieve Size	MABC	BSBC
2"	—	100
1½"	—	90 - 100
1"	100	80 - 100
3/4"	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:

LIMITATION	METHOD OF TEST
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:

REQUIREMENT	LIMITATION	METHOD OF TEST
LOSS OF IGNITION	LESS THAN 10%	ASTM C311, SECTION 13
COMBINED SILICA (SI 02) AND ALUMINUM OXIDE (A12 03)	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 MIXTER 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 EXTACTOR, 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 LIGHTLY 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 SUBSEQJENT 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 STABLIZIED 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:

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

WHEPE 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 T238.

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

PRCVIDE 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 RECOMPACT 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.

CCMPENSATION.

2.8.20. METHOD OF MEASUREMENT.

AGGREGATE-LIME-POZZOLAN STABILIZED BASE COURSE OF THE THICKNESS SHCWN 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	TON
FLY ASH	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:

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

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
LIME CREST
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

LIMESTONE PRODUCTS CORPORATION
LIME CREST
SUBSIDIARY OF PENN VIRGINIA CORPORATION
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

SIEVE SIZES	COARSE AGGREGATE #57	= 50%	FINE AGGREGATE #10	= 50%	AGGREGATE COMBINATION	DENSE AGGREGATE SPECKS
1½ 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
LIME CREST
SUBSIDIARY OF PENN VIRGINIA CORPORATION
P. O. BOX 217 · SPARTA NEW JERSEY 07871 · TELEPHONE (201) [illegible]

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

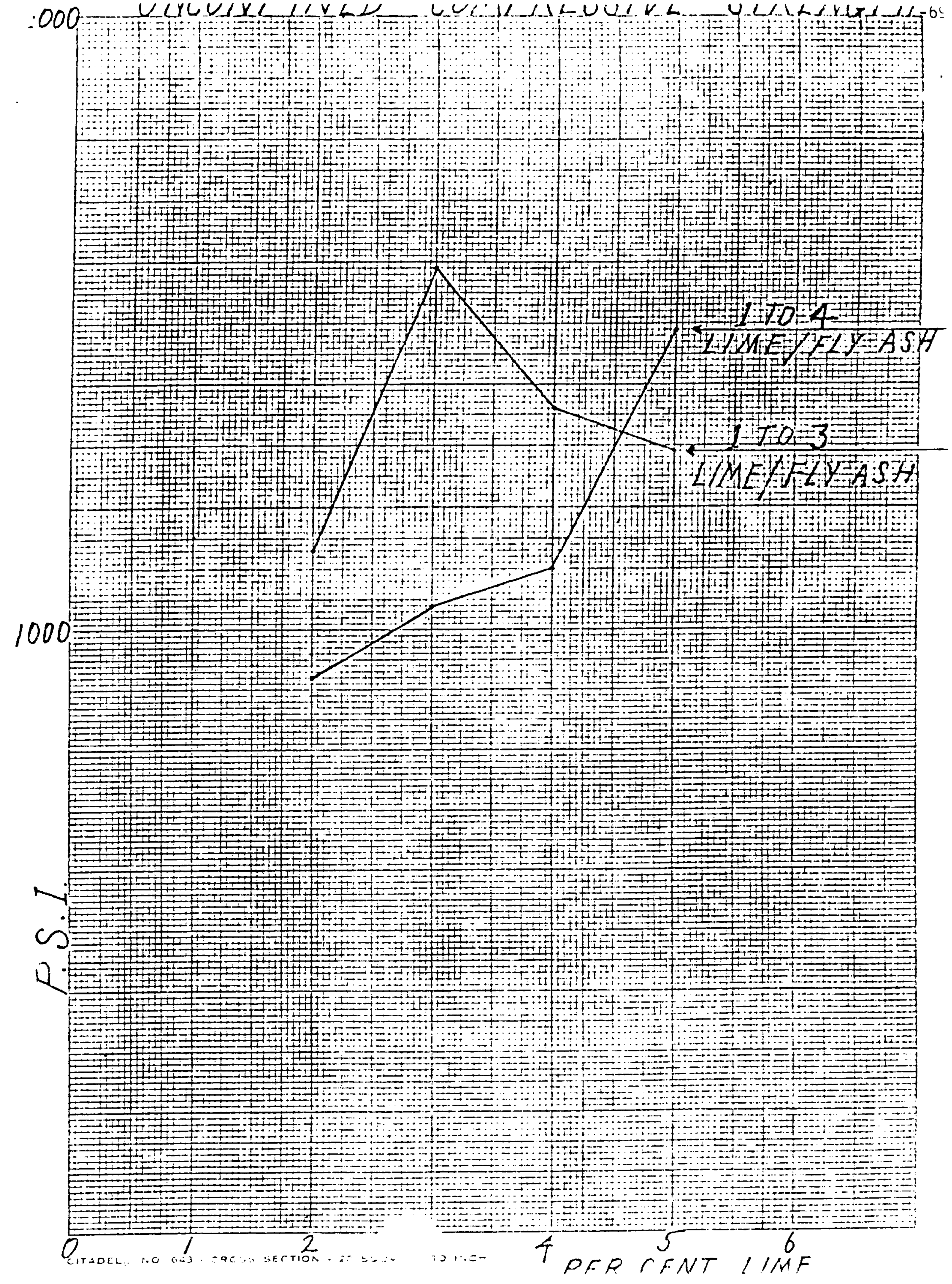
The first table is unconfined compressive strength development, Part 8, as stated in ASTM C593.

