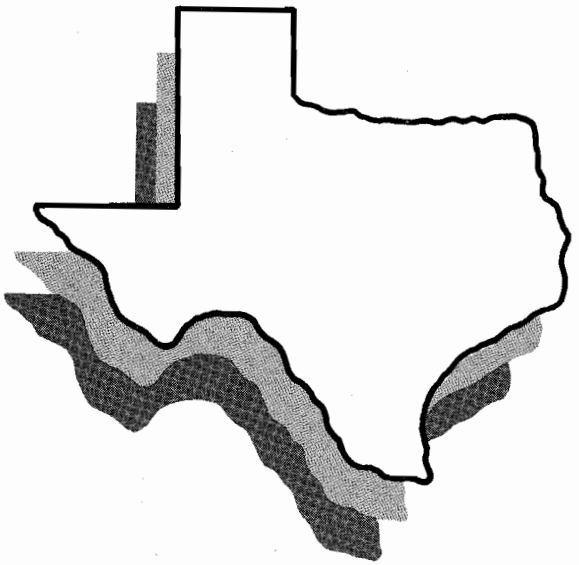
EXPERIMENTAL FLY ASH BASE

DHT-17



DEPARTMENTAL INFORMATION EXCHANGE

STATE DEPARTMENT OF HIGHWAYS
AND
PUBLIC TRANSPORTATION

RESEARCH SECTION, FILE D10-R, P.O. BOX 5051 AUSTIN, TX 78763-5051, 512-465-7403, STS 241-7403

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
DHT-17		

4. Title and Subtitle	5. Report Date
Experimental Fly Ash Base Farm-to-Market Road 1093 Fulshear, Texas	July, 1989
	6. Performing Organization Code
7. Author(s)	8. Performing Organization Report No.
Constance Wong and Michael K. Ho, P.E.	DHT-17
9. Performing Organization Name and Address	10. Work Unit No.
State Department of Highways and Public Transportation – Transp. Plng. Div., P.O. Box 5051 Austin, Texas 78763-5051	11. Contract or Grant No.
	13. Type of Report and Period Covered
12. Sponsoring Agency Name and Address	
State Department of Highways and Public Transportation 11th and Brazos, Austin, Texas 78701	14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

This report documents the use of a 100% fly ash base, with no additives or aggregate. The coal from which the fly ash was derived originated in Wyoming and Montana, principally. It was burned at the Houston Lighting and Power plant in Thompsons, Texas.

Difficulty was experienced in placement and compaction. Expected ultimate strengths were not achieved. The significant difference in lab specimens and field specimens was attributed mainly to retempering at the job site.

17. Key Words		18. Distribution Statement
sulfate	sieve	
fly ash	gradation	
alkali-silica	corrugations	
aggregate	retempering	

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of pages	22. Price
		35	

EXPERIMENTAL FLY ASH BASE
FARM-TO-MARKET ROAD 1093
FULSHEAR, TEXAS

By Constance Wong and Michael K. Ho, P.E.
District 12 Laboratory
Houston, Texas

The contents of this report reflect the views of the authors who are responsible for the facts and the accuracy of the data presented in the report. The contents do not necessarily reflect the official views or policies of the State Department of Highways and Public Transportation. This report does not constitute a standard, specification or regulation.

Acknowledgements:

Alvis C. Schmidt – State Department of Highways and Public Transportation, Rosenberg Residency, for technical field information;

Paul Rush – State Department of Highways and Public Transportation, Rosenberg Residency, for technical laboratory information;

James Darden, P.E. – State Department of Highways and Public Transportation, Rosenberg Resident Engineer, Fort Bend County, for feedback and cooperation.

EXPERIMENTAL FLY ASH BASE ON FM. 1093, FULSHEAR, TEXAS

CONTENTS PAGE

LIST OF FIGURES AND PICTURES OF THE FLY ASH BASE PAGE

INTRODUCTION

The application of fly ash as a major component of base material has not been attempted before in District 12, although its use as a cementitious and pozzolanic additive in concrete is commonplace. Limed fly ash stabilized base has been used in a dozen states, but it consists of only 10% to 15% fly ash. Much research has shown fly ash as an additive effective in reducing alkali-silica reactions,[1] increasing sulfate resistance[2] and increasing compressive strength. For example, limed fly ash stabilized bases can reach 800 to 2,000 p.s.i. in 7 days. This is approximately double the strength of regular limestone bases.[3] Overall, fly ash seems a good candidate for base material, although long-term performance depends on type of fly ash, quality control during construction and compositional variation.

This report documents the use of a 100% fly ash base, with no additives or aggregate. The coal from which the fly ash was derived originated in Wyoming and Montana, principally.[4] It was burned at the Houston Lighting and Power plant in Thompsons, Texas. Some chemical properties of this fly ash are listed in Table 1.[5]

A Type B (ASTM Type C) fly ash base, described in Appendix B, was mixed at optimum moisture of 14.8%. It was placed on a 500-foot stretch of eastbound FM 1093 between Simonton and Fulshear in Fort Bend County, Texas and assigned project C.S.J. number 1258-02-021. Figure 1 shows the profile and extent of fly ash base placed. From Station 75+00 to 77+50, 14 inches of fly ash was placed on March 29, March 30, and April 4 of 1988 and sealed on March 30, March 31, and April 5, 1988, respectively.

Table 1. Summary of evaluated fly ash properties

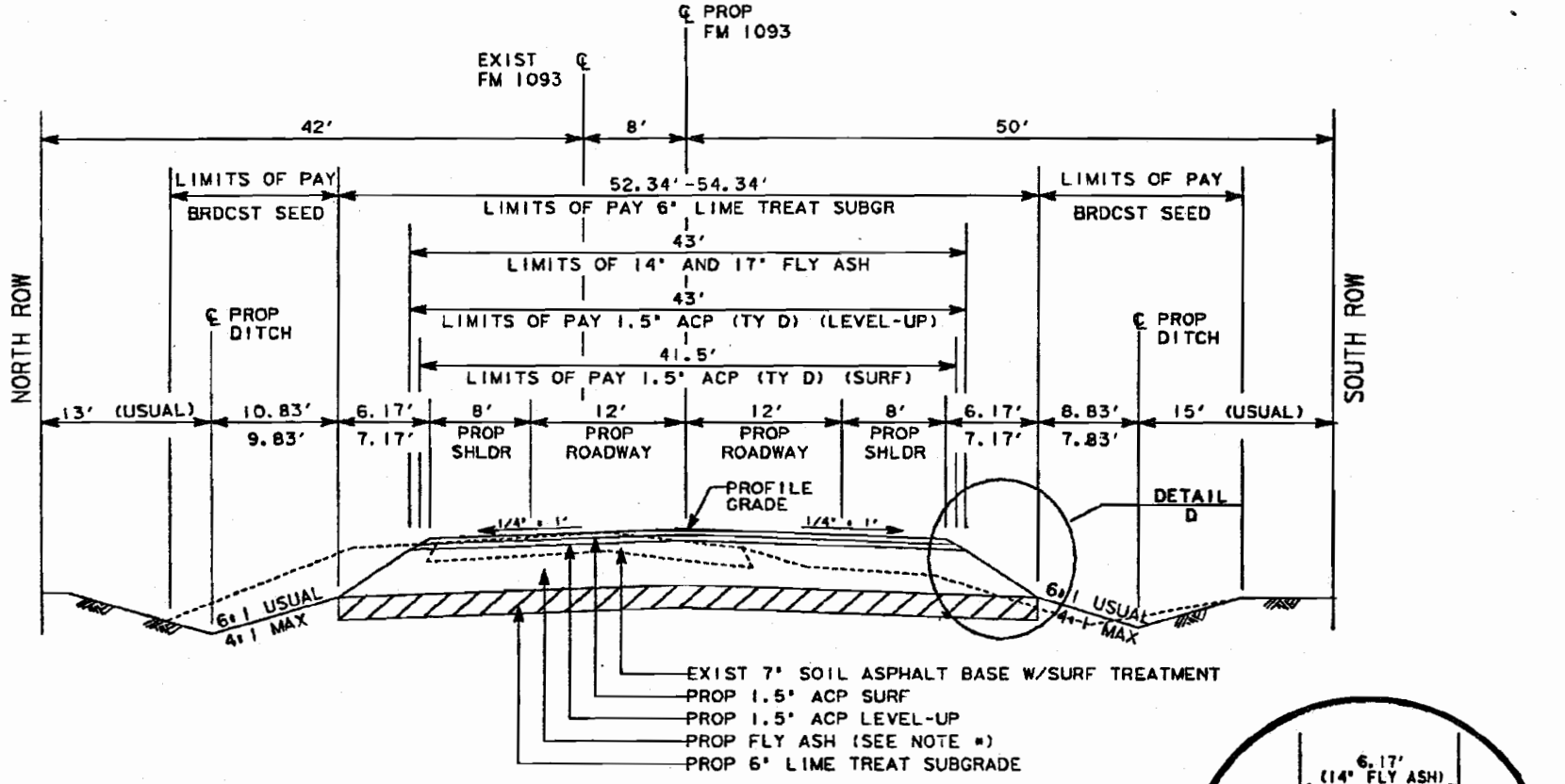
	Specific Gravity	Fineness: % Retained on No. 200 Sieve	Fineness: % Retained on No. 325 Sieve	Total CaO[c] Content	pH[a] (pH units)
Average	2.64	7.8	12.1	25.4[b]	12.0
Std. Dev.	0.01	0.10	0.62	0.64	0.00
Range	2.63-2.65	7.7-7.9	11.6-12.8	24.8-26.3	12.0-12.1

