Houston Lighting & Power Company

Electric Tower
P.O. Box 1700
Houston, Texas 77001

January 10, 1979
AC-HL-AE-274

Mr. Roger S. Boyd, Director
Division of Project Management
Nuclear Regulatory Commission
Washington, D. C. 20555

Dear Mr. Boyd:

Allens Creek Nuclear Generating Station
Unit 1
Docket No. 50-466
Question 361.4

Please find attached a report concerning question 361.4 of the Allens Creek PSAR. A copy of the report has been sent directly to Mr. Cunny of the Corps of Engineers for his review. Based on telephone conversations with Mr. Cunny this report should resolve his concerns and allow the NRC to resolve this open issue. To fully document this issue, HL&P plans to file an amendment to the PSAR next week which will contain this report.

Very truly yours,

E. A. Turner

E. A. Turner
Vice President
Power Plant Construction
& Technical Services

JGW/bkl
Enclosure

cc: C. Thrash (Baker & Botts) (without enclosure)
R. Gordon Gooch (Baker & Botts) (without enclosure)
J. R. Newman (Lowenstein, Newman, Reis, Axelrad, & Toll) (without enclosure)
P. A. Horn (without enclosure)
R. Cunny (Corps of Engineers)

B001 SE/1 1 SET OF DRWGS TO GEOSCIENCES

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APPENDIX M TO SECTION 2.5 ACNGS-PSAR DESIGN OF ULTIMATE HEAT SINK SLOPES USING SPECIAL RESIDUAL CLAY STRENGTHS

M1 INTRODUCTION

In order to completely respond to the NRC question concerning slickensided clays at the UHS and to obtain additional data for design of the UHS a subsurface investigation was performed in April and May, 1978.

M2 FIELD INVESTIGATION

Subsurface soil conditions at the site were investigated by 7 borings drilled to depths ranging from 8 to 150 ft. at locations illustrated on Fig. No. M1. A cross section through the borings is shown in Fig. No. M2. 50
Detailed descriptions of the soils encountered are given on the boring logs 361.4
presented on Figures M3 through Figures M9. A key to the symbols and terms appearing on the logs is included on Figure M10.

Borings were drilled with truck-mounted drilling equipment. In the ultimate heat sink area, samples were obtained continuously to 20 ft or completion depth, whichever was the lesser, 5-ft intervals to 100 ft and at 10-ft intervals below 100 ft. Samples of cohesive soils were generally obtained by alternating a 3-in. thin-walled tube and a 2-in. split-barrel. Most granular samples were obtained with a 2-in. split-barrel. Driving resistances for the split-barrel sampler are recorded in the "Blows Per Foot" column on the boring logs. Each of these samples was removed from the sampler in the field and examined and classified by a soil technician. Representative portions of each sample were sealed and packaged for transportation to the laboratory.

A Hvorslev-type stationary piston sampler, with a 3-in. thin-walled tube was used to obtain undisturbed granular samples from Borings H-42A, H-43A and H-44A. The tubes and soil were weighed immediately after sampling to determine the undrained density of the soil. The samples were retained in the tube by using porous caps (to allow drainage) and transported to the laboratory for further testing. Density results obtained from the piston samples are presented on Table M1.

The depth to water in most boreholes was measured at least 24 hours after completion. The depths to water and the dates of observations are recorded in the lower-right corner of the individual boring logs. In addition, four piezometers were installed to monitor groundwater level; two were installed in Boring H-44 to 10 and 25-ft depth and a similar installation was done in Boring H-48.

Test Pits

A test pit was excavated near each of the ultimate heat sink borings for the purpose of visually examining the surface clays and in-place density testing and bulk sampling of the near surface sands. In-place density tests were performed at several depths with a rubber balloon-densometer

in accordance with ASTM Procedure D 2167-66. Results of these tests are presented on Table M2. Bulk samples were sealed for transportation to the laboratory.

M3 LABORATORY INVESTIGATION

The laboratory program was directed towards evaluation of strength, compressibility and classification properties of the foundation soils, primarily of the slickensided clays.

Strength Tests 50

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In order to estimate the undrained residual shear strength parameters of the foundation soils, several repeated direct shear tests were performed on two typical samples of the clay. These tests were conducted as consolidated-undrained multiple-specimen type tests at incremental normal stresses. The samples were strained forward and moved back manually in the shear box several times until the minimum shear stress (residual strength) was obtained for each load. Results are presented as Mohr's diagram. Stress-strain curves are presented for the respective tests. Figures No. M11 through M16 present the results.

Consolidated drained repeated direct shear tests were performed in accordance with Appendix IXA of EM 1110-2-190 Engineering and Design, Laboratory Soils Testing, Drained Repeated Direct Shear Test. This procedure includes presplitting samples and the repeated straining of them to simulate the drained strength along slickensided surfaces. Results are presented as Mohr's diagrams. Stress-strain curves are presented for the respective tests on Figure No. M17 through M19 present the results.

The shear strength properties of the near surface sands were estimated by performing consolidated-drained triaxial tests. These tests were conducted on undisturbed sand samples obtained from a Hvorslev piston-type sampler. The results of these tests are presented as a Mohr's diagram on Figure No. M20.

Density Tests

Modified Proctor (ASTM D 1557-70) and Maximum-Minimum Density (ASTM D 2049-69) tests were performed on each bulk sample of granular material. Maximum-Minimum density tests were performed by the dry method. Results of these tests are presented on Figure Nos. M21 through M25, and Table M3.

Consolidation and Classification Tests

The compressibility characteristics of the foundation materials were investigated by consolidation tests conducted on undisturbed cohesive samples. Results are presented on Figure Nos. M26 through M30.

Atterberg limit tests were performed for several samples to evaluate soil plasticity and aid in soil identification. Grain-size analyses were performed on all Hvorslev and bulk samples and on several other selected granular samples to aid in soil identification.

<u>Laboratory Classification Test Results</u>

The results of the soil classification tests performed for this study are plotted or tabulated on the boring logs presented on Fig. Nos. M3 through M9 or on the following figures and tables. 50

Grain size analyses are presented on Figure Nos. M31 through M33. Table No. M4 presents additional classification tests on the samples tested in accordance with the WES procedure for drained repeated direct shear tests shown on Figure Nos. M17 through M19. 361.4

M4 GROUNDWATER LEVEL

Observations in open boreholes and all piezometers indicated that the groundwater level in the ultimate heat sink area was about EL +94 at the time of the investigation during the month of May 1978. Measurements in the piezometers on July 24, 1978 indicate that the groundwater level was also about EL +94. Groundwater levels can be expected to fluctuate with seasonal and climatic conditions.

M5 ADDITIONAL INVESTIGATIONS

Section 2.5.6.7 of the PSAR presents all of the field and laboratory test results performed in the Ultimate Heat Sink area. Borings H-37 through H-41 drilled in May 1977 provide additional data in the area of the causeway, intake and basin area of the UHS. Figure No. 2.5.4-5C indicates the location of all the borings in the UHS with the exception of the most recent borings.

M6 DESIGN PARAMETERS - SHEAR STRENGTH

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Several shear strength values are needed to completely define the strength of the clay in the UHS under drained and undrained conditions. The purpose of this section is to discuss the different types of strength and when each value is applicable.

Figure 2.5.6-26 of the PSAR indicates the undrained shear strength of the recent flood plain clays with depth. The undrained shear strength ranges from 0.5 ksf to 3.0 ksf with a lower bound average of 1.0 ksf for all depths.

Figure 2.5.6-27AA of the PSAR presents the Mohr circle results of triaxial unconsolidated undrained tests on near surface samples of clay in the area of the UHS. The undisturbed shear strength varies from 0.8 ksf to 1.9 ksf with a lower bound average of approximately 1.0 ksf.

Figure 2.5.6-27AA also presents the Mohr circle results of the remolded unconsolidated undrained shear strength. The remolded strength was obtained from samples kneaded, reshaped and retested. The values range from 0.4 ksf to 3.8 ksf with an average value of 1.0 ksf. Based on this result the undrained strength of the clay could be assigned a value of 1.0 ksf. This includes in some way the effect of slickensided surfaces since the samples were remolded.

Figures 2.5.6-27G, 27I and 27J of the PSAR present the Mohr circle results of triaxial consolidated undrained triaxial tests with pore pressure measurements on undisturbed and remolded samples from the area of the UHS. The total strength or undrained results from undisturbed samples shown on Figure 2.5.6-27G varies from 0.7 ksf to 1.2 ksf with an average of approximately 0.8 ksf. The remolded undrained strength shown on Figure 2.5.6-27G varies from 0.4 ksf to 2.4 ksf with an average of 1.0 ksf.

The effective strength or drained results from undisturbed sample shown on Figure 2.5.6-27I varies from $\phi = 28^{\circ}$ to $\phi = 21^{\circ}$ and C = 0 using the maximum deviator stress as the peak and varies from $\phi = 33^{\circ}$ to $\phi = 25^{\circ}$ and C = 0.3 ksf using the maximum effective stress ratio as the peak. From this data a conservative effective or drained strength would be $\phi = 21^{\circ}$ and C = 0.3 ksf. The samples presented on Figure 2.5.6-27I were recompacted to 90 pcf which is approximately 95% of the maximum density obtained using ASTM D 698 as the base standard. The drained strength as shown on Figure 2.5.6-27J varies from $\phi = 30^{\circ}$ to $\phi = 43^{\circ}$ using the maximum deviator stress as the peak and varies from $\phi = 30^{\circ}$ to $\phi = 47^{\circ}$ using the maximum effective stress ratio as the peak. Both of these drained strengths are considerably greater than those shown on the undisturbed samples in Figure 2.5.6-27I suggesting that the samples in

the undisturbed state failed along some weak plane, which can be assumed to be along the slickensides. Therefore it would not be unreasonable to use the drained strength from Figure 2.5.6-27I as the drained residual shear strength of the UHS clays.

Figure Nos. M34 through M36 presents the results of unconsolidated undrained triaxial tests on samples recently obtained in Boring H44. The stress strain curves were carried out to 25% strain to develop the ordinary residual undrained shear strength of the clays. The undisturbed strength of the peak is approximately 1.5 ksf similar to that shown on Figure 2.5.6-26, 2.5.6-27A and 2.5.6-27G. The residual shear strength is 0.5 to 0.8 ksf shown on the lower portion of Figure M34. This compares favorable with the values from 2.5.6-27AA (remolded).

The lower bound average of shear strength for all the undrained undisturbed 50
shear strength samples is therefore 1.0 ksf for undisturbed samples and C = 361.4
0.5 ksf for a remolded sample. The lower bound of shear strength for all the drained shear strength samples is therefore $\phi = 21^{\circ}$, C = 0.3 ksf for undisturbed samples and $\phi = 30^{\circ}$ for a remolded sample.

At the NRC's consultants (WES) request tests were performed on presplit and repeated direct shear samples. This dated is summarized on Figures M11 & M12 for undrained condition and Figure M17 for drained conditions. The lowest undrained residual strength is $\phi = 8.5^{\circ}$, C = 0.1 ksf shown on Figure M12. The lowest drained residual strength is $\phi = 9^{\circ}$. As is the normal case for this type of shear test there is practically no difference in strength in drained or undrained conditions suggesting that both tests measure drained parameters. Therefore the absolutely lowest drained shear strength is $\phi = 9^{\circ}$ using the most critical test procedures, of Appendix IX A, EM 110-2-1906 of the Corps of Engineers. This value is extremely conservative for use at Allens Creek since the clays at the site are slickensided as a result of drying and shrinkage, not large scale movements. There are no large scale slickensided surfaces in the Allens Creek clays, slickensides are approximately 1/4" in size, irregular and nonplanar. Only large scale movements could result in the reduction to residual shear strength values. At Allens Creek, as discussed in the following section, large scale slope movements will not occur.

Two articles presented in the ASCE publication, Research Conference on Shear Strength of Cohesive Soils, University of Colorado June, 1960 discuss the use of residual strength of saturated clay, Article 1. The Physical Components of the Shear Strength of Saturated Clays by M Juul Hvorslev indicates that the residual strength of some clays is attained only after very large deformations and that the decrease in shear strength after failure is primarily caused by a transient increase in pore water pressure and a thixotropic loss in strength, which is regained in time upon cessation of the deformations. This artical supports the statements previously noted and indicates that the strength can be regained. Article 2, The Relevance of the Triaxial Test to the Solution of the Stability Problems by Alan W. Bishop and Lauritus Bjerrum states that the presence of fissures is reflected in the factors of safety obtained using the effective stress analysis. Article 2 recommends that a factor of safety of at least 1.0 be ensured. Table M5 attached presents the recommended

safety factors from the Corps of Engineers publication EM1110-2-1902, April 1, 1970. Discussions with WES indicated that they would like to see a safety factor of 1.25 for Class I slopes using the residual strength. While we believe that the design shear strength of $\phi = 9^{o}$ and a safety factor of 1.25 for effective stress conditions is very unrealistic as discussed above we will use it in appropriate places in our analyses.

M7 STABILITY ANALYSES

Two representative cross-sections covering the various soil strata were
analyzed to determine the slope stability characteristics under different 50
conditions. Figure M2 indicates the cross-sections, designated E-E, UHS 361.4
Causeway and F-F, UHS Basin. Section D-D on Figure M2 indicates the different soil strata, standard penetration test results and field descriptions.

The range of soil parameters used in the analyses are indicated in tables for each cross-section. The parameters considered for the various cases are consistent with the recommendations of Table M5 and developed as the result of laboratory tests as noted in Section M3. Drained and undrained parameters are used for static conditions including the consolidated drained repeated direct shear test results from Figure No. M17. Undrained parameters are used for rapid drawdown and dynamic analyses. At Allens Creek rapid drawdown can only occur from El.118 to 100 as a result of loss of the Main Dam. Below El.100 the water is contained within the UHS basin and is recirculated. A drained state of soil properties would be characteristic of a long term static condition in which any buildup of pore pressures in the soil due to construction is considered to be dissipated. The laboratory tests yielding drained soil strength properties were therefore established to simulate this field condition of normal water level pore pressures. An undrained soil condition is one whereby the pore pressure in the soil has been built up as a result of a quick load application as characterized by the water level rapid drawdown or design seismic event.

Two methods of analysis, the simplified Bishop slip circle method and the U.S. Army Corps of Engineers sliding wedge method were used to investigate the stability of all the slopes.

In performing the slip circle method of stability analysis the Ebasco computer program was used. The method employed by the program, the simplified Bishop approach, is one in which a circular failure surface is assumed to form about its center of rotation. The circle through the slope is then divided into vertical slices and the tangential resisting and driving forces along the circular surface are computed for each slice. The factor of safety against sliding is computed as the ratio of the sum of the resisting moments taken about the center of rotation to the sum of the driving moments about the same center of rotation.

To use the program the slope geometry must be fully defined on a coordinate grid system along with changes in soil layers. The soil encountered on the slope being analyzed must be fully defined with respect to its saturated unit weight and shear strength. Water levels along the slope must also be defined, whether it be in the form of freestanding water, groundwater, or pore pressure built up within the soil. Finally, if

applicable, the horizontal (0.1g) and vertical (0.067g) components of the design basis earthquake are input.

To find the worst possible radius and center of rotation yielding the circle with the lowest factor of safety, a search routine is built into the program by which a trial center of rotation is selected. The program will investigate different radii from that center of rotation computing and recording the safety factor for each radius. It then moves the center of rotation at a prescribed increment to a different trial location and the above process is repeated until the lowest safety factor is reached.

The simplified Bishop solution yields results that are conservative in 50
that shear resistance between slices, which would tend to raise the fac-
tor of safety against sliding, is neglected. When the simplified Bishop 361.4
solution is used to compute a factor of safety under dynamic loading additional conservatism is built into the program in that the computed safety factor is calculated assuming the components of the design earthquake acceleration act only in one direction, neglecting any back and forth motion, and the magnitude of the acceleration of the design earthquake is taken to be a constant over the entire slope for an infinite length of time.

In performing the sliding wedge method the Ebasco computer program was also used. The sliding wedge method consists of an active wedge being mobilized against a neutral horizontal block and a passive resisting wedge. The factor of safety is calculated as the ratio of the sum of the resisting forces in the horizontal direction to the sum of the driving forces in the horizontal direction. In applying the sliding wedge method to the two cross-sections the input data and search routine is similar to that of the slip circle analysis previously discussed. This method also includes a seismic loading in the analyses. This was done by including the product of the weights of the wedges and the neutral block with the horizontal acceleration factor of 0.1g. This force was then considered to act in the direction of the postulated slide as a driving force. The vertical component of the seismic loading is also incorporated into the solution tending to reduce frictional resistance between the sliding wedges. This vertical seismic force is computed as the product of the weights of the neutral block and the wedges with the vertical acceleration factor of 0.067g.

The results of each of these analyses are presented on the tables on Figure M2. In all cases the actual safety factor exceeds the recommended minimum safety factor from Table M5, indicating that the slopes are safe.

M8 SUMMARY AND CONCLUSIONS

The above described detailed investigation has accurately established the soil conditions in the area of the ultimate heat sink at Allens Creek. The continuous sampling in the upper soils and careful undisturbed sampling of clays and sand establishes a sound basis for the selection of lower bound strength samples. Selection of design strength parameters incorporated the use of lower bound strength parameters from the test results, using very conservative test procedures. Results of the analyses indicated

satisfactory safety factors. Reflected in the analyses are the changes
required to obtain the required safety factors. In order to maintain
the 1 vertical to 3 horizontal slope of the causeway it was necessary to 50
excavate the surface clays from beneath the causeway. Additionally the
slopes of the ultimate heat sink basin have been flattened to 1 vertical 361.4
to 8 horizontal from the original 1 vertical to 3 horizontal. These
changes are the result of using the $\phi = 9^{o}$ from the consolidated drained
repeated direct shear tests.

TABLE M1

UNIT WEIGHTS OF SAND SAMPLED WITH HVORSLEV PISTON SAMPLER

Boring No	Penetration Feet	Wet Unit Weight, pcf Undrained	Wet Unit Weight, pcf Drained	Dry Unit Weight, pcf	
H-42A	7-9	101	101	96	50 361
	10-12	110	none	none	.4
	13-15	116	109	98	
H-43A	4-6	114	113	97	
H-44A	4-6	111	109	86	
	6-8	117	116	96	

Note: Drained wet unit weights were determined by allowing the tubes to drain through porous caps for 48 hours, inverting the tube at the end of 24 hours.