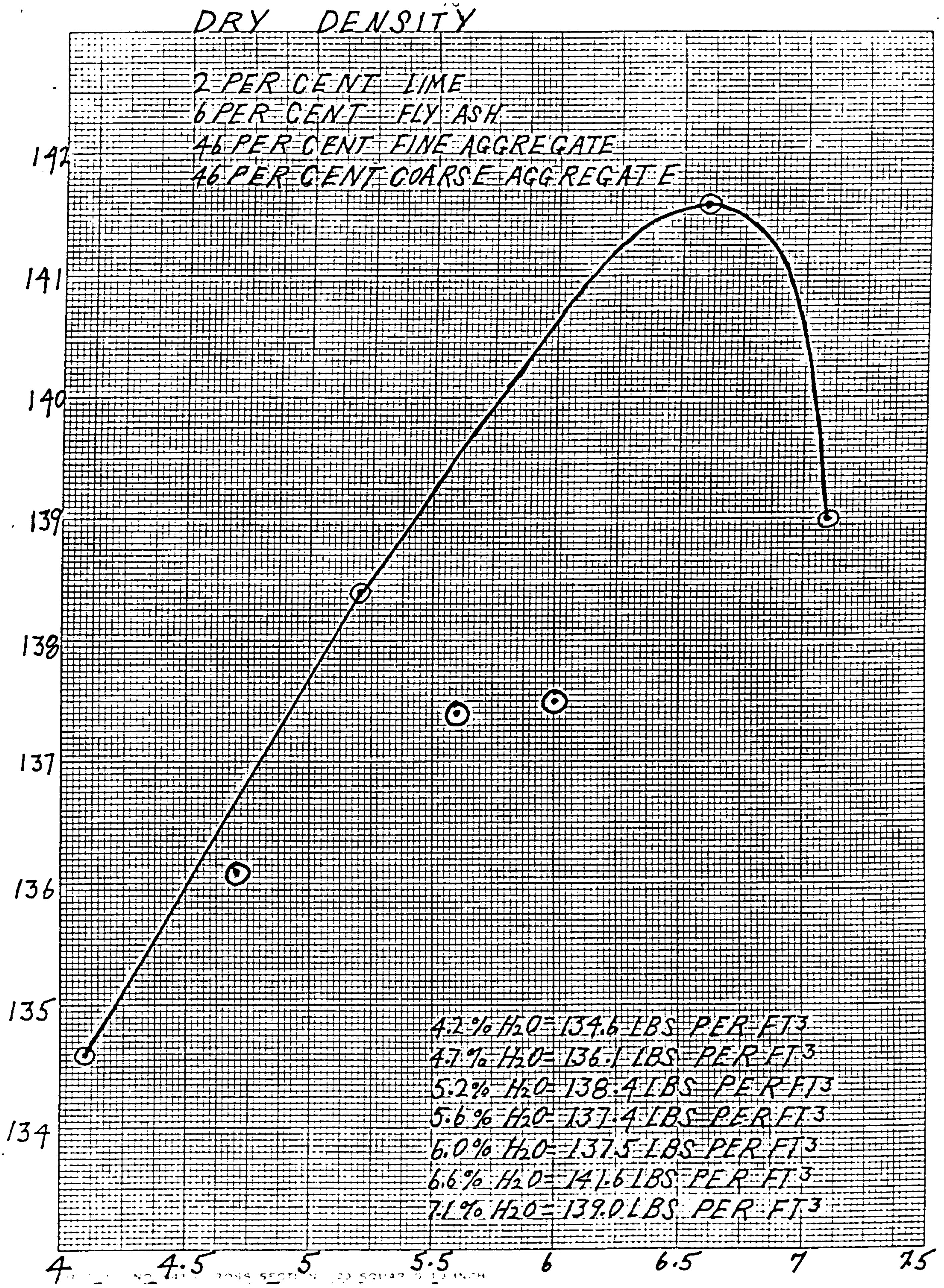
PERCENT LIME	PERCENT FLY ASH	PERCENT FINE AGG.	PERCENT COARSE AGG.	P.S.I. #1 PLUG	P.S.I. #2 PLUG	P.S.I. #3 PLUG	AVG.	PERCE AVERA RESID STREN
2	6	46	46	1275	1050	1065	1130	-----
3	9	44	44	1550	1530	1695	1590	-----
4	12	42	42	1410	1340	1330	1360	-----
5	15	40	40	1180	1320	1360	1285	-----
2	8	45	45	960	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, Part9, as stated in ASTM C593.

2	6	46	46	1160	1195	1225	1195	106
3	9	44	44	1770	1550	1460	1595	100
4	12	42	42	1360	1060	1600	1340	99
5	15	40	40	1515	1375	1660	1515	118
2	8	45	45	1300	1105	955	1120	122
3	12	42.5	42.5	1050	1360	1275	1230	118
4	16	40	40	1335	1360	995	1230	112
5	20	37.5	37.5	1195	1260	1210	1230	83

UNCONFINED COMPRESSIVE STRENGTH




DRY DENSITY
2 PER CENT LIME
6 PER CENT FLY ASH
46 PER CENT FINE AGGREGATE
46 PER CENT COARSE AGGREGATE
142
141
140
139
138
137
136
135
134
4.2% H2O = 134.6 LBS PER FT3
4.7% H2O = 136.1 LBS PER FT3
5.2% H2O = 138.4 LBS PER FT3
5.6% H2O = 137.4 LBS PER FT3
6.0% H2O = 137.5 LBS PER FT3
6.6% H2O = 141.6 LBS PER FT3
7.1% H2O = 139.0 LBS PER FT3
4
4.5
5
5.5
6
6.5
7
7.5

