FIELD EVALUATION OF FLY ASH IN AGGREGATE SHOULDER MATERIALS

Final Report

By

JAMES L. MELANCON
SENIOR SOILS RESEARCH GEOLOGIST

And

ATHA E. PITTMAN
ENGINEERING SPECIALIST

Research Report No. 177

Research Project No. 81-1S

Conducted by
LOUISIANA DEPARTMENT OF TRANSPORTATION
AND DEVELOPMENT
Research and Development Section
In Cooperation with
U. S. Department of Transportation
FEDERAL HIGHWAY ADMINISTRATION

JUNE 1985

ACKNOWLEDGMENTS

The authors wish to acknowledge the cooperation of the fly ash marketers, Gifford Hill and Company (Cason Power Plant, Cason, Texas, and Rodamacher Power Plant, Boyce, Louisiana), Bayou Ash (Cajun Power Plant No. 2, New Roads, Louisiana), and Ash Management Systems (Nelson Power Plant, Westlake, Louisiana) during this study.

The construction effort provided by the maintenance forces of Districts 03 and 58 is also appreciated; in particular, Mr. Paul Stagg and Mr. Roland Babin of District 03 and Mr. Bill Young of District 58.

ABSTRACT

This study consisted of an evaluation of self-hardening fly ash (Class C) used as an additive in the treatment of shoulders surfaced with sand clay gravel and/or shell (oyster). This was accomplished through construction of fly ash treated aggregate shoulder test sections at four sites in two phases. In the first phase test sections were constructed with fly ash from two sources. In the second phase fly ash from two new sources, as well as portland cement, was used to treat existing shoulders.

Periodic visual condition surveys were conducted over a four-year period for test sections constructed in the first phase and over two years for those constructed in the second phase. Deflection measurements were also taken at selected time intervals.

Based on visual condition surveys, the physical condition and performance of the sand clay gravel treated test sections were equally good for all levels and types of additives, as well as sources of fly ash. Deflection measurements indicated approximately the same level of stiffness in the fly ash treated sections as was measured in the 6 percent portland cement treated sections at one year, with the latter sections experiencing no additional increase after one year. The deflection measurements of fly ash sections at site 3 did not indicate any appreciable increase in stiffness level after one year. The physical condition of all shoulder sections containing shell stabilized fly ash or portland cement was judged only fair after two years. The deflection measurement for these sections indicated a decrease in SNs from that of preconstruction. The cause for poor results in all test sections at site 4 was not determined.

IMPLEMENTATION STATEMENT

The results of this study showed that the use of fly ash (Class C) as the primary additive in the treatment of existing raw sand clay gravel will result in a stable and impoved all-weather material. Therefore, recommendation in the use of fly ash to upgrade existing raw sand clay gravel shoulder material is made to the Department through this report. The construction technique and acceptable material, physical and chemical limits are included.

The diverse results between test sections of the two shell test sites indicate a need for additional field trials before implementation recommendations can be made. Therefore, recommendations for the use of fly ash in upgrading existing raw shell shoulder material are not made at this time.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES (CONTINUED)

LIST OF FIGURES (CONTINUED)

INTRODUCTION

Fly ash, a pozzolanic material, has been used along with hydraulic cement and lime for many years (1, 2)* to enhance their cementing qualities. Some fly ashes produced by the burning of lignitic coals show a low degree of cementing properties themselves when combined with water. This type of fly ash is presently designated by A.S.T.M. (3) as a Class C fly ash. Power plants in Louisiana and neighboring states are presently burning this type of coal-making Class C fly ash available for possible use in portland cement concrete and soil treatment. Work by others (4, 5, 6) has shown the potential in improving the strength of soil and aggregates through the mixing of Class C fly ash with them.

This evaluation was undertaken to determine if this particular class of fly ash would improve the performance of aggregate shoulders in Louisiana. If fly ash can produce a stiffening of the existing material through some degree of cementation or modification, it will have the potential to reduce shoulder maintenance and provide an improved surface for use by the motoring public.

The fly ashes used in this study were from four different power plants and are identified in this study as fly ash 1 through 4.

---

*Underlined numbers in parentheses refer to list of references.

OBJECTIVE/SCOPE

The objective of this study was to gain some experience with self-hardening fly ash (ASTM Class C) which was produced in Louisiana and neighboring states for the first time in the late seventies and early eighties. This was to be accomplished through limited field trials which encompassed the addition of various percentages of locally available fly ash to existing sand clay gravel and shell (oyster) aggregate surfaced shoulders. The test sections were to be constructed by district maintenance forces. The self-hardening characteristics of Class C fly ash, as well as the construction and performance of the aggregate shoulder, would be evaluated.

The scope of the study was expanded during the course of the evaluation. Additional test sections to include fly ash from other Louisiana sources and to include portland cement as an additive would be constructed in close proximity to sections of phase 1.

LOCATION OF TEST SITES

The sand clay gravel test sites, 1 and 3, are located in east central Louisiana, on route U.S. 84, and are on either side of the city of Jonesville in Catahoula Parish. Site 1 is just west of Jonesville and site 3 is 1.7 miles east of the city. Both sites are considered in rural areas.

The shell test sites, 2 and 4, are located in south central Louisiana, on route U.S. 90 near the city of New Iberia, approximately six miles east, in Iberia Parish. The two test sites adjoin each other and are located in a rural area. The area adjacent to the shoulder test sections is predominantly agricultural, the crop being sugar cane. During the course of the evaluation, oil field service companies built several facilities along the roadway of test site 4. A truck stop was also established at the midpoint of test site 4. The geographic location of each test site is shown in Figure 1.

The test sites for evaluation were selected based on availability of maintenance personnel to construct the test sections; roadways having uncovered, untreated aggregate shoulders six to ten feet in width with a minimum of six inches of depth of aggregate material; and moderate vehicular traffic. The Jonesville-U.S. 84 sand clay gravel sites met the criteria very nicely with ample shoulder width and depth of material. The ADT at sites 1 and 3 is listed in Table 1 (all tables are in appendix).

The New Iberia-U.S. 90 test sites had shoulders of ample width but less than six inches in depth of aggregate material. The ADT for sites 2 and 4, listed in Table 1, was higher than desired; however, the location was selected due to the possible benefits in the immediate area if the evaluation resulted in any positive results. There are many miles of similar existing shoulders along U.S. 90 in Iberia Parish.

LOCATION OF TEST SITES

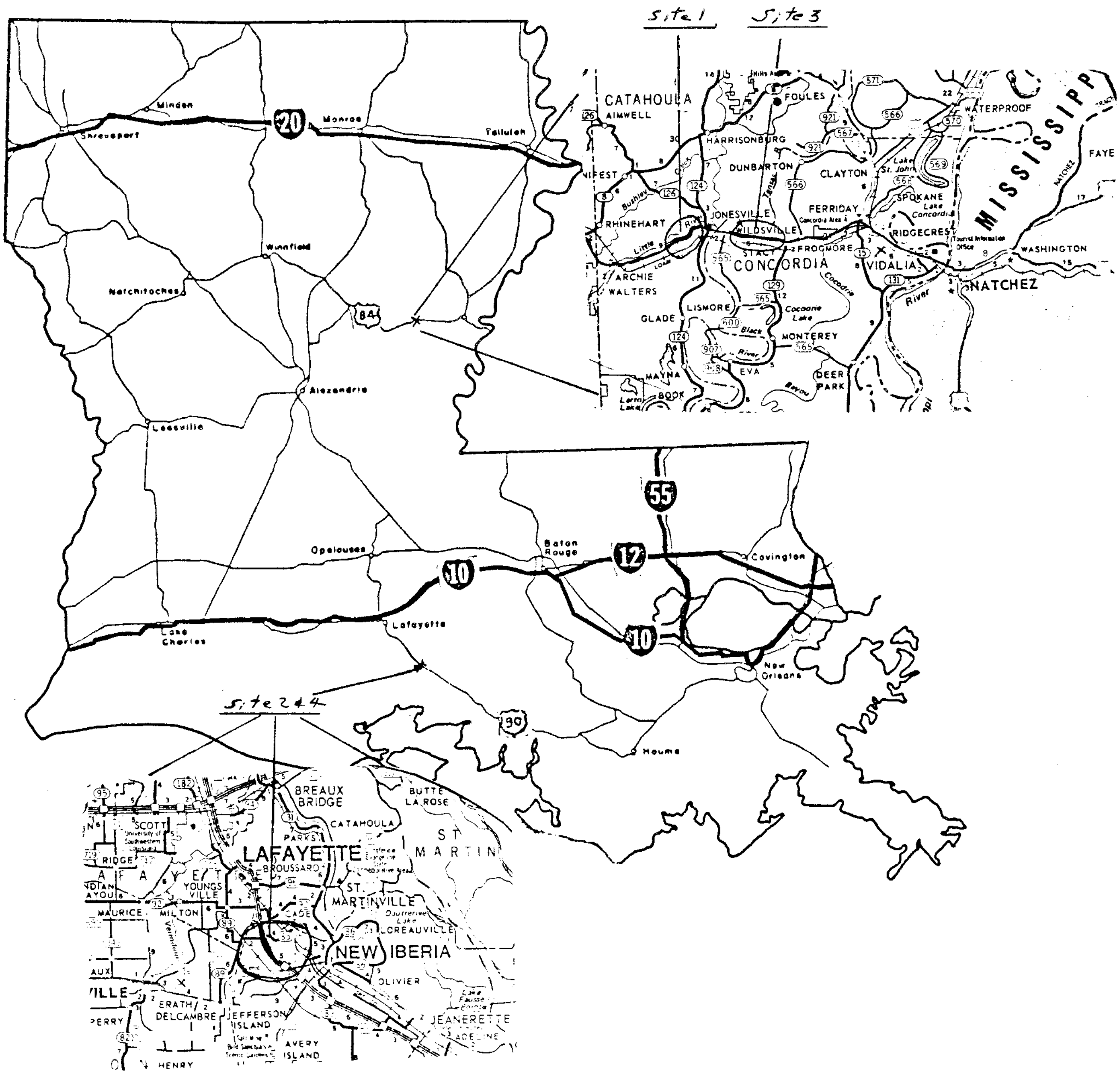


FIGURE 1

CONSTRUCTION OF TEST SECTIONS

General

The construction of test sections was accomplished in two phases. The sand clay gravel sections at site 1 and the shell (oyster) sections at site 2 were constructed in phase one. Sand clay gravel test sections at site 3 and shell test sections at site 4 were constructed in phase two, approximately two years later. The two phases differ primarily by inclusion of portland cement test sections and target compaction densities (95 percent of laboratory maximum dry weight density) and layer thicknesses (6 inches) at sites 3 and 4. The generalized plan view of test sections at each site is shown in Figures 2 and 3. Laboratory test results of fly ash and sand clay gravel gradation analysis are included in the appendix. All quantities of additives listed in this report are volumetric proportions.

The width of each test section was eight feet. The thicknesses of the treated shoulder aggregate after construction are shown in Tables 2 and 3 along with the in situ compacted dry unit weight and percent of laboratory maximum density.

The length of each test section was determined at the time of delivery and according to the quantity of additive (fly ash and/or portland cement) in the transport for each respective test section. The additives for all test sections were applied directly from the transport by means of a row of holes on the underside of a spreader bar attached to the rear of the transport. It was forced out pneumatically. Blowing the fine additives caused dusting problems at most sites. As expected, the severity of the problem depended on wind conditions.