All values are an average of 3 values except as otherwise noted.

[a] 1:1 Ratio (grams: milliliters)

[b] Average of 5 repetitions

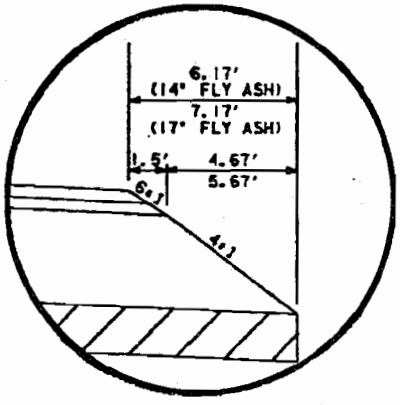
[c] As determined by the CaO heat evolution test



TYPICAL CROSS SECTION

TEST SECTION
CONTROL 1258-02-021

* 14" FLY ASH FROM STA. 75.00 TO STA. 77.00
17" FLY ASH FROM STA. 77.50 TO STA. 80.00



DETAIL D

Figure 1

DESIGN

Designing the criteria consisted of combining various fly ash components in certain percentages, determining optimum moisture and maximum dry density, and setting compressive strength and gradation requirements. The following criteria were established:

Combining percentages were to be:

40.2% cured/crushed fly ash

19.8% bottom ash

40.0% live fly ash

(The specification, in Appendix A, was written as 67% crushed/cured fly ash to 33% bottom ash. This refers only to what the ratio of the two should be, not to the percentages of them in the final mix.)

Optimum moisture was found to be 14.8%.

Maximum dry density was 97.3 p.c.f.

An average seven-day compressive strength was set at 180 p.s.i.

The fly ash gradation after blending was set according to the field change:

	Percent Retained	
Sieve Size	Minimum	Maximum
2 1/4"		0
1 3/4"	0	10
No. 4	15	60
No. 40	40	80

After they had been mixed at optimum water content and placed on the roadway, the following gradation requirements were set for the fly ash materials:

100% Minimum Passing 2 1/4" sieve

70% Minimum Passing 3/4" sieve

After the limits on gradations and strength requirements had been set, it was determined that the fly ash had the following strength and gradations:

Average seven-day compressive strength, after moist curing,[6] was determined at 720 p.s.i. by the laboratory at Law Engineering.

Gradations after blending were:

Sieve Size	Percent Retained Minimum	Percent Retained Maximum	Cumulative Percent Retained
2 1/4"	0	0	0
1 3/4"	0	10	0
No. 4	15	60	35.8
No. 40	40	80	74.1

Gradations after mixing with water were:

100% Passing 2 1/4"
88.6% Passing 3/4"

OTHER RESULTS

Unconfined compressive strength data of molded field specimens obtained from Law Engineering's laboratory (Figure 2) shows the compressive strengths averaging 132 p.s.i. at seven days, 140 p.s.i. at fourteen days, 155 p.s.i. at twenty-one days and 169 p.s.i. at twenty-eight days.

Field moisture contents, taken by nuclear gauge, were 11.2% at seven days, 8.1% at fourteen days, 10.7% at twenty-one days and 6.7% at twenty-eight days. The average reading is 9.2%, which is 5.6% below optimum moisture. Oven dried field moisture contents taken after extra water was added in the field were 16.0%, 18.5% and 15.7%, with the average at 16.7%. This is 3% higher than the average moisture content calculated using nuclear gauge moisture contents. Tolerance given in the specification was two percentage points above and three and one half percentage points below optimum moisture.

Field densities, taken by nuclear gauge method, were 96.6%, 91.6%, 98.8% and 97.2%. Required percent density was 95% and the average percent density of 96.1% was above the required percent density by 1.1%. Most of the percent densities show the fly ash base was overcompacted.

Observations made in August of 1988, about 4 to 5 months after the placement, reveal that the asphaltic pavement had corrugations on the edge of the east-bound lane at about Stations 75+00 and 79+00. A hole in the asphaltic pavement, approximately 1/2 foot wide, exposed some of the base, but was filled in with gravel at Station 77+00.[7]

DISCUSSION

Results of the compressive strength data show that this base did not meet the 180 p.s.i. average requirement at 7 days. Most molds, out of the 7 to 28 day molds, were below 150 p.s.i., which is the 7-day strength below which no individual compressive

