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Utilization of SRS Pond Ash in Controlled Low Strength Material

by

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MASTER

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UTILIZATION OF SRS POND ASH IN CONTROLLED LOW STRENGTH MATERIAL(U)

SUMMARY

Design mixes for Controlled Low Strength Material (CLSM) were developed which incorporate pond ashes (fly ashes) from the A-Area Ash Pile, the old F-Area Ash Basin and the D-Area Ash Basin. CLSM is a pumpable, flowable, excavatable backfill used in a variety of construction applications at SRS.

Results indicate that CLSM which meets all of the SRS design specifications for backfill, can be made with the A-, D-, and F-Area pond ashes. Formulations for the design mixes are provided in this report. Use of the pond ashes may result in a cost savings for CLSM used at SRS and will utilize a by-product waste material, thereby decreasing the amount of material requiring disposal.

This work was conducted under WADs VT116923 and VE116956 at the request of S. E. Smith, Site Utilities.

See attached report, WSRC-RP-95-1026.

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Technical Report
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SUMMARY

Design mixes for Controlled Low Strength Material (CLSM) were developed which incorporate pond ashes (fly ashes) from the A-Area Ash Pile, the old F-Area Ash Basin and the D-Area Ash Basin. CLSM is a pumpable, flowable, excavatable backfill used in a variety of construction applications at SRS.

Material from the A- and F-Area sites is not very uniform in color, size, and texture because it is a mixture of fine fly ash and coarse bottom ash. Therefore, it is recommended for use only in common backfill. The material form the D-Area Basin is finer grained and is recommended for use in both structural backfill and common backfill. These pond ashes are not recommended for use in structural concrete because they do not meet ASTM C 618 specification for concrete pozzolans.

Ashes from A-, D-, and F-Areas were collected and characterized. Since the ashes were collected from the storage/disposal basins and are weathered, they are referred to as pond or basin ashes. (Fresh ashes from the electrostatic precipitators were not sampled or tested.)

Five trial mixes were prepared using ashes from each area. These specimens were tested by ASTM procedures and the data were used to specify CLSM design mixes incorporating pond ash from each basin. The design mixes were subjected to additional testing to evaluate engineering properties required for backfill materials.

Results indicate that CLSM which meets all of the SRS design specifications for backfill, can be made with the A-, D-, and F-Area pond ashes. Formulations for the design mixes are provided in this report. Use of the pond ashes may result in a cost savings for CLSM used at SRS and will utilize a by-product waste material, thereby decreasing the amount of material requiring disposal.

OBJECTIVES

The objective of this program was to determine whether SRS pond/basin ashes can be used in CLSM. Use of this material has the potential to decrease 1) the cost and effort associated with closing the existing basins, 2) long-term environmental liability associated with these sites and 3) the cost of CLSM used for backfill at SRS.

This work was requested by S. E. Smith, Site Services.

BACKGROUND

Controlled Low Strength Material

CLSM is a construction material defined by the American Concrete Institute (ACI) as a self- compacted, cementitious material used primarily as a backfill in lieu of compacted soil[1]. Backfilling with CLSM is usually less expensive than backfilling with compacted soil because CLSM placement requires less time and labor. In addition CLSM can be placed in wet weather, whereas, soil can not be compacted in the rain. More details concerning the use of CLSM as a construction material are given in Appendix I.

CLSM is preferred for use in radioactively contaminated areas where ALARA is an important consideration because it can be remotely emplaced. CLSM is typically pumped to the placement location and does not require further handling in the work area by construction personnel.

Uses for CLSM at SRS can be divided into two categories; 1) common fill and 2) structural fill. Common fill is typically used in place of soil in trenches or large excavations where structural properties of the material are not always tightly controlled. Structural backfill is typically used in foundation preparation or foundation remediation where structural properties require more attention to detail.

The ingredients and proportions in the current CLSM mix design, which is used at SRS, are given Table 1. This mix is referred to in this report as the reference CLSM mix (referenced in procurement specification C-SPS-G-00085, Mix ID EXE-X-P-O-X). The physical and engineering properties of this mix are listed in Table 2. Current uses of CLSM at SRS require that the material be excavatable, i.e., have a low (soil-like) compressive strength, as documented in Table 2. However, CLSM as defined by ACI includes materials which have compressive strengths up to 1200 psi. This can be easily achieved with the SRS pond ashes by increasing the cement content in the mix designs in the event that applications for higher strength structural backfills are identified at SRS.

WSRC currently purchases about 5,000 cubic yards (3,825 cubic meters) of CLSM per year from Claussen Concrete, Inc. This quantity may vary in the future. The cost of the CLSM is $46.00/cubic yard. The current design mix contains 600 lbs of Class F fly ash per cubic yard (1500 tons of fly ash/year). The fly ash in the current CLSM mix is purchased from a commercial fly ash vendor by Claussen.

Pond Ash

Site Services generates approximately 20,000 tons of fly ash and bottom ash per year as a by-product waste from coal combustion in the D-Area power plant and A-Area steam plant. Most of this material is generated in D-Area and is transferred via a slurry to the D-Area holding ponds for storage/disposal. In D-Area approximately 18,540 tons of ash are produced per year as the result of burning about 206,000 tons of coal (9 wt.% waste). Presently, over one million cubic meters of ash are stored in the D-Area basins.

The A-Area steam plant generates about 1424 tons of fly ash and bottom ash per year. This material is trucked to the A-Area Ash Pile which is 300 x 140 x 20 ft. in size (about 23,500 cubic meters). The F-Area basin does not receive regular transfers of ash. It is approximately 1050 x 275 x 20 ft. in size and contains about 1.5 million cubic meters of fly ash from the F- and H-Area Steam Plants. It has not been closed and is consequently readily available for use in a construction material. The proximity of the old F-Area basin to E-Area, Z-Area, and the Tank Farm make it a convenient source of ash for CLSM which may be used in environmental closure landfill and in filling tanks.

APPROACH

The overall approach was to characterize the A-, D-, and F-Area ashes and use them directly in the current CLSM mix design (Table 1) without processing. The particle size distributions of the pond ashes were the bases for the trial mix designs. The goal was to substitute the SRS ashes for 100% of the fly ash in the Reference CLSM mix. In the cases where the pond ashes contained significant amounts of coarse material (bottom ash and clinker), the ash was also substituted for a portion of the sand in the reference mix. This approach was selected in order to eliminate the need for sieving the pond ashes.

EXPERIMENTAL PROCEDURE

A plan for sampling the basins was prepared by J. H. Weber[2] (See Attachment 1). Due to limited time and funding, samples were collected from only 5 of the 15 to 20 sites identified in the plan for each basin. Figures 1, 3 and 5 illustrate the approximate sample locations in each Area. The D-Area basin was sampled as the ash was being removed from the original storage basin shown in Figure 4 to a near by storage location. The D-Area samples were collected after the ash was dumped at the new location. Sample locations in A- and F-Areas were excavated and cored to a depth of about 14 feet. Holes resulting from the sampling were backfilled for safety. Approximately 250 pounds of ash were collected from each sample site for the total about 1000 pounds per basin.

The ash samples were delivered to the Raytheon test facility in N-Area for sieving, sorting, and blending. The sand used in the CLSM mixture was also sieved to characterize the particle size distribution. These results along with chemical and physical property data for the portland cement used in this study are included in Appendix II.

Composite samples were prepared for chemical and physical analyses in accordance with ASTM C 618 and for use in the trial and design mixes. Chemical analyses of the composite samples were conducted by Singleton Laboratories, Inc. These analyses included:

Specific gravity	ASTM	C 188
Fineness % retained on No. 325 sieve	ASTM	C 430
$SiO_2+Al_2O_3+Fe_2O_3$	ASTM	C 114
SO_3	ASTM	C 114
Moisture Content	ASTM	C 114
Loss on Ignition	ASTM	C 114
Available Alkali	ASTM	C 311

Trial Mixes were generated by BSRI and SRTC and were prepared and tested by Raytheon concrete technicians. Compressive strengths were measured at 14 and 28 days. These data were used for developing the final CLSM design mixes. The following test procedures were used for the trial mix evaluation.

CLSM Sample Preparation and Curing	ASTM	D 4832
Compressive Strength	ASTM	D 4832
Fresh Unit Weight	ASTM	C 138

Three CLSM design mixes were ultimately developed - one for ash from each basin. These mixes were also prepared by Raytheon personnel. Compressive strengths were measured after 14, 28 and 90 days curing. The following tests were conducted by Raytheon on the design mixes.

In-situ Wet Density	ASTM	C 2922
Dry Density	ASTM	C 567
Fresh Unit Weight	ASTM	C 138
pH	ASTM	G 51
Set Time	ASTM	C 403
Permeability	ASTM	D 2434
Compressive Strength	ASTM	D 4832
Shrinkage/Settlement	BSRI procedure	

Engineering properties required for evaluating backfill materials were also measured. This work was conducted by LAW Engineering Inc., an off-site testing facility. Test methods for the engineering property evaluation are listed below:

Cohesion	ASTM	D 2850
Elastic Modules	ASTM	D 4015
Shear Strength	ASTM	D 3999
Angle of Internal Friction	ASTM	D 3999

RESULTS AND DISCUSSION

Ash Characterization

Raytheon personnel performed coarse sieve analyses for each of the five samples collected from each of the three areas. Based on the similarity of these results, it was decided to blend all of the material from each basin into one composite sample. Coarse sieve analyses from the composite samples are presented in Tables 3, 4, and 5. The ashes from the A-Area Pile and the old F-Area Basin are much coarser than the ash from the D-Area Basin. Only 32 and 19 weight percent of the ash passed the No. 200 sieve (less than 75 µm or 0.0029 in.) for the A- and F-Area ashes, respectively, compared to 91 wt.% for D-Area.

Based strictly on the sieve analyses presented in Tables 3 to 5, the A- and F-Area ashes can be used to replace all of the fly ash and some of the sand in the Reference CLSM mix. However, the D-Area pond ash can be used to replace only the fly ash in the Reference CLSM mix.

Physical and chemical requirements of fly ashes intended for use in concrete are specified in ASTM C 618. Results for the pond ashes are shown in Table 6. The A-, F-, and D-Area ashes do not qualify for use in concrete. In all cases they are too coarse and too high in moisture and carbon (loss on ignition) for use in concrete. However, they all pass the chemical requirements for use in cementitious systems such as CLSM. In fact, the low SO_3 and alkali content is worth noting for other potential applications of these ashes, such as raw material for masonry block production. Physical and chemical property testing of the SRS pond ashes was carried out by Singleton Laboratories.

Trial Mixes

Five trial mixes were developed by BSRI and SRTC personnel. These mixes were prepared from composite ash samples by Raytheon technicians at their on-site testing facility. Ingredients and proportions in the trial mixes are listed on Tables 7, 8, and 9 for CLSM containing A-, F-, and D-Area ashes, respectively. The range of cement quantities were specified such that the resulting CLSM would have compressive strength of 30 to 150 psi at 28 days. Pond ash was adjusted to maintain a 1:12 cement:fly ash ratio. Sand was adjusted to maintain a constant total weight per cubic yard. The sieve data of the A- and F- Area samples were used to proportion the pond ash into the fly ash or sand fraction of the CLSM mix. The fresh unit weights and 14 and 28 day compressive strengths for these mixes are also shown in Tables 7 to 9. The Raytheon technicians reported that the workability and appearance of the CLSM made with D-Area ash was better than or equal to that of the current CLSM reference mix.

The 28 day compressive strength results for the trial mixes were used to specify the cement contents in the final design mixes, one for each of the three composite ash samples. The target 28 day compressive strength for the design mix was selected as 80 ± 10 psi. The amount of cement in each of the design mixes was determined by interpolation of the 28 day strength versus cement content results shown in Figures 7 to 9.

Design Mixes

The design mixes were developed from the trail mix results as described above. The ingredients and proportions for the three design mixes are given in Table 10. Cement contents of 165 lbs/cubic yard were selected for CLSM containing the A- and F-Area ashes. 100 lbs of cement per cubic yard was selected for CLSM made with the D-Area pond ash.

Raytheon technicians prepared and tested samples for 14, 28, and 90 days compressive strengths (Figure 13) as well as fresh properties such a pH, and density. Initial set times were also measured by the resistance to penetration test. Initial set time is defined as the time corresponding to a resistance of 500 psi. These CLSM mixes set in 26 to 30 hours and shown on Figures 10 to 12. Hydraulic conductivity was also measured. Values are in the range of compacted sandy soil, 1×10^{-3} to 2×10^{-4} cm/sec. Shrinkage/settlement of CLSM was also measured and results are reported in Table 13 for the CLSM made from D-Area ash. After 14 days of curing, no additional settlement was observed. Similar settlements were observed for the CLSM made from the A- and F-Area ashes but measurements were not taken. Values are typical of the reference CLSM currently used.

Raytheon also prepared samples for evaluation of elastic modulus, cohesion and shear strength. These samples were shipped to LAW Engineering for testing. Results are presented in Table 10 and Attachment 2. All of the test results are with the acceptable range for CLSM used as backfill at SRS.

CONCLUSIONS

Use Of SRS Pond Ashes In CLSM

The pond ashes from A-, D-, and F-Areas are suitable for use in CLSM. The D-Area pond ash is suitable for making CLSM used in both common backfills and structural fills. The A- and F-Area ashes are less suitable for use in structural applications because they are less homogeneous than the D-Area ash and contain a larger amount of clinker and bottom ash. Ashes from these two areas are suitable for CLSM used in common flowable fill. Since the A- and F-Area ashes have similar properties, a single CLSM design mix is recommended. This mix contains 165 lbs of portland cement/cubic yard of CLSM. The pond ash in this mix replaces all of the fly ash and a portion of the fine aggregate (sand) in the current CLSM. (Procurement specification C-SPS-G-00085; WSRC CLSM Mix Identification No. is EXE-X-P-O-X).[3]

Ingredients and proportions for the two CLSM pond ash design mixes are shown in Table 14.

Potential Uses of CLSM At SRS

CLSM has been available for use as a flowable backfill at SRS since 1989. The current design mix has been used since 1992. Approximately 5,000 cubic yards of CLSM were placed as backfill in trenches, excavations, and behind retaining walls at SRS in 1995.

In addition, CLSM has the potential for use in areas where ALARA is a concern and in radioactive landfill stabilization efforts at SRS. CLSM is ideal for:

- underground voids
- soil stabilization
- filling voids in radioactive waste containers (drums and boxes)
- stabilizing waste disposal vaults (LAW, ILNT)
- stabilizing waste disposal culverts and Greater Confinement Disposal, GCD, Units
- filling empty left in place underground tanks
- filling emptied high-level waste tanks
- stabilizing abandoned process sewer lines
- backfill around vaults and in landfills

Eliminating voids in these containers and structures prevents deterioration due to subsidence and thereby contributes to the overall success of site closures.

Production of CLSM from SRS Pond Ash

Several options are possible for making CLSM containing SRS ash. Selection of an option will depend on the amount and production rate of CLSM required, the location of the placement site relative to the SRS ash basins, and the specifications of the finished product.

The approach that requires the least capital investment involves requiring the CLSM vendor (Claussen Concrete Inc.) to use SRS ash in CLSM purchased for use on site. The current procurement contract with Claussen sets the WSRC purchase price of ASTM C 618 Class F fly ash at approximately $0.0121 per pound. This quality of fly ash is not necessary for CLSM. Removal of the pond ash from the basins and transportation and storage of pond ash to the Claussen facility or other batch plant vendor may be accomplished for less than this amount and may result in an overall cost savings for CLSM.

Another option involves on site batching using a small mobile facility. CLSM manufactures typically use volumetric proportioning equipment and a truck mounted auger mixing system. Cemented Inc. and Zimmerman Industries both manufacture this type of equipment for CLSM slurry production. DOE-SR owns two 9 cubic yard concrete trucks which could be used for delivering the CLSM to the placement Site. (These trucks are operated by construction personnel.) CLSM may also be mixed in the conventional concrete delivery trucks provided care is taken to achieve sufficient blending.

Other Potential Uses of SRS Pond Ash in Low-Strength Concrete

The D-Area ash in particular appears suitable for use in low-strength concrete mixes which do not require air entraining admixtures for freeze-thaw resistance, plasticizers to improve workability and/or vibration to achieve compaction. Examples include road base material, working slabs/mud mats, and encasements for unreinforced duct banks. In addition, the SRS pond ashes can be used as an ingredient in compacted soil-cement mixtures used for road bases and foundation mats.

The D-Area pond ash may also be suitable for low strength concrete mixes used to construct sidewalks, curbs, gutters, splash blocks, drainage, and ditches, and to fabricate fence, bumper, and protection posts. These products require freeze-thaw protection and possibly plasticizers. Consequently, special consideration must be used in the selection of additives which are compatible with the high carbon content of the ash.

RECOMMENDATIONS

Substitute D-Area pond ash for ASTM C 618 class F fly ash CLSM used as structural fill and/or common backfill at SRS.

Substitute A- and F-Area ashes for ASTM C 618 class F fly ash in CLSM used as common backfill at SRS.

Evaluate options for producing CLSM using SRS pond ashes. Options include:

- Batching at the off-site facility which currently supplies CLSM
- Batching at an off-site facility under a special procurement contract
- Batching on-site in a mobile facility using BSRI construction personnel
- Batching on-site in a vendor facility

These feasibility and cost studies should take into consideration the fact that use of the pond ash will reduce waste at SRS and, if extensive use of this material is made, it may reduce the cost of closing the basins.

Promote the use of CLSM by private and state/federal agencies in the local area via the Economic Development Group and vendor solicitations. Fly ash vendors such as American Fly Ash and JTL Industries and grouting/foundation stabilization subcontractors are currently in the business of marketing pond ashes and producing as well as selling CLSM.

Investigate the feasibility of beneficiating the pond ash for use in other commercial products such as concrete or masonry and fired bricks. Expertise is available through fly ash brokers.

REFERENCES

1. American Concrete Institute Committee Report ACI 229R-94, Controlled Low Strength Material (CLSM), ACI Manual of Concrete Practice, October 1, 1994.

2. J. H. Weber, Sampling Units for the A-, D-, and F-Area Ash Piles, SRT-AG-950006, February 3, 1995.

3. Procurement specification C-SPS-G-00085, Rev. 1.

TABLE 1 - REFERENCE CASE CLSM MIX DESIGN USED AT SRS

INGREDIENTS	LBS/CU.YD	KG/CU.M	WEIGHT %
PORTLAND CEMENT	50	29	1.4
CLASS F FLY ASH	600	341	16.2
SAND (ASTM C 33)	2515	1431	67.6
WATER (GAL)	66 MAX	251 LITRE	14.8
ADDITIVES	NONE	NONE	NONE

TABLE 2 - PROPERTIES OF REFERENCE CLSM USED AT SRS*

DESCRIPTION	STRENGTH RESULTS	STRENGTH RESULTS
FRESH UNIT WEIGHT	125 - 128 lbs/ft^3	2000 - 2050 Kg/m^3
DRY UNIT WEIGHT	112 - 118 lbs/ft^3	1795 - 1890 Kg/m^3
IN-SITU WET DENSITY	115 - 145 lbs/ft^3	1840 - 2320 Kg/m^3
COMP. STRENGTH @ 28 DAY	30 - 120 Psi	0.207 - 0.827 Mpa
SHEAR MODULUS (AVE.)	3600 Ksf	172 Mpa
COHESION (AVE.)	2.5 Ksf	0.120 Mpa
ELASTIC MODULUS (AVE.)	900 Ksi	6205 Mpa
PERMEABILITY	2 10^{-5} cm/sec @20° C	
ANGLE OF INTERNAL FRICTION	34°	
pH VALUE	9.5 ± 2	

* Pumpable, Self-Leveling and Excavatable

TABLE 3 - SIEVE ANALYSIS OF A-AREA POND ASH

SIEVE SIZE	WEIGHT RETAINED	Wt. % RETAINED	% PASSING
3/4"	0	0	100
1/2"	26.0	2	98
3/8"	51.3	4	96
#4	141.4	12	88
#8	269.7	24	76
#16	393.5	34	66
#30	500.7	44	56
#50	606.5	53	47
#100	703.9	62	38
#200	778.7	68	32

TABLE 4 - SIEVE ANALYSIS OF F-AREA POND ASH

SIEVE SIZE	WEIGHT RETAINED	Wt. % RETAINED	% PASSING
1"	0	0	100
5/8"	50.7	4	96
1/2"	100.0	9	91
3/8"	144.6	13	87
#4	251.5	22	78
#8	380.0	33	67
#16	512.3	44	56
#30	636.4	55	45
#50	751.8	65	35
#100	852.3	74	26
#200	934.3	81	19

TABLE 5 - SIEVE ANALYSIS OF D-AREA POND ASH

SIEVE SIZE	WEIGHT RETAINED	Wt. % RETAINED	% PASSING
1"	0	0	100
5/8"	0	0	100
1/2"	0	0	100
3/8"	2.0	0.4	100
#4	2.0	0.4	100
#8	2.3	0.5	100
#16	3.5	0.7	99
#30	5.2	1.0	99
#50	10.2	2.0	98
#100	22.6	4.5	96
#200	44.2	9.0	91

TABLE 6 - POND ASH PROPERTIES

Test Name	ASTM Procedure	Test Results			ASTM C 618 Limitation for Use in Concrete
		A BASIN	F BASIN	D BASIN	
Specific Gravity	ASTM C 188	1.96	1.95	2.27	N/A
Fineness by #325 Sieve, % Retained	ASTM C 430	68.0	74.4	58.8	34% Maximum
SiO_2	ASTM C 114*	46.83	40.73	41.31	*See note below
Al_2O_3	ASTM C 114*	24.14	22.69	17.41	*See note below
Fe_2O_3	ASTM C 114*	3.65	8.64	19.24	*See note below
$SiO_2 + Al_2O_3 + Fe_2O_3$ (%)	ASTM C 114	74.62	72.06	77.96	70% Minimum
SO_3	ASTM C 114	0.05	<0.01	0.05	5% Maximum
Moisture Content (%)	ASTM C 114	14.8	14.9	11.7	3% Maximum
Loss on Ignition (%)	ASTM C 114	21.03	19.83	13.43	6% Maximum
Available Alkali (%)	ASTM C 311	0.18	0.21	0.44	1.5% Maximum

Shaded areas identify the attribute which pass ASTM C 618 requirements for concrete
Unshaded areas do not meet the ASTM C 618 requirements
* No ASTM requirements, just for information only

TABLE 7 - TRIAL MIX PROPORTIONS AND TEST RESULTS FOR A-AREA ASH

INGREDIENTS	MIX 1	MIX 2	MIX 3	MIX 4	MIX 5
CEMENT, lbs/cu.yd	40	50	80	120	200
SAND, lbs/cu.yd	2185	2190	2205	2230	2195
COAL ASH, lbs/cu.yd	940	925	880	815	770
WATER, lbs/cu.yd	729	738	810	729	698
PROPERTIES					
FRESH UNIT WEIGHT, lbs/cu.ft	111.6	112.2	115.3	115.5	116.6
COMPRESSIVE STRENGTH					
14-DAY (Psi)	4	6	14	34	94
28-DAY (Psi)	6	9	23	51	135

TABLE 8 - TRIAL MIX PROPORTIONS AND TEST RESULTS FOR F-AREA POND ASH

INGREDIENTS	MIX 1	MIX 2	MIX 3	MIX 4	MIX 5
CEMENT, lbs/cu.yd	40	50	80	120	200
SAND, lbs/cu.yd	2110	2115	2135	2160	2215
COAL ASH, lbs/cu.yd	1015	1000	950	885	750
WATER, lbs/cu.yd	720	720	810	738	689
PROPERTIES					
FRESH UNIT WEIGHT, lbs/cu.ft	109.5	110.2	111.8	113.2	116.0
COMPRESSIVE STRENGTH					
14-day (Psi)	4	7	12	25	80
28-day (Psi)	8	12	18	39	128 . .