APPENDIX D

LABORATORY AND FIELD TEST RESULTS

TABLE D-1

SOILS GRADATIONS FROM EXPERIMENTAL SECTIONS

Percent Passing (Average of three tests)

Sieve Size	Subgrade	I-11	I-3	D.G.A.B.
2"	100	100	100	100
1½"	100	100	100	100
3/4"	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

New Jersey Department of Transportation

LABORATORY SOIL ANALYSIS

Form LB-200 (b) 6 72

MOISTURE – DENSITY RELATIONSHIP

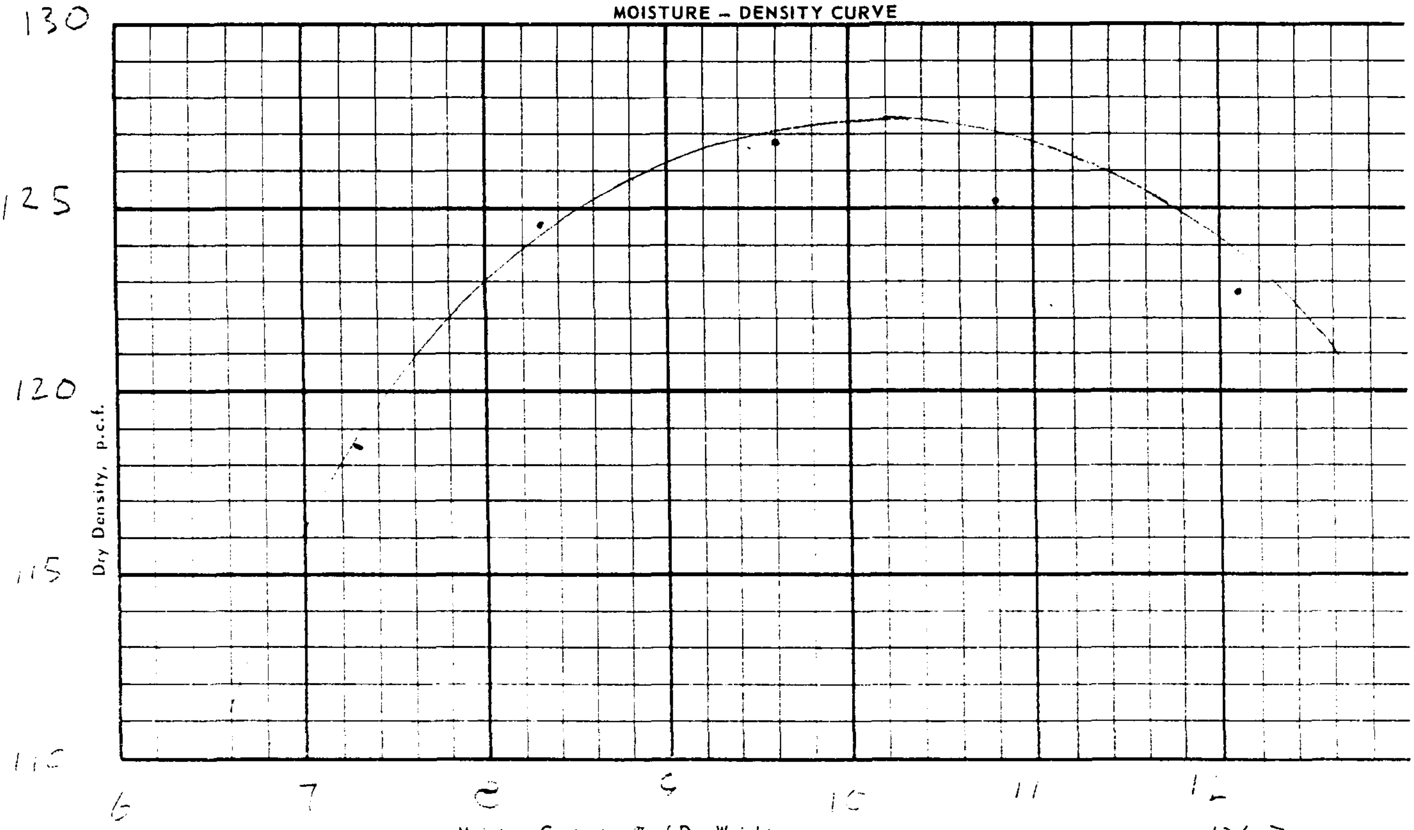
Serial No. Subgrade Date Tested 10/19/83 Producer

