GEORGIA INSTITUTE OF TECHNOLOGY — OFFICE OF CONTRACT ADMINISTRATION

PROJECT ADMINISTRATION DATA SHEET

[X] ORIGINAL [ ] REVISION NO. _____

Project No. E-20-616 (R5878-0A0) GTRI/~~GIT~~ DATE 1 / 25 / 85

Project Director: Dr. Quentin L. Robnett School/~~Lab~~ Civil Engineering

Sponsor: Southern Company Services, Inc.

Type Agreement: Contract No. 195-84-026 (Letter Agreement dated ~~12/21~~/84)*

Award Period: From 12/21/84 To ~~12/31/85~~ 9-30-86 (Performance) 7-31-86 (Reports)

Sponsor Amount:

	This Change	Total to Date
Estimated:	$ 1,000	$ 1,000
Funded:	$ 1,000	$ 1,000

Cost Sharing Amount: $ _____ Cost Sharing No: _____

Title: Ash Field Demonstration Project - Alabama

ADMINISTRATIVE DATA

OCA Contact Brian J. Lindberg X4820

1) Sponsor Technical Contact:

C. Lamar Larrimore
Southern Company Services, Inc.
Research and Development Dept.
P. O. Box 2625
Birmingham, AL 35202
(205) 870-6920

2) Sponsor Admin/Contractual Matters:

Charles L. Hughes
Contract Services
Southern Company Services, Inc.
P. O. Box 2625
Birmingham, AL 35202
(205) 877-7568

Defense Priority Rating: N/A

Military Security Classification: N/A

(or) Company/Industrial Proprietary: See Below

RESTRICTIONS

See Attached N/A Supplemental Information Sheet for Additional Requirements.

Travel: Foreign travel must have prior approval – Contact OCA in each case. Domestic travel requires sponsor approval where total will exceed greater of $500 or 125% of approved proposal budget category.

Equipment: Title vests with None Proposed or Anticipated

COMMENTS:

*Letter agreement to be superceded by final contract currently being drafted. Non-disclosure agreement will be a part of the agreement and executed along with the final contract.

COPIES TO:

I. D. No. 02.218.000.85.003

Project Director
Research Administrative Network
Research Property Management
Accounting
Procurement/EES Supply Services
Research Security Services
Reports Coordinator (OCA)
Research Communications (2)
GTRI
Library
Project File
Other A. Jones

FORM OCA 4:383

GEORGIA INSTITUTE OF TECHNOLOGY OFFICE OF CONTRACT ADMINISTRATION

SPONSORED PROJECT TERMINATION/CLOSEOUT SHEET

Date 11/20/86

Project No. E-20-616 School/~~Lab~~ CE

Includes Subproject No.(s) N/A

Project Director(s) Dr. Quentin L. Robnett GTRC / ~~GIT~~

Sponsor Southern Company Services, Inc.

Title Ash Field Demonstration Project - Alabama

Effective Completion Date: 9/30/86 (Performance) _____ (Reports)

Grant/Contract Closeout Actions Remaining:

- [ ] None
- [XX] Final Invoice or Final Fiscal Report
- [ ] Closing Documents
- [ ] Final Report of Inventions
- [ ] Govt. Property Inventory & Related Certificate
- [ ] Classified Material Certificate
- [ ] Other _____

Continues Project No. _____ Continued by Project No. _____

COPIES TO:

Project Director
Research Administrative Network
Research Property Management
Accounting
Procurement/GTRI Supply Services
Research Security Services
Reports Coordinator (OCA)
Legal Services

Library
GTRC
Research Communications (2)
Project File
Other I. Newton
A. Jones
R. Embry

FORM OCA 69.285

FINAL REPORT
SCEGIT-86-112

USE OF POWER PLANT ASH IN PAVEMENT CONSTRUCTION ON U.S. 280 NEAR HARPERSVILLE, AL

Prepared by

Dr. Quentin L. Robnett

Prepared for

Southern Company Services, Inc.
Birmingham, Alabama

July 1986

GEORGIA INSTITUTE OF TECHNOLOGY
A UNIT OF THE UNIVERSITY SYSTEM OF GEORGIA
SCHOOL OF CIVIL ENGINEERING
ATLANTA, GEORGIA 30332

1986

SCEGIT-86-112

Use of Power Plant Ash in Pavement Construction on U. S. 280 Near Harpersville, AL

FINAL REPORT

Prepared by

Dr. Quentin L. Robnett
School of Civil Engineering
Georgia Institute of Technology

Prepared for

Southern Company Services, Inc.
Birmingham, Alabama

SCS Project Manager
C.L. Larrimore
Research and Development Department

July, 1986

ACKNOWLEDGEMENTS

The progress and success of this project benefited greatly from the assistance and cooperation of a number of individuals and organizations. Recognition and sincere appreciation are due the following:

Southern Company Services - S.R. Hart, Jr. (retired), Charles Goodman, Randall Rush

Alabama Power Company - Dennis Cole, Glen Gowens

Alabama Highway Department - J.P. Bohannon, Thomas Ingram, Larry Lockett, Fred McCullough (retired), Bill Page

Dunn Construction Company - Robert Dykes

Wilson Brothers Construction Company - Pat Wilson, Jr.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Section 1

INTRODUCTION

Utilities in the Southern electric system currently produce approximately 5 million tons of bottom ash and flyash each year. In addition, there is an estimated 50 million tons of ash currently stored in ponds and landfills around the system. Space limitations at many plants, together with high disposal costs, have provided incentives to find ways to use this waste material as a resource.

Presently most ash sales in the Southern electric system involve the use of dry flyash as a partial replacement for cement in concrete or as feed-stock for the manufacture of cement.

A potentially large-volume use in Alabama and other states in the Southern electric system is in highway construction, principally as a substitute for aggregate materials such as crushed stone and gravel in base and subbase layers. As shown in Figure 1.1, significant areas of Alabama have shortages of locally available aggregate for pavement construction. In many areas, local sources of paving material such as clay-gravel and chert are becoming harder to find and/or are of a quality not meeting current AHD specifications [1].

Transportation charges to import quality paving materials into these areas often represent a very significant portion of paving material costs. Hence, locally available materials such as power plant ash need to be carefully evaluated as to their technical and economic feasibility for providing paving materials, particularly for base and subbase layers.

During the period 1982-1985, the School of Civil Engineering, Georgia Institute of Technology (Atlanta, Ga.), conducted an extensive research program sponsored by Southern Company Services to evaluate the relative potential of various Southern electric system ash materials as a paving material. As a part of this study, basic properties and characteristics of a broad range of ash materials were determined. In addition, engineering and fundamental properties of various types of untreated and treated paving mixtures containing ash were carefully evaluated. This work, summarized in a final report to Southern Company Services [2] in conjunction with a

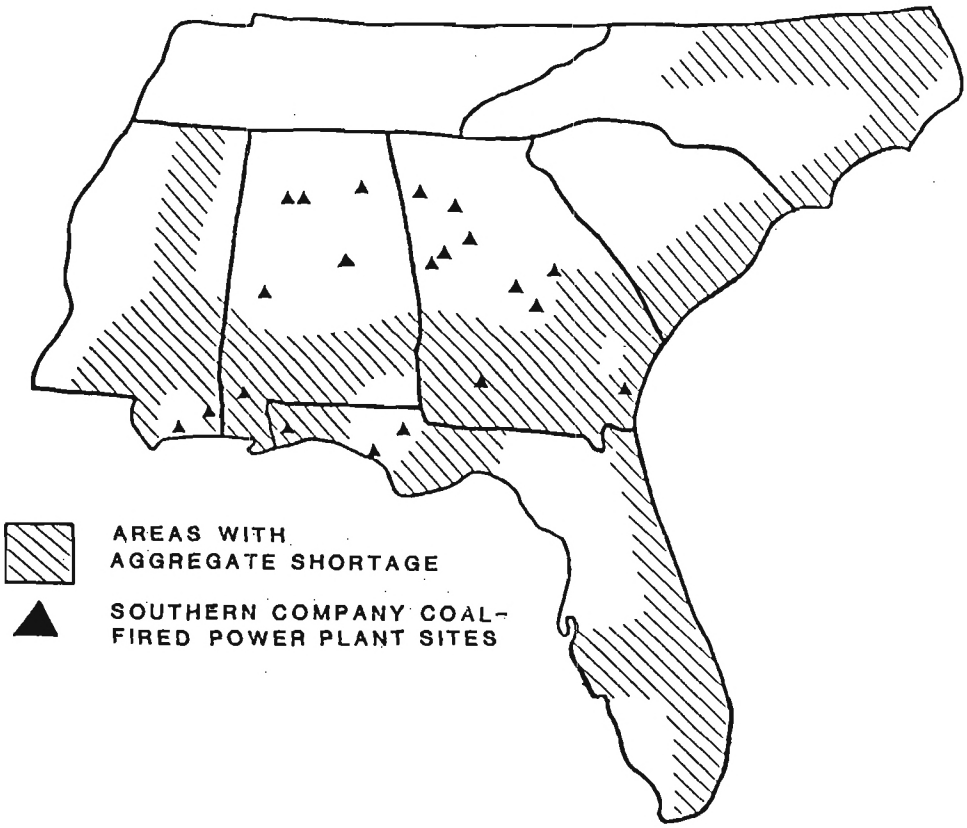


Figure 1.1. Areas of Southeast with Aggregate Shortages [Ref. 1].

previous literature study [3] showed that the coarse ash fraction can provide excellent quality paving material and that a number of power plants in the Southern electric system currently produce an excellent ash material suitable for base and subbase applications.

A necessary follow-up to this literature and laboratory study is verification of findings with field demonstrations on actual construction projects in the Southern electric system (Alabama, Florida, Georgia, and Mississippi). Field demonstration projects have been constructed in Alabama and Georgia during late 1984 and 1985. A project in Mississippi is scheduled for construction during 1986 and efforts are being made to obtain an ash demonstration project in Florida.

This report presents a description of the Alabama demonstration project constructed as a part of U.S. 280 reconstruction near Harpersville, Alabama (about 40 miles south and east of Birmingham) during late 1984 and 1985.

Section 2

PROJECT DESCRIPTION

GENERAL

After a number of discussions and meetings with the State of Alabama Highway Department (AHD) representatives from the Bureau of Materials and Tests in Montgomery as well as from the Division 4 office in Alexander City, an ash demonstration project site was identified along with the expected forms of ash utilization.

The primary AHD contacts during the project were:

Fred McCullough, Research Engineer, Bureau of Materials and Tests, Montgomery (now retired)

Thomas Ingram, District 4 Materials Engineer, AHD District 4, Alexander City

J. P. Bohannan, Project Engineer, AHD District 4, Alexander City

PROJECT LOCATION

The ash demonstration project site was a part of new construction along U.S. Highway 280 southeast of Birmingham near Harpersville in eastern Shelby County. This location is less than 10 miles from Alabama Power Company's (APC) Plant Gaston, which is located near Wilsonville. Figure 2.1 provides a general area location map for the construction site and Plant Gaston.

GENERAL PROJECT DESCRIPTION

The project required that the old highway 280 be widened to a total of 4 lanes (each 12 ft. wide) with two lanes in each direction separated by a 42-ft. wide grassed median except within Harpersville where a 14 ft. wide center-turn lane was included between the north and southbound lanes along with concrete curb and gutter along the sides of the 62 ft. wide paved area. Outside of Harpersville, shoulders were included, the outside and inside paved shoulders being 8 ft. and 4 ft. wide, respectively, with an additional 2 ft. unpaved portion.

Actually, this project involved two projects in that the work on Highway 280 was split into adjoining segments by AHD and contracted

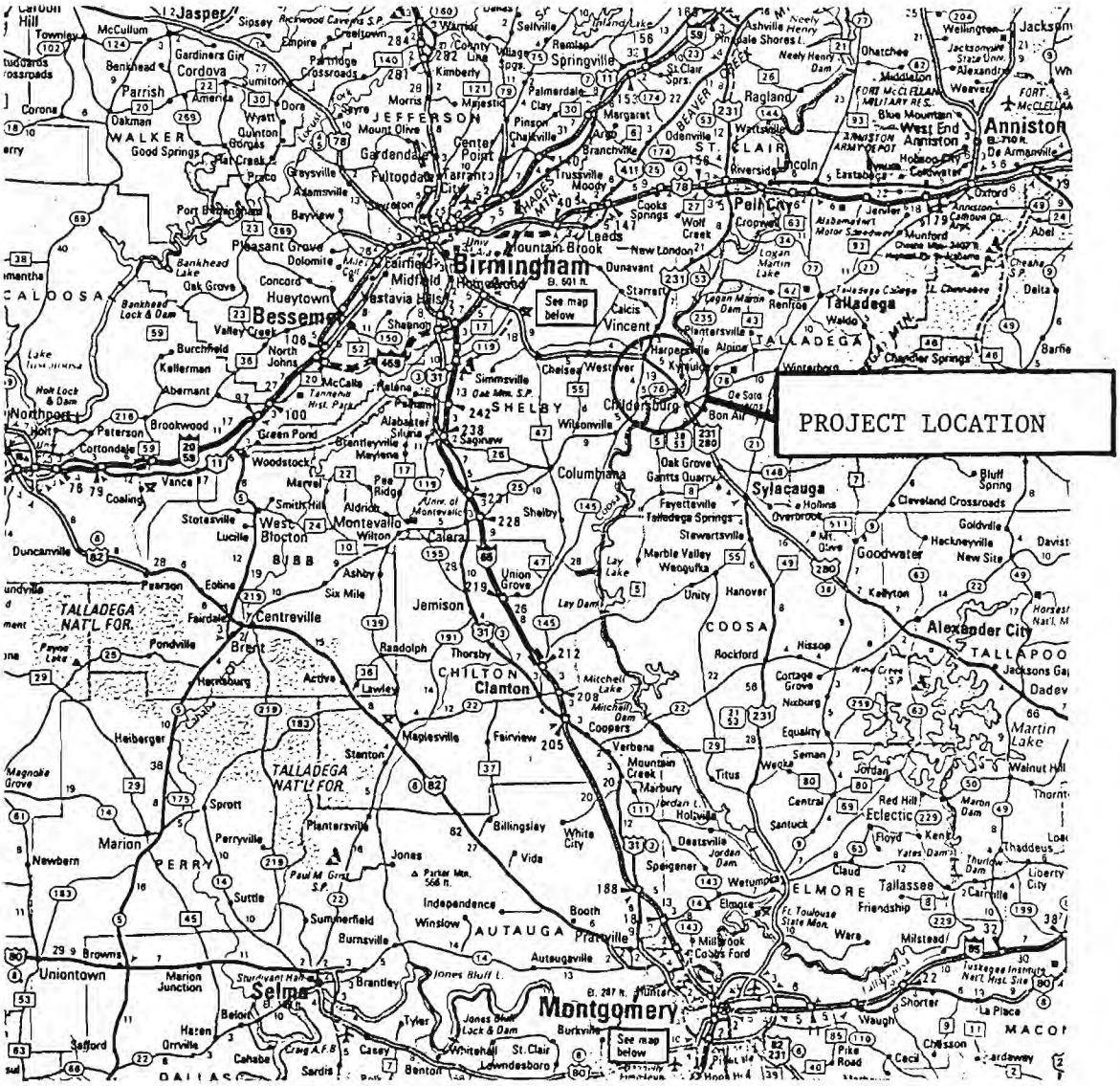


Figure 2.1. General Area Location Map.

separately to Dunn Construction Company (Dunn) of Birmingham and Wilson Brothers Construction Company (Wilson) of Childersburg. Dunn's work covered approximately 2.7 miles and ran from about 1.26 miles north (started at Station 1040 + 00) of the intersection with State Highway 25 (in Harpersville, Station 1116 + 34) to about 1.44 miles south (Station 1183 + 00) of this intersection. Wilson's work extended from the south terminus of the Dunn project over a distance of approximately 4.8 miles to approximately the Coosa River (Station 1436 + 14) at the north edge of Childersburg.