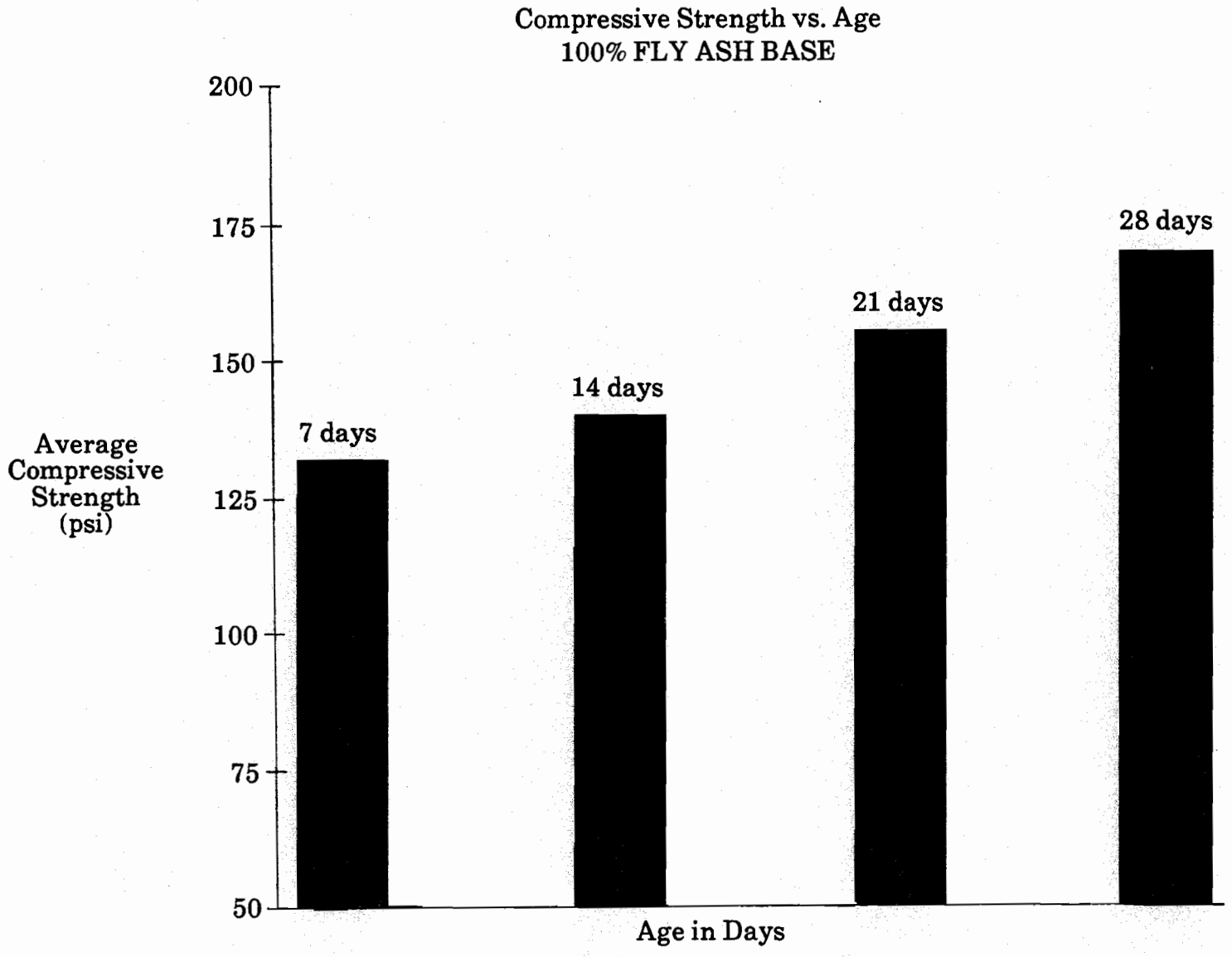

Compressive Strength vs. Age
100% FLY ASH BASE
200
175
150
125
100
75
50
Average Compressive Strength (psi)
7 days
14 days
21 days
28 days
Age in Days

Figure 2

strength would be acceptable. None of the averages for molds broken at 7, 14, 21 and 28 days achieved over 180 p.s.i. Before attempting to explain why this has occurred, some graphs will be reviewed here such as dry density versus moisture content, strength versus age and strength versus dry density graphs.

The dry density versus moisture content graph, in Figure 3, shows dry density of molded field samples decreasing with increasing moisture, which is a reasonable occurrence.

The compressive strength versus age in days graph shows average compressive strength slowly increases with the number of days of moist curing; the 28-day average compressive strength increased only 37 p.s.i. over the 7-day average (Figure 2).

For compressive strength plotted against dry density graphs, the dearth of data points may explain the lack of a well-defined and consistent trend. For 7 and 21 days, graphs shown in Figures 4 and 5, compressive strength decreases as dry density increases, but for 14 and 28 days, graphs shown in Figures 6 and 7, the opposite trend occurs.

Low strength of the compacted field samples could be due to fly ash compositions or non-uniformity of the fly ash and particular field conditions. In regard to the former, a chemical analysis of the fly ash used here revealed the alkali content varied from 2.2% to 1.2%,[8] while the calcium oxide content ranged from 24.8% to 26.3%, as shown in Table 1. Calcium oxide can either benefit or degrade the performance of the product with fly ash, depending on the particular amount and type. For example, limed fly ash stabilized base with ASTM Type C fly ash (high calcium, high alkali) will set up faster than those with Type F, and the mixture has been known to set up in the trucks.[9]

Fly ash with abundant calcium oxide and tricalcium aluminate[12] may cause false setting by the rapid cementitious reactions occurring and other problems as well. For example, fly ash with calcium oxide = 15% to 30% by weight will harden in less than 45 minutes[10] after hydrating. Tricalcium aluminate, the most reactive compound in Portland Cement, is also the most abundant compound in Type C fly ash.[11] In addition to setting, the rapid cementitious reactions caused by high calcium oxide and tricalcium aluminate contents result in an immediate higher content of hydration products[13] and consequently, lower workability. To obtain equal workability, concrete with Type C fly ash will require higher amounts of water than that with Type F.[14] While high calcium fly ash contents can cause the ultimate strength to equal or exceed control strength, this excessive strength can also lead to cracking.[15]

The fly ash used for base here had a moderate to high calcium oxide content of 25.4% on the average. It is possible the water reacted with the calcium oxide, became chemically bound and set up in the trucks, making it difficult to place. As Picture A shows, the fly ash did not fall out of the dump trucks easily. Compaction of the fly ash

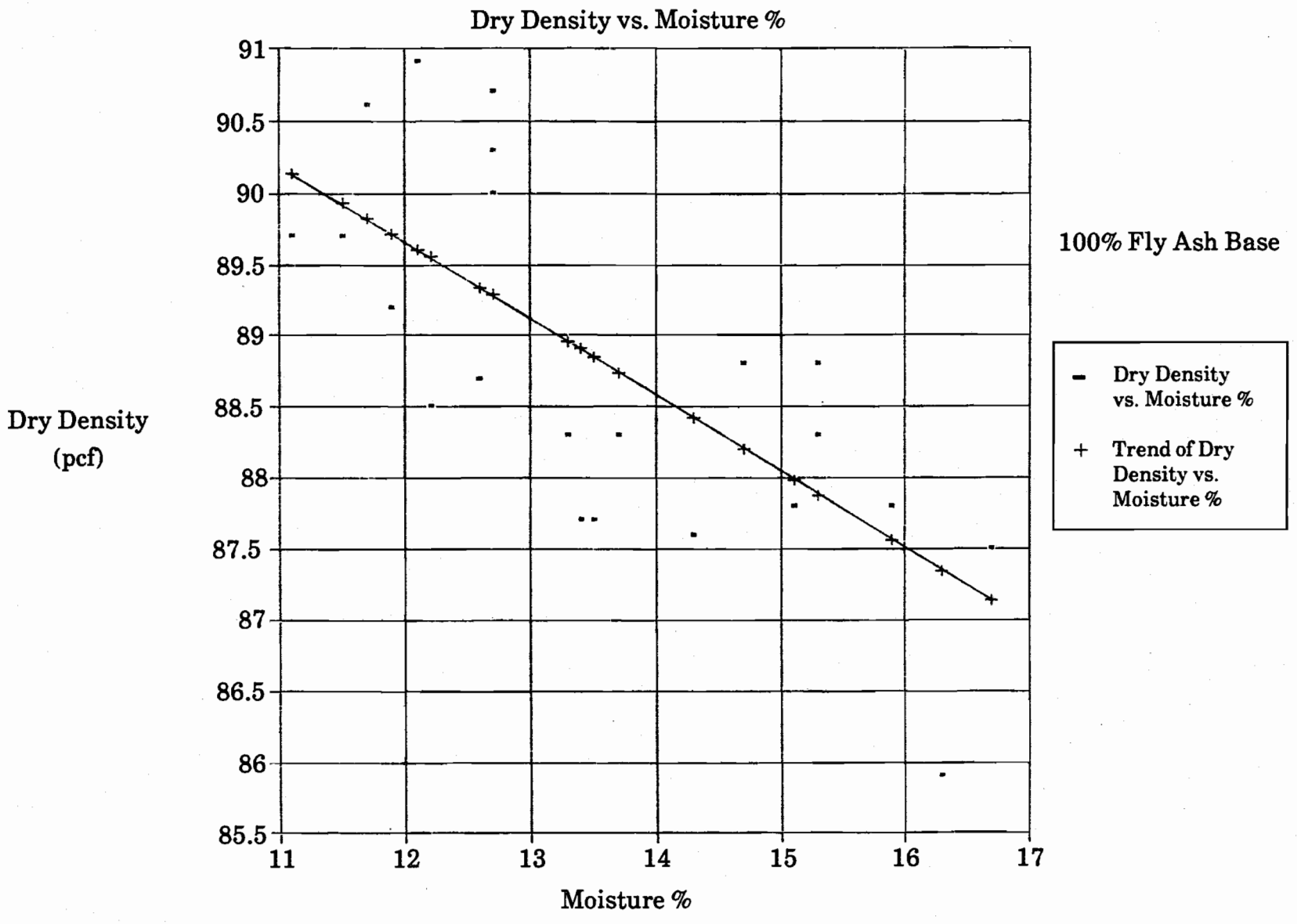

Dry Density vs. Moisture %
Dry Density (pcf)
91
90.5
90
89.5
89
88.5
88
87.5
87
86.5
86
85.5
11
12
13
14
15
16
17
Moisture %
100% Fly Ash Base
Dry Density vs. Moisture %
Trend of Dry Density vs. Moisture %

