

H. Q. GOLDER & ASSOCIATES LTD.

SOIL AND FOUNDATION ENGINEERS

H. Q. GOLDER  
V. MILLIGAN  
L. G. SODERMAN  
J. L. SEYCHUK

3151 WHARTON WAY  
COOKSVILLE, ONTARIO  
625-0094  
AREA CODE 416

68-F-203C

W.P. 240-66

REPORT

TO

DEPARTMENT OF HIGHWAYS, ONTARIO

ON

FINAL FOUNDATION INVESTIGATION

ADDENDUM C

DIRECTIONAL SHEAR STRENGTH PROPERTIES OF

IRREGULARLY LAYERED SILTY CLAY STRATUM

PROPOSED CROSSING OF THE RE-ALIGNED WELLAND CANAL

MAIN STREET EAST TUNNEL

WELLAND

ONTARIO

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## ABSTRACT

The results of laboratory tests carried out to determine the directional undrained shear strength properties of an irregularly layered silty clay stratum which underlies the site of the proposed Main Street East tunnel crossing of the Re-aligned Welland Canal in Welland, Ontario are presented in this report. The report forms addendum "C" to the final foundation investigation report and should be read in conjunction with Volume I of the report.

The stratum previously described as irregularly layered silty clay has a generally massive or homogeneous texture and is distinctly but irregularly layered only in the lower few feet. We recommend that for both the massive and layered portion of the stratum an average undrained shear strength value of 1,000 lb/sq.ft. be used in design.

INTRODUCTION

The results of laboratory tests carried out to determine the directional undrained shear strength properties of an irregularly layered silty clay stratum which underlies the site of the proposed Main Street East tunnel crossing of the Re-aligned Welland Canal in Welland, Ontario are presented in this report. The report forms addendum "C" to the final foundation investigation report and should be read in conjunction with Volume I of the final report.

As discussed in Volume I of the final report, the site is underlain at a depth of about 50 to 90 feet by a discontinuous stratum of irregularly layered silty clay. The measured undrained shear strength of the silty clay varied generally between 1,000 and 2,000 lb/sq.ft. The undrained shear strength measured in situ by means of a field vane was greater than strengths measured during triaxial compression tests on relatively undisturbed samples in the laboratory.

Some concern has been expressed that the irregularly layered silty clay stratum was anisotropically consolidated and hence the undrained shear strength measured along a horizontal plane is less than the undrained shear strength measured along an inclined or vertical plane. Should failure of the side slopes of the excavations proposed at the site occur, the failure surface

would be relatively horizontal within the irregularly layered silty clay stratum. Thus, to ensure overall stability, the cut slopes should be designed taking into consideration the undrained shear strength of the silty clay stratum measured along horizontal or near horizontal planes.

The undrained shear strength of axially loaded triaxial compression test specimens inclined at various angles to the horizontal was measured to determine if the irregularly layered silty clay stratum exhibited directional shear strength characteristics and to confirm the shear strength previously used in design of the proposed cut slopes.

#### SAMPLING PROCEDURE

Five inch nominal diameter samples of the irregularly layered silty clay stratum were obtained in the 6 inch and 8 inch diameter borings put down at the site for the installation of rebound gauges R.G.2, R.G.3, and R.G.4 (See Addendum "B" to final foundation report "Installation of Rebound Gauges"). The locations of the sampled rebound gauge borings are shown on Figure C-1 together with the locations of adjacent sampled borings previously put down at the site.

Where possible, continuous sampling was carried out within the irregularly layered silty clay stratum. No sampling was attempted in any other soil strata.

The sampler consisted of a 2 ft. long, 4-7/8 in. ID, by 3/16 in. wall seamless steel tube with a sharpened cutting edge. The sampler had an area ratio of 16 per cent. Each sample was advanced in one continuous movement using the mechanical winch on the drillrig. This was accomplished by passing the winch cable under a pulley at the bottom of the rig and then attaching the cable to the top of the sampling rods.

Initially the inside of the sampling tubes were lubricated with petroleum jelly to reduce sample disturbance. This however, resulted in the loss of several of the initial samples during withdrawal of the sampler from the boring (R.G.2) and therefore the remaining tubes were cleaned but not lubricated.

#### LABORATORY TESTING PROCEDURE

When the samples arrived in the laboratory each tube was cut longitudinally and a slice was removed from each sample. A portion of each slice was dried and saved to provide a continuous visual record of the soil profile in each sampling tube. The remainder of the slice was used to determine an in situ water content profile for each sample and, if applicable, liquid and plastic limits or gradation characteristics of a portion of the sample.

When each sample had been classified representative

samples were selected for detailed strength testing. Two to four additional longitudinal cuts were made in each of these tubes and the tubes removed in sections from the samples. The exposed 5 in. diameter samples were cut in a pre-determined pattern and triaxial test specimens inclined to various angles to the horizontal were trimmed from the resulting blocks.

The triaxial samples were trimmed such that the axis of the sample (ie. the plane in which the sample was loaded) was either horizontal, vertical or inclined at an angle of  $30^{\circ}$ ,  $45^{\circ}$  or  $60^{\circ}$  to the horizontal.

Initially 4 in. long by 2 in. diameter triaxial samples were trimmed from the 5 in. diameter tube samples. However, it was found that the number of this size of sample which could be obtained from a given tube was insufficient for a complete series of tests and therefore 3 in. long by 1-1/2 in. diameter samples were used.

The detailed stratigraphy within the sampled zone at each of rebound gauge borings R.G.2, R.G.3 and R.G.4 is shown on the Record of Sampling sheets following the text of this report. The undrained shear strength results for each of the 5 in. diameter tube samples tested are summarized on Figures C-5 to C-15, inclusive. The results of all triaxial compression tests

carried out on samples of the massive and layered portions of the silty clay stratum are summarized on Figures C-16 and C-17, respectively. A modified soil stratigraphy section on which the massive and irregularly layered portions of the silty clay stratum are indicated is shown on Figure C-1.

#### SAMPLE DISTURBANCE

Cross-sections cut from samples of the horizontally or near horizontally layered portion of the silty clay stratum showed some distortion of the layers extended for a distance of about 1/4 in. to 3/8 in. from the outside of the samples. Within the 4-1/2 in. diameter core from which the triaxial samples were cut no distortion of the layers was observed and the samples appeared to be relatively undisturbed. Some minor unavoidable disturbance due to a release of in situ stresses or pressures must however be assumed. Thus, although the laboratory test results closely approximate the in situ undrained shear strength of the material, the results probably slightly underestimate the in situ strength.

#### STRATIGRAPHY

As shown on the Record of Sampling sheets and on the stratigraphy section (Figure C-1) the stratum previously referred to as an irregularly layered silty clay (Volume I of the final



foundation investigation report) exhibits distinct but irregular layering only in the lower few feet of the deposit. In general, the deposit consists of massive or homogeneous silty clay to clayey silt containing a trace to some sand and gravel with occasional cobbles or boulders. Gradation envelopes for both the massive and layered portion of the stratum are given on Figure C-2.

#### Massive Silty Clay to Clayey Silt

As shown on the Plasticity Chart (Figure C-3) the massive silty clay to clayey silt portion of the deposit may be classified as a glacial clay of low to medium plasticity. The in situ water content of the deposit varies between about 20 and 25 per cent but is apparently constant with depth. The in situ water content is about 5 per cent to 10 per cent greater than the plastic limit.

The total unit weight of the homogeneous portion of the stratum varies between about 123 lb/cu.ft. and 136 lb/cu.ft. with an average value of about 129 lb/cu.ft.

#### Irregularly Layered Silty Clay

The irregularly layered portion of the deposit consists generally of layers of red-brown, grey-brown and grey silty clay but some silt seams and partings occur throughout the layered zone. The silty clay layers vary in thickness from about 1/4 in.

to about 5 in.

As shown on the Plasticity Chart (Figure C-4) the silty clay is of medium to high plasticity and, although the liquid limit of the clay is variable there appears to be little correlation between colour and liquid limit (ie. grey-brown layers are not consistently more plastic than red-brown layers etc). The in situ water content varies between layers and ranges between about 30 per cent and 50 per cent. The in situ water content of the inter-bedded silt seams is about 20 per cent to 30 per cent.

The total unit weight of the irregularly layered portion of the stratum varies between about 109 lb/cu.ft. and 122 lb/cu.ft. with an average value of about 116 lb/cu.ft.

#### UNDRAINED SHEAR STRENGTH OF SILTY CLAY STRATUM

The results of undrained triaxial compression tests carried out on vertical, horizontal and inclined samples trimmed from each of the 5 in. diameter thin walled tube samples tested are presented on Figures C-5 to C-15, inclusive. The directional shear strength characteristics of the massive and the layered portion of the silty clay stratum are summarized on Figures C-16 and C-17, respectively.