This method of spreading additives (portland cement and hydrated lime) in base or embankment treatment was common in Louisiana at

GENERALIZED PLAN VIEW OF SAND CLAY GRAVEL TEST SECTIONS

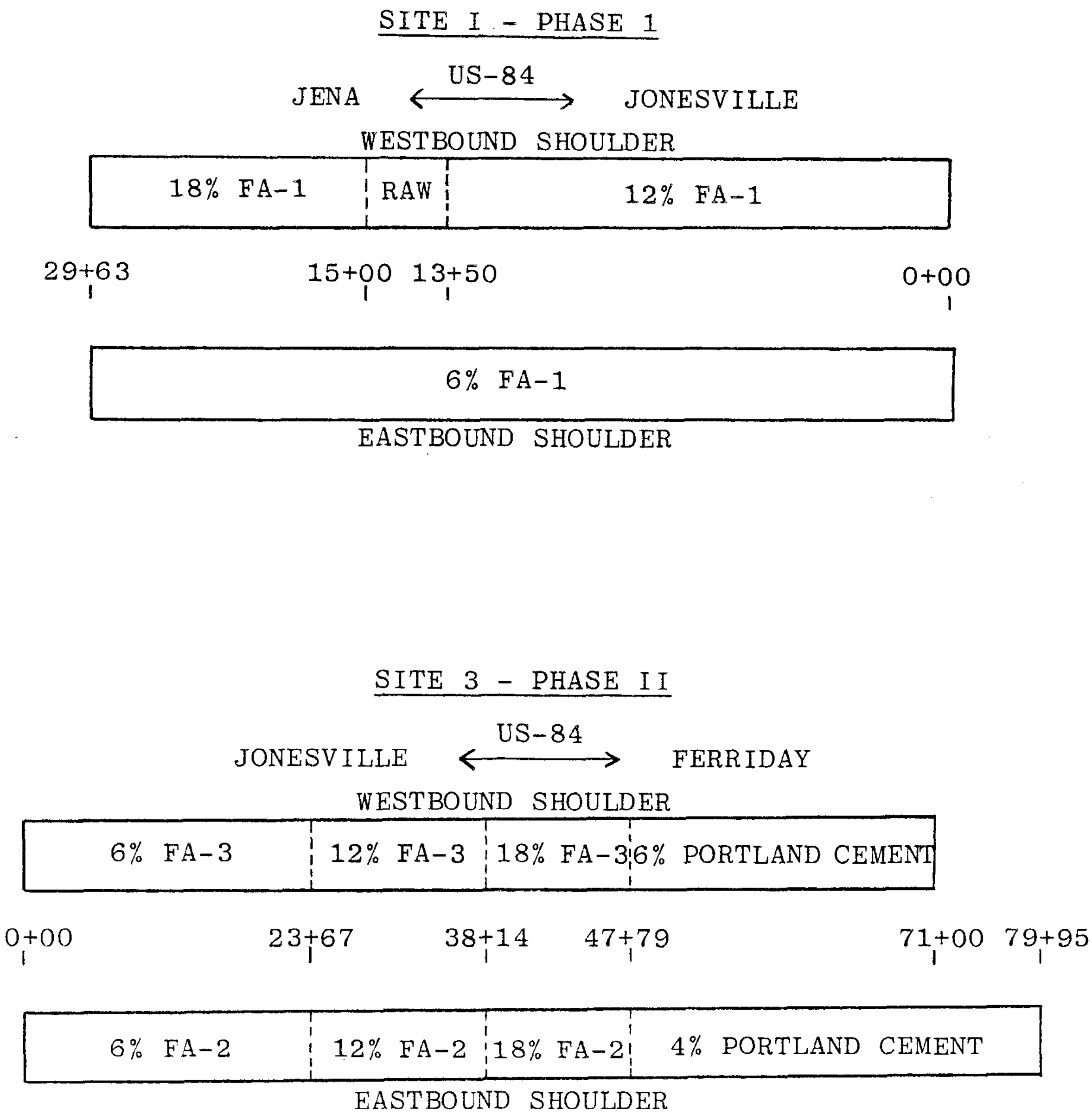
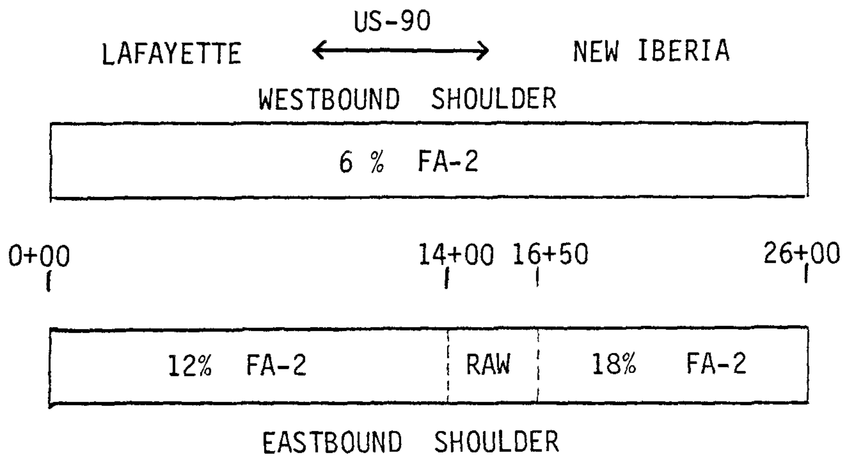


FIGURE 2

GENERALIZED PLAN VIEW OF SHELL
TEST SECTIONS

SITE 2 - PHASE I



SITE 4 - PHASE II

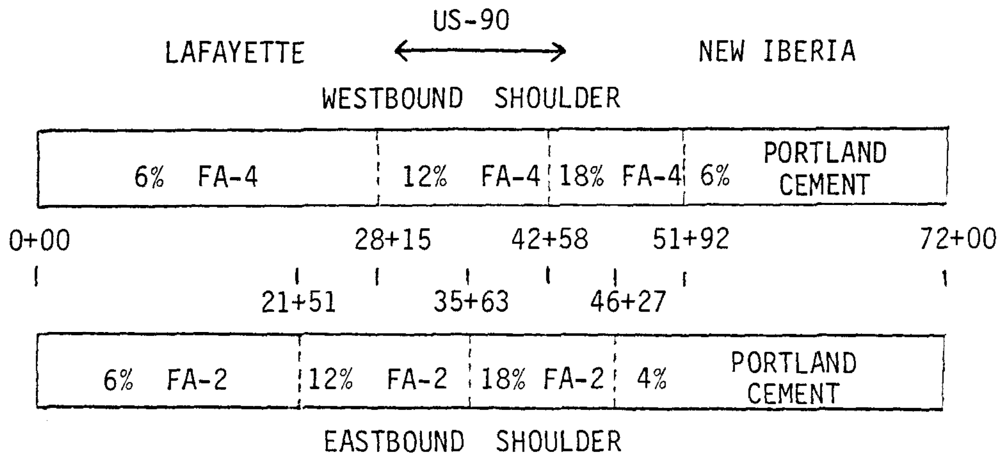


FIGURE 3

the time of test section construction. The method has generally produced a non-uniform distribution of fly ash and/or portland cement. It was impossible to work out all variables involved (truck speed, required manifold pressure, etc.) to get even and total section distribution in one spread, particularly since each test section required only one transport of additive.

One physical characteristic of fly ash, spherical shape, initially caused some laydown problems in the 12 percent and 18 percent test sections. The fly ash, when blown onto the shoulder surface, would flow towards the low side of the shoulder, towards the ditch in most cases. This problem was averted in most test sections by scarifying the in-place material prior to applying the fly ash.

All test sections were constructed by maintenance forces using their respective equipment and techniques for normal shoulder stabilization. The equipment was basically the same with a Bros single-pass and smaller Rex stabilizers used on all test sections. Compaction was accomplished by a sheepsfoot roller. Two separate single drum sheepsfoot units, pulled by rubber tired tractors, were used in construction of sand clay gravel test sections. A caterpillar was used to pull the sheepsfoot roller in compacting the shell. Small pneumatic rollers were used in the final stage of compaction in all test sections.

Generally, the existing shoulder materials were treated. Some sand clay gravel was added as needed to raise low spots to grade. The shell shoulders were originally built in 1966 under one construction project. Blading and addition of shell have been required periodically since that time as a result of loss and degradation caused through shoulder use by heavy agricultural equipment, particularly during the sugar cane harvest season. Shell was not available for general filling of low areas; therefore, the shell on the outside edge of the shoulder was bladed towards the pavement, sacrificing the thickness at the outside edge. This also resulted in the addition of organic sugar cane pulp (bagasse) material to the shell.

Sand Clay Gravel

The test sections at site 1 were constructed in November of 1980. The roadway segment used for this study consists of a two-lane soil-cement stabilized base surfaced with bituminous concrete mixture and shoulders eight to ten feet in width. The pavement, constructed on a high embankment, is well drained. Fly ash 1 was used in all test sections at this site. Construction of test sections at this site was accomplished with no major difficulties. A minor problem did develop in one segment of the 12 percent section which was heavily prewetted prior to the addition of fly ash in order to determine the possible problems in wet weather construction. Several areas within this segment became very soft and yielding under the action of the rubber tired roller. These areas were rerolled the following day, appeared to harden with time and caused no further difficulties. The remaining areas of the test sections were left without surfacing for a period of one year, after which a two-course, siliceous and lightweight (burnt clay) aggregate surface treatment was placed on all sections. The asphalt used was a cationic emulsion (CR-52 rapid set). There were two short segments surfaced immediately after construction--a 300-foot segment in the 12 percent section and an 800-foot segment in the 6 percent section. Test sections without surfacing abraded due to weather action and intermittent traffic even though the sand clay gravel appeared to be cemented.

The test sections at site 3 were constructed in the latter part of November 1982 in the manner and by the same maintenance group as those at site 1. The existing roadway consisted of an old concrete pavement covered with bituminous concrete mixture. The elevation of the pavement is near that of the natural ground outside of the right-of-way. The drainage is not as good as that of site 1 with shallow ditches sometimes retaining water for long periods. There is no evidence of pavement pumping. The surface water entering the pavement joints and cracks appears to drain to the ditches through the sand clay gravel shoulder material. In checking the depth of treated material many zones of saturated materials, three to four inches thick, were found under the stabilized layers. Fly ash 2 was used in test sections of the eastbound shoulder and fly ash 3 was used in test sections of the westbound shoulder. There were no major difficulties during the construction of the test sections at this site. All treated materials appeared to harden prior to being surfaced, approximately one month after shoulder construction, with bituminous surface treatment, similar to that used at site 1.

Shell

The test sections at site 2 were built in the early part of February of 1981. The existing roadway was constructed on a low embankment with the elevation of the pavement surface being approximately two to three feet above that of natural ground. The roadway is a four-lane concrete pavement separated by a ditch median. The shoulders are eight to ten feet in width. The thickness of the shell varies across the width of the shoulder according to the slope, being the thickest at the pavement edge. The varying thickness of the shell caused a problem in maintaining a constant depth of cut across the full width of the shoulder when mixing the fly ash with the shell. In many locations some of the underlying embankment clay material, particularly from the center of the shoulder to the outside edge, was cut into and mixed with the shell. This problem was further complicated in areas where the shell had been bladed from the outside edge and towards the concrete pavement. Generally, in all shell sections there was less thickness of material than desired. Fly ash 2 was used in all test sections at this site. The treated shoulders were left unsurfaced for one year, at which time 1.5 inches of bituminous concrete mixture was put on by maintenance forces.

Shell test sections at site 4 were constructed in early December of 1982. The same equipment and maintenance group, with some key personnel changes, used to construct site 2 also was used to construct the test sections within this site. Site 4 adjoins site 2; therefore, the roadway described above is continuous through site 4. Basically the same problems of thin areas of shell also occurred in these sections. There were moisture control problems in some sections as a result of improperly functioning equipment. Rainy weather during this time period complicated matters even more. Due to the sheepsfoot roller's track being within the caterpillar's tracks, only partial compaction was achieved next to the concrete pavement. Only the caterpillar's tracks and rubber tired roller applied a compaction effort to the shell next to the concrete pavement edge. This area consolidated under traffic and increased the "constructed" pavement drop-off. After construction of the shoulders it was planned to place a 1.5-inch layer of bituminous concrete mixture as shoulder cover; however, due to budgetary constraints only a thin bituminous surface treatment, similar to that used at sites 1 and 3, was placed, resulting in a built-in pavement drop-off.

FIELD MEASUREMENTS AND VISUAL CONDITION SURVEYS

Visual condition surveys were conducted periodically from construction through March 1985. Pictures taken in March, 1985, are included in this report. They show the physical condition of test sections at all sites at approximately four (sites 1 and 2) and two (sites 3 and 4) years after construction.

In-place density and depth measurements of treated materials were obtained after construction of each test section. Results are shown in Tables 2 and 3.