Figure 3

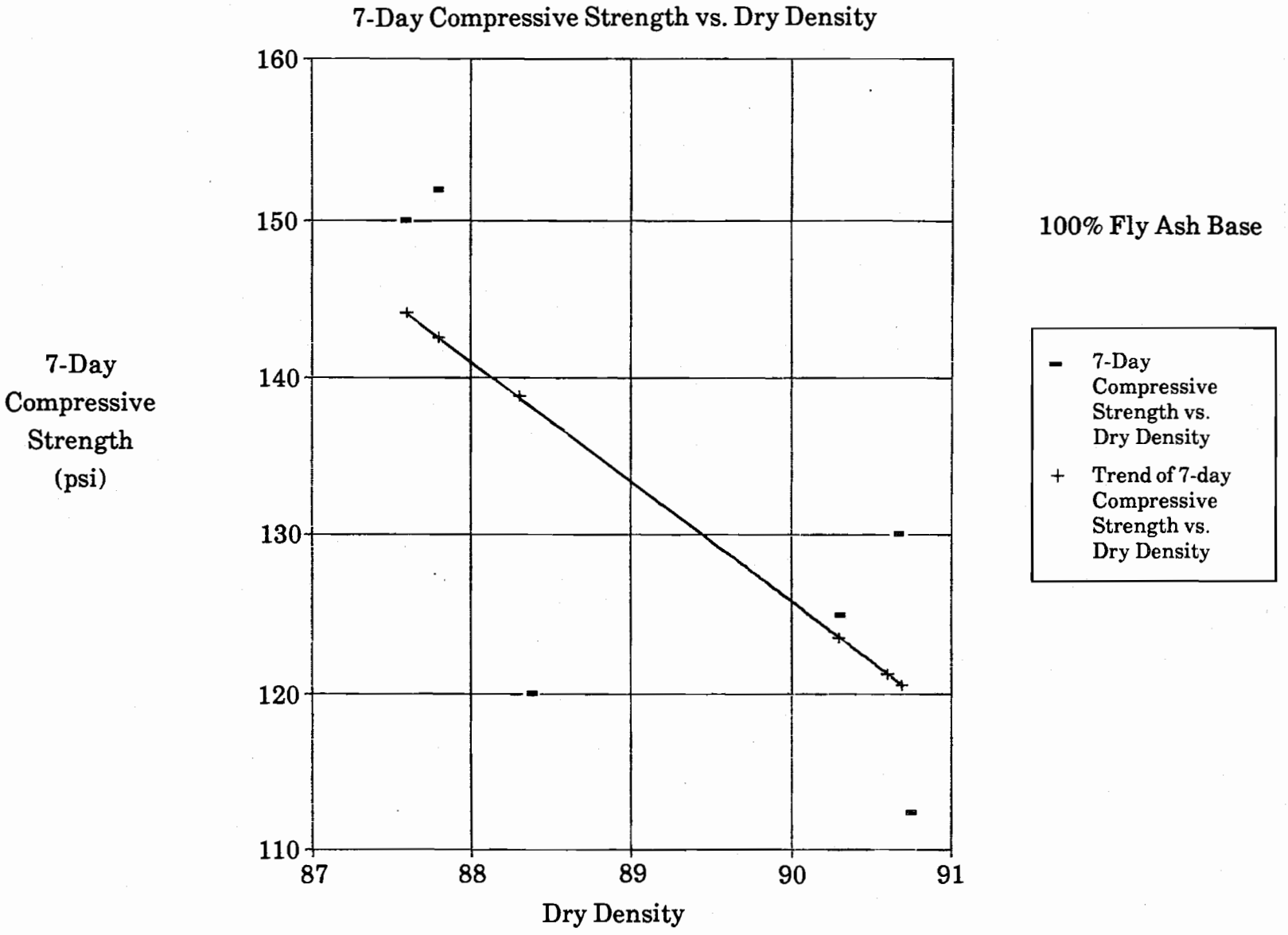

7-Day Compressive Strength vs. Dry Density
160
150
140
130
120
110
87
88
89
90
91
Dry Density
7-Day Compressive Strength (psi)
100% Fly Ash Base
7-Day Compressive Strength vs. Dry Density
Trend of 7-day Compressive Strength vs. Dry Density

Figure 4

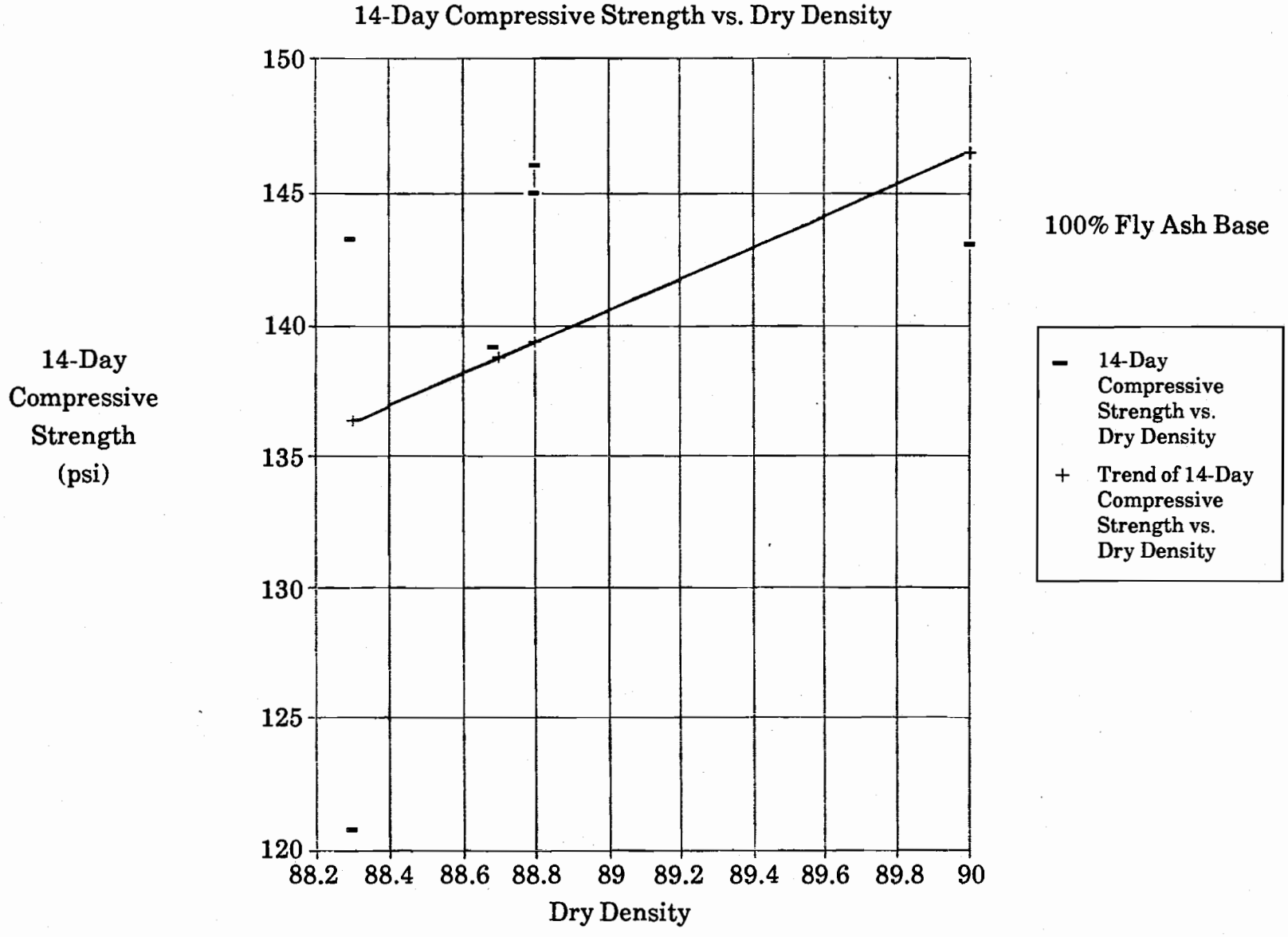

14-Day Compressive Strength vs. Dry Density
150
145
140
135
130
125
120
88.2
88.4
88.6
88.8
89
89.2
89.4
89.6
89.8
90
Dry Density
14-Day Compressive Strength (psi)
100% Fly Ash Base
14-Day Compressive Strength vs. Dry Density
Trend of 14-Day Compressive Strength vs. Dry Density