TABLE M2

SUMMARY OF IN-PLACE DENSITIES
Balloon Densometer
Allens Creek

Test Pit No.	Penetration Feet	Material	Wet Density pcf	Moisutre Content, %	Dry Density pcf
6	5.5	Fine sand	95.5	5.1	90.9
6	5.5	Fine sand	104.9	4.8	100.1
6	10.5	Fine sand with clay pockets	85.0	11.3	76.4
6	10.6	Fine sand	97.7	11.8	87.4
7	4.5	Fine sand	119.8	15.3	103.9
7	4.6	Fine sand	118.5	18.5	100.0
8	4.0	Fine sand	121.0	21.7	99.4
8	4.0	Fine sand	120.9	21.7	99.3
9	4.0	Fine sand	122.8	22.1	100.6
9	3.9	Fine sand	120.8	25.2	96.5

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TABLE M3

RELATIVE DENSITY TEST RESULTS

Test Pit No.	Penetration Feet	Material	Densities, pcf Minimum	Maximum	
6	5	Fine sand	86	107	
	10	Fine sand	89	107	
7	5	Fine sand	85	104	
8	5	Fine sand	83	100	50
9	5	Silty fine sand	79	96	361.4

Note: Relative densities determined by dry method

TABLE M4

CLASSIFICATION AND DENSITY TEST RESULTS

Boring	Sample Depth (ft)	W (%)	LL	PL	G	γ (pcf)
H44	14	-	82	29	2.73	
H44	16	35	-	-	-	87
H44	17.5	36	85	27	-	-
H44	20	39	-	-	-	81

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TABLE M5

Minimum Factors of Safety (Reproduced from EM 1110-2-1902 April 1, 1970)

Case No.	Design Condition	Minimum Factor of Safety	Shear Strength	Remarks
I	End of construction	1.3††	Q or S‡	Upstream and downstream slopes
II	Sudden drawdown from maximum pool	1.0‡‡	R, S	Upstream slope only. Use composite envelope. See Fig. 4
III	Sudden drawdown from spillway crest or top of gates	1.2‡‡	R, S	Upstream slope only. Use composite envelope. See Fig. 4
IV	Partial pool with steady seepage	1.5	$\frac{R + S}{2}$ for $R < S$ S for $R > S$	Upstream slope only. Use intermediate envelope. See Fig. 5
V	Steady seepage with maximum storage pool	1.5	$\frac{R + S}{2}$ for $R < S$,	Downstream slope only. Use intermediate envelope. See Fig. 5
VI	Steady seepate with surcharge pool	1.4	S for $R > S$	
VII	Earthquake (Cases I, IV and with seismic loading)	1.0 1.15*	#	Upstream and downstream slopes

† Not applicable to embankments on clay shale foundations.

†† For embankments over 50 ft high on relatively weak foundations use minimum factor of safety of 1.4.

‡ In zones where no excess pore water pressures are anticipated, use S strength.

‡‡ The safety factor should not be less than 1.5 when drawdown rate and pore water pressures developed from flow nets (Appendix III) are used in stability analyses.

Use shear strength for case analyzed without earthquake except that it is not necessary to analyze sudden drawdown for earthquake effects

* The minimum safety factor of 1.15 is suggested in NAVFAC DM.7, since this is more conservative it will be utilized in design.

2.5-M13

Am. No. 50, 1/15/79

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LOG OF BORING NO. H-42

ALLENS CREEK NUCLEAR GENERATING STATION
ULTIMATE HEAT SINK
WALLIS, TEXAS

TYPE: 3" thin-walled tube & 2" split-barrel LOCATION: See Plate 1

SURF. EL: 104.1'

DEPTH, FT	DESCRIPTION OF MATERIAL	BLOWS PER FT	UNIT DRY WT LB/CU FT	-#200, %
	Very stiff dark gray & brown silty clay -with roots to 1' -with very stiff gray sandy clay layer below 3.5'			
5		15		
	Tan fine sand	17		
10		15		
		15		12
		28		
15	-with clay seams below 15'	22		5
	-with clay layers below 17'	18		
20		24		
25		50		
30	-coarse to fine with gravel below 31'	50		
35		42		13
40		15		8
	Tan silty clay with clay seams -with calcareous nodules to 48'			
45		23		
	-with sandy clay seams & coarse sand pockets below 49.5'			
50		30		

UNDRAINED SHEAR STRENGTH, TONS/SQ FT: 0.2 0.4 0.6 0.8 1.0 1.2 1.4

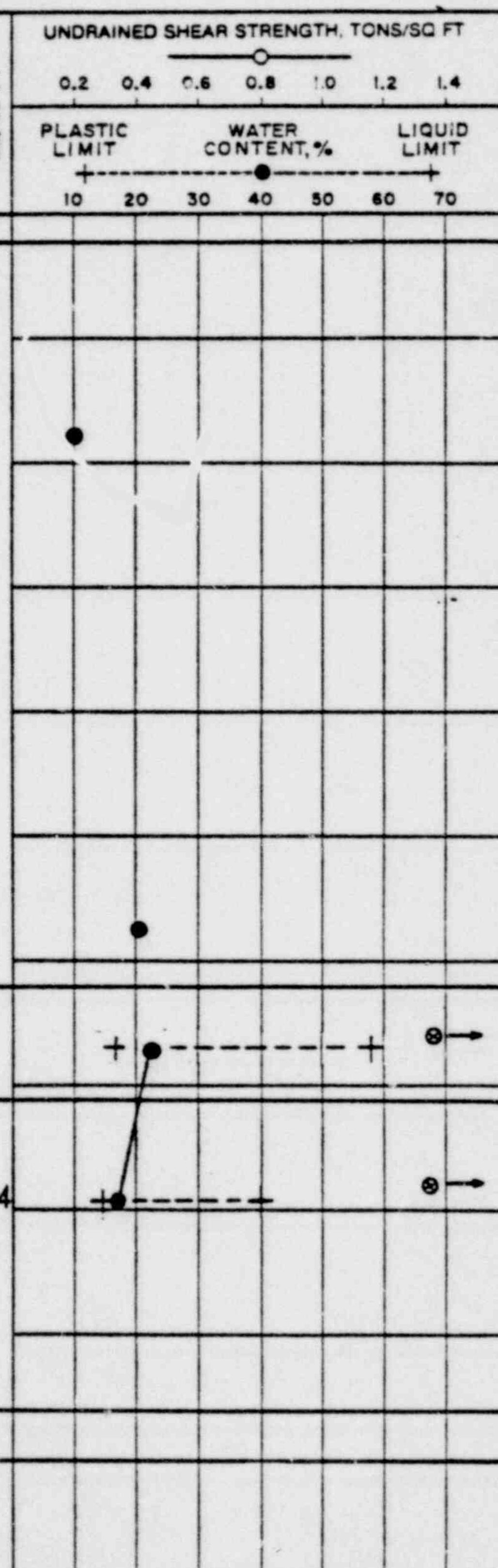
PLASTIC LIMIT — WATER CONTENT, % — LIQUID LIMIT: 10 20 30 40 50 60 70

(Continued on Plate 2b)

FIG NO. M3a

LOG OF BORING NO. H-42 (Cont'd)
ALLENS CREEK NUCLEAR GENERATING STATION
ULTIMATE HEAT SINK
WALLIS, TEXAS

DEPTH, FT	DESCRIPTION OF MATERIAL	BLOWS PER FT	UNIT DRY WT LB/CU FT	-#200, %
	Tan silty clay with clay, sandy clay seams & coarse sand pockets			
55	Tan coarse to fine sand -gravelly with clay pockets to 72'	33		
60		50/9"		6
65		35		
70		50/11"		
75	-medium to fine below 72'	50/3"		
80		50/6"		6
	Very stiff light gray clay with calcareous nodules & deposits			
85	Very stiff light gray sandy clay			
90			114	
95	-with clayey sand seams below 92'	43		
100	Light gray fine sand	50/8"		



COMPLETION DEPTH: 99.5'
DATE: April 29, 1978

DEPTH TO WATER IN BORING: 10.5' Caved at 10.7' DATE: May 1, 1978

FIG NO. M3b

LOG OF BORING NO. H-42A

ALLENS CREEK NUCLEAR GENERATING STATION
ULTIMATE HEAT SINK
WALLIS, TEXAS

TYPE: 3" thin-walled tube & Hvorslev Piston Sampler

LOCATION: See Plate 1

DEPTH, FT	SYMBOL	SAMPLES	DESCRIPTION OF MATERIAL (SURF. EL: 104.1')	UNIT DRY WT LB/CU FT	UNDRAINED SHEAR STRENGTH, TONS/SQ FT (0.2, 0.4, 0.6, 0.8, 1.0, 1.2, 1.4) / PLASTIC LIMIT, WATER CONTENT, %, LIQUID LIMIT (10, 20, 30, 40, 50, 60, 70)	-#200, %
0–5			Very stiff dark gray & brown silty clay -with roots to 1' -very stiff gray sandy clay layer below 3.5'	101	2.53	
5–15			Tan fine sand	96		5
						7
				98		5

Depth scale: 5, 10, 15, 20, 25, 30, 35, 40, 45, 50

COMPLETION DEPTH: 15'
DATE: April 26, 1978

DEPTH TO WATER IN BORING: grouted

DATE: April 26, 1978

FIG NO. M4

LOG OF BORING NO. H-43

ALLENS CREEK NUCLEAR GENERATING STATION
ULTIMATE HEAT SINK
WALLIS, TEXAS

TYPE: 3" thin-walled tube & 2" split-barrel LOCATION: See Plate 1

SURF. EL: 100.7'

UNDRAINED SHEAR STRENGTH, TONS/SQ FT: 0.2 0.4 0.6 0.8 1.0 1.2 1.4

PLASTIC LIMIT — WATER CONTENT, % — LIQUID LIMIT: 10 20 30 40 50 60 70

DEPTH, FT	DESCRIPTION OF MATERIAL	BLOWS PER FT	UNIT DRY WT LB/CU FT	-#200, %
0–3.5	Very stiff brown silty clay -with roots to 1.5' -with clay seams below 1.5' -dark gray below 3'			
3.5–13	Gray fine sand	13		
	-with gray sandy clay layers, 6.5' to 7.5'	15		
	-with clay pockets below 7.5'	15		
	-coarse to fine below 8.5' -tan below 12'	20		
13–19	Tan clay with fine sand seams & pockets	15		
	-with gravel pockets, 14' to 18'	20		
		12		
19–41	Red coarse to fine sand with gravel seams & pockets	22		
	-with clay layers, 24' to 25'	14		60
	-light gray with clay pockets below 26'	17		
		31		
		18		6
41–47	Light gray sandy clay	9		
47–50	Light gray & tan coarse to fine sand with gravel	50		

(Continued on Plate 4b)

FIG NO. M5a

LOG OF BORING NO. H-43 (Cont'd)
ALLENS CREEK NUCLEAR GENERATING STATION
ULTIMATE HEAT SINK
WALLIS, TEXAS

DEPTH, FT	DESCRIPTION OF MATERIAL	BLOWS PER FT	UNIT DRY WT LB/CU FT	-# 200, %
	Light gray & tan coarse to fine sand with gravel			
55	-with gravel seams & pockets to 60'	49		5
	-with gravel layer at 57'			
60		50		
	-light gray below 61'			
	-with clay seams, 61' to 67'			
65		25		
	-with clay layers, 66' to 67'			
70		50/11"		7
75		50/5"		
	Very stiff light gray & brown clay			
80		19		
85			110	
90	Light gray fine sand with clay pockets	30		
95		50/7"		
100	Tan & light gray sandy clay	24		

Chart headings: UNDRAINED SHEAR STRENGTH, TONS/SQ FT (0.2, 0.4, 0.6, 0.8, 1.0, 1.2, 1.4); PLASTIC LIMIT, WATER CONTENT, %, LIQUID LIMIT (10, 20, 30, 40, 50, 60, 70)

COMPLETION DEPTH: 100'
DATE: April 28, 1978

DEPTH TO WATER IN BORING: 7.2' Caved at 40'
DATE: May 1, 1978

FIG NO. M5b

LOG OF BORING NO. A-43A

ALLENS CREEK NUCLEAR GENERATING STATION
ULTIMATE HEAT SINK
WALLIS, TEXAS

TYPE: 3" thin-walled tube & Hvorslev Piston Sampler

LOCATION: See Plate 1

SURF. EL: 100.7'

DEPTH, FT	DESCRIPTION OF MATERIAL	UNIT DRY WT LB/CU FT	-#200, %
0–3	Very stiff brown silty clay -with roots to 1.5' -with shell fragments at 1' -with clay seams below 1.5'	108 76	
3–10	Gray fine sand -with sandy clay layers, 6.5' to 7.5' -with clay pockets below 7.5 -coarse to fine below 8.5'	103	15

UNDRAINED SHEAR STRENGTH, TONS/SQ FT: 0.2, 0.4, 0.6, 0.8, 1.0, 1.2, 1.4

PLASTIC LIMIT — WATER CONTENT, % — LIQUID LIMIT: 10, 20, 30, 40, 50, 60, 70

1.42

COMPLETION DEPTH: 10'
DATE: April 26, 1978

DEPTH TO WATER IN BORING: grouted

DATE: April 26, 1978

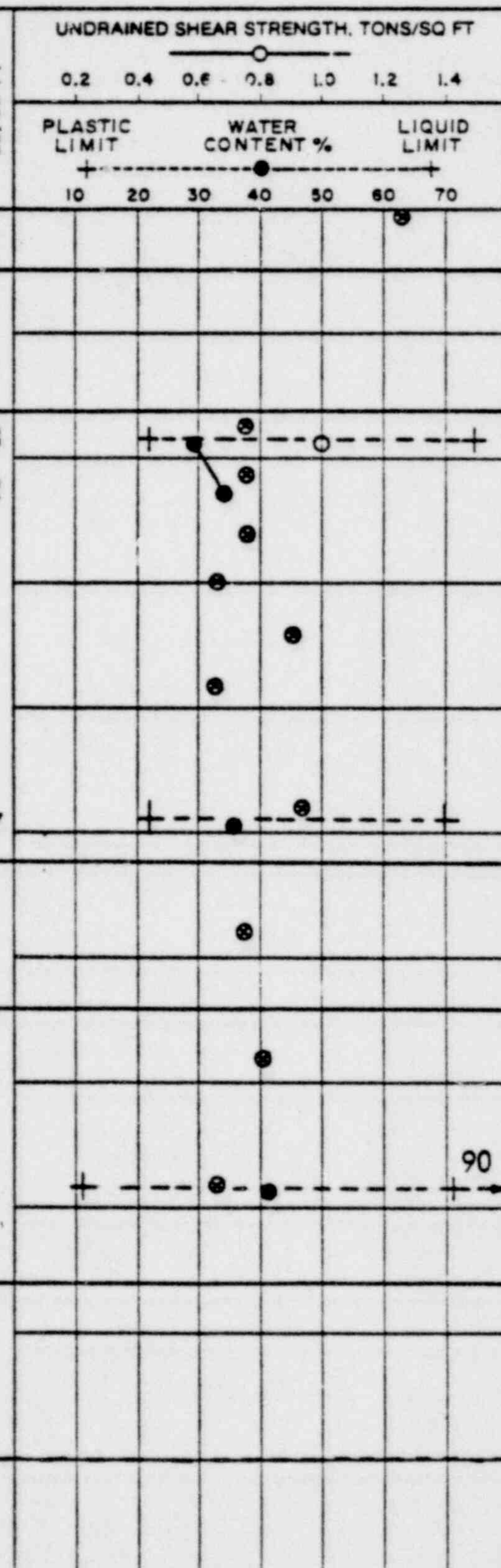
FIG NO. M6

LOG OF BORING NO. H-44
ALLENS CREEK NUCLEAR GENERATING STATION
ULTIMATE HEAT SINK
WALLIS, TEXAS

TYPE: 3" thin-walled tube & 2" split-barrel LOCATION: See Plate 1

SURF. EL: 98.9'

DEPTH, FT	DESCRIPTION OF MATERIAL	BLOWS PER FT	UNIT DRY WT LB/CU FT
0–2	Very stiff brown clay -with roots to 2'		
2–7	Gray fine sand -with silty clay seams to 6' -with clayey silt seams below 7'		
7–25	Stiff tan & light gray clay, slickensided with calcareous nodules -light gray & brown below 16'		98 92 87
25–31	Stiff light gray & brown sandy clay with shell fragments		
31–43	Stiff gray clay -slickensided to 36' -with organic matter & shell fragments, 36' to 41.5' -with fine sand seams below 39' -with sandy clay layers below 42'	7	
43–50	Tan fine to medium sand -with gravel seams, 44' to 56' -with sandstone layer, 44.5' to 47'	50/8" 38	



(Continued on Plate 6b)

FIG NO. M7a

LOG OF BORING NO. H-44 (Cont'd)
ALLENS CREEK NUCLEAR GENERATING STATION
ULTIMATE HEAT SINK
WALLIS, TEXAS

DEPTH, FT	DESCRIPTION OF MATERIAL	BLOWS PER FT	UNIT DRY WT LB/CU FT	-#200, %
	Tan fine to medium sand			
	-coarse to fine, 53.5' to 55'	50/9"		6
55	-with sandy clay seams below 56'			
	-fine, 59' to 67'	50/10"		
60				
65		50		
	-tan & light gray below 67'			
70		35		6
	-with clay layers, 72' to 73'			
75	Brown and light gray clay	29		
	-with fine sand seams, 77' to 81'			
80	-with sandy clay seams below 81'	30		
85				
	Light gray fine sand	50/11"		
90	-with sandy clay seams to 88'			
95		50/6"		
100	Light gray sandy clay with calcareous nodules & deposits	50/9"		

UNDRAINED SHEAR STRENGTH, TONS/SQ FT: 0.2 0.4 0.6 0.8 1.0 1.2 1.4

PLASTIC LIMIT — WATER CONTENT, % — LIQUID LIMIT: 10 20 30 40 50 60 70

COMPLETION DEPTH: 100'
DATE: April 26, 1978

DEPTH TO WATER IN BORING: 4.2' Caved at 24.1'
DATE: May 1, 1978

FIG NO. M7b

LOG OF BORING NO. H-44A
ALLENS CREEK NUCLEAR GENERATING STATION
ULTIMATE HEAT SINK
WALLIS, TEXAS

TYPE: 3" thin-walled tube & Hvorslev Piston Sampler

LOCATION: See Plate 1

SURF. EL: 98.9'

DEPTH, FT	DESCRIPTION OF MATERIAL	UNIT DRY WT LB/CU FT	-# 200, %
0–2	Very stiff brown clay -with roots to 2'		
2–8	Gray clayey fine sand -with silty clay seams to 6' -with clayey silt seams below 7'	86 96	18 66

UNDRAINED SHEAR STRENGTH, TONS/SQ FT: 0.2, 0.4, 0.6, 0.8, 1.0, 1.2, 1.4

PLASTIC LIMIT — WATER CONTENT, % — LIQUID LIMIT: 10, 20, 30, 40, 50, 60, 70

COMPLETION DEPTH: 8'
DATE: April 26, 1978

DEPTH TO WATER IN BORING: grouted

DATE: April 26, 1978

FIG NO. M8

LOG OF BORING NO. H-45
ALLENS CREEK NUCLEAR GENERATING STATION
ULTIMATE HEAT SINK
WALLIS, TEXAS

TYPE: 3" thin-walled tube & 2" split-barrel LOCATION: See Plate 1

SURF. EL: 98.5'

