FINAL REPORT

FHWA DEMONSTRATION PROJECT 59

THE USE OF FLY ASH IN HIGHWAY CONSTRUCTION

U.S. 84/98 ADAMS COUNTY

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16. Abstract

Much attention has been focused in recent years on conserving natural resources and energy. Numerous waste products and/or byproducts from various industrial and commercial processes, normally deposited in landfills, have been proposed for use as alternate construction materials. One byproduct that has shown considerable promise as an alternate construction material is fly ash when used in a lime-fly ash (LFA) base course. This paper describes the use of this waste product in LFA stabilized granular materials as an alternative to cement treated materials for base construction. The primary disadvantage of a cement treated base (CTB) is the environmental (shrinkage) cracking that leads to the infiltration of rain water and incompressibles, pumping of subgrade soils, spalling of the crack faces and other problems that adversely effect pavement performance. It has been shown that the slow strength gain associated with LFA leads to a condition where the microcracks in the material are generally healed before they can develop into macrocracks. Continued chemical reactions, known as autogenous healing, within the mix are largely responsible for this behavior.

MDOT was introduced to the concept of using fly ash and lime to chemically treat granular materials for use as base and subbase courses in 1981 when the Federal Highway Administration began promoting the use of fly ash in Demonstration Project No. 59, "The Use of Fly Ash in Highway Construction". In conjunction with this project MDOT adopted a three-phase program to evaluate LFA mixtures for base and subbase construction. This report addresses the construction and evaluation of the second phase of the three-phase program on U.S. 84/98 in Adams County.
Primary conclusions and recommendations resulting from this study include the following:

CONCLUSIONS
1. The overall evaluation of the roadway in phase two of the three-phase program indicates good performance of the LFA base despite the poor quality of construction. This performance indicates that a LFA stabilized granular material is a viable option for replacement of a bituminous material in base course construction.
2. An economic analysis of the phase two project indicated significant savings of approximately $30,000 per 2-lane mile by using a LFA stabilized material instead of a bituminous material for the base course construction.

RECOMMENDATIONS
1. Research should be conducted to develop a mix design procedure that more closely predicts the field properties of a LFA stabilized material.

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Recycling waste products, lime-fly ash base course, cement treated base course, shrinkage cracking of CTB

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The authors wish to express their appreciation to Mr. Gary S. Browning for his support in preparing the tables for this report.

During the period of this study, the Executive Director of MDOT was Dr. Robert L. Robinson followed by Mr. Kenneth I. Warren. The Deputy Executive Director / Chief Engineer was Mr. James D. Quin and Mr. Kenneth I. Warren, respectively.

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CHAPTER 1: INTRODUCTION

BACKGROUND

Much attention has been focused in recent years on conserving natural resources and energy. Numerous waste products and/or byproducts from various industrial and commercial processes, normally deposited in landfills, have been proposed for use as alternate construction materials. The use of alternate materials needs to be encouraged for both the economy of construction and conservation of materials. One byproduct that has shown considerable promise as an alternate construction material is fly ash. This paper describes the use of this waste product in lime-fly ash (LFA) stabilized granular materials as an alternative to cement treated materials for base construction.

Fly ash is a pozzolanic material recovered from the flue gases of coal combustion processes. A pozzolan is defined by ASTM as “A siliceous or siliceous and aluminous material, which by itself possess little or no cementitious value, but will, when in a finely divided form and in the presence of moisture, chemically react with calcium hydroxide at ordinary temperature to form compounds possessing cementitious properties.” Thus a LFA mixture can act as a cementing agent for soil stabilization.

From the 1950's until the mid 1980’s the Mississippi Department of Transportation (MDOT) extensively used cement treated bases (CTB) and subbases in pavement structures. Many miles of secondary, primary and interstate routes utilized CTB. One negative characteristic of CTB is the significant shrinkage cracking that this material experiences subsequent to construction. The cracking poses no problems in a concrete pavement since this pavement type will bridge over the cracks. An asphalt pavement, however, reflects these cracks, which leads to water infiltration, spalling of the crack faces and other problems producing an unacceptably rough riding surface.