TABLE 9 - TRIAL MIX PROPORTIONS AND TEST RESULTS FOR D-AREA POND ASH

INGREDIENTS	MIX 1	MIX 2	MIX 3	MIX 4	MIX 5
CEMENT, lbs/cu.yd	40	50	80	120	200
SAND, lbs/cu.yd	2515	2515	2515	2515	2215
COAL ASH, lbs/cu.yd	610	600	570	530	450
WATER, lbs/cu.yd	608	567	540	500	509
PROPERTIES					
FRESH UNIT WEIGHT, lbs/cu.ft	125.1	126.0	126.4	126.7	127.4
COMPRESSIVE STRENGTH					
14-day (Psi)	8	11	29	85	234
28-day (Psi)	11	15	40	126	338

TABLE 10 - DESIGN MIX PROPORTIONS AND TEST RESULTS FOR CLSM CONTAINING A, F AND D-AREA ASHES

DESIGN MIX	A-AREA	F-AREA	D-AREA
CEMENT (lbs/cu.yd)	165	165	100
SAND (lbs/cu.yd)	2190	2030	2515
POND ASH (lbs/cu.yd)	810	970	550
WATER (lbs/cu.yd)	700	720	507
FRESH UNIT WEIGHT (lbs/cu.ft)	112.8	111.8	124.8
IN-SITU WET DENSITY (lbs/cu..ft))	112.7	117.1	123.9
DRY UNIT WEIGHT (lbs/cu.ft)	93.2	89.4	107.4
pH	12.67	12.44	11.78
INITIAL SET TIME(hr) @500 psi Penetration	30	26	30
COMPRESSIVE STRENGTH 14-day (psi) 28-day (psi) 90-day (psi)	 46 69 135	 34 51 107	 46 62 150
PERMEABILITY, cm/sec	1.06×10^{-3}	1.03×10^{-3}	1.75×10^{-4}
SETTLEMENT, % after 28 days (Ave.)			4.9
COHESION, Ksf	11.9	6.58	8.17
ANGLE OF INTERNAL FRICTION	25°	32.8°	25.3°
SHEAR STRENGTH, Ksf	30.81	25.06	21.7

TABLE 11 - TIME OF SETTING OF CONCRETE MIXTURES BY PENETRATION RESISTANCE (ASTM C403)

A BASIN		F BASIN		D BASIN	
Elapsed Time (day)	Penetration Resistance(psi)	Elapsed Time (day)	Penetration Resistance(psi)	Elapsed Time (day)	Penetration Resistance(psi)
1	330	1	420	1	320
2	800	2	840	2	720
6	1400	6	1400	7	2720
14	1920	14	1920	14	Not Performed
21	2280	21	2080	21	Not Performed
28	2360	28	2280	28	3800

TABLE 12 - PERMEABILITY OF POND ASH CLSM MIX DESIGN USING FALLING HEAD (ATMOSPHERIC)

DESIGN MIX AREA	Q FLOW, ml	A AREA, mm^2	T TIME, sec	PERMEABILITY cm/sec @ 20°C*
A	5780	8008	68400	1.06×10^{-3}
F	6963	8008	84300	1.03×10^{-3}
D	2368	8008	169000	1.75×10^{-4}

* PERMEABILITY = [Q ÷ (A×T)]

TABLE 13 - SETTLEMENT(SHRINKAGE) MONITORING TEST RESULTS FOR D-AREA DESIGN MIX

DESCRIPTION	SPECIMEN 1				SPECIMEN 2			
LOCATION	1	2	3	4	1	2	3	4
INITIAL	0.149"	0.130"	0.106"	0.135"	0.145"	0.122"	0.128"	0.118"
7-DAY	0.144"	0.129"	0.100"	0.129'	0.142"	0.119"	0.119"	0.108"
DIFFERENCE w.r.t INITIAL	0.005"	0.001"	0.006"	0.006"	0.003'	0.003"	0.009"	0.010"
SHRINKAGE, %	3.36	0.77	5.66	4.44	2.07	2.46	7.03	8.48
14-DAY	0.144"	0.129"	0.100"	0.129"	0.140"	0.119"	0.119"	0.108"
DIFFERENCE w.r.t INITIAL	0.005"	0.001"	0.006"	0.006'	0.005"	0.003"	0.009"	0.010"
SHRINKAGE, %	3.36	0.77	5.66	4.44	3.45	2.46	7.03	8.48
28-DAY	0.144"	0.126"	0.100"	0.129"	0.140"	0.118"	0.118"	0.108"
DIFFERENCE w.r.t INITIAL	0.005"	0.004"	0.006"	0.006"	0.005"	0.004"	0.010"	0.010"
SHRINKAGE, %	3.36	3.08	5.66	4.44	3.45	3.28	7.81	8.48

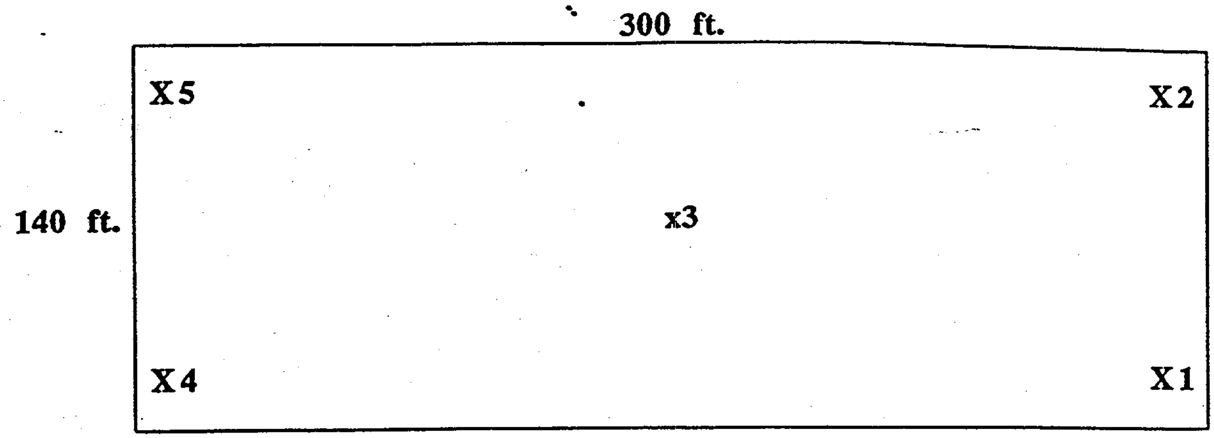
AVERAGE. SHRINKAGE (Specimen 1and Specimen 2)

7-day = 4.28%
14-day = 4.46%
28-day = 4.94%

TABLE 14 - FINAL POND ASH CLSM DESIGN MIXES

MIX INGREDIENT	MIX 1 FOR A AND F AREAS	MIX 2 FOR D AREA
CEMENT (lbs/cu.yd)	165	100
SAND (lbs/cu.yd)	2190	2515
POND ASH (lbs/cu.yd)	810	550
WATER (lbs/cu.yd)	700	507

Figure 1. Schematic drawing of the A-Area ash pile. The pile is surrounded by a clay soil impoundment and is approximately 300 x 140 x 20 ft. in size. Approximate sample locations are indicated.



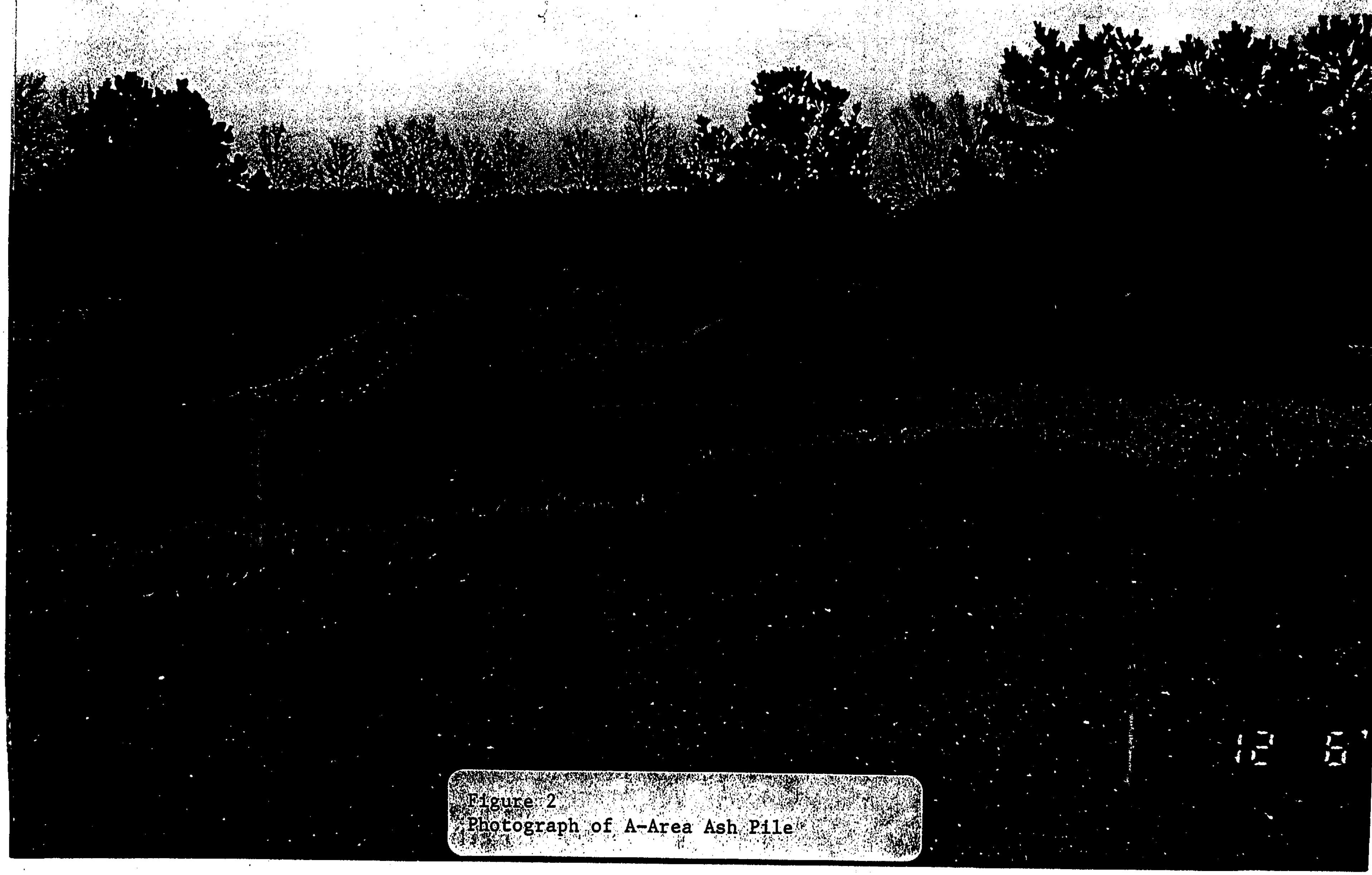


Figure 2
Photograph of A-Area Ash Pile

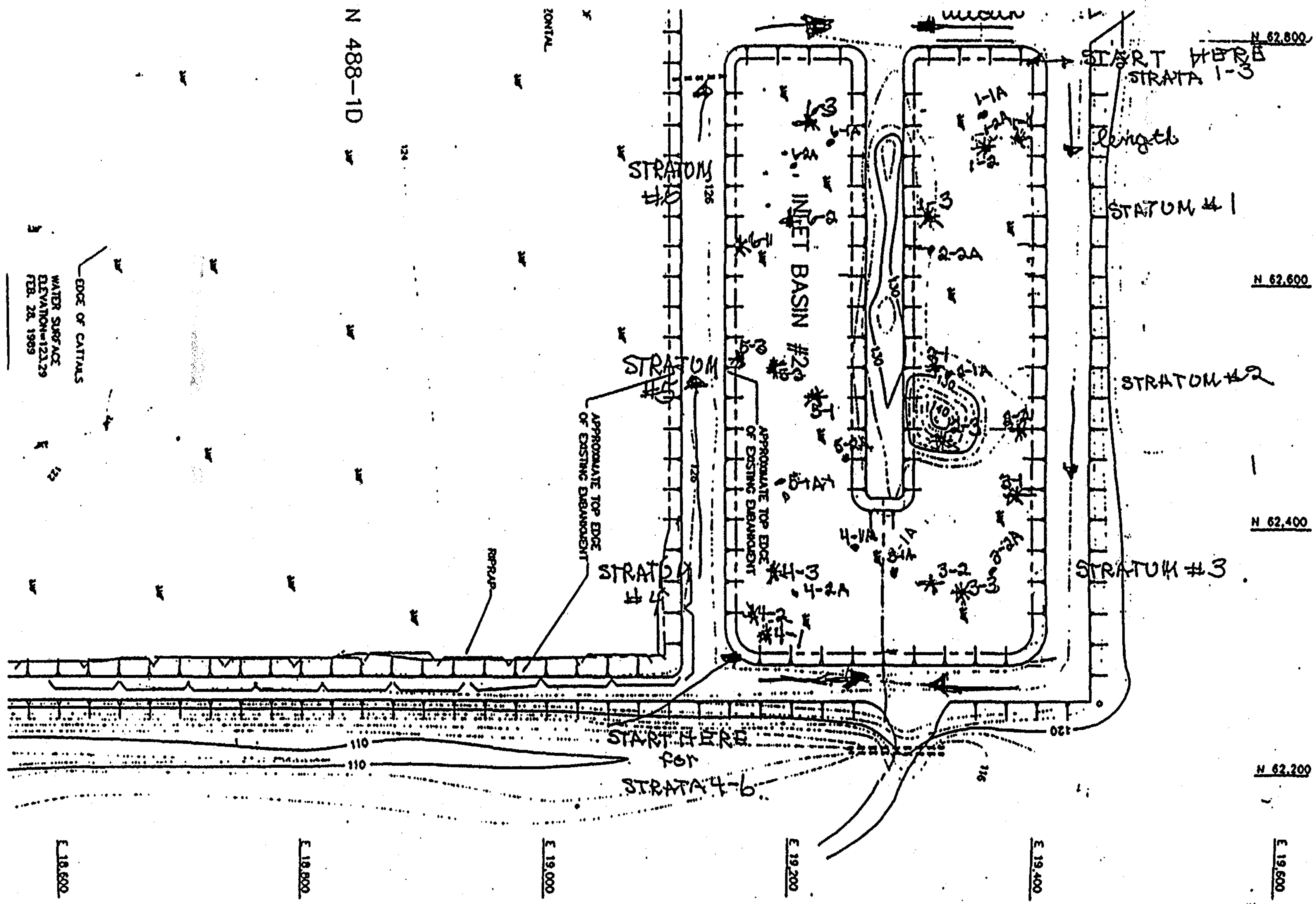


Figure 3. Schematic drawing of the D-Area Inlet Basin #2. Samples were collected from material removed from this basin. These samples roughly correspond to locations 6 - 1, 6 - 2, 6 - 2A, 6 - 3, and 1 - 1. (The remainder of the basin was not accessible for sample collection.)

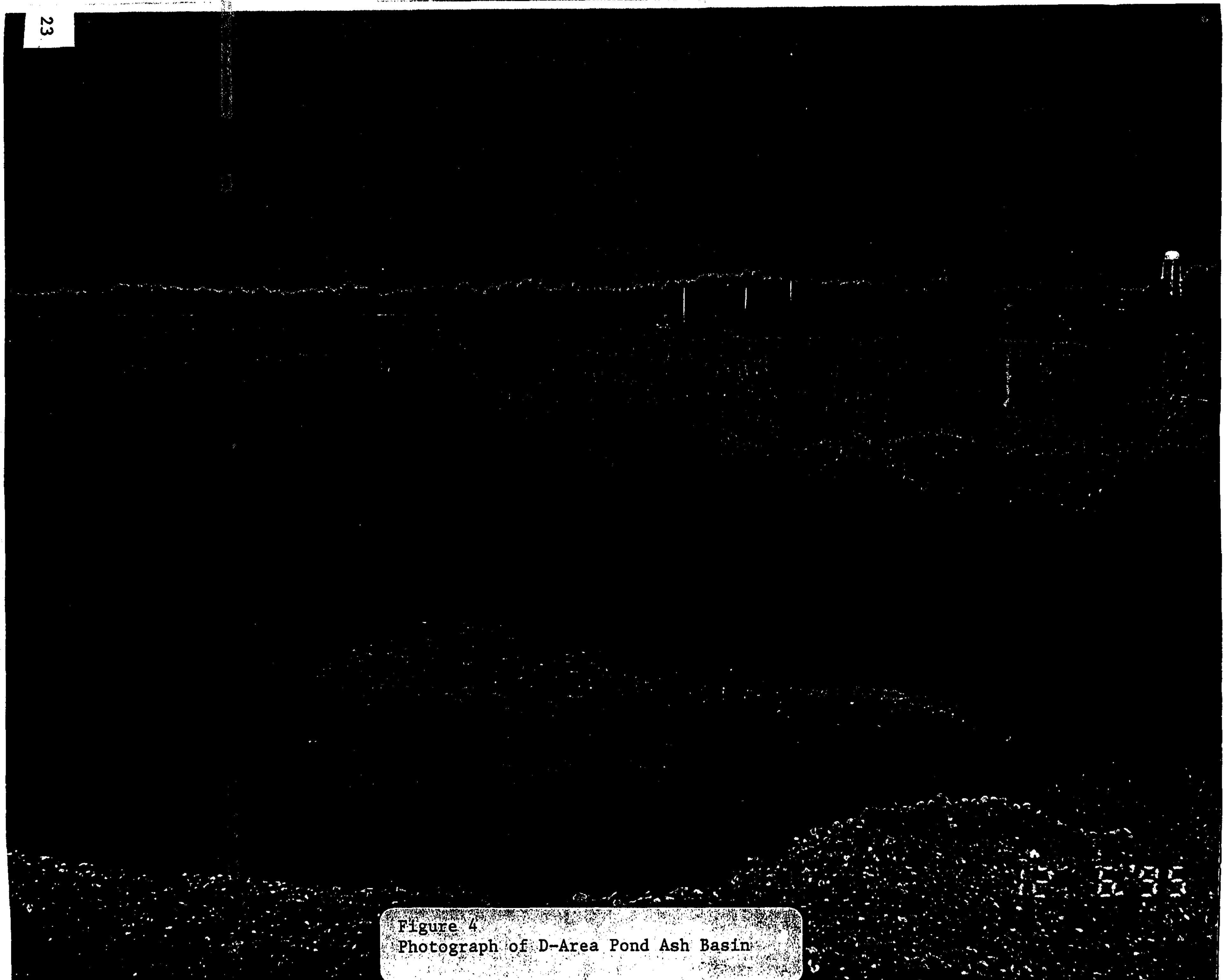


Figure 4
Photograph of D-Area Pond Ash Basin

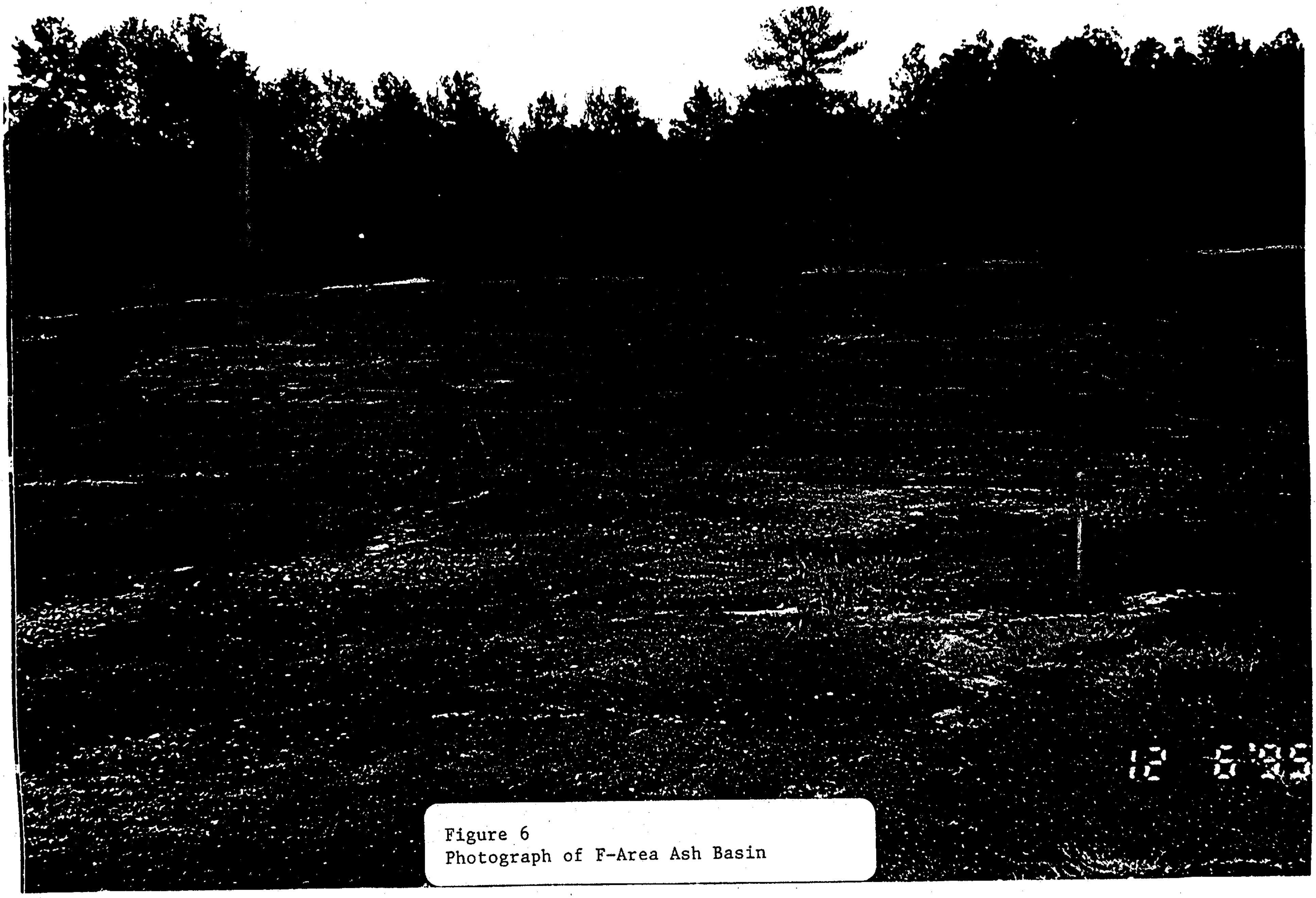


Figure 6
Photograph of F-Area Ash Basin

FIGURE 7 . Compressive Strength Versus Cement Content in CLSM Trial Mixes Made with the A-Area Ash (The target compressive strength for the design mix is 80 ± 10 psi at 28 days)