DEPTH, FT	DESCRIPTION OF MATERIAL	BLOWS PER FT	UNIT DRY WT LB/CU FT	-#200, %
0–5.5	Stiff tan clay -with roots to 1' -with sand seams below 1' -gray, 2' to 4' -light gray below 4' -sandy below 4.5'	2 4		
5.5–10	Light gray & tan silty sand with sandy clay seams	3 4		
10–23	Brown & light gray clay, with calcareous & ferrous nodules -brown below 18'	10 11 11 12		
23–31	Brown silty clay -with sandy silt layers & clay seams below 26' -with sand partings below 28'	6	95	
31–40	Gray clay with shell fragments & calcareous nodules	10		
40–50	Tan coarse to fine sand -with clay seams to 47.5' -with gravel seams & pockets, 47.5' to 59'	23 37		5

Chart column headings: UNDRAINED SHEAR STRENGTH, TONS/SQ FT (0.2, 0.4, 0.6, 0.8, 1.0, 1.2, 1.4); PLASTIC LIMIT, WATER CONTENT, %, LIQUID LIMIT (10, 20, 30, 40, 50, 60, 70)

(Continued on Plate 8b)

FIG NO. M9a

LOG OF BORING NO. H-45 (Cont'd)
ALLENS CREEK NUCLEAR GENERATING STATION
ULTIMATE HEAT SINK
WALLIS, TEXAS

DEPTH, FT	DESCRIPTION OF MATERIAL	BLOWS PER FT	UNIT DRY WT LB/CU FT	WATER CONTENT, %	-#200,%
	Tan coarse to fine sand				
53		47			
58		50/5"			
63		50/11"		● (≈14)	10
66	-fine below 66'				
68		50/5"			
73	Brown & light gray clay with calcareous nodules	17			
78				⊗ (≈68) →	
82	-with sandy clay seams below 82'				
83		50/10"			
88	Light gray fine sand	50/7"			
91	-with clayey sand seams to 91'				
93		50/7"			
97	-with sandstone seams at 97'				
99	Very stiff light gray tan sandy clay			⊗ (≈64)	

Chart header: UNDRAINED SHEAR STRENGTH, TONS/SQ FT (0.2, 0.4, 0.6, 0.8, 1.0, 1.2, 1.4); PLASTIC LIMIT — WATER CONTENT, % — LIQUID LIMIT (10, 20, 30, 40, 50, 60, 70)

(Continued on Plate 8c)

FIG NO. M9b

LOG OF BORING NO. H-45 (Cont'd)
ALLENS CREEK NUCLEAR GENERATING STATION
ULTIMATE HEAT SINK
WALLIS, TEXAS

DEPTH, FT	DESCRIPTION OF MATERIAL	BLOWS PER FT
100–105	Very stiff light gray & tan sandy clay with sandstone nodules & deposits, sand seams & layers	
105–122	Light gray clayey sand with clay seams & sand seams -with sandstone nodules to 108'	50/1"
		50/2"
122–149	Light gray fine sand	50/3"
	-with clay seams below 137'	50/6"
	-with cemented sand layers below 141'	
149–149.5	Gray silt	50/6"

Column headings: DEPTH, FT; SYMBOL; SAMPLES; DESCRIPTION OF MATERIAL; BLOWS PER FT; UNIT DRY WT LB/CU FT; UNDRAINED SHEAR STRENGTH, TONS/SQ FT (0.2, 0.4, 0.6, 0.8, 1.0, 1.2, 1.4); PLASTIC LIMIT, WATER CONTENT, %, LIQUID LIMIT (10, 20, 30, 40, 50, 60, 70)

COMPLETION DEPTH: 149.5'
DATE: May 2, 1978

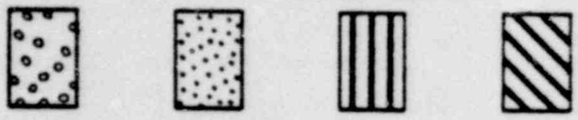
DEPTH TO WATER IN BORING: grouted

DATE: May 2, 1978

FIG NO. M9c

SYMBOLS AND TERMS USED ON BORING LOGS

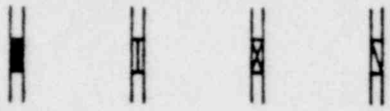
SOIL TYPES
(SHOWN IN SYMBOL COLUMN)



Gravel Sand Silt Clay

Predominant type shown heavy

SAMPLER TYPES
(SHOWN IN SAMPLES COLUMN)



Shelby Tube Piston Split Spoon No Recovery

TERMS DESCRIBING CONSISTENCY OR CONDITION

COARSE GRAINED SOILS (major portion retained on No. 200 sieve): includes (1) clean gravels and sands, and (2) silty or clayey gravels and sands. Condition is rated according to relative density, as determined by laboratory tests.

DESCRIPTIVE TERM	RELATIVE DENSITY
Loose	0 to 40%
Medium dense	40 to 70%
Dense	70 to 100%

FINE GRAINED SOILS (major portion passing No. 200 sieve): includes (1) inorganic and organic silts and clays, (2) gravelly, sandy, or silty clays, and (3) clayey silts. Consistency is rated according to shearing strength, as indicated by penetrometer readings or by unconfined compression tests.

DESCRIPTIVE TERM	UNCONFINED COMPRESSIVE STRENGTH TON/SQ FT
Very soft	less than 0.25
Soft	0.25 to 0.50
Firm	0.50 to 1.00
Stiff	1.00 to 2.00
Very stiff	2.00 to 4.00
Hard	4.00 and higher

Note: Slickensided and fissured clays may have lower unconfined compressive strengths than shown above, because of planes of weakness or cracks in the soil. The consistency ratings of such soils are based on penetrometer readings.

TERMS CHARACTERIZING SOIL STRUCTURE

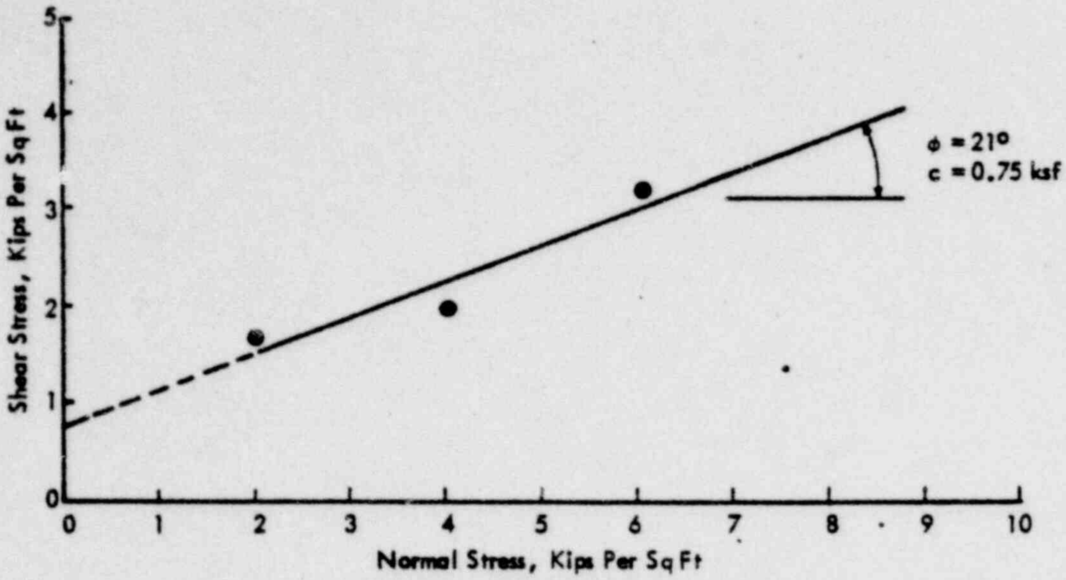
Slickensided	– having inclined planes of weakness that are slick and glossy in appearance.
Fissured	– containing shrinkage cracks, frequently filled with fine sand or silt; usually more or less vertical.
Laminated	– composed of thin layers of varying color and texture.
Interbedded	– composed of alternate layers of different soil types.
Calcareous	– containing appreciable quantities of calcium carbonate.
Well graded	– having wide range in grain sizes and substantial amounts of all intermediate particle sizes.
Poorly graded	– predominantly of one grain size, or having a range of sizes with some intermediate size missing.

Terms used in this report for describing soils according to their texture or grain size distribution are in accordance with the UNIFIED SOIL CLASSIFICATION SYSTEM, as described in Technical Memorandum No 3-357, Waterways Experiment Station, March 1953

FIG NO. M10

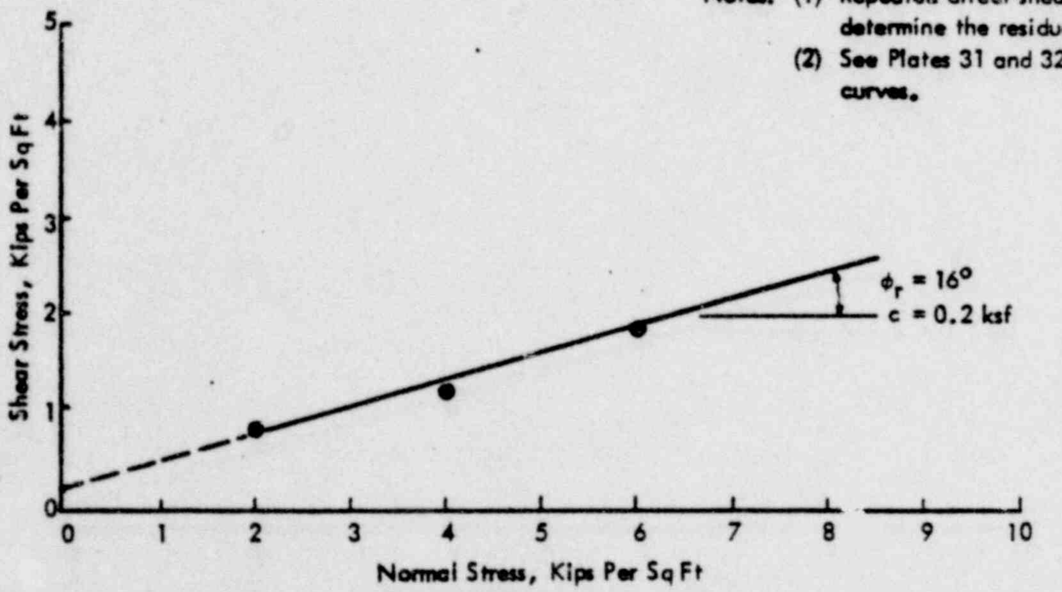
Boring: H-43A Depth: 3'
Material: Stiff dark gray sandy clay with clay pockets and calcareous deposits

γ_d = 102 psf
wl = 18
LL = 36
PL = 14



UNDISTURBED

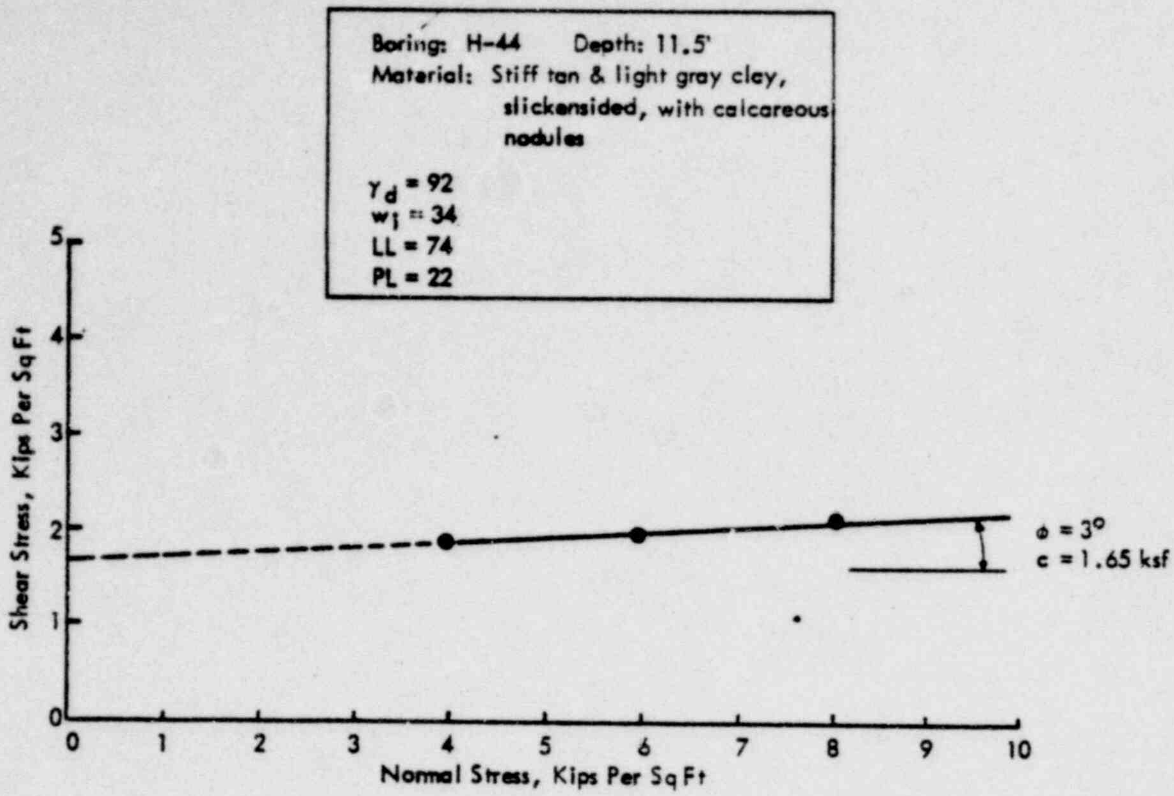
Notes: (1) Repeated direct shear test used to determine the residual shear strength.
(2) See Plates 31 and 32 for stress-strain curves.