Route I-295 – ¾" + #4 =

Section 7C Station 625 to S.B. – #4 =

AASHO 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

New Jersey Department of Transportation

LABORATORY SOIL ANALYSIS

Form LB-200 (b) 6 72

MOISTURE – DENSITY RELATIONSHIP

Serial No. I-11 (Zone II) Date Tested 10/8/83 Producer ______

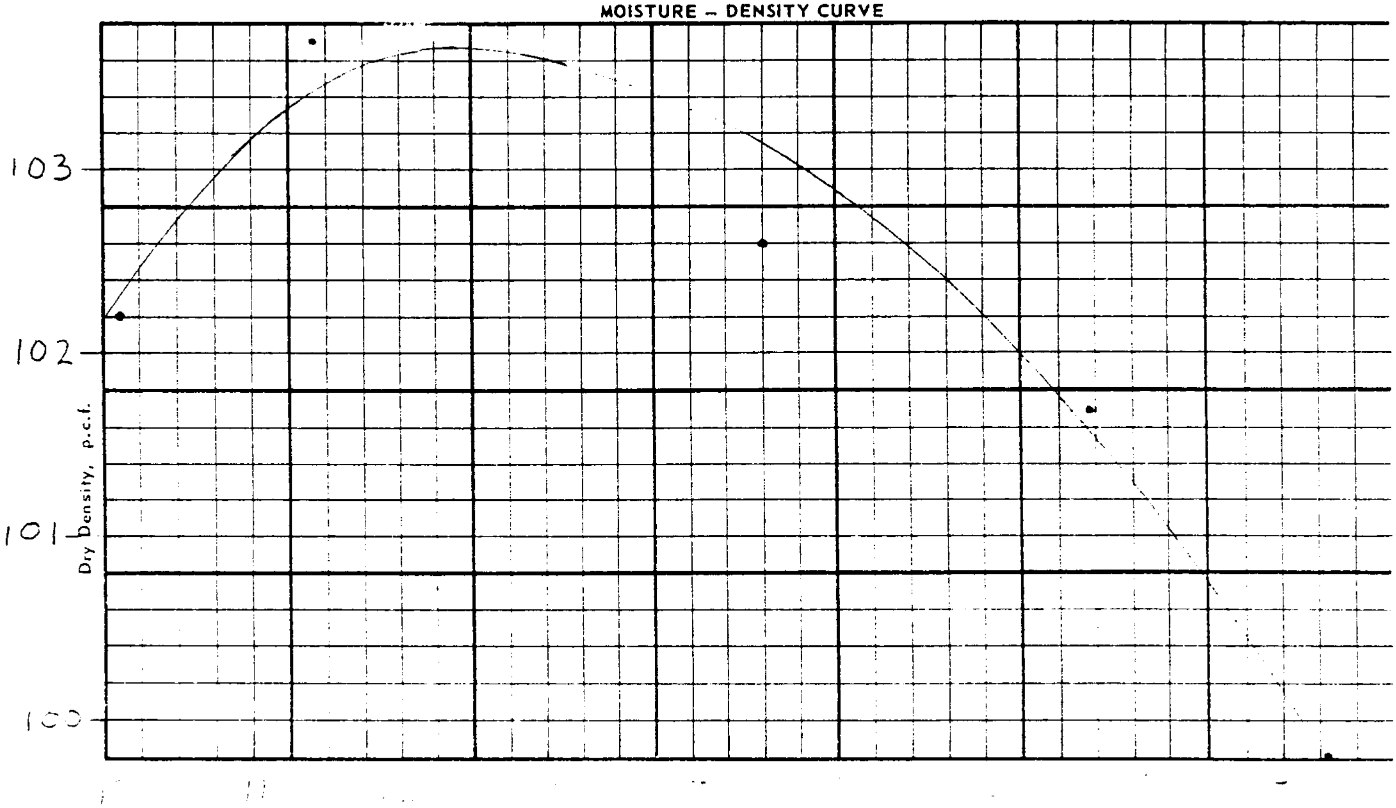
Route I-295 $-\frac{3}{4}$" + #4 = ______

Section 7C Station 615+0 S.B. – #4 = ______

AASHO or ASTM Designation D 698 Method D

REST 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%	19.3%				
Dry Density p.c.f.	102.2	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 ______