Deflection measurements were obtained in all test sections prior to construction and, periodically, during a one-year period after with the Dynaflect (7). In some test sections these measurements were obtained over a three-year period. Deflection measurements obtained were translated to the AASHTO design strength parameter SN (structural number). The measurements were intended to reflect any change in aggregate shoulder stiffness when compared to the respective untreated material values. Mean values were calculated for all test sections and are shown in Figures 43 through 46.

Visual Condition Surveys

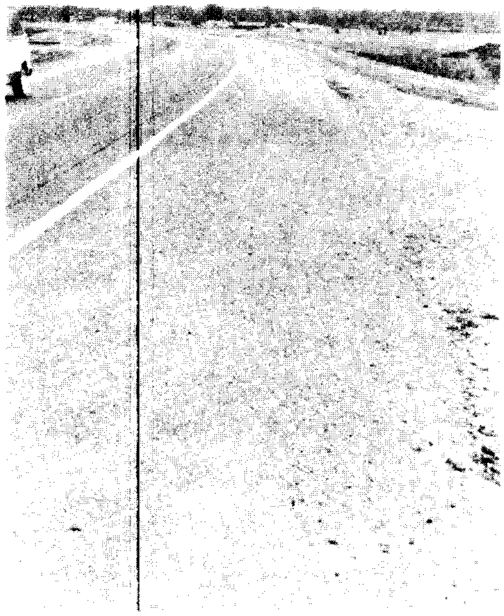
Sand Clay Gravel Test Sections - The physical condition of all the test sections at site 1 after more than four years of performance is very good. The typical physical condition of each test section is shown in Figures 4 through 6. The only unusual feature in any test section is one shrinkage crack, shown in Figure 6A, that appeared in the 18 percent section between one and two years after construction. There are no visual differences between any two sections, regardless of percent fly ash added.

Figures 7 through 17 show the physical condition of test sections at site 3 after more than two years of performance. These show test sections of fly ash 2 (eastbound shoulder) and 3 (westbound shoulder) and portland cement (4 and 6 percent). Figures 7 through 9 show the typical, good condition of 6, 12 and 18 percent fly ash 2 test sections. Potholes have recently developed at the pavement-shoulder joint in one area of the 18 percent fly ash 2 test section as shown in Figure 10. As in the portland cement test sections at this site, the breaks in the shoulder appear to develop in conjunction with the joints or cracks of the concrete pavement. Overall, the physical condition of the shoulders is very good and, here as in site 1, the condition of all the test sections of fly ash 2 appears to be equally good.

Figures 11 through 13 show the typical physical condition of fly ash 3 test sections on the westbound shoulders. Figure 14 shows the junction of the 6 percent portland cement and 18 percent fly ash 3 test section. There is no discernible difference in the physical condition of one over the other; the dark spots in the figure were caused by oil. Again, the overall physical condition of all fly ash 3 test sections is very good and, visually, equally good.

Figure 15 is of the 4 percent portland cement test section and shows the generally good condition of the portland cement sections. As discussed above, Figures 16 and 17 show the pothole development in the two portland cement test sections. The physical condition of either portland cement test section, visually, appears to be equal to any and all fly ash test sections at site 3.

PHYSICAL CONDITION OF TEST SECTIONS AT SITE 1

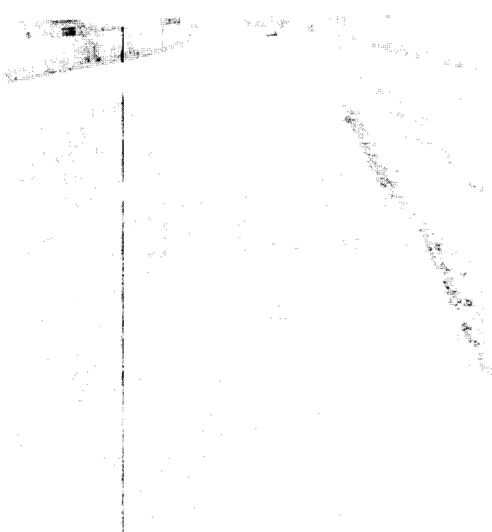


6% Fly Ash 1

FIGURE 4

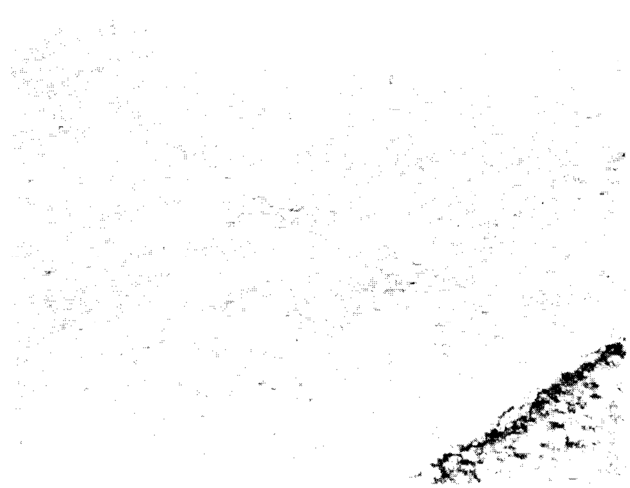
12% Fly Ash 1

FIGURE 5



18% Fly Ash 1

FIGURE 6



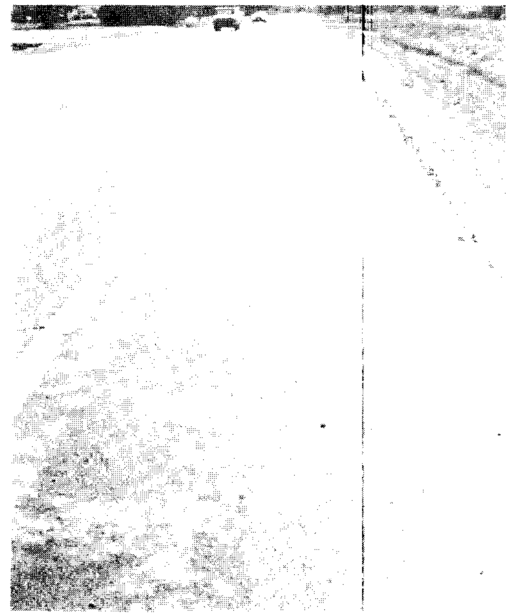
18% Fly Ash 1

FIGURE 6A

PHYSICAL CONDITION OF TEST SECTIONS AT SITE 3

6% Fly Ash 2 - Eastbound

FIGURE 7

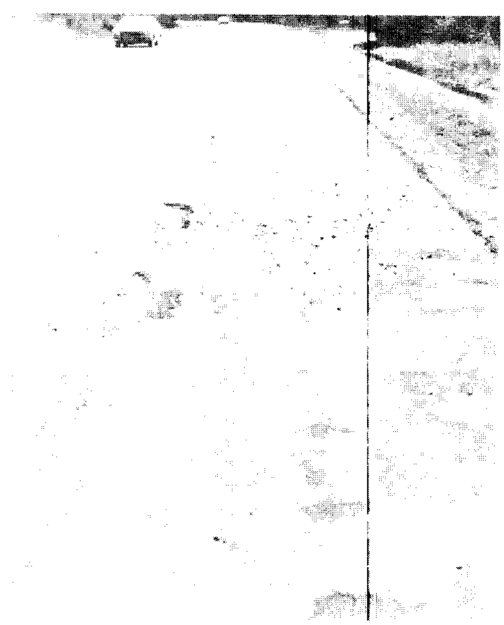


12% Fly Ash 2 - Eastbound

FIGURE 8

18% Fly Ash 2 - Eastbound

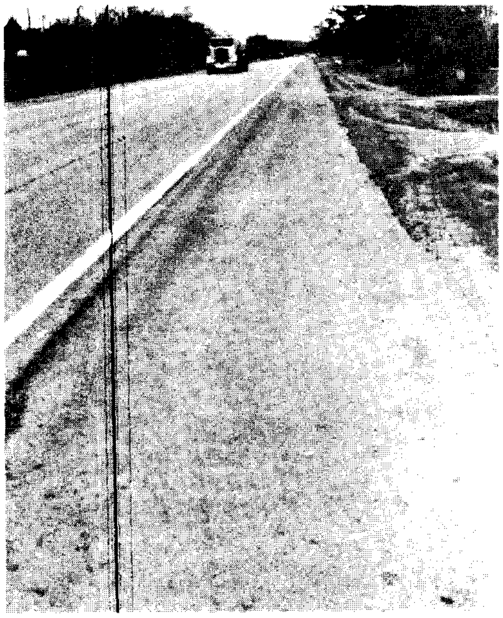
FIGURE 9



18% Fly Ash 2 - Eastbound

FIGURE 10

PHYSICAL CONDITION OF TEST SECTIONS AT SITE 3

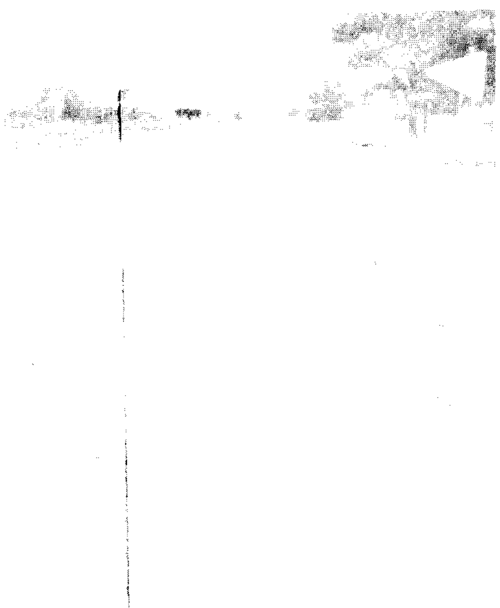


6% Fly Ash 3 - Westbound

FIGURE 11

12% Fly Ash 3 - Westbound

FIGURE 12



18% Fly Ash 3 - Westbound

FIGURE 13

18% Fly Ash 3/6% Portland Cement

FIGURE 14

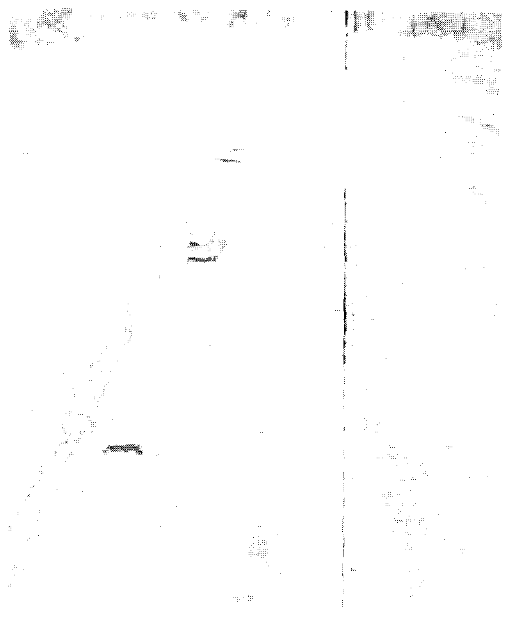
PHYSICAL CONDITION OF TEST SECTIONS AT SITE 3

4% Portland Cement - Eastbound

FIGURE 15

6% Portland Cement - Westbound

FIGURE 16



4% Portland Cement - Eastbound

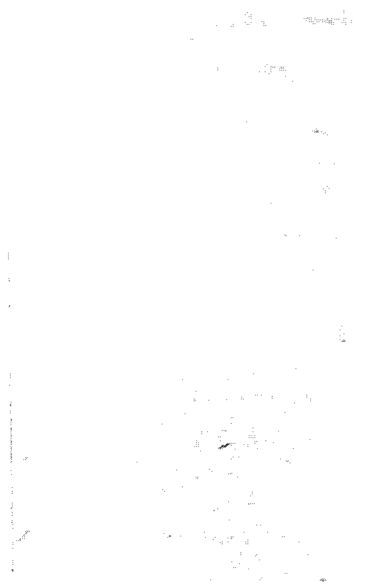
FIGURE 17

Visual Condition Surveys

Shell Test Sections - The physical condition of the test sections at site 2 after more than four years of performance is generally good. Fly ash 2 was used in all test sections at this site. The 18 percent test section is in very good condition as shown in Figures 18 and 19. The 12 percent section is in good condition with some deterioration along the pavement-shoulder edge as seen in Figures 20 and 21. The 6 percent fly ash section is for the most part in fair condition as shown in Figures 22 and 23. Figures 24 and 25 show the shoulder edge breakup that is beginning to occur in two areas of the 6 percent test section. Overall, considering the traffic volume and less-than-desired material thickness and as-built densities, the shoulders at this site are considered in good shape.