The rate of chemical reaction between the lime and fly ash to effect strength gain in the stabilized material is slower than the rate experienced with soil cement stabilization. This relatively slow rate of strength gain acts to retard shrinkage or environmental cracking which is a benefit for the long-term performance of hot mix asphalt pavements. Shrinkage cracks begin at the top surface of the stabilized course and their propagation through the depth is a function of the drying rate. The top fiber shrinkage stress is a function of the "modulus" and, in turn, the strength of the material. The initial low modulus, and, in turn, reduced slab action of the LFA stabilized layer, retard initiation of shrinkage cracking. It can be shown that these bases exhibit numerous fine cracks instead of the relatively wide cracks spaced further apart in stiff slabs; i.e., soil cement stabilized layers. Fine, light cracks are least likely to reflect through the pavement surface, promoting better performance and longevity.

The continued chemical reaction of LFA mixes plays a crucial role in healing the shrinkage microcracks mentioned in the previous section. It is hypothesized that some or all of the microcracks are healed due to this autogenous healing trait before they become visible to the naked eye. This hypothesis is substantiated by the condition surveys done on the LFA projects that indicate minimal cracking in these base courses. The combination of slow strength gain and self-healing due to continued chemical reactions are the major reasons for the general absence of cracking. This property is conducive to addressing the problem posed by the use of a cement stabilized material. By controlling the crack development in the underlying base and/or subbase course any potential subsequent reflective cracking can be minimized in an overlying asphalt course.

Another advantage of LFA stabilization is the very forgiving nature of the resulting material. The reaction time of the LFA mixture is usually measured in days or weeks instead of hours, as is generally the case with CTB. If the proper density is not achieved because of improper moisture content, there is ample opportunity to add additional water or aerate the mixture to get the moisture content corrected. Compaction to the specified density is not overly difficult as long as the moisture content is within 1% or 2% of optimum.

MDOT was introduced to the concept of using fly ash and lime to chemically treat granular materials for use as base and subbase courses in 1981 when the Federal Highway Administration began promoting the use of fly ash in Demonstration Project No. 59, "The Use of Fly Ash in Highway Construction". In conjunction with this project MDOT adopted a three-phase program to evaluate LFA mixtures for base and subbase construction.

Due to the uncertainties involved with trying a new material for pavement construction MDOT chose a conservative approach for evaluating LFA stabilization in the first phase of the program. To minimize any potential risk to the integrity of the pavement structure should the LFA stabilized material not obtain the increase in strength as expected, the first phase involved stabilizing the subgrade of a project instead of either the subbase or base layers.

The phase one project was built in 1982-83 on SR 63 in Jackson County. This 15 mile project consisted of adding 2 new lanes parallel to the existing 2 lanes of the highway. Soil conditions on the site include A-2, A-3 and A-4 sandy soils and A-4 silty clays. The main purpose of the soil stabilization was to create a good working platform on which to place the pavement. If sufficient strength was obtained the stabilized subgrade would also act as a subbase. Fly ash and quick lime were spread on the subgrade, mixed in place and compacted without difficulty. Percentages of lime and fly ash were 4 and 12, respectively. Performance has been excellent. Testing conducted since construction indicates strength characteristics are similar to CTB. Cracking is essentially nonexistent. Economic analysis shows significant savings, approximately $20,000 per 2-lane mile, over the conventional treatment. It became apparent that this product offered considerable promise as a high quality base course material.

The second phase involved central plant mixing of LFA with a high quality bank-run sand gravel aggregate and the third phase utilized road mixing of LFA with a bank-run, low plasticity sand topping. The LFA courses were 6 inches thick and used for either base or subbase under a flexible pavement. This report addresses the construction and evaluation of the second phase of the three-phase program.