New Jersey Department of Transportation

LABORATORY SOIL ANALYSIS

Form LB-200 (b) 6 72

MOISTURE – DENSITY RELATIONSHIP

Serial No. Subbase (I-3) Date Tested 7/30/84 Producer

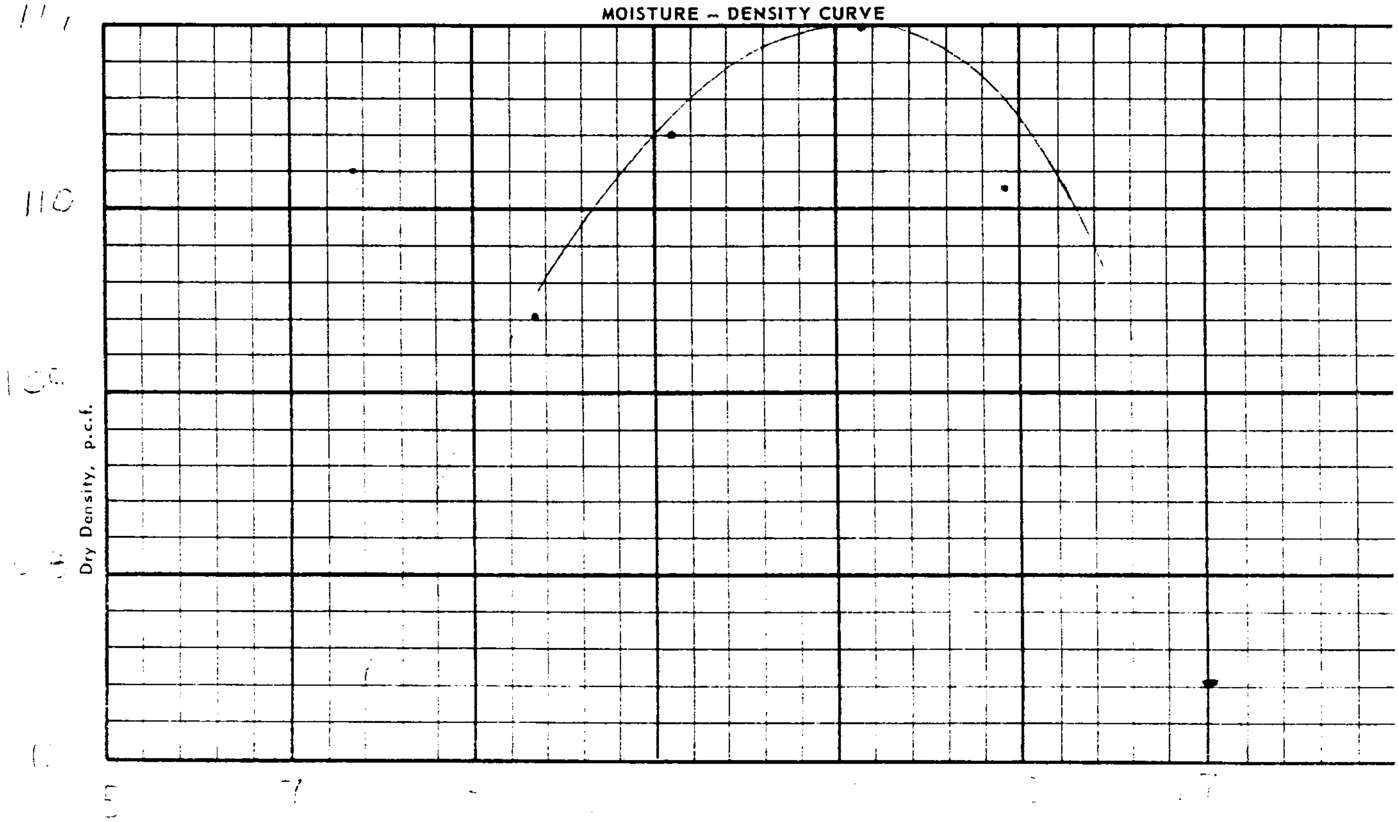
Route I-295 – ¾" + #4 =

Section 7C Station 617+50 S.B. – #4 =

AASHO or ASTM Designation D698 Method D

REST 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.	[illegible]	119.9	122.8	[illegible]	[illegible]	125.7			
Can Number		1	2	3	4	5	6			
Weight Wet Soil & Can	gms.	195.1	197.4	176.9	202.9	[illegible]	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	23.2	25.7			
Weight of Can	gms.	35.1	35.1	34.9	34.6	34.8	[illegible]			
Weight of Dry Soil	gms.	[illegible]	147.9	127.7	[illegible]	156.2	[illegible]			
Moisture %		7.7%	[illegible]	11.2%	13.3%	[illegible]	17.0%			
Dry Density	p.c.f.	[illegible]	10?3	110.4	[illegible]	[illegible]	107.4			

MOISTURE – DENSITY CURVE



Moisture Content – % of Dry Weight

Max. Dry Density 111.9 p.c.f.

Optimum Moisture 13.3 %

SIGNED

New Jersey Department of Transportation

LABORATORY SOIL ANALYSIS

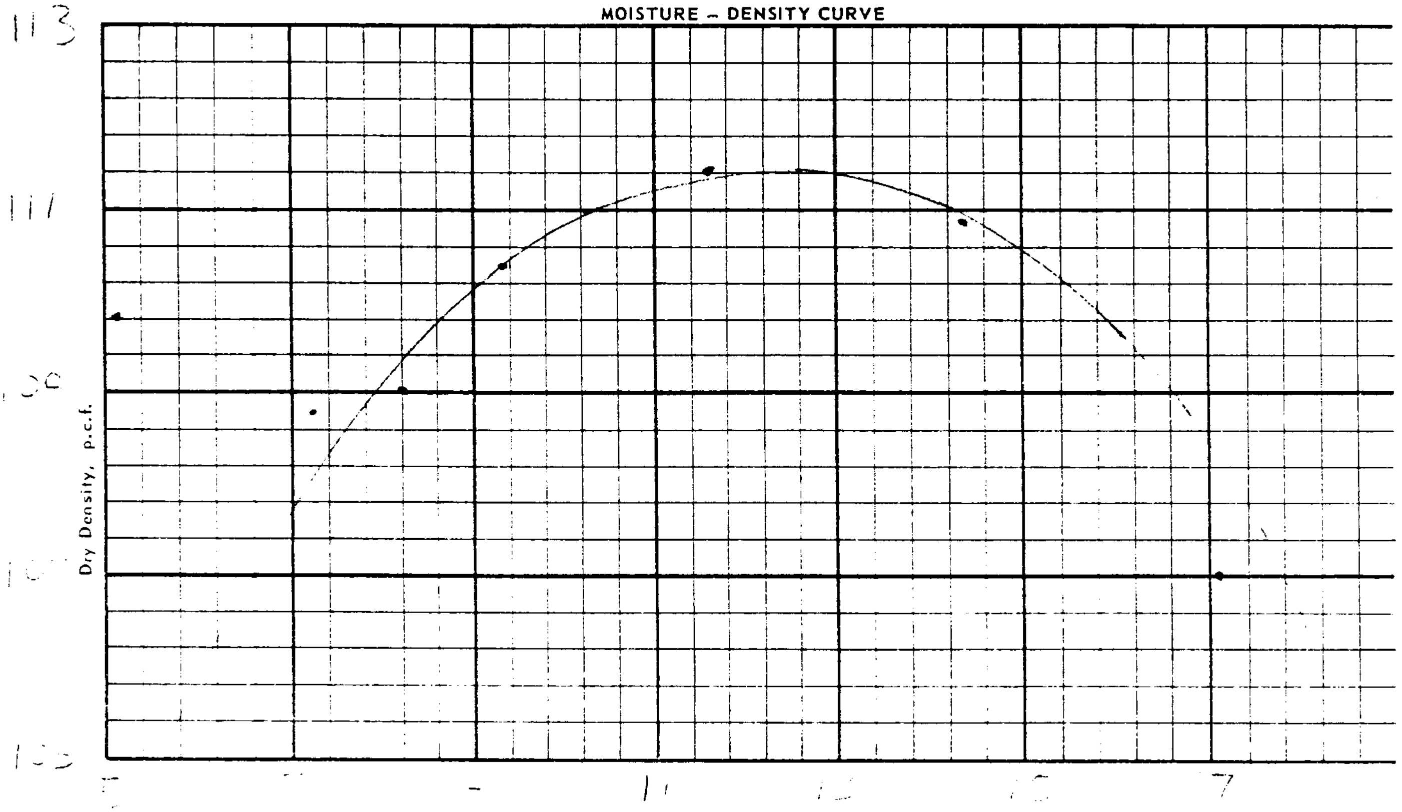
Form LS-200 (b) 5 72 | **MOISTURE – DENSITY RELATIONSHIP**