#### Massive Silty Clay to Clayey Silt

As shown on Figure C-16 the undrained shear strength

is slightly less for samples tested in a vertical direction than it is for samples loaded in a horizontal direction. For samples loaded horizontally or at an angle of inclination of as much as  $30^{\circ}$  to the horizontal the average undrained shear strength is about 1,400 lb/sq.ft. For samples inclined at an angle of  $60^{\circ}$  to the horizontal or greater the average undrained shear strength is about 1,200 lb/sq.ft. About 15 per cent of the undrained shear strength test results are less than 1,000 lb/sq.ft. with the lowest measured value being about 800 lb/sq.ft.

#### Irregularly Layered Silty Clay

As shown on Figure C-17 the layered portion of the silty clay stratum exhibits definite directional shear strength characteristics. Although the average undrained shear strength of samples trimmed and loaded in a vertical plane is slightly less than the strength of samples tested in a horizontal direction the lowest average undrained shear strength occurs for samples trimmed and tested at an angle of inclination of between  $30^{\circ}$  and  $60^{\circ}$  to the horizontal. As the samples generally failed along a plane inclined at about  $45^{\circ}$  to the axis of loading, the failure plane of samples trimmed and tested at an angle between about  $30^{\circ}$  and  $60^{\circ}$  to the horizontal was parallel to the bedding plane of the layered material. Based on the measured values, the average undrained shear strength of the layered portion of the

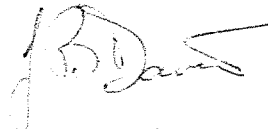
silty clay stratum is about 1,100 lb/sq.ft. when failure is induced along a single horizontal layer. If failure is induced across several layers, the average undrained shear strength is greater than 1,100 lb/sq.ft.

About 20 per cent of the measured undrained shear strengths were less than 1,000 lb/sq.ft. about 7 per cent of the strengths (4 test results) were less than 800 lb/sq.ft. Three of the four lowest values occurred within a single relatively thick reddish-brown silty clay layer encountered near the upper surface of the layered portion of the stratum in the boring for rebound gauge number 2 (R.G.2, sample 15). Thus it appears that occasional small local discontinuous pockets of softer material occur within the generally stiff layered portion of the silty clay stratum.

#### CONCLUSIONS AND RECOMMENDATIONS

Based on the detailed laboratory testing carried out on horizontal, vertical and inclined samples from the silty clay stratum it is concluded that the stratum consists generally of stiff massive silty clay to clayey silt and is distinctively but irregularly layered only in the lower few feet. The consistency of the lower layered zone is generally stiff but occasional small discontinuous pockets of firm material occur within the zone.

We recommend that for both the massive and irregularly layered portions of the silty clay stratum an average undrained shear strength of 1,000 lb/sq.ft. be used in the analysis of the overall stability of the slopes proposed at the site. We further recommend that for design of the cut slopes a factor of safety of 1.3 against overall instability be used in conjunction with the average undrained shear strength value.



J. B. Davis, P. Eng.



V. Milligan, P. Eng.

JBD:jg  
67106  
November 26, 1968

## LIST OF ABBREVIATIONS

The abbreviations commonly employed on each "Record of Borehole," on the figures and in the text of the report, are as follows:

### I. SAMPLE TYPES

<i>AS</i>	auger sample
<i>CS</i>	chunk sample
<i>DO</i>	drive open
<i>DS</i>	Denison type sample
<i>FS</i>	foil sample
<i>RC</i>	rock core
<i>ST</i>	slotted tube
<i>TO</i>	thin-walled, open
<i>TP</i>	thin-walled, piston
<i>WS</i>	wash sample

### II. PENETRATION RESISTANCES

Dynamic Penetration Resistance: The number of blows by a 140-pound hammer dropped 30 inches required to drive a 2-inch diameter, 60 degree cone one foot, where the cone is attached to 'A' size drill rods and casing is not used.

Standard Penetration Resistance, *N*: The number of blows by a 140-pound hammer dropped 30 inches required to drive a 2-inch drive open sampler one foot.

<i>WH</i>	sampler advanced by static weight—weight, hammer
<i>PH</i>	sampler advanced by pressure—pressure, hydraulic
<i>PM</i>	sampler advanced by pressure—pressure, manual

### III. SOIL DESCRIPTION

#### (a) Cohesionless Soils

<i>Relative Density</i>	<i>N, blows/ft.</i>
Very loose	0 to 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very dense	over 50

#### (b) Cohesive Soils

<i>Consistency</i>	<i>c<sub>u</sub>, lb./sq. ft.</i>
Very soft	Less than 250
Soft	250 to 500
Firm	500 to 1,000
Stiff	1,000 to 2,000
Very stiff	2,000 to 4,000
Hard	over 4,000

### IV. SOIL TESTS

<i>C</i>	consolidation test
<i>H</i>	hydrometer analysis
<i>M</i>	sieve analysis
<i>MH</i>	combined analysis, sieve and hydrometer <sup>1</sup>
<i>Q</i>	undrained triaxial <sup>2</sup>
<i>R</i>	consolidated undrained triaxial <sup>2</sup>
<i>S</i>	drained triaxial
<i>U</i>	unconfined compression
<i>V</i>	field vane test

### NOTES:

<sup>1</sup>Combined analyses when 5 to 95 per cent of the material passes the No. 200 sieve.

<sup>2</sup>Undrained triaxial tests in which pore pressures are measured are shown as  $\bar{Q}$  or  $\bar{R}$ .

## LIST OF SYMBOLS

### I. GENERAL

$\pi$	= 3.1416
$e$	= base of natural logarithms 2.7183
$\log_e a$ or $\ln a$	natural logarithm of $a$
$\log_{10} a$ or $\log a$	logarithm of $a$ to base 10
$t$	time
$g$	acceleration due to gravity
$V$	volume
$W$	weight
$M$	moment
$F$	factor of safety

### II. STRESS AND STRAIN

$u$	pore pressure
$\sigma$	normal stress
$\sigma'$	normal effective stress ( $\bar{\sigma}$ is also used)
$\tau$	shear stress
$\epsilon$	linear strain
$\epsilon_{xy}$	shear strain
$\nu$	Poisson's ratio ( $\mu$ is also used)
$E$	modulus of linear deformation (Young's modulus)
$G$	modulus of shear deformation
$K$	modulus of compressibility
$\eta$	coefficient of viscosity

### III. SOIL PROPERTIES

#### (a) Unit weight

$\gamma$	unit weight of soil (bulk density)
$\gamma_s$	unit weight of solid particles
$\gamma_w$	unit weight of water
$\gamma_d$	unit dry weight of soil (dry density)
$\gamma'$	unit weight of submerged soil
$G_s$	specific gravity of solid particles $G_s = \gamma_s / \gamma_w$
$e$	void ratio
$n$	porosity
$w$	water content
$S_r$	degree of saturation

#### (b) Consistency

$w_L$	liquid limit
$w_P$	plastic limit
$I_P$	plasticity index
$w_s$	shrinkage limit
$I_L$	liquidity index = $(w - w_P) / I_P$
$I_C$	consistency index = $(w_L - w) / I_P$
$e_{\max}$	void ratio in loosest state
$e_{\min}$	void ratio in densest state
$D_r$	relative density = $(e_{\max} - e) / (e_{\max} - e_{\min})$

#### (c) Permeability

$h$	hydraulic head or potential
$q$	rate of discharge
$v$	velocity of flow
$i$	hydraulic gradient
$k$	coefficient of permeability
$j$	seepage force per unit volume

#### (d) Consolidation (one-dimensional)

$m_v$	coefficient of volume change = $-\Delta e / (1+e) \Delta \sigma'$
$C_c$	compression index = $-\Delta e / \Delta \log_{10} \sigma'$
$c_c$	coefficient of consolidation
$T_v$	time factor = $c_v t / d^2$ ( $d$ , drainage path)
$U$	degree of consolidation

#### (e) Shear strength

$\tau_f$	shear strength
$c'$	effective cohesion
$\phi'$	effective angle of shearing resistance, or friction
$c_u$	apparent cohesion*
$\phi_u$	apparent angle of shearing resistance, or friction
$\mu$	coefficient of friction
$S_i$	sensitivity

$\left. \begin{array}{l} \text{in terms of effective stress} \\ \tau_f = c' + \sigma' \tan \phi' \end{array} \right\}$

$\left. \begin{array}{l} \text{in terms of total stress} \\ \tau_f = c_u + \sigma \tan \phi_u \end{array} \right\}$

\*For the case of a saturated cohesive soil,  $\phi_u = 0$  and the undrained shear strength  $\tau_f = c_u$  is taken as half the undrained compressive strength.