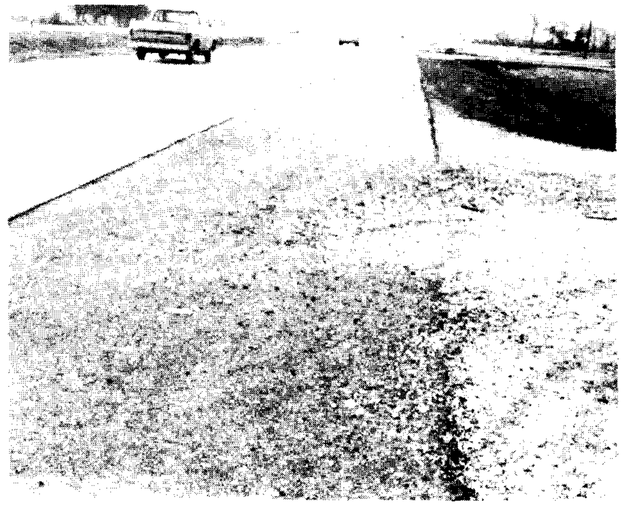
The physical condition of the test sections at site 4 is shown in Figures 26 through 42. Fly ash 2 was used in test sections on the eastbound shoulder and fly ash 4 in the test sections on the westbound shoulder. The overall physical condition of the shoulder test sections is fair. With the possible exception of the 18 percent fly ash 2 and 4 test sections, all sections show some loosening of material, pothole development and shoulder edge breakup. The pavement drop-off discussed elsewhere in this report has increased in some test sections, probably due to traffic densification, and is easily seen in many figures covering this site. Figures 26 through 29 show the physical condition of the 18 percent fly ash test sections. The 18 percent fly ash 4 test section has a truck stop located within the section limits. As a result, trucks egressing onto its parking area and back onto the roadway caused early problems. Within the first year after construction it became apparent that bituminous concrete mixture overlay was needed to prevent total deterioration of the shoulder. Since the addition of the overlay, the shoulder, as shown in Figure 29, has maintained good performance. The portion of the 4 percent portland cement test section across from the truck stop has failed; even the patches are breaking out as shown in Figure 30. The remaining portion of the 4 percent test section is in fair shape with some shoulder edge breakup. The fair condition of the 6 percent portland cement test section is surprising. This section was expected to outperform all other test sections at sites 2 and 4; however, it contains areas of pothole development and edge breakout as shown in Figures 32 and 33. Some portions of the 6 percent test section, as shown in Figure 34, are in fairly good condition.

PHYSICAL CONDITION OF TEST SECTIONS AT SITE 2



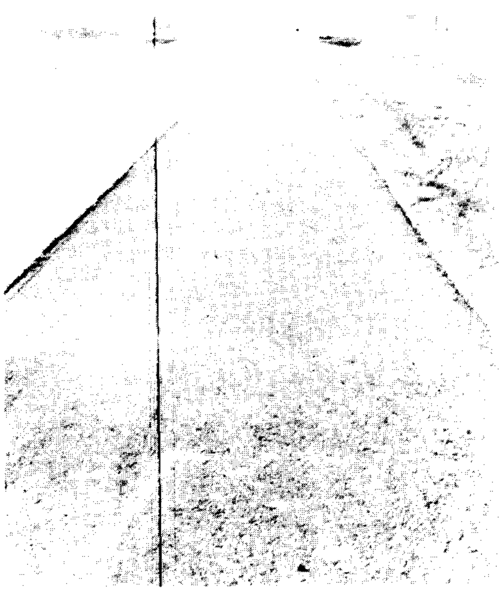
18% Fly Ash 2

FIGURE 18



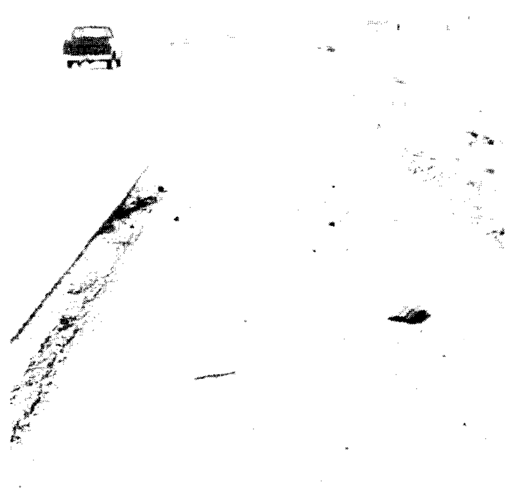
[illegible]% Fly Ash [illegible]

[illegible]URE 19



12% Fly Ash 2

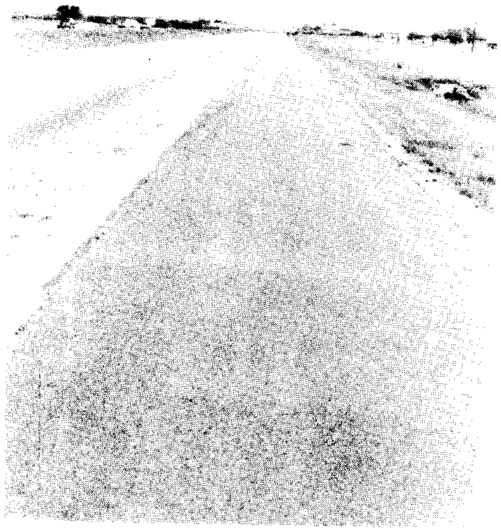
FIGURE 20



[illegible] Fly Ash [illegible]

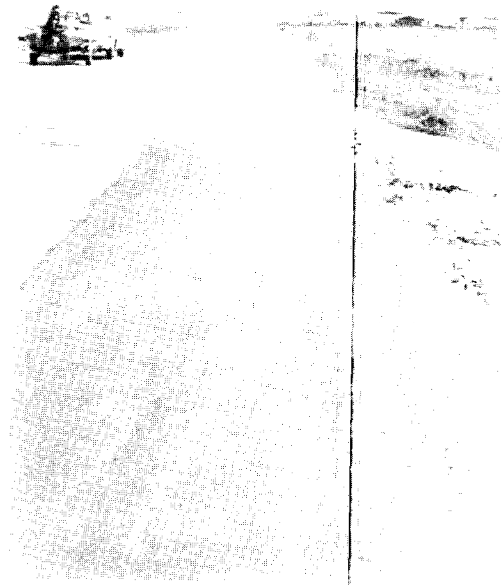
[illegible]