OBJECTIVE

Typically a bituminous material is used for the base course in a hot mix asphalt (HMA) pavement structure since a soil cement stabilized base course layer causes reflective cracking in this pavement type. One of the objectives of this study is a recommendation for the use of LFA stabilized material as an alternative to bituminous material for this pavement layer. This recommendation is based on several factors including the economic benefits and the performance of the pavement subsequent to construction.

A second objective of this study is to determine the cost effectiveness of manufacturing the LFA base course material in a central mixing plant. Central plant mixing generally produces a more uniform, higher quality material than does roadmixing.

SCOPE

The phase two project was constructed in 1985-86 near Natchez in southwest Mississippi. This project involved adding 2 new lanes parallel to the existing 2 lanes of US 84/98. The ten year pavement design for this route was based on an ADT of 3500 and an estimated 810,000 eighteen-kip ESALs. The average ambient temperature for the Natchez area is 66.3 ^{o}F with an average annual rainfall of 57.4 inches.

The total pavement structure for this roadway called for a 6-inch sand-clay gravel subbase, an option for either a 6-inch LFA or a 4.5-inch bituminous base and 4.0 inches of hot plant-mixed bituminous pavement. Of the three contractors submitting bids on the project, bidders one and three selected the LFA base option. The four inches of asphalt paving consisted of two 1.5-inch lifts of binder course mix and a one-inch wearing course.

CHAPTER 2: DESIGN AND CONSTRUCTION

This chapter covers the design of the LFA stabilized material and the construction of the base course.

MIX DESIGN

The Natchez area has a good supply of pit-run sand-clay gravel and this untreated material is commonly used locally for bases and subbases. This material was utilized with lime and fly ash for the base course.

The MDOT mix design procedure used at the time this project was constructed involved preparing trial mix batches of lime, fly ash and granular material. Weight percentages of the lime usually ranged from 2% to 4% and from 6% to 15% for the fly ash. Specimens at the various lime and ash contents were blended and compacted generally following the procedure given in AASHTO T-99. Replicate specimens were cured both in a fog room and in a 100 ^{o}F hot room and then tested in unconfined compression at 7, 14 and 28 days. After reaching their maximum load, each of the specimens that were cured in the hot room were unloaded and placed in the fog room for retesting at an additional 28 days. Most of these retest results indicated higher strengths than the initial 28-day strength due to the autogenous healing property of the LFA material.

The selection of the job mix formula was based largely on the 28-day breaks of the cylinders cured in the hot room. It was generally desirable to have these strengths in the range of 400 to 600 psi. The other strength data was used to evaluate strength gain characteristics, autogenous healing capability and other items peculiar to a given area.

It is important to note that the laboratory strength data was not considered to be an estimate of the in-place strength of the LFA material at 28 days. What the laboratory strength criteria did was to help insure that this material would have sufficient strength to perform its function in place on the road. One of the perplexing problems experienced in Mississippi in designing LFA courses has been the inability to get good correlation between strengths of molded cylinders and cores cut from the in-place material. The problem appears to be due either to the inability to extrude LFA samples from the mold without damaging them or significant differences in the moisture-density properties of the materials. Based on limited coring of LFA materials, ultimate core strengths between 400 and 900 psi will perform adequately without excessive cracking. An investigation of this problem is continuing.

The fly ash for this project was a Class F ash supplied by Trinity Materials that originated from a generating station located near Purvis, Mississippi. This ash and hydrated lime were used to treat the pit-run Class 6 granular material. Four-inch diameter by 4.59-inch high specimens of varying lime-fly ash content were prepared, cured and tested in unconfined compression. The original mix design called for 16% ash and 4% lime but the ash content was reduced to 12% after the first few days of construction. The 12% fly ash mixture provided an average 28-day laboratory strength of 414 psi.