Serial No. Subbase (I-3) Date Tested 7/27/84 Producer ______
Route RT. I-295 – ¾" + #4 = ______
Section 7C Station 616+0 N.B. – #4 = ______
AASHO or ASTM Designation D698 Method D

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	6085	6133	6185	6225	6201		
Weight of cyl.	gms.	4302	4302	4302	4302	4302	4302	4302		
Weight of Soil	gms.	1748	[illegible]	178[illegible]	1831	1883	1923	[illegible]		
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.[illegible]%	9.3%	11.6%	14.4%	1[illegible]%		
Dry Density	p.c.f.	109.8	[illegible]	109.[illegible]	110.5	11[illegible].4	110.9	[illegible]		

MOISTURE – DENSITY CURVE



Moisture Content – % of Dry Weight

Max. Dry Density 111.4 p.c.f.

Optimum Moisture 11.6 %

SIGNED ______

New Jersey Department of Transportation

LABORATORY SOIL ANALYSIS

Form LB-200 (b) 6/72

MOISTURE – DENSITY RELATIONSHIP

Serial No. D.G. A.B. Date Tested 10/11/84 Producer Blast Furnace Slag

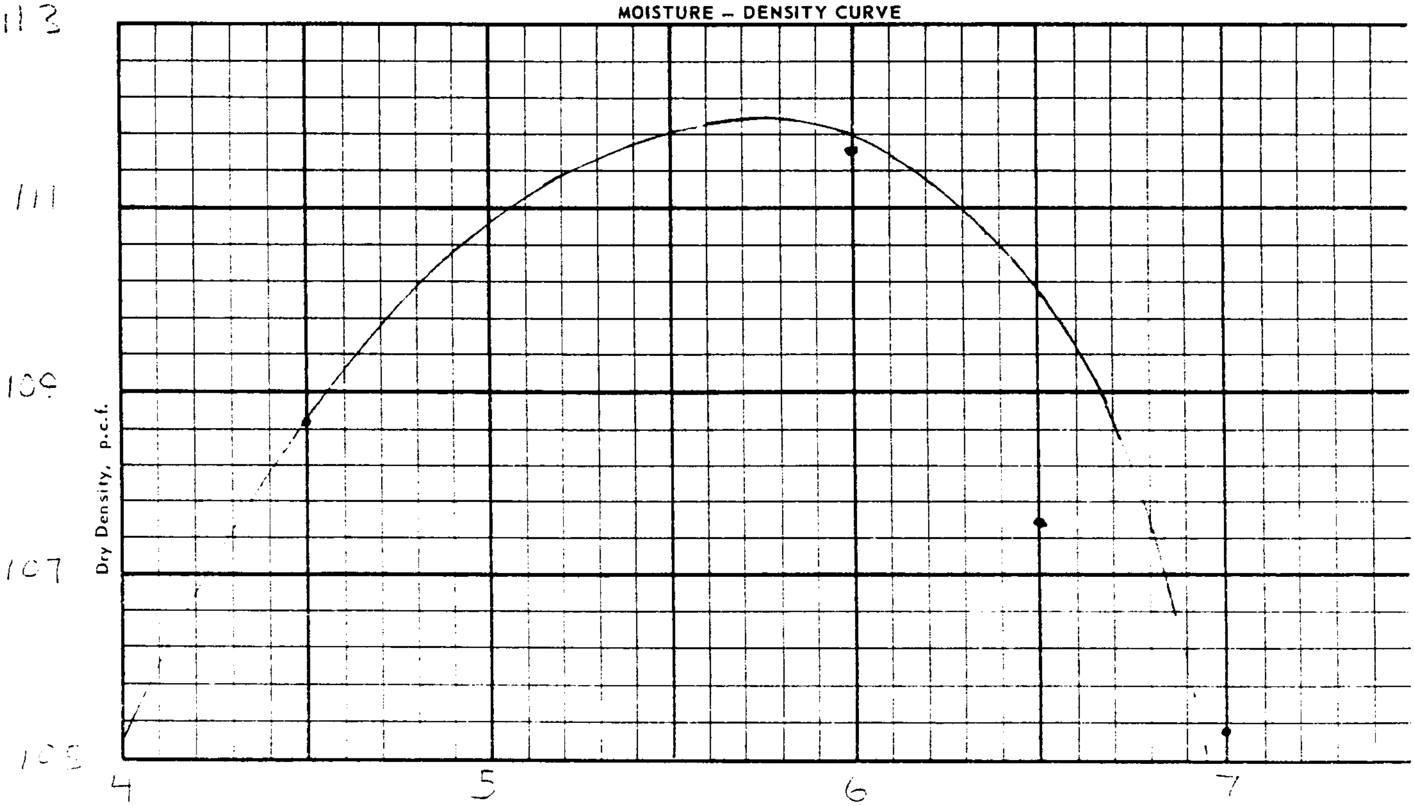
Route I-295 — 3/4" + #4 =

Section 7C Station 620+0 N.B. — #4 =

AASHO 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	4314	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.	1660.2	1698.5	1601.9	1586.5					
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