Separate from these two projects, new bridges were built over the Coosa River at the south end of the Wilson section (northbound only) and at the north end, over the Seaboard Coastline Railroad (carries both north and southbound traffic).

Throughout this alignment, old Highway 280 consisted of a two-lane, 22 ft. wide pavement. The old pavement was used extensively as a part of the construction project, particularly on Wilson's portion. For example, on the Wilson project, the old pavement was widened from 22 ft. by adding 2 ft. of pavement on the inside, followed by subsequent overlaying of the old pavement with about 1.5 inches of bituminous concrete plus the addition of shoulders. This reconstructed section provided the southbound lanes. The northbound lanes were newly constructed.

On Dunn's project the old U. S. 280 pavement was used as follows:

Station		
1044 to 1064	-	old U.S. 280 used in northbound lanes; southbound lanes newly constructed
1064 to 1107	-	old U.S. 280 removed and both north and southbound sections newly constructed
1107 to 1183	-	(within Harpersville) old pavement retained, and about 20 ft. of new pavement built on each side.

FORMS OF ASH USE

Ash from Plant Gaston was used extensively on both the Dunn and Wilson projects although in a slightly different way for each.

On the Dunn project, Plant Gaston coarse ash excavated from the pond close to the outfall pipes was used as the subbase layer under all shoulders and most of the new mainline pavement. A total of about 20,000 tons of coarse ash was used. Early in the Dunn project, chert was used as the subbase material (all mainline pavement subbase north of the railroad) but

problems with excessive plasticity forced a change.

On the Wilson project, finer-textured ash (previously excavated by Alabama Power from the ash pond and stockpiled close to the entrance of Plant Gaston) was used to mechanically stabilize an "out-of-spec" clay-gravel obtained from a pit adjacent to the roadway near the south end of the project. This blend was utilized by Wilson to construct the subbase layer for the shoulders and new pavement. The primary purpose of the ash treatment was to reduce the plasticity index of the clay-gravel to within an acceptable range as set forward by AHD specifications for Type B-1 or B subbase material. Early in Wilson's project, a manufactured sand from a marble production facility at Sylacauga was used to treat the clay-gravel. However, high FOB cost plus transportation costs forced Wilson to look for an alternative material with which to treat the clay-gravel.

For most of the project, Wilson used the ash at a rate of 40 to 50% by dry weight of the clay-gravel. A total of 12,000 to 14,000 tons of ash was used during construction of the clay-gravel subbase.

Subsequent discussion will provide more details of the ash utilization on each project.

PAVEMENT CROSS-SECTIONS

The **standard** pavement section designed by AHD and selected for use on these two projects is depicted in Figures 2.2 (Dunn) and 2.3 (Wilson). The standard pavement section essentially was to consist of:

Surface	-	plant mix bituminous concrete about 4-1/2 inches thick
Base	-	crushed stone (10 inches to 12 inches thick)
Subbase	-	chert or clay-gravel (6 inches thick)
Improved Subgrade	-	about 6 inches of mechanically-stabilized (with crushed stone) native subgrade
Subgrade	-	native subgrade (includes borrow as needed, particularly for the approach embankments at the bridges)

As mentioned previously, **ash** was used to modify (Wilson) or replace (Dunn) the originally intended clay-gravel or chert subbase. Figure 2.3 shows the typical pavement cross-section constructed by Wilson where ash was used to mechanically stabilize the clay-gravel subbase. Figure 2.2 depicts the pavement cross-section used by Dunn where coarse pond ash was used as the subbase layer.

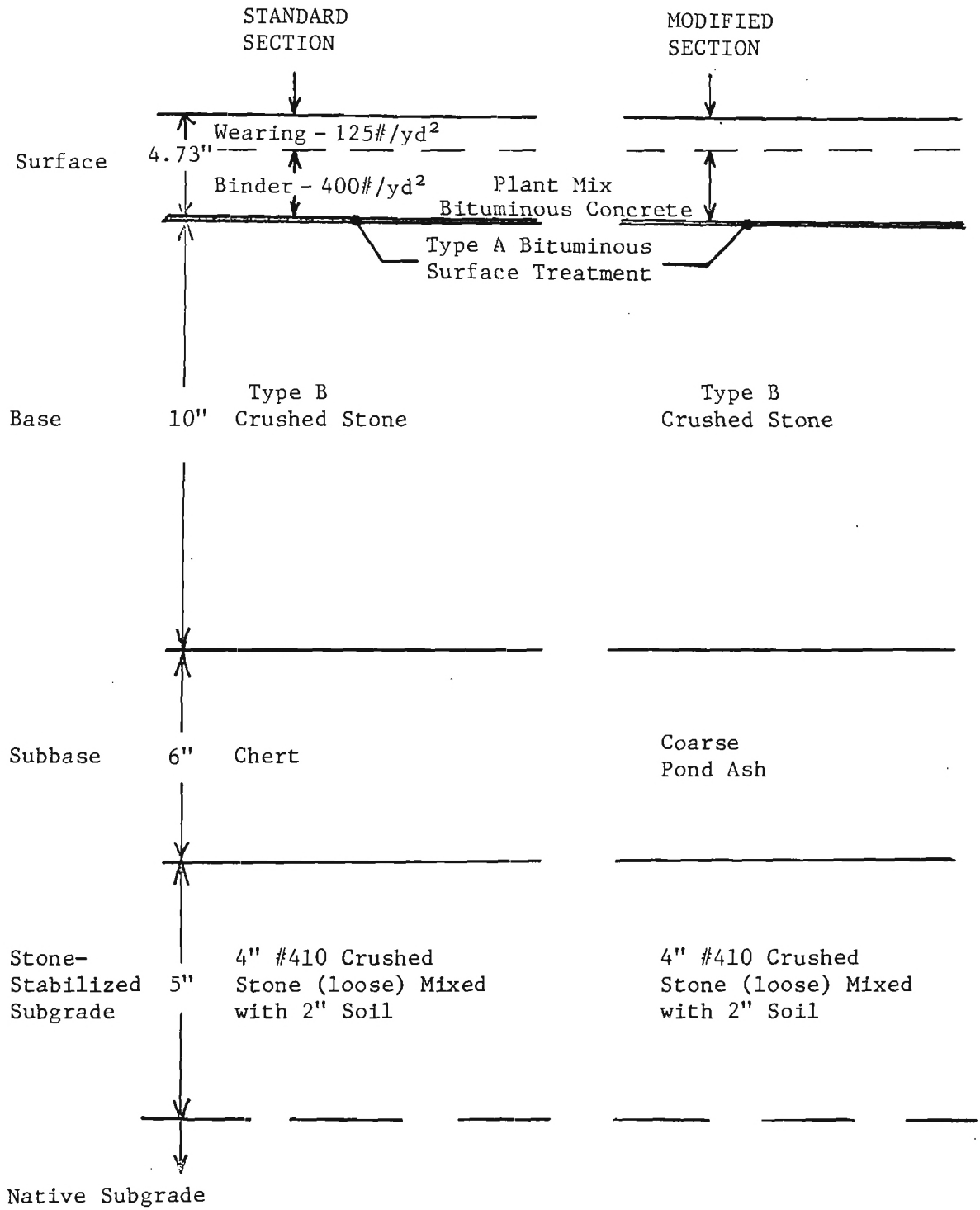


Figure 2.2. Standard and Modified Pavement Sections - Dunn Construction Company

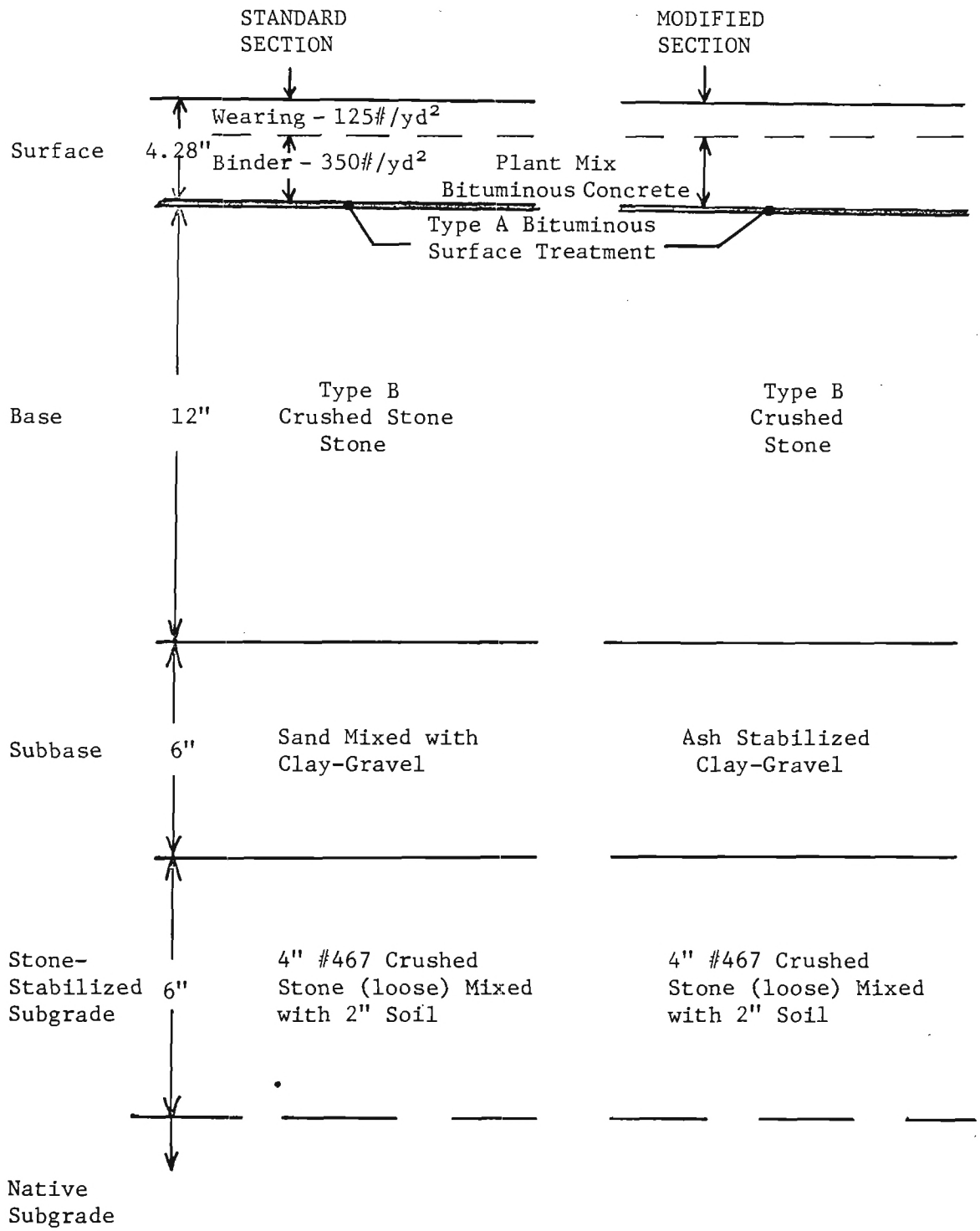


Figure 2.3. Standard and Modified Pavement Sections - Wilson Brothers Construction Company.

Where the old U.S. 280 pavement was used, it was widened with bituminous concrete as required and then overlaid with bituminous concrete. On the Dunn project, the overlay was slightly more than 4 inches thick whereas on the Wilson project, about 1-1/2 inches of overlay was used. Differences in overlay thicknesses are as a result of different projected traffic and different condition of the old pavement.

SIGNIFICANT DESIGN INFORMATION

During the design stages for these two projects, information shown in Table 2.1 was used in the thickness design calculations for the various pavement sections.

The old Highway 280 pavement cross-section was observed at the south edge of Harpersville and consisted of about 7 inches of bituminous concrete (included numerous overlays) and 8-10 inches of soil-aggregate base. The condition of the old pavement, in those locations where it was used as part of the new structure, was reasonably good but it did exhibit some longitudinal and alligator cracking, slight rutting and general surface roughness.

Table 2.1. Summary of Pertinent Pavement Design Information.

Design Information	Contract/Project Dunn	Contract/Project Wilson
Traffic (daily)		
1983-1984	6080-6940[a]	6670-9470[a]
20 yr projection	9970-11370[a]	10930-15520[a]
% trucks	11-15[a]	12
daily equiv. 18 kip single axle loads	219-261[a]	441-626[a]
Design CBR	7	9
Regional Factor	2	2
Terminal Serviceability Index	2.5	2.5
Structural Number		
Design	4.08	4.12-4.31[a]
Constructed	4.0-4.22[a]	4.42
Layer Coefficients		
Bituminous concrete surface	0.44	0.44
crushed stone base	0.14	0.14
subbase (all types on project)	0.10	0.10
stone-stabilized subgrade	0.05	0.05

(a) Actual values depended on location within the specific project.

Section 3

CONSTRUCTION OF ASH SUBBASE LAYERS

GENERAL

As previously described, ash was used in two slightly different ways on this demonstration project. Wilson used fine-grained ash to mechanically stabilize through dilution, the "out-of-spec" clay-gravel (obtained from pit near south end of the project). This blend was then used in lieu of sand-stabilized clay-gravel as the subbase layer. Dunn reclaimed relatively coarse pond ash from the ash pond at Plant Gaston and used it as the subbase material in lieu of the originally intended chert. For both contractors, only slightly different than normal construction methods were required. In general, the only unusual equipment required by either contractor for their construction of the paving components containing ash was the Rex Rotary Mixer used by Wilson.

The following subsections describe in detail the methods and equipment used by the contractors to construct the subbase components which incorporated ash from Plant Gaston.

ASH STABILIZED CLAY-GRAVEL

Initially, a 1000 ft. long test section of the ash stabilized clay-gravel was constructed by Wilson to demonstrate to AHD that a high quality subbase could be reasonably and practically constructed.

The general construction sequence used by Wilson was as follows:

1. Prepare the subgrade to design density and elevation.
2. Add 4 inches (loose) of AHD #467 crushed aggregate and mix with 2-3 inches of subgrade. Compact this blend to required density (compacted thickness was to be 5 inches).
3. Haul in clay-gravel, spread and lightly compact with traffic roller. The actual thickness of clay-gravel depended on the amount of ash to be blended with the clay-gravel (C-G/ash blends of 60/40 and 50/50 were used).
4. Haul in and windrow longitudinally the amount of ash necessary for the desired blend (see Figure 3.1).