PHYSICAL CONDITION OF FLY ASH TEST SECTION AT SITE 2



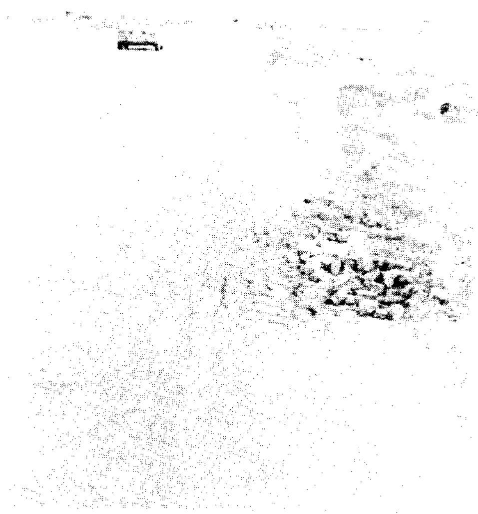
6% Fly Ash 2

FIGURE 22



6% Fly Ash 2

FIGURE 23



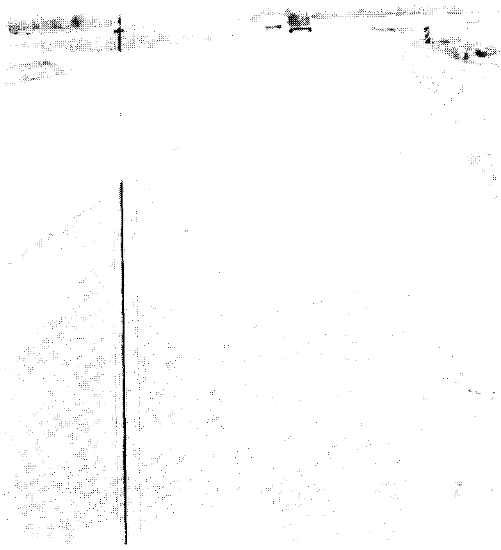
6% Fly Ash 2

FIGURE 24

6% Fly Ash 2

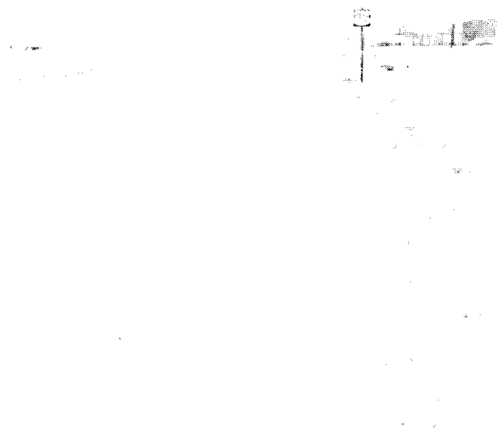
FIGURE 25

PHYSICAL CONDITION OF TEST SECTIONS AT SITE 4



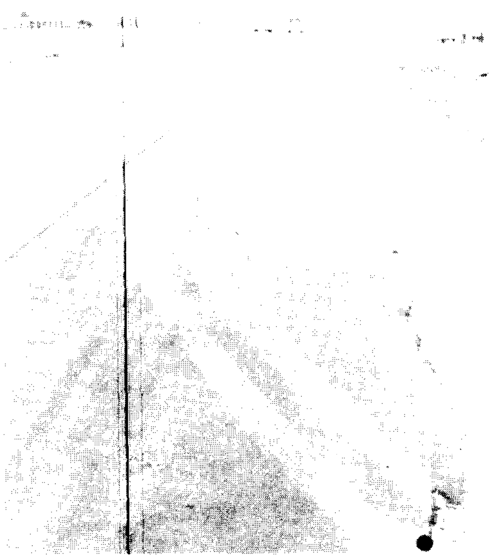
18% Fly Ash 2 - Eastbound

FIGURE 26



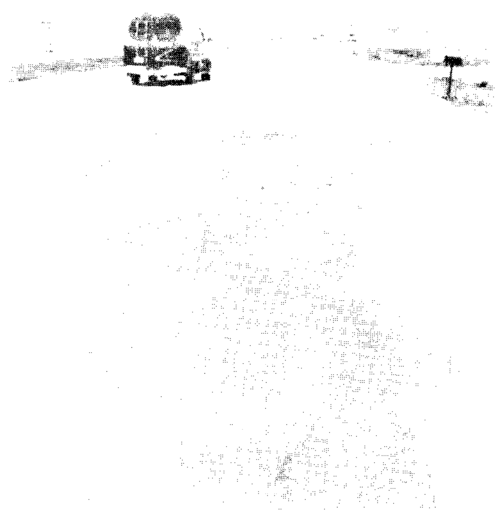
18% Fly Ash 2 - Eastbound

FIGURE 27



18% Fly Ash 4 - Westbound

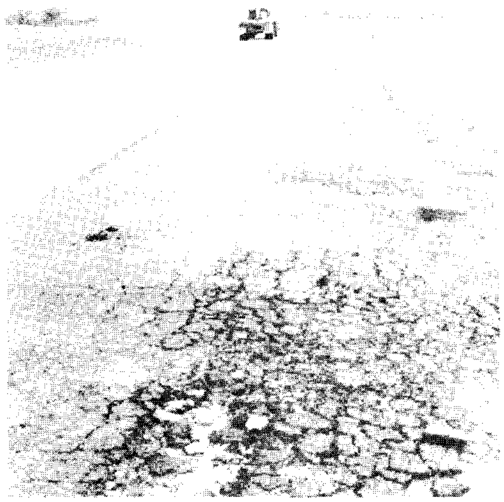
FIGURE 28



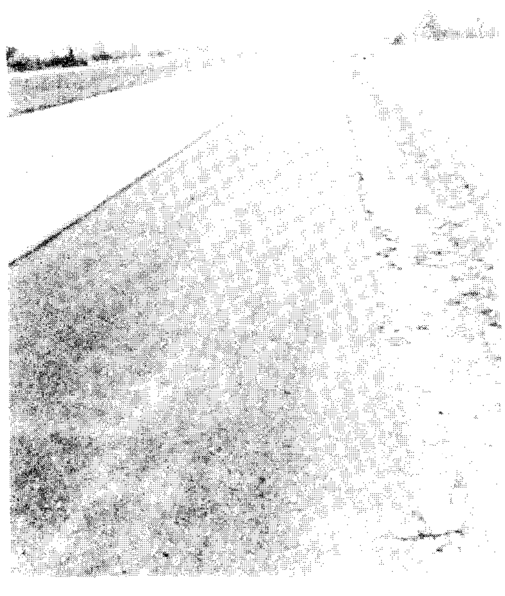
18% Fly Ash 4 - Westbound

FIGURE 29

PHYSICAL CONDITION OF
PORTLAND CEMENT TEST SECTION AT SITE 4

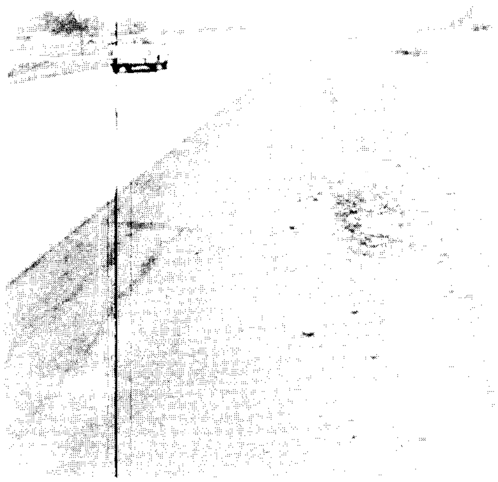


4% Portland Cement - Eastbound
FIGURE 30



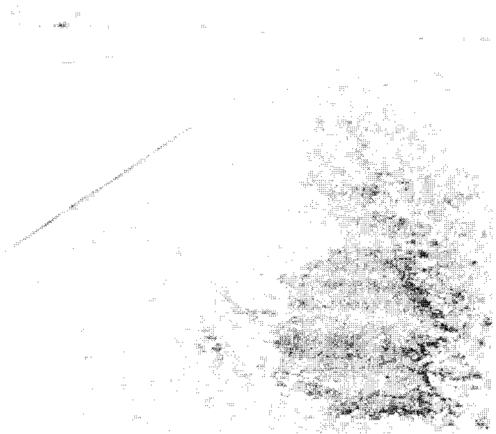
4% Portland Cement - Eastbound
FIGURE 31

PHYSICAL CONDITION OF
PORTLAND CEMENT TEST SECTION AT SITE 4



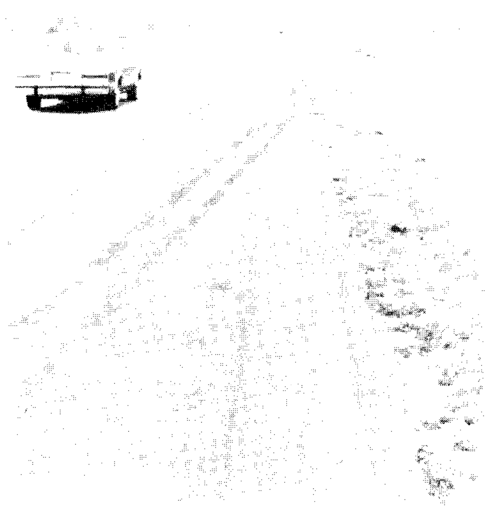
6% Portland Cement - Westbound

FIGURE 32



6% Portland Cement - Westbound

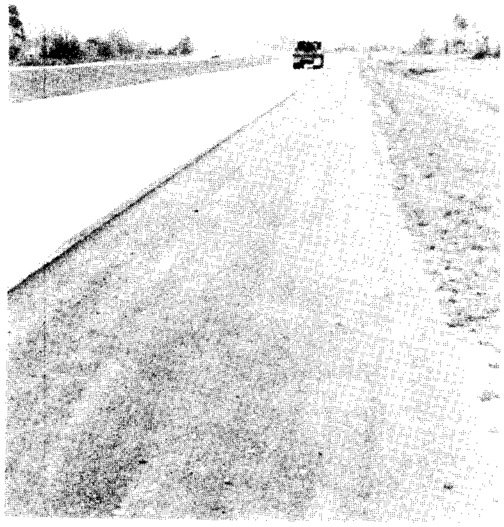
FIGURE 33



6% Portland Cement - Westbound

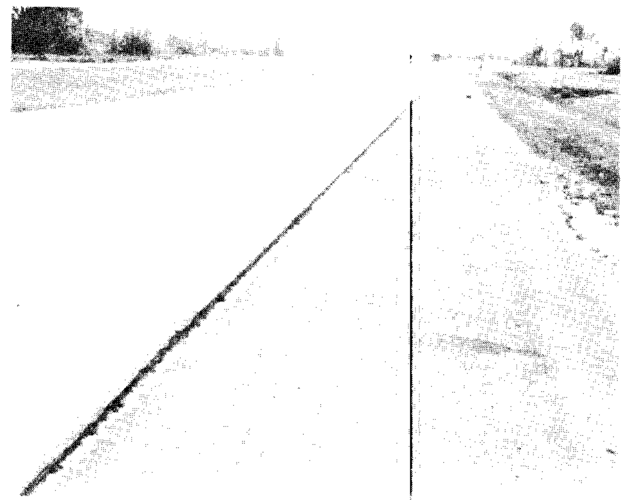
FIGURE 34

PHYSICAL CONDITION OF FLY ASH TEST SECTIONS AT SITE 4



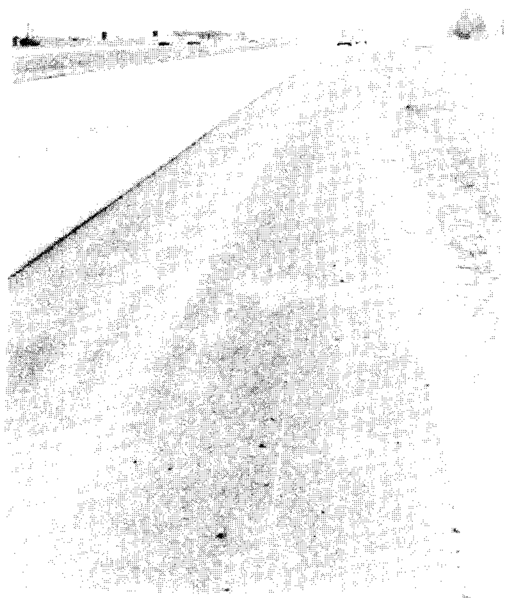
6% Fly Ash 2 - Eastbound

FIGURE 35



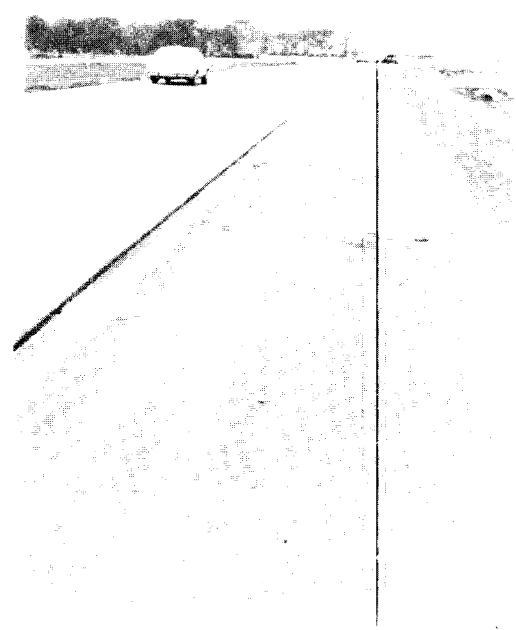
6% Fly Ash [illegible] - [illegible]

FIGURE [illegible]



6% Fly Ash 4 - Westbound

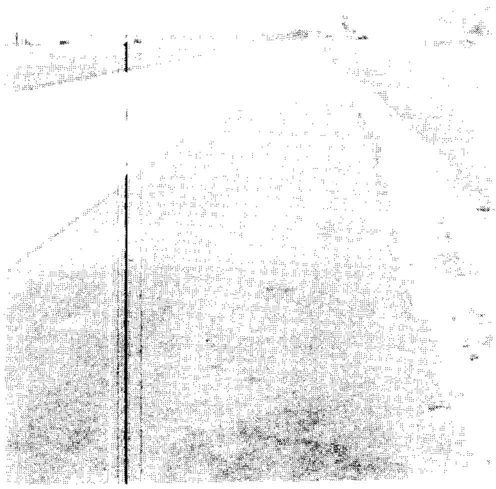
FIGURE 37



6% Fly Ash 4 - [illegible]

FIGURE [illegible]

PHYSICAL CONDITION OF FLY ASH TEST SECTIONS AT SITE 4

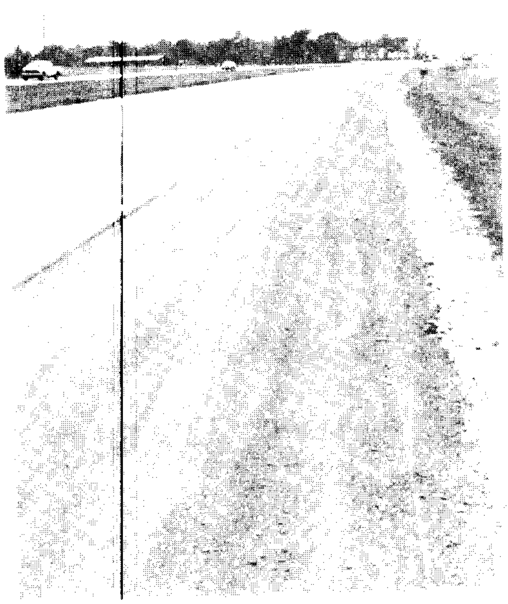


12% Fly Ash 2 - Eastbound

FIGURE 39

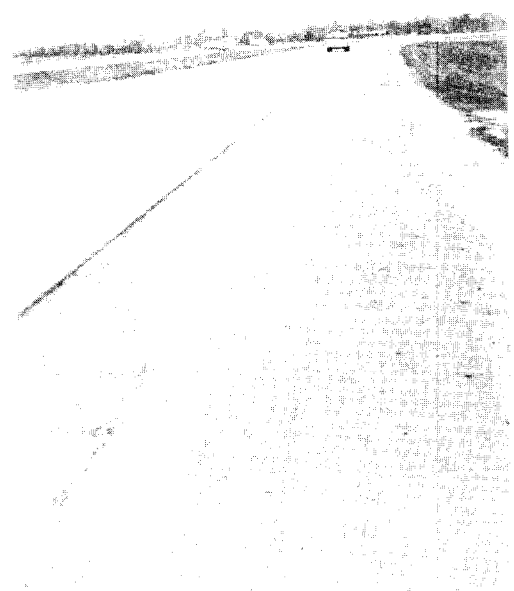
[illegible] - [illegible]tbound

[illegible] 40



12% Fly Ash 4 - Westbound

FIGURE 41



[illegible]

[illegible]

Deflection Measurements

Sand Clay Gravel Test Sections - Deflection measurements were taken periodically at site 1 from November 1980 to November 1983. Mean SN values for test sections at each test date are shown in Figure 43. All measurements taken prior to December 1981 were on unsurfaced shoulders. After this date, the shoulders were covered with bituminous surface treatment as described earlier. The SN values increased during the first year after construction, reaching a high point at 7.4 months of age. The values showed a decrease, especially the 6 and 12 percent fly ash sections, between the measurements of September and December of 1981. The only visual change in the condition of the test sections between these two test periods was the addition of the surfacing.