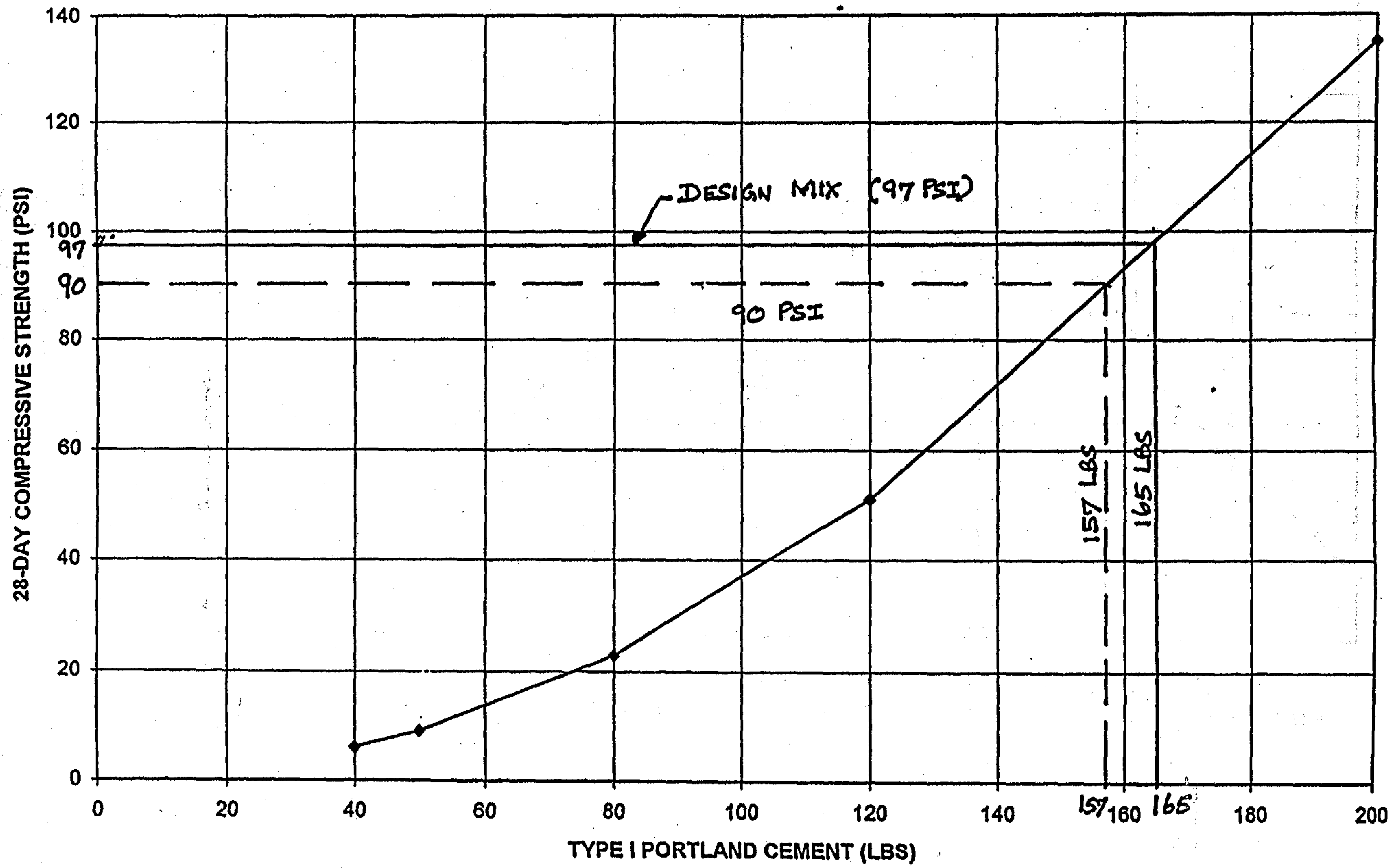


FIGURE 8. Compressive Strength Versus Cement Content in CLSM Trial Mixes Made with the F-Area Ash (The target compressive strength for the design mix is 80 ± 10 psi at 28 days)

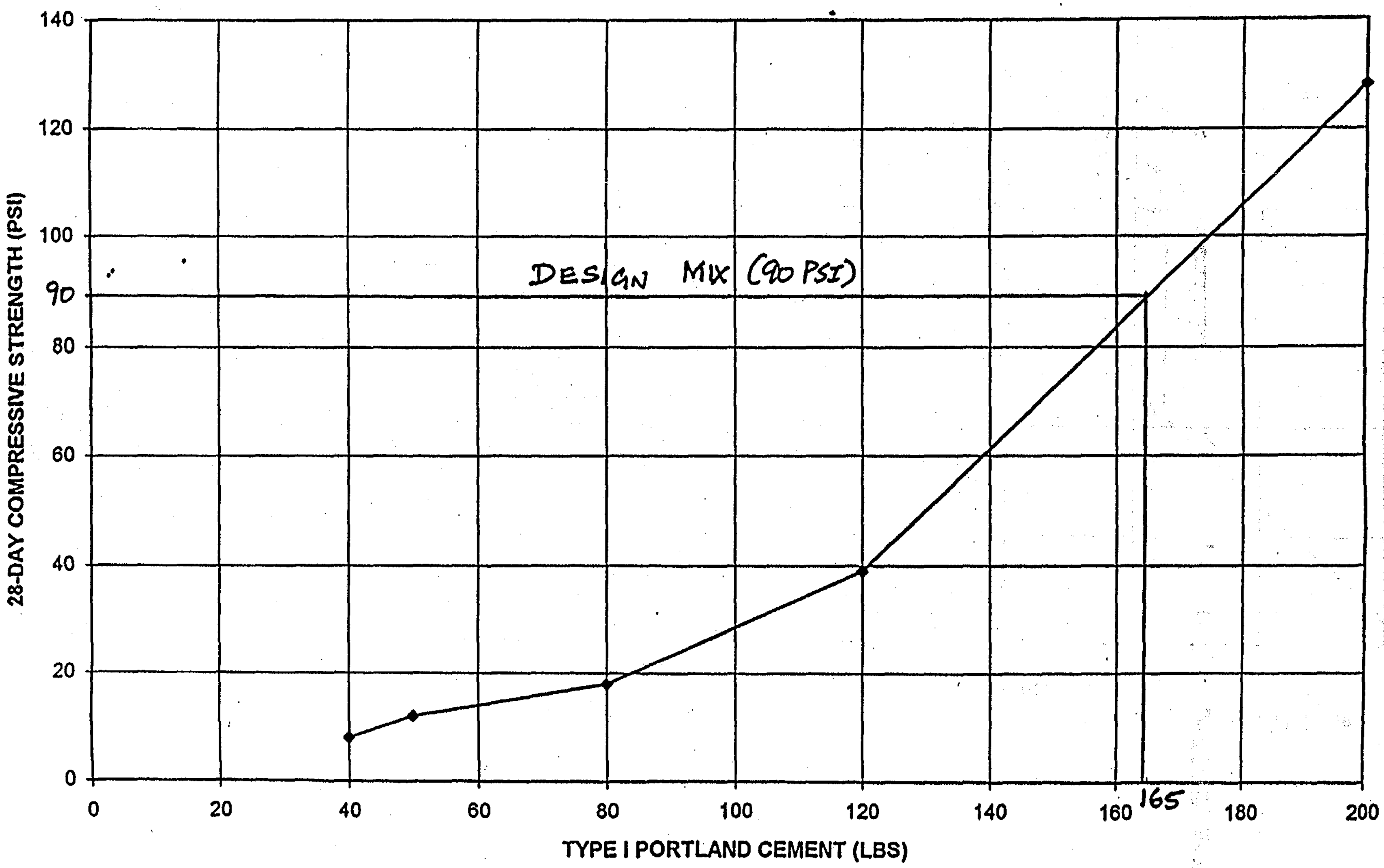


FIGURE 9. Compressive Strength Versus Cement Content in CLSM Trial Mixes Made with the D-Area Ash (The target compressive strength for the design mix is 80± 10 psi at 28 days)

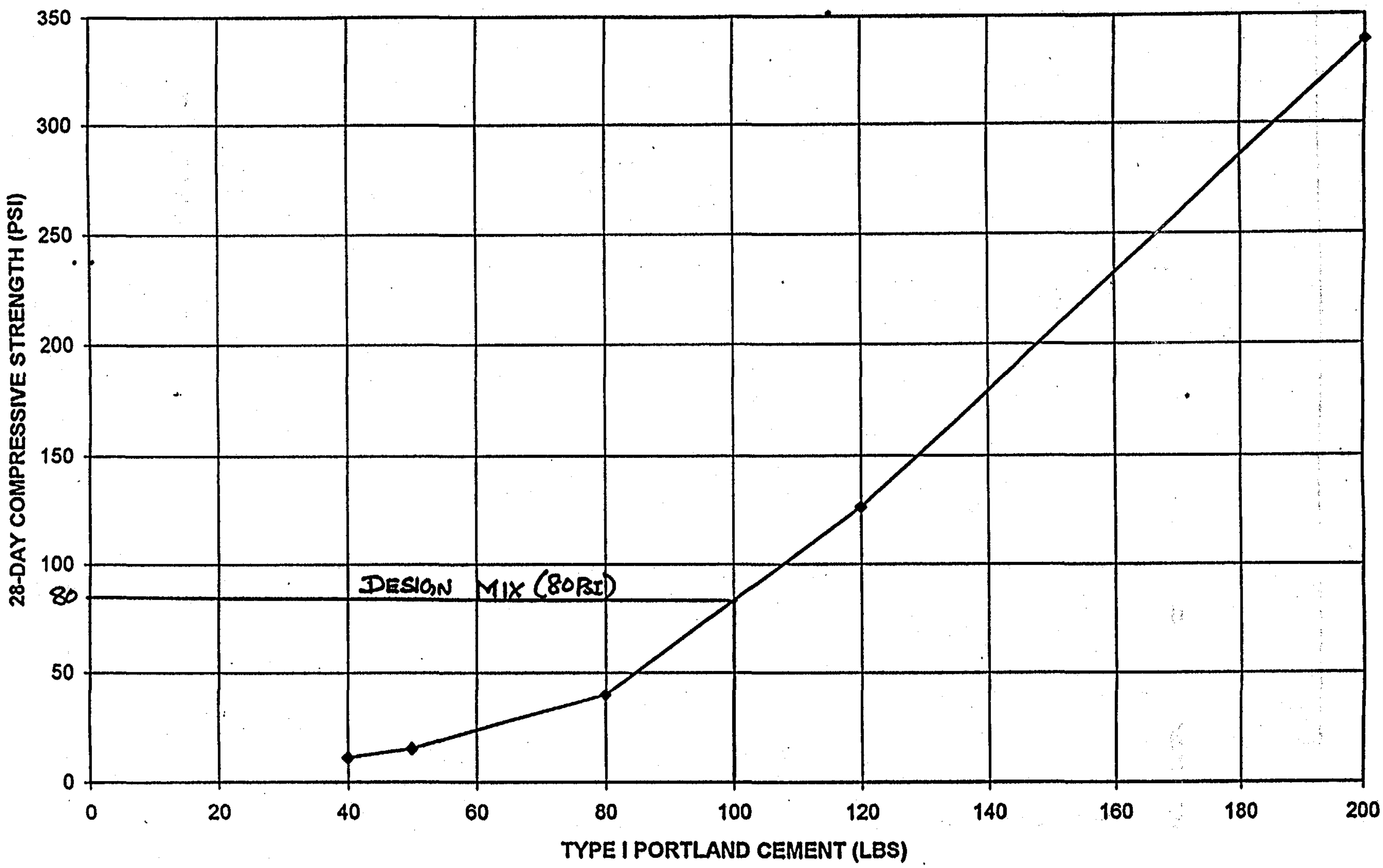


FIGURE 10- Penetration Resistance Versus Elapsed Time for A-Area Pond Ash Design Mix

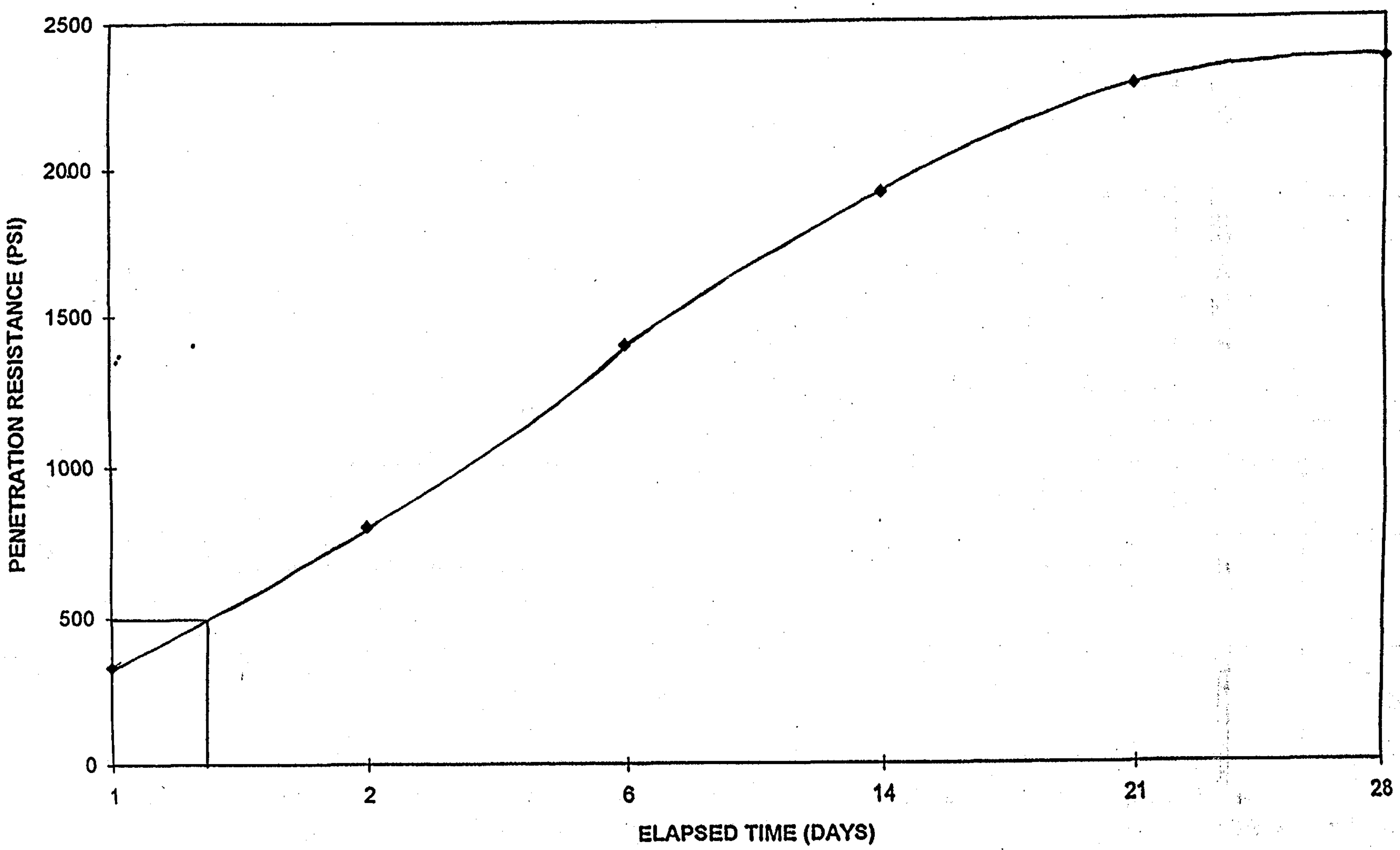


FIGURE 11- Penetration Resistance Versus Elapsed Time for F-Area Pond Ash Design Mix

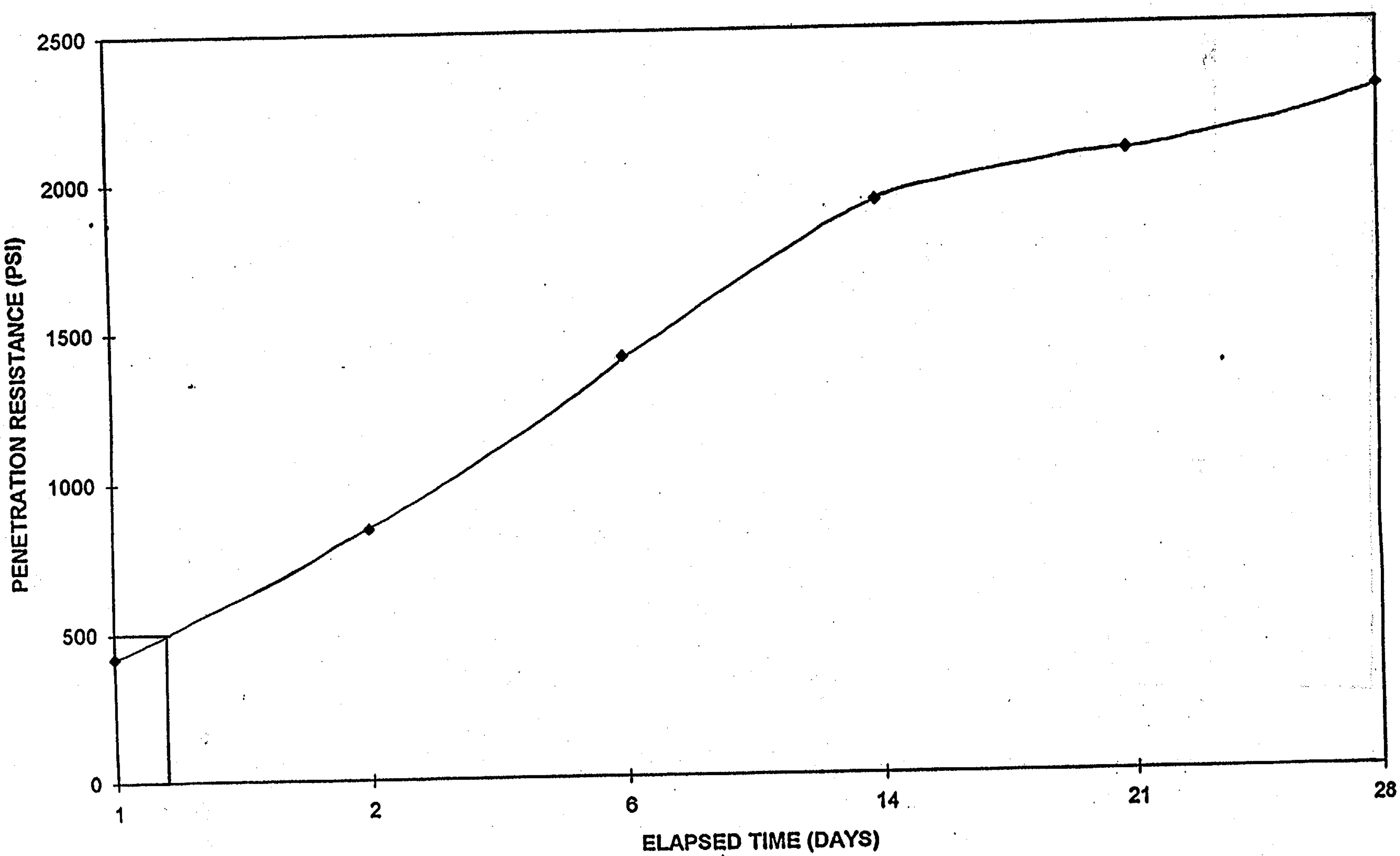


FIGURE 12- Penetration Resistance Versus Elapsed Time for D-Area Pond Ash Design Mix

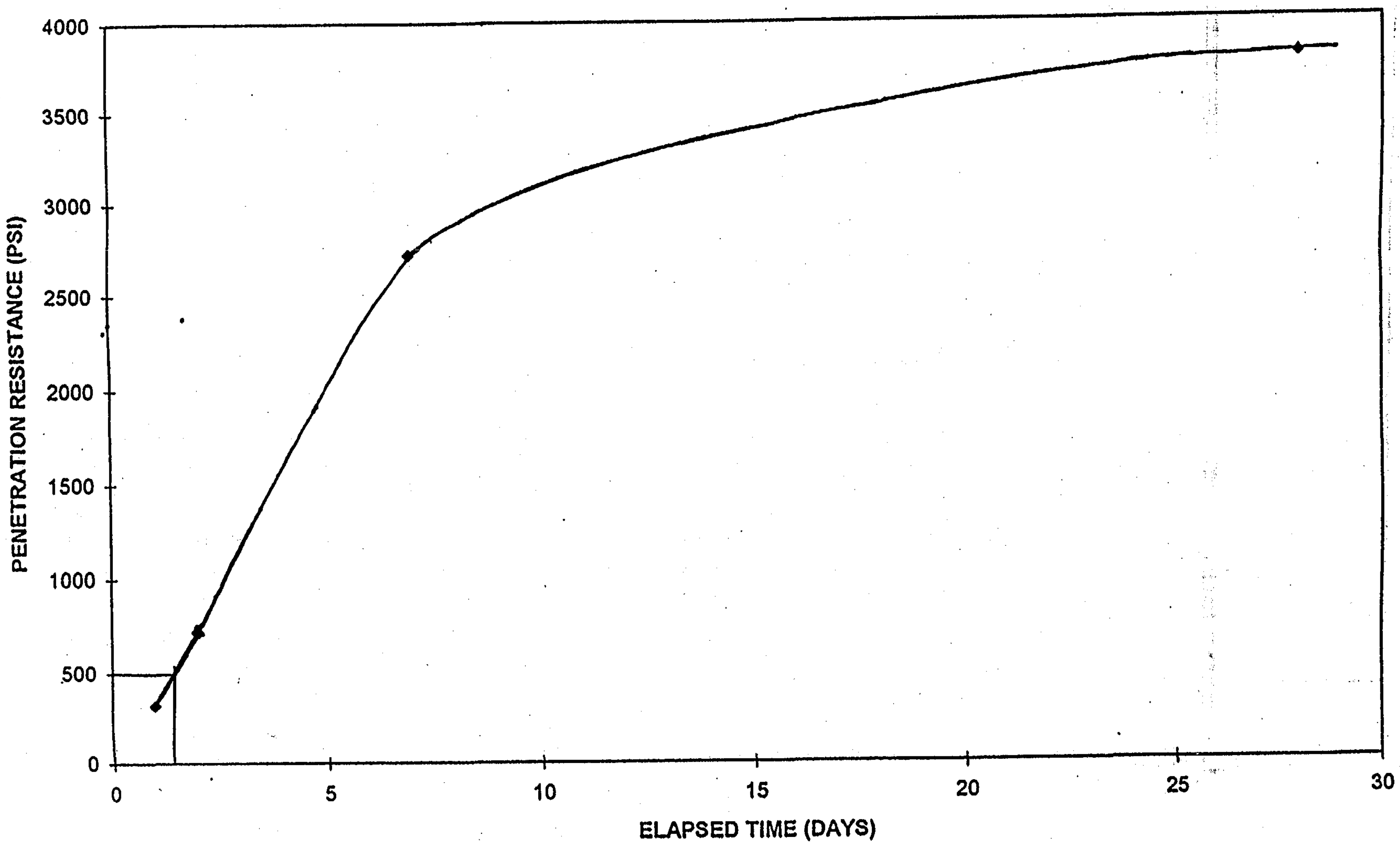
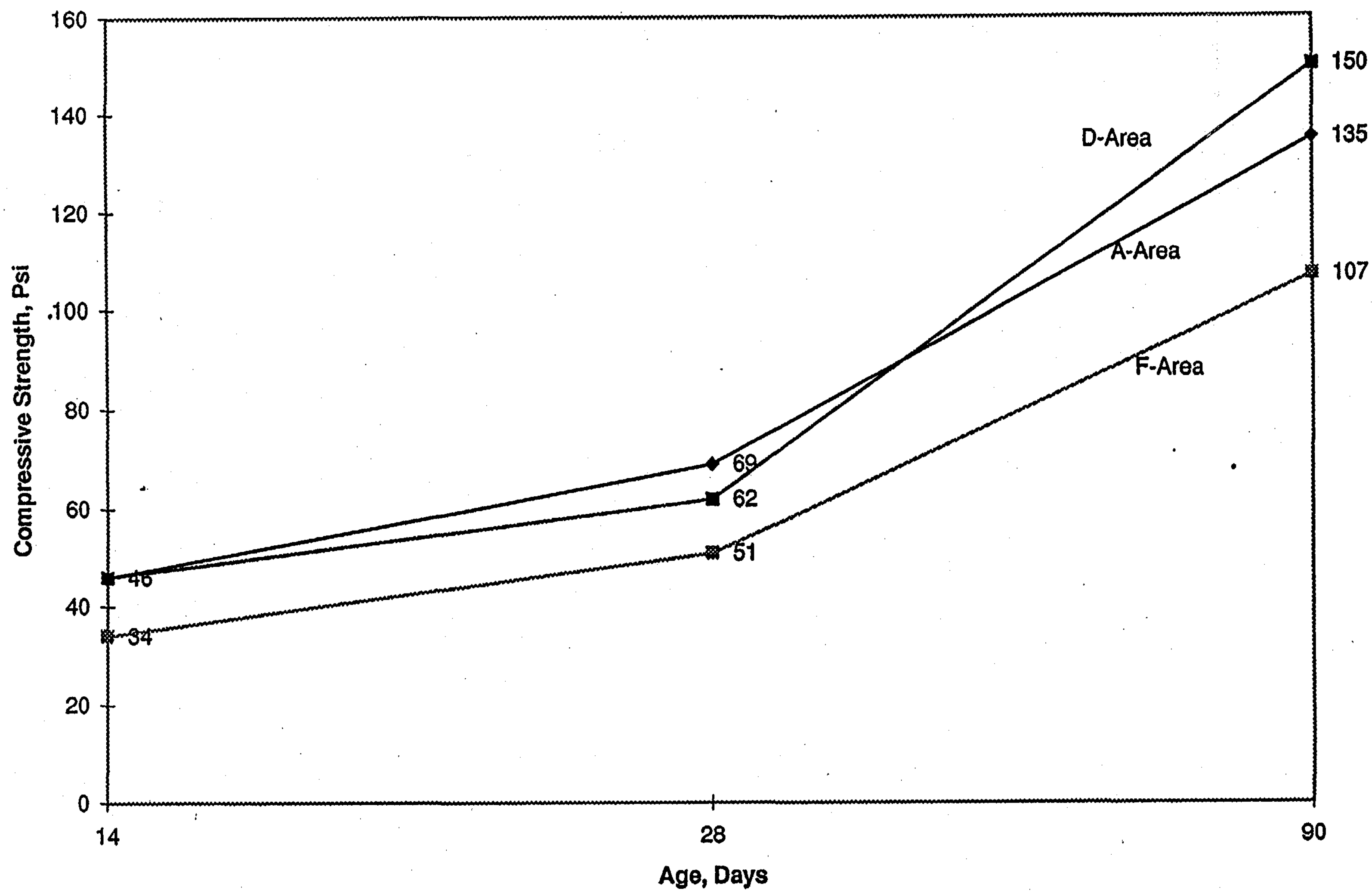


Figure 13 - Compressive Strength Versus Age for Design Mix A, F and D Areas Pond Ash



APPENDIX I: Use of CLSM as a Construction Material

USE OF CLSM AS A CONSTRUCTION MATERIAL

The American Concrete Institute defines controlled low-strength materials as cementitious systems which result in a compressive strength of 1200 psi (8.3 MPa) or less. In general, current use of CLSM is limited to materials with unconfined compressive strengths of less then 300 psi. CLSM is a self-leveling, self-compacting, cementitious material and, as such, minimizes construction placement efforts. It is designed to flow like a fluid, level without tamping or vibration to reach 100% compaction and to support loads like compacted soils. In most cases, it is designed to have properties similar to the surrounding soil after it has obtained full strength.