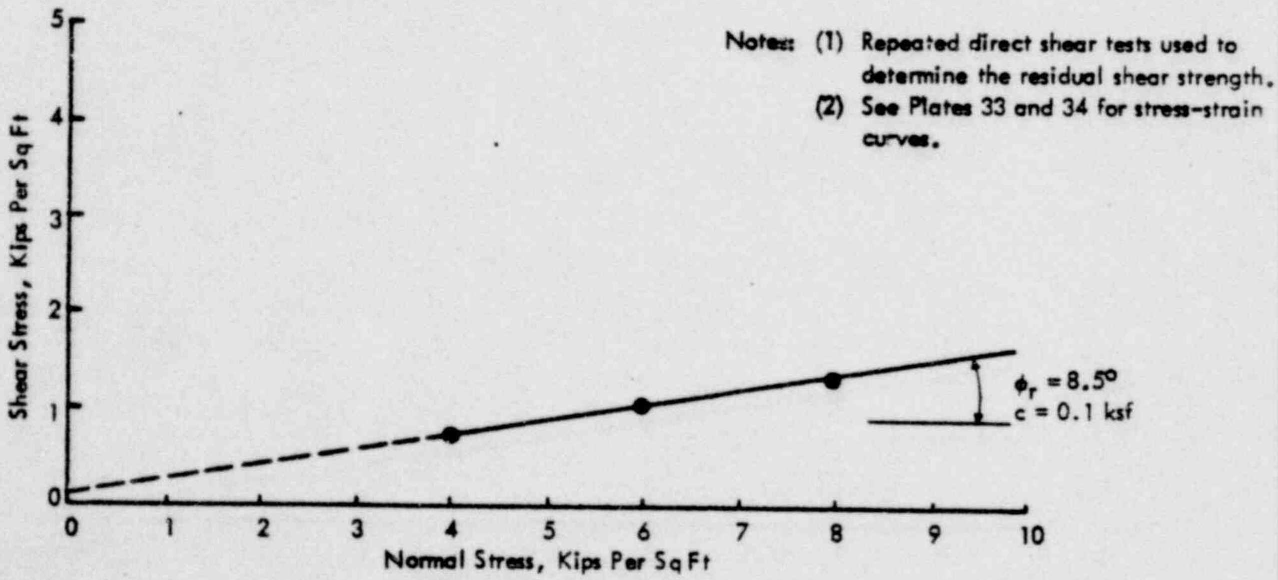
RESIDUAL

DIRECT SHEAR TEST RESULTS
Consolidated-Undrained
Multiple-Stage Type

FIG NO. M11



UNDISTURBED



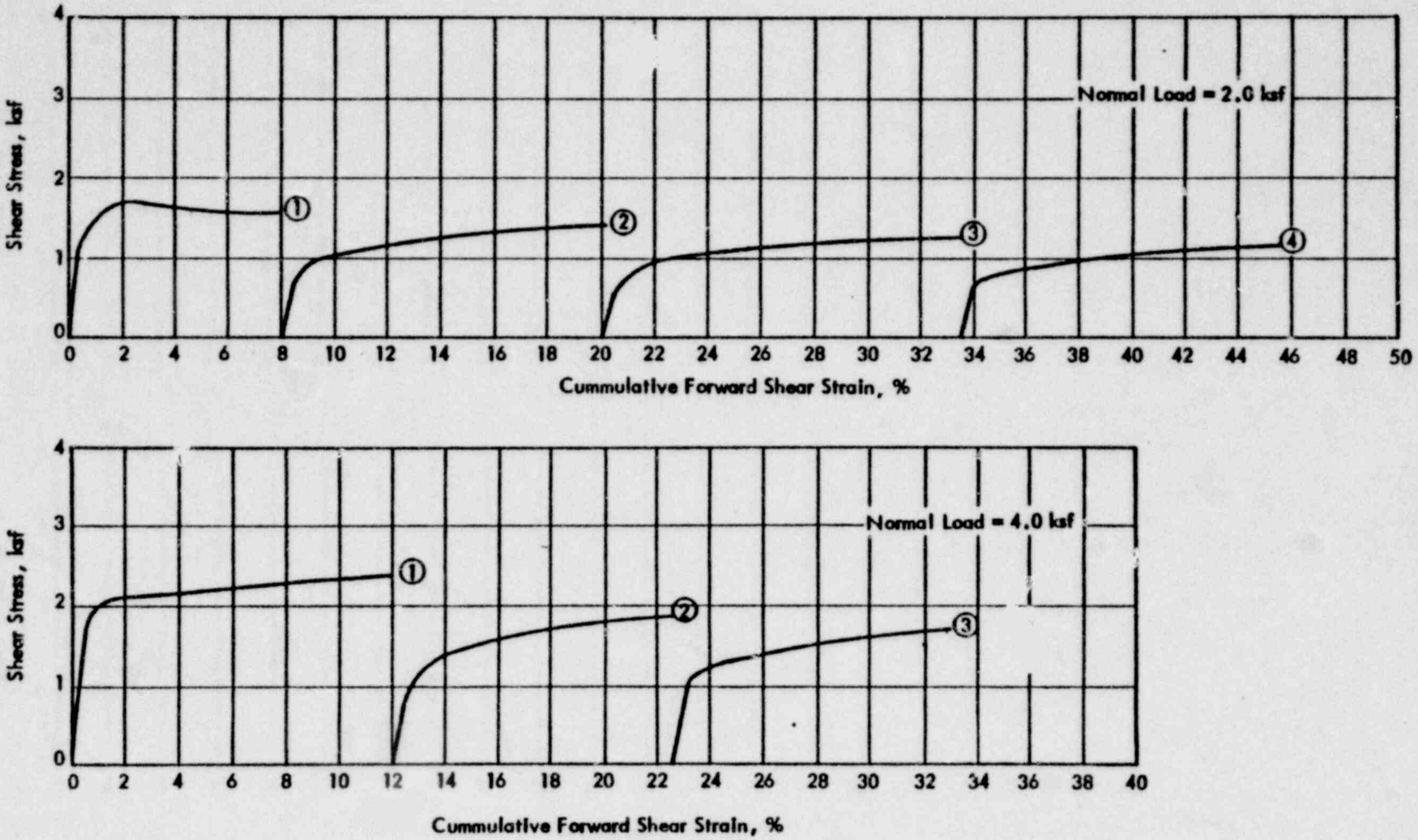
RESIDUAL

DIRECT SHEAR TEST RESULTS

Consolidated-Undrained

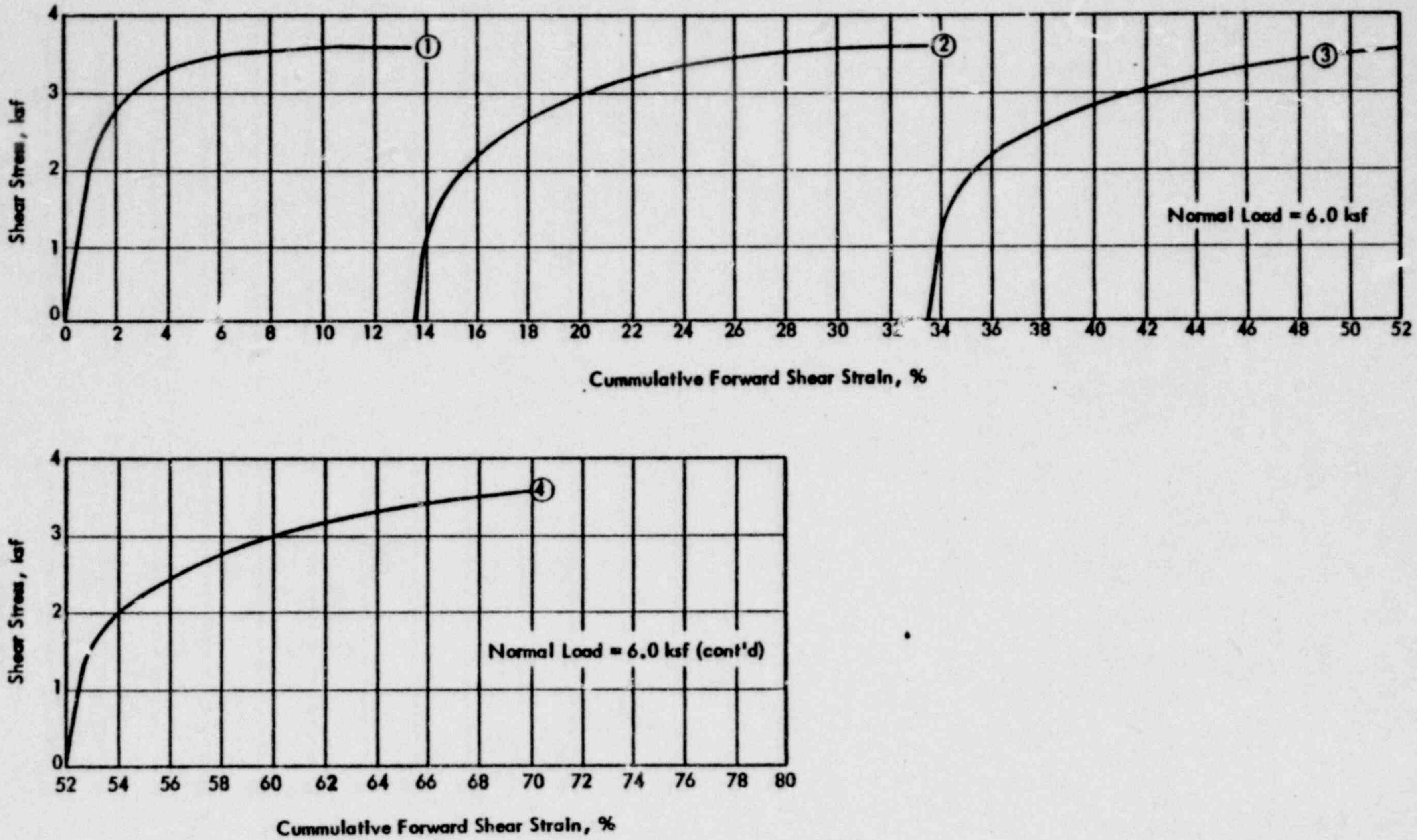
Multiple-Specimen Type

FIG NO. M12



REPEATED DIRECT SHEAR
Stress-Strain Curves
Boring H-43A, 3-ft Depth

FIG NO. M13

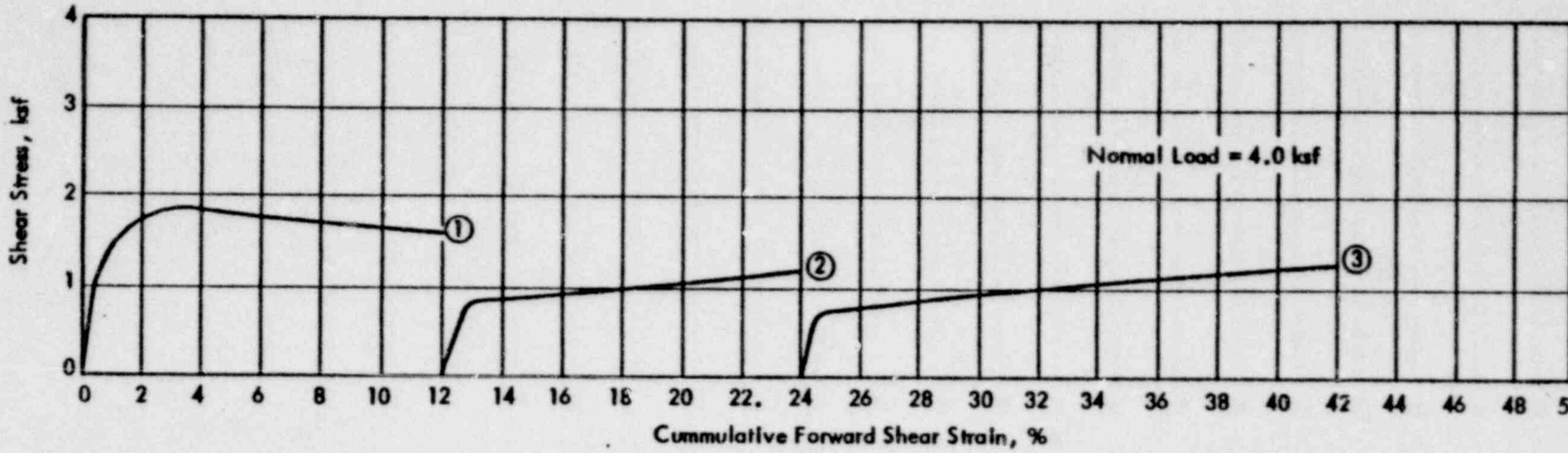


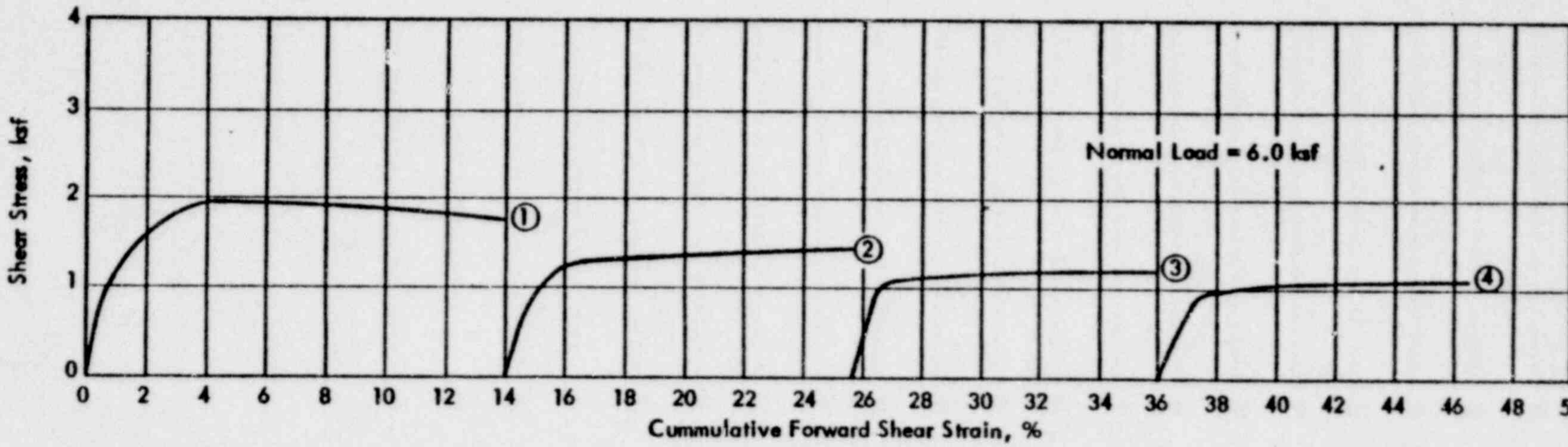
REPEATED DIRECT SHEAR

Stress-Strain Curves

Boring H-43A, 3-ft Depth

FIG NO. M14



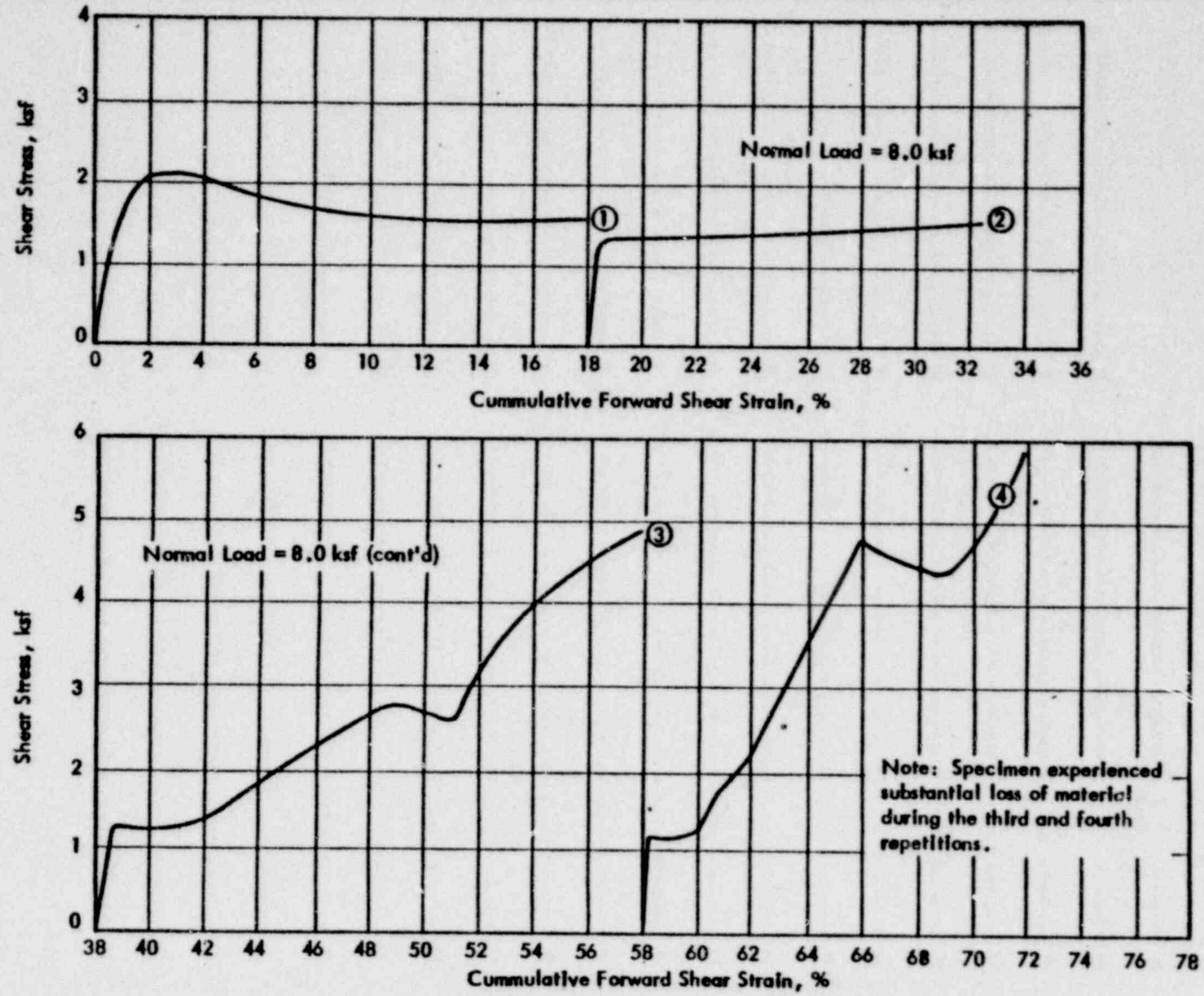


REPEATED DIRECT SHEAR

Stress-Strain Curves

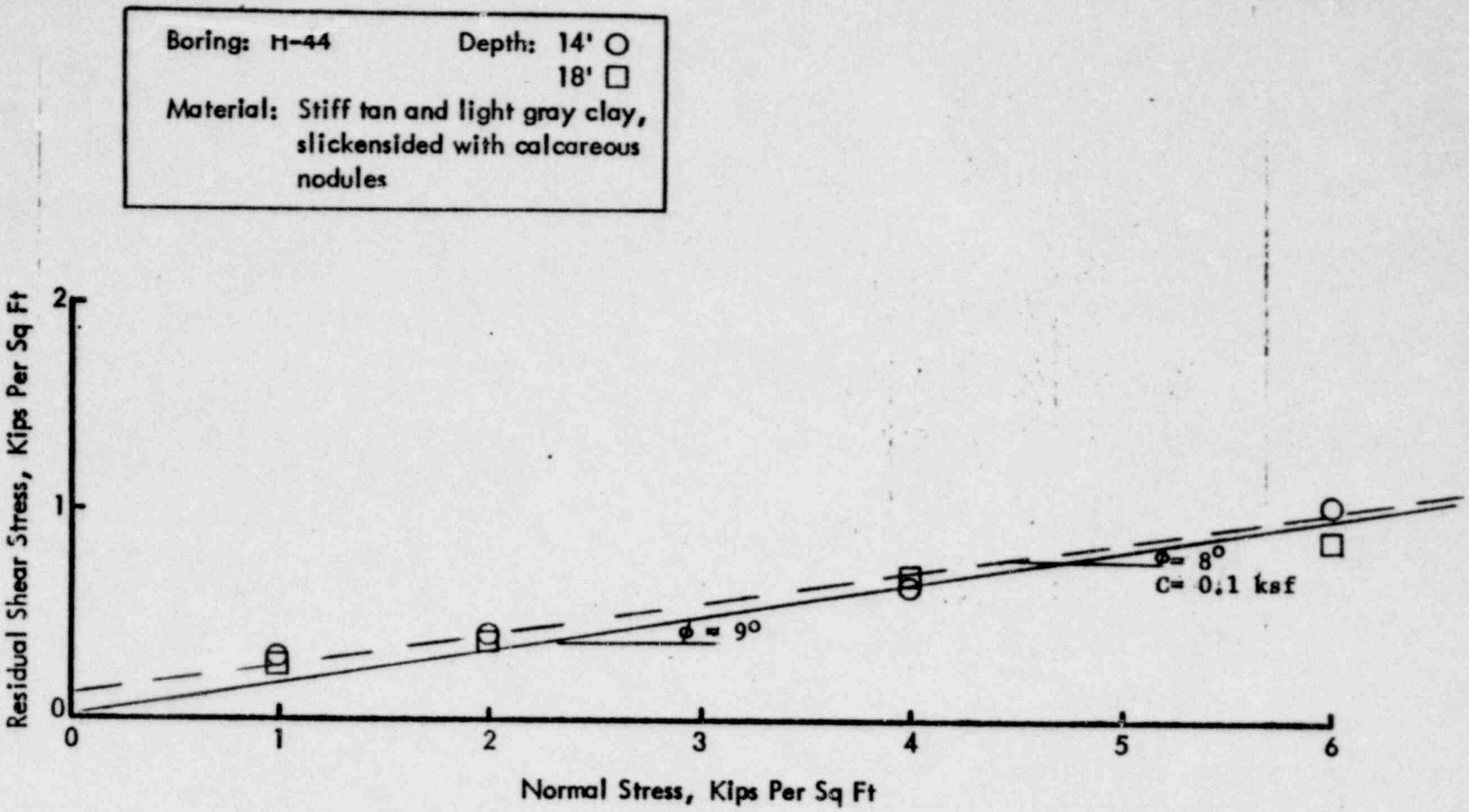
Boring H-44, 11.5-ft Depth

FIG NO. M15



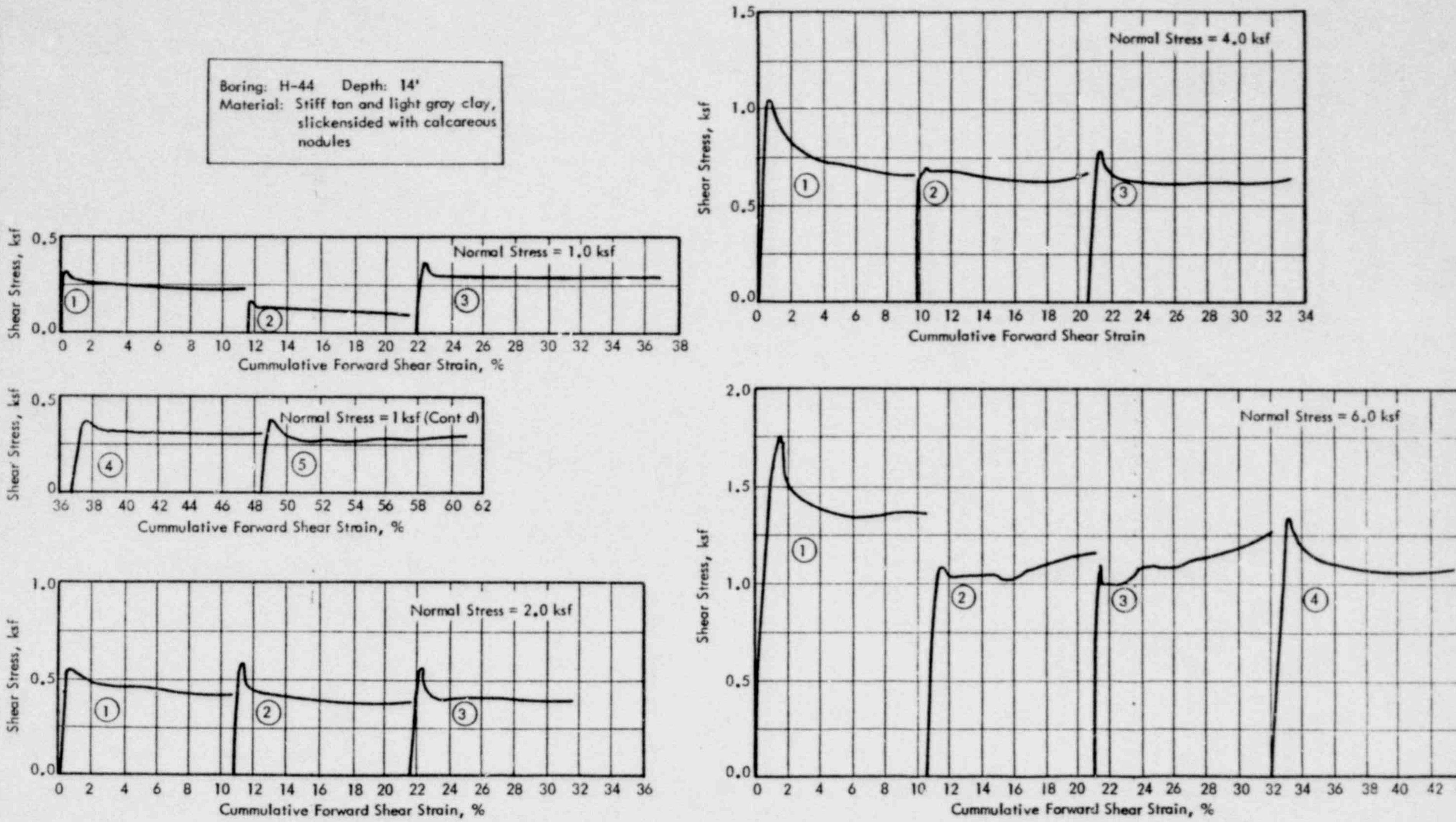
REPEATED DIRECT SHEAR
Stress-Strain Curves
Boring H-44, 11.5-ft Depth