CONSTRUCTION

The construction contract was awarded to Dickerson and Bowen, Inc. of Brookhaven, Mississippi, in November of 1984. Specifications required the lime, fly ash, aggregate and water to be mixed in a central mixing plant. The contractor elected to use a continuous type pugmill mixing plant, which was set up in the aggregate pit. The aggregate feed bin was located at the end of the belt conveyor while separate vertical silos for the fly ash and powdered hydrated lime straddled the belt. A weigh bridge on the belt conveyor was used to calibrate the aggregate bin gate opening. The ash and lime were fed volumetrically through vane feeders, which were manually calibrated through fixed-time cycles. Water was obtained from a nearby stream.

Some of the loads of LFA material obviously did not have the proper amounts of lime and ash and this was due to the numerous problems that were encountered with the mixing plant, primarily with the lime and fly ash metering system. The equipment was old, well worn and operated in an unreliable manner.

The LFA mixture was hauled in uncovered dump trucks for an average distance of approximately four miles to the roadway and was deposited on the subbase through a windrow spreader. Twin windrows were used to provide sufficient distribution of the LFA material so the automatic grade control spreader could efficiently complete the spreading operation across the 27-foot width of the base course with reversible augers. Initial compaction was accomplished with a vibratory roller, followed by a pneumatic tire roller. Following compaction a curing seal of emulsified asphalt was applied. The base course construction began in mid-June and was completed in mid-August. All the LFA base course was covered with at least one lift of binder course by mid-September of 1985 and the pavement construction was essentially complete by late spring of 1986.

During construction the major problem experienced on the roadway was the contractor's lack of equipment to maintain the proper moisture content in the LFA material throughout the spreading and compaction operations and until the bituminous curing seal was applied. Surface drying of the LFA material led to crusting of the top portion (up to 1") of the base course. For all practical purposes this crusted material is of little structural value and can cause problems such as slippage and difficulty of compaction during the asphalt paving operation.

Shrinkage cracks in the LFA base were noticed in random locations on the project prior to its being covered with asphalt. The cracking was noticed in only a few areas and presented no problems. The probable cause for the cracking was variations in moisture and mixture components. In some sections of the LFA base course the strength gain was much more rapid than in other sections. It is the rapid strength gain in soil cement that lends that material to crack from shrinkage and this may be the cause for the shrinkage cracking in the base course of this project. In some of these areas the LFA base was of a strength approximating lean concrete.

Since the pavement has been completed, reflection cracks from the LFA base have been noticed in the asphalt surface in several locations. The cracking is not widespread and the cracks are generally tight. Some of the cracks appear to be healing back together, probably due to autogenous healing in the LFA base and the kneading action of traffic on the asphalt pavement.

COST

An economic analysis of the phase one project indicated significant savings by using a LFA stabilized material in the construction, approximately $20,000 per 2-lane mile, over the conventional treatment.

MDOT considers a 6-inch LFA base to be structurally equivalent to a 4.5-inch bituminous base. Another project adjoining the phase two project was constructed during the same time period as the phase two construction. Both pavement structures were identical with the exception that this other pavement included a 4.5-inch bituminous base instead of a 6-inch LFA base. A cost comparison between the two projects shows that the use of the LFA base course resulted in savings of about $30,000 per 2-lane mile as compared to a bituminous base.

CHAPTER 3: POST CONSTRUCTION EVALUATION

A total of twenty-nine four-inch diameter cores and three test pits were cut at 23 locations across the project. Table 1 gives a summary of core and test pit locations along with brief descriptions of asphalt pavement and LFA base conditions. Table 2 gives a summary of core data.

The core locations represent areas of good, average and poor performance. Cores were taken both in the wheel path and between wheel paths, across cracks and in uncracked areas, in patched areas and unpatched areas, in areas of good drainage and poor drainage, in cuts and in fills, and in areas with different pavement structures.