CLSM has been used since the mid 1960's as a backfill material to provide a faster, more economical method of filling trenches and excavations. It is specified and used extensively by utility companies, state and federal transportation departments and federal agencies such as the US Bureau of Land Reclamation and the US Army Corps of Engineers.

Applications for common CLSM backfill include:

Sewer trenches
Utility trenches
Building excavations
Bridge abutments
conduit trenches

Applications of structural CLSM backfill include:

Structural fill
Mud jacking
Road base
Subbase
Floor slab base
Pipe bedding

Other common uses of CLSM include:

filling abandoned underground storage tanks
Slope stabilization
Soil erosion control
Mud mats
Abandoned sewer line remediation

Some of the benefits of using CLSM instead of conventional compacted soil backfill include:

Voids can be filled in areas which are inaccessible to compaction equipment. This includes tight or restricted areas or areas where exposure to radioactivity, chemicals, or other hazards may be of importance.

Minimal settlement - Consequently no deterioration caused by settlement such as pot holes or broken or unlevel slabs.

The number of personnel required in the fill area is minimized.

Minimal labor and equipment is required for installation.

Installation time is minimized.

Placement is not sensitive to freezing or rainy weather conditions.

Quality Control can be provided by monitoring batches.

CLSM is environmentally safe and non toxic.

APPENDIX II: Characterization of Fine Aggregate and Cement Used in Pond Ash Controlled Strength Material

TABLE II-1 - CHEMICAL AND PHYSICAL PROPERTIES OF PORTLAND CEMENT, TYPE I*

CHEMICAL

Silicon Dioxide (SiO_2)	20.53%
Aluminum Oxide (Al_2O_3)	6.00%
Ferric Oxide (Fe_2O_3)	2.65%
Calcium Oxide (CaO)	64.57%
Magnesium Oxide (MgO)	0.92%
Sulfur Trioxide (SO_3)	2.95%
Ignition Loss	1.08%
Insoluble Residue	0.13%
Alkalies (Na_2O eqv.)	0.20%

PHYSICAL

FINENESS
325 Mesh 92.3 % Passing
7.7% Retained
SETTING TIME
Initial 65 minutes
Final 233 minutes
False Set 72.2%
Air content 6.4%
Soundness 0.292%

POTENTIAL COMPOUNDS

C3S	54.3%
C2S	17.9%
C3A	11.4%
C4AF	8.1%

COMPRESSIVE STRENGTH

1 DAY	1818 PSI
3 DAYS	3474 PSI
7 DAYS	4776 PSI
28 DAYS	6241 PSI

* This cement meets *ASTM C 150 requirements.*

TABLE II-2 - SIEVE ANALYSIS OF FINE AGGREGATE (ASTM C 136)

Sieve Size	Cumulative Wt. Retained	Cumulative % Retained	% Passing	ASTM Limits % Passing
3/8"	0	0	100	100
#4	7.8	1.3	99	95 - 100
#8	34.4	5.8	94	80 - 100
#16	125.1	21.3	79	50 - 85
#30	293.5	49.9	50	25 - 60
#40	390.5	N/A	N/A	N/A
#50	484.2	82.2	18	10 - 30
#100	575.9	97.8	2	2 - 10

Fineness Modulus: Sum of Cumlative % Retained/100 = 2.58
Test Results Conforming to the ASTM Specification

APPENDIX II: Characterization of Fine Aggregate and Cement Used in WSRC Controlled Low Strength Material (Mix No. EXE-X-P-O-X)

TABLE II-1-CHEMICAL AND PHYSICAL PROPERTIES OF PORTLAND CEMENT, TYPE I *

CHEMICAL

Silicon Dioxide (SiO_2)	20.53%
Aluminum Oxide (Al_2O_3)	6.00%
Ferric Oxide(Fe_2O_3)	2.65%
Calcium Oxide (CaO)	64.57%
Magnesium Oxide (MgO)	0.92%
Sulfur Trioxide (SO_3)	2.95%
Ignition Loss	1.08%
Insoluble Residue	0.13%
Alkalies (Na_2O eqv.)	0.20%

PHYSICAL

FINENESS		
	325 MESH	92.3% Passing
		7.7% Retained
SETTING TIME		
	Initial	65 minutes
	Final	233 minuets
	False Set	72.2%
	Air content	6.4%
	Soundness	0.292%

POTENTIAL COMPOUNDS

C3S	54.3%
C2S	17.9%
C3A	11.4%
C4AF	8.1%

*This cement meets ASTM C 150 Requirements.

COMPRESSIVE STRENGTH

1 DAY	1818 PSI
3 DAYS	3473 PSI
7 DAYS	4776 PSI
28 DAYS	6241 PSI

TABLE II-2 - SIEVE ANALYSIS OF FINE AGGREGATE (ASTM C 136)

Sieve Size	Cumulative Wt. Retained	Cumulative % Retained	% Passing	ASTM Limits % Passing
3/8"	0	0	100	100
#4	7.8	1.3	99	95 - 100
#8	34.4	5.8	94	80 - 100
#16	125.1	21.3	79	50 - 85
#30	293.5	49.9	50	25 - 60
#40	390.5	N/A	N/A	N/A
#50	484.2	82.2	18	10 - 30
#100	575.9	97.8	2	2 - 10

ATTACHMENT 1

Sample Units for the A-, D-, and F-Area Ash Piles

J. H. Weber

SRT-ASG-950006

Savannah River Technology Center
Savannah River Site
INTER-OFFICE MEMORANDUM

February 3, 1995 SRT-ASG-950006

To: C. A. Langton, 773-43A

From: J. H. Weber, 773-42A JHW

CC: S. E. Smith,
N. Rajendran, 704-65H

Technical Reviewer: E P Shine
E. P. Shine, 773-42A

Manager, Applied Statistics Group: R. C. Tuckfield
R. C. Tuckfield, 773-42A

Subject: Sample Units for the A-, D-, and F-Area Ash Piles

Approximately 15-18 core samples will be collected from each of three ash piles (one each in A-, D- and F-Areas). The sample locations will be specified in feet along the length and width of the pile starting with zero in one corner (or in the case of the D-area pile, 2 starting corners for sample selection). The core drilling must extend from the top of the pile vertically to the bottom of the basin. The sampling is designed to gather information concerning the physical and chemical properties of the ash to ascertain whether it is suitable for at least one of several potential uses. Based on the findings of this study, additional samples may be required.

Once the core samples are selected, the cores will be examined for vertical stratification. If there is no stratification, the core will be divided into three equal sized sub-cores. These are the top, middle, and bottom. Each sub-cores will be sieved separately to determine particle size and then one sample will be selected from each sub-core. If there is visual evidence of vertical stratification, then each stratum will be sieved separately and a sample selected from each core stratum. Record the height of each core stratum starting with 0 to represent the top. These selected sub-samples will be sent to the laboratory for the required chemical and physical analyses.

Each core and sub-sample must be uniquely identified. The numbering system I propose consists of the following:

Letter for Area (A, D, or F)
Stratum number (1 through 6)
Sample selection number within stratum (1 through 15).
Letter to identify original sample or alternate sample (O for original and A for alternate)
Letter to identify core strata where 1 equals the top core stratum. (For vertically unstratified cores, three sub-samples will be selected. For vertically stratified cores, one sub-sample will be selected from each stratum.)

I have provided alternate samples which must be used in the order given and only within the same stratum. The alternates are to be used only if the selected sample falls outside the basin or the core sample could not be drilled at the selected location. The selected locations are given to 6 in (0.5 ft). Sampling units were considered to be approximately 5 ft by 5 ft, although this could vary along the edges of the basin. The sample location given is in the middle of each 5 ft by 5 ft sampling unit. You should be able to locate the sample within about ±1.5 ft. The selected sample locations are given in increasing distances along the length of the basin within each stratum.

A-Area Ash Pile

The A-area ash pile is approximately rectangular in shape 300 ft long and 140 ft wide. It is assumed that there is no horizontal stratification. Therefore, only one stratum is defined. Fifteen core samples are randomly selected throughout the basin. An additional five samples are given as alternates. The first 15 are given in increasing distance along the length of the basin. The alternates are given in the order they are to be used. Since there is only one stratum, select any of the four corners as the starting point. This starting point will be zero length and zero width. Record coordinates of starting corner.

Sample No.	Length (feet)	Width (feet)
A-1-1-O	7.5	2.5
A-1-2-O	12.5	72.5
A-1-3-O	32.5	62.5
A-1-4-O	52.5	92.5
A-1-5-O	67.5	12.5
A-1-6-O	92.5	97.5
A-1-7-O	122.5	67.5
A-1-8-O	142.5	77.5
A-1-9-O	177.5	37.5
A-1-10-O	192.5	102.5
A-1-11-O	192.5	127.5
A-1-12-O	197.5	37.5
A-1-13-O	232.5	22.5
A-1-14-O	257.5	52.5
A-1-15-O	297.5	52.5

Alternates if needed, use in order given, and if selected, record alternate number.

A-1-1-A	17.5	42.5
A-1-2-A	267.5	47.5
A-1-3-A	42.5	122.5
A-1-4-A	2.5	112.5
A-1-5-A	222.5	37.5

D-Area Ash Basin

The sample locations in the D-Area Bah Basin are identified in the attached map. The D-Area basin is in the shape of a horseshoe. Start at the top of the horseshoe, approximately N 62,800 and E 19,400. Six strata are defined, three for each half of the horseshoe. The starting origin for the first three is at N 62,800 and E 19,400 and will progress to the bottom of the horseshoe. The three strata for the other half are defined starting at the bottom of the horseshoe, coordinates, approximately N 62,300 and E 19,150. For strata 4 through 6 the samples increase in distance along the length until you reach the top of the horseshoe. Three samples will be selected from each stratum. There are two alternates per stratum.

	Selected Sample			Alternate Sample		
Stratum No.	Sample No.	Length	Width	Sample No.	Length	Width
1	D-1-1-O	62.5	7.5	D-1-1-A	42.5	42.5
	D-1-2-O	67.5	42.5	D-1-2-A	62.5	27.5
	D-1-3-O	127.5	87.5			
2	D-2-1-O	292.5	82.5	D-2-1-A	297.5	72.5
	D-2-2-O	307.5	12.5	D-2-2-A	187.5	82.5
	D-2-3-O	312.5	72.5			
3	D-3-1-O	392.5	72.5	D-3-1-A	442.5	112.5
	D-3-2-O	452.5	82.5	D-3-2-A	442.5	32.5
	D-3-3-O	462.5	57.5			
Starting from bottom of horseshoe (approximately N 62,300 and E 19,150)						
4	D-4-1-O	12.5	22.5	D-4-1-A	82.5	97.5
	D-4-2-O	22.5	12.5	D-4-2-A	47.5	42.5
	D-4-3-O	62.5	27.5			
5	D-5-1-O	212.5	62.5	D-5-1-A	142.5	37.5
	D-5-2-O	262.5	27.5	D-5-1-A	187.5	92.5
	D-5-3-O	272.5	2.5			
6	D-6-1-O	347.5	2.5	D-6-1-A	442.5	77.5
	D-6-2-O	382.5	42.5	D-6-2-A	402.5	42.5
	D-6-3-O	462.5	57.5			

The D-area ash basin is a wet basin with an island in the middle of the horseshoe (top of the horseshoe). The island extends through the middle of the basin until you are approximately to strata 3 and 4 (about N 62,400). The length of the basin is approximately 500 ft by 250 ft. The width of the two prongs is approximately 95 ft.

F-Area Ash Pile.

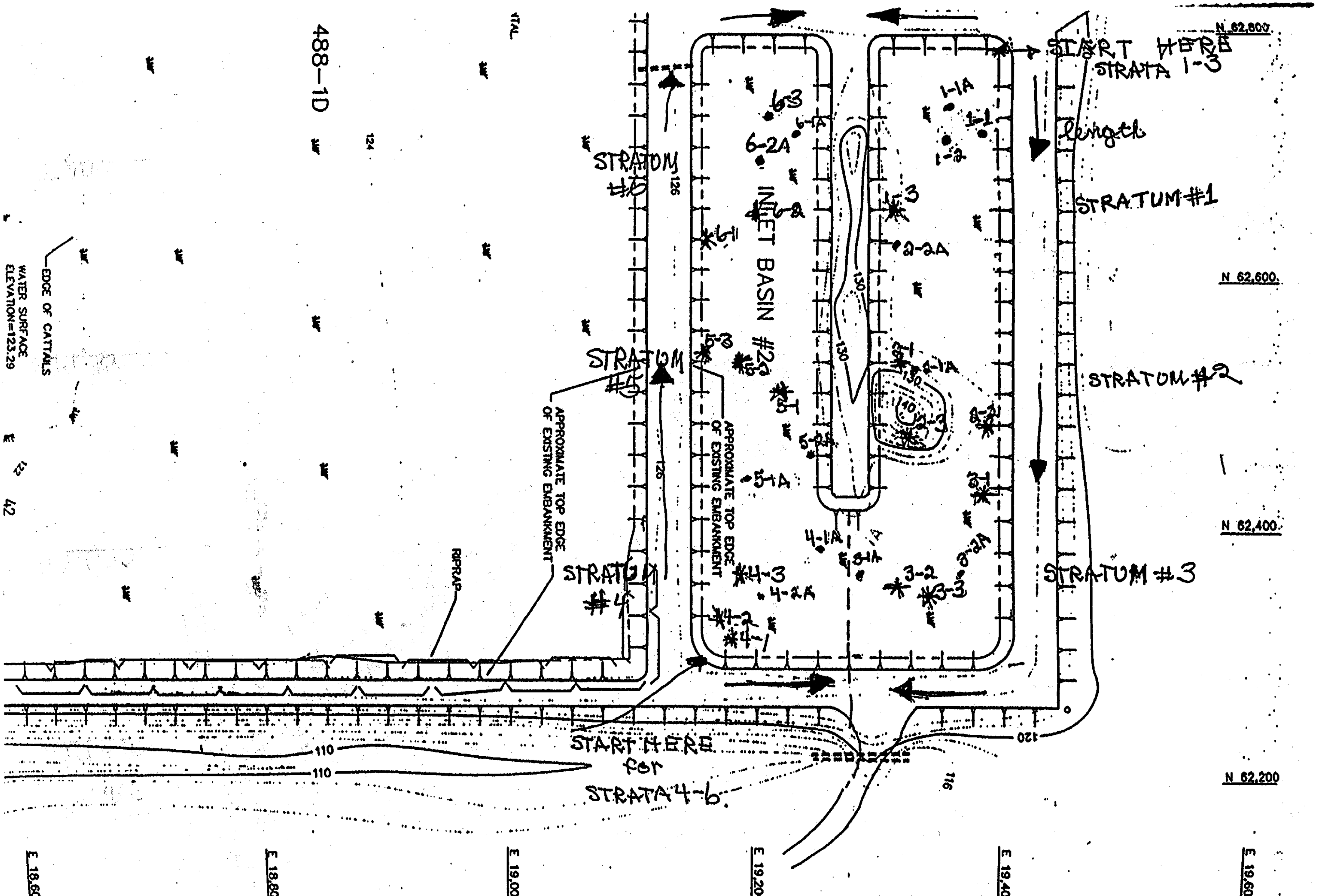
The sampling locations for the F-Area ash pile are identified on the attached map. The ash pile basin is approximately rectangular. However, the bottom portion of the basin is not included in the sampling frame as it was underwater and would be difficult to select samples. The exact location of the portion under water is not known. Also there are ash piles from A area piled along one side of the basin. These ash piles are to be sampled separately. The basin is approximately 1050 ft in length by 275 ft in wide. The A-area ash piles are along the length close to the boundary. This basin is the one in which the alternates are most likely to be needed as the selected sample locations may not be drillable. The sampling frame is assumed to extend lengthwise for only about 700 ft of the 1050 ft. If part of stratum 5 is under water and cannot be sampled, use the alternate samples. Also one of the samples may be under the A-area ash piles.

This sample is only for the portion under the ash piles. If this is impossible, use the alternate. The sample for the ash pile is given last. If one of the original samples for the basin is under the ash pile and you are unable to samble just the F-area ash under the A-area piles, use the alternate and then sample for both the A-area ash and the F-area ash underneath using the sample from the A-area ash. The starting corner is the one closest to the gravel road at approximately E 55,400 and N 77,800. The ash piles are along the length boundary where the starting point is. If you use alternates, use only those within the same stratum as the original one that couldn't be sampled. The sample locations are distances from the starting point.

	Selected Sample			Alternate Sample		
Stratum No.	Sample No.	Length	Width	Sample No.	Length	Width
1	F-1-1-O	22.5	18.5	F-1-1-A	82.5	52.5
	F-1-2-O	147.5	57.5	F-1-2-A	107.5	102.5
	F-1-3-O	212.5	122.5			
2	F-2-1-O	212.5	142.5	F-2-1-A	367.5	42.5
	F-2-2-O	282.5	187.5	F-2-2-A	117.5	167.5
	F-2-3-O	342.5	37.5			
3	F-3-1-O	222.5	247.5	F-3-1-A	402.5	167.5
	F-3-2-O	317.5	257.5	F-3-2-A	167.5	202.5
	F-3-3-O	407.5	217.5			
4	F-4-1-O	487.5	27.5	F-4-1-A	492.5	217.5
	F-4-2-O	527.5	182.5	F-4-2-A	482.5	172.5
	F-4-3-O	527.5	187.5			
5	F-5-1-O	627.5	182.5	F-5-1-A	567.5	27.5
	F-5-2-O	677.5	32.5	F-5-2-A	667.5	242.5
	F-5-3-O	677.5	102.5			

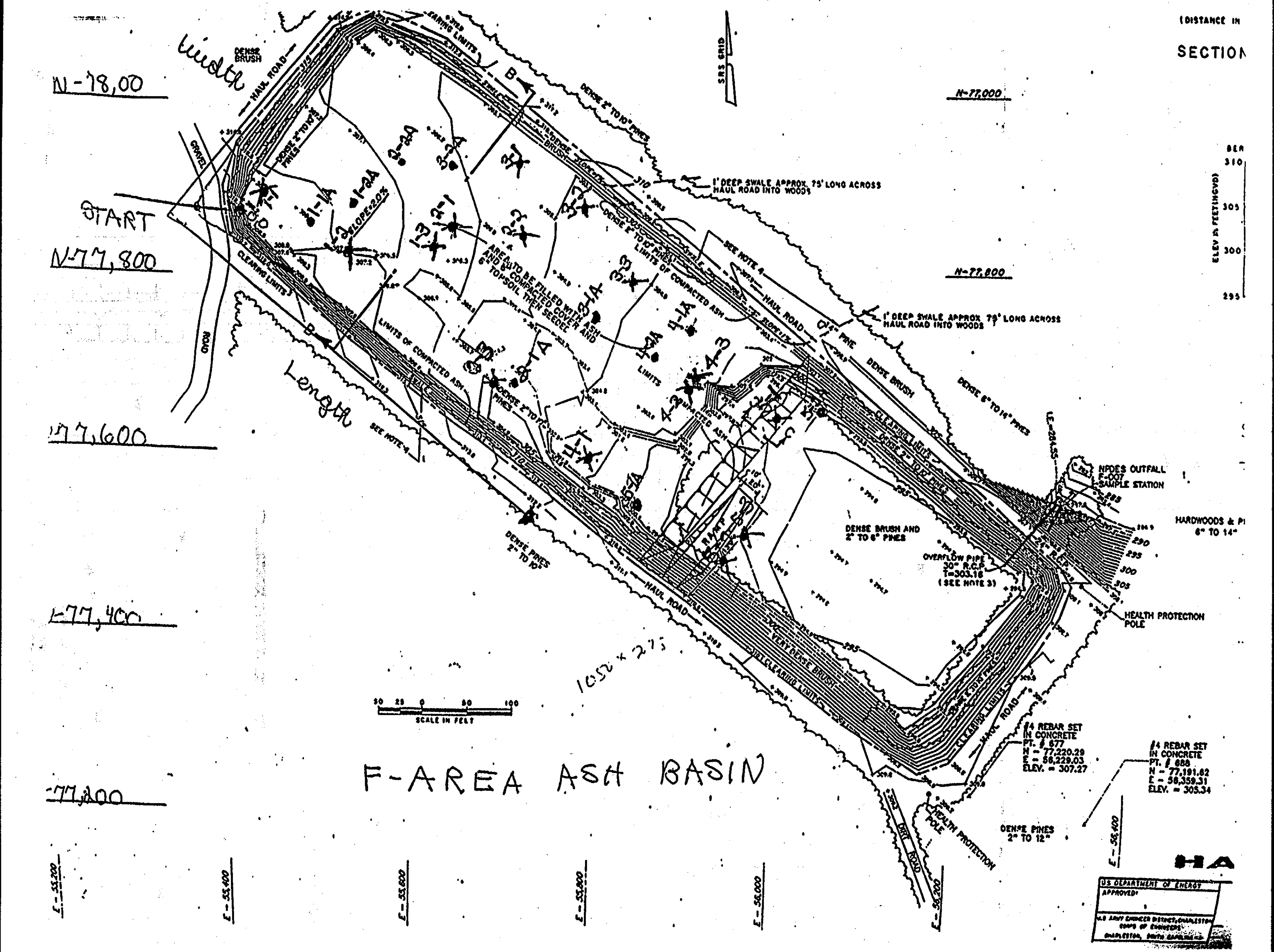
The ash pile starting coordinates will be along the length on the same boundary as the basin starting point. The exact width and length of the ash piles are not known. Only one sample is to be selected but two alternates are provided in case the selected sample falls outside the boundary of the ash pile. The ash pile will be designated as stratum 6.