Figure 3.1. Ash Being Dumped on Clay-Gravel Prior to Blending - Wilson Project.

5. Using a motor-grader, blade the ash transversely to a full-width loose layer of the desired thickness.

6. Initially scarify with the motor-grader through the ash into the clay-gravel layer and blade the loose material into a windrow.

7. Thoroughly blend the ash with the clay-gravel. Blending was accomplished with 4 passes of a Rex rotary mixer, Figure 3.2, followed by numerous passes of a disk, Figure 3.3, and continued blading with a motor-grader, Figure 3.4. Blending continued until all streaking of the gray ash in the red clay-gravel was eliminated. (Wilson believed that the use of the Rex mixer could be eliminated; all blending could be accomplished with the disk and motor-grader. However, it was obvious that the Rex mixer provided a much more efficient way to accomplish mix blending).

8. During the blending operations, adjust the moisture content (either through aeration or water addition) to bring the mix to optimum moisture content. (Typically, the mix had to be aerated since the clay-gravel from the pit had excessive moisture.)

9. Following the blending operations, with the motor-grader blade the mix into a loose lift of uniform thickness over the width desired.

10. Compact the ash-stabilized clay-gravel using a tamping foot roller with large contact area and short shanks, Figure 3.5.

11. After satisfying compaction specifications (100% AASHTO T-180 @ a moisture content within ±2% of laboratory optimum), use a motor-grader to smooth and trim the surface to final grade. A vibratory steel wheel roller was then used to compact and seal the surface.

Through some experimentation, Wilson found that the most efficient compaction was accomplished with a tamping foot roller which consisted of short-shanked pads with about 4 inches cross-face dimension, Figure 3.5. An extremely heavy (50 ton) Hyster tapered-shank, tamping foot roller did not work well. Also, a Cat Model 815 sheepsfoot roller with tapered shanks was found to be unsatisfactory. Apparently both of these compactors initially densified the mix; however, with additional passes, these compactors seemed to tear up or fluff the compacted layer causing actual loss of density.

Overall, no problems were encountered in meeting AHD specifications for the subbase layer. Gradation and plasticity index values were well within specification limits for the blends used. Once the correct compaction equipment and sequence were identified, no problems were encountered in meeting density requirements.

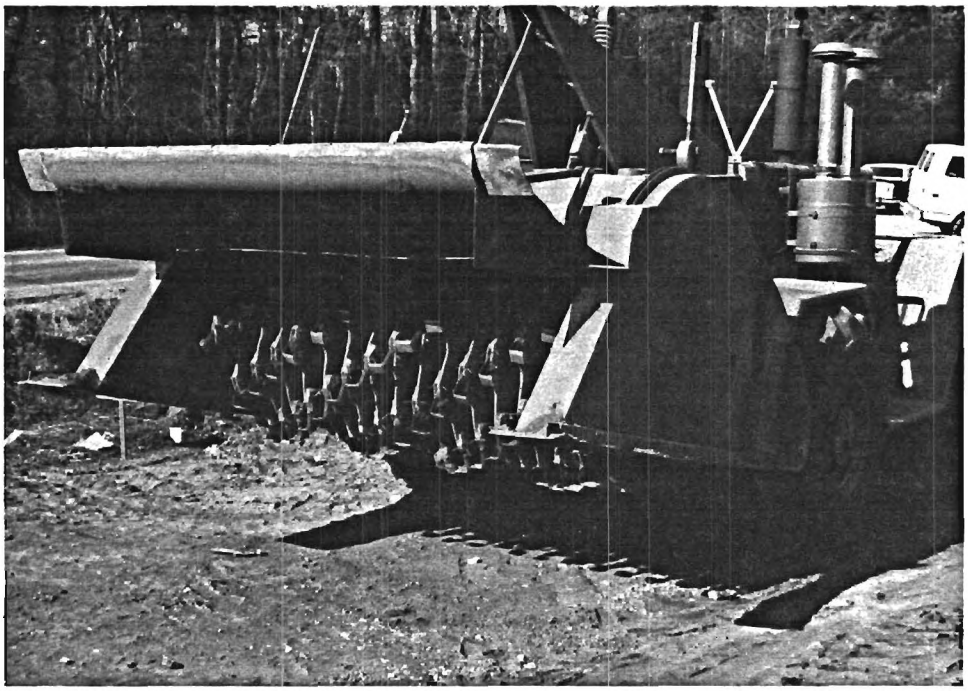


Figure 3.2. Blending of Ash with Clay-Gravel Using Rex Rotary Mixer - Wilson Project.

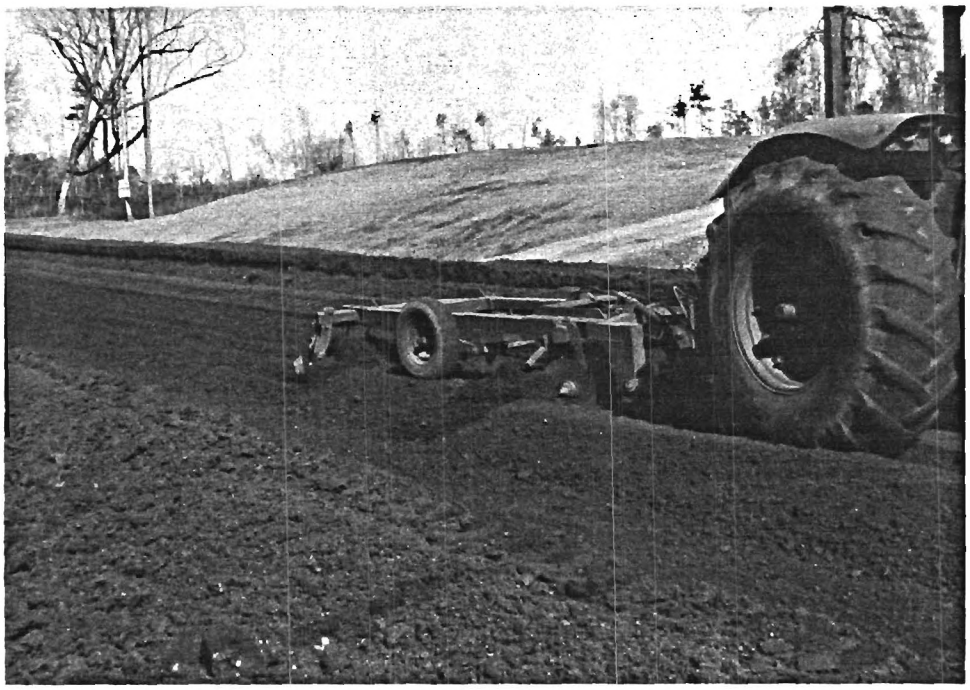


Figure 3.3. Blending of Ash with Clay-Gravel Using Disk - Wilson Project.

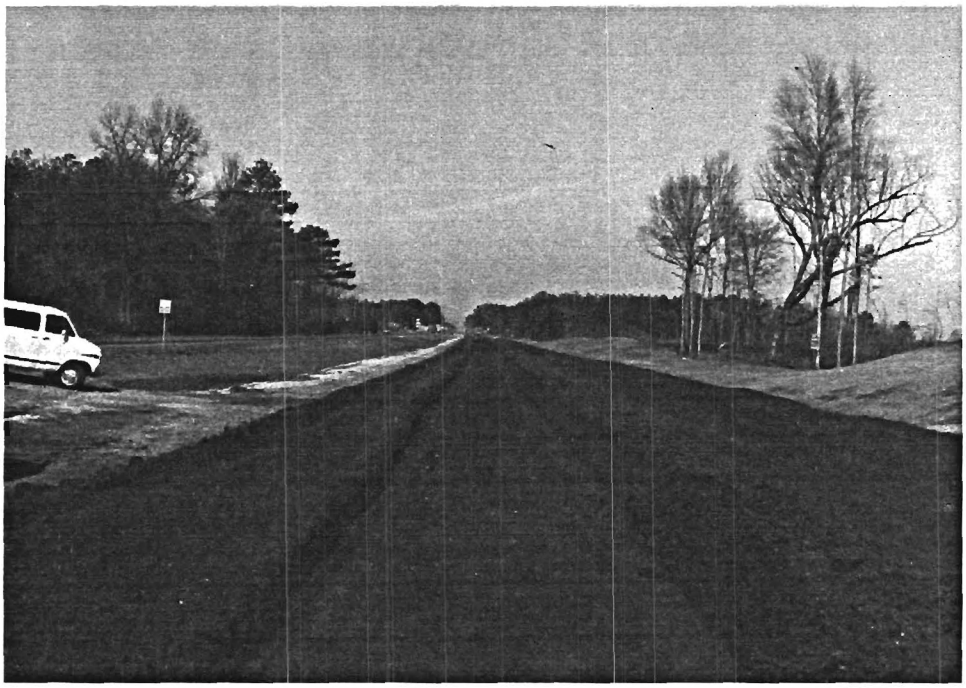


Figure 3.4. Blading Ash - Clay-Gravel Mix - Wilson Project.

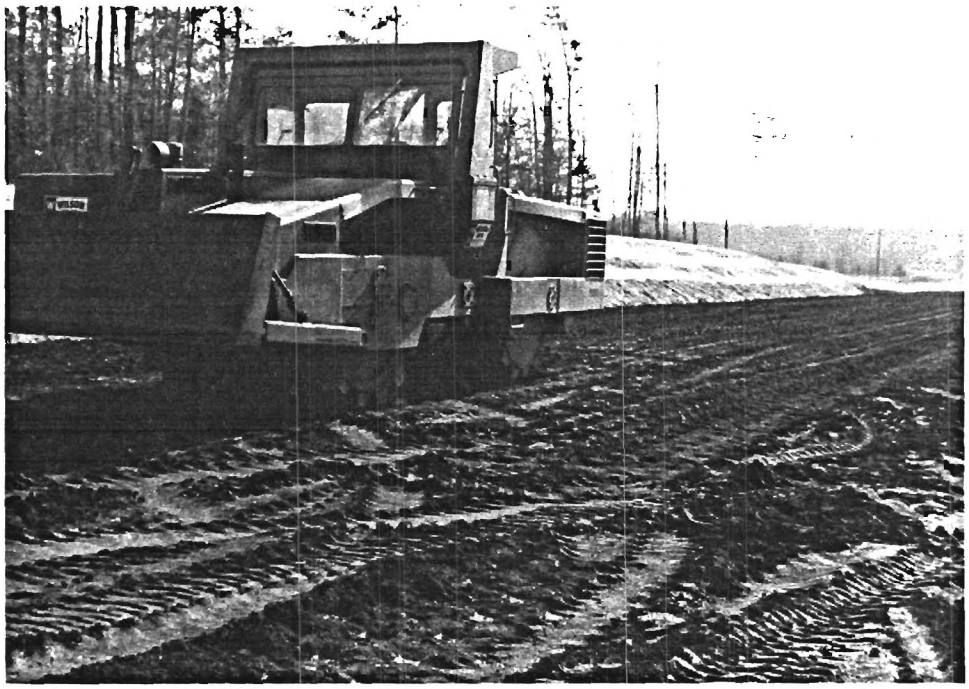


Figure 3.5. Compaction of Ash - Clay-Gravel Subbase - Wilson Project.

COARSE POND ASH SUBBASE

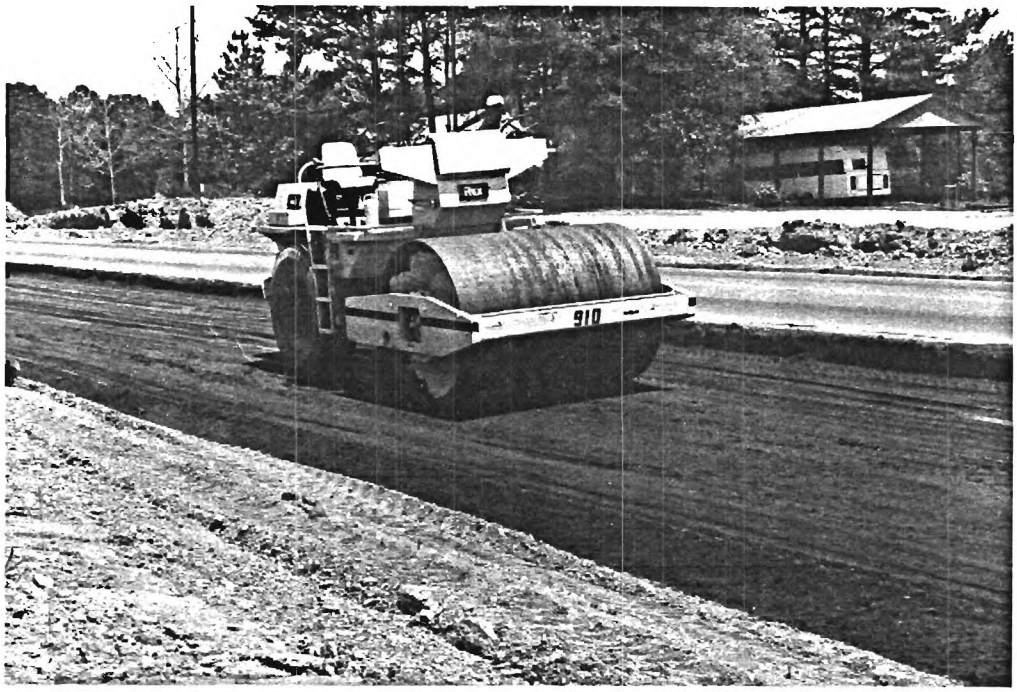
On the Dunn project, initial plans were to use chert as the subbase. The source of chert used by Dunn produced a material which periodically exceeded allowable plasticity limits for AHD Type B-1 subbase (PI ≤ 15). Consideration was given to mechanical stabilization of the chert to reduce the plasticity. However, Dunn also proposed to AHD that coarse pond ash from Plant Gaston be substituted for the chert.

The initial effort by Dunn to use the coarse pond ash consisted of constructing a short test section. A combination of a Rex vibratory steel wheel roller, heavy rubber tire roller, and a heavy steel wheel roller was used for compaction. On this early attempt, only 90-95% of laboratory maximum dry density was obtained (specs require 100% of laboratory AASHTO T-180c density at ±2% moisture of optimum).

Later (Feb. 20, 1985) a carefully controlled 500 ft. long ash subbase test section was constructed as a part of a county road just south of the bridge over the railroad. Here the coarse ash was placed and the moisture content adjusted by sprinkling with a water truck. Continued compaction with a heavy Rex vibratory roller, Figure 3.6, did not provide sufficient densification to meet compaction specifications. Density checks were made with a nuclear gage using the direct transmission mode. The problem was thought to be related to an abnormally high laboratory density obtained when compacting the friable, noncohesive coarse ash into a steel mold which provided unrealistic confinement compared to typical job conditions.

After some discussions by AHD personnel from Montgomery and FHWA representatives, it was decided to use the control strip method (AHD 225) to establish field compaction target density. This method basically requires the following:

1. Place the ash on a 500 ft. long tangent section and bring it to approximately optimum moisture content by sprinkling heavily with a water truck.
2. Begin rolling with proposed equipment with occasional light blading of the surface (Dunn used a 32,600 lb. rubber tire and a 19,400 lb. Rex vibratory steel wheel).
3. Select 10 random locations for density evaluation.
4. At each location obtain duplicate nuclear readings.
5. Continue to roll with periodic density determinations.