To summarize this data, the following trends are noticed:

-cracking of some type is present throughout the project

-about half the cracks come from the asphalt layer and half from the LFA base

-moisture entering through cracks does not damage the LFA base

-stripping was observed in about half the locations

-stripping is almost always present at cracks

-stripping occurs more often in the wheel paths

-stripping is present in all asphalt layers, but more concentrated in the surface and top binder

-stripping in the asphalt layers does not correlate well with the condition of the LFA base

-in about 80% of the locations tested, the LFA base was in good condition

-some of the asphalt patching material is not of good quality.

GENERAL COMMENTS ON THE CONDITION OF THE ROADWAY

The project has serious cracking throughout its length. The type of cracking found includes transverse, longitudinal, block and alligator. Surface weathering and raveling are present in some areas. There are numerous patched areas across the pavement surface. From the coring and test pit work, it appears that most of the failures are due to one of the following:

-saturated subgrade conditions

-rapidly oxidizing asphalt

-isolated areas of poor LFA base.

Alligator cracking is indicative of fatigue failure in the pavement structure. This could be due to several factors such as inadequate subgrade soil support or overloading of the pavement structure due to traffic loading exceeding the design loading.

During construction of the pavement pumping of the granular subbase and design soil were observed in at least two locations and subsequent to that construction saturated subgrade conditions were noticed in some areas of the project. One remedy for the post construction saturation problems is to maintain the ditches to avoid ponding of water. This ponding is due to the sloughing of the loess cut slopes, which impede the drainage of water from these ditches. A minimum ditch depth of 4' below pavement grade is recommended. Due to the permeability of the existing subgrade, it is not considered feasible to add underdrains.

One factor not to be overlooked is the traffic loading. As the Department gets more accurate data on unbiased truck weights, it is becoming more apparent that traffic loading is underestimated for the purpose of pavement design. Numerous heavily loaded log trucks were observed during the three days that MDOT personnel were on the project site performing the pavement condition surveys.

The entire project has regular transverse and longitudinal cracking in a block pattern. The lime fly ash base course achieved high strengths as evidenced by roadway cores cut one year after construction averaging 1110 psi. Shrinkage cracking of the LFA base course can be expected and indeed did occur with strengths of this magnitude. Some of these cracks reflected through the overlying asphalt pavement. A recent investigation suggests, however, that about half of the cracking observed in the asphalt pavement was due to factors such as rapidly oxidizing asphalt and poor subdrainage.

There are a small number of failed areas, probably about 10, which are attributable to poor quality of the LFA mixture. As discussed in Chapter 2 of this report there were problems with obtaining a uniform blend of lime, fly ash and Class 6 material from the central mixing plant. This is the probable explanation for the isolated areas of poor LFA base and resulting pavement distress reported in these areas. The overall evaluation of this roadway indicates good performance of the LFA base even though construction quality was poor.

TABLE 1 CORE AND TEST PIT SUMMARY.