6	F-6-1-O	122.5	37.5	F-6-1-A	112.5	62.5
(A-area ash pile)				F-6-2-A	82.5	12.5



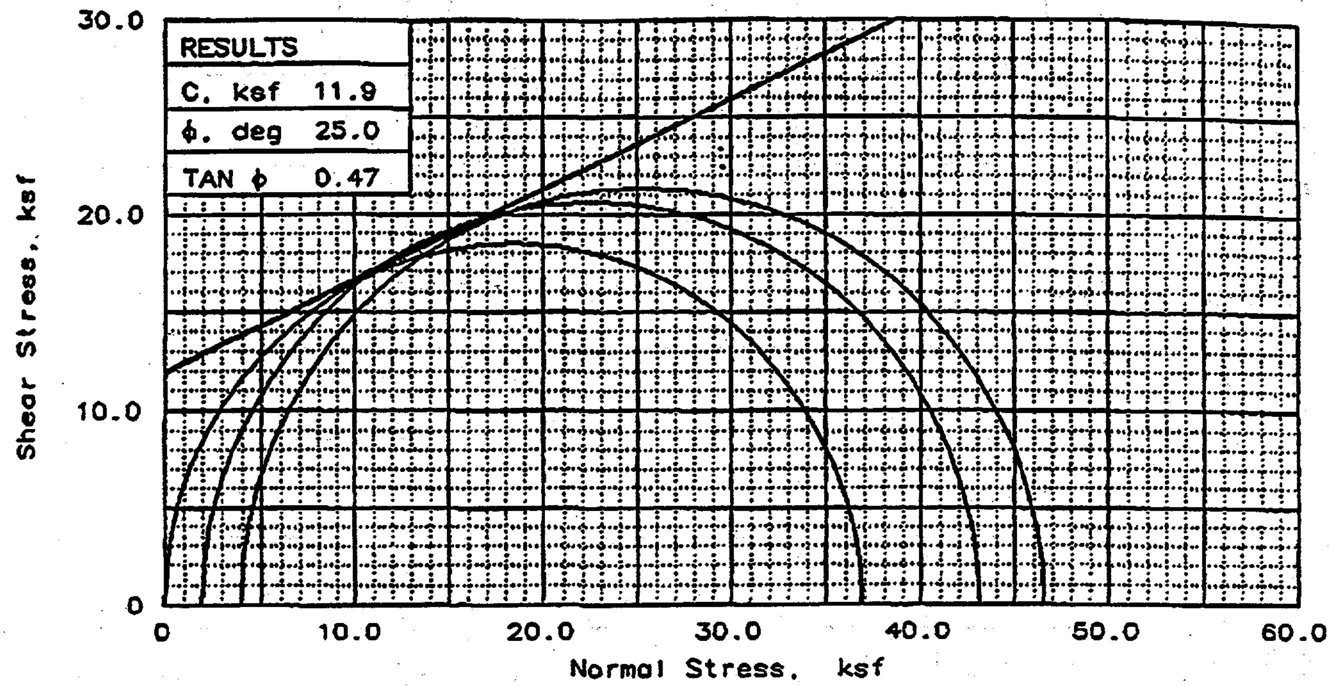
D-AREA ASH BASIN

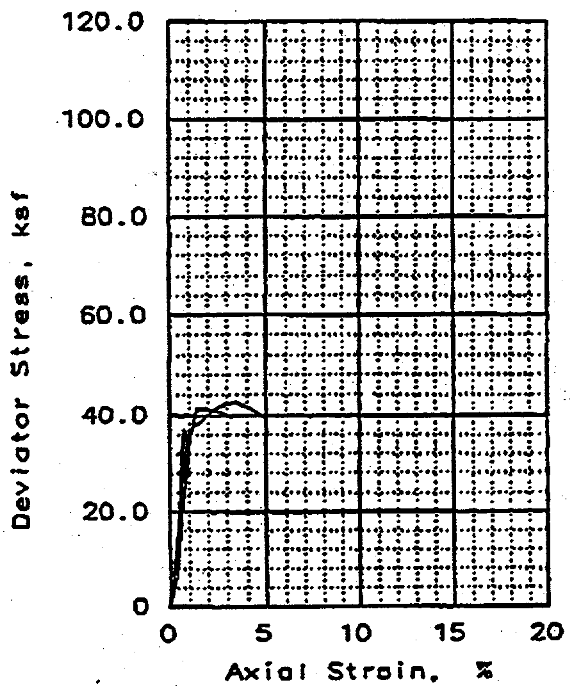
42


F-AREA ASH BASIN
START
Width
Length
1050 x 275
N-78,00
N-77,800
N-77,600
N-77,400
N-77,200
N-77,000
SRS GRID
SECTION
DISTANCE IN
ELEV IN FEET (NGVD)
HAUL ROAD
GRAVEL ROAD
DIRT ROAD
CLEARING LIMITS
DENSE BRUSH
DENSE 2" TO 10" PINES
DENSE 8" TO 14" PINES
1' DEEP SWALE APPROX. 75' LONG ACROSS HAUL ROAD INTO WOODS
LIMITS OF COMPACTED ASH
AREA TO BE FILLED WITH ASH AND 6" COMPACTED COVER AND 6" TOPSOIL THEN SEEDED
SEE NOTE 4
DENSE BRUSH AND 2" TO 6" PINES
OVERFLOW PIPE 30" R.C.P. T=303.16 (SEE NOTE 3)
NPDES OUTFALL F-007 SAMPLE STATION
HARDWOODS & PI 6" TO 14"
HEALTH PROTECTION POLE
VERY DENSE BRUSH
DENSE PINES 2" TO 10"
DENSE PINES 2" TO 12"
#4 REBAR SET IN CONCRETE PT. # 677 N - 77,220.29 E - 56,229.03 ELEV. = 307.27
#4 REBAR SET IN CONCRETE PT. # 688 N - 77,191.62 E - 56,359.31 ELEV. = 305.34
SCALE IN FEET
E - 55,200
E - 55,400
E - 55,600
E - 55,800
E - 56,000
E - 56,200
E - 56,400
US DEPARTMENT OF ENERGY
APPROVED:
U.S. ARMY ENGINEER DISTRICT, CHARLESTON CORPS OF ENGINEERS
CHARLESTON, SOUTH CAROLINA

ATTACHMENT 2

Law Engineering Test Results for the SRS Coal Ash CLSM Design Mix





SAMPLE NO.		1	2	3
INITIAL	WATER CONTENT, %	23.6	24.5	24.4
	DRY DENSITY, pcf	92.9	89.6	92.6
	SATURATION, %	80.0	76.8	82.0
	VOID RATIO	0.781	0.847	0.787
	DIAMETER, in	2.83	2.83	2.83
	HEIGHT, in	5.99	5.43	5.99
AT TEST	WATER CONTENT, %	23.5	24.5	24.4
	DRY DENSITY, pcf	92.9	89.6	92.6
	SATURATION, %	79.8	76.8	82.0
	VOID RATIO	0.781	0.847	0.787
	DIAMETER, in	2.83	2.83	2.83
	HEIGHT, in	5.99	5.43	5.99
BACK PRESSURE, ksf		0.0	0.0	0.0
CELL PRESSURE, ksf		0.0	2.0	4.0
FAILURE STRESS, ksf		36.9	41.2	42.6
PORE PRESSURE, ksf				
STRAIN RATE, %/min.		0.500	0.500	0.500
ULTIMATE STRESS, ksf				
PORE PRESSURE, ksf				
σ_1 FAILURE, ksf		36.9	43.2	46.6
σ_3 FAILURE, ksf		0	2	4

TYPE OF TEST:
Unconsolidated undrained
SAMPLE TYPE: Poured
DESCRIPTION: Coal Ash Mix Design
LL= PL= PI=
SPECIFIC GRAVITY= 2.65
REMARKS: Tested by: HD
Reviewed by: RLB

FIG. NO.

CLIENT: Savannah River Site

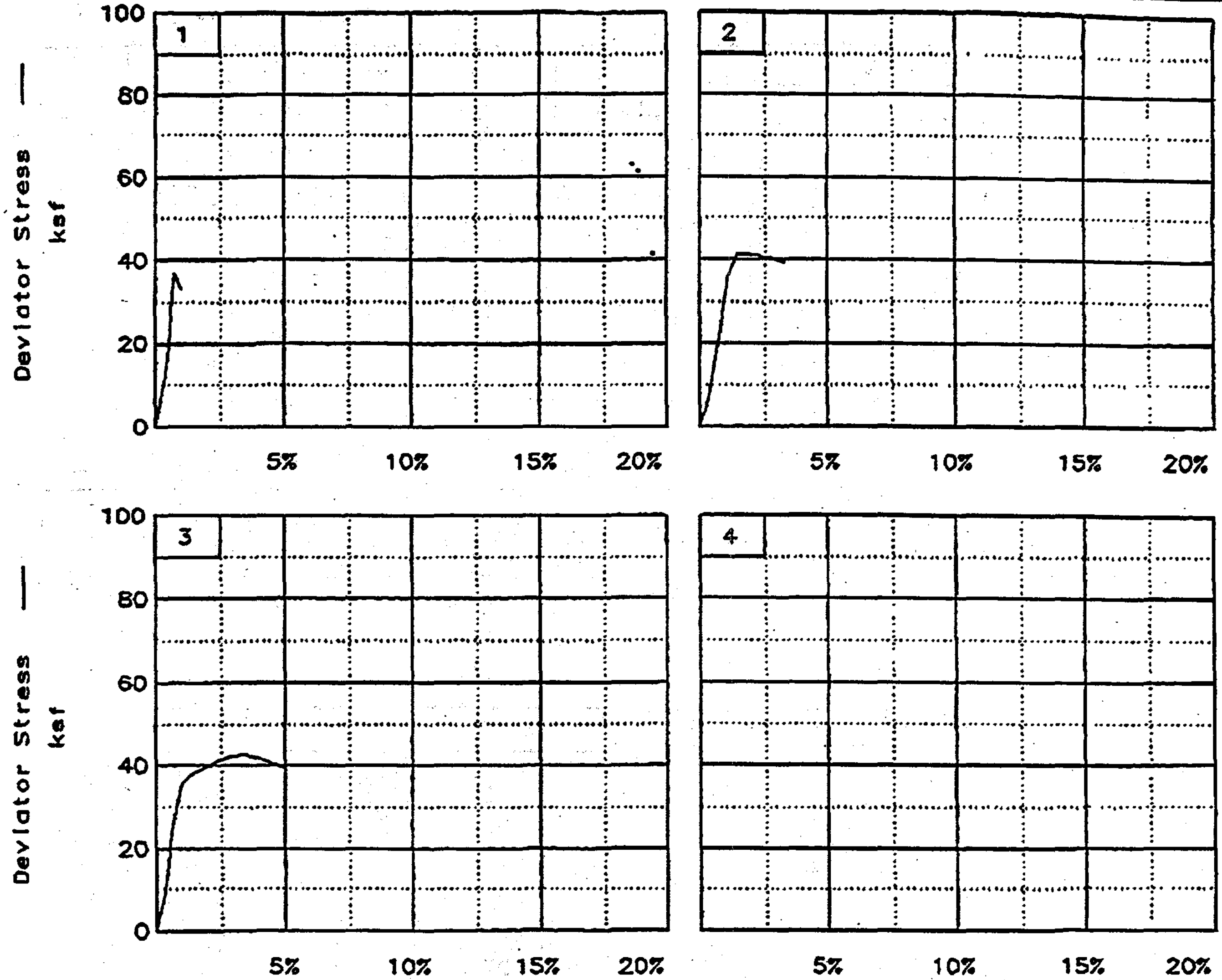
PROJECT: SRS Task 13

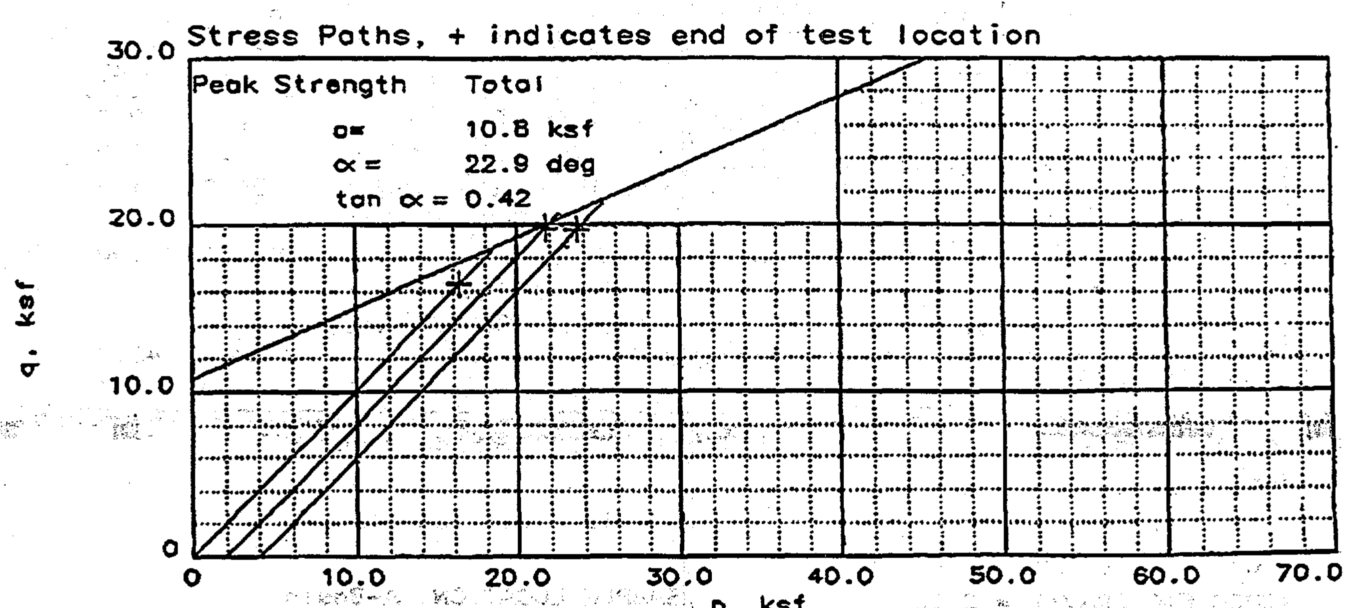
SAMPLE LOCATION: A-Basin
Sampled on 9/19/95

PROJ. NO.: 5016155756 DATE: Feb. 27, 1996

TRIAXIAL COMPRESSION TEST

LAW ENGINEERING, INC.



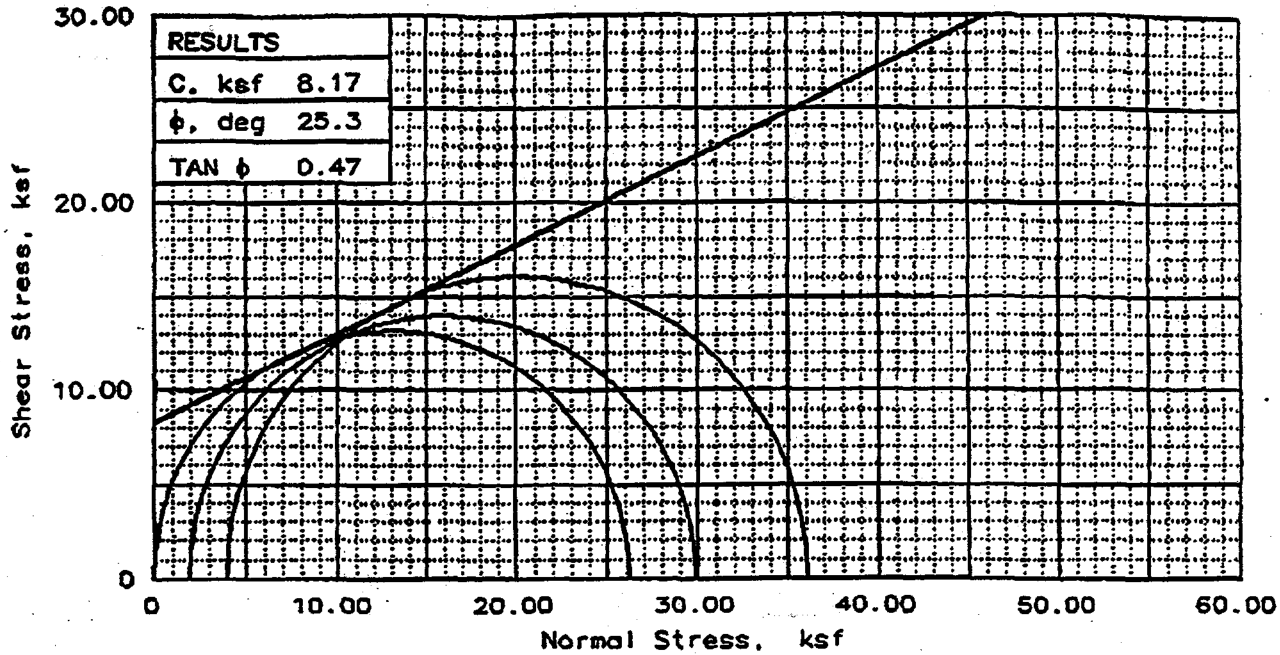


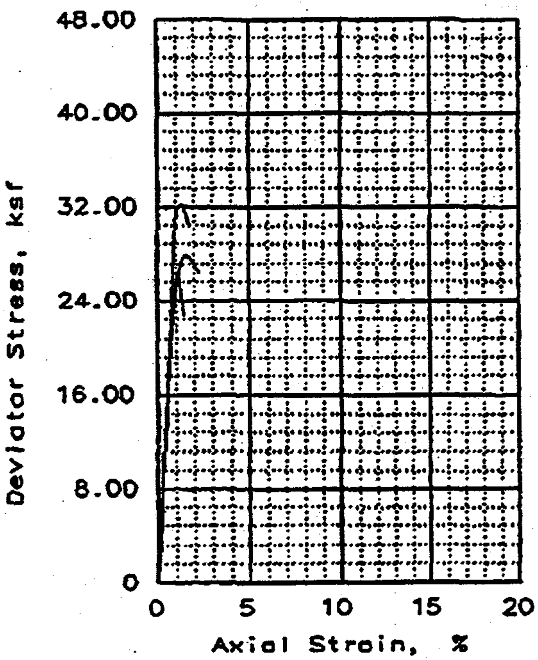
Client: Savannah River Site

Project: SRS Task 13

Location: A-Basin Sampled on 9/19/95

File: 5756H Project No.: 5016155756 Page 2/2 Fig. No. ____





SAMPLE NO.		1	2	3
INITIAL	WATER CONTENT, %	19.7	17.7	18.7
	DRY DENSITY, pcf	101.7	102.8	102.1
	SATURATION, %	83.3	77.0	79.9
	VOID RATIO	0.626	0.609	0.620
	DIAMETER, in	2.85	2.84	2.84
	HEIGHT, in	5.60	5.60	5.60
AT TEST	WATER CONTENT, %	19.7	17.7	18.7
	DRY DENSITY, pcf	101.7	102.8	102.1
	SATURATION, %	83.3	77.0	79.9
	VOID RATIO	0.626	0.609	0.620
	DIAMETER, in	2.85	2.84	2.84
	HEIGHT, in	5.60	5.60	5.60
BACK PRESSURE, ksf		0.00	0.00	0.00
CELL PRESSURE, ksf		0.00	1.99	4.00
FAILURE STRESS, ksf		26.29	27.95	32.11
PORE PRESSURE, ksf				
STRAIN RATE, %/min.		0.500	0.500	0.500
ULTIMATE STRESS, ksf				
PORE PRESSURE, ksf				
σ_1 FAILURE, ksf		26.29	29.93	36.11
σ_3 FAILURE, ksf		0	1.99	4

TYPE OF TEST:
Unconsolidated undrained
SAMPLE TYPE: Poured
DESCRIPTION: Coal Ash Mix Design
LL= PL= PI=
SPECIFIC GRAVITY= 2.65
REMARKS: Tested by: HJ

Reviewed by: RLB

FIG. NO.