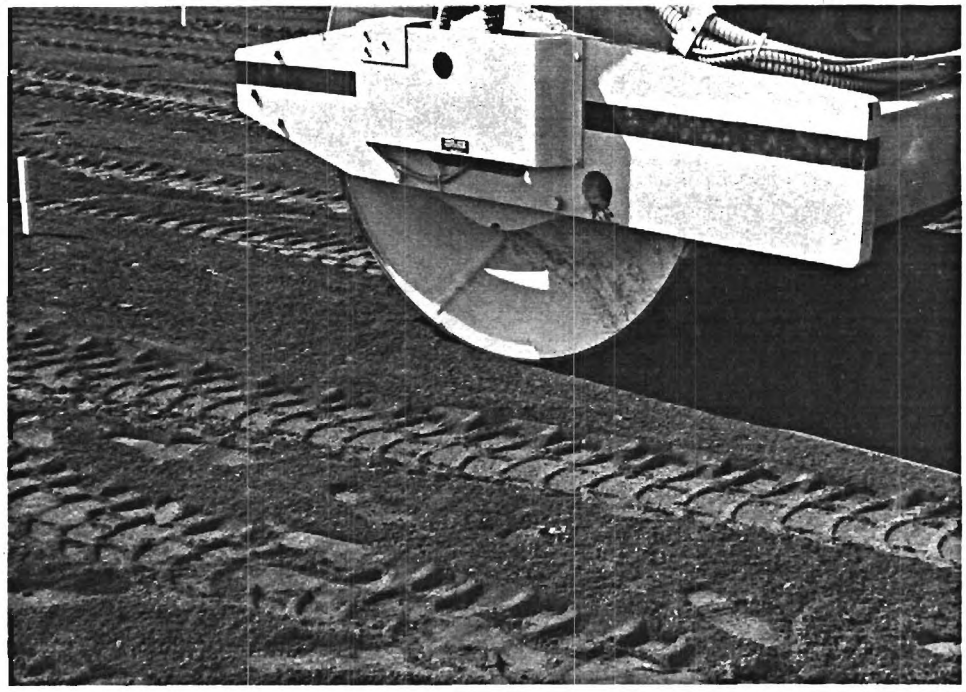


Figure 3.6. Compaction of Ash Subbase with Rex Vibratory Roller - Dunn Project.

6. Determine the maximum attainable dry density based on the average of the 20 readings (this is established as the subsequent target density). The individual readings shall be within ±7% of the mean.

A total of 2 passes of the rubber tire and 12 passes of the Rex vibratory roller produced maximum density although at other control strips, less effort was required.

When a significant change (as defined by AHD) occurs in the material from a given source, an additional control strip must be constructed. AHD established an allowable gradation band for the pond ash based on the #8 and #200 sieves. Four control strips were constructed with the pond ash subbase material during the Dunn project.

After implementing the control strip method for density control, Dunn had little trouble in obtaining density (specifications required ≥98% of target density) on subsequent coarse ash subbase construction. Some slight changes in ash gradation during the course of subbase construction did require the construction of additional control strips as previously mentioned.

The general construction sequence used by Dunn for the coarse pond ash subbase is as follows:

1. Prepare the subgrade to specified density and elevation.
2. Add about 4 inches (loose) of AHD #410 crushed stone and mix with about 2-3 inches of subgrade. Compact this blend to required density (compacted thickness was about 6 inches).
3. Load ash from pond at Plant Gaston and haul to a stockpile at job site. Allow excess water to drain from ash. Then haul ash to roadway and end-dump into place, see Figure 3.7.
4. Use motor-grader to blade ash to approximate loose thickness required for a 6-inch thick compacted layer, see Figure 3.8.
5. Using water truck (see Figure 3.9), add a large amount of water to the surface - a quantity sufficient to "flood" the subbase such that excess water flowed-out of the ash onto the shoulder (much the same as flooding of crushed stone materials). That portion of water retained by capillary tension was sufficient to provide ±2% of optimum compaction moisture.
6. Compact the coarse ash subbase with a Rex vibratory steel wheel roller (about 6 passes in general were found to be necessary), see Figure 3.6, and two passes of the rubber tire roller.

Figure 3.7. Dumping Pond Ash Subbase Material - Dunn Project.

Figure 3.8. Motorgrader Blading Loose Ash Subbase Material Prior to Compaction - Dunn Project.

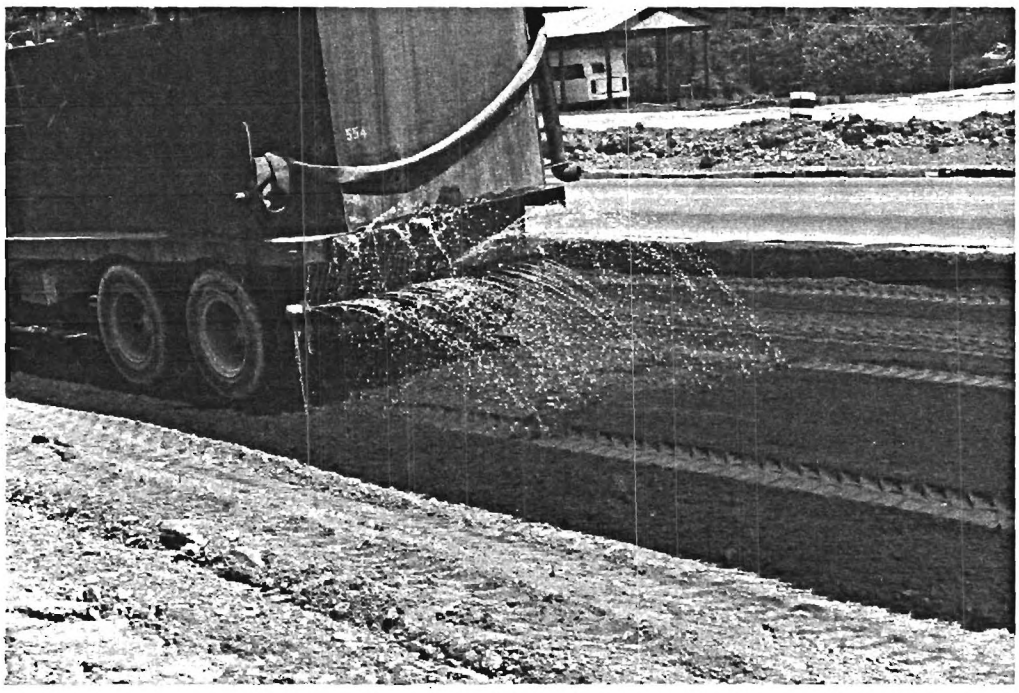


Figure 3.9. Watering Ash Subbase Material Prior to Compaction - Dunn Project.

7. Check density.

8. Trim to final grade with motor-grader.

9. Final-roll surface of coarse ash with traffic roller or steel wheel roller.

Several important observations were made during the coarse ash subbase construction:

1. When the surface is wet (immediately after application of water) some tracking may occur under traffic. However, when the surface dries, excellent resistance was developed to surface disturbance by construction traffic.

2. Because of the coarseness of the ash, surface-applied water easily penetrates the layer, minimizing the need for processing to distribute moisture. Uniform moisture distribution is needed during compaction.

3. At unconfined edges, the coarse ash tends to move out from under the vibratory roller. This may cause problems in maintaining thickness control and densification at the edges. The use of trench construction or the placement of a small berm along the edge would help to minimize this potential problem.

4. Flooding of the coarse ash with water seemed to be a practical way of providing moisture and also seems to cause the particles to flow together. However, care must be exercised if trench construction is used because the excess water will be trapped, causing a very spongy, uncompactable mass which would actually tend to liquify under vibratory compaction.

5. After reclaiming ash from below the water level in the ash pond, excess water is often present. It is advisable to create a stockpile to allow the excess moisture to drain. This excessively wet material should not be dumped directly on the grade. However, if reasonably dry ash material is reclaimed (e.g., only slightly wet of optimum compaction moisture) intermediate stockpiling is not necessary.

The overall behavior of the coarse pond ash during construction was good. The contractor's (Dunn) personnel were enthusiastic about the ease with which the material handled. Tom Ingram and J. P. Bohannon of AHD both were pleased with the ash material and the way in which it facilitated high quality construction.

Section 4

MATERIALS AND TEST RESULTS

GENERAL

Construction of the U.S. Highway 280 projects required a number of different paving materials. Most of these materials were those typically used by the AHD for pavement construction and were required to conform to AHD specifications. The ash material that came from Plant Gaston however, has not been used in Alabama, although existing AHD specifications were used to control quality for the two different ash applications.

In this section, certain details will be presented concerning the specific types of paving materials used in the pavement construction. Characteristics of the pond ash used by Dunn as a subbase and the ash used by Wilson to mechanically stabilize the local clay-gravel will be discussed. Specific information are also presented relative to the properties and characteristics of the paving materials containing ash. In this regard, selected AHD laboratory and field quality control test results are included, in addition to results from special tests conducted by Georgia Tech.

CONVENTIONAL PAVING MATERIALS

The typical cross-sections of the pavements constructed by Dunn and Wilson have previously been presented in Figures 2.2 and 2.3. Following is a more detailed presentation of the pavement sections, compositional materials, and associated AHD Specification:

DUNN PAVEMENT

- Surface
  - Bituminous concrete wearing surface -- AHD Spec. 416A
  - Bituminous concrete binder -- AHD Spec. 414A
  - Tack coat -- AHD Spec. 405A
  - Bituminous surface treatment -- AHD Spec. 401A
- Base
  - Crushed stone, Type B -- AHD Spec. 825

- Subbase
  - Pond ash, Type B -- AHD Spec. 820.03
- Stone Stabilized Subgrade
  - AHD #410 crushed stone mixed with subgrade soil -- AHD Spec. 231-B
- Subgrade -- AHD Spec. 210 and 306

WILSON PAVEMENT

- Surface
  - Bituminous concrete wearing surface -- AHD Spec. 416A
  - Bituminous concrete binder -- AHD Spec. 414A
  - Bituminous surface treatment - Type A -- AHD Spec. 401A
- Base
  - Crushed stone, Type B -- AHD Spec. 825
- Subbase
  - Coarse pond ash, Type B -- AHD Spec. 820.03
- Stone Stabilized Subgrade
  - AHD #467 crushed stone mixed with subgrade soil -- AHD Spec. 321-B
- Subgrade -- AHD Spec. 210 and 306

Surface and Base Materials

Although substantial data were collected for the surface and base course paving materials by AHD prior to and during construction, the data are not presented in this report. The previous pavement descriptions and Figures 2.2 and 2.3 provide information as to the surface and base material types and thicknesses. If more detail is desired, the AHD Fourth Division Office in Alexander City, Alabama can be contacted.

Subgrade Soils

Because of the inherent variation of subgrade soil along the Highway 280 alignment and because of the importance of the subgrade in pavement design, construction and ultimate performance of the pavement, selected information for the subgrade soil is presented.

Preconstruction Test Results. In order to raise the grade to proper elevation, most of the pavement were placed on fill obtained from local borrow. According to the AHD pavement design study, the subgrade soils along the alignment contained the following AASHTO Classified soils: A-2-4, A-4, A-6, and A-7. The A-7 variety was stated to be predominant.

CBR tests conducted on representative samples of the soil along the alignment showed CBR values ranging from 5 to 11 for the Dunn project and 6 to 15 for the Wilson project. Effective design CBR values of 7 and 9 were used for thickness design calculations, respectively, for the Dunn and Wilson project pavements.

Construction Test Results - Wilson Project. A total of 24 tests of grain size and Atterberg Limits was obtained by AHD along the Wilson project length during the subgrade construction. The AASHTO Soil Classification of the samples ranged from A-4 to A-7 with 9 being classified as A-4, 14 being classified as A-6 and 1 being classified as A-7. For the 24 samples, the following were the range and average for selected index properties:

- Passing #200 sieve
  - range 44-82%
  - average 71%
- Liquid Limit
  - range 25-46%
  - average 33%
- Plasticity Index
  - range 9-15%
  - average 10.3%

In addition, numerous determinations were made of compacted density of the subgrade to ensure conformance to specifications (≥100% AASHTO T-99). These results are not presented in this report since all areas were found to meet specifications.

Construction Test Results - Dunn Project. A few subgrade characterization tests were conducted along the alignment of the Dunn project. The AASHTO Soil Classification of the samples ranged from A-4 to A-6.

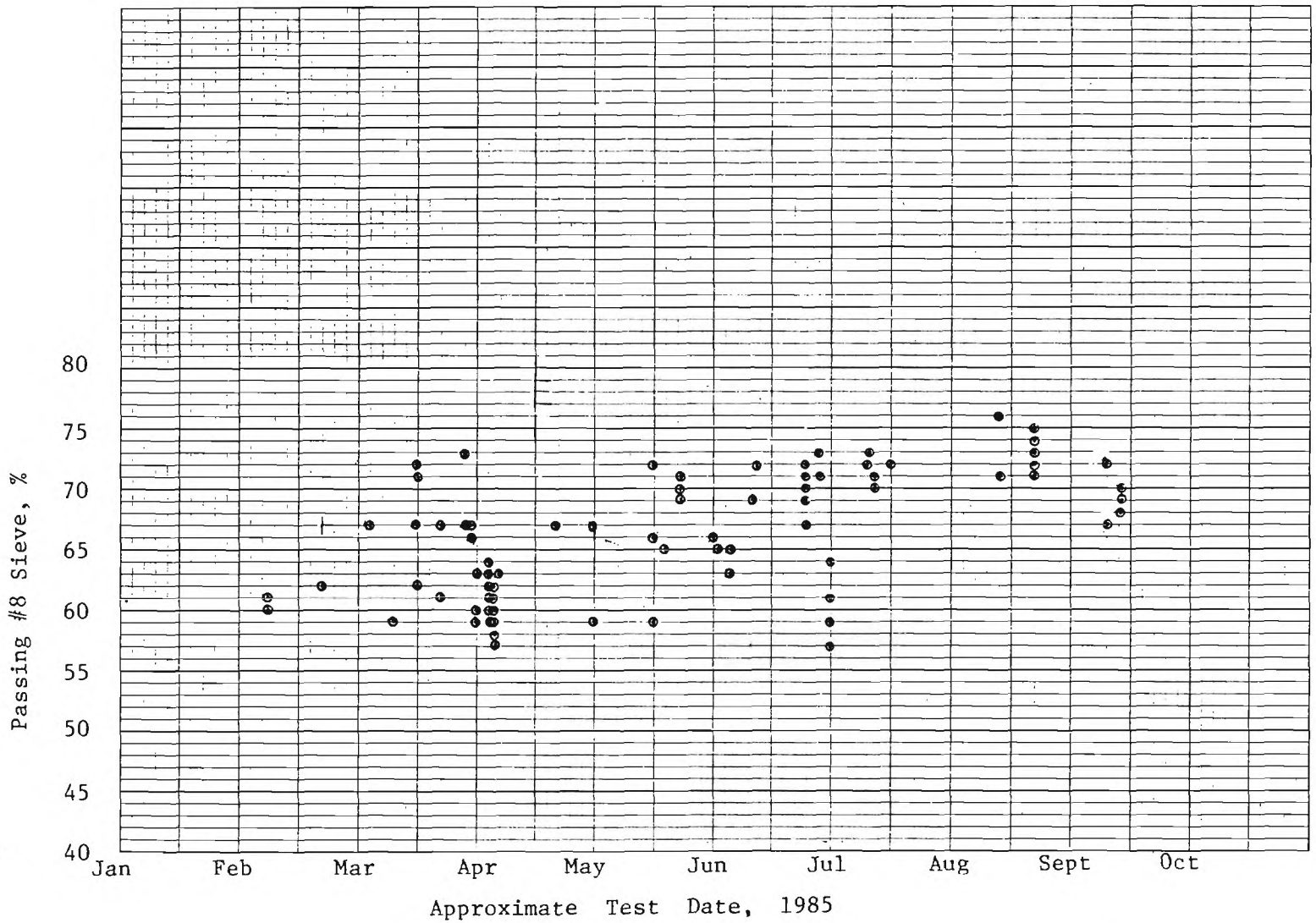


Figure 4.1a. Test Results for Percentage Passing #8 and #200 Sieve vs. Time for Coarse Ash Used by Dunn.