				CONDITION			
CORE NO.	STATION NO.	DIRECTION	LFA BASE	BOTTOM BINDER	TOP BINDER	SURFACE	NOTE:
1A	71+33	EAST BOUND	GOOD	GOOD	GOOD	GOOD	CORE IN MIDLANE; EXTENSIVE RAVELING AND CRACKING IN WHEEL PATH IN THIS AREA
1B	71+33	EAST BOUND	GOOD	POOR	POOR	POOR	CORE IN WHEEL PATH THROUGH CRACK; ASPHALT HEAVILY STRIPPED
2	71+56	EAST BOUND	GOOD	FAIR	FAIR	FAIR	CORE IN WHEEL PATH
3A	92+20	EAST BOUND	GOOD	GOOD	FAIR	POOR	CORE IN MIDLANE THROUGH CRACK; CRACK WENT FROM TOP DOWN THROUGH TOP BINDER; NOT A REFLECTION CRACK;
3B	92+20	EAST BOUND	GOOD	GOOD	GOOD	GOOD	CORE IN WHEEL PATH
4	108+64	EAST BOUND	GOOD	STR	FAIR	FAIR	CORE IN MIDLANE THROUGH CRACK; CRACK IN SC ONLY; NOT A REFLECTION CRACK; BLOCK CRACKING IN
5	145+31	EAST BOUND	GOOD	FAIR	FAIR	STR	CORE IN AREA OF OLD PATCH IN MIDLANE
6	169+13	EAST BOUND	POOR	FAIR	FAIR	STR	AREA HAS TWO PREVIOUS PATCHES; LFA BASE TENDER-NO CEMENTING ACTION; CORE IN MIDLANE
7	170+67	EAST BOUND	POOR	FAIR	STR	STR	AREA HAS EARLY STAGE OF ALLIGATOR CRACKING; LFA BASE TENDER-NO CEMENTING ACTION; CORE IN WHEEL PATH
8	177+50	EAST BOUND	GOOD	GOOD	GOOD	GOOD	AREA HAS OLD PATCH; CRACK IN LFA BASE THAT DOES NOT EXTEND INTO PAVEMENT; CORE IN MIDLANE
9	181+53	EAST BOUND	GOOD	STR	STR	GOOD	CORE IN MIDLANE THROUGH TRANS. CRACK; SURFACE STAINING FROM PUMPING OF FLY ASH
10	183+11	EAST BOUND	GOOD	GOOD	GOOD	GOOD	AREA HAS AT LEAST TWO PATCHES; PATCHES HAVE EXTREMELY HIGH AC CONTENT, SEVERE BLEEDING
11	191+25	EAST BOUND	N/A	GOOD	GOOD	GOOD	NO EVIDENCE OF LIME OR FLY ASH IN BASE, ONLY GRN MTL; CORE IN WHEEL PATH
12A	191+69	EAST BOUND	GOOD	GOOD	GOOD	GOOD	CORE IN MIDLANE
12B	191+79	EAST BOUND	N/A	GOOD	GOOD	GOOD	BLACK BASE IN-PLACE INSTEAD OF LFA BASE; CORE IN MIDLANE
13	213+95	EAST BOUND	GOOD	FAIR	POOR	STR	PATCHED AREA; CORE IN MIDLANE

TABLE 1 CORE AND TEST PIT SUMMARY (continued).

				CONDITION			
CORE NO.	STATION NO.	DIRECTION	LFA BASE	BOTTOM BINDER	TOP BINDER	SURFACE	NOTE:
14	224+58	EAST BOUND	GOOD	FAIR	FAIR	STR	PATCHED AREA; TEST PIT EXCAVATED IN THIS AREA AT STA. NO. 224+43; MODERATE STRIPPING IN AC PAVEMENT IN PIT CORE IN MIDLANE
15	228+46	EAST BOUND	GOOD	FAIR	POOR	POOR	NO. 15 IN MIDLANE ON CRACK; CRACK IS ONLY IN SC; MODERATE STRIPPING IN TOP BC AND SC
16	245+66	EAST BOUND	N/A	GOOD	GOOD	GOOD	BLACK BASE IN-PLACE INSTEAD OF LFA BASE; CORE IN MIDLANE
17A	147+00	WEST BOUND	POOR	GOOD	GOOD	GOOD	PATCHED AREA, LFA BASE VERY TENDER; CORE IN MID-LANE
17B	147+00	WEST BOUND	FAIR	GOOD	GOOD	GOOD	PATCHED AREA; CORE IN WHEEL PATH
18A	145+89	WEST BOUND	GOOD	GOOD	GOOD	FAIR	PATCHED AREA; CORE IN MID-LANE
18B	145+89	WEST BOUND	POOR	GOOD	FAIR	STR	PATCHED AREA; CORE IN WHEEL PATH; LFA BASE VERY TENDER
19A	144+64	WEST BOUND	GOOD	GOOD	GOOD	GOOD	PATCHED AREA; CORE IN MID-LANE
19B	144+64	WEST BOUND	GOOD	FAIR	STR	STR	PATCHED AREA; CORE IN WHEEL PATH
20	142+39	WEST BOUND	GOOD	FAIR	STR	STR	PATCHED AREA; CORE IN MID-LANE; TEST PIT IN THIS AREA; MODERATE STRIPPING OF AC IN TEST PIT; LFA BASE IN PIT IN GOOD CONDITION; SUBGRADE APPEARS TO HAVE EXCESS MOISTURE
21	108+09	WEST BOUND	GOOD	STR	STR	POOR	CORE TAKEN ON CRACK; STAINING FROM PUMPING OF FLY ASH ALONG CRACK; PONDED WATER IN DITCH; CRACK ONLY IN SC
22	107+00	WEST BOUND	GOOD	FAIR	POOR	POOR	TEST PIT LOCATION; TRANS. AND LONG. CRACKS THROUGH PIT AREA; TOP BC HAD MUCH UNCOATED AGGREGATE; CRACKS IN LFA REFLECTED THROUGH AC; CRACKS IN LFA ARE VERY TIGHT; SUBBASE APPEARS TO HAVE EXCESS MOISTURE
23	105+47	WEST BOUND	GOOD	STR	STR	POOR	CORE THROUGH TRANS. CRACK; CRACK IS REFLECTION FROM LFA CRACK THAT HAD PARTIALLY HEALED; UNREACTED LIME CLODS THE SIZE OF BBs IN LFA