Form LB-9 12/77

NEW JERSEY DEPARTMENT OF TRANSPORTATION
Trenton, New Jersey

SERIAL NO. 354725

REPORT OF ANALYSIS OF AGGREGATE

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	BM 1				
SAMPLED BY	R. Mason				
DATE TAKEN	5-10-84				
DATE REC'D. AT LAB.	5-21-84				
SEAL NO.					
LAB. SERIAL NO.	354725				
SIZE OF OPENING SQUARE	TOTAL PERCENT PASSING			REQUIRED Min.	REQUIRED Max.
4"					
3 ½"					
3"	Compressive strength psi				
2 ½"	Cyl. #1	1237			
2"	2	1082			
1 ½"	3	1057			
1"	Avg.	1125 (Design Strength)		950	psi
¾"					
½"	Vacuum Saturated (PSI)				
3/8"	Cyl. 4	1240			
No. 4	5	1033			
No. 8	6	1264			
No. 16	Avg.	1179		961	psi 85% Design Strength
No. 30					
No. 50					
No. 100					
No. 200					
PLASTICITY INDEX					
ABSORPTION					
SODIUM SULFATE LOSS					

REPORTED TO

Limestone Prods.

T. Corcoran

C. Heckman

P. Marchetti ✓

M. Liao

F. Stia

REMARKS: Mix Design proportions

2.0% Lime(Warner Dihydrate)
6.0% Fly Ash(Metropolitan Edison, Portlan PA.
46.0% Fine Aggr.(#10 Limecrest Limestone)
6 % Moisture.

Complies.

PM:cam

Original Signed P. Marchetti

Form LB-14 11/71

New Jersey Department of Transportation

ANALYSIS OF MISCELLANEOUS MATERIALS

8-10-84

Serial No. 354727

Charged To: Li-estone Products Corp

Type of Material: Fly Ash

Proposed Use: Lime Fly Ash Stabilized Base

Producer: Metropolitan Edison Co. Location: Portland, Pa.

Plant: Location:

Sample Taken From	Silo at Limestone Prods.		
Quantity Represented	100 Tons		
Marks on Sample	RM #3		
Sampled By	R. Mason		
Grade Specified			
Lot No. Shipped From			
Submitted on Inspector's Daily Report No.			
Date Taken	5-10-84		
Date Received at Laboratory	5-21-84		
Seal Number			
Laboratory Serial No.	354727		

TESTS	ANALYSES		REQUIRED MIN.	REQUIRED MAX.
Combined Silica & Aluminum Oxides %	68		50	
Loss on Ignition %	4			10
Moisture %	0.06			0.5

REPORTED TO

Limestone Prods.

T. Corcoran

C. Heckman

P. Marchetti ✓

M. Liao

F. Stia

REMARKS: Complies. for mix design approval.

JV:cam

Original Signed J. Vanelli

Form LB-14 11/71

New Jersey Department of Transportation

ANALYSIS OF MISCELLANEOUS MATERIALS

8-10-84

Serial No. 354726

Charged To: Limestone Prods. Corp.

Type of Material: Lime (Warners Dihydrate)

Proposed Use: Lime Flyash Stabilized Base

Producer: Warner Co. Location:

Plant: Location:

Sample Taken From	Silo at Limestone Prods.		
Quantity Represented	100 Tons		
Marks on Sample	RM 2		
Sampled By	R. Mason		
Grade Specified			
Lot No. Shipped From			
Submitted on Inspector's Daily Report No.			
Date Taken	5-10-84		
Date Received at Laboratory	5-21-84		
Seal Number			
Laboratory Serial No.	354726		

TESTS	ANALYSES		REQUIRED MIN.	REQUIRED MAX.
Moisture %	0.4			4
CaO + MgO %	93		90	

REPORTED TO

Limestone Prods.

T. Corcoran

C. Heckman

P. Marchetti ✓

M. Liao

F. Stia

REMARKS:

Complies. For mix design approval.

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 SURFACE	BINDER	BASE	TOTAL THICK	VOIDS LOT NO.	AIR VOIDS - PERCENT SURFACE	BINDER	BASE
	SPECIFIED THICKNESS					1.50	6.00	7.50				
B31	NB	0634+57	L3	5.0		1.51	6.31	7.82	3A		6.4	4.9
B32	NB	0632+93	LOS	10.0		2.57	8.20	10.77	3A		6.5	3.1
B33	NB	0627+52	LIS	5.0		2.18	7.24	9.42	3A		7.8	5.7
B34	NB	0625+40	L1	1.0		1.60	7.30	8.90	3A		8.6	6.4
B35	NB	0623+41	L2	7.0		1.52	8.13	9.65	3A		6.8	3.6
B36	NB	0621+62	L3	5.0		1.83	6.96	8.79	3B		7.4	5.1
B37	NB	0620+91	LOS	10.0		1.35	8.12	9.47	3B		12.8	5.0
B38	NB	0618+59	LIS	3.0		1.60	6.77	8.37	3B		11.7	6.0
B39	NB	0618+16	L1	7.0		1.48	8.00	9.48	3B		6.9	6.0
B40	NB	0615+27	L2	3.0		1.45	6.25	7.70	3B		6.7	5.5
B41	NB	0614+43	L3	10.0		2.00	6.83	8.83	3C		6.1	5.8
B42	NB	0611+56	LOS	1.0		2.74	5.27	8.01	3C		8.0	11.4
B43	NB	0611+19	LIS	8.0		1.78	6.72	8.50	3C		11.4	9.6
B44	NB	0609+68	L1	4.0		1.67	7.29	8.96	3C		9.7	10.3
B45	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 B32 VALUE(S) 2.57
CORE B42 VALUE(S) 2.74