CLIENT: Savannah River Site

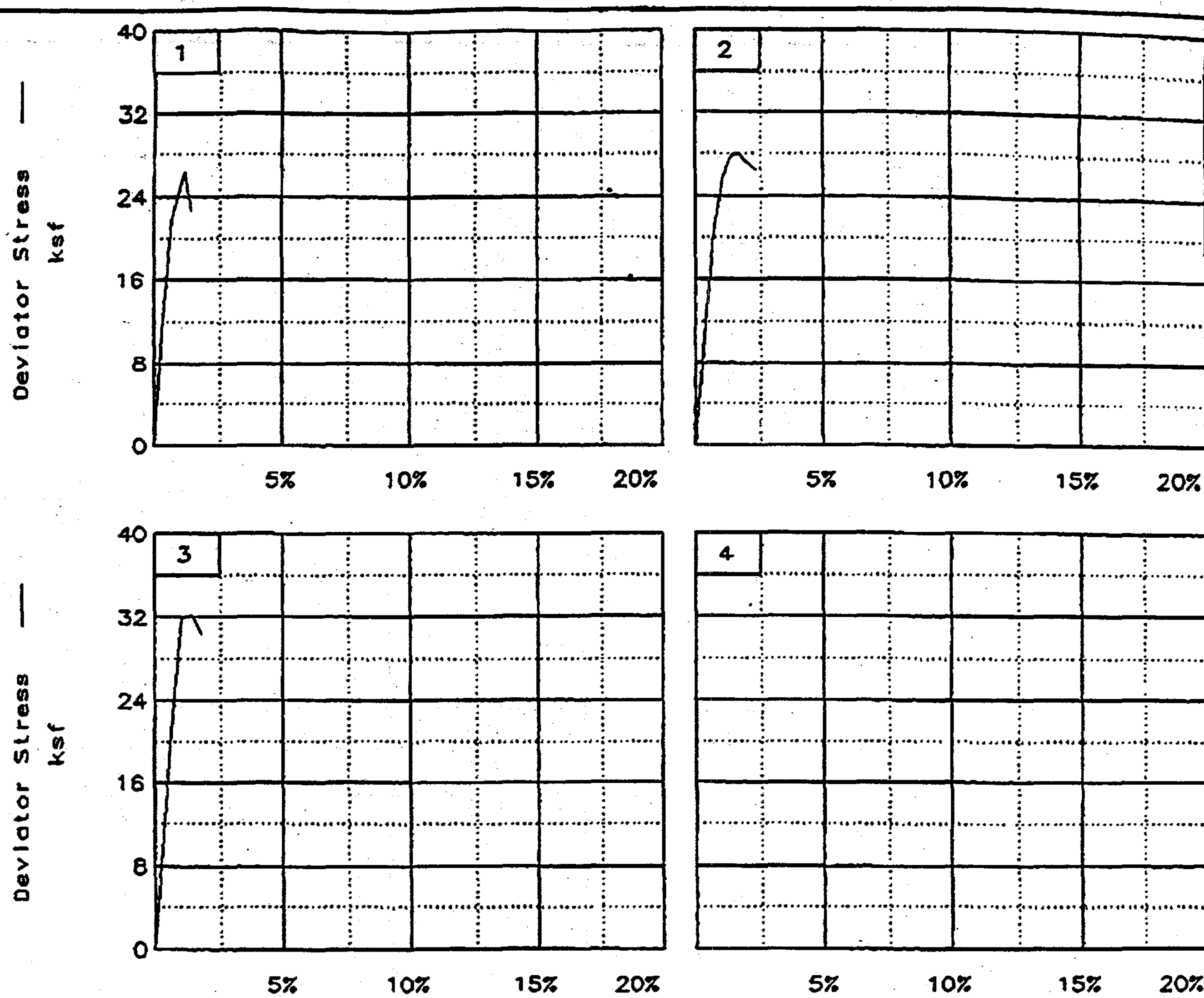
PROJECT: SRS Task 13

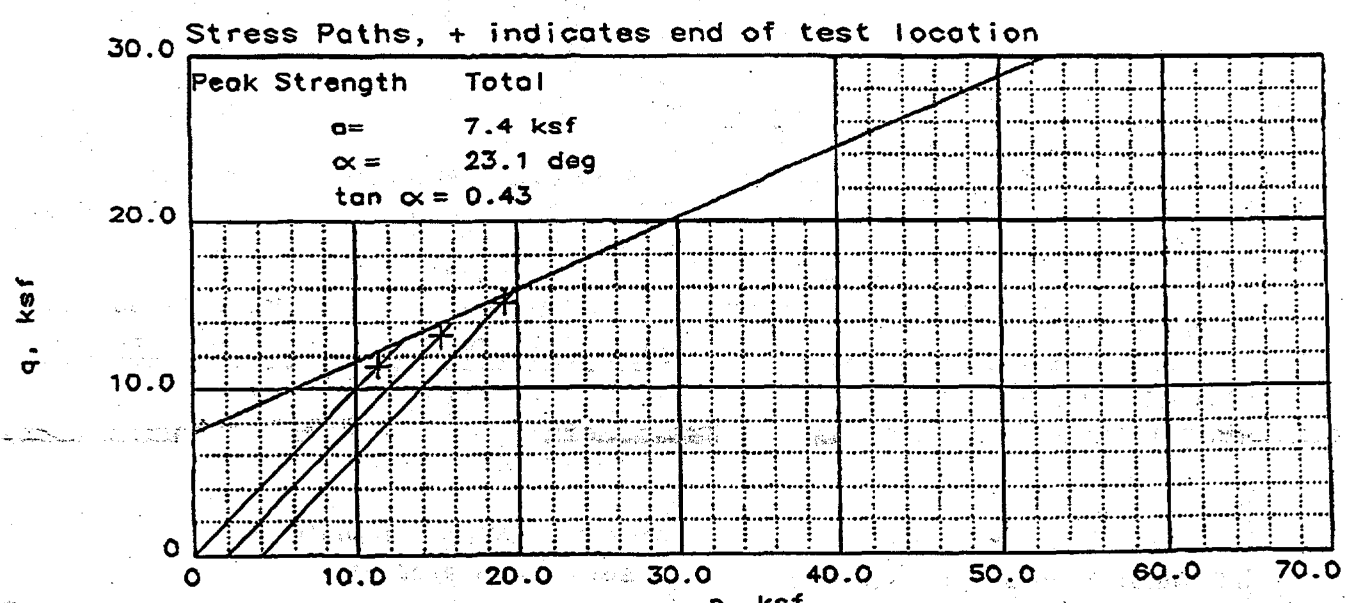
SAMPLE LOCATION: D-Basin
Sampled on 9/26/95

PROJ. NO.: 5016155756 DATE: Feb. 27, 1996

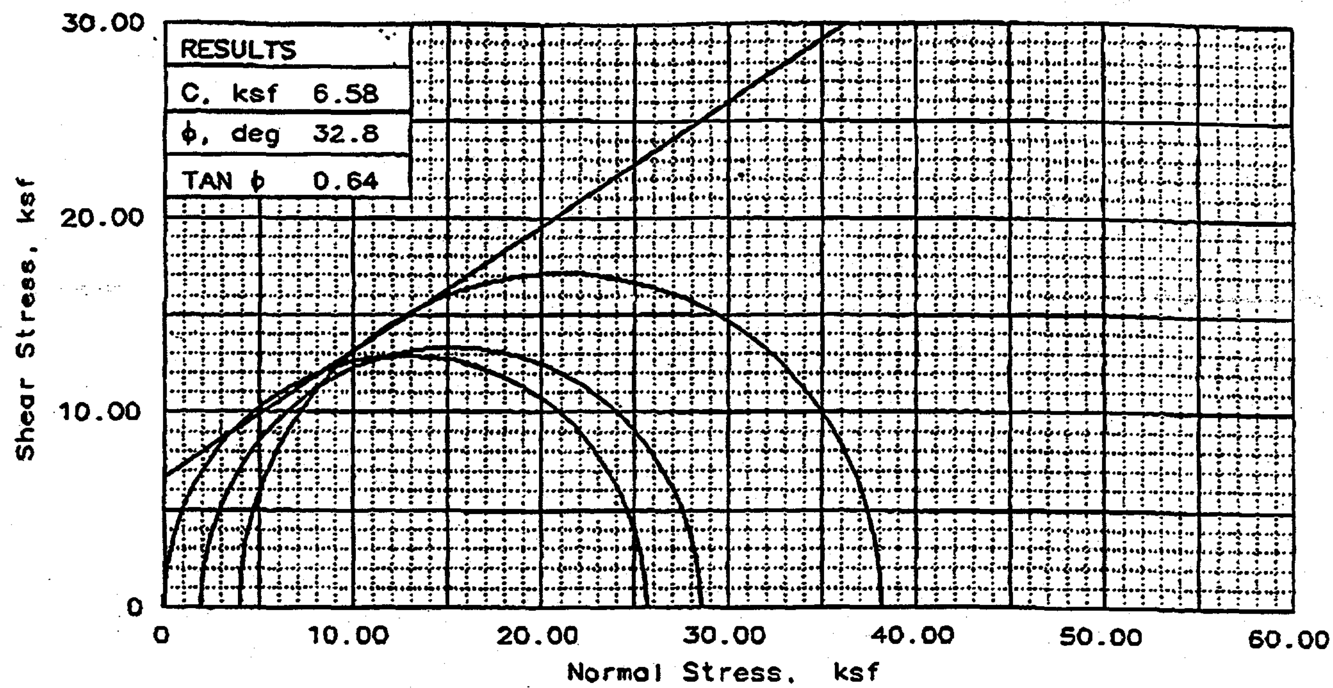
TRIAXIAL COMPRESSION TEST

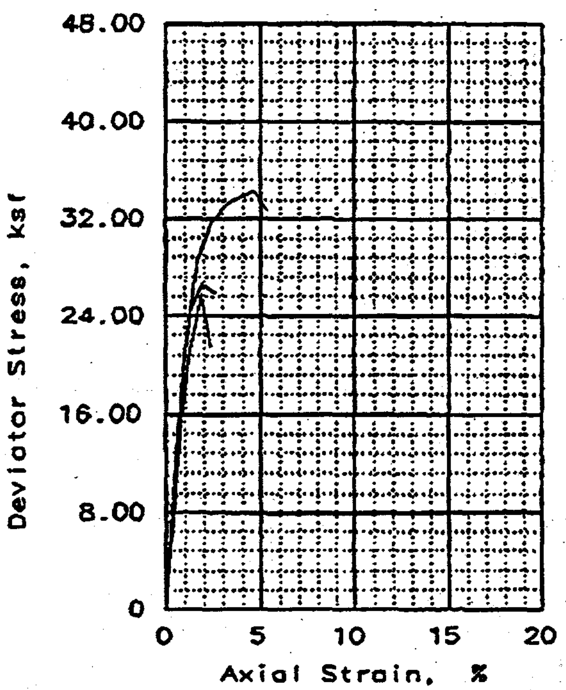
LAW ENGINEERING, INC.





Client: Savannah River Site
Project: SRS Task 13
Location: D-Basin Sampled on 9/26/95
File: 5756F Project No.: 5016155756 Page 2/2 Fig. No. ____





SAMPLE NO.		1	2	3
INITIAL	WATER CONTENT, %	25.7	26.7	27.7
	DRY DENSITY, pcf	87.2	84.4	85.6
	SATURATION, %	75.9	73.7	78.8
	VOID RATIO	0.897	0.961	0.932
	DIAMETER, in	2.83	2.83	2.83
	HEIGHT, in	5.97	6.00	5.97
AT TEST	WATER CONTENT, %	25.7	26.7	27.7
	DRY DENSITY, pcf	87.2	84.4	85.6
	SATURATION, %	75.9	73.7	78.8
	VOID RATIO	0.897	0.961	0.932
	DIAMETER, in	2.83	2.83	2.83
	HEIGHT, in	5.97	6.00	5.97
BACK PRESSURE, ksf		0.00	0.00	0.00
CELL PRESSURE, ksf		0.00	2.00	4.00
FAILURE STRESS, ksf		25.73	26.61	34.26
PORE PRESSURE, ksf				
STRAIN RATE, %/min.		0.500	0.500	0.500
ULTIMATE STRESS, ksf				
PORE PRESSURE, ksf				
σ_1 FAILURE, ksf		25.73	28.61	38.26
σ_3 FAILURE, ksf		0	2	4

TYPE OF TEST:
Unconsolidated undrained

SAMPLE TYPE: Poured

DESCRIPTION: Coal Ash Mix Design

LL= PL= PI=

SPECIFIC GRAVITY= 2.65

REMARKS: Tested by: HS

Reviewed by: RLB

FIG. NO.

CLIENT: Savannah Rive Site

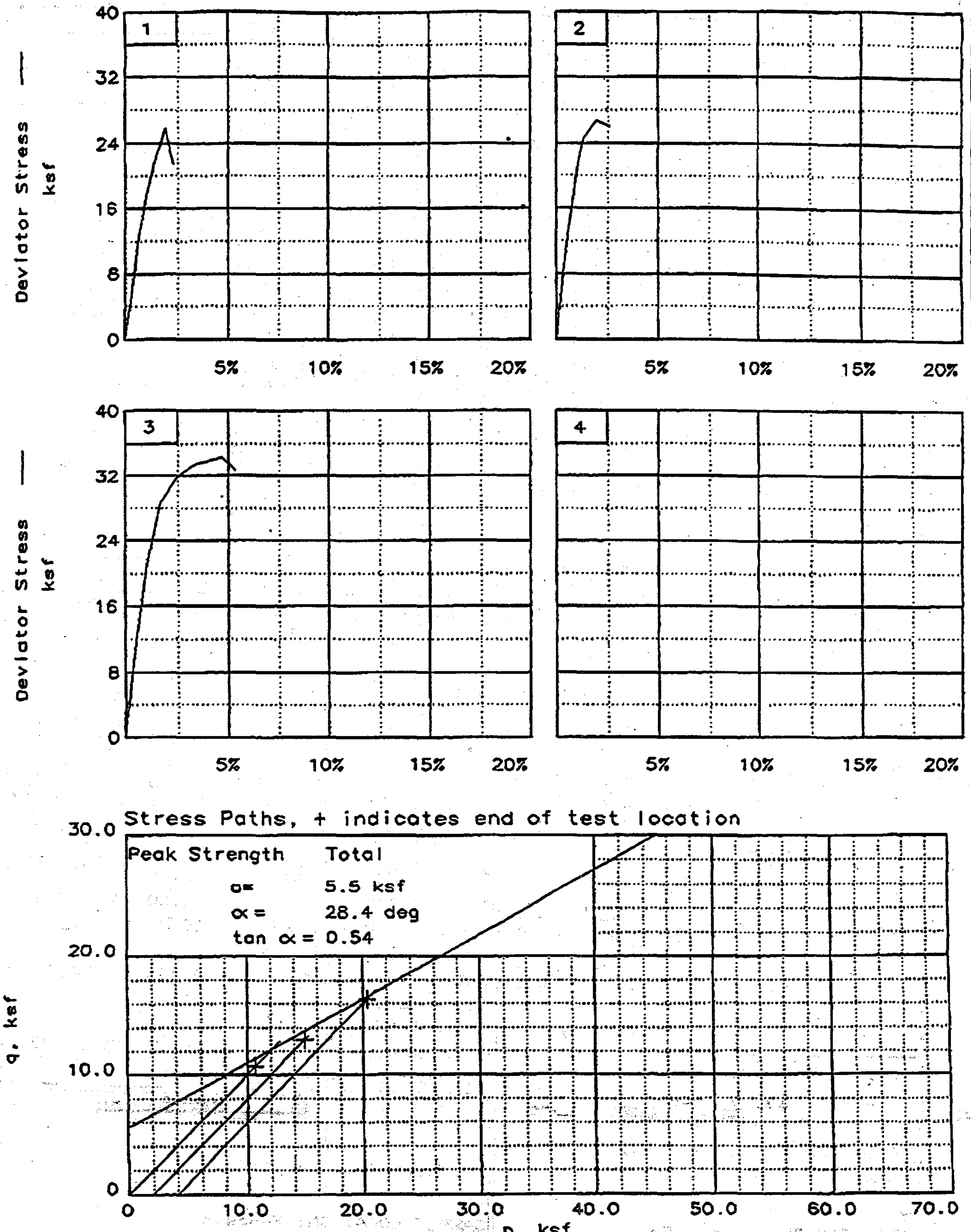
PROJECT: SRS Task 13

SAMPLE LOCATION: F-Basin
Sampled 9/19/95

PROJ. NO.: 5016155756 DATE: Feb. 27, 1996

TRIAXIAL COMPRESSION TEST

LAW ENGINEERING, INC.



Client: Savannah Rive Site

Project: SRS Task 13

Location: F-Basin Sampled 9/19/95

File: 5756G Project No.: 5016155756 Page 2/2 Fig. No.

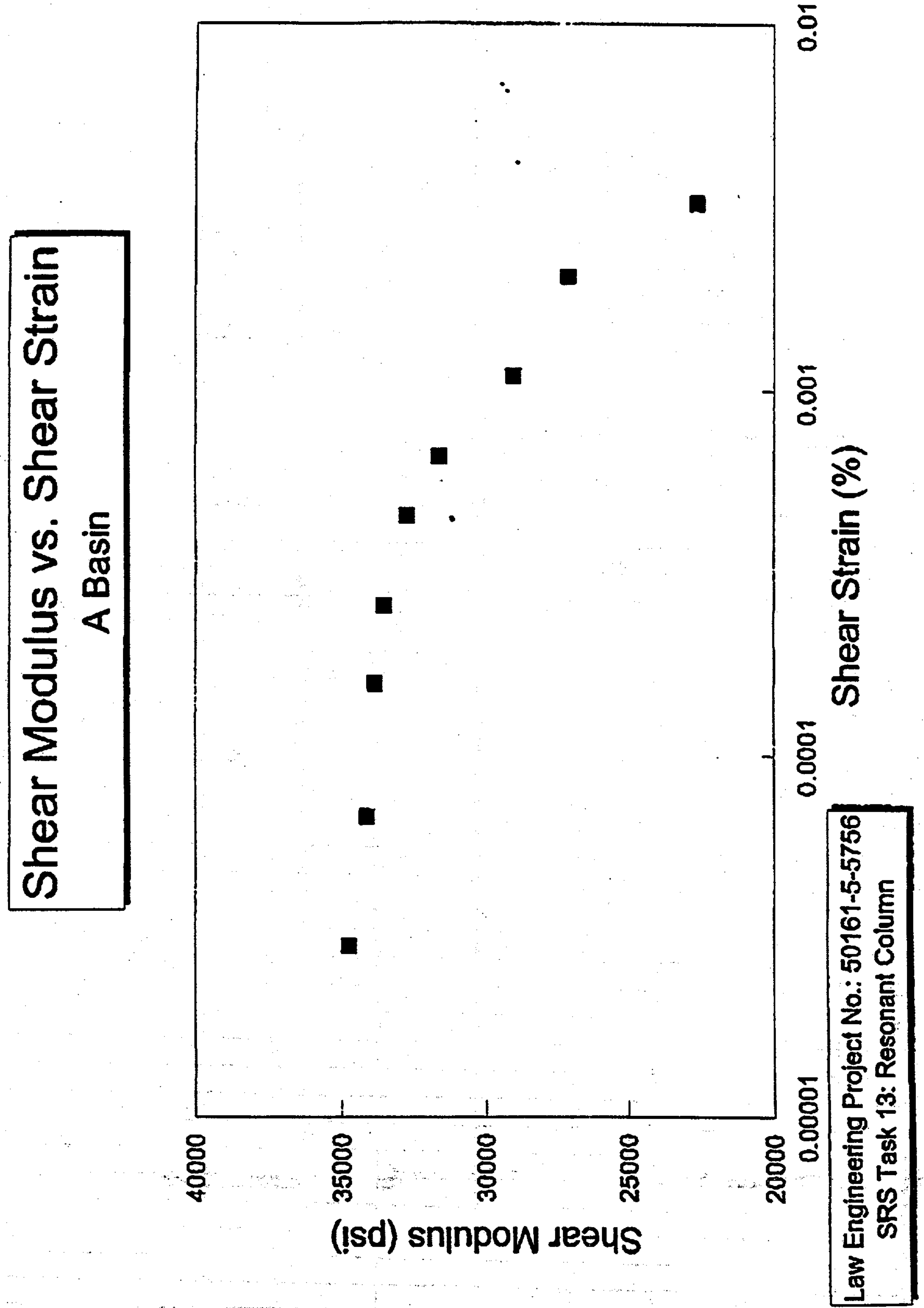
Resonant Column Test (ASTM D4015-87)
TEST RESULTS SUMMARY

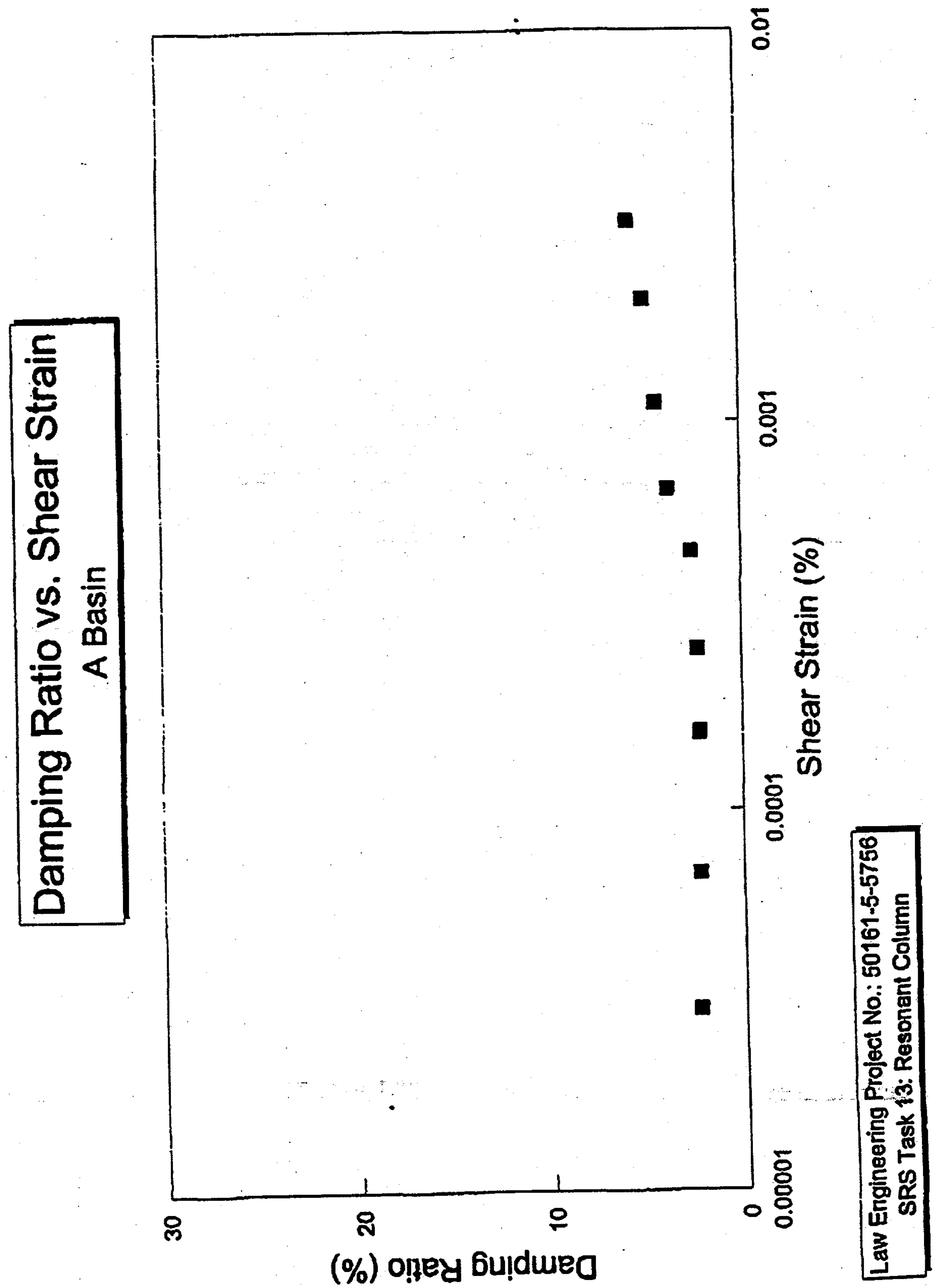
LAW ENGINEERING

Project No.: 50161-5-5756
Tested By: HEJ
Test Date: 2/8/96
Reviewed By: RLB
Reviewed Date: 2/14/96

Project Name: SRS Task 13
Boring No: A Basin
Sample No.: 95-0005
Depth: Molded 9/19/95
Sample Description: Coal Ash Mix Design

Line No.	Effective Confining Stress [kPa]	Principal Stress Ratio	Void Ratio e	Longitudinal or Torsional	No. of Vibration Cycles	Shear Modulus G [Mpa]	Shear Strain Amplititude [%]	Damping Ratio [%]	Shear Modulus G [psi]
1	96.46	1.00	0.818	T	4876	239.33	0.00003	2.32	34736
2	96.46	1.00	0.818	T	7198	235.08	0.00007	2.25	34120
3	96.46	1.00	0.818	T	6758	233.08	0.00016	2.20	33829
4	96.46	1.00	0.818	T	6829	230.95	0.00025	2.27	33520
5	96.46	1.00	0.818	T	5539	225.48	0.00046	2.55	32725
6	96.46	1.00	0.818	T	9700	217.81	0.00067	3.72	31612
7	96.46	1.00	0.818	T	8443	200.07	0.00110	4.31	29038
8	96.46	1.00	0.818	T	7612	187.02	0.00206	4.88	27143
9	96.46	1.00	0.818	T	7582	155.80	0.00326	5.62	22612
10	96.46	1.00	0.818	T	6322	110.82	0.00718	6.47	16085


Shear Modulus vs. Shear Strain
A Basin
Shear Modulus (psi)
40000
35000
30000
25000
20000
Shear Strain (%)
0.00001
0.0001
0.001
0.01
Law Engineering Project No.: 50161-5-5756
SRS Task 13: Resonant Column


Damping Ratio vs. Shear Strain
A Basin
Damping Ratio (%)
30
20
10
0
0.00001
0.0001
0.001
0.01
Shear Strain (%)
Law Engineering Project No.: 50161-5-5756
SRS Task 13: Resonant Column

CYCLIC TRIAXIAL PROPERTIES TEST
(Deformation Controlled)
(ASTM D 3999-91)