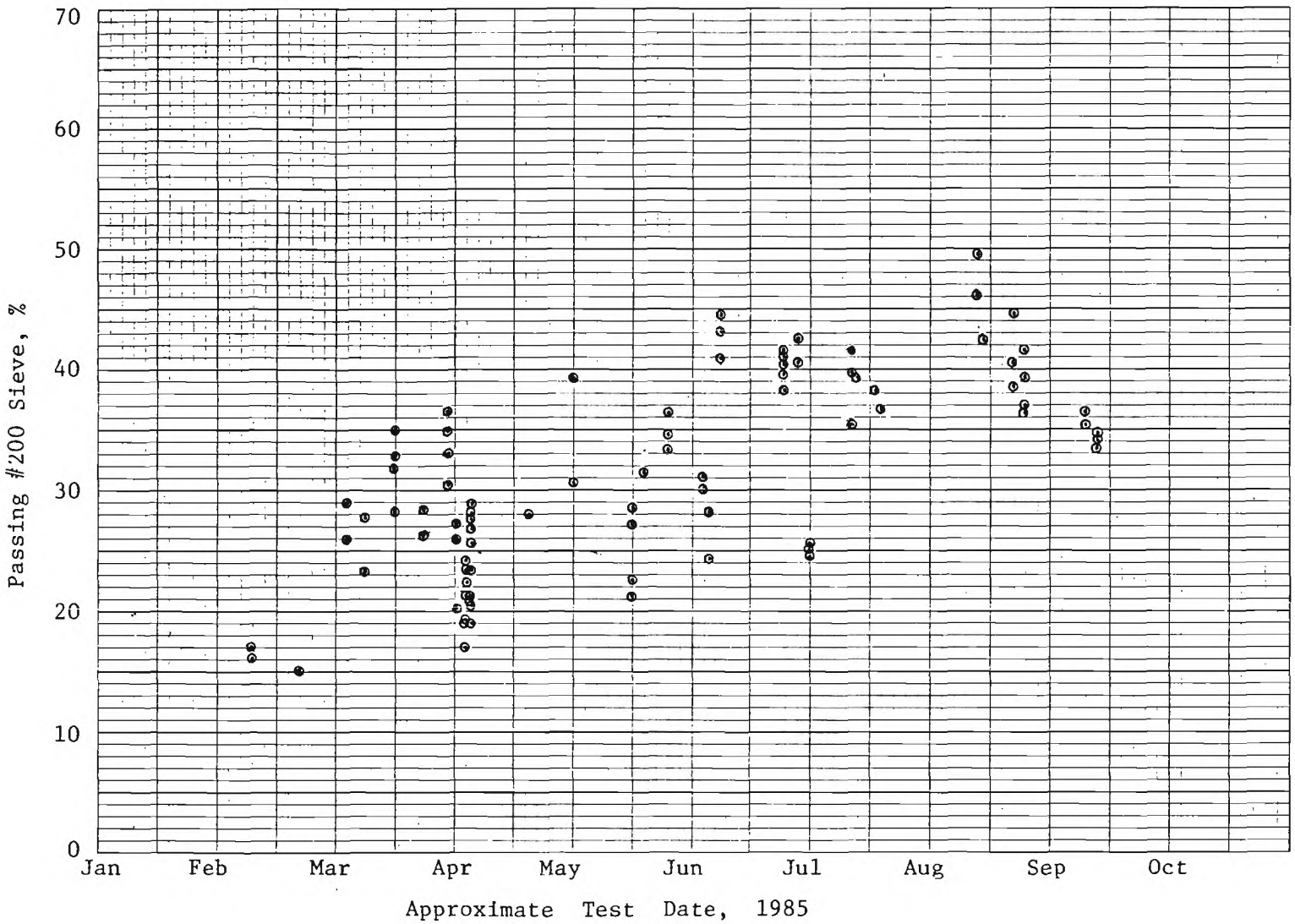


Figure 4.1b. Test Results for Percentage Passing #8 and #200 Sieve vs. Time for Coarse Ash Used by Dunn.

The following range for selected index properties was reported for the subgrade soils on the Dunn project:

- Passing #200 sieve
  range 57-71%
- Liquid Limit
  range 25-36%
- Plasticity Index
  range 8-15%

ASH MATERIALS

The source of ash used on this project is Plant Gaston which is located about 10 miles from the project. The ash used by Dunn was reclaimed through excavation close to the outfall pipes in the ash pond and from excavated material which had been stockpiled near the perimeter of the pond. The Wilson ash was slightly finer-grained and had previously been excavated by Alabama Power and stockpiled close to the entrance of Plant Gaston. The primary difference between the two ash materials was gradation.

Dunn Ash

The ash used by Dunn was reclaimed from the ash pond at Plant Gaston. A dozer was used to push the ash from the pond into a stockpile. A front-end loader was then used to load trucks for transport to the project site. Normally, the pond ash was stockpiled at the project site to allow drainage of any excess water.

Dunn used this coarse ash to replace the chert subbase material. Type B (Section 820.02) subbase material specifications were imposed by AHD on the ash. Because of quality control requirements associated with control strip determination of compaction target density, numerous gradation tests were conducted on the coarse pond ash during the construction period. Some variation and change in gradation was noted throughout the duration of the Dunn project. Figure 4.1 depicts the test results for percentage passing the #8 and #200 sieve as a function of time. Note that there was an increased amount passing both the #8 and #200 sieves during later stages of the project. This is probably attributable to use of ash which had been excavated at greater distances from the outfall pipe in the ash pond.

This change in gradation also necessitated the construction of new control strips for compaction control. The following is pertinent test information for the control strips:

Date	Roadway Location	Station	Maximum Dry Density, pcf	Optimum Moisture, %	Gradation Band % Passing #8 Sieve	Gradation Band % Passing #200 Sieve
3/7/86	Left	1089 to 1094	103.9	14.5	57-75	20-35
3/14/86	Right Shoulder	1055 to 1060	104.2	14.1	50-70	15-35
2/21/85	County Road #444	-	101.0	13.5	None (other than Type B or B1 subbase)	None
4/2/85	Right Shoulder	1045 to 1050	106.5	12.3	50-70	12-35
7/10/85	Left	1132 to 1137	107.5	9.6	55-75	30-50
8/21/85	Left Shoulder	1069+50 to 1074+50	103.6	13.2	55-75	30-50

It should be noted that laboratory testing of the coarse pond ash indicated a substantially higher (6-8 lbs/ft^3) maximum dry density (AASHTO T-180c) than the control strips. It is believed that confinement during lab compaction caused by the steel mold causes the higher maximum dry density. Because of this phenomenon, it was decided that the laboratory maximum dry density values were not practical for use to control field compaction; rather, field compaction (with actual compaction equipment) on control strips should be used to establish target density.

During laboratory evaluation of the coarse pond ash, a soaked CBR of 86.9 was found. Whether this is a reasonable estimate of field CBR values is not known, although it is likely that confinement due to the steel mold (and resulting higher density than typical of the field) may cause this CBR value to be an unreasonably high estimate of the true CBR.

No testing was conducted on the abrasion, soundness or specific gravity of the coarse pond ash. Typical values, however, found for Plant Gaston ash in a previous study [2] showed:

Abrasion loss - 42%

Soundness loss - 12.6%

Specific gravity

bulk - 2.14

apparent - 2.24

Absorption - 2.0%

Wilson Ash

The purpose of the ash used by Wilson was to reduce the plasticity index of the locally available clay-gravel so that AHD Type B-1 (Section 820.03) subbase specifications could be satisfied. Laboratory tests conducted by AHD indicated the following for the Wilson ash:

Sieve Size	% Passing
2 inch	100
#8	62
#200	18

Liquid Limit } nonplastic

Plasticity Index

Because of the gradation and nonplastic nature of the ash, it could be blended with the excessively plastic clay-gravel (see subsequent discussion) to reduce the plasticity (through dilution) while not adversely affecting the gradation.

Blends of 40 to 50% (by dry weight of the clay-gravel) were used with a resulting lowering of the plasticity index.

SUBBASE MATERIALS

The subbase materials used on the Highway 280 project included the following:

- sand-stabilized clay-gravel (Wilson)
- ash-stabilized clay-gravel (Wilson)
- chert (Dunn)
- pond ash (Dunn)

The following subsections present characteristics of the various materials (except ash, which was previously presented) and subbase mixtures.

Clay-Gravel

The clay-gravel was a reddish material obtained from the Hightower Pit toward the south end of the Wilson project. It had the following characteristics:

Grain Size

Sieve	% Passing
2 in. sieve	100
1 inch sieve	94-97
#4 sieve	65-72
#8 sieve	51-59
#200 sieve	38.8-40.6

Atterberg Limits

Liquid limit	34-38%
Plasticity Index	18-22%

CBR - 31.3

Chert

The chert initially used by Dunn came from the Gulf States Pit north of the project. It had the following characteristics:

Grain Size

Sieve	% Passing
2 inch	100
#8 sieve	30-45
#200 sieve	56.8-65.6

Atterberg Limits

Liquid Limit	30-41
Plasticity Index	14-22

This chert material was found to be periodically "out-of-spec" primarily due to excessive liquid limit and excessive plasticity index values. In fact, about 1500 lineal feet of chert subbase with excessive PI was left in place from Station 1055 to 1060 and 1065 to 1075 with a 10% reduction made by AHD to the unit price paid Dunn.

Manufactured Sand

Manufactured sand (tailings from washing operation) from a marble producer in Sylacauga was initially used by Wilson at a treatment level of 30% (by dry weight of the clay-gravel) to dilute the plasticity of the clay-gravel subbase material. This sand was nonplastic and had about 100% passing a #4 sieve with less than 4-8% passing a #200 sieve.

Wilson had to pay $1.00 per ton F.O.B. plus haul the sand to the job site, where it was used for stabilization of the clay-gravel subbase from Stations 1375 to 1409.

Figure 4.2 depicts the results of plasticity index determinations for samples of sand + clay-gravel subbase material taken at different stations along the alignment.

Ash-Stabilized Clay-Gravel

The ash-stabilized clay-gravel was used by Wilson for all subbase material constructed from Stations 1183 to 1375. A 60/40 blend (60% clay-gravel, 40% ash) was used from Stations 1325 to 1375 and a 50/50 blend was used from Stations 1183 to 1325.

Compaction test (AASHTO T-180c) results indicated the maximum dry density ranged 122-136 pcf and optimum moisture contents ranged 6.4-10.8%, Table 4.1.

The plasticity index test results for samples of ash-stabilized clay-gravel taken at various stations along the Wilson project are depicted in Figure 4.2. Note that the PI was significantly less when 50/50 blends were used than 60/40 blends. It is not known, however, whether this is attributable to the ash or a change in characteristics of the clay-gravel from the Hightower Pit.

A laboratory CBR was determined for the 50/50 blend and found to be 49 compared to 31.3 for the "untreated" clay-gravel.

Pond Ash Subbase (Dunn)

(See previous discussion for Dunn ash)

SPECIAL TEST PROGRAM CONDUCTED BY GEORGIA TECH

A few selected samples of the base, subbase, stone-stabilized subgrade, and subgrade material were taken along the U.S. Highway 280 project. These

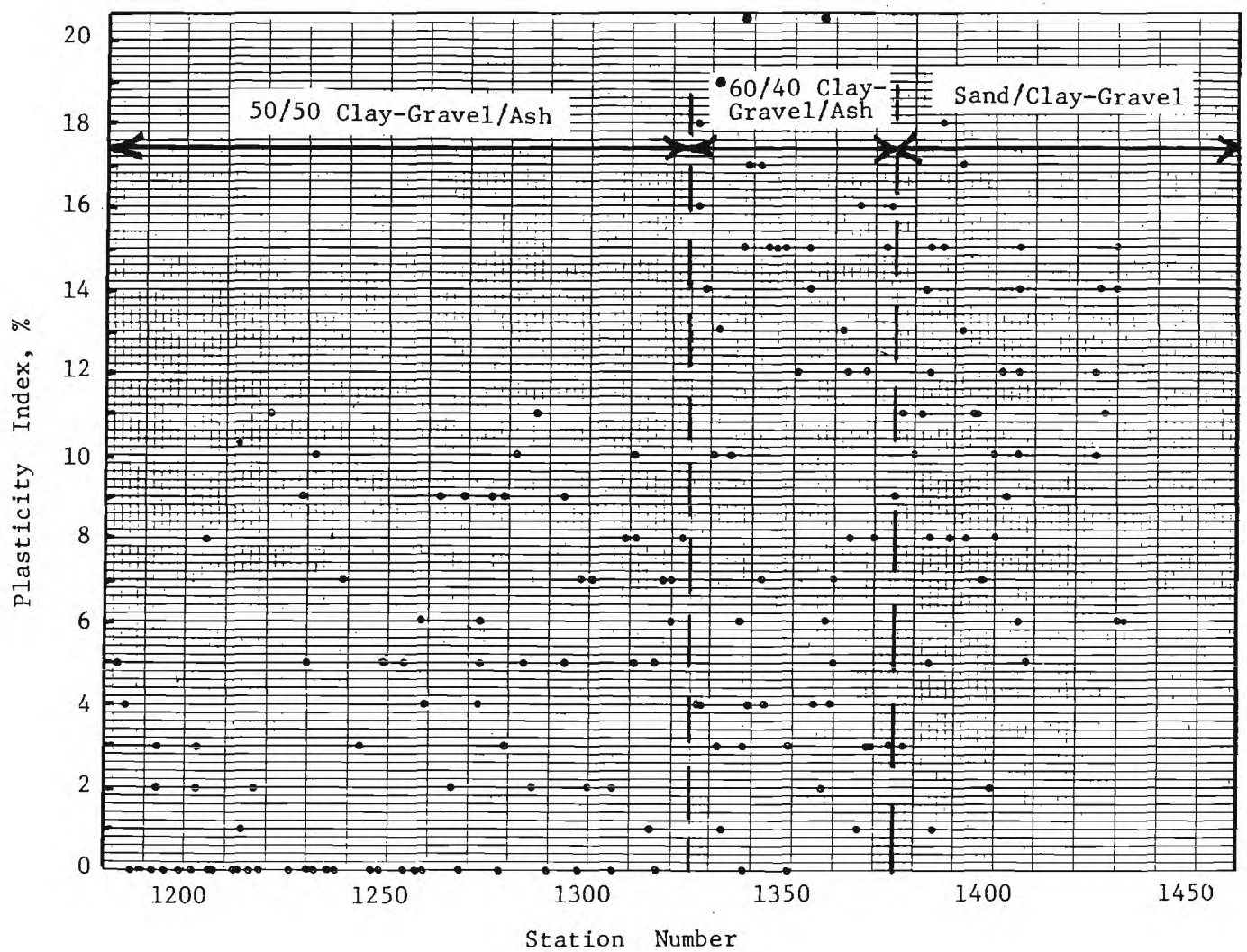


Figure 4.2. Results by Station for AHD Testing of Clay-Gravel Subbase (Untreated and Treated) Used by Wilson.