# RECORD OF SAMPLING BORING FOR REBOUND GAUGE No. 2

LOCATION, See Figure C-1

SAMPLING DATE, JULY 25 - 29, 1968

DATUM, Geodetic (1966)

BORING TYPE, CABLE - TOOL BORING SAMPLE DIAMETER, 5 INCH

GROUND SURFACE ELEVATION, 601.37

BOREHOLE DIAMETER, 6 INCH

GENERAL SOIL PROFILE			SAMPLE DETAILS			ELEVATION SCALE	WATER CONTENT, PERCENT	ADDITIONAL LAB. TESTING	
ELEV. DEPTH	DESCRIPTION	STRAIT PLUG ELEV. DEPTH	NUMBER	DESCRIPTION & NOTES	DETAILED STRAIT PLUG SECTION FOR CORRELATION WITH TESTED LINES				W <sub>p</sub>
555.77 48.28	START OF SAMPLING	555.77 48.28		START OF SAMPLING		555			
	FIRM TO STIFF RED-BROWN MASSIVE SILTY CLAY TO CLAYEY SILT WITH A TRACE TO SOME SAND AND GRAVEL		1	FIRM TO STIFF RED-BROWN MASSIVE SILTY CLAY TO CLAYEY SILT WITH A TRACE TO SOME SAND AND GRAVEL		552			
		551.47 49.32	2	SOFT RED-BROWN MASSIVE SILTY CLAY TO CLAYEY SILT WITH A TRACE TO SOME SAND AND GRAVEL		551			
549.80 51.57		549.80 51.57	3	STIFF RED-BROWN MASSIVE CLAYEY SILT TO SANDY SILT WITH A TRACE TO SOME SAND & GRAVEL BELOW		550			
		549.16 52.12		REFUSAL ON CORREL. AT ELEV. N. 549.16		549			
		548.67 52.63	4	COMPACT RED-BROWN SILT TO SANDY SILT WITH SAND CLAY AND GRAVEL		548			
	COMPLEX MIXTURE OF STIFF RED-BROWN MASSIVE CLAYEY SILT WITH SOME SAND AND	547.5 52.80		REFUSAL ON CORREL. AT ELEV. N. 547.5		547			
	AND					546			
	COMPACT RED-BROWN SILT TO SANDY SILT WITH SOME CLAY, SOME GRAVEL AND OCCASIONAL BERGIES TO Boulders EMPLOYED					545			
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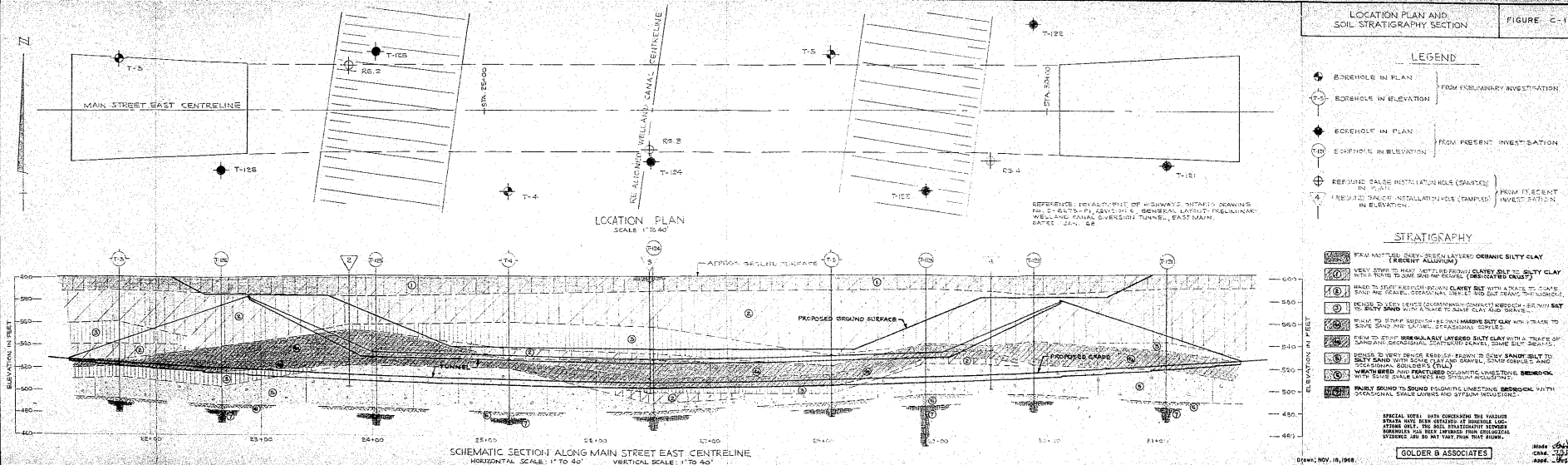


## GROUND SURFACE ELEVATION, 601.44

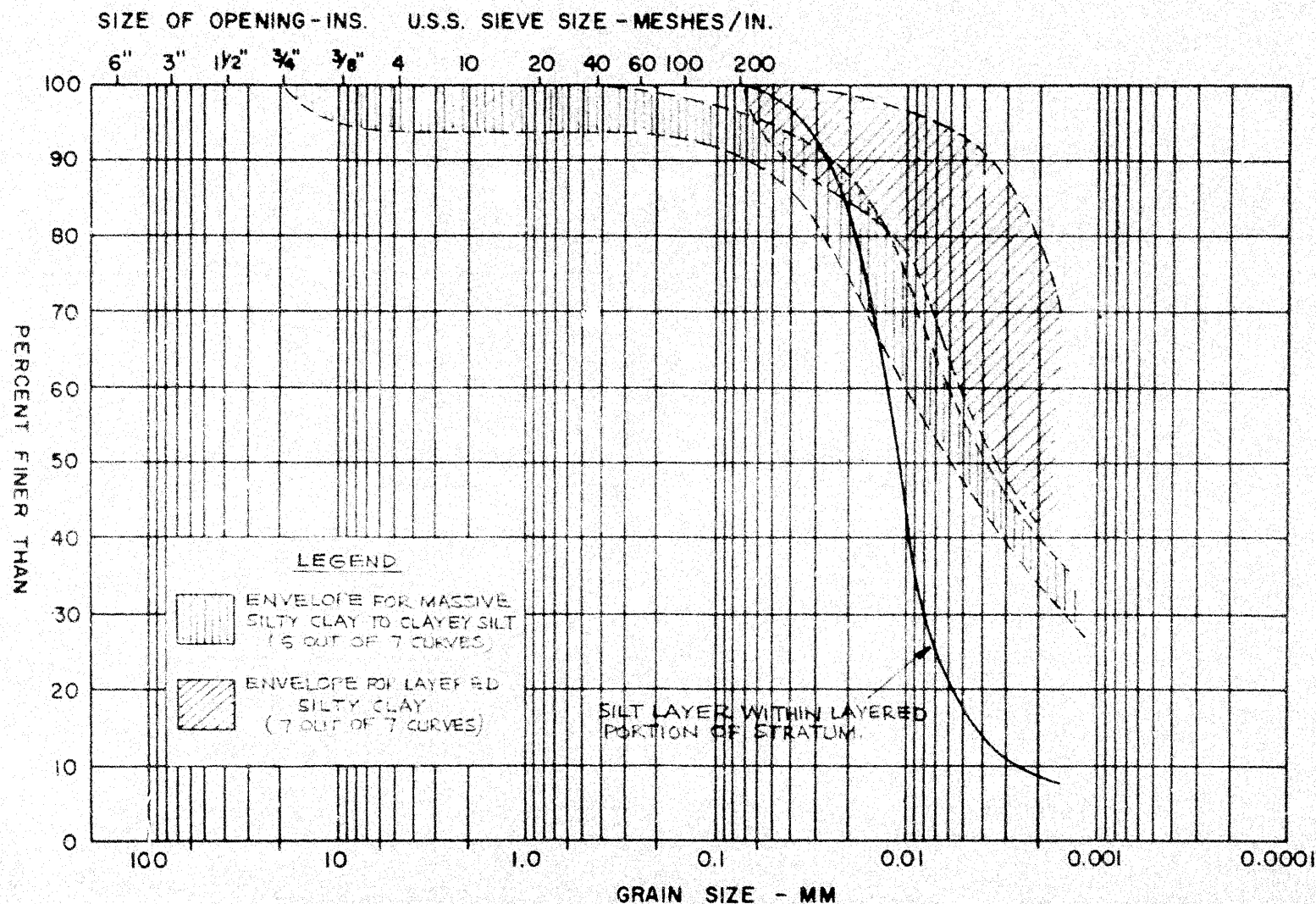
BOREHOLE DIAMETER, 6 INCH

DRAWN, M.W.  
CHECKED, JED





M.I.T. GRAIN SIZE SCALE



COBBLE SIZE	COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	SILT SIZE	CLAY SIZE
	GRAVEL SIZE			SAND SIZE			FINE GRAINED	