The deflection measurements at site 3 were taken between September 1982 and November 1983, inclusive. The mean SN values of each test section obtained at each test interval are shown in Figure 44. Other than the portland cement treated sections, there was no significant increase in SN values as found at site 1. (There was a slight trend of an increase in SN for the 18 percent fly ash test section of the westbound shoulder.) The deflection measurements do not seem to reflect the performance and present physical condition of all test sections at this site. The portland cement test sections, as shown in the condition survey discussion, do not appear to have performed better than the other test sections at this site. There was a saturated layer, 3 to 4 inches thick, found underlying the treated layer scattered in some test sections when checking the depth of treatment. This was particularly common in the 18 percent fly ash section of the eastbound shoulder (fly ash). This layer was not found in either of the portland cement test sections. This layer, where it occurs, may be less dense than that of the overlying treated material, thereby decreasing overall measured stiffness.

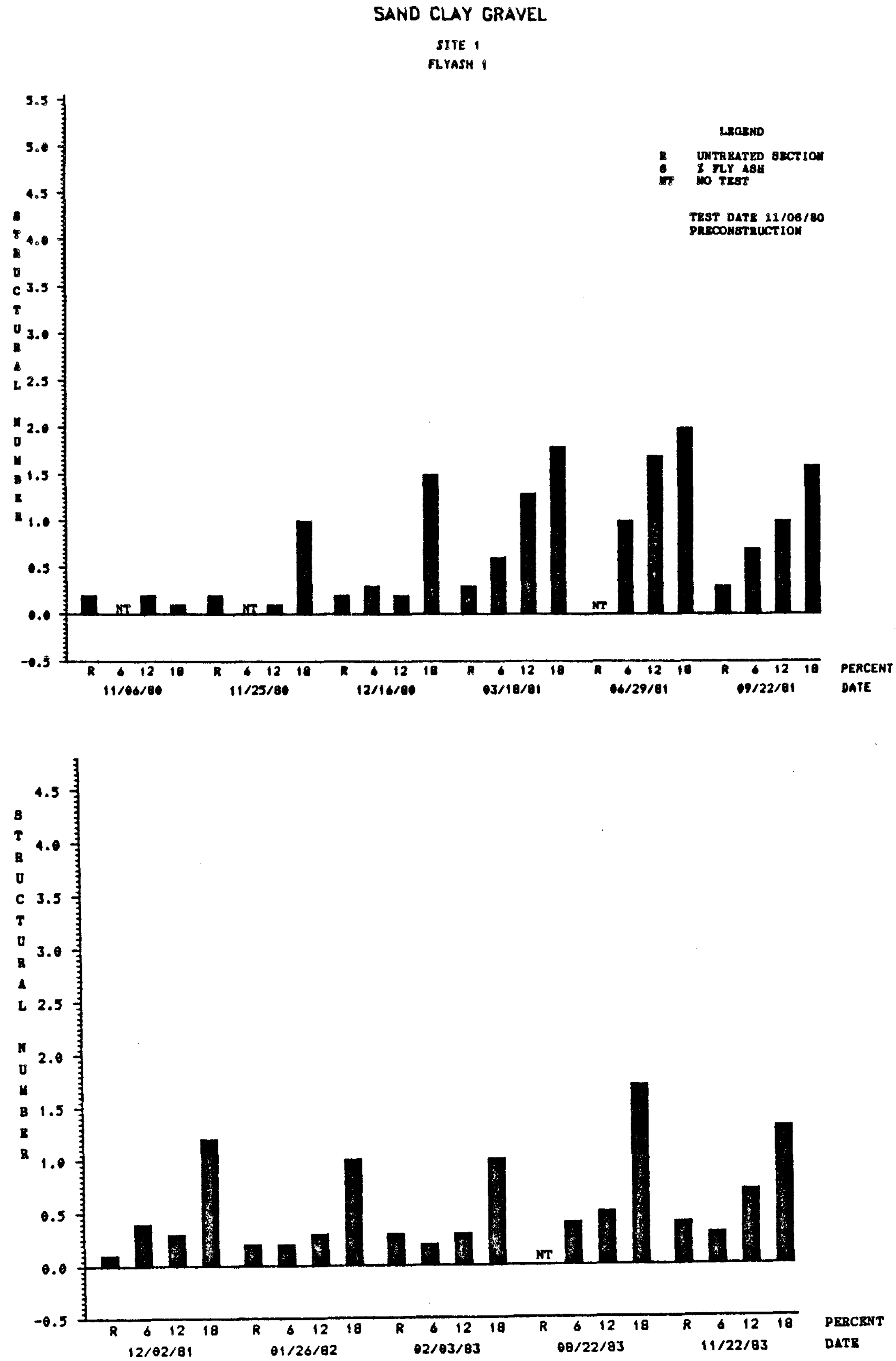
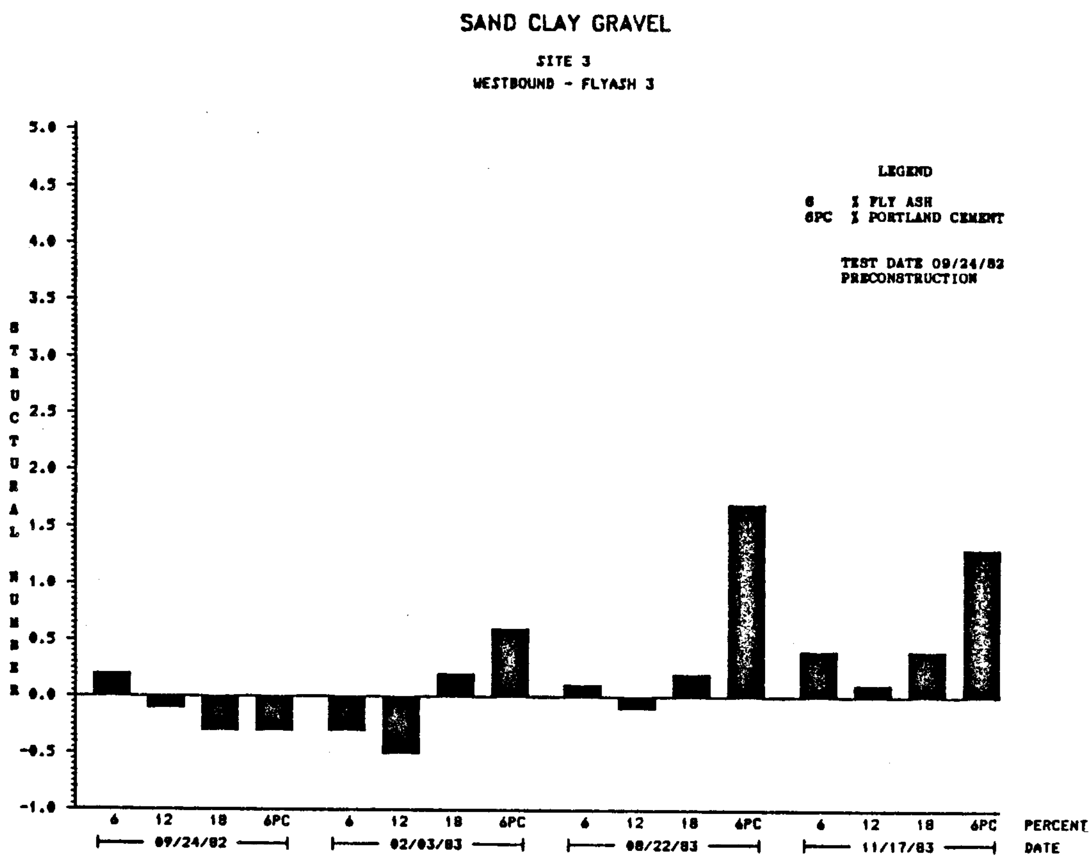

SAND CLAY GRAVEL
SITE 1
FLYASH 1
LEGEND
R UNTREATED SECTION
6 % FLY ASH
NT NO TEST
TEST DATE 11/06/80
PRECONSTRUCTION
STRUCTURAL NUMBER
NT
PERCENT
DATE
11/06/80
11/25/80
12/16/80
03/18/81
06/29/81
09/22/81
12/02/81
01/26/82
02/03/83
08/22/83
11/22/83

FIGURE 43


SAND CLAY GRAVEL
SITE 3
WESTBOUND - FLYASH 3
LEGEND
6 % FLY ASH
6PC % PORTLAND CEMENT
TEST DATE 09/24/82
PRECONSTRUCTION
STRUCTURAL NUMBER
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
6 12 18 6PC 6 12 18 6PC 6 12 18 6PC 6 12 18 6PC
PERCENT
09/24/82 02/03/83 08/22/83 11/17/83
DATE

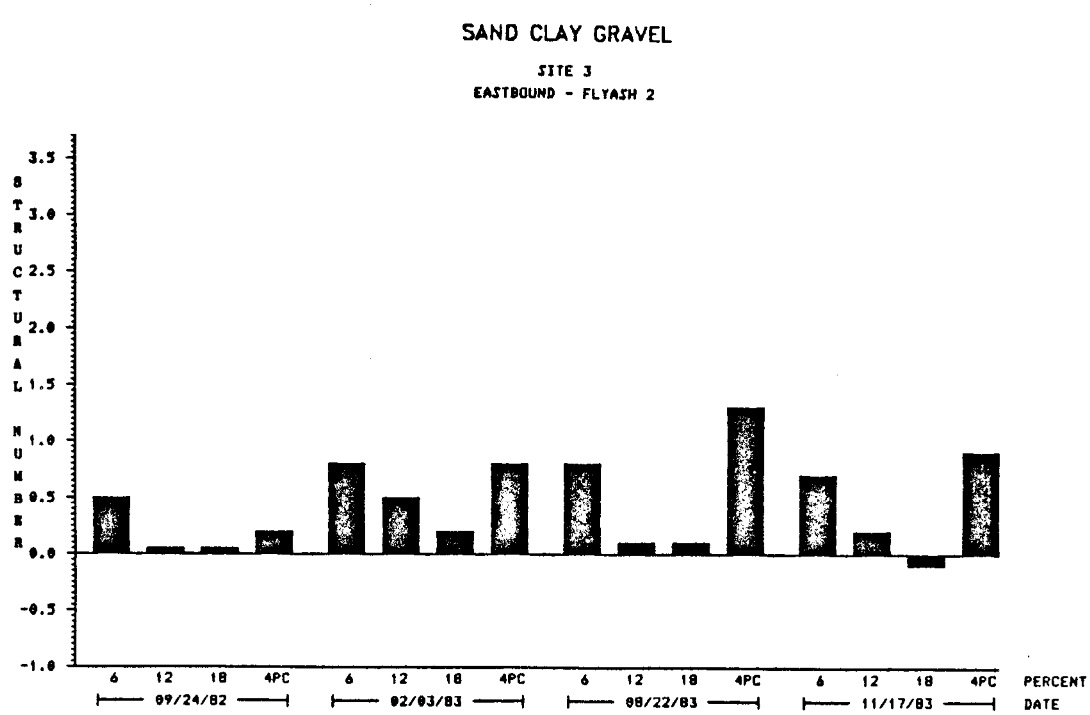
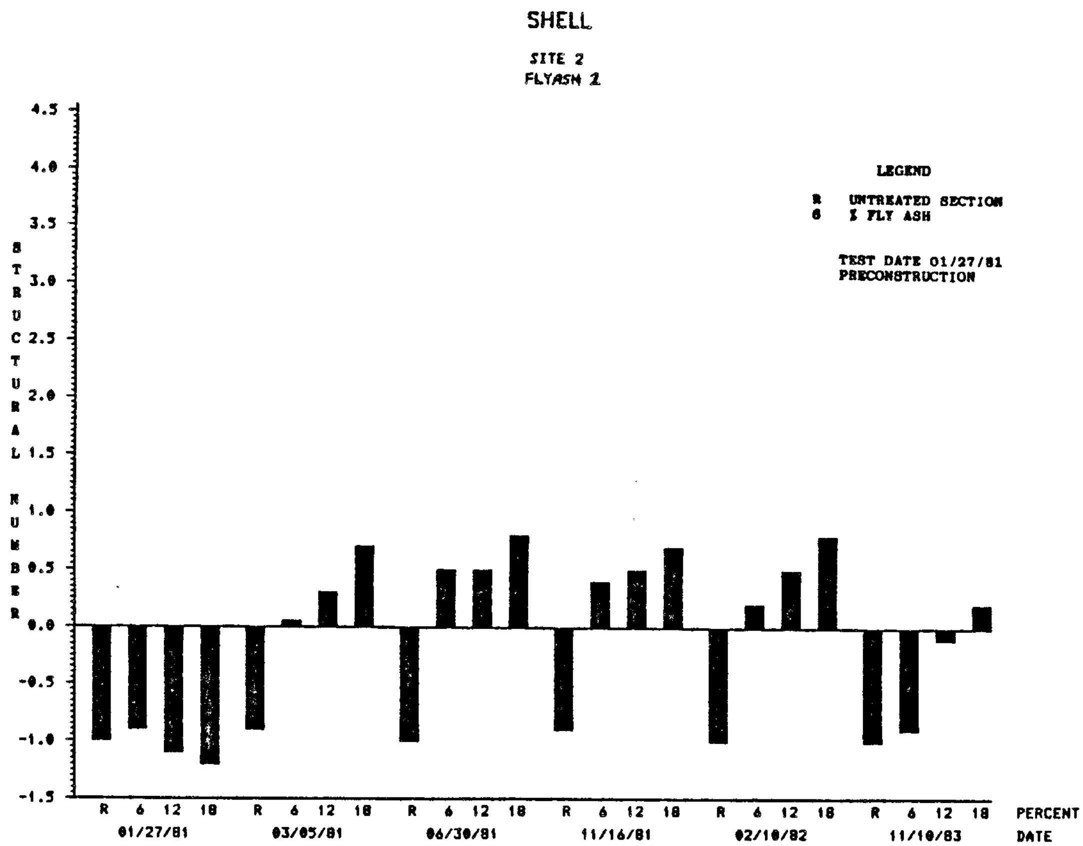