LAW ENGINEERING

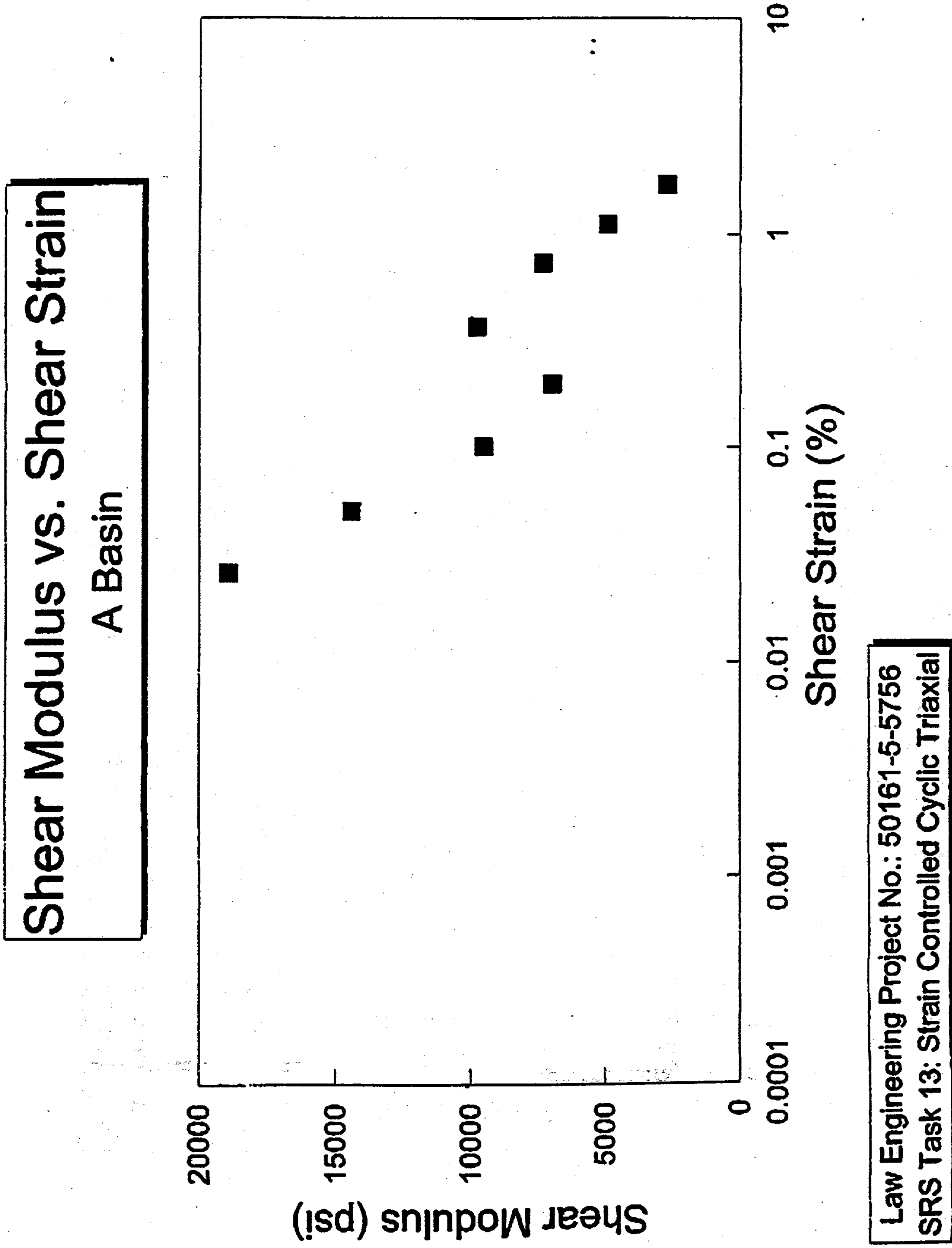
Project No.:	50161-5-5756	Project Name:	SRS Task 13
Tested By:	HEJ/RLB	Boring No.:	A Basin
Test Date:	2/9/96 - 2/12/96	Sample No.:	95-0005
Reviewed By:	JW	Depth:	Cast 9/19/95
Review Date:	2/12/96	Sample Description:	Coal Ash Mix Design

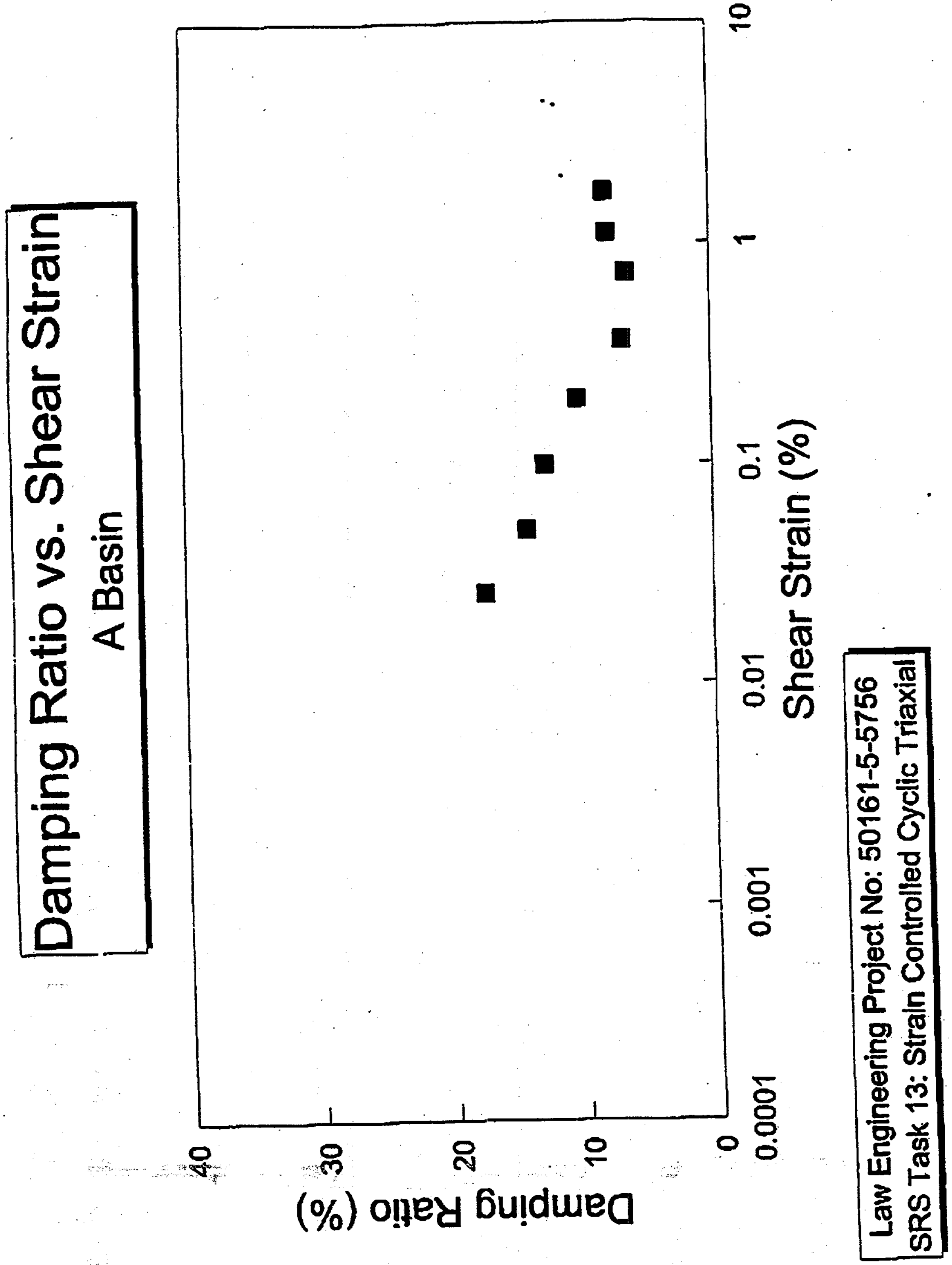
Effective Consolidation Stress 14 psi

Deformation Stage No.	Cyclic Stress (psi)	Axial Strain ε (%)	Young's Modulus E, (psi)	Damping Ratio D, (%)	Shear* Modulus G, (psi)	Shear* Strain γ (%)
1	9.7	0.017	56778	17.25	18926	0.026
2	14.4	0.033	43150	14.07	14383	0.050
3	18.9	0.066	28455	12.66	9485	0.100
4	27.4	0.132	20813	10.14	6938	0.197
5	70.9	0.243	29187	6.67	9729	0.365
6	106.7	0.489	21824	6.31	7275	0.733
7	108.7	0.742	14653	7.75	4884	1.112
8	90.1	1.132	7959	7.91	2653	1.698

* Calculated based on assumed Poisson's Ratio value, 0.5.

All calculations are based on 5th cycle.


Shear Modulus vs. Shear Strain
A Basin
Shear Modulus (psi)
20000
15000
10000
5000
0
0.0001
0.001
0.01
0.1
1
10
Shear Strain (%)
Law Engineering Project No.: 50161-5-5756
SRS Task 13: Strain Controlled Cyclic Triaxial


Damping Ratio vs. Shear Strain
A Basin
Damping Ratio (%)
0
10
20
30
40
0.0001
0.001
0.01
0.1
1
10
Shear Strain (%)
Law Engineering Project No: 50161-5-5756
SRS Task 13: Strain Controlled Cyclic Triaxial

LAW ENGINEERING

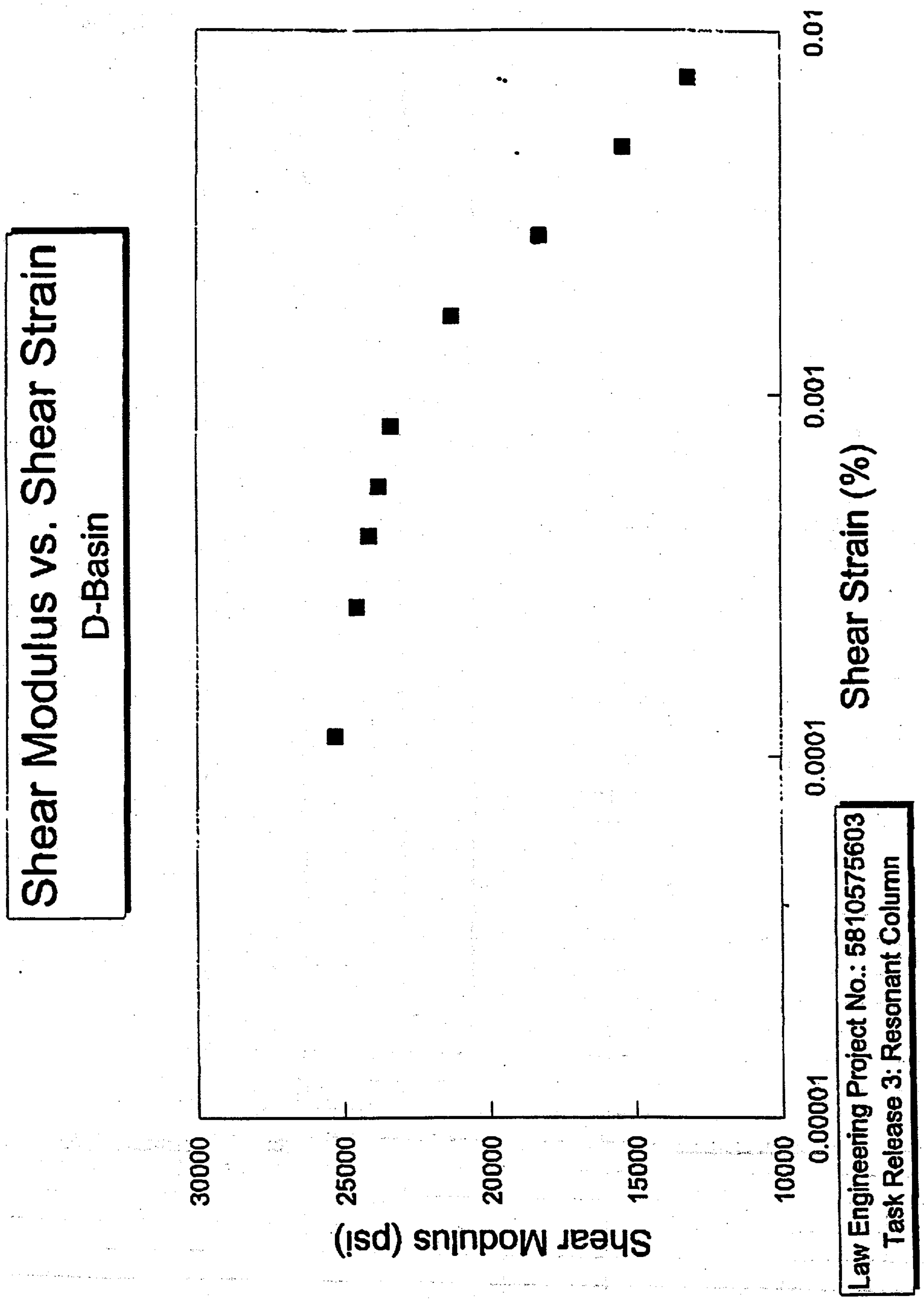
Resonant Column Test (ASTM D4015-87)

TEST RESULTS SUMMARY

Project No.: 50161-5-5756
Tested By: HEJ
Test Date: *******
Reviewed By: JW
Reviewed Date: *******

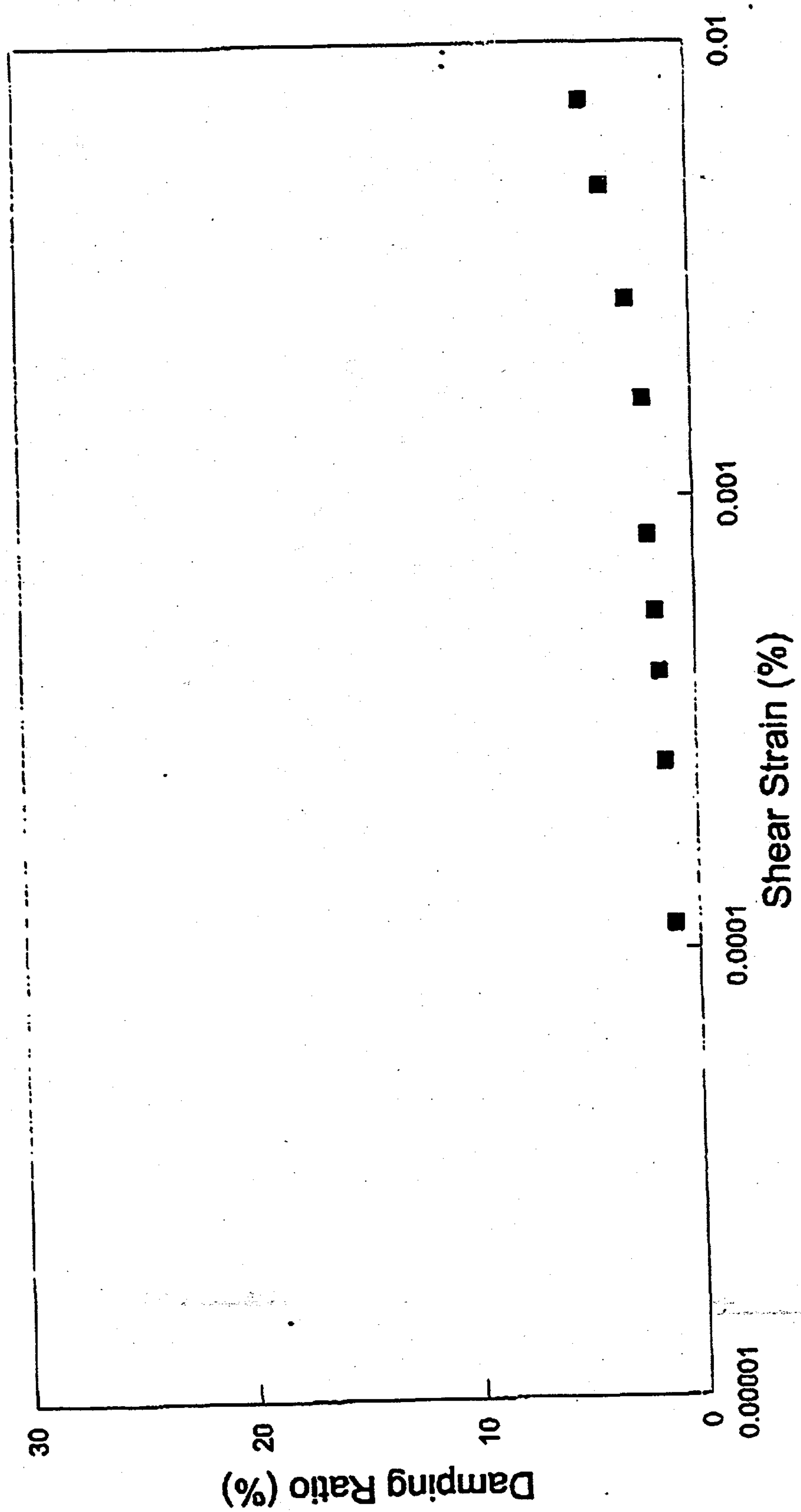
Project Name: SRS Task 13
Boring No: D-Basin
Sample No.: 95-0007
Depth: Molded 9/26/95
Sample Description: Coal Ash Mix Design

Line No.	Effective Confining Stress [kPa]	Principal Stress Ratio	Void Ratio e	Longitudina or Torsional	No. of Vibration Cycles	Shear Modulus G [Mpa]	Shear Strain Amplititude [%]	Damping Ratio [%]	Shear Modulus G [psi]
1	48.23	1.00	0.609	T	3071	174.12	0.00011	1.12	25271
2	48.23	1.00	0.609	T	7778	168.94	0.00026	1.41	24520
3	48.23	1.00	0.609	T	6427	166.10	0.00041	1.61	24108
4	48.23	1.00	0.609	T	5701	163.80	0.00056	1.78	23774
5	48.23	1.00	0.609	T	6158	160.96	0.00082	2.06	23361
6	48.23	1.00	0.609	T	6199	146.61	0.00163	2.20	21279
7	48.23	1.00	0.609	T	4705	126.17	0.00270	2.89	18312
8	48.23	1.00	0.609	T	4799	106.34	0.00479	3.91	15434
9	48.23	1.00	0.609	T	4751	90.77	0.00742	4.77	13174
10	48.23	1.00	0.609	T	4379	77.12	0.01029	5.63	11193


Shear Modulus vs. Shear Strain
D-Basin
Shear Modulus (psi)
30000
25000
20000
15000
10000
0.00001
0.0001
0.001
0.01
Shear Strain (%)
Law Engineering Project No.: 5810575603
Task Release 3: Resonant Column

Damping Ratio vs. Shear Strain

D-Basin



Law Engineering Project No.: 5810575603
Task Release 3: Resonant Column

LAW ENGINEERING

CYCLIC TRIAXIAL PROPERTIES TEST
(Deformation Controlled)
(ASTM D 3999-91)

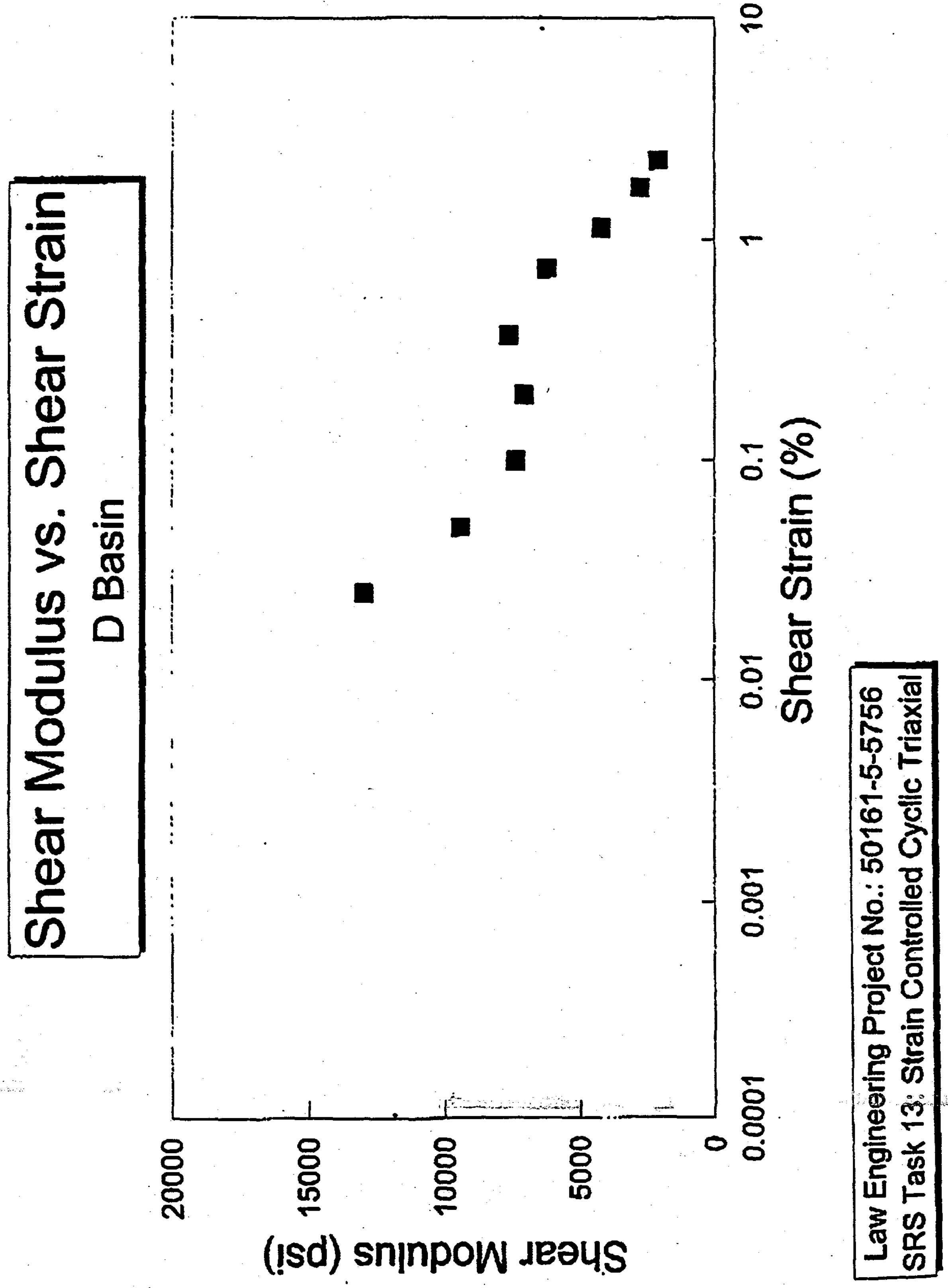
Project No.: 50161-5-5756
Tested By: HEJ/RLB
Test Date: 2/12/96 - 2/15/96
Reviewed By: JW
Review Date: 2/12/96