Table 2 SUMMARY OF CORE DATA

TOTAL CORES		29
CORES TAKEN ON CRACKS		8
CRACKS ORIGINATING FROM LFA		4
CRACKS ORIGINATING FROM SURFACE		4
CORES WITH STRIPPING		7
LFA WITH GOOD CONDITION		8
CRACKS IN WHEEL PATH		3
CRACKS IN MIDLANE		5
	1 CORE HAD A CRACK IN LFA THAT HAD NOT REFLECTED THROUGH AC	
CORES NOT TAKEN ON CRACK		21
CORES WITH STRIPPING		8
CORES WITHOUT STRIPPING		13
LFA IN GOOD CONDITION		13
LFA IN POOR CONDITION		5
OTHER TYPE BASE		3
CORES IN MIDLANE		19
CORES ON CRACK		6
CORES WITH STRIPPING		9
LFA IN GOOD CONDITION		15
LFA IN POOR CONDITION		2
OTHER TYPE BASE		2
CORES IN WHEEL PATH		10
CORES ON CRACK		3
CORES WITH STRIPPING		6
LFA IN GOOD CONDITION		6
LFA IN POOR CONDITION		3
OTHER TYPE BASE		1
CORES WITH STRIPPING		15
ON CRACK		7
IN MIDLANE		9
IN WHEELPATH		6
STRIPPING IN SURFACE		11
STRIPPING IN TOP BINDER		9
STRIPPING IN BOTTOM BINDER		5
LFA IN GOOD CONDITION		12
LFA IN POOR CONDITION		3
CORES WITHOUT STRIPPING		14
ON CRACK		1
IN MIDLANE		10
IN WHEEL PATH		4
LFA IN GOOD CONDITION		9
LFA IN POOR CONDITION		2
OTHER TYPE BASE		3
LFA BASE CONDITION	TOTAL CORES	29
LFA IN GOOD CONDITION		21
LFA IN POOR CONDITION		5
OTHER TYPE BASE		3

CHAPTER 4: CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

1. The overall evaluation of the roadway in phase two of the three-phase program indicates good performance of the LFA base despite the poor quality of construction. This performance indicates that a LFA stabilized granular material is a viable option for replacement of a bituminous material in base course construction.

2. An economic analysis of the phase two project indicated significant savings of approximately $30,000 per 2-lane mile by using a LFA stabilized material instead of a bituminous material for the base course construction.

RECOMMENDATIONS

1. Research should be conducted to develop a mix design procedure that more closely predicts the field properties of a LFA stabilized material.