SAND CLAY GRAVEL
SITE 3
EASTBOUND - FLYASH 2
STRUCTURAL NUMBER
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
6 12 18 4PC 6 12 18 4PC 6 12 18 4PC 6 12 18 4PC
PERCENT
09/24/82 02/03/83 08/22/83 11/17/83
DATE

FIGURE 44

Deflection Measurements

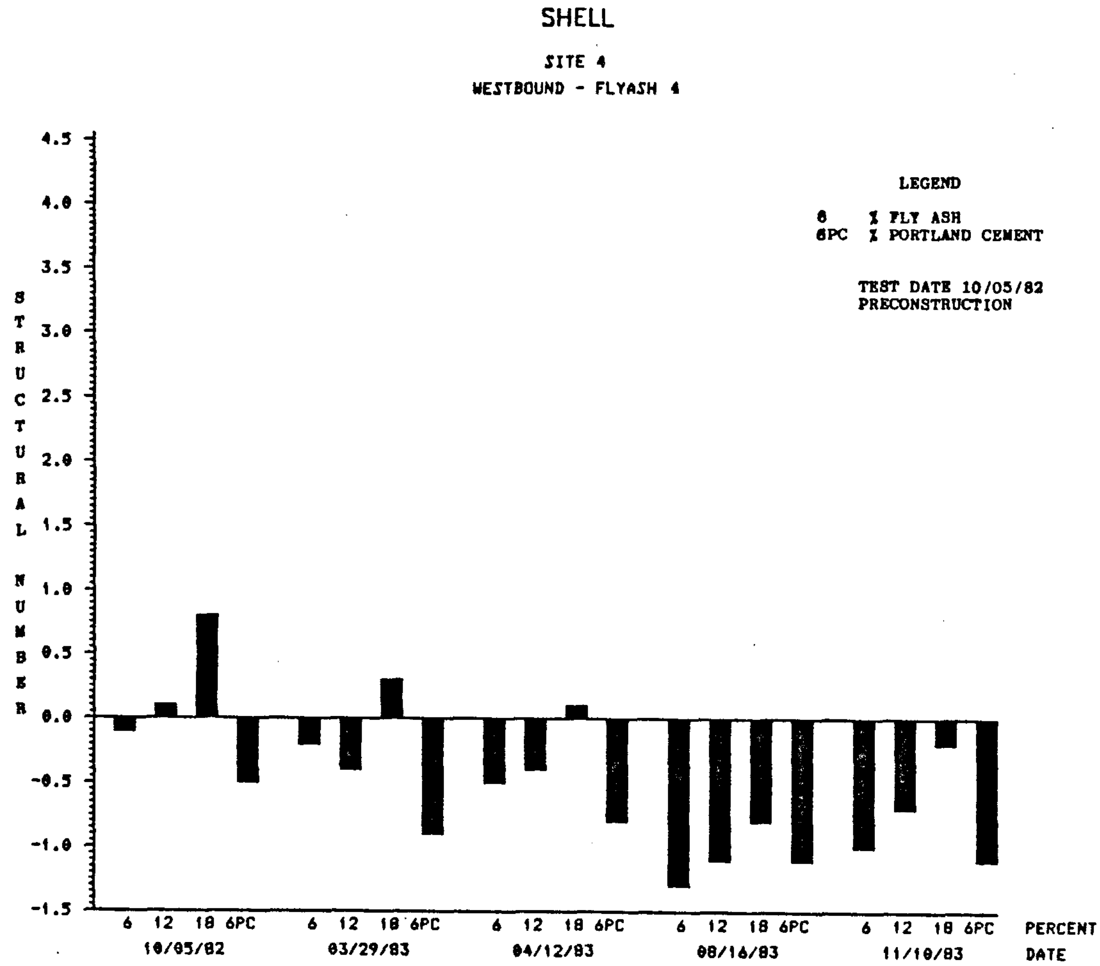
Shell Test Sections - Field deflection measurements were obtained at site 2 at various time intervals between January 1981 and November 1983. The mean SN values are shown in Figure 45. The testing was conducted on unsurfaced shoulders at all but the last test date. The results show an increase in SNs in all test sections during the first year after construction. The change, for that time period, in SN units from the preconstruction values range from a + 1.1 in the 6 percent fly ash test section to + 2.0 in the 18 percent fly ash section. The test results at the last test date, 2.75 years after construction, showed a loss of stiffness in the 6 percent section down to the preconstruction level. The SN values for the 12 and 18 percent sections decreased to 1.0. These results reflect the generally good physical condition of the 12 and 18 percent fly ash sections and the deteriorating condition of the 6 percent fly ash test section. Surfacing caused deflection increase in all sections due to its very soft nature.

The mean SN values for all sections at site 4, fly ash and portland cement, show a decrease from the preconstruction values with time. The decrease is apparent at the first test interval and remains relatively constant at all other test dates as shown in Figure 46. The difference in SN values between test sections of sites 2 and 4 is significant. The major differences between the two test sites are the surfacing at site 2 and more shoulder use by agricultural vehicles and trucks at site 4. As mentioned earlier, the 6 percent portland cement test section was expected to outperform any and all other test sections at site 4 as well as site 2. Crushed shell treated with portland cement has been used as a base course material in many other locations of south Louisiana with relatively good performance. The shell, from site 4, was subjected to laboratory unconfined strength tests with 4 percent and 6 percent portland cement, by volume, prior to construction of the test sections. The results after seven-day moist cure were 614 and 920 psi (Table 6), respectively. This shows normal compatibility of materials (shell and portland cement) as expected. These tests were run as a check on possible sugar cane juice (sucrose) contamination. There is a history in this region of this contamination problem resulting in weak cementation of particles by the portland cement. The as-built construction data of the 6 percent portland cement section is similar to or better than that of the test sections of test site 2. Holes were dug in selected areas of the 6 percent portland cement test section in an attempt to find a cause for the low deflection values. Investigation of the failing areas showed loose shell with very little cementation for the full depth. The good area, based on visual appearance, showed a weakly cemented layer of approximately one inch in thickness between the soft surface treatment and a dense, well-cemented underlying layer. The construction notes do not indicate anything that would affect cementation. Since the condition of all test sections is virtually the same, it is surmised that the problem is common to all. Heavy use of the shoulders by the local sugar cane haulers combined with sporadic truck usage during the green or early curing period of the treated sections could weaken or break up entirely the cement bounded particles. The actual cause of low cementation was not determined in this study.



SHELL
SITE 2
FLYASH 2
STRUCTURAL NUMBER
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
LEGEND
R UNTREATED SECTION
6 % FLY ASH
TEST DATE 01/27/81
PRECONSTRUCTION
R 6 12 18 R 6 12 18 R 6 12 18 R 6 12 18 R 6 12 18 R 6 12 18 PERCENT
01/27/81 03/05/81 06/30/81 11/16/81 02/10/82 11/10/83 DATE

FIGURE 45


SHELL
SITE 4
WESTBOUND - FLYASH 4
LEGEND
6 % FLY ASH
6PC % PORTLAND CEMENT
TEST DATE 10/05/82
PRECONSTRUCTION
STRUCTURAL NUMBER
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
6 12 18 6PC 6 12 18 6PC 6 12 18 6PC 6 12 18 6PC 6 12 18 6PC PERCENT
10/05/82 03/29/83 04/12/83 08/16/83 11/10/83 DATE

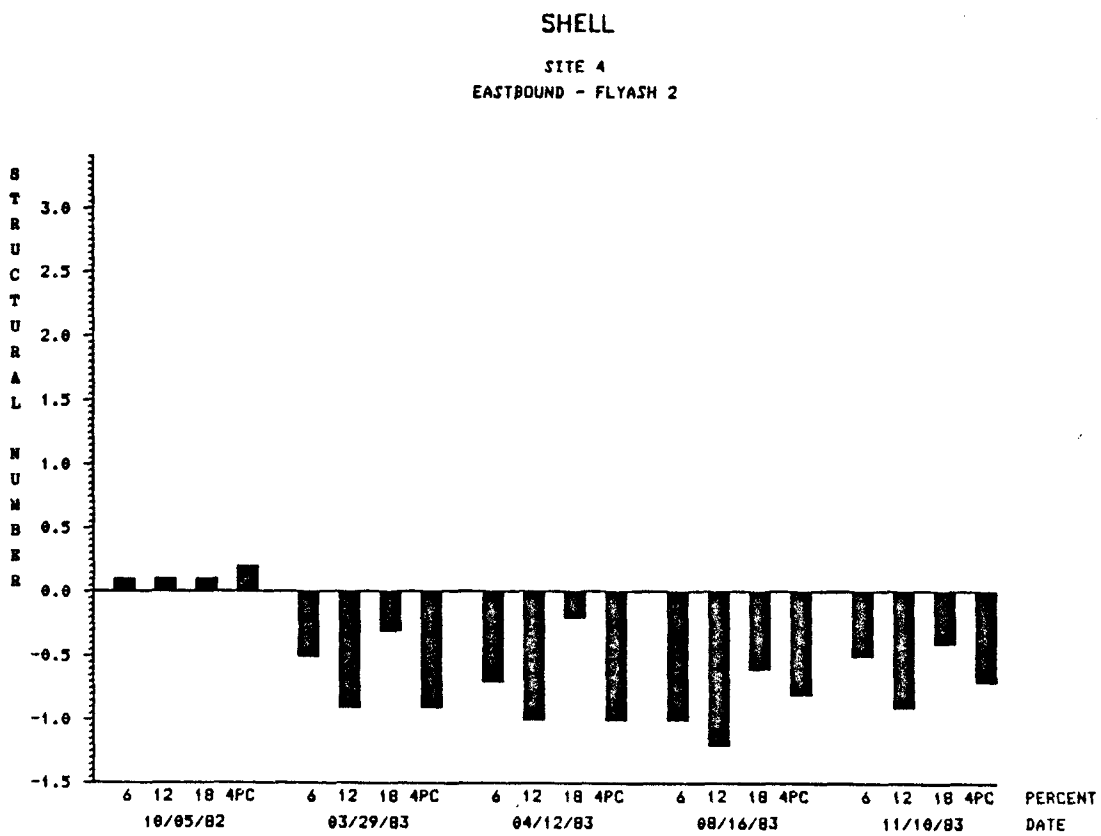

SHELL
SITE 4
EASTBOUND - FLYASH 2
STRUCTURAL NUMBER
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
6 12 18 4PC 6 12 18 4PC 6 12 18 4PC 6 12 18 4PC 6 12 18 4PC PERCENT
10/05/82 03/29/83 04/12/83 08/16/83 11/10/83 DATE

FIGURE 46

DISCUSSION OF RESULTS OF VISUAL CONDITION SURVEYS AND FIELD DEFLECTION MEASUREMENTS

Based on visual condition surveys, the physical condition and performance of the treated sand clay gravel test sections was equally good for all levels and types of additives, as well as sources of fly ash. As a result, there was no maintenance scheduled for the shoulders at site 1 in 3.5 years. The only maintenance required at site 3 in 2.5 years was the patching of several small potholes which developed towards the end of the observation period in both portland cement test sections and one of the 18 percent fly ash test sections at the shoulder-pavement joint. These potholes developed where transverse joints meet shoulder joints.