Figure 5

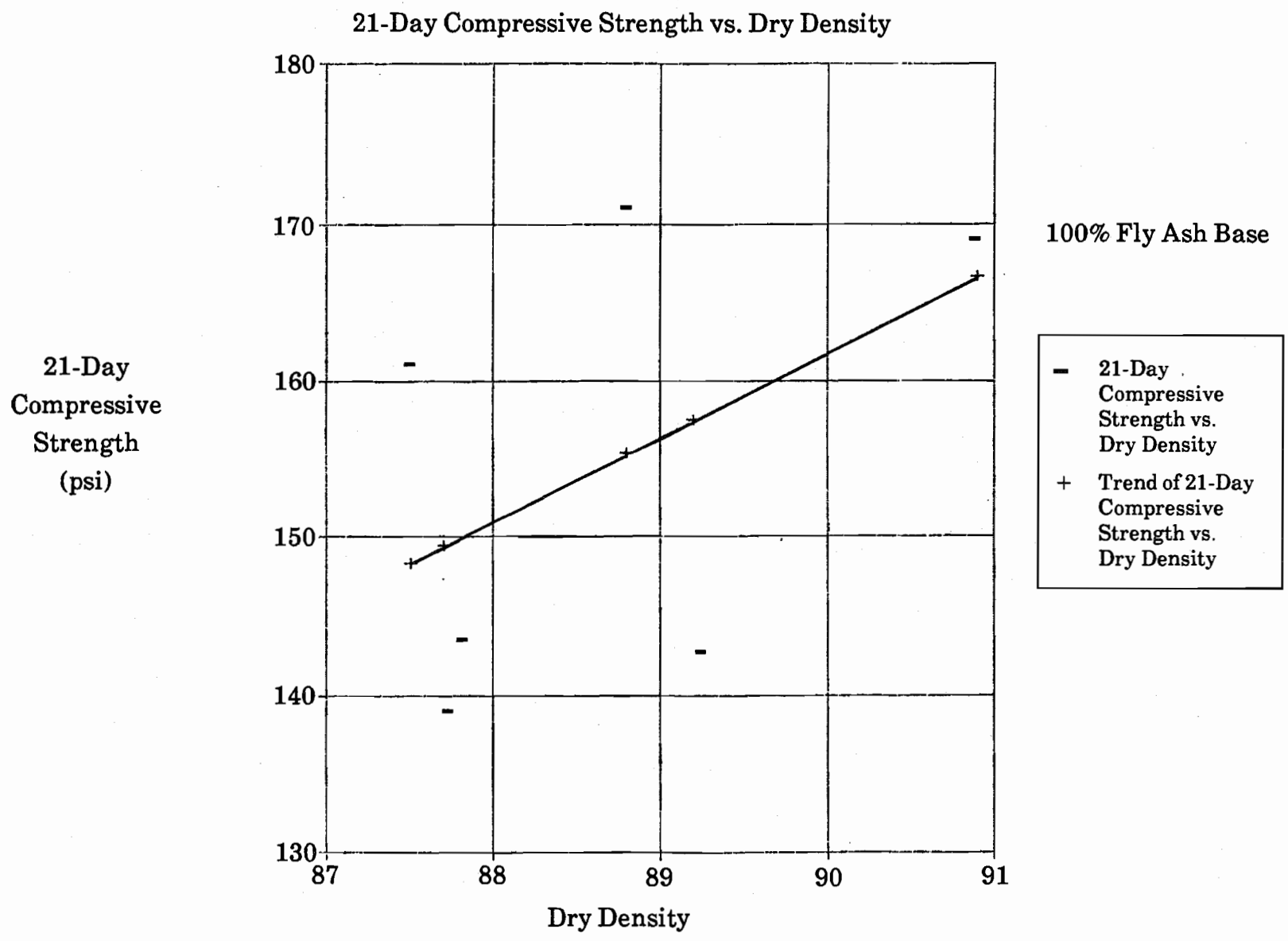

21-Day Compressive Strength vs. Dry Density
180
170
160
150
140
130
87
88
89
90
91
Dry Density
21-Day Compressive Strength (psi)
100% Fly Ash Base
21-Day Compressive Strength vs. Dry Density
Trend of 21-Day Compressive Strength vs. Dry Density