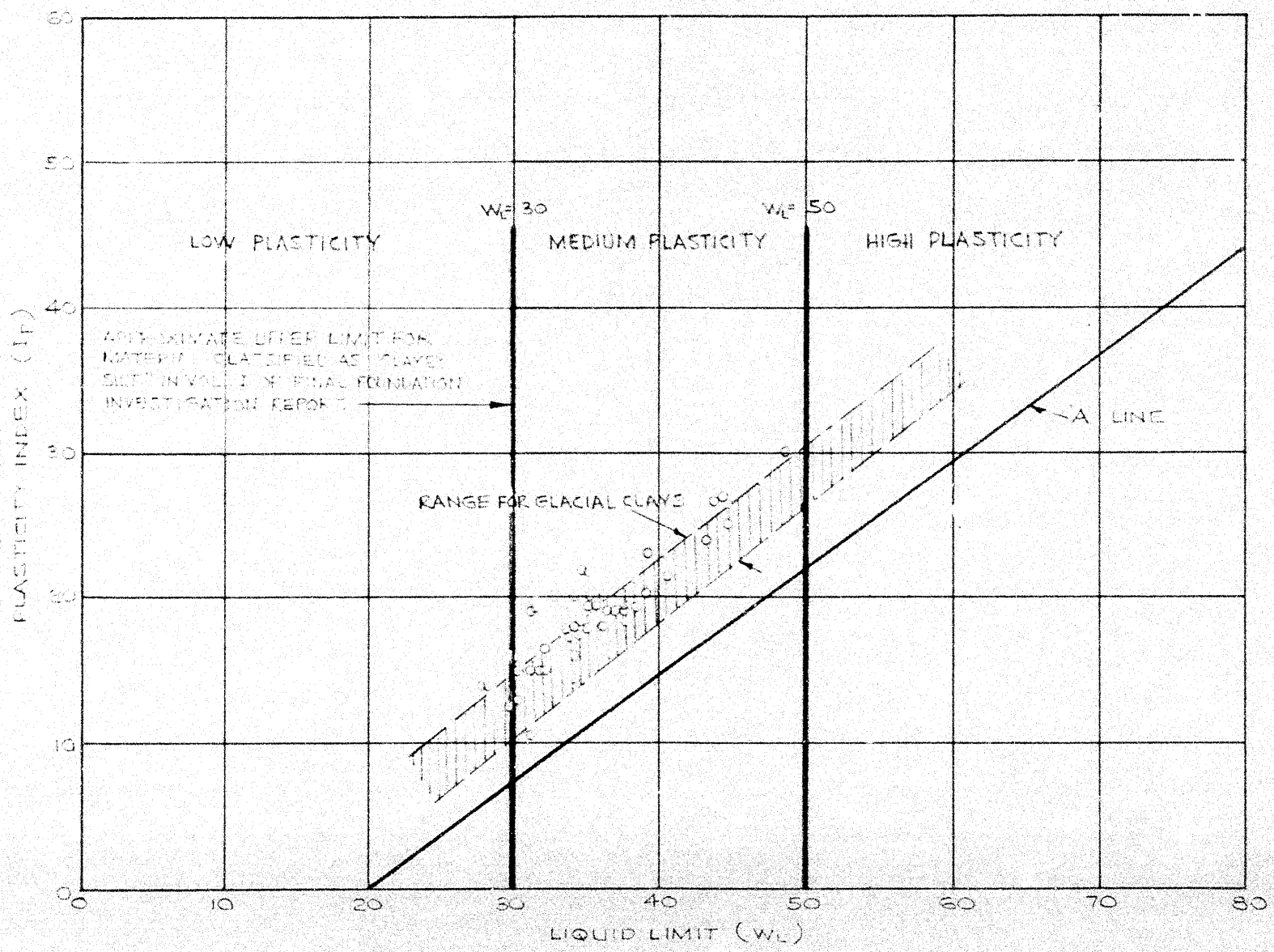
GOLDER & ASSOCIATES

GLACIATION ENVELOPES

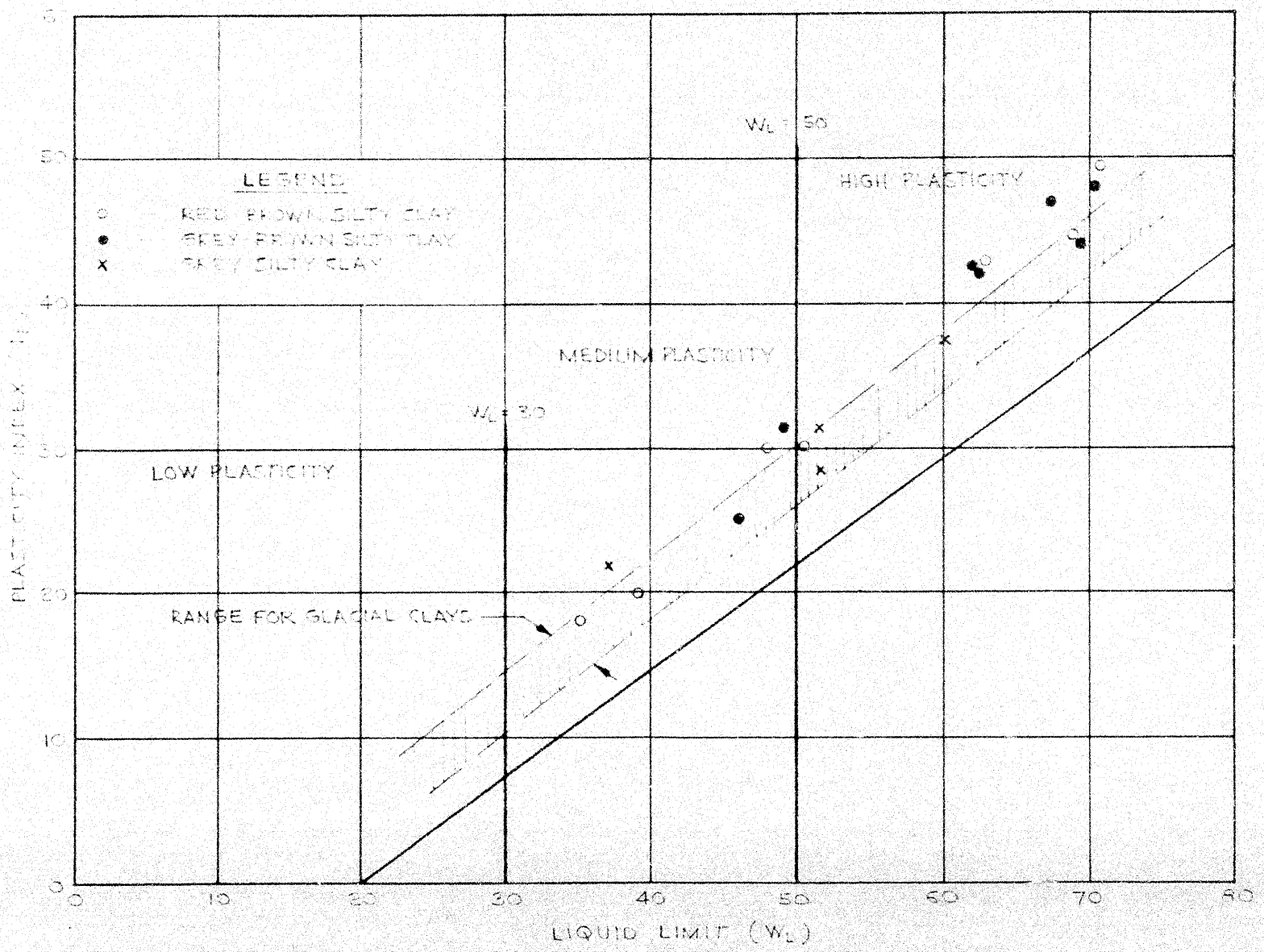
FIGURE C-2

PLASTICITY CHART  
MASSIVE SILTY CLAY TO CLAYEY SILT

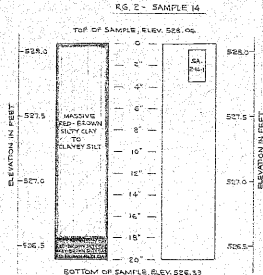
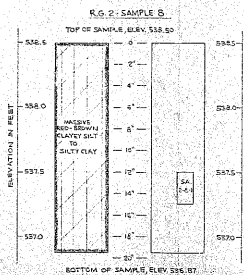
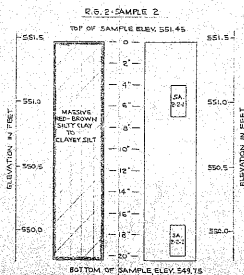
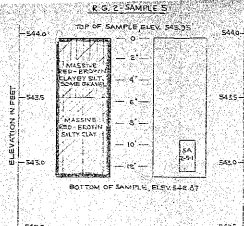
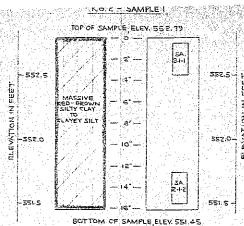
FIGURE C-3