FIG NO. M16



CONSOLIDATED-DRAINED REPEATED DIRECT SHEAR TEST RESULTS

FIG NO. M17

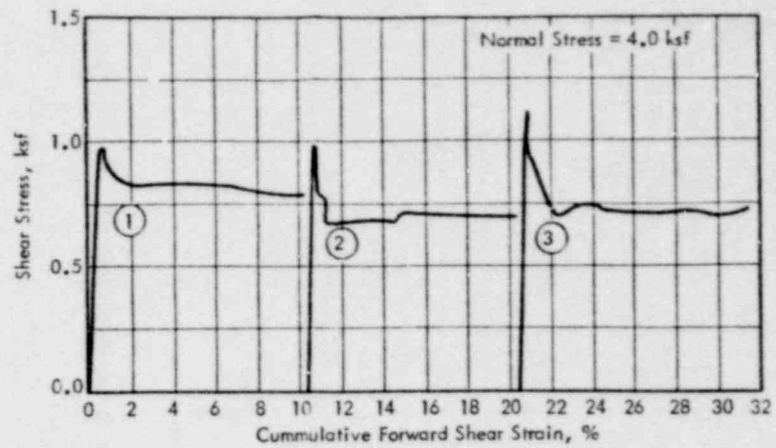


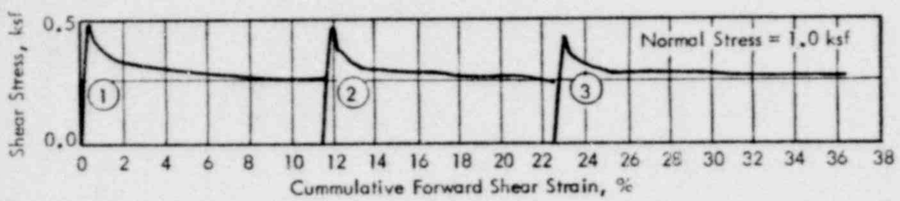
CONSOLIDATED-DRAINED REPEATED DIRECT SHEAR

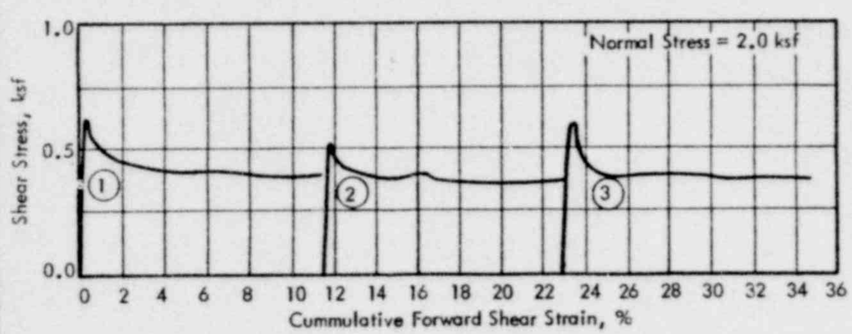
Stress-Strain Curves

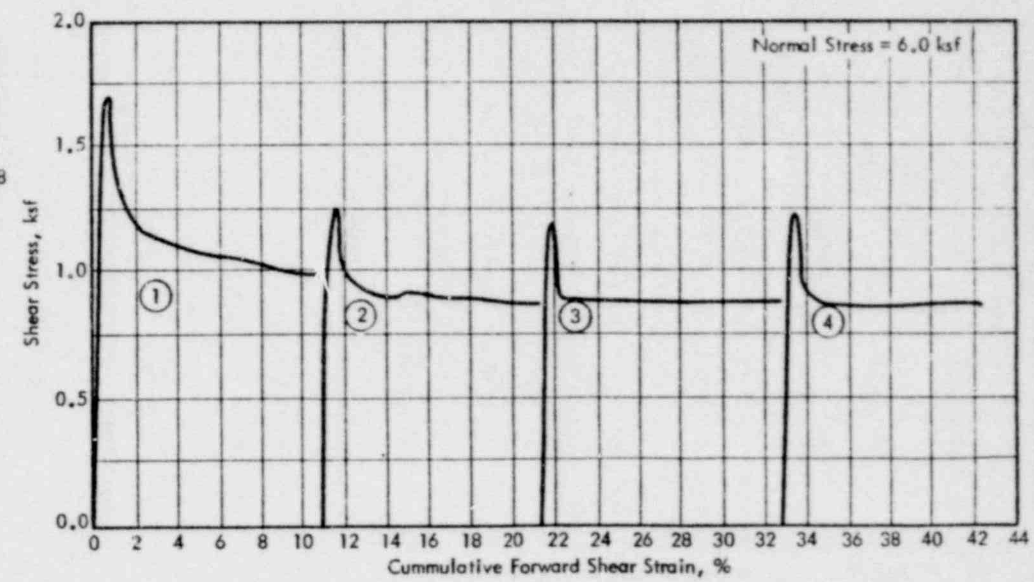
Boring: H-44 Depth: 18'
Material: Stiff tan and ligh* gray clay, slickensided with calcareous nodules

Notes: (1) Tests were mutiple-specimen type
(2) Samples were allowed to consolidate to equilibrium prior to each shear cycle.



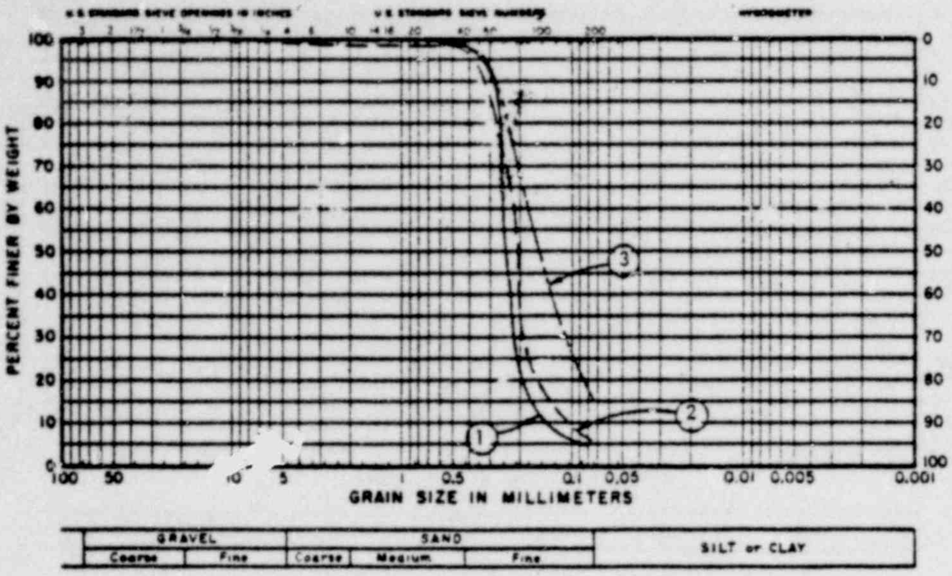






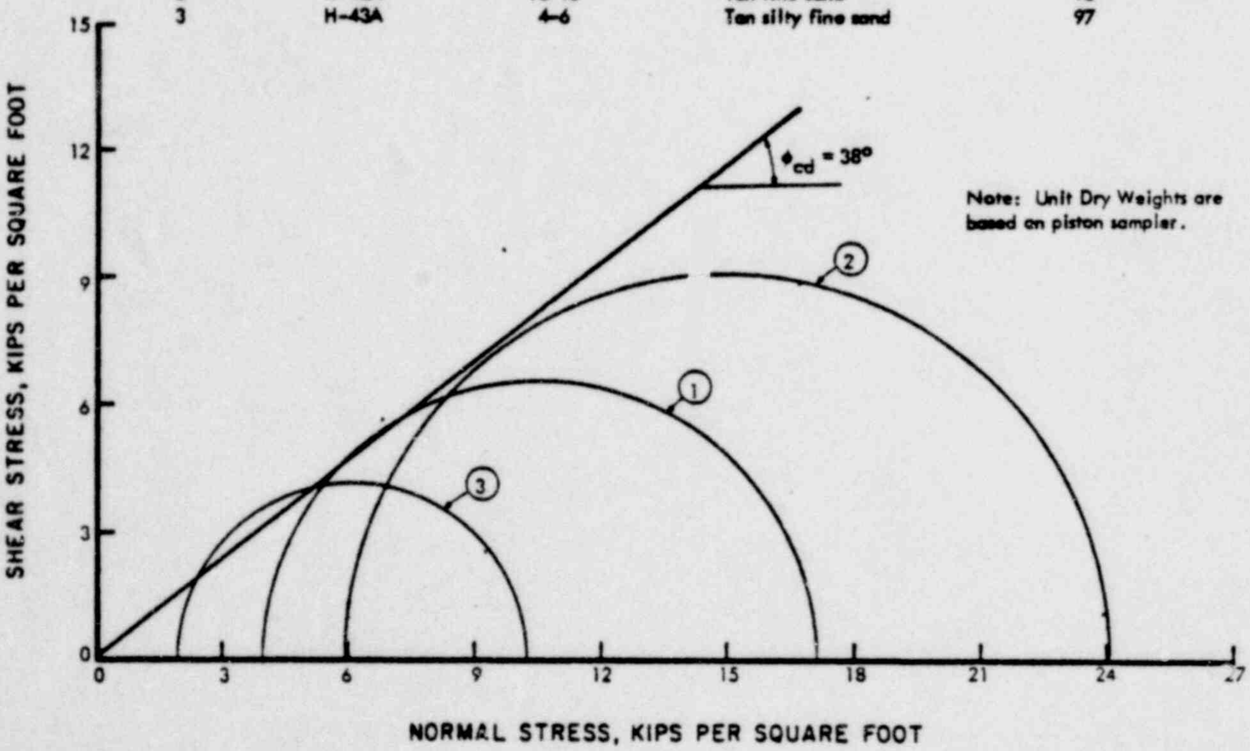
CONSOLIDATED-DRAINED REPEATED DIRECT SHEAR
Stress-Strain Curves

FIG NO. M19



GRADATION OF TEST SPECIMEN

Curve	Boring	Penetration	Material	Unit Dry Weight, pcf
1	H-42A	7-9	Tan fine sand	96
2	H-42A	13-15	Tan fine sand	98
3	H-43A	4-6	Tan silty fine sand	97