Figure 6

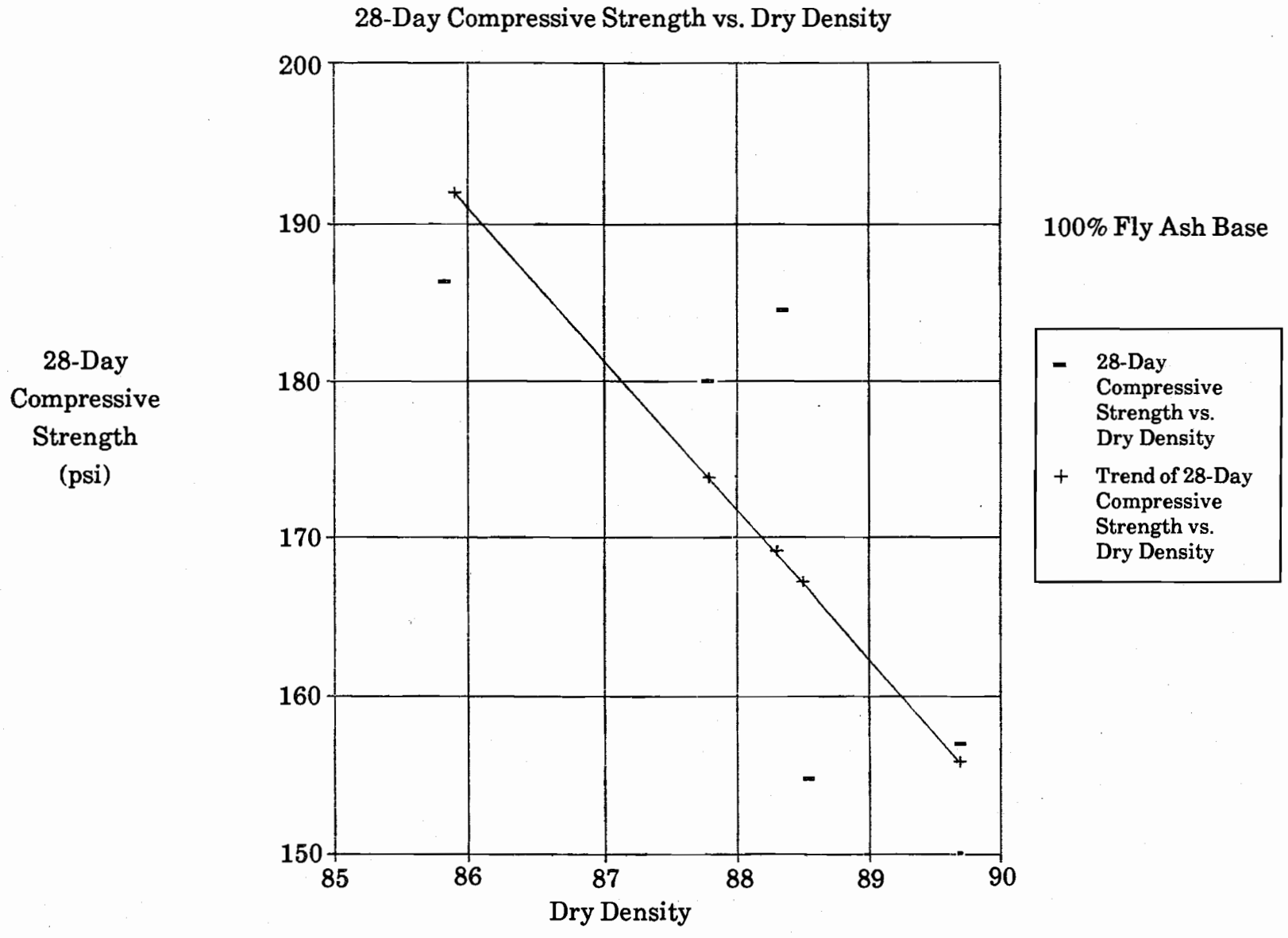

28-Day Compressive Strength vs. Dry Density
200
190
180
170
160
150
85
86
87
88
89
90
Dry Density
28-Day Compressive Strength (psi)
100% Fly Ash Base
28-Day Compressive Strength vs. Dry Density
Trend of 28-Day Compressive Strength vs. Dry Density

Figure 7

after it had been dumped may have broken the physical bonds formed in the initial hydration. Extra water was applied to the fly ash, as it looked dry and dispersed like dust (Picture E). Other pictures (B, C, D and F) show the fly ash being leveled off, compacted and sealed, respectively. The field moisture contents retrieved through the oven drying were above optimum moisture by 3%, which agrees with the fact that extra water was added. The nuclear moisture contents, below optimum by about 6%, do not concur with this observation.

CONCLUSION

The effects of retempering the fly ash base at the jobsite were not fully examined. However, the significant difference in strength between specimens mixed and molded in the laboratory and field specimens mixed in the plant and molded in the laboratory indicates that retempering with water at the jobsite may have been responsible for strength reduction. The difficulty encountered during the compacting process in the field probably was due to the dryness of the fly ash base. If further research is pursued, the following recommendations should be implemented:

1) Provide 2 to 3 percent water above the optimum moisture at the plant in order to allow for the loss of moisture before field compaction.
2) Field density can be achieved easily if the proper type of equipment is used. Heavier compacting equipment should be tried in order to obtain the desirable density in the field.
3) Use of a retardant may prevent flash setting.
4) Use of lime as an additive would increase the compressive strength.

A

This picture, taken March 29, 1988, shows that it was difficult to get the fly ash out of the dump truck. Here the hydraulic lift on the truck was up all the way, yet the fly ash was still in the truck.

B

This picture shows fly ash that was just dumped being leveled off on March 29, 1988.

C

Fly ash is being leveled off in this picture taken on March 29, 1988.

D

In this picture, taken on March 29, 1988, fly ash is being compacted.

E

The fly ash in the section from Station 75 + 00 to 77 + 50 appeared too dry, so water was added to it on March 29, 1988.

F

The 14" section of fly ash from Station 75 + 00 to 77 + 50 was sealed on April 5, 1988.

REFERENCE NOTES

1. Josef Farbiarz and Ramon L. Carrasquillo, "Effectiveness of Fly Ash Replacement in the Reduction of Damage Due to Alkali-Aggregate Reaction in Concrete," Center for Transportation Research, University of Texas, Austin, May 1986, p. 88.

2. P.J. Tikalsky and R.L. Carrasquillo, "The Effect of Fly Ash on the Sulfate Resistance of Concrete," Proceedings of the Tenth International Conference on Cement Microscopy, San Antonio, Texas, April 1988, p. 256.

3. Ronald E. Heinz, "Use of Coal Ash in Embankments and Bases," Federal Highway Administration Technical Advisory T 5080.9, May 1988, p. 8.

4. Jay Schmidt, personal communication, Ash Management Systems, Thompsons, Texas, June 1988.

5. Chuck A. Gregory, et al, "Laboratory Investigation of Phosphogypsum from Mobile Pile 2," Texas Transportation Institute, Texas A&M University, College Station, October 3, 1983, p. 14.

6. Steve Kaiser, personal communication, Law Engineering, Houston, Texas, June 1988.

7. Constance Wong, personal observation, State Department of Highways and Public Transportation, District 12 Laboratory, Houston, Texas, August 12, 1988.

8. Jay Schmidt, personal communication, Ash Management Systems, Thompsons, Texas, June 1988.

9. Heinz, "Use of Coal Ash . . . ," p. 8.

10. Seven H. Kosmatka and William C. Panarese, *Design and Control of Concrete Mixtures*, 13th Edition, Portland Cement Association, 1988, p. 69.

11. J. Olek, et al, "Production of Concrete Containing Fly Ash for Pavement Applications," Center for Transportation Research, University of Texas, Austin, May 1986, p. 8.

12. L.G. Archuleta Jr., et al, "Production of Concrete Containing Fly Ash for Structural Applications," Center for Transportation Research, University of Texas, Austin, May 1986, p. 15.

13. Ibid, p. 49.

14. Ibid, p. 49

15. Heinz, "Use of Coal . . . ," p. 9.

16. Tikalsky and Carrasquillo, "The Effect of Fly Ash . . . ," p. 256.

APPENDIX A

SPECIAL SPECIFICATION

ITEM 2061

FLY ASH BASE

1. DESCRIPTION.

This item shall consist of a base course composed of the items described under 2. MATERIALS. This item shall also include the placement, compaction, finishing and shaping of the base course in accordance with the requirements of this specification and the plans and to the lines and grades as established by the Engineer.

2. MATERIALS. Materials shall meet the following requirements.

A. Crushed, Cured Fly Ash, a fly ash which has set, cured, been mined, crushed and sized.

B. Bottom ash consisting of the heavier residue from the burning of coal.

C. Fly ash meeting requirements of Departmental Materials Specification D-9-8900, "Fly Ash".

D. Water meeting the requirements of water for the item, "Concrete Pavement".

The combination of (1) and (2) above is hereinafter called "aggregate". The Aggregate shall be free of injurious or hazardous products and free of organic material or other foreign matter. The source shall be approved by the Engineer prior to use.

3. PROPORTIONING OF MIXES.

The Fly Ash Base shall be proportioned as set out below.

A. The Aggregate shall be blended at a ratio of 67 percent crushed, cured fly ash, to 33 percent bottom ash, and shall meet the following requirements when tested according to Test Method Tex-110-E:

Square Sieve	Percent Retained	
	Min	Max
2 1/4"		0
1 3/4"	0	10
No. 4	30	60
No. 40	40	65

The Fly Ash content shall not be less than 40 percent of the dry weight of the Fly Ash Base.

B. Strength Design. The mix will be designed with the intention of producing a minimum average compressive strength of 180 pounds per square inch at the age of seven days using unconfined compression testing procedures unless otherwise specified on the plans. The Fly Ash Base specimens shall be prepared, cured and tested as outlined in Test Method TEX-120-E.

C. Test Specimens. The strength of the mix will be checked by tests of the mix as placed on the roadway. A minimum of 12 test specimens shall be made for each 500 tons of material or fraction thereof placed. For these tests, the material will be sampled prior to compaction. Nine of the 12 specimens shall be furnished to the Engineer for future tests and the remaining three specimens shall be tested for acceptance. The material will not be acceptable if the average compressive strength of these specimens is less than 180 PSI when tested as outlined in Test Method TEX-120-E. No individual compressive strength below 150 PSI will be acceptable.

4. CONSTRUCTION METHODS.

A. General. It is the primary requirement of this specification to secure a completed base course of fly ash base uniformly compacted to the specified density with no loose or poorly compacted areas, with uniform moisture content, well bound throughout its full depth and with a surface finish suitable for placing a surface course. It shall be the responsibility of the Contractor to regulate the sequence of work, maintaining the work, and rework the courses as necessary to meet the requirements of this specification.