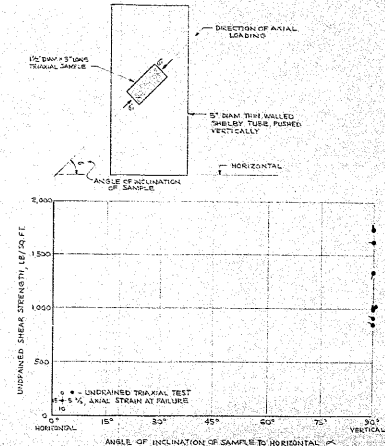
GOLDER & ASSOCIATES







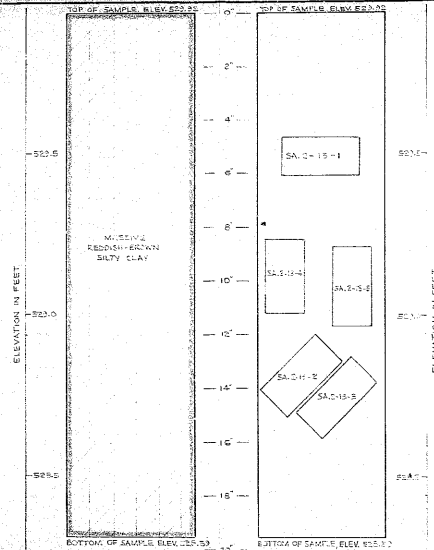
TRIAXIAL SAMPLE NUMBER	ANGLE OF SAMPLE TO HORIZONTAL PLANE	WATER CONTENT, PERCENT			UNDRAINED SHEAR STRENGTH (LB/SQ. FT.)	FAILURE STRAIN PERCENT	TOTAL UNIT WEIGHT (LB/CU FT.)
		PORTION OF SAMPLE (RELATIVE TO VERTICAL PLANE)	W %	PLASTIC LIQUID LIMIT			
2-1-1	90°	TOP	26	19	990	20	125
		AVERAGE	26	19			
2-1-2	90°	TOP	26	19	1,340	12	135
		AVERAGE	26	19			
2-2-1	90°	TOP	12	15	1,740	20	131
		AVERAGE	12	15			
2-2-2	90°	TOP	22	15	1,520	15	123
		AVERAGE	22	15			
2-5-1	90°	TOP	19	15	850	17	130
		AVERAGE	19	15			
2-8-1	90°	TOP	22	14	910	17	130
		AVERAGE	22	14			
2-14-1	90°	TOP	14	15	1,080	14	151
		AVERAGE	14	15			







# DETAILED STRATIGRAPHY OF SAMPLE



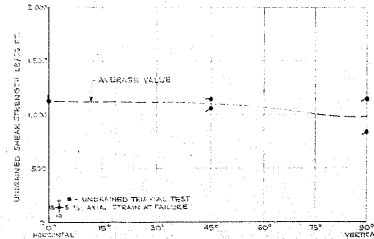
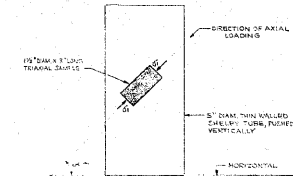
# LOCATION OF TRIAXIAL SAMPLES TRIMMED FROM 5" DIAM. THIN WALLED SHELL TUBE

TRIAXIAL SAMPLE NUMBER	ANGLE OF SAMPLE TO HORIZONTAL PLANE	WATER CONTENT, PERCENT				UNDRAINED SHEAR STRENGTH (PSF. TO 100%)	FAILURE STRAIN (PERCENT)	TOTAL UNIT WEIGHT (LB/FT <sup>3</sup> )
		POSITION OF SAMPLE (LATITUDE, LONGITUDE)	W. N.	FLUIDS	LIQUID			
2-15-1	0°	TOP	10	13	13	1120	24	126
2-15-2	45°	TOP	10	13	13	1140	15	120
2-15-3	45°	TOP	10	13	13	1120	14	120
2-15-4	90°	TOP	10	13	13	1150	15	127
2-15-5	135°	TOP	10	13	13	1150	15	128

DEFECTS IN NEGATIVE DUE TO CONDITION OF ORIGINAL DOCUMENT

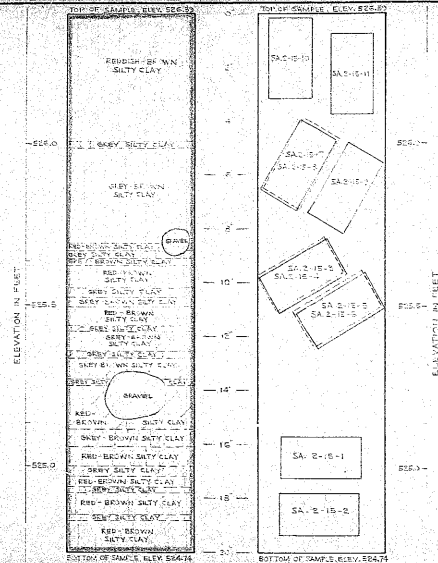
# RESULTS OF UNDRAINED SHEAR STRENGTH TESTS REBOUND GAUGE No. 2, SAMPLE No. 13

FIGURE 6-7



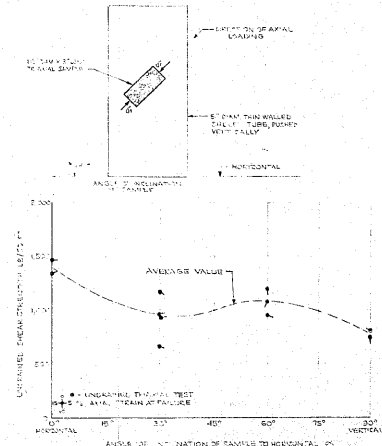
Drawn, OCT. 29, 1968. **GOLDER & ASSOCIATES**

MADE IN U.S.A.  
CHD. 100  
APP. 100



DEFECTS IN NEGATIVE DUE TO  
CONDITION OF ORIGINAL DOCUMENT

TEST NO. SAMPLE NUMBER	APPROX. DEPTH T. (FOOT)	TEST		RESULT		UNIT WEIGHT (LB./CU. FT.)	WATER CONTENT (%)	TEST TEMP. (DEG. F.)
		UNCONSOLIDATED SAND	PLASTIC LIMIT	UNCONSOLIDATED SAND	PLASTIC LIMIT			
2-15-1	0	RED-BROWN SILTY CLAY	40	21	48	1,470	5	115
		GRAY SILTY CLAY	37					
		RED-BROWN SILTY CLAY	45					
2-15-2	0	GRAY SILTY CLAY	45			1,350	4	112
		RED-BROWN SILTY CLAY	35					
2-15-3	30	GRAY SILTY CLAY	34			1,180	7	123
		RED-BROWN SILTY CLAY	32					
2-15-4	30	GRAY SILTY CLAY	34			1,200	5	111
		RED-BROWN SILTY CLAY	30					
2-15-5	30	GRAY SILTY CLAY	37			1,400	5	118
		RED-BROWN SILTY CLAY	35					
2-15-6	30	GRAY SILTY CLAY	36					
		RED-BROWN SILTY CLAY	30	22	51	1,270	5	114
		GRAY SILTY CLAY	37					
2-15-7	40	RED-BROWN SILTY CLAY	31					
		GRAY SILTY CLAY	30			1,250	7	116
		RED-BROWN SILTY CLAY	34					
2-15-8	50	GRAY SILTY CLAY	34			1,330	11	119
		RED-BROWN SILTY CLAY	31					
2-15-9	50	GRAY SILTY CLAY	30					
		RED-BROWN SILTY CLAY	40	21	67	1,300	10	115
		MIDDLE BOTTOM	38					
2-15-10	50	MIDDLE BOTTOM	36			800	15	119
		MIDDLE BOTTOM	37					
2-15-11	50	MIDDLE BOTTOM	37	21	55	740	10	113
		MIDDLE BOTTOM	38					



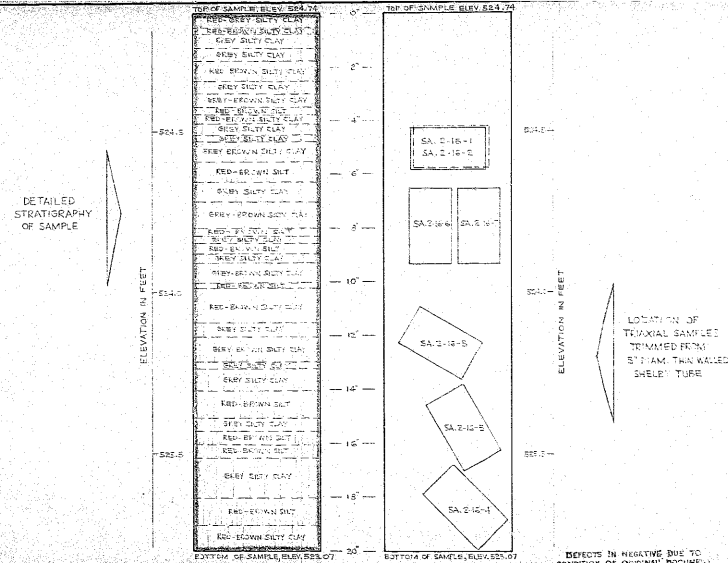
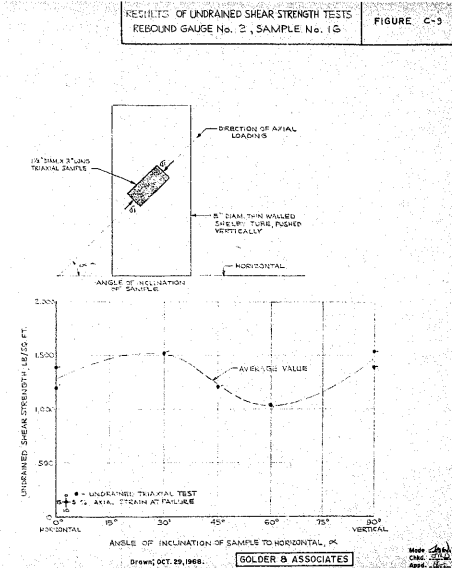
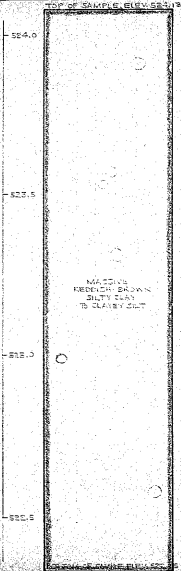