Table 4.1. Summary of AHD Laboratory Data for Clay-Gravel Subbase Used by Wilson.

Date	Station	Maximum[a] Dry Density, pcf	Optimum[a] Moisture,%
9/7/84	1397+00	129.4	10.6
9/18/84	1397+50	128.3	8.3
10/2/84	1430+76	128.0	9.9
11/21/84	1310+82	125.4	7.6
12/14/84	1269+08	122.0	9.3
3/18/85	1232+50	135.6	7.3
3/18/85	1368+40	126.5	10.8
3/20/85	1248+16	135.4	6.4
3/20/85	1349+60	133.3	8.8
3/29/85	1306+11	127.5	7.9

samples were transported to the Civil Engineering Materials Laboratory at Georgia Tech in Atlanta, GA, and subjected to a selected suite of special tests. The primary purpose of the special tests was to evaluate fundamental repeated loading characteristics of the various paving materials. A comparison could then be made between conventional AHD base, subbase, stabilized-subgrade, and subgrade materials and the ash and ash-treated clay-gravel subbase paving materials using fundamental as well as index property information.

Materials Sampled

A listing of the materials sampled for use in this special test program is presented in Table 4.2. Note that not all paving materials were sampled. Large bulk samples of each of the materials were collected at the locations noted in Table 4.2, placed in plastic buckets, sealed and transported to the laboratory.

Tests and Methods

Tests. A listing of the special tests conducted on the various bulk samples is presented in Table 4.3. The primary testing conducted included special repeated load triaxial (resilience and rutting) as well as some index property testing of grain size, CBR, and compaction.

Test Methods. The methods used for the various tests were as follows:

1. Grain Size

The grain size analysis testing for all except the subgrade sample (Sample No. 10) consisted of conducting a washed analysis of the material through a nest of selected sieves. For the subgrade sample, both a sieve and hydrometer analysis were conducted.

2. Compaction

A compaction test was conducted on the subgrade sample using AASHTO Method T-99. For other materials, AHD compaction test results were assumed to be adequate since the materials were collected adjacent to locations where compaction tests had been conducted by AHD.

3. CBR

CBR testing was conducted on selected samples as listed in Table 4.3

Table 4.2. Listing of Material Samples Taken for Special Testing Program Conducted by Georgia Tech.

Project	Sample Number	Material	Date	Location General	Location Station
Wilson	1	Clay-Gravel	2/20/85	mainline	1195
	2	50/50 C-G/Ash	2/20/85	shoulder	1240
	3	50/50 C-G/Ash	2/21/85	mainline	1214
	4	crushed stone base	2/21/85	mainline	1235
	5	Gaston fine ash	-	stockpile at Plant Gaston	
	6	stone-stabilized subgrade	2/21/85	stockpile of excess material (N. end of project)	
Dunn	8	coarse ash	2/20/85	control strip on county road	
	9	stone-stabilized subgrade	2/20/85	mainline	1108
	10	subgrade	2/20/85	mainline	1108

Table 4.3. Listing of Tests Conducted by Georgia Tech.

Project	Sample Number	Grain Size	Moisture-Density Tested	AHD Data	CBR	Repeated Load Resilience	Perm. Deform.
Wilson	1	x	-	x	x	x	x
	2	x	-	x	x	x	x
	3	x	-	x	x	x	x
	4	x	-	x	-	x	x
	5	(a)	-	x	-	-	-
	6	x	-	x	x	-	-
Dunn	8	-	-	x	-	x	x
	9	-	-	x	-	-	-
	10	x	x	-	x	x	x

Notes:

(a) Grain size of Wilson ash presented in text
x = test conducted
- = no test conducted

using AASHTO Method T-193. The subbase materials were thoroughly blended with sufficient water to bring them to optimum compaction moisture content and then compacted into the CBR mold using AASHTO Method T-180c compactive effort. The stone-stabilized subgrade and subgrade samples were prepared in a similar manner, except AASHTO Method T-99 compactive effort was used.

All CBR specimens were tested for CBR immediately after compaction (using trimmed end) and then placed to soak for 4 days. After the 4 day soak, the CBR was determined with two surcharge weights in place during penetration. Swell readings were taken also.

4. Resilience Testing

The resilient modulus of the various materials was determined as a function of stress state by placing prepared cylindrical specimens in a triaxial cell and subjecting these specimens to a repeatedly applied deviator stress of known magnitude and a stress pulse time of about 0.2 sec. at a repetition rate of 30 loads per minute. A schematic of the testing apparatus is shown in Figure 4.3.

For the subgrade soil and coarse ash subbase (Dunn) materials, cylindrical specimens 2.8 inches in diameter and 5.8 inches high were used. For the crushed stone, clay-gravel, and 50/50 clay-gravel/ash materials, 6-inch diameter by 13-inch high cylindrical specimens were used. Each specimen was carefully prepared to the desired moisture and density conditions. For each of the materials, the target moisture content and density values are given in Table 4.4.

After initial repeated loading (N=1,000) to condition the specimen, each specimen was subjected to about 10 load applications at each applied stress level desired and the associated resilient (or elastic) deformation was measured by Linear Variable Differential Transducers (LVDT's) and the results recorded on a strip-chart. These data were later converted to resilient modulus by dividing the applied deviator stress by the associated resilient strain.

For the subgrade soil, the various specimens were tested with the confining pressure σ_3 = 0 psi (i.e., unconfined) whereas for the other materials, σ_3 varied from 3 psi to 10 psi with the applied deviator stress (σ_1-σ_3) varying from 6 psi to 50 psi.

5. Permanent Deformation Testing

The permanent deformation of the various materials listed in Table 4.3

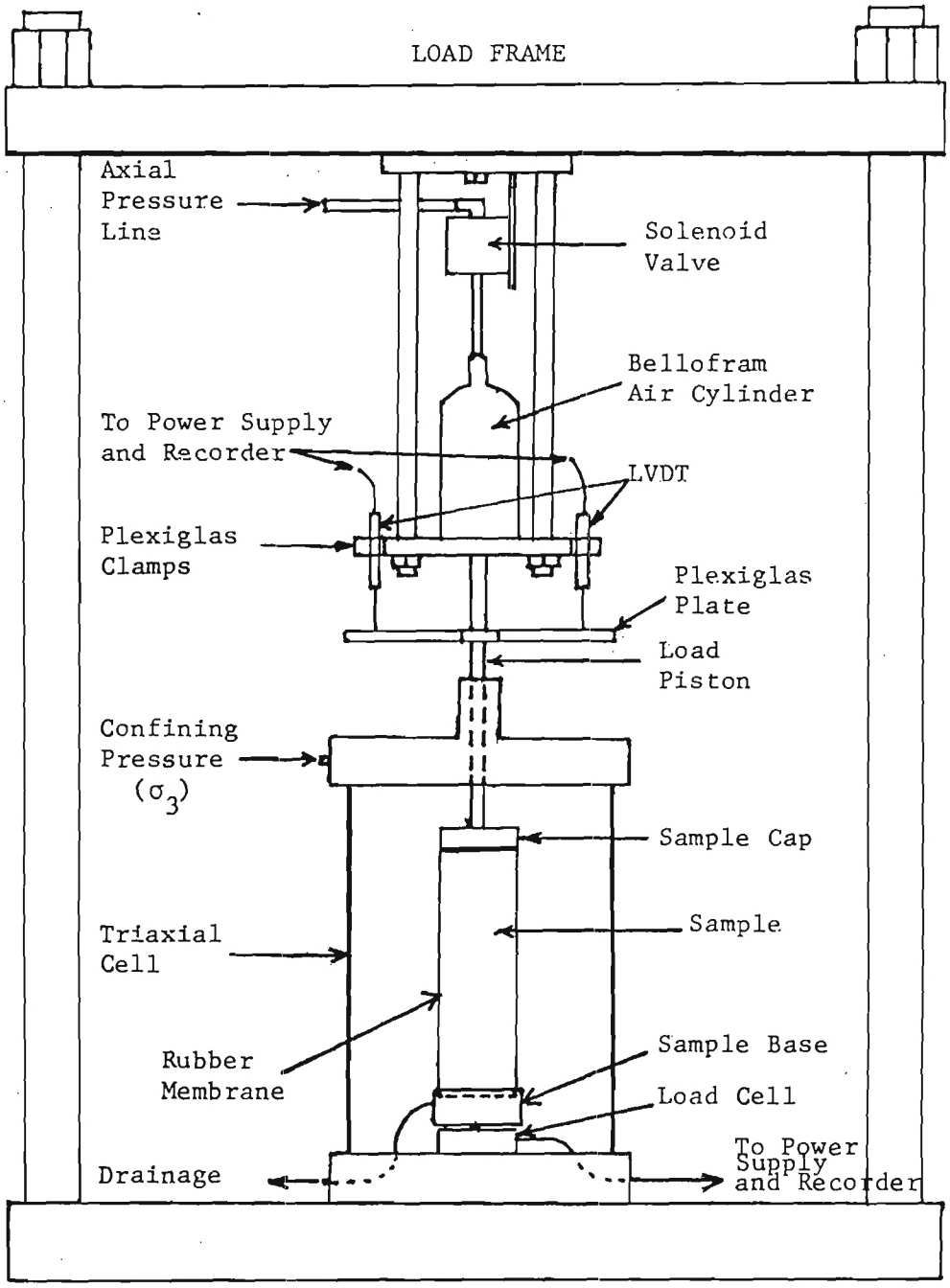


Figure 4.3. Schematic Diagram of Repeated Load Triaxial Testing Equipment.

Table 4.4. Summary of Target and Actual Compaction Values for Materials Tested - Georgia Tech Special Testing Program.

Material Type	Sample Number	Test Specimen Type	Target Compaction Values Dry Density,pcf	Target Compaction Values Moisture, %	Actual Values Density/Moist. pcf	Actual Values Density/Moist. %
C-G	1	CBR	128.3	8.3	118.2	8.0
		Resil	128.3	8.3	111.4	8.2
		Perm	128.3	8.3	112.0	8.7
50/50 C-G/Ash	2&3	CBR	120.4	9.5	123.7	9.3
		Resil	120.4	9.5	120.2	9.6
		Perm	120.4	9.5	116.1	9.3
Crushed Stone	4	Resil	146.0	6.8	146.0	6.4
		Perm	146.0	6.8	146.0	6.4
Stone-Stabil. Subgrade	6	CBR	131.2	6.8	118.4	6.5
Coarse Ash	8	Resil	111.6	12.3	111.5	11.8-12.2
		Perm	111.6	12.3	108.2-109.3	12.3-12.5
Subgrade	10	CBR	113.4	16.0	113.2	16.0
		Resil	113.4	16.0	112.3	16.1
		Perm	113.4	16.0	112.3	16.1

was determined using the same triaxial equipment as previously described and shown schematically in Figure 4.3. The main differences in testing are (a) no pretest repeated load conditioning, (b) a constant stress state (repeated deviator and constant confining stress) is applied during the duration of test, and (c) only permanent deformation which accumulates during the application of up to 40,000 to 100,000 repeated loads is monitored with LVDT's and recorded on a strip chart (these data were later converted to permanent strain).

The stress state imposed during the repeated load triaxial permanent deformation testing was as follows:

Material	Specimen	Major Principal Stress σ_1, psi	Confining Pressure σ_3, psi	Ratio of $\frac{\sigma_1-\sigma_3}{\sigma_3}$
Subgrade	1	20	5	3
	2	20	5	3
Pond Ash Subbase	1	40	10	3
	2	65	10	5.5
	3	65	10	5.5
50/50 Clay-Gravel/ Ash	1	65	10	5.5
Clay-Gravel	1	65	10	5.5
Crushed-Stone	1	65	10	5.5

Test Results. The test results obtained from the previously described testing program will be presented in a series of figures and tables.

1. Grain Size

The grain size analysis results are presented in Figure 4.4.

2. Compaction

The compaction results for the subgrade soil sample are summarized in Figure 4.5 and Table 4.4. Compaction test results used as target values for various types of test specimens for the CBR and repeated load testing are presented in Table 4.4.

3. CBR

The CBR test results are summarized in Table 4.5.

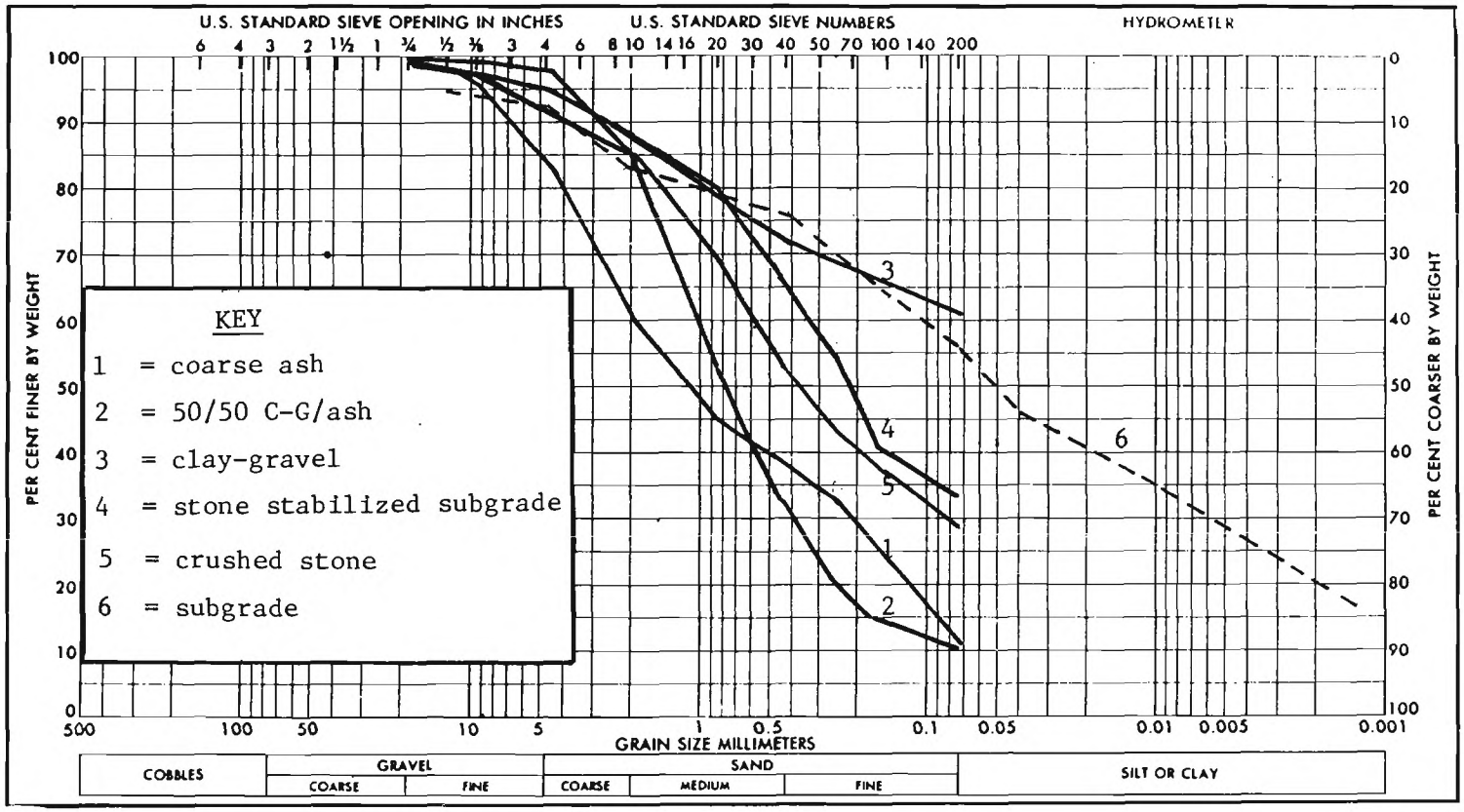


Figure 4.4. Summary of Grain Size Test Results for Materials Used in Special Testing Program Conducted by Georgia Tech.