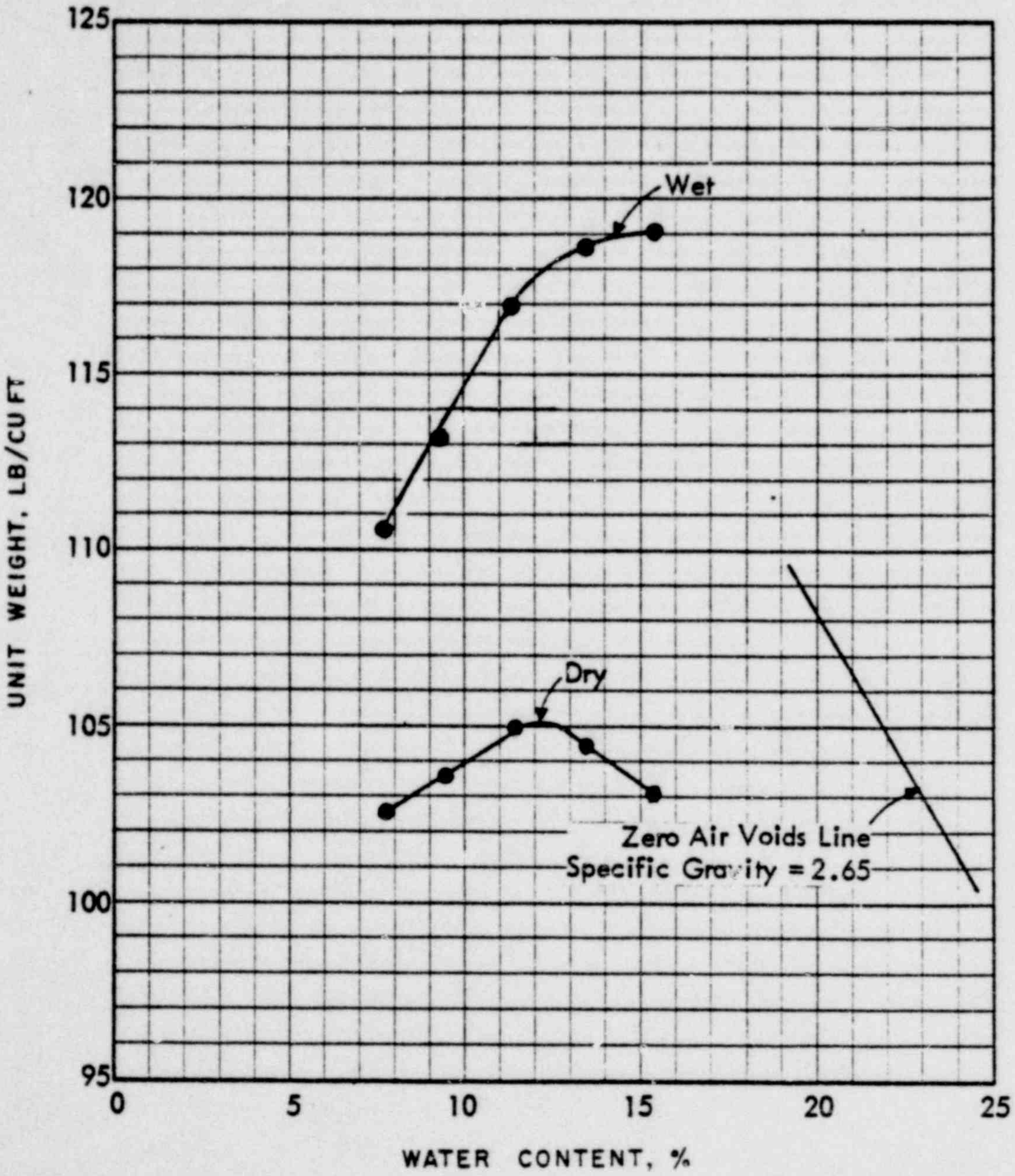
TRIAXIAL COMPRESSION TEST RESULTS

Consolidated-Drained, Multiple-Specimen Type

FIG NO. M20

Test Pit: 6
Depth: 5'
TEST METHOD: ASTM 1557
MATERIAL: Tan fine sand

OPTIMUM WATER CONTENT: 12 %
MAX UNIT DRY WEIGHT: 105 LB/CU FT

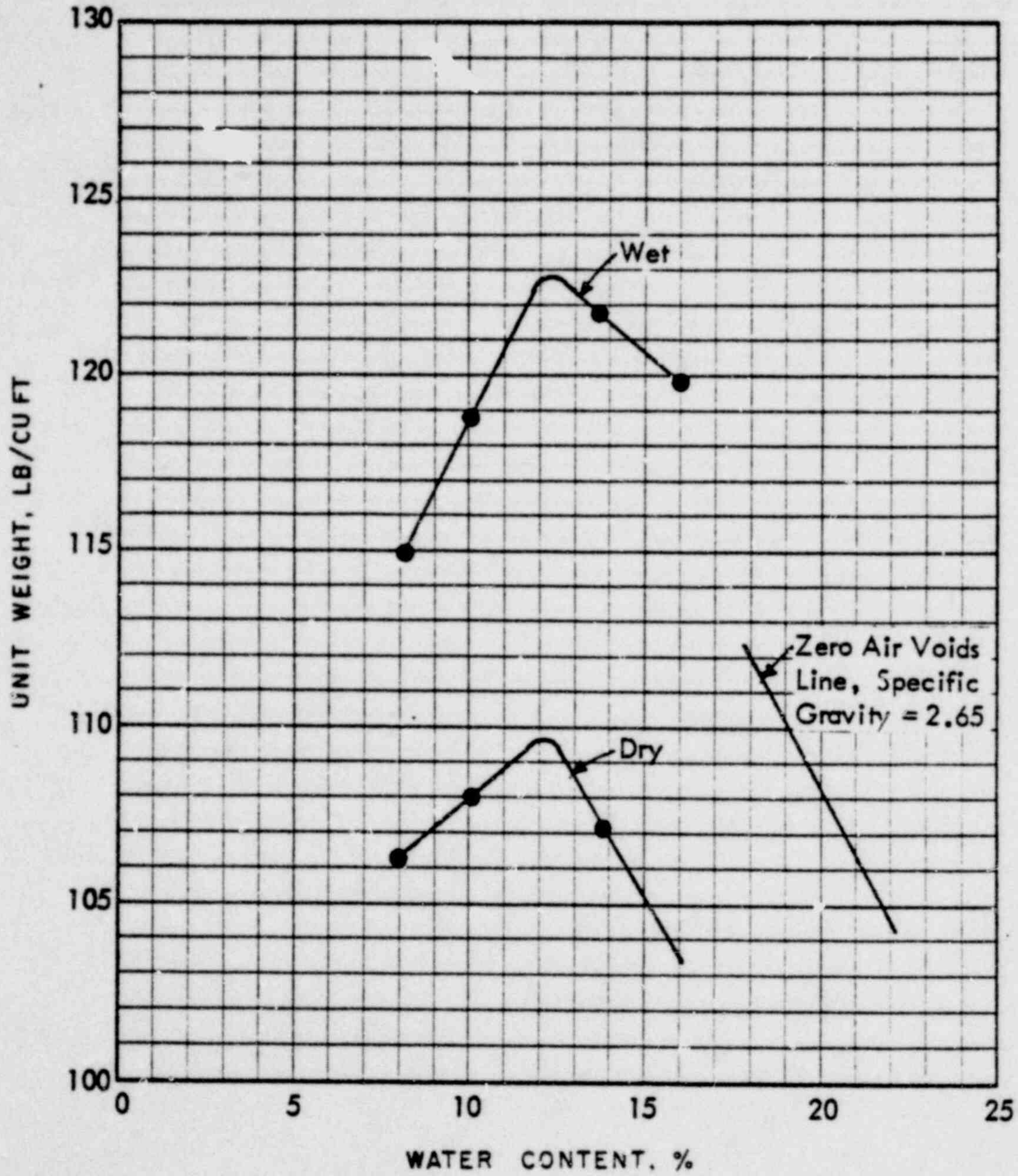


COMPACTION TEST RESULTS

FIG NO. M21

Test Pit: 6
Depth: 10'
TEST METHOD: ASTM 1557
MATERIAL: Tan fine sand

OPTIMUM WATER CONTENT: 12 %
MAX UNIT DRY WEIGHT: 110 LB/CU FT

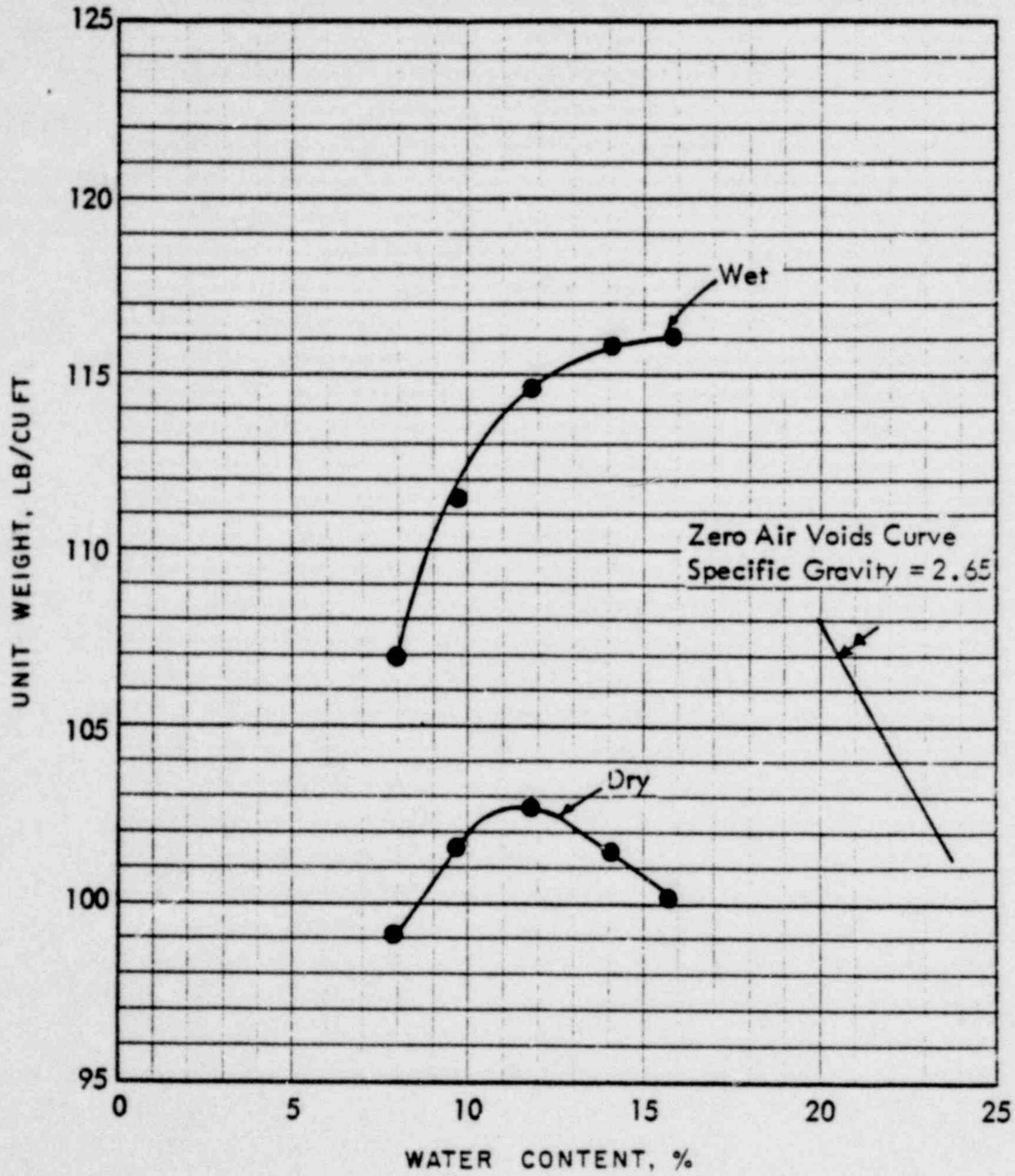


COMPACTION TEST RESULTS

FIG NO. M22

Test Pit: 7
Depth: 5'
TEST METHOD: ASTM 1557
MATERIAL: Tan fine sand

OPTIMUM WATER CONTENT: 12 %
MAX UNIT DRY WEIGHT: 103 LB/CU FT

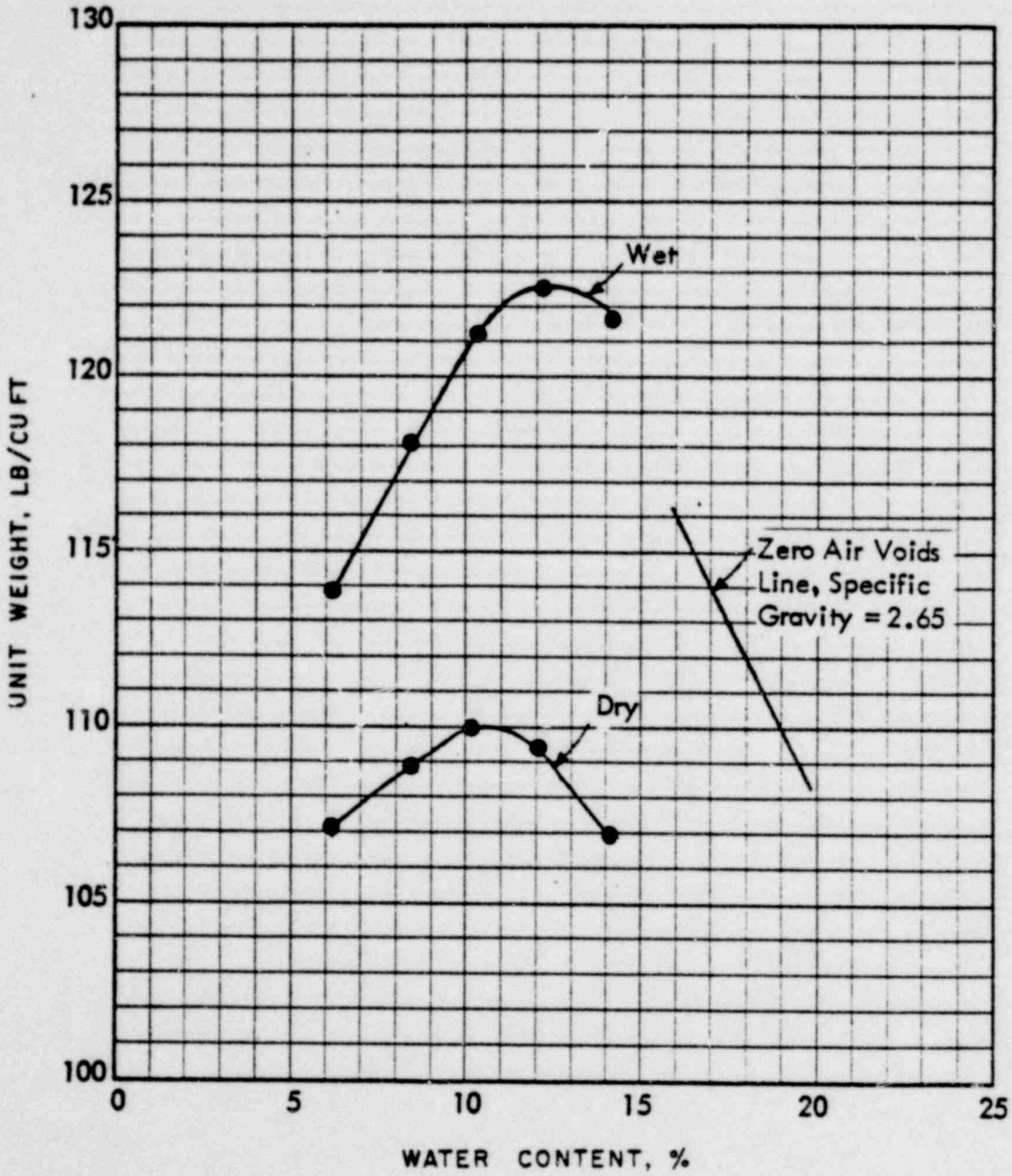


COMPACTION TEST RESULTS

FIG NO. M23

Test Pit: 8
Depth: 5'
TEST METHOD: ASTM 1557
MATERIAL: Tan fine sand

OPTIMUM WATER CONTENT: 11 %
MAX UNIT DRY WEIGHT: 110 LB/CU FT

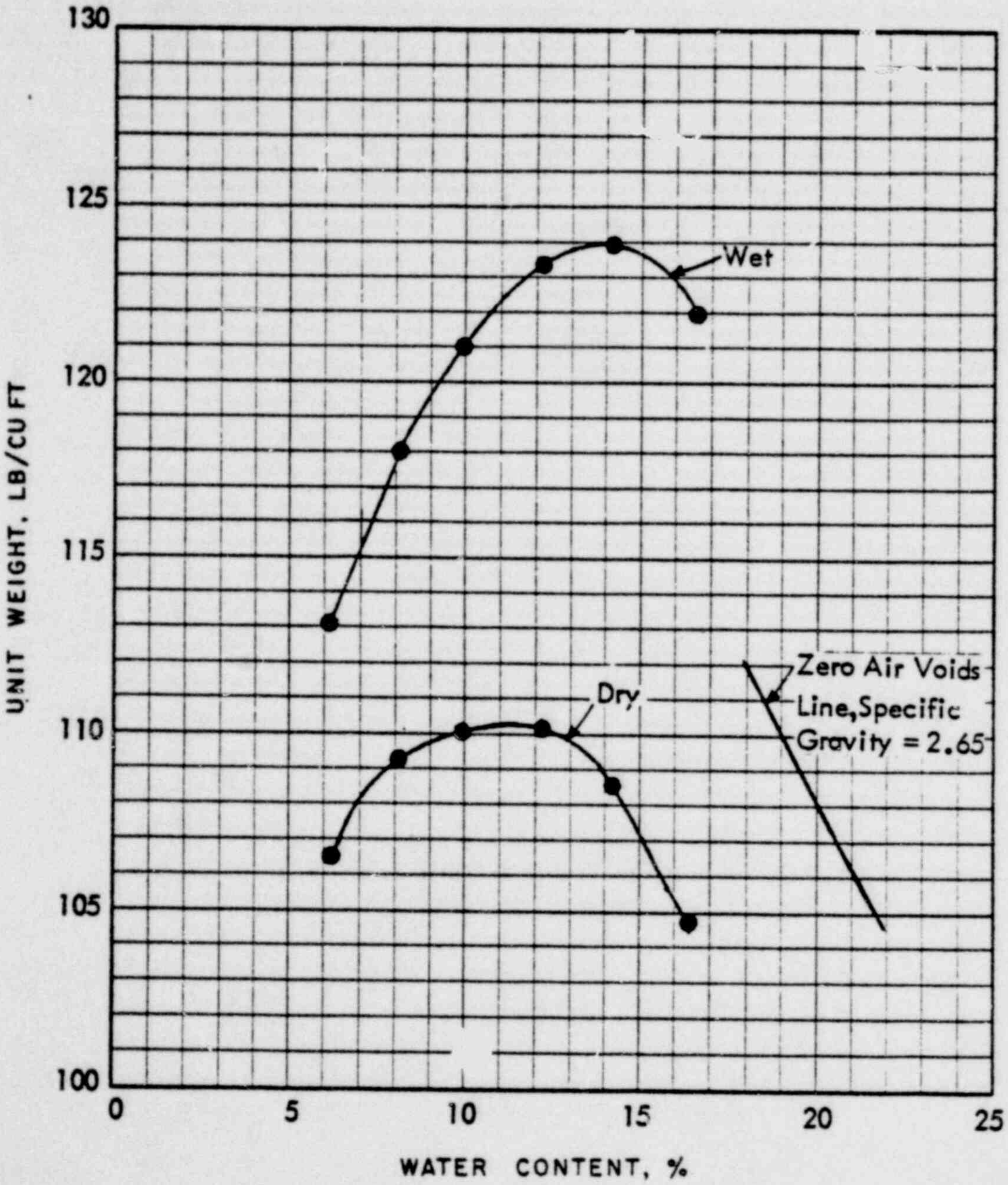


COMPACTION TEST RESULTS

FIG NO. M24

Test Pit: 9
Depth: 5'
TEST METHOD: ASTM-1557
MATERIAL: Tan silty fine sand

OPTIMUM WATER CONTENT: 11 %
MAX UNIT DRY WEIGHT: 110 LB/CU FT

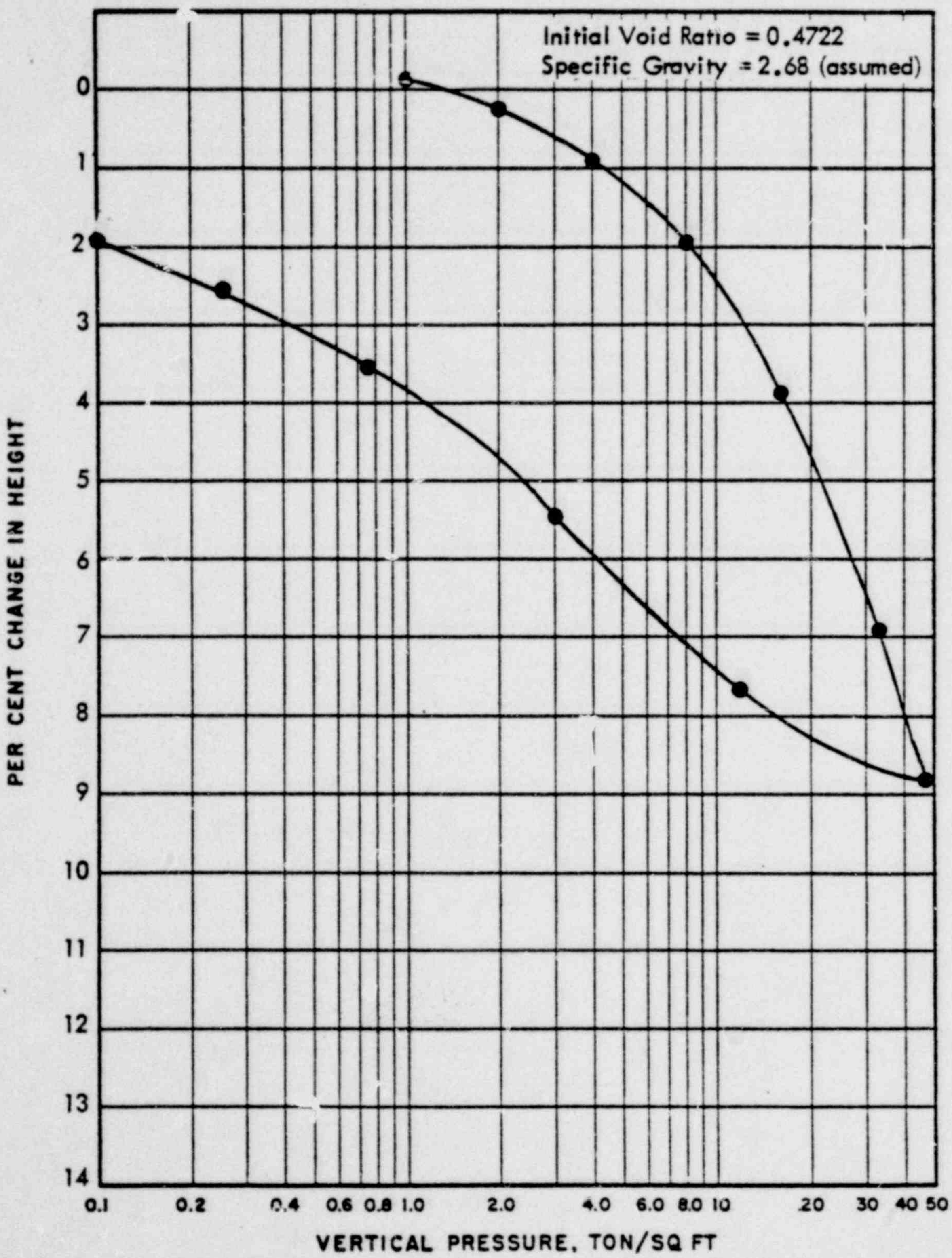


COMPACTION TEST RESULTS

FIG NO. M25

BORING: H-42 **DEPTH:** 90'
MATERIAL: Very stiff light gray sandy clay

UNIT DRY WEIGHT: 114 LB/CU FT
WATER CONTENT: 17 %
LIQUID LIMIT: 39
PLASTIC LIMIT: 14



CONSOLIDATION TEST RESULTS

FIG NO. M26

BORING: H-42A DEPTH: 3'