TABLE OF RESULTS							
TINIAIAL SAMPLE NUMBER	ANGLE OF SAMPLE TO HORIZONTAL PLANE	WATER CONTENT PERCENT			UNIFORMED SHEAR STRESS IN (LB / SQ FT)	FAILURE STRAIN PERCENT	TOTAL U WEIGHT (LB/CU)
		PERCENT OF SAMPLE (RELATIVE TO WATER)	W/%	PLASTIC LIMIT			
0-10-1	0°	SANDY SILTY CLAY	48				112
		SANDY SILTY CLAY	46				
		SANDY SILTY CLAY	46				
0-10-2	0°	SANDY SILTY CLAY	48			1,500	112
		SANDY SILTY CLAY	46				
0-10-3	20°	SANDY SILTY CLAY	48	18	50	1,510	101
		SANDY SILTY CLAY	46				
0-10-4	40°	SANDY SILTY CLAY	48	27	51	1,530	99
		SANDY SILTY CLAY	46				
0-10-5	60°	SANDY SILTY CLAY	48			1,540	97
		SANDY SILTY CLAY	46				
0-10-6	80°	SANDY SILTY CLAY	48			1,550	95
		SANDY SILTY CLAY	46				
0-10-7	90°	SANDY SILTY CLAY	48	46	46	1,560	93
		SANDY SILTY CLAY	46				
				</			



DETAILED STRATIGRAPHY OF SAMPLE

ELEVATION IN FEET

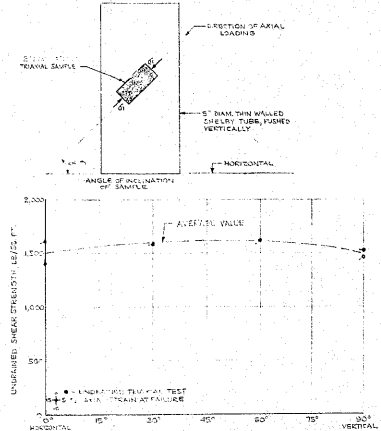


ELEVATION IN FEET

LOCATION OF TRIAXIAL SAMPLES TRIMMED FROM 5" DIAM. THIN WALLED SHELL TUBE

TRIAXIAL SAMPLE NUMBER	ANGLE OF SAMPLE TO HORIZONTAL PLANE	WATER CONTENT (%)		FLASTIC LIMIT	LIQUID LIMIT	UNCONSOLIDATED SHEAR STRENGTH (LB/IN <sup>2</sup> )	FACTOR OF SAFETY	TOTAL UNIT WEIGHT (LB/IN <sup>3</sup> )
		UNDRAINED	RECENT					
3-4-1	0°	21	21	17	25	1.40	1.1	12.1
3-4-2	0°	21	21	17	25	1.30	1.1	12.1
3-4-3	90°	21	21	17	25	1.30	1.1	12.1
3-4-4	91°	21	21	17	25	1.30	1.1	12.1
3-4-5	90°	21	21	17	25	1.30	1.1	12.1
3-4-6	90°	21	21	17	25	1.30	1.1	12.1

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DRAWN: OCT. 29, 1968.

GOLDER & ASSOCIATES

MOORE  
CHAS. H. D.  
APP. 10/27/68

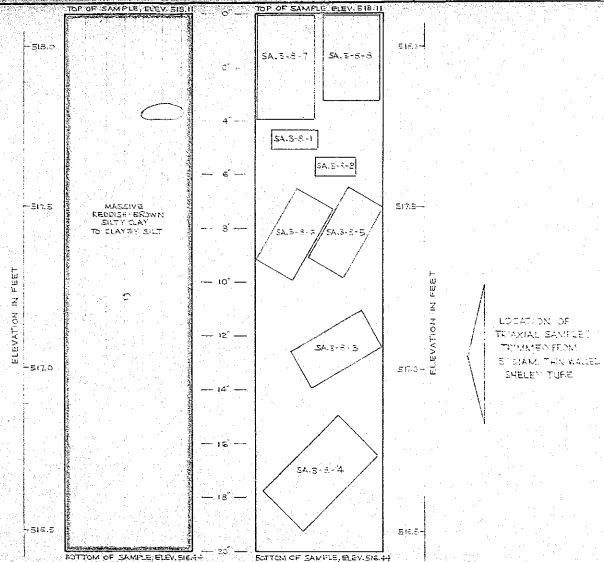
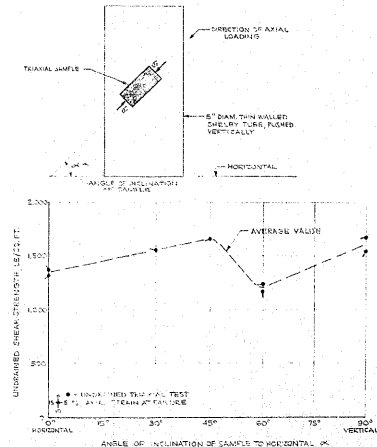


FIGURE C-11

THERMAL SAMPLE NUMBER	ANGLE OF SAMPLE TO HORIZONTAL PLANE	WATER CONTENT		PLASTICITY		UNIT WEIGHT (G/CC)	FALLING TENSILE STRENGTH	TOTAL TENSILE STRENGTH	TENSILE WORK (G/CC)
		PERCENT OF SAMPLE (RELATIVE TO WATER, RANGE)	W. %	PLASTIC LIMIT	LIQUID LIMIT				
S-1	0°	TOP	51	13	44	1.800	12	122	
		MIDDLE	52						
		TOP	52	15	37	1.870	13	123	
S-2	0°	BOTTOM	51	15	36	1.860	13	124	
		MIDDLE	52						
		TOP	52	13	41	1.880	13	124	
S-3	30°	BOTTOM	51	16	35	1.850	14	123	
		MIDDLE	52						
		TOP	52	16	35	1.850	14	123	
S-4	45°	BOTTOM	51	13	37	1.800	12	121	
		MIDDLE	52						
		TOP	52	13	41	1.880	13	124	
S-5	60°	BOTTOM	51	17	34	1.800	14	122	
		MIDDLE	52						
		TOP	52	17	34	1.800	14	122	
S-6	90°	BOTTOM	51	17	34	1.800	14	122	
		MIDDLE	52						
		TOP	52	17	34	1.800	14	122	



DEFECTS IN NEGATIVE DUE TO  
CONDITION OF ORIGINAL DOCUMENT

Drawn: OCT. 29, 1968

**GOLDER & ASSOCIATES**

Made   
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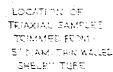
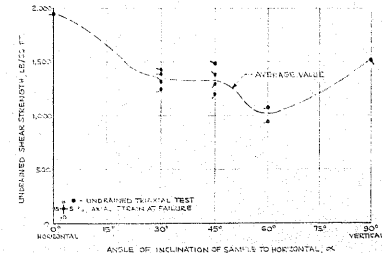
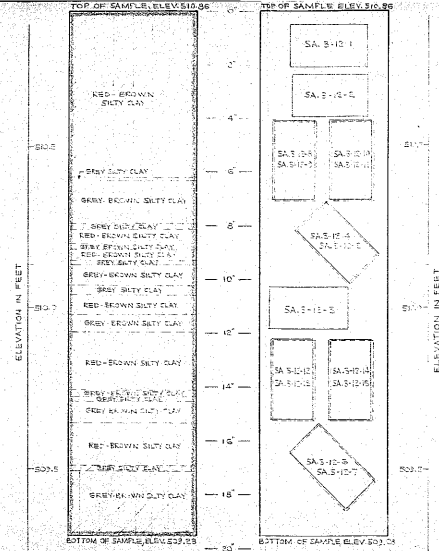


Diagram illustrating the setup for the axial loading test. A 1/8" diam x 3/8" triangular sample is shown at an angle of inclination. The direction of axial loading is indicated by an arrow pointing upwards. The 6" diam. thin wall is pushed vertically. The horizontal reference line is also shown.