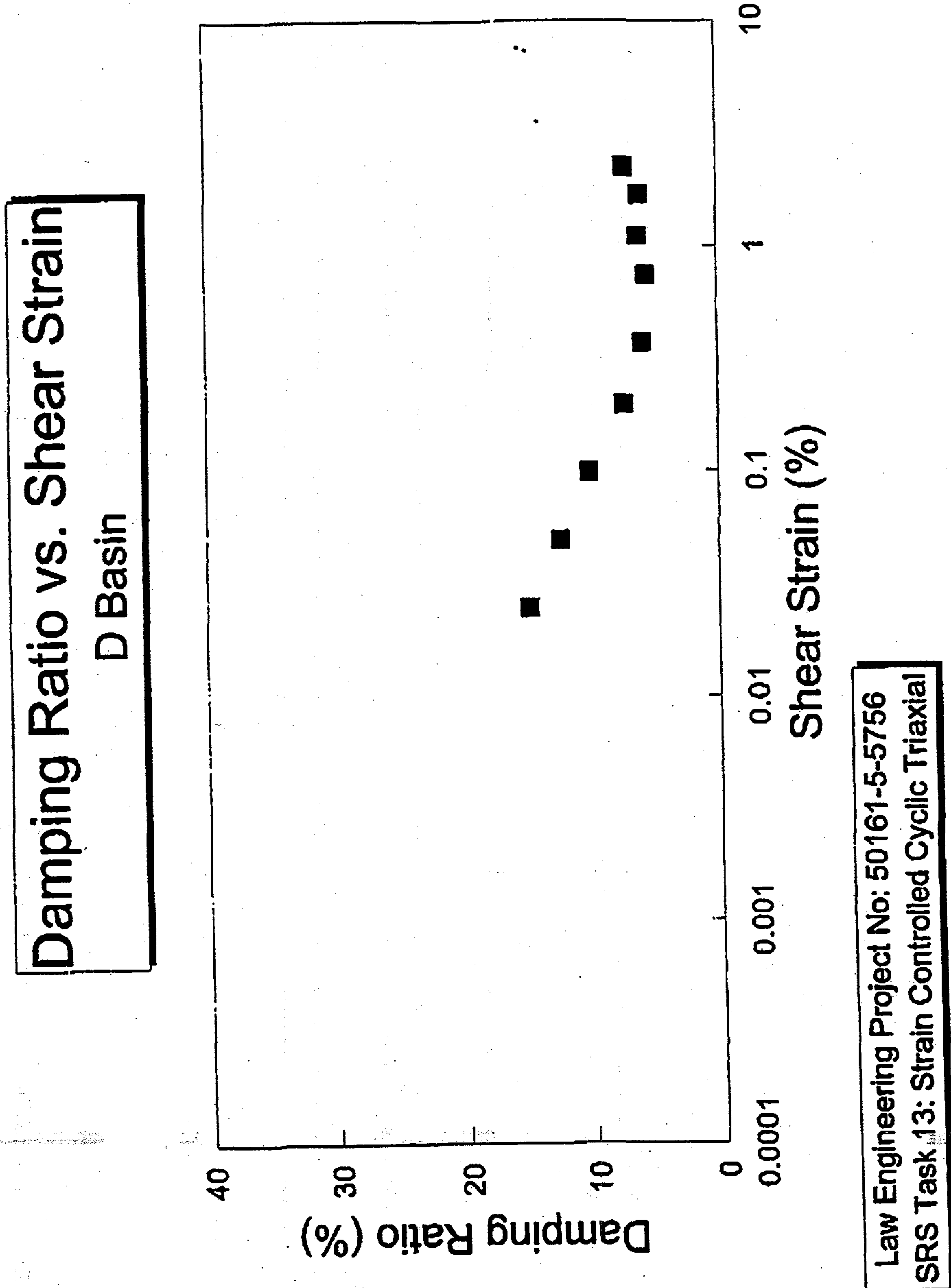
Project Name: SRS Task 13
Boring No.: D Basin
Sample No.: 95-0007
Depth: Cast 9/26/95
Sample Description: Coal Ash Mix Design

Effective Consolidation Stress 7 psi

Deformation Stage No.	Cyclic Stress (psi)	Axial Strain ε (%)	Young's Modulus E, (psi)	Damping Ratio D, (%)	Shear* Modulus G, (psi)	Shear* Strain γ (%)
1	6.3	0.017	38166	14.83	12722	0.025
2	9.2	0.033	27680	12.39	9227	0.050
3	14.4	0.066	21704	10.04	7235	0.099
4	27.4	0.131	20825	7.36	6942	0.197
5	55.2	0.246	22475	5.84	7492	0.368
6	90.9	0.494	18381	5.53	6127	0.741
7	92.5	0.748	12370	6.09	4123	1.122
8	90.9	1.136	8002	6.06	2667	1.705
9	91.1	1.508	6037	7.20	2012	2.263

* Calculated based on assumed Poisson's Ratio value, 0.5.
All calculations are based on 5th cycle.


Shear Modulus vs. Shear Strain
D Basin
Shear Modulus (psi)
20000
15000
10000
5000
0
0.0001
0.001
0.01
0.1
1
10
Shear Strain (%)
Law Engineering Project No.: 50161-5-5756
SRS Task 13: Strain Controlled Cyclic Triaxial


Damping Ratio vs. Shear Strain
D Basin
Damping Ratio (%)
40
30
20
10
0
0.0001
0.001
0.01
0.1
1
10
Shear Strain (%)
Law Engineering Project No: 50161-5-5756
SRS Task 13: Strain Controlled Cyclic Triaxial

LAW ENGINEERING

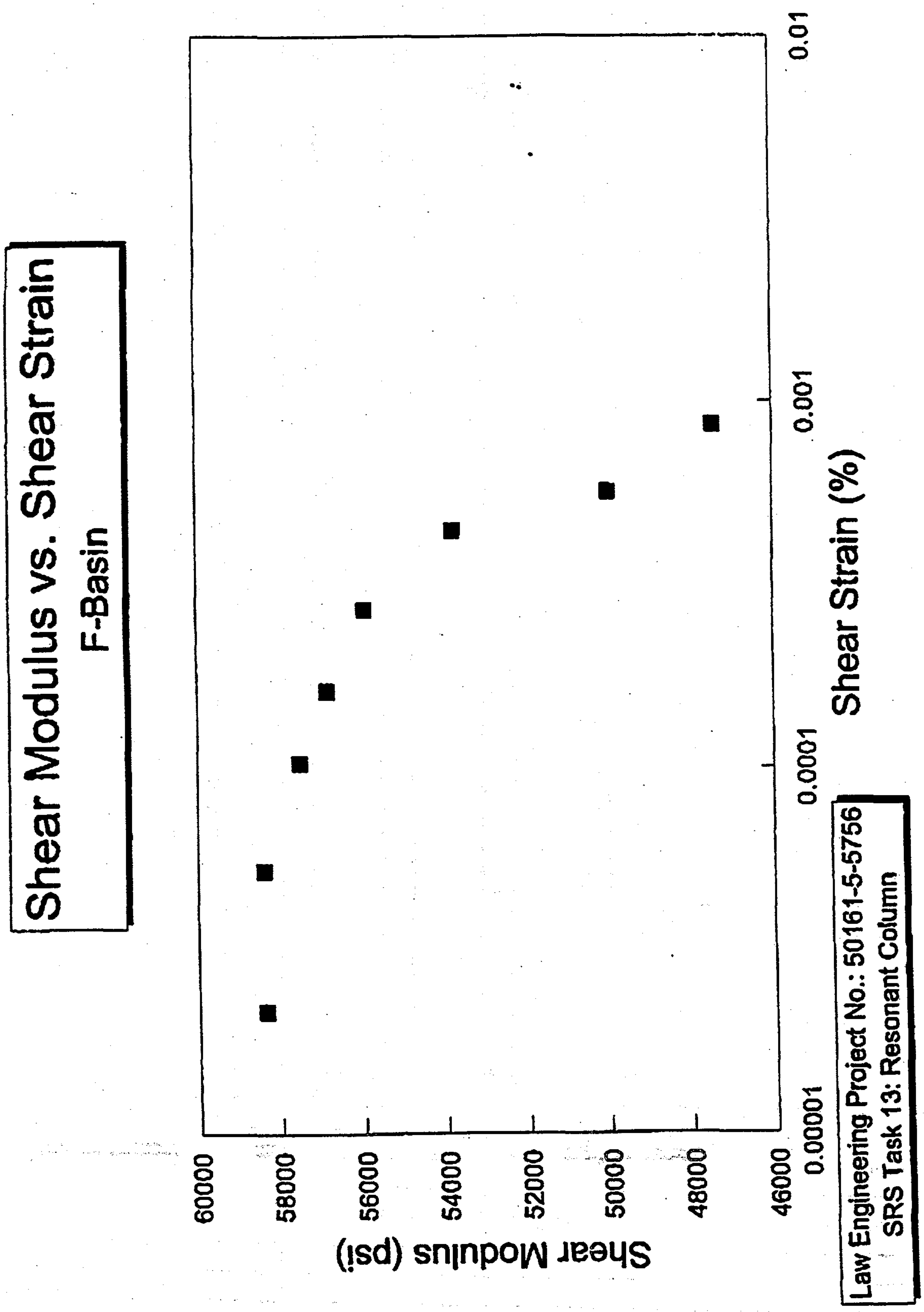
Resonant Column Test (ASTM D4015-87)

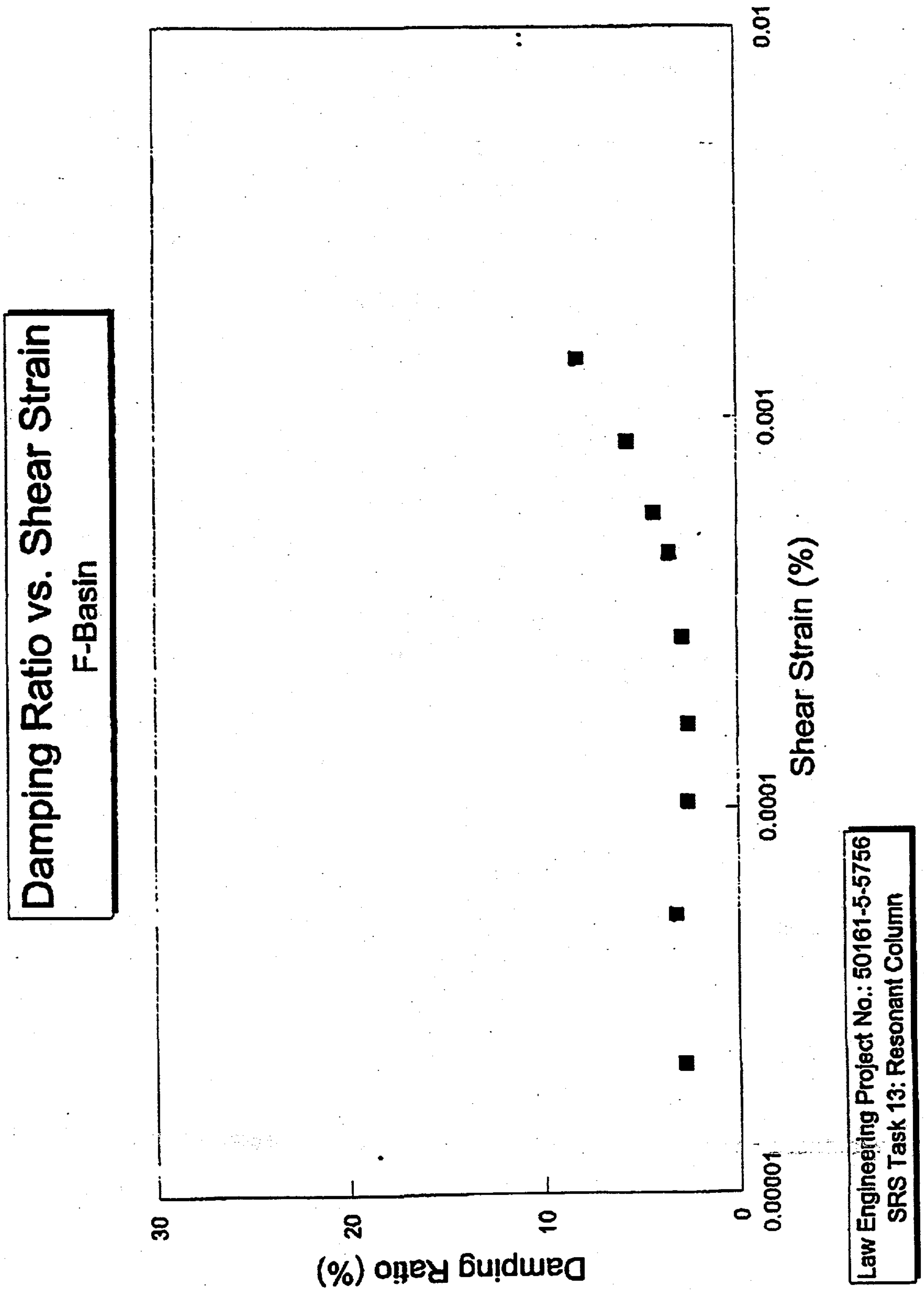
TEST RESULTS SUMMARY

Project No.: 50161-5-5756
Tested By: HEJ
Test Date: 2/14/96
Reviewed By: JW
Reviewed Date: 2/14/96

Project Name: SRS Task 13
Boring No: F-Basin
Sample No.: 95-0006
Depth: Molded 9/19/95
Sample Description: Coal Ash Mix Design

Line No.	Effective Confining Stress [kPa]	Principal Stress Ratio	Void Ratio e	Longitudinal or Torsional	No. of Vibration Cycles	Shear Modulus G [Mpa]	Shear Strain Amplititude [%]	Damping Ratio [%]	Shear Modulus G [psi]
1	120.58	1.00	0.945	T	10174	402.08	0.00002	2.84	58357
2	120.58	1.00	0.945	T	11805	402.26	0.00005	3.23	58384
3	120.58	1.00	0.945	T	10503	396.15	0.00010	2.62	57496
4	120.58	1.00	0.945	T	8032	391.57	0.00016	2.58	56831
5	120.58	1.00	0.945	T	6639	385.18	0.00027	2.85	55904
6	120.58	1.00	0.945	T	9766	370.45	0.00045	3.52	53766
7	120.58	1.00	0.945	T	6904	344.27	0.00057	4.29	49966
8	120.58	1.00	0.945	T	7336	326.68	0.00086	5.62	47413
9	120.58	1.00	0.945	T	9643	225.13	0.00141	8.18	32674
10	120.58	1.00	0.945	T	9488	196.68	0.00246	8.43	28546


Shear Modulus vs. Shear Strain
F-Basin
Shear Modulus (psi)
60000
58000
56000
54000
52000
50000
48000
46000
Shear Strain (%)
0.00001
0.0001
0.001
0.01
Law Engineering Project No.: 50161-5-5756
SRS Task 13: Resonant Column


Damping Ratio vs. Shear Strain
F-Basin
Damping Ratio (%)
30
20
10
0
0.00001
0.0001
0.001
0.01
Shear Strain (%)
Law Engineering Project No.: 50161-5-5756
SRS Task 13: Resonant Column

CYCLIC TRIAXIAL PROPERTIES TEST

LAW ENGINEERING

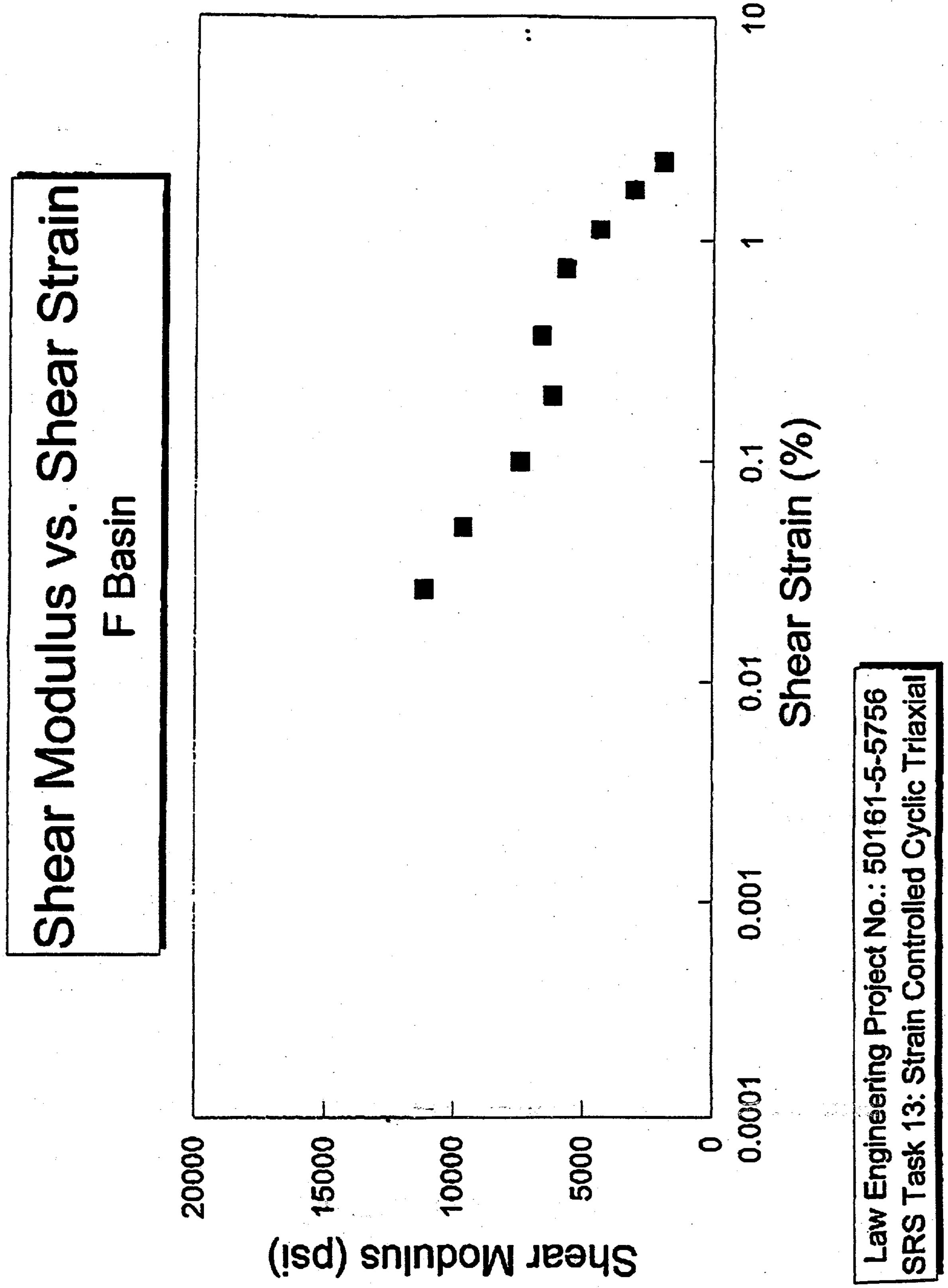
(Deformation Controlled)
(ASTM D 3999-91)

Project No.:	50161-5-5756	Project Name:	SRS Task 13
Tested By:	HEJ/DMJ	Boring No.:	F Basin
Test Date:	2/13/96 - 2/14/96	Sample No.:	95-0006
Reviewed By:	JW	Depth:	Cast 9/19/95
Review Date:	2/14/96	Sample Description:	Coal Ash Mix Design

Effective Consolidation Stress 17.5 psi

Deformation Stage No.	Cyclic Stress (psi)	Axial Strain ε (%)	Young's Modulus E, (psi)	Damping Ratio D, (%)	Shear* Modulus G, (psi)	Shear* Strain γ (%)
1	5.8	0.017	33494	10.83	11165	0.026
2	9.5	0.033	28872	9.47	9624	0.049
3	14.7	0.066	22353	8.82	7451	0.099
4	24.5	0.131	18643	7.22	6214	0.197
5	48.9	0.246	19866	5.68	6622	0.369
6	84.4	0.495	17049	5.27	5683	0.742
7	98.6	0.746	13213	5.65	4404	1.120
8	104.8	1.134	9245	5.93	3082	1.701
9	88.0	1.508	5834	6.39	1945	2.262

* Calculated based on assumed Poisson's Ratio value, 0.5.
All calculations are based on 5th cycle.


Shear Modulus vs. Shear Strain
F Basin
Shear Modulus (psi)
20000
15000
10000
5000
0
0.0001
0.001
0.01
0.1
1
10
Shear Strain (%)
Law Engineering Project No.: 50161-5-5756
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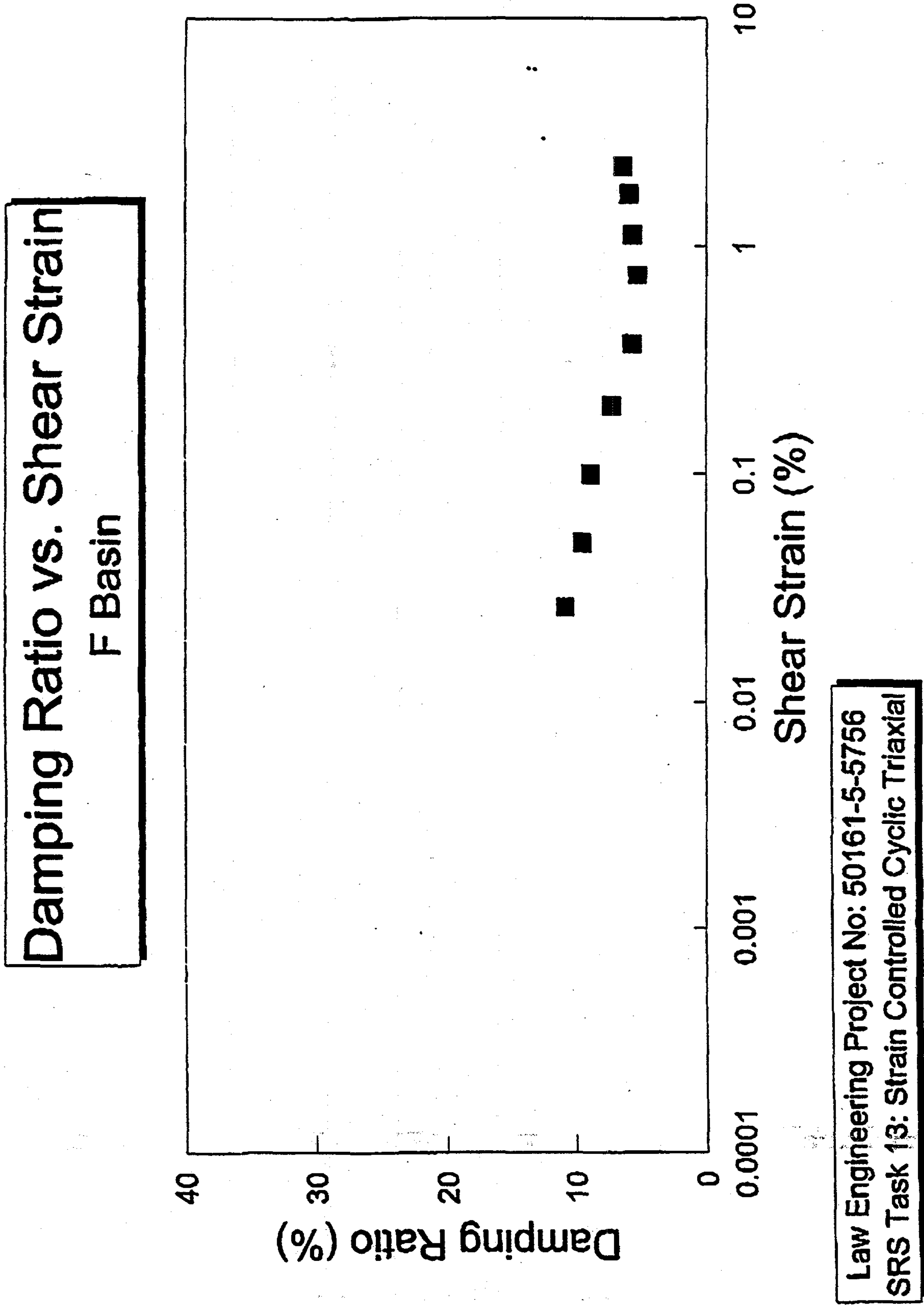

Damping Ratio vs. Shear Strain
F Basin
Damping Ratio (%)
40
30
20
10
0
0.0001
0.001
0.01
0.1
1
10
Shear Strain (%)
Law Engineering Project No: 50161-5-5756
SRS Task 13: Strain Controlled Cyclic Triaxial