B. Preparation of Subgrade. The roadbed shall be excavated and shaped in conformity with the typical sections shown on the plans to the lines and grades established by the Engineer. All suitable or otherwise objectionable material or roots shall be removed from the subgrade and replaced with approved material. All holes, ruts and depressions shall be filled with approved material and, if required, the subgrade shall be thoroughly wetted with water and reshaped and rolled to the extent directed in order to place the subgrade in an acceptable condition to receive the base material. The surface of the subgrade shall be finished to lines and grades as established and shall be in conformity with the typical sections shown on the plans. A subgrade planer may be used. Any deviation in excess of one-half inch in cross section and in a length of 16 feet measured longitudinally shall be corrected by loosening, adding or removing material, reshaping and compacting by sprinkling and rolling. Sufficient subgrade shall be prepared in advance to insure satisfactory prosecution of the work. Material excavated in preparation of the subgrade shall be utilized in the construction of adjacent shoulders and slopes or otherwise disposed of as

directed by the Engineer. Excavation and embankment required for preparation of subgrade will be measured and paid for under the Special Specification Items "Excavation" and "Embankment" respectively.

C. Mixing. The fly ash, aggregate material and water shall be thoroughly mixed in an approved processing plant. The mixer shall be a stationary pug mill. Batch or continuous type mixers which may produce a uniform material will be allowed. The plant shall be equipped with feeding and metering devices which will add the aggregate material, fly ash and water into the mixer in the specified quantities. Regardless of the type of mixer employed, the resulting mixture shall be homogeneous and uniform in appearance, and shall meet the following requirements when tested from the roadway in the roadway condition by Test Method Tex-101-E, Part 3:

	Percent
Minimum Passing 2 1/4" Sieve	100
Minimum Passing 3/4" Sieve	70

D. Placing. The fly ash base shall be placed in uniform layers on the prepared subgrade to produce the depth specified on the plans. The material shall be consolidated with rollers capable of compacting from the bottom up. The depth of layers shall be as approved by the Engineer. To insure homogeneous distribution of the fly ash base material in each layer, the material shall be placed using an approved spreader. The spreading operations shall be done in such a manner as to eliminate nests or pockets of material of nonuniform gradation resulting from segregation in the hauling or dumping operations and in such a manner as to eliminate planes of weakness.

The fly ash base shall not be placed when the air temperature is below 40 F and is falling, but may be placed when the air temperature is above 35 F, and is rising, the temperature being taken in the shade and away from artificial heat and with further provision that fly ash base shall be mixed or placed only when weather conditions in the opinion of the Engineer are suitable for such work.

E. Construction Joints. If a road section is not completed at the end of a construction day, a straight transverse construction joint shall be formed by cutting back into the completed work to form a vertical face.

F. Compaction. Unless shown otherwise on the plans, the fly ash base shall be compacted to a density of not less than 95 percent of compaction ratio density, Test Method TEX-114-E and shall be checked in the field by Test Method TEX-115-E. The moisture content of the mixture during compaction operations shall be maintained within a range from optimum percentage to two percentage points above or 3.5 percentage points below

the optimum percentage or within the range directed by the Engineer. If the obtained density does not satisfy requirements, the Contractor shall make adjustments in roller weight, lift thickness or material moisture level or replace the material in question. The material shall not be compacted until the necessary shape and thickness has been achieved by grading. When additional lifts are necessary, the existing layer shall be lightly sprinkled prior to placing the additional courses.

G. Finishing. After the final course of the fly ash base, except the top mulch, is compacted, the surface shall be finished to grade and section by blading and shall be sealed with approved pneumatic tire rollers. When directed by the Engineer, surface finishing methods may be varied from this procedure provided a dense uniform surface is produced and further provided that the construction of compaction planes is avoided. Unless otherwise shown on plans, (1) not more than 90 minutes shall elapse between the start of mixing and the time of starting the compaction of the fly ash base on the prepared subgrade, (2) any mixture of aggregate, fly ash and water that has not been compacted shall not be left undisturbed for more than 60 minutes, and (3) all finishing operations shall be completed within a period of five (5) hours after fly ash is added to the aggregate and water.

H. Curing. Immediately after the fly ash base has been brought to line and grade, an asphaltic membrane shall be placed on the fly ash base to prevent evaporation of water and provide curing. The asphalt used for curing shall be of the type and grade shown on the plans or as approved by the Engineer and shall be applied at the rate of approximately 0.1 gallon per square yard unless the plans require otherwise. Asphalt shall meet the requirements of the Item, "Asphalts, Oils and Emulsions".

If there is a time delay prior to application of the asphalt membrane which is sufficient to cause surface drying, the Engineer may require the surface to be moistened.

I. TRAFFIC. The fly ash base shall be opened to traffic as specified on the plans or as directed by the Engineer, but in no case before being cured at least three days.

5. MAINTENANCE.

The Contractor will be required within the limits of his contract to maintain the fly ash base in good condition until all work has been completed and accepted. Maintenance shall include immediate repair of any defects that may occur. This work shall be done by the Contractor at his entire expense and shall be repeated as often as may be necessary to keep the area continuously intact. Repairs to fly ash base shall be effected by replacing the fly ash base for its full depth rather than by adding a thin layer of fly ash base to the layer of base in need of repair.

6. PENALTY FOR DEFICIENT BASE THICKNESS.

It is the intent of this specification that the fly ash base be constructed in strict conformity with the thickness and typical sections shown on the plans. Where any such base is found not so constructed, the following rules relative to adjustment of payment for acceptable fly ash base and to replacement of faulty fly ash base shall govern.

A. Base Thickness. The fly ash base will be measured for thickness by the Department prior to final acceptance. The thickness of the base will be determined by measurement of the base in a finished grade condition.

For the purpose of establishing an adjusted unit price for fly ash base, the unit to be considered is the full length of the fly ash base placement as shown on the plans. Three measurements will be taken at random by the Department in the unit. When the measurement from the unit is not deficient more than 0.5 inch from the plan thickness, full payment will be made. When such measurement is deficient more than 0.5 inch and not more than 1.5 inches from the plan thickness, an adjusted unit price as provided in Subarticle (2) will be paid for the unit represented.

In calculating the average thickness of the fly ash base, measurements which are in excess of the specified thickness by more than 0.2 inch will be considered as the specified thickness plus 0.2 inch, and measurements which are less than the specified thickness by more than 1.5 inches will not be included in the average.

When any measurement is less than the specified thickness by more than 1.5 inches, the actual thickness of the fly ash base in this area will be determined by taking additional measurements at 10-foot intervals parallel to the center line in each direction from the affected location until in each direction a thickness is found which is not deficient by more than 1.5 inches. Areas found deficient in thickness by more than 1.5 inches shall be evaluated by the Engineer and, if in his judgment the deficient areas warrant removal, they shall be removed and replaced with fly ash base of the thickness shown on the plans.

Exploratory measurements for deficient thickness will not be used in averages for adjusted unit price.

9. Price Adjustments. Where the average thickness of fly ash base is deficient in thickness by more than 0.5 inch, but not more than 1.50 inches, payment will be made at an adjusted price as specified in the following table.

Fly Ash Base Deficiency

Deficiency in Thickness Inches	Proportional Part of Contract Price Allowed
0.00 thru 0.50	100 Percent
0.51 thru 0.75	80 Percent
0.76 thru 1.00	70 Percent
1.01 thru 1.25	60 Percent
1.26 thru 1.50	50 Percent

When the thickness of fly ash base is deficient by more than 1.50 inches and the judgment of the Engineer is that the area of such deficiency should not be removed and replaced, there will be no payment for the area retained.

C. No additional payment over the contract unit price will be made for any fly ash base of thickness exceeding that required by the plans.

7. MEASUREMENT.

Fly ash base will be measured by the square yard of surface area of completed and accepted work.