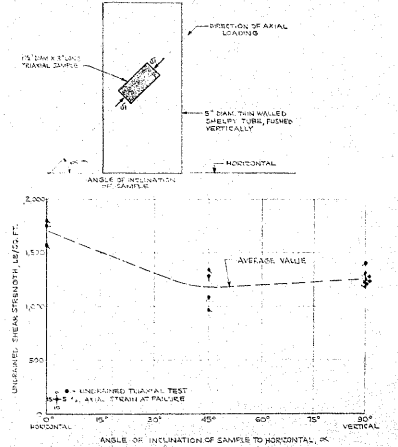
DETAILED STRATIGRAPHY OF SAMPLE



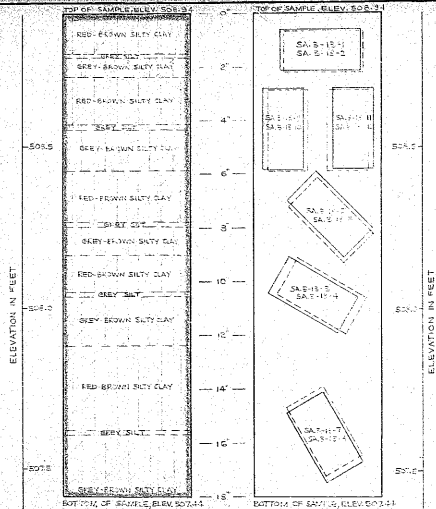
LOCATION OF TRIAXIAL SAMPLES TRIMMED FROM 5" DIAM. THIN WALLED SHELLY TUBE

DEFECTS IN NEGATIVE DUE TO CONDITION OF ORIGINAL DOCUMENT

TABLE OF RESULTS									
TRIAxIAL SAMPLE NUMBER	ANGLE OF SAMPLE TO HORIZONTAL PLANE	WATER CONTENT (%)			FLUID UNIT	LIQUID UNIT	UNDRAINED SHEAR STRENGTH (PSF)	FAILURE STRAIN (PERCENT)	TOTAL UNIT WEIGHT (LB/CF)
		PORTION OF SAMPLE	WATER CONTENT (%)	WATER CONTENT (%)					
5-12-1	0°	1.00	1.00	1.00			1.00	0	11.0
5-12-2	0°	1.00	1.00	1.00			1.00	0	11.0
5-12-3	0°	1.00	1.00	1.00			1.00	0	11.0
5-12-4	45°	1.00	1.00	1.00			1.00	0	11.0
5-12-5	45°	1.00	1.00	1.00			1.00	0	11.0
5-12-6	45°	1.00	1.00	1.00			1.00	0	11.0
5-12-7	45°	1.00	1.00	1.00			1.00	0	11.0
5-12-8	45°	1.00	1.00	1.00			1.00	0	11.0
5-12-9	45°	1.00	1.00	1.00			1.00	0	11.0
5-12-10	45°	1.00	1.00	1.00			1.00	0	11.0
5-12-11	45°	1.00	1.00	1.00			1.00	0	11.0
5-12-12	45°	1.00	1.00	1.00			1.00	0	11.0
5-12-13	45°	1.00	1.00	1.00			1.00	0	11.0
5-12-14	45°	1.00	1.00	1.00			1.00	0	11.0
5-12-15	45°	1.00	1.00	1.00			1.00	0	11.0
5-12-16	45°	1.00	1.00	1.00			1.00	0	11.0
5-12-17	45°	1.00	1.00	1.00			1.00	0	11.0
5-12-18	45°	1.00	1.00	1.00			1.00	0	11.0
5-12-19	45°	1.00	1.00	1.00			1.00	0	11.0
5-12-20	45°	1.00	1.00	1.00			1.00	0	11.0
5-12-21	45°	1.00	1.00	1.00			1.00	0	11.0
5-12-22	45°	1.00	1.00	1.00			1.00	0	11.0
5-12-23	45°	1.00	1.00	1.00			1.00	0	11.0
5-12-24	45°	1.00	1.00	1.00			1.00	0	11.0
5-12-25	45°	1.00	1.00	1.00			1.00	0	11.0
5-12-26	45°	1.00	1.00	1.00			1.00	0	11.0
5-12-27	45°	1.00	1.00	1.00			1.00	0	11.0
5-12-28	45°	1.00	1.00	1.00			1.00	0	11.0
5-12-29	45°	1.00	1.00	1.00			1.00	0	11.0
5-12-30	45°	1.00	1.00	1.00			1.00	0	11.0
5-12-31	45°	1.00	1.00	1.00			1.00	0	11.0
5-12-32	45°	1.00	1.00	1.00			1.00	0	11.0
5-12-33	45°	1.00	1.00	1.00			1.00	0	11.0
5-12-34	45°	1.00	1.00	1.00			1.00	0	11.0
5-12-35	45°	1.00	1.00	1.00			1.00	0	11.0
5-12-36	45°	1.00	1.00	1.00			1.00	0	11.0
5-12-37	45°	1.00	1.00	1.00			1.00	0	11.0
5-12-38	45°	1.00	1.00	1.00			1.00	0	11.0
5-12-39	45°	1.00	1.00	1.00			1.00	0	11.0
5-12-40	45°	1.00	1.00	1.00			1.00	0	11.0
5-12-41	45°	1.00	1.00	1.00			1.00	0	11.0
5-12-42	45°	1.00	1.00	1.00			1.00	0	11.0
5-12-43	45°	1.00	1.00	1.00			1.00	0	11.0
5-12-44	45°	1.00	1.00	1.00			1.00	0	11.0
5-12-45	45°	1.00	1.00	1.00			1.00	0	11.0
5-12-46	45°	1.00	1.00	1.00			1.00	0	11.0
5-12-47	45°	1.00	1.00	1.00			1.00	0	11.0
5-12-48	45°	1.00	1.00	1.00			1.00	0	11.0
5-12-49	45°	1.00	1.00	1.00			1.00	0	11.0
5-12-50	45°	1.00	1.00	1.00			1.00	0	11.0
5-12-51	45°	1.00	1.00	1.00			1.00	0	11.0
5-12-52	45°	1.00	1.00	1.00			1.00	0	11.0
5-12-53	45°	1.00	1.00	1.00			1.00	0	11.0
5-12-54	45°	1.00	1.00	1.00			1.00	0	11.0
5-12-55	45°	1.00	1.00	1.00			1.00	0	11.0
5-12-56	45°	1.00	1.00	1.00			1.00	0	11.0
5-12-57	45°	1.00	1.00	1.00			1.00	0	11.0
5-12-58	45°	1.00	1.00	1.00			1.00	0	11.0
5-12-59	45°	1.00	1.00	1.00			1.00	0	11.0
5-12-60	45°	1.00	1.00	1.00			1.00	0	11.0
5-12-61	45°	1.00	1.00	1.00			1.00	0	11.0
5-12-62	45°	1.00	1.00	1.00			1.00	0	11.0
5-12-63	45°	1.00	1.00	1.00			1.00	0	11.0
5-12-64	45°	1.00	1.00	1.00			1.00	0	11.0
5-12-65	45°	1.00	1.00	1.00			1.00	0	11.0
5-12-66	45°	1.00	1.00	1.00			1.00	0	11.0
5-12-67	45°	1.00	1.00	1.00			1.00	0	11.0
5-12-68	45°	1.00	1.00	1.00			1.00	0	11.0
5-12-69	45°	1.00	1.00	1.00			1.00	0	11.0
5-12-70	45°	1.00	1.00	1.00			1.00	0	11.0
5-12-71	45°	1.00	1.00	1.00			1.00	0	11.0
5-12-72	45°	1.00	1.00	1.00			1.00	0	11.0
5-12-73	45°	1.00	1.00	1.00			1.00	0	11.0
5-12-74	45°	1.00	1.00	1.00			1.00	0	11.0
5-12-75	45°	1.00	1.00	1.00			1.00	0	11.0
5-12-76	45°	1.00	1.00	1.00			1.00	0	11.0
5-12-77	45°	1.00	1.00	1.00			1.00	0	11.0
5-12-78	45°	1.00	1.00	1.00			1.00	0	11.0
5-12-79	45°	1.00	1.00	1.00			1.00	0	11.0
5-12-80	45°	1.00	1.00	1.00			1.00	0	11.0
5-12-81	45°	1.00	1.00	1.00			1.00	0	11.0
5-12-82	45°	1.00	1.00	1.00			1.00	0	11.0
5-12-83	45°	1.00	1.00	1.00			1.00	0	11.0
5-12-84	45°	1.00	1.00	1.00			1.00	0	11.0
5-12-85	45°	1.00	1.00	1.00			1.00	0	11.0
5-12-86	45°	1.00	1.00	1.00			1.00	0	11.0
5-12-87	45°	1.00	1.00	1.00			1.00	0	11.0
5-12-88	45°	1.00	1.00	1.00			1.00	0	11.0
5-12-89	45°	1.00	1.00	1.00			1.00	0	11.0
5-12-90	45°	1.00	1.00	1.00			1.00	0	11.0
5-12-91	45°	1.00	1.00	1.00			1.00	0	11.0
5-12-92	45°	1.00	1.00	1.00			1.00	0	11.0
5-12-93	45°	1.00	1.00	1.00			1.00	0	11.0
5-12-94	45°	1.00	1.00	1.00			1.00	0	11.0
5-12-95	45°	1.00	1.00	1.00			1.00	0	11.0
5-12-96	45°	1.00	1.00	1.00			1.00	0	11.0
5-12-97	45°	1.00	1.00	1.00			1.00	0	11.0
5-12-98	45°	1.00	1.00	1.00			1.00	0	11.0
5-12-99	45°	1.00	1.00	1.00			1.00	0	11.0
5-12-100	45°	1.00	1.00	1.00			1.00	0	11.0