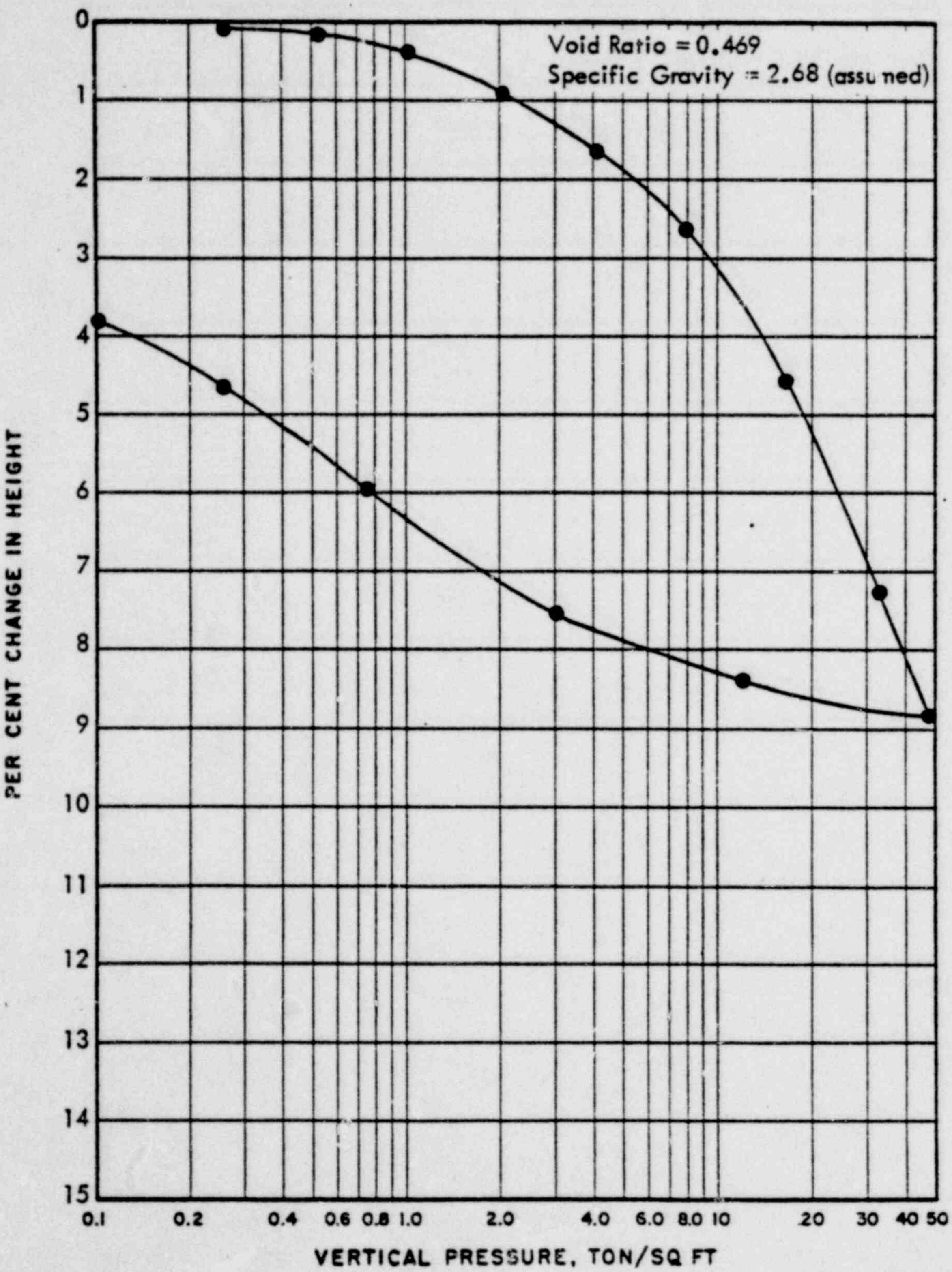
MATERIAL: Very stiff dark gray & brown silty clay

UNIT DRY WEIGHT: 114 LB/CU FT

WATER CONTENT: 16 %

LIQUID LIMIT: 32

PLASTIC LIMIT: 13



CONSOLIDATION TEST RESULTS

FIG NO. M27

BORING: H-43 DEPTH: 85'

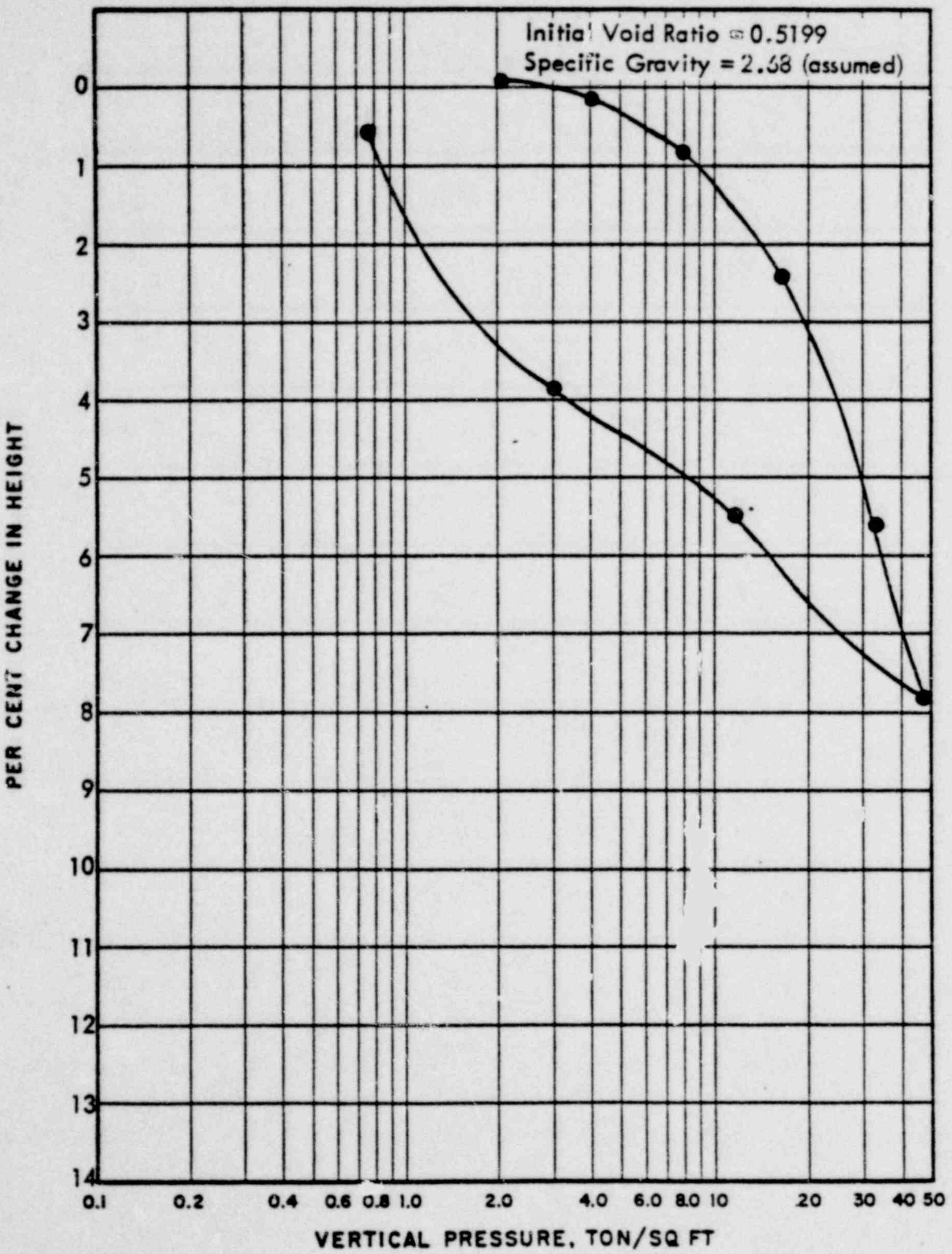
MATERIAL: Very stiff light gray sandy clay

UNIT DRY WEIGHT: 110 LB/CU FT

WATER CONTENT: 18 %

LIQUID LIMIT: 59

PLASTIC LIMIT: 17

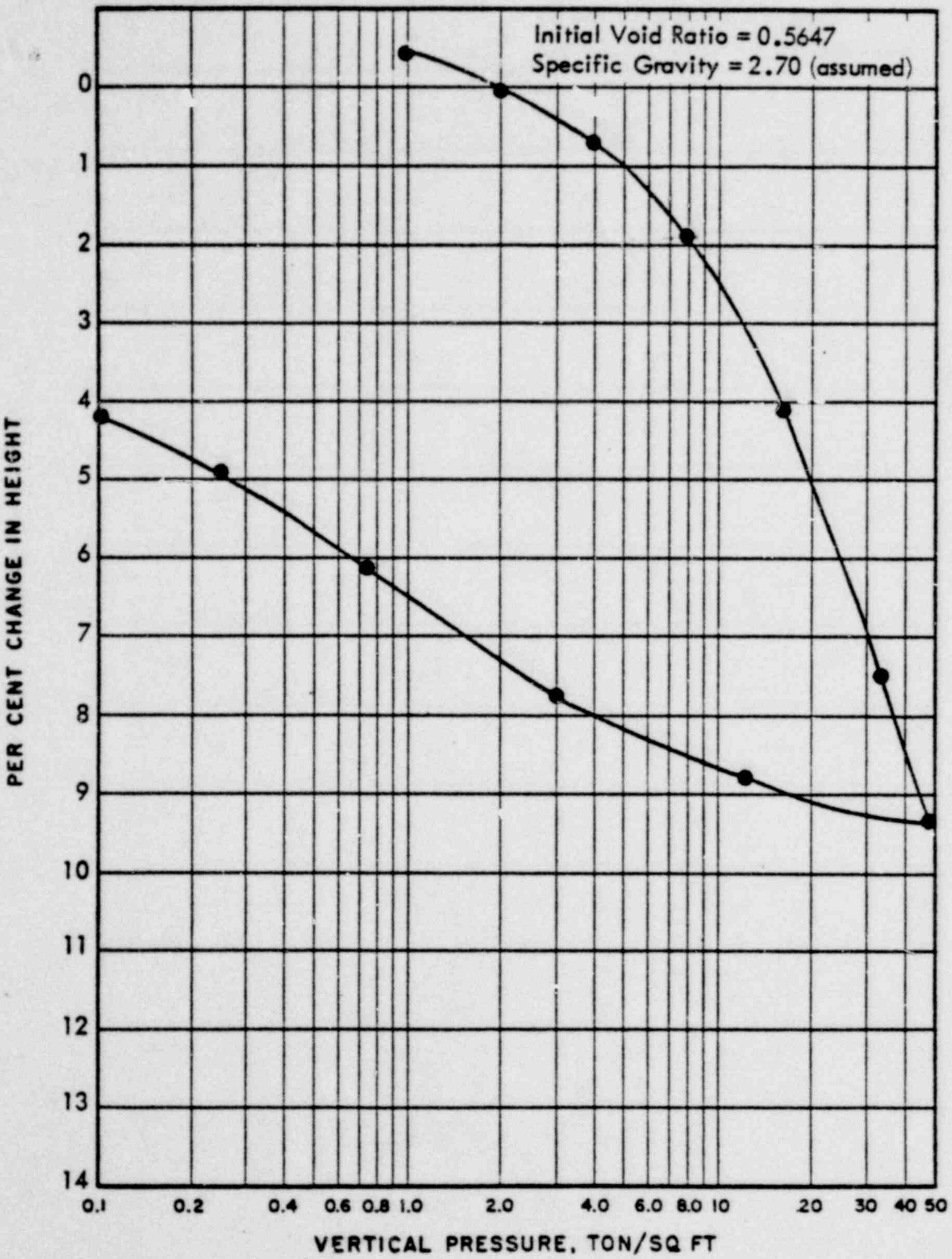


CONSOLIDATION TEST RESULTS

FIG NO. M28

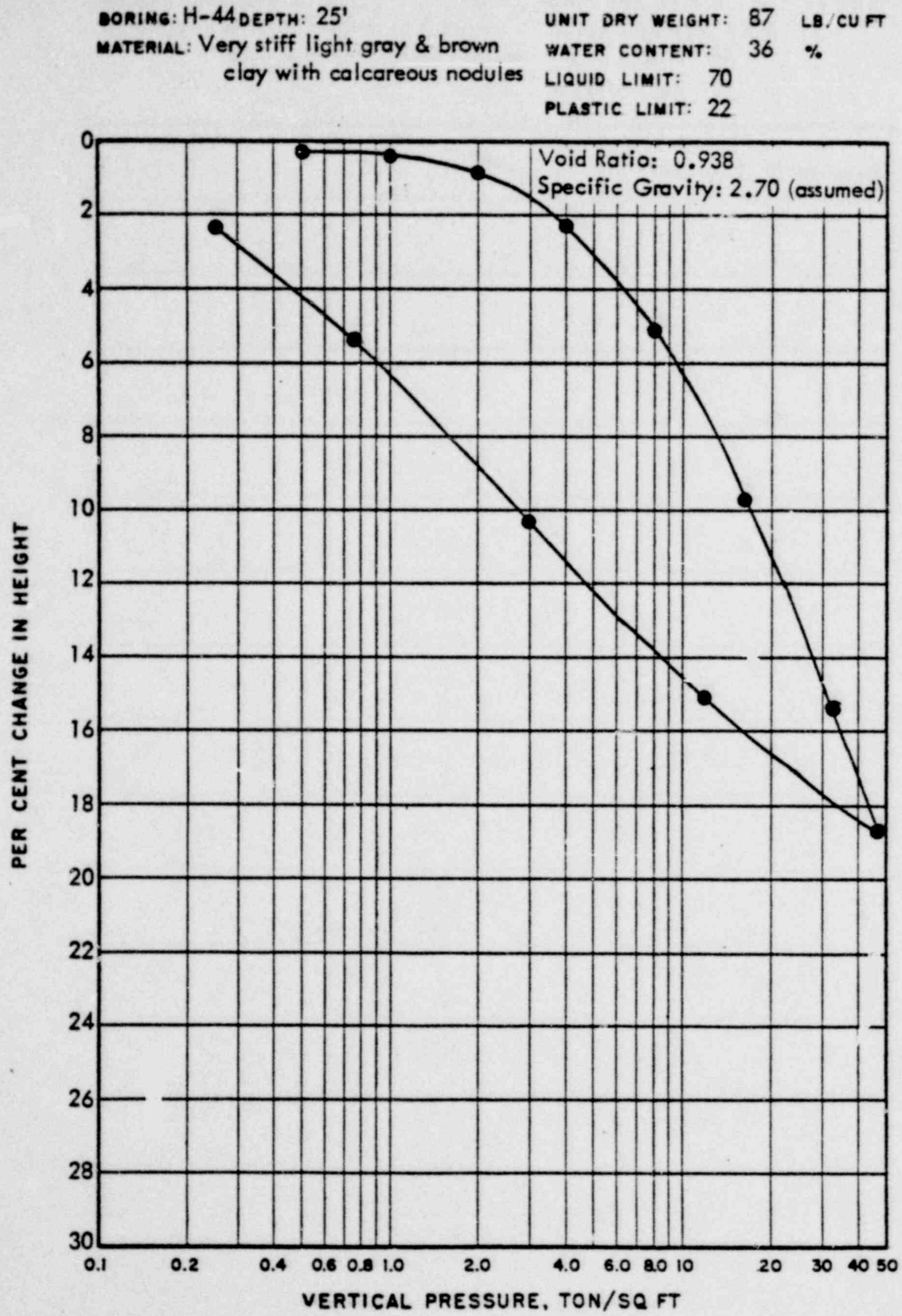
BORING: H-43A DEPTH: 1.5'
MATERIAL: Very stiff brown silty clay

UNIT DRY WEIGHT: 108 LB/CU FT
WATER CONTENT: 13 %
LIQUID LIMIT: 36
PLASTIC LIMIT: 14



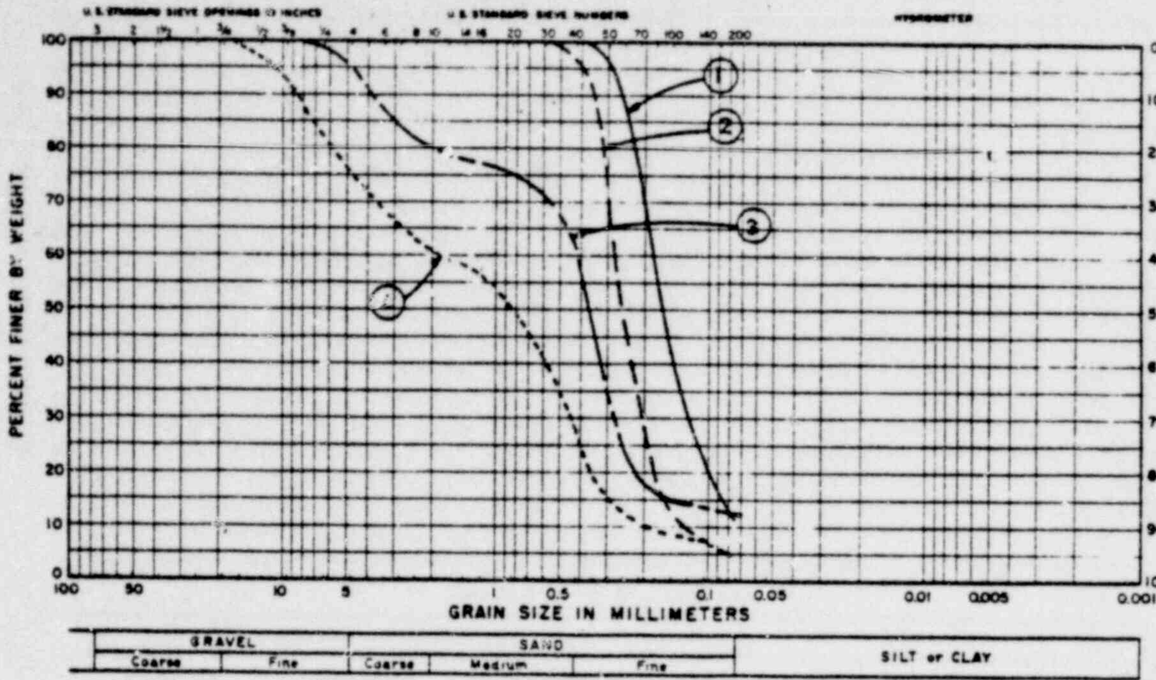
CONSOLIDATION TEST RESULTS

FIG NO. M29



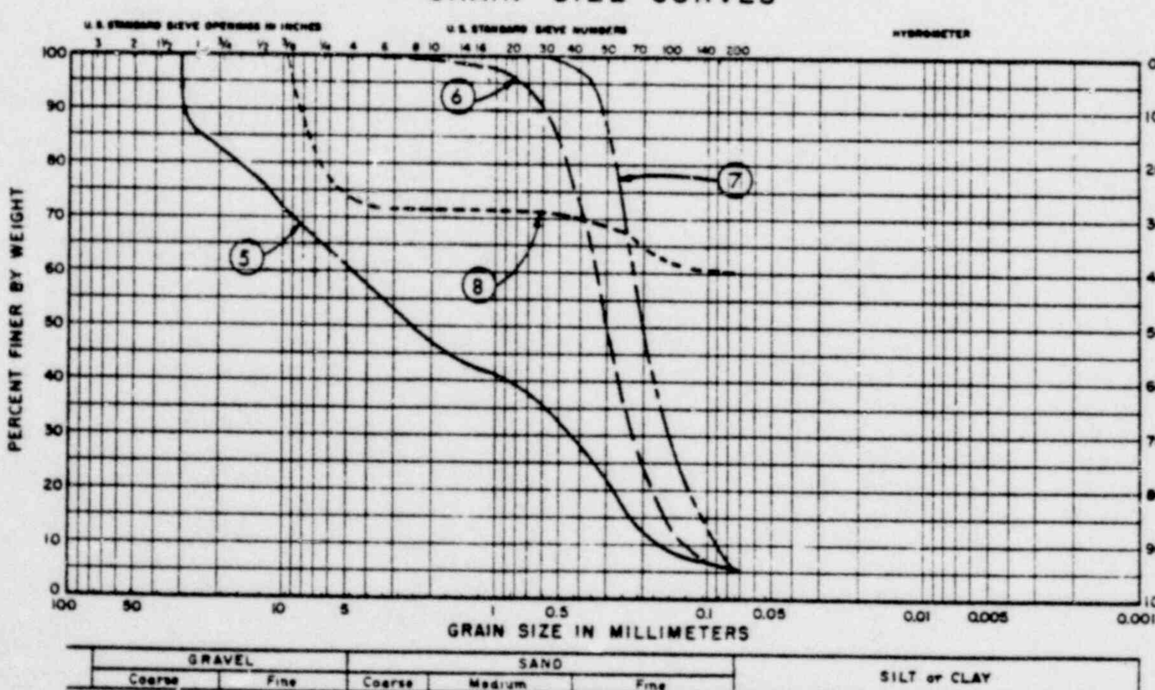
CONSOLIDATION TEST RESULTS

GRAIN SIZE CURVES



Curve No.	Boring No.	Penetration, Ft	Material
1	H-42	11.5	Tan fine sand
2	H-42	15.5	Tan fine sand
3	H-42	34.5	Tan coarse to fine sand with gravel
4	H-42	39.5	Tan coarse to fine sand with gravel