8. PAYMENT.

The work performed and materials furnished as prescribed by this item and measured as provided under "Measurement" above will be paid for at the unit prices bid per square yard for "Fly Ash Base (Density Control)" of the depth specified.

The unit prices bid will be full compensation for securing and furnishing all materials; including all royalty, freight and storage involved; for all processing, crushing and loading; for all hauling, delivering, stockpiling, placing, spreading, blading, mixing, stripping, dragging, finishing, curing and maintaining; for all fine grading; for wetting and compacting and all manipulation, labor, tools, and incidentals necessary to complete the work.

STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION

Departmental Materials Specification: D-9-8900
Fly Ash

I. **Description:** This specification shall govern for the composition, quality, sampling and testing of two types of fly ash. Fly ash is hereby defined as the finely divided residue or ash that remains after burning finely pulverized coal at high temperatures.

II. **Bidder's and/or Supplier's Requirements:**

A. **Procurement by the State:** All prospective bidders are hereby notified that, before any bid is considered, the material proposed for submission shall be a material on the list of approved sources of material covered by this specification maintained by the Department.

B. **Contracts:** All contractors and/or suppliers on contracts are hereby notified that all fly ash, utilized in production of products for the Department shall be a fly ash from a source shown on the list of approved sources of fly ash maintained by the Department.

III. **Payment:**

A. **Procurement by the State:** Payment for all materials under this specification shall be in accordance with the conditions prescribed in the contract awarded by the State.

B. **Contracts:** All materials under this specification utilized in the production of products for the Department will be paid for in accordance with the governing specifications for the items of construction in which fly ash is used.

IV. **Prequalification and Performance History:**

A. **Establishment of Prequalification as an Approved Source:** Prospective Bidders and/or Suppliers who desire to establish prequalification for materials governed by this specification, should contact the Materials and Tests Engineer, State Department of Highways and Public Transportation, Austin, Texas 78703.

The following information must accompany the request for approval:

1. The name of the supplier or company
2. Location of the power plant
3. Coal origin
4. Storage facilities and capacity
5. Production procedures. Production procedures shall be one of the following:
   a. Use coal from only one origin.
   b. Use coal from two or more origins blended uniformly at a constant ratio prior to burning.
   c. Use coal from two or more origins with the fly ash from each stored in separate, identifiable units.
   d. Use coal from two or more origins stored and burned separately, and the fly ash kept separately until blended uniformly at a constant ratio prior to placing in storage.
6. Copies of test reports showing results obtained in their quality control program. (At least one test report per month for the previous six months shall be submitted.) The test reports shall include the coal origin, sampling and test date and all chemical requirements specified elsewhere in this specification.
7. Details of Quality Control Program shall be submitted along with request for prequalification. Details shall include measures taken to ensure that fly ash not meeting the requirements of this specification produced during shut-down or start-up and other operations is kept separated from material meeting the requirements of this specification.

B. **Sampling for Prequalification:** Sampling for establishment of prequalification as an approved source shall be in accordance with Test Method Tex-733-I. Prospective Bidders and/or Suppliers will be notified, after their material has been evaluated, as to conformance with requirements of this specification.

C. **Quality Control of Approved Sources:** Sources on the approved list must furnish the following items to the Materials and Tests Division on a monthly basis:

1. A copy of a test report showing results obtained in their routine quality control program. The test report shall include the coal origin, test date and results of all chemical requirements specified except available alkalies, as Na_2O.

2. A sample from the same material represented by the test report in 1, above, shall be submitted along with test report. Minimum sample size shall be 1 pint.

D. **Sampling for Quality Control of Approved Sources:** Sampling for quality control of sources on the approved source list shall be in accordance with Test Method Tex-733-I.

E. **Performance History:** Some of the tests required by this specification extend over a prolonged period of time and some tests cannot be made after the material is used. Therefore, testing for acceptance of materials supplied on any contract or State purchase order will only be considered on those materials which are identifiable by the Materials and Tests Engineer as being a material having an established performance history of compliance with the criteria established by this specification and shown on the list of approved sources.

F. **Re-evaluation:** When it is determined that changes have been made in the composition, burning process, or quality of a prequalified material that may affect its performance, a re-evaluation of the performance may be required. The Department reserves the right to conduct whatever tests are deemed necessary to identify a prequalified material and to determine if a change has been made in composition, burning process, or quality that may affect its performance. Changes that are detected in composition, burning process, or quality that may affect performance and have not been reported by the source may be cause for removal of that source from the list of approved sources of fly ash.

G. **Withdrawal, Approved Source:** A source may be removed from the approved list for the following reasons:

1. Any change in the production procedures, including the use of precipitator performance additives, from those shown in the original request for approval.

2. Failure of any project or source sample to comply with specification requirements.

3. A source becomes inactive and/or does not furnish fly ash to Department projects for a period of one year.

H. **Re-establishment as an Approved Source:** Any source that has been removed from the list of approved sources for any reason and desires to be re-established as an approved source shall document, in writing, to the Materials & Tests Engineer that the cause for removal has been corrected and request prequalification in accordance with Article IV. Prequalification and Performance History of this specification. In addition, the supplier seeking re-establishment as an approved source shall stipulate that all costs associated with re-establishment will be borne by the supplier and shall be paid to the Department prior to replacement on the list of approved sources.

V. **Sampling and Testing:** Sampling and testing shall be in accordance with the Department of Highways and Public Transportation, Materials and Tests Division Manual of Testing Procedures, Test Method Tex-733-I. Easy access shall be provided for sampling.

VI. **Packaging:** When packaged in bags for shipment and/or delivery to a project, each bag shall contain approximately one cubic foot of fly ash, volume shall be based on bulk density. Each bag shall be labeled with the following:

A. Supplier

B. Power Plant Location

C. Net Weight *

D. Type of Fly Ash

* Weight from bag to bag shall not vary more than plus or minus 5% of the weight shown on bag.

VII. **Material Requirements:** This specification covers the general and specific requirements for two types of fly ash. Both types of fly ash shall meet all requirements of this specification except when specific requirements are shown for a particular type of fly ash.

A. **Chemical Requirements:** Fly ash shall conform to the chemical requirement for each type as shown in the following table.

	Type A	Type B
Silicon dioxide (SiO_2) plus aluminum oxide (Al_2O_3) plus iron oxide (Fe_2O_3), min, %	65.0	50.0
Sulfur trioxide (SO_3), max, %	5.0	5.0
Calcium Oxide (CaO), Variation in percentage points of CaO from the average of the last 10 samples (or less provided 10 have not been tested) shall not exceed plus or minus	4.0	4.0
Magnesium Oxide (MgO), max, %	5.0*	5.0*
Available alkalies, as Na_2O, max, %	1.5	1.5
Moisture content, max, %	2.0	2.0
Loss on ignition, max, %	3.0	3.0

* When the autoclave expansion or contraction limit is not exceeded, an MgO content above 5.0% may be acceptable.

B. **Physical Requirements:** Fly ash shall conform to the physical requirements for each type as shown in the following table.

	Type A	Type B
Fineness —— retained on 325 sieve (45 cm), max. %	30.0	30.0
Variation in percentage points retained on the 325 sieve from the average of the last 10 samples (or less provided 10 have not been tested) shall not exceed	5.0	5.0

Pozzolanic activity index with portland cement as a minimum percentage of the control at 28 days	75	75
Water requirement, maximum percentage of control	100	100
Soundness autoclave expansion or contraction, maximum %	0.8	0.8
Increase of drying shrinkage of mortar bars at 28 days, maximum percent	0.03	0.03
Reactivity with cement alkalis mortar expansion at 14 days, maximum percent	0.020	0.020
Specific gravity, maximum variation from average %	5.0	5.0

Drying shrinkage shall be tested in accordance with ASTM C 157.

Alkali reactivity shall be tested in accordance with ASTM C 441.

Specific gravity shall be tested in accordance with ASTM C 188.

All other physical requirements shall be tested in accordance with ASTM C 311.

D-9-8900
9-83