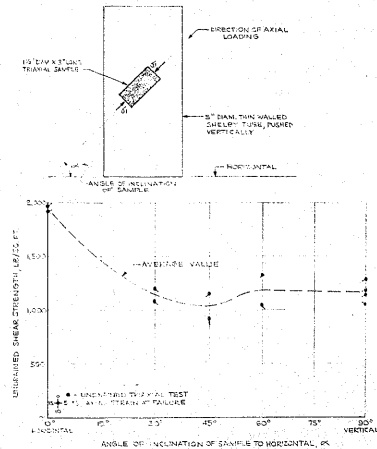


DETAILED STRATIGRAPHY OF SAMPLE



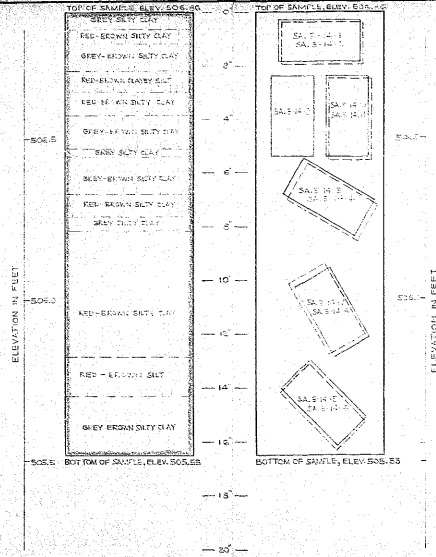
LOCATION OF TRIAXIAL SAMPLES TRIMMED FROM 5" DIAM. THIN WALLED SHELEV TUBE

TRIAXIAL SAMPLE NUMBER	ANGLE OF SAMPLE TO HORIZONTAL PLANE	WATER CONTENT PERCENT	PLASTIC LIMIT	LIQUID LIMIT	UNDRAINED SHEAR STRENGTH (LB/SG. FT.)	FAILURE STRAIN PERCENT	TOTAL UNIT WEIGHT (LB/SG. FT.)
SA-13-1	0	42	15	62	1,070	5	100
SA-13-2	0	42	15	62	1,070	5	100
SA-13-3	0	42	15	62	1,070	5	100
SA-13-4	0	42	15	62	1,070	5	100
SA-13-5	0	42	15	62	1,070	5	100
SA-13-6	0	42	15	62	1,070	5	100
SA-13-7	0	42	15	62	1,070	5	100
SA-13-8	0	42	15	62	1,070	5	100
SA-13-9	0	42	15	62	1,070	5	100
SA-13-10	0	42	15	62	1,070	5	100





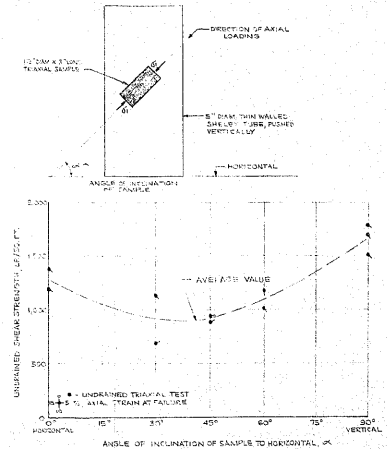
DETAILED  
STRATIGRAPHY  
OF SAMPLE



LOCATION OF  
TRIAXIAL SAMPLES  
OBTAINED FROM  
5" DIAM. THIN-WALLED  
SHELLY TUBE

TRIAXIAL SAMPLE NUMBER	ANGLE OF SAMPLE TO HORIZONTAL PLANE	WATER CONTENT IN PERCENT				UNDRAINED SHEAR STRENGTH (LB/IN <sup>2</sup> )	FAILURE STRAIN PERCENT	TOTAL UNIT WEIGHT (LB/IN <sup>3</sup> )
		PERCENT OF SAMPLE MOISTURE IN WATER	W	PLASTIC LIMIT	LIQUID LIMIT			
14-1	0°	RED-BROWN SILTY CLAY	24	18	42	1.17	5	117
14-2	0°	RED-BROWN SILTY CLAY	24	18	42	1.17	5	117
14-3	0°	RED-BROWN SILTY CLAY	24	18	42	1.17	5	117
14-4	0°	RED-BROWN SILTY CLAY	24	18	42	1.17	5	117
14-5	0°	RED-BROWN SILTY CLAY	24	18	42	1.17	5	117
14-6	0°	RED-BROWN SILTY CLAY	24	18	42	1.17	5	117
14-7	0°	RED-BROWN SILTY CLAY	24	18	42	1.17	5	117
14-8	0°	RED-BROWN SILTY CLAY	24	18	42	1.17	5	117
14-9	0°	RED-BROWN SILTY CLAY	24	18	42	1.17	5	117
14-10	0°	RED-BROWN SILTY CLAY	24	18	42	1.17	5	117
14-11	0°	RED-BROWN SILTY CLAY	24	18	42	1.17	5	117
14-12	0°	RED-BROWN SILTY CLAY	24	18	42	1.17	5	117
14-13	0°	RED-BROWN SILTY CLAY	24	18	42	1.17	5	117
14-14	0°	RED-BROWN SILTY CLAY	24	18	42	1.17	5	117
14-15	0°	RED-BROWN SILTY CLAY	24	18	42	1.17	5	117
14-16	0°	RED-BROWN SILTY CLAY	24	18	42	1.17	5	117
14-17	0°	RED-BROWN SILTY CLAY	24	18	42	1.17	5	117
14-18	0°	RED-BROWN SILTY CLAY	24	18	42	1.17	5	117
14-19	0°	RED-BROWN SILTY CLAY	24	18	42	1.17	5	117
14-20	0°	RED-BROWN SILTY CLAY	24	18	42	1.17	5	117
14-21	0°	RED-BROWN SILTY CLAY	24	18	42	1.17	5	117
14-22	0°	RED-BROWN SILTY CLAY	24	18	42	1.17	5	117
14-23	0°	RED-BROWN SILTY CLAY	24	18	42	1.17	5	117
14-24	0°	RED-BROWN SILTY CLAY	24	18	42	1.17	5	117
14-25	0°	RED-BROWN SILTY CLAY	24	18	42	1.17	5	117
14-26	0°	RED-BROWN SILTY CLAY	24	18	42	1.17	5	117
14-27	0°	RED-BROWN SILTY CLAY	24	18	42	1.17	5	117
14-28	0°	RED-BROWN SILTY CLAY	24	18	42	1.17	5	117
14-29	0°	RED-BROWN SILTY CLAY	24	18	42	1.17	5	117
14-30	0°	RED-BROWN SILTY CLAY	24	18	42	1.17	5	117
14-31	0°	RED-BROWN SILTY CLAY	24	18	42	1.17	5	117
14-32	0°	RED-BROWN SILTY CLAY	24	18	42	1.17	5	117
14-33	0°	RED-BROWN SILTY CLAY	24	18	42	1.17	5	117
14-34	0°	RED-BROWN SILTY CLAY	24	18	42	1.17	5	117
14-35	0°	RED-BROWN SILTY CLAY	24	18	42	1.17	5	117
14-36	0°	RED-BROWN SILTY CLAY	24	18	42	1.17	5	117
14-37	0°	RED-BROWN SILTY CLAY	24	18	42	1.17	5	117
14-38	0°	RED-BROWN SILTY CLAY	24	18	42	1.17	5	117
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14-40	0°	RED-BROWN SILTY CLAY	24	18	42	1.17	5	117
14-41	0°	RED-BROWN SILTY CLAY	24	18	42	1.17	5	117
14-42	0°	RED-BROWN SILTY CLAY	24	18	42	1.17	5	117
14-43	0°	RED-BROWN SILTY CLAY	24	18	42	1.17	5	117
14-44	0°	RED-BROWN SILTY CLAY	24	18	42	1.17	5	117
14-45	0°	RED-BROWN SILTY CLAY	24	18	42	1.17	5	117
14-46	0°	RED-BROWN SILTY CLAY	24	18	42	1.17	5	117
14-47	0°	RED-BROWN SILTY CLAY	24	18	42	1.17	5	117
14-48	0°	RED-BROWN SILTY CLAY	24	18	42	1.17	5	117
14-49	0°	RED-BROWN SILTY CLAY	24	18	42	1.17	5	117
14-50	0°	RED-BROWN SILTY CLAY	24	18	42	1.17	5	117
14-51	0°	RED-BROWN SILTY CLAY	24	18	42	1.17	5	117
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14-55	0°	RED-BROWN SILTY CLAY	24	18	42	1.17	5	117
14-56	0°	RED-BROWN SILTY CLAY	24	18	42	1.17	5	117
14-57	0°	RED-BROWN SILTY CLAY	24	18	42	1.17	5	117
14-58	0°	RED-BROWN SILTY CLAY	24	18	42	1.17	5	117
14-59	0°	RED-BROWN SILTY CLAY	24