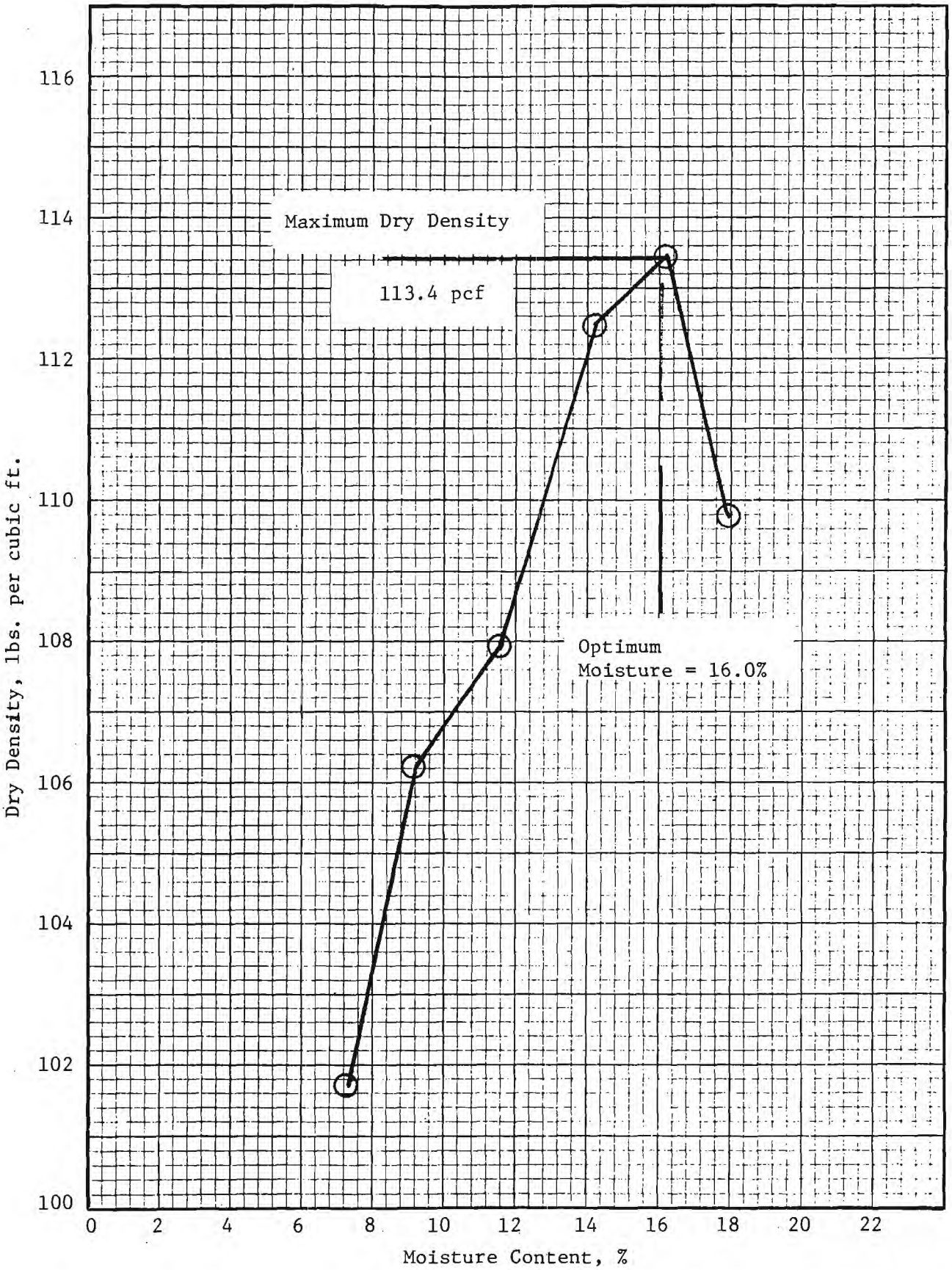


Figure 4.5. Compaction Moisture-Density Test Results for Subgrade Soil Sample.

Table 4.5. Summary of CBR Test Results from Georgia Tech Special Testing Program.

Material Type	Sample Number	CBR Test Values Unsoaked	Soaked	Swell
Clay-Gravel	1	-	15	2.2%
50/50 Clay-Gravel	2&3	10.8	36.3	0.02%
Stone-Stabilized Subgrade	6	-	2.6	2.2%
Subgrade	10	8.4	4.0	0.13%

4. Resilience Testing

Results of the repeated load resilience testing are presented in Figures 4.6 and 4.7.

5. Permanent Deformation Testing

Results of the repeated load permanent deformation testing are presented in Figure 4.8.

Discussion of Test Results

CBR. CBR test results, Table 4.5, for the various materials tested in the Georgia Tech program revealed values slightly lower than those previously determined by AHD. For example, the following is the comparison of CBR values:

Material	GaTech	AHD
Clay-Gravel	15	31.3
50/50 CG/Ash	36	49
Subgrade	4	5-15 (for all tests)
Coarse Ash	27-46 (Previous GaTech Study [2])	87

Also, the Ga Tech tests showed a very low CBR for the stone-stabilized subgrade (2.6). The reason for this extremely low value is not known.

It is interesting to note that the ash-stabilized clay-gravel and coarse ash both displayed substantially higher CBR values than the natural clay-gravel, suggesting that both materials should be superior to the clay-gravel.

Although no CBR testing was conducted on the coarse ash by Ga Tech, the high value obtained by AHD and previous CBR data for Gaston ash suggests that the coarse ash is structurally an excellent subbase material.

Resilience. The resilient testing of the various materials, as summarized in Figures 4.6 and 4.7 revealed the following range of resilient modulus, E_R, as a function of the imposed stress state:

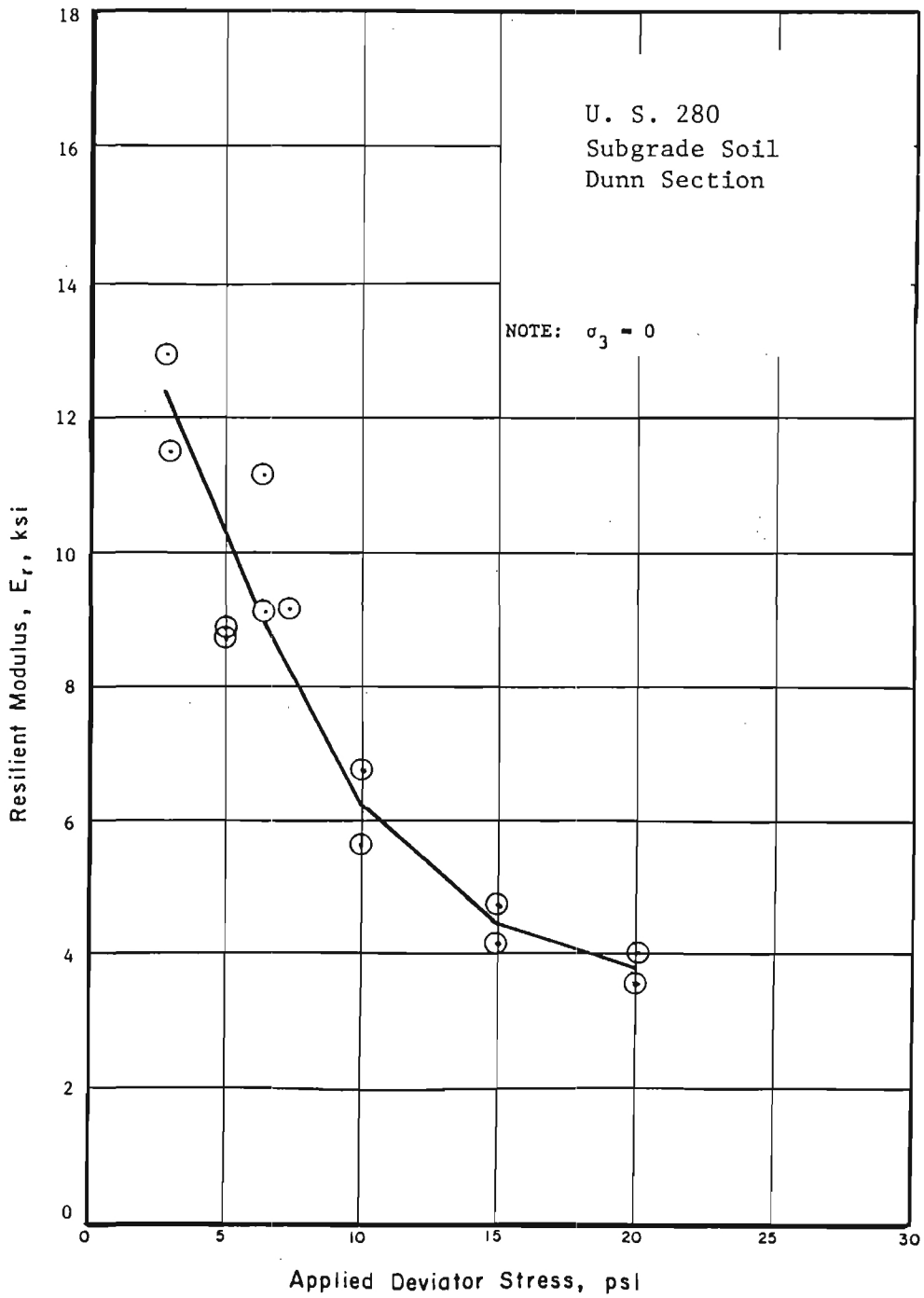


Figure 4.6. Resilient Modulus vs. Applied Stress for Subgrade Soil Sample.

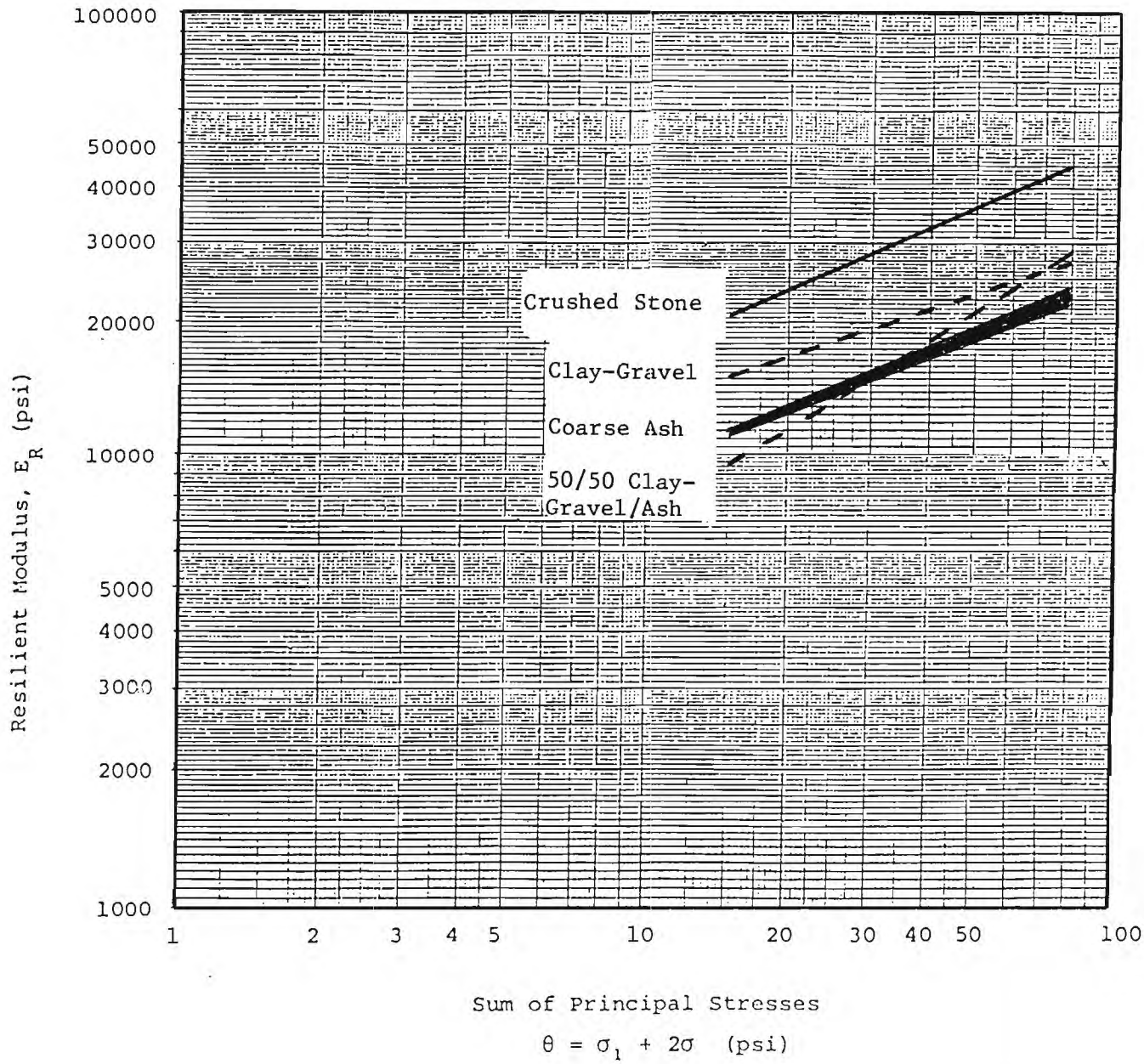


Figure 4.7. Resilient Modulus vs. Applied Stress for Crushed Stone, Clay-Gravel (Untreated and Treated), and Coarse Ash.