The results of the deflection measurements for the 18 percent fly ash treated sand clay gravel sections at site 1 indicated the improvement, from preconstruction, in stiffness (SN) at three years of age to be virtually equal to that for the 6 percent portland cement treated sections at site 3 at one year of age. The deflection measurements of the fly ash test sections at site 3 did not show any appreciable increase in stiffness level after one year. The measurements may have been confounded by a saturated layer, apparently draining water from the pavement to the ditch, found underlying the treated materials in some of the test sections treated with fly ash.

The visual condition surveys, conducted over a period of four years, for fly ash treated shell shoulders at site 2 indicated generally good performance; very good for the 18 percent fly ash test section. Maintenance was not required for the 18 percent fly ash test section in 2.9 years. The 12 percent fly ash test section showed a need for maintenance along the pavement-shoulder joint at the last condition survey. The 6 percent test section has required periodic repairs along the outside edge of the shoulder at several locations during the last 1.5 years of visual surveys.

The results of deflection measurements for the 18 percent fly ash test section at site 2 indicated an increase in stiffness (SN) level to approximately equal to that for the 6 percent portland cement test section at site 3. The 6 percent fly ash section SNs deteriorated to the preconstruction level after 2.75 years.

There was a significant difference in the physical condition and results of deflection measurements of the shell test sections at site 4 from those at adjoining site 2 at the last survey and test interval. Based on visual surveys, the physical condition of all test sections at site 4, fly ash or portland cement, was judged to be only fair. The results of deflection measurements for all site 4 test sections showed a decrease in stiffness (SN) below that of preconstruction levels. Some degree of shoulder maintenance has been required in all test sections since construction. The cause for the equally poor results of all site 4 test sections was not determined. Investigation of the failing areas of the 6 percent portland cement test section showed loose shell with only slight cementation for the full depth of treated material. This condition appears to be common to all test sections regardless of the additive; therefore, the cause is surmised to also be common to all test sections at site 4.

CONCLUSIONS

The following conclusions are based upon the visual observations made and data obtained during the course of this study.

1. Based on visual observations, the treatment of the existing sand clay gravel at the test sites in this study resulted in an improvement in the quality of the shoulders, functioning for over four years (site 1) and requiring only limited (site 3) or no (site 1) maintenance during the period of observations.

2. Fly ash (Class C) treated sand clay gravel and shell (at site 2 only) appeared from visual observations to harden with time. Results of laboratory compression tests of molded specimens consisting of shell and fly ash obtained from the test sections at site 4, before and during construction, also indicated a hardening and gain in compressive strength with time.

3. Results of deflection measurements taken on the sand clay gravel treated test sections did not, in all cases, reflect the physical condition and performance of the respective test section. Underlying layers of low density and/or high moisture content tend to increase overall deflections and therefore mask the gain in stiffness of the treated layers as measured with the Dynaflect device. The shoulder sections are sufficiently stiff to function as an improved shoulder for roadways having less than 10,000 ADT.

4. Self-hardening fly ash used as an additive to improve the quality of shell aggregate shoulders has very good potential. Results of visual observations and deflection measurements at site 2 and limited laboratory tests of material used in construction of site 4 test sections indicated fly ash treated shell will improve the stiffness level of surface shoulder aggregate. However, due to the poor performance of the test

sections at site 4 additional field evaluations should be undertaken before implementation can be recommended.

5. Fly ash (class C) treatment of sand clay gravel shoulder material can be accomplished without major difficulties by using a construction technique similar to that used in portland cement treatment of aggregate shoulder surface courses. Other means of spreading the additives than that used in this study should be explored in order to decrease the dusting problem and achieve more uniformity of distribution. Treated shoulders should be covered with at least a bituminous surface treatment as soon as practical after construction in order to prevent degradation of the shoulder.

RECOMMENDATIONS

The treated sand clay gravel shoulder surface course in this study has performed its function of providing a stable, all-weather shoulder along with a reduction in maintenance for the duration of the evaluation. The final visual condition survey conducted indicated this condition will be maintained for some time in the future. It also showed that the fly ash treated shoulders were performing as well as the portland cement treated shoulders constructed under this study.

Based on these results, it is recommended that the Department consider the use of fly ash (class C) when upgrading, whether in a maintenance mode or under contract, a raw sand clay gravel shoulder surface course on roadways having a maximum of 10,000 ADT. A minimum of fifteen percent fly ash, by volume, is recommended to be used, along with a maximum plasticity index of ten for the sand clay gravel. Additional evaluations should be continued to determine if these limits can be modified to increase the economics and range of sand clay gravel used. The fly ash should conform to the material specifications for fly ash recently adopted by the Department.

The construction technique used should be similar to that presently required for portland cement treatment of similar shoulder materials. The treated shoulder material should be surfaced with a minimum of a two-course bituminous surface treatment as soon as practical after construction.

The results of the treated shell shoulder materials at the two sites in this study are diverse, the test sections at site 2 significantly performing better than those at site 4. The cause for the poor performance of all test sections at site 4 was not determined; therefore, additional field experimentation should be undertaken before implementation in the treatment of shell shoulder material with fly ash can be recommended.

REFERENCES

1. Meyers, J. F., et al., Fly Ash As a Construction Material, Report No. FHWA-IP-76-16, U.S. Department of Transportation, Federal Highway Administration, June 1976.

2. Barenberg, E. J., Lime-Fly Ash-Aggregate Mixtures in Construction, National Ash Association.

3. American Society of Testing and Materials, ASTM Designation C-618, 1981 Annual Book of ASTM Standards, Part 14, pp. 375-378.

4. Pachowski, Jan, et al., The Application of Brown Coal Fly Ash to Road Base Courses, Report No. FHWA-RD-79-101, U.S. Department of Transportation, Federal Highway Administration, September 1979.

5. Thornton, S. I. and Parker, D. G., Fly Ash As Fill and Base Material in Arkansas Highways, Department of Civil Engineering, University of Arkansas, October 1975.

6. Ledbetter, W. B., et al., Construction of Fly Ash Test Sites and Guidelines for Construction, Report No. FHWA/TX-81/40+240-2, Texas Transportation Institute, Texas A&M University, October 1981.

7. Temple, W. H., and Cumbaa, S. L., Evaluation of Graded Limestone Base Course on a Low Volume Road, Research Report No. 175, Louisiana Department of Transportation and Development, 1985.

A P P E N D I X

TABLE 1

AVERAGE DAILY TRAFFIC AT TEST SITES

Year	Site 1	Site 3	Sites 2 and 4
1980	3,160	6,390	11,840
1981	3,850	6,410	12,890
1982	3,920 (16% trucks)	6,500 (16% trucks)	18,060 (18% trucks)
1983	4,538 (21% trucks)	6,490 (20% trucks)	21,202 (13% trucks)

TABLE 2

SAND CLAY GRAVEL TEST SITES
CONSTRUCTION DATA

SITE 1 FLY ASH 1			
Test Sections	6%	12%	18%
Density[1]	123.3	119.3	121.2
% Theoretical[2]	93.0	90.0	91.4
Thickness (inches)	6.1	7.5	7.4

SITE 3 FLY ASH 2 - EASTBOUND				
Test Sections	6%	12%	18%	4%-P.C.
Density[1]	128.7	130.2	130.3	122.7
% Theoretical[2]	95.1	97.3	101.3	96.9
Thickness (inches)	9.2	8.2	7.2	8.3

SITE 3 FLY ASH 3 - WESTBOUND				
Test Sections	6%	12%	18%	6% P.C.
Density[1]	127.1	129.2	128.6	125.8
% Theoretical[2]	92.6	96.4	94.6	94.9
Thickness (inches)	8.3	8.0	7.9	7.7

[1]Density - Dry unit weight in pounds per cubic foot.

[2]Theoretical - Determined in the laboratory according to DOTD 418F (28 blows/layer, 3 layers, 10-pound weight, 18-inch drop).

TABLE 3

SHELL TEST SITES
CONSTRUCTION DATA

SITE 2 FLY ASH 2				
Test Section	Control[1]	6%	12%	18%
Density[2]	120.7	117.7	120.0	121.2
% Theoretical[3]	90.7	88.3	90.1	91.0
Thickness (inches)		5.0	4.5	4.8

SITE 4 FLY ASH 2 - EASTBOUND				
Test Section	6%	12%	18%	4% P.C.
Density[2]	114.7	119.7	119.1	119.8
% Theoretical[3]	88.6	91.7	93.0	92.3
Thickness (inches)	5.1	4.7	4.7	4.1

SITE 4 FLY ASH 4 - WESTBOUND				
Test Section	6%	12%	18%	6% P.C.
Density[2]	118.5	125.9	129.4	118.3
% Theoretical[3]	91.7	96.5	96.6	93.9
Thickness (inches)	4.7	5.0	7.1	4.9

[1]Control - Untreated test section.

[2]Density - Dry unit weight in pounds per cubic foot.

[3]Theoretical - Determined in the laboratory according to DOTD TR-418D (150 blows/layer, 3 layers, 10-pound weight, 18-inch drop).

TABLE 4

TYPICAL GRADATION OF SAND CLAY GRAVEL
AT SITES 1 AND 3

Sieve Size	Site 1	Site 3 Eastbound	Site 3 Westbound
1-1/2 inch	100	100	100
3/4 inch	90	96	96
No. 4	69	62	63
No. 40	41	39	38
No. 200	13	20	16
Liquid limit	19	20	18
Plastic limit	10	16	15
Plastic Index	9	4	3

Note: Gradations listed as percent passing.

TABLE 5

TYPICAL CHEMICAL AND FINENESS TEST[1] RESULTS OF FLY ASH

CHEMICAL PROPERTIES	FLY ASH 1	FLY ASH 2			FLY ASH 3	FLY ASH 4
	SITE 1	SITE 2	SITE 3	SITE 4	SITE 3	SITE 4
LOI, %	1.3	2.4	2.3	1.3	1.0	1.8
Sulfur trioxide, %	3.3	3.1	2.4	3.1	4.9	1.8
Total[2] oxides, %	65.1	64.6	67.2	64.6	63.6	74.5
Calcium oxide, %	26.2	21.2	21.7	22.3	22.2	20.2
Magnesium oxide, %	1.2	3.8	4.2	4.3	4.0	2.6
Alkalies, as NaO, %	1.26	--	1.48	1.29	2.03	0.85
Specific Gravity	2.64	2.67	2.67	2.67	2.51	2.50
Physical Property						
Fineness, % Ret. #325	20.2	21.1	15.7	16.0	17.3	20.7

[1]Test - Material tested according to ASTM Designation: C311.

[2]Total - $S_iO_2 + Al_2O_3 + Fe_2O_3$.

TABLE 6

RESULTS[1] OF COMPRESSION TESTS FOR MATERIALS USED IN CONSTRUCTION AT SITE 4

	SITE 4							
	FLY ASH 2			FLY ASH 4			PORTLAND CEMENT	
AGE[2]	6%	12%	18%	6%	12%	18%	4%	6%
7	160	200	195	75	165	205	614	920
28	170	220	275	95	160	190	707	979
56	160	290	310	94	150	255	807	

[1]Results - in psi

[2]Age - in days

Note: % of fly ash and portland cement by volume.
All specimens soaked four hours prior to testing.