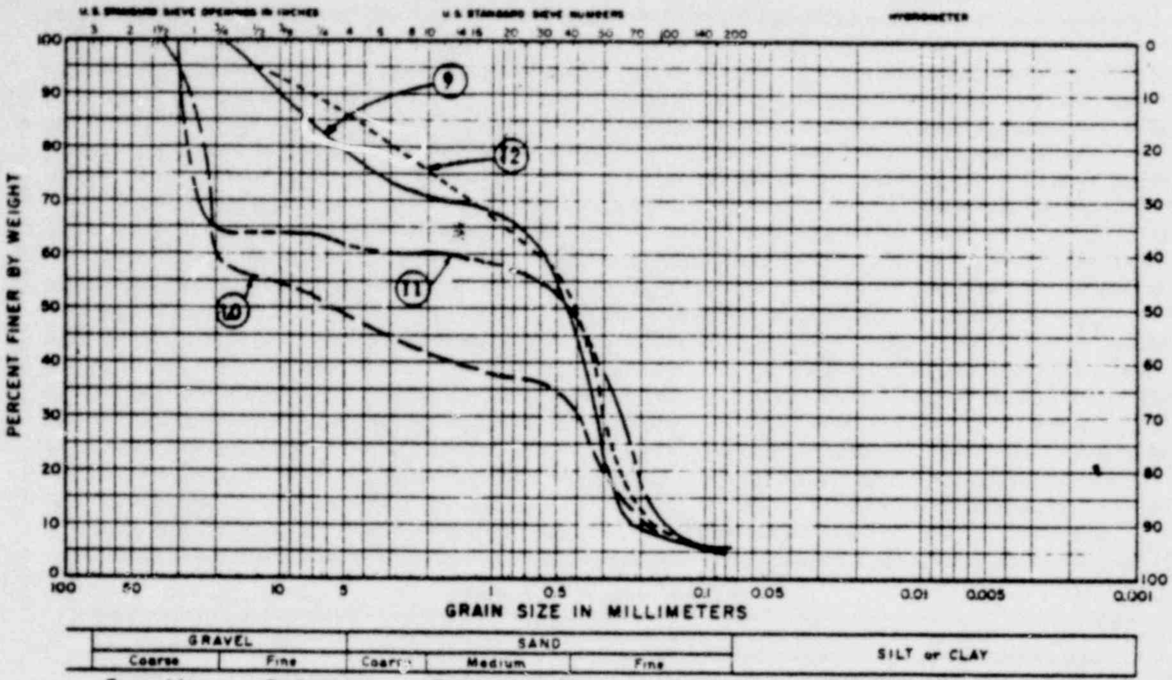
GRAIN SIZE CURVES



Curve No.	Boring No.	Penetration, Ft	Material
5	H-42	59.0	Tan gravelly coarse to fine sand
6	H-42	79.0	Tan medium to fine sand
7	H-42A	12.0	Tan fine sand
8	H-43	25.0	Red coarse to fine sand with gravel & clay layers

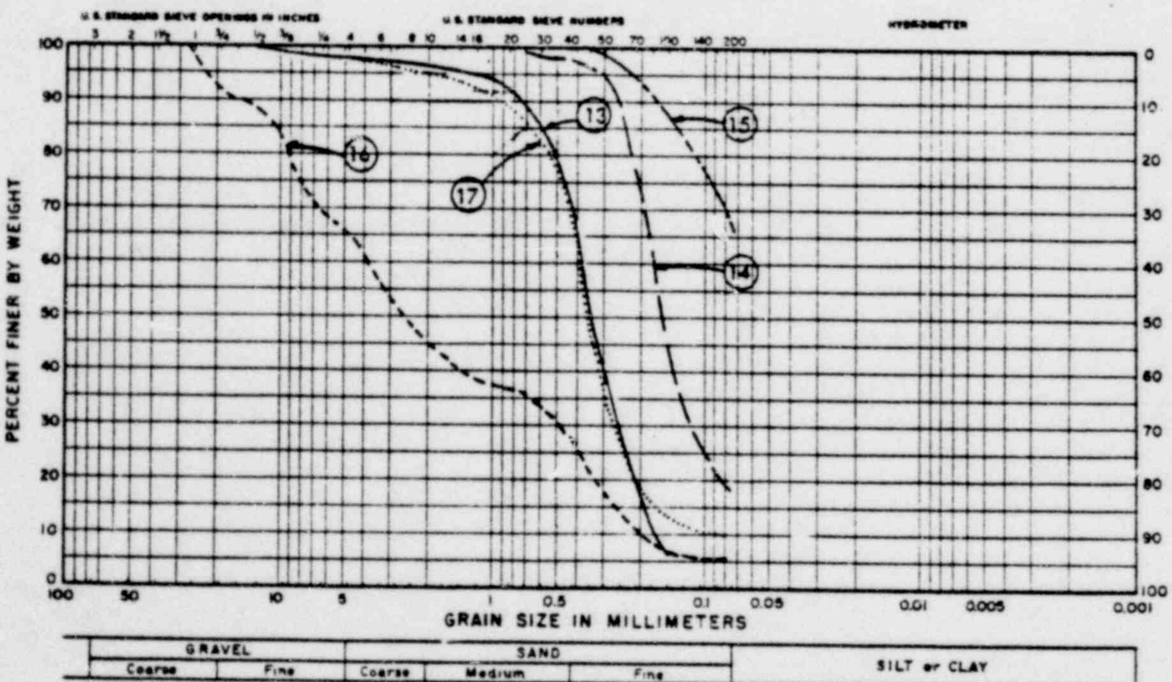
FIG NO. M31

GRAIN SIZE CURVES



Curve No.	Boring No.	Penetration, Ft	Material
9	H-43	39.5	Light gray coarse to fine sand with gravel
10	H-43	54.0	Light gray & tan coarse ro fine sand with gravel
11	H-43	69.0	Light gray coarse to fine sand with gravel
12	H-44	54.5	Tan coarse to fine sand with gravel

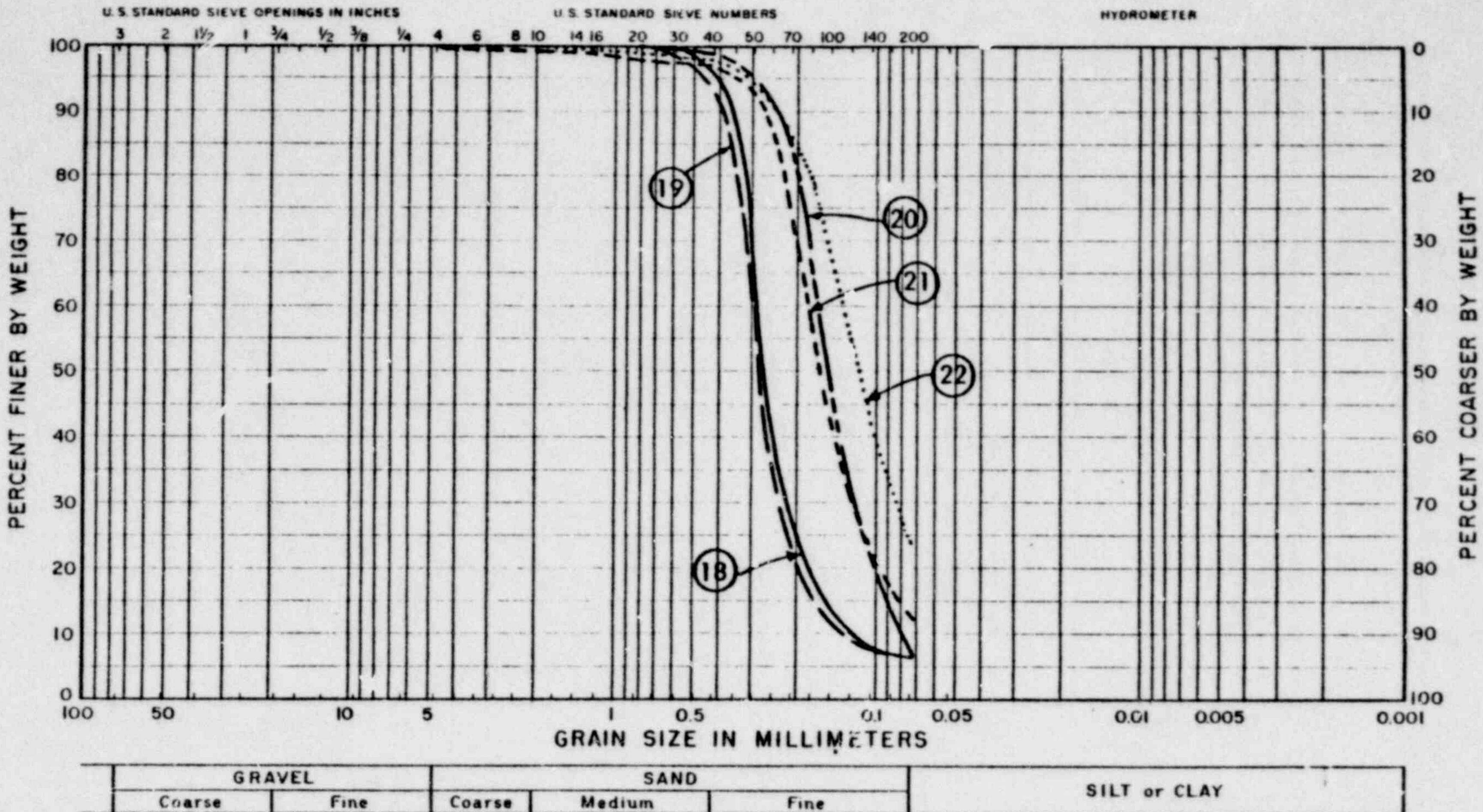
GRAIN SIZE CURVES



Curve No.	Boring No.	Penetration, Ft	Material
13	H-44	69.0	Tan & light gray medium to fine sand
14	H-44A	4-6	Gray clayey fine sand
15	H-44A	6-8	Light brown clayey sand
16	H-45	49.5	Tan coarse to fine sand with gravel
17	H-45	64.5	Brown coarse to fine sand

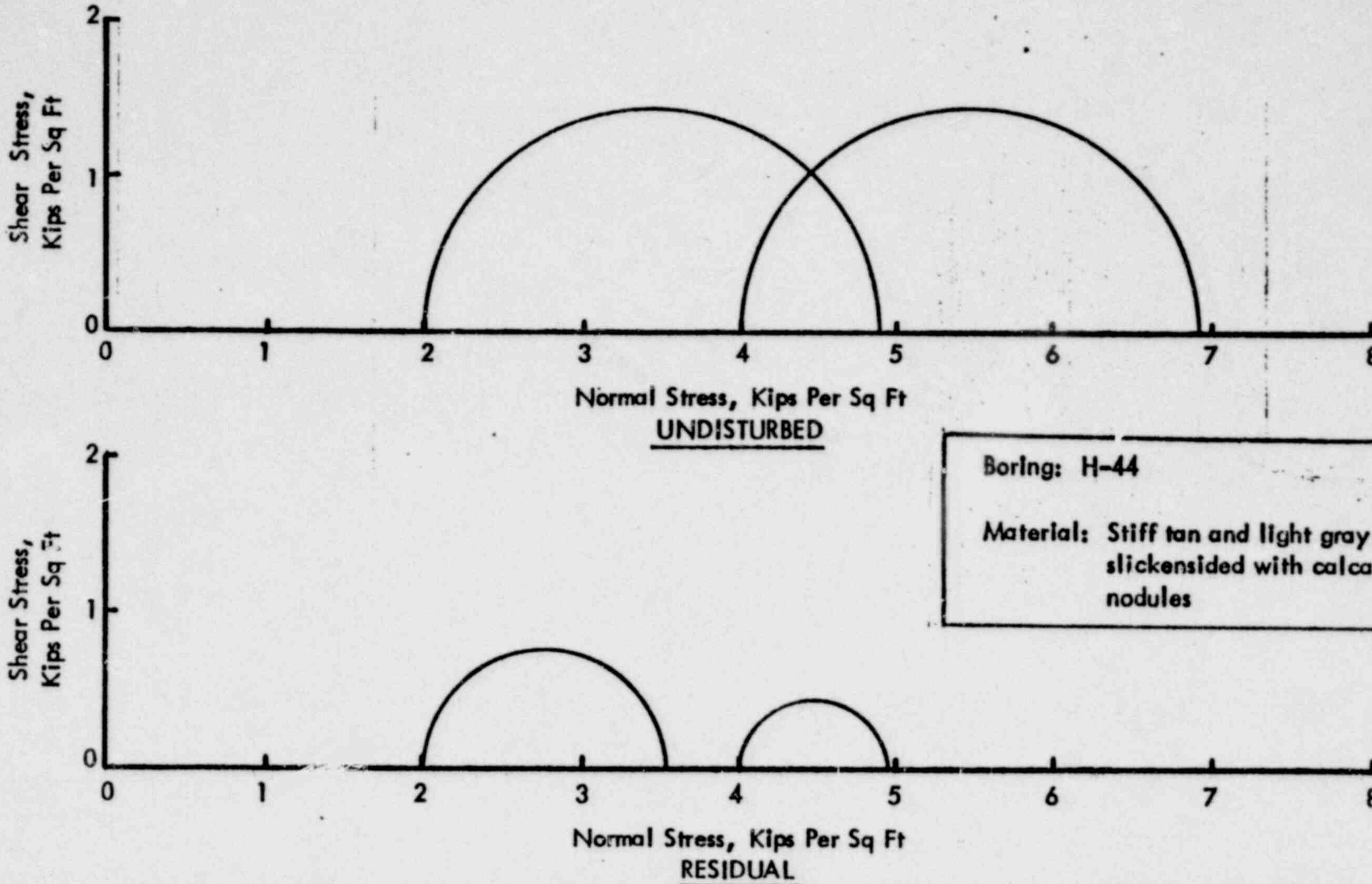
FIG NO. M32

GRAIN SIZE CURVES



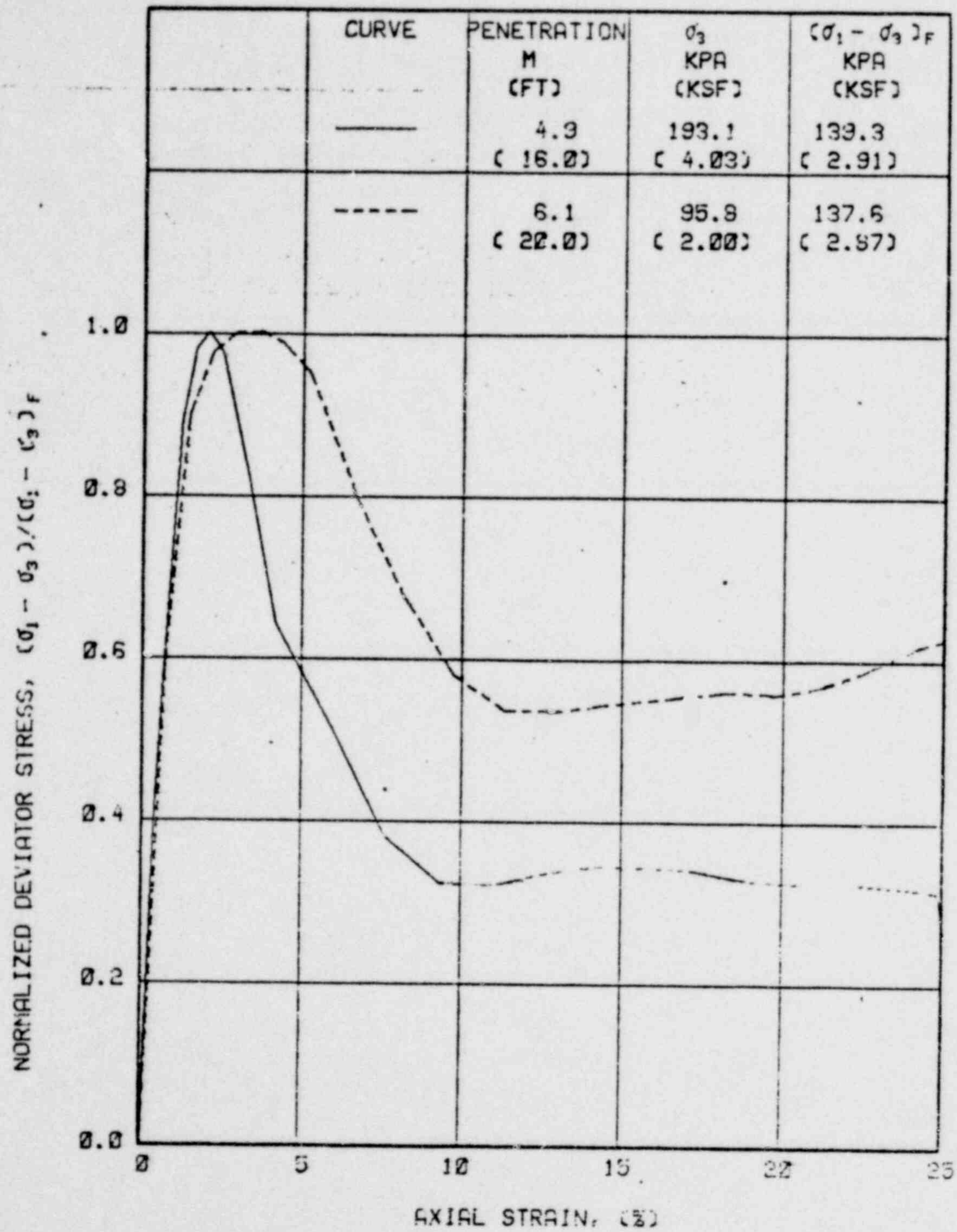
Curve No.	Test Pit No.	Penetration, Ft	Material
18	6	5	Brown fine sand
19	6	10	Brown fine sand
20	7	5	Brown fine sand
21	8	5	Light brown fine sand
22	9	5	Brown silty fine sand

FIG NO. M33



UNCONSOLIDATED-UNDRAINED TRIAXIAL COMPRESSION TEST RESULTS

FIG NO. M34



UNCONSOLIDATED-UNDRAINED TRIAXIAL COMPRESSION TEST
Stress-Strain Curves

FIG NO. 35 & 36