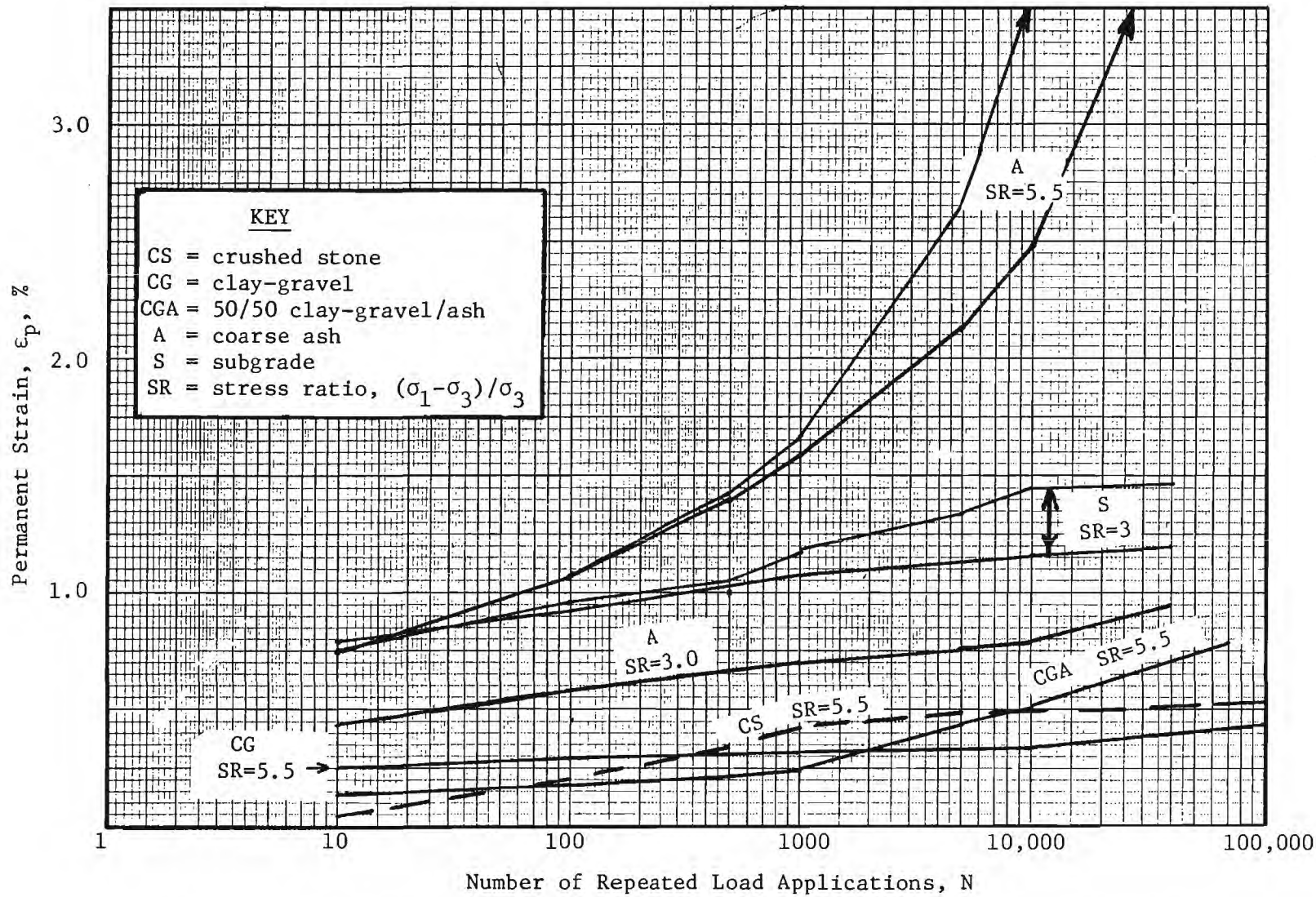


Figure 4.8. Permanent Deformation Results from Repeated Load Test Program.

Material	E_R,psi
Crushed stone	20,000-45,000
Clay-gravel	15,000-27,000
Coarse ash	11,000-22,500
50/50 CG/ash	9,900-29,000
Subgrade	4,000-12,000

Although the crushed stone has a substantially higher range of E_R-values, the coarse ash, clay-gravel and 50/50 clay-gravel/ash all have about the same range of E_R. Of course, as expected, the subgrade soil has a substantially lower E_R range with the subgrade E_R-values being highest for the very low values of applied stress.

Permanent Deformation. The permanent deformation test results, Figure 4.8, can be used to provide an estimate of potential rutting which would develop in the particular material for the given stress state imposed.

The clay-gravel, crushed stone, and 50/50 clay-gravel/ash all had similar rutting response under an imposed stress ratio ($(\sigma_1-\sigma_3)/\sigma_3$) of 5.5. The coarse pond ash performed poorly at the same stress ratio; however, reducing the stress ratio to 3.0 brought the rutting behavior of the coarse ash to about the same as the other base and subbase materials. This suggests that coarse ash may not perform in a higher stress setting (such as a base course) as would the clay-gravel or 50/50 clay-gravel/ash. However, the clay-gravel materials (natural and ash-treated) may be much more susceptible to softening and rapid rutting at the high stress levels, if the material becomes highly saturated. Higher levels of saturation may not adversely affect pond ash as long as it is confined.

The subgrade soil rutted about twice as much as the other materials even when the stress-ratio was 3.0. More rutting should be expected from the subgrade at a higher degree of saturation (which commonly develops after construction) than that which was present in the test specimens at optimum compaction moisture (samples prepared at optimum moisture content).

Section 5

PERFORMANCE EVALUATION

The pavement sections on the U.S. 280 project were opened to traffic as they were completed. Generally, the south end of the project (Wilson) was opened to traffic first in July, 1985, with the north end (Dunn) being opened in December, 1985. At least 2-lanes of traffic were always open through Harpersville to maintain traffic flow while adjacent lanes (of the 5 lanes) were under construction. Figures 5.1 and 5.2 show typical views of the completed pavement.

To date, the performance of the pavement sections containing ash in the subbase has been excellent. No differences in performance between the pavements which contain the various types of subbase materials (chert, sand-stabilized clay-gravel, coarse ash, and ash-stabilized clay-gravel) have been noted.

No special nondestructive evaluation of the pavement sections has been made nor is any planned. No post-construction roughness determinations were made either.

It is hoped that a thorough pavement condition survey can be made in a few years to determine if any differences exist between and among the pavement sections containing the different subbase materials.

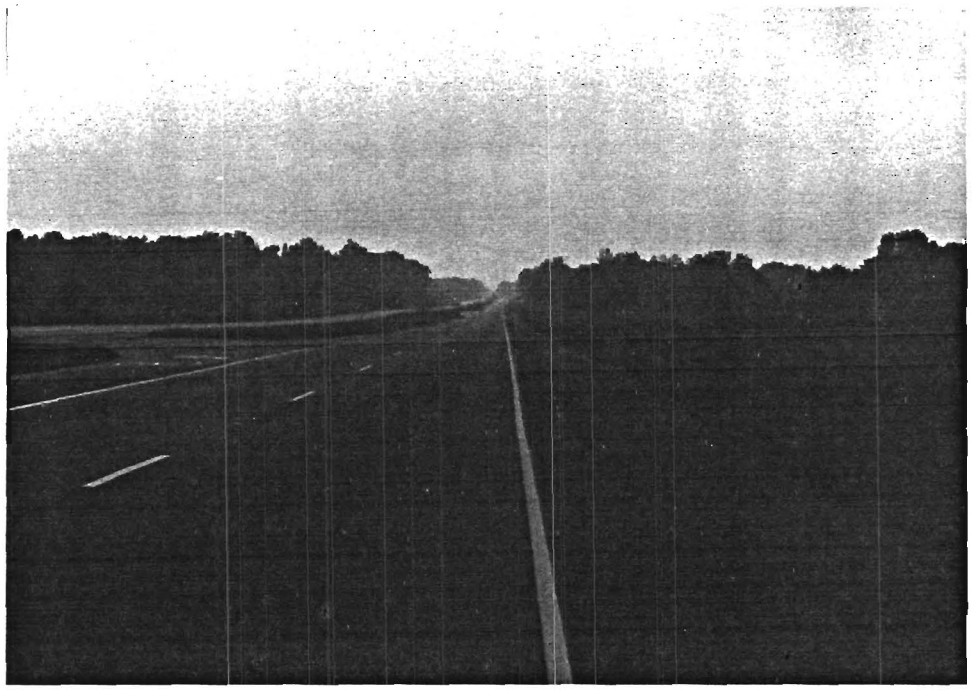


Figure 5.1. Finished Roadway Outside Harpersville.

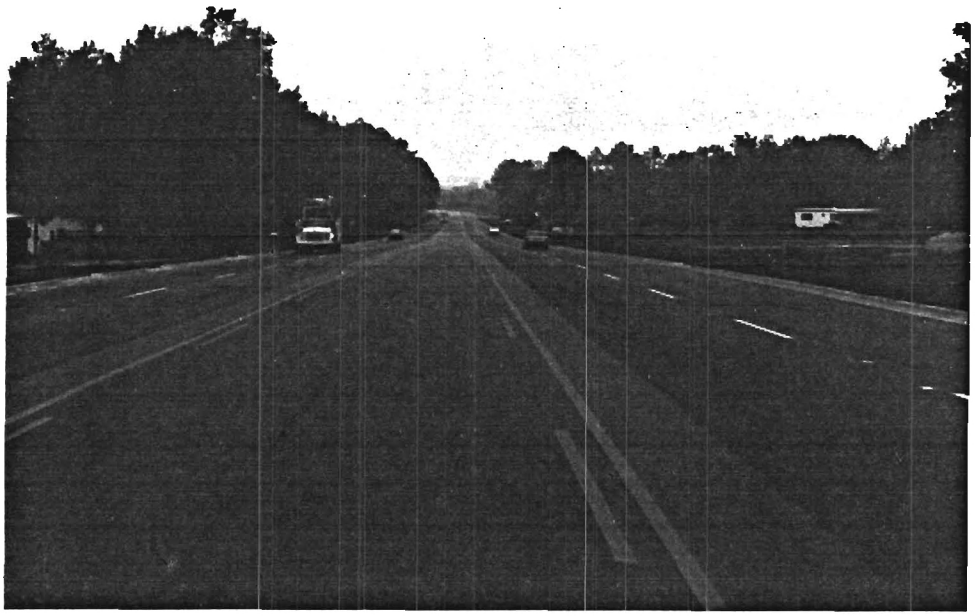


Figure 5.2. Finished Roadway Within Harpersville.

Section 6

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

SUMMARY

A large scale highway construction effort on U.S. Highway 280 southeast of Birmingham near Harpersville used ash from Plant Gaston in two slightly different ways in a 6-inch thick subbase layer. On one portion, the ash was used to mechanically stabilize (through dilution by addition of 40 to 50% ash) a local clay-gravel which did not, in its natural form, meet AHD specifications because of excessive plasticity. The other application used coarse pond ash from Plant Gaston to replace locally available chert. The total quantity of ash used on the project is estimated to be slightly more than 30,000 tons.

Some of the pavement was constructed with two conventional subbase materials (sand-stabilized clay-gravel and chert) which will allow future comparison of performance of the different sections. To date all sections are exhibiting excellent performance.

Both forms of ash utilization were relatively easily accommodated by existing AHD subbase specifications and as a result, no special supplemental agreements had to be executed with the two contractors involved.

The techniques used by the contractors for construction of the subbase layers were basically the same as those used for the other subbase materials. The only noteworthy change was the use of control strips to establish target density for compaction of the coarse ash subbase layer.

Both contractors were favorably impressed with the handling characteristics of the ash material during construction. In fact, one of the contractors has since used ash in a similar manner (mechanical stabilization) and the other contractor has seriously evaluated the use of coarse ash from Plant Gorgas for similar subbase construction.

CONCLUSIONS

A number of conclusions are warranted based on the results and findings from this ash demonstration project:

1. Untreated power plant ash can provide an excellent and economically attractive material for use in subbase layers.

2. Power plant ash can be used to up-grade locally available paving materials such as the "non-spec" clay-gravel. Mixing of the ash with clay-gravel is easily accomplished with a rotary mixer such as the Rex used on the U.S. 280 project supplemented by a disk. Compaction was easily accomplished with a large-size tamping foot roller.

3. Coarse ash can provide a subbase material which meets current AHD specifications, without the need of cement, lime, or asphalt treatment. The ash can be economically attractive, particularly close to the power plant and in those regions where local sources of aggregate are becoming depleted or are virtually nonexistent.

4. Other specific conclusions relative to the use of coarse pond ash are:

   a. Some variation in the gradation of coarse pond ash can be expected. Generally, the coarsest material will come from close to the outfall pipe location in an ash pond. The ash will become increasingly finer as distances from the outfall pipe increases, particularly in those ash ponds where flyash is co-disposed with the coarser bottom ash.

   b. The coarser pond ash has about the same CBR, and repeated load behavior (resilience and permanent deformation) as the other typical subbase materials used on the U.S. 280 project.

   c. Target density for field compaction should be established by use of a control strip method such as AHD #225 rather than laboratory compaction methods (such as AASHTO T-180).

   d. Compaction of the coarse pond ash is readily obtained with primarily a vibratory steel wheel roller although a rubber tire and steel wheel might be used to supplement.

   e. Excess water often present in reclaimed pond ash should be allowed to drain prior to placement in a pavement layer.

   f. The capillary retention of water in coarse pond ash after heavy sprinkling (virtual flooding) and some drainage appears to provide sufficient moisture for compaction. On this job it was typically within ±2% of optimum. Potential

problems might develop, however, with wet grades and/or no outlet for the free water when using trench construction.

g. Lateral confinement is needed at the edge of the coarse pond ash during compaction in order to prevent lateral movement of the ash from under the vibratory roller, and subsequent problems with density and thickness control. A small berm or trench construction might be considered for provision of the lateral confinement.

RECOMMENDATIONS

1. It is recommended that power plant ash be considered for all future subbase construction. It might also be considered as an untreated base material in lower volume roads. For use of ash in the base course of higher volume roads, stabilization with cement or lime plus flyash is required (see below). Listing of the ash as an alternative material in bid documents will alert paving contractors of its potential use and allow them to carefully consider the possible economic savings.

2. Power plant ash should be considered for other pavement applications. Other previous work [2] and a large-scale demonstration project constructed during 1985 in Georgia have both shown the technical merits and feasibility of using cement or lime + flyash-treated ash as a high structural capacity base or subbase layer.

3. A short information bulletin should be prepared and distributed to all highway contractors and highway agencies.

REFERENCES

1. Miller, R. H. and Collins, R. J., "Waste Materials as Potential Replacements for Highway Aggregates, Report 166, National Cooperative Highway Research Program, Transportation Research Board, 1976.

2. Robnett, Q. L., "Use of Southern Electric System Bottom Ash as a Paving Material", Final Report to Southern Company Services, School of Civil Engineering, Georgia Institute of Technology, October, 1985.

3. Robnett, Q. L., "Use of Boiler Bottom Ash as a Paving Material - A Technical Data Base", PHASE I Report, School of Civil Engineering, Georgia Institute of Technology, January, 1983.