INFORMATION CORRECT

ACCBTCED-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	DEV. ABOVE/ BELOW CONTROL	LOTSIZE (SQ YDS)	AVER. THICK (INCHES)	REDUCTIONS PERCENT	TONS
3A	BINDER	7.1	2-8	0.0	5767	1.88 > 9.32	0	0
3A	BASE	4.7	2-8	0.0	5767	7.44	0	0
3B	BINDER	9.1	2-8	1.1	5767	1.54 > 8.76	10	52
3B	BASE	5.7	2-8	0.0	5767	7.22	0	0
3C	BINDER	8.4	2-8	0.4	5767	1.95 > 8.45	5	33
3C	BASE	8.5	2-8	0.5	5767	6.50	5	112

$\frac{26.53}{3} = 8.84$ Ave Lot Thick

AL = 6.80

R1	R2	R3	Av. R
2.95	1.78	1.01	1.91

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

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

QL = 1.07 = NO REDUCTION

AQCBTCED-2 11/15/85

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

THICKNESS LOT NO. 4

CORE NO.	LOCATION	STATION	LANE	OFF SET	THICKNESS - INCHES SURFACE	BINDER	BASE	TOTAL THICK	VOIDS LOT NO.	AIR VOIDS - PERCENT SURFACE	BINDER	BASE
	SPECIFIED THICKNESS					1.50	4.00	5.50				
B46	SB	0609+20	RIS	6.0		1.82	3.72	5.54	4A		9.8	6.2
B47	SB	0610+51	R1	5.0		2.23	5.12	7.35	4A		6.0	6.4
B48	SB	0612+44	R2	11.0		4.21	5.68	9.89	4A		8.0	4.0
B49	SB	0613+30	R3	2.0		2.26	3.58	5.84	4A		7.4	5.8
B50	SB	0614+41	ROS	8.0		1.65	5.09	6.74	4A		8.3	4.7
B51	SB	0615+93	RIS	5.0		3.17	4.39	7.56	4B		4.8	2.7
B52	SB	0617+44	R1	10.0		3.12	4.39	7.51	4B		5.7	4.3
B53	SB	0619+22	R2	2.0		3.35	4.24	7.59	4B		5.3	2.7
B54	SB	0619+76	R3	7.0		4.27	3.48	7.75	4B		4.8	5.1
B55	SB	0621+46	ROS	5.0		2.40	4.03	6.43	4B		7.9	7.4
B56	SB	0622+03	RIS	5.0		2.99	4.14	7.13	4C		5.1	4.0
B57	SB	0623+88	R1	3.0		2.63	4.22	6.85	4C		4.4	3.1
B58	SB	0624+45	R2	7.0		2.06	4.29	6.35	4C		5.0	3.2
B59	SB	0626+45	R3	5.0		1.93	4.87	6.80	4C		5.1	3.9
B60	SB	0627+61	ROS	9.0		1.61	3.89	5.50	4C		8.4	5.2

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

CORE B48	VALUE(S)	4.21
CORE B51	VALUE(S)	3.17
CORE B52	VALUE(S)	3.12
CORE B53	VALUE(S)	3.35
CORE B54	VALUE(S)	4.27
CORE B56	VALUE(S)	2.99
CORE B57	VALUE(S)	2.63

INFORMATION CORRECT

AQCBTCED-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	DEV. ABOVE/ BELOW CONTROL	LOTSIZE (SQ YDS)	AVER. THICK (INCHES)	REDUCTIONS PERCENT	TONS
4A	BINDER	7.9	2-8	0.0	4105	2.43	0	0
4A	BASE	5.4	2-8	0.0	4105	4.64 > 7.07	0	0
4B	BINDER	5.7	2-8	0.0	4105	3.26	0	0
4B	BASE	4.4	2-8	0.0	4105	4.11 > 7.37	0	0
4C	BINDER	5.6	2-8	0.0	4105	2.24	0	0
4C	BASE	4.0	2-8	0.0	4105	4.28 > 6.52	0	0

20.96 = 6.99

AL = 4.85

R1	R2	R3	Av. R
4.35	1.32	1.63	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	
Asphalt Cement	BTU/TON
Refine asphalt cement	587,500
Haul 50 miles x 2 x 1960 BTU/Ton miles	196,000
Total for A.C.	783,500
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
	130,130
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
	166,060
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
	254,254
HAUL AND PLACE AT JOB SITE	
Haul mix, 12 miles x 2 at 3,800 BTU/Ton	91,200
Spread and compact	16,700
	107,900
TOTAL FOR ASPHALT CONCRETE	
Mix Composition	166,060
Plant Operations	254,254
Haul and Place	107,900
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
	241,550
Haul mix to job site, 75 mi. x 2 x 1960 BTU/Ton mi.	294,000
Spread and compact	16,700
	310,700

TOTAL FOR LFA	
Mix Composition and Plant Operations	241,550
Haul and Place	310,700
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.

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

ENERGY CALCULATIONS FOR SUBBASE (BANK RUN GRAVEL)

Given

Source located 15 miles from job site.

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

ENERGY CALCULATIONS FOR PRIME COAT (AND CURING COMPOUND)

Given

MC-30 256 gallons/ton

ENERGY TO REFINE AND ENERGY IN THE MATERIAL	BTU/TON
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	113,664
TOTAL BTU/TON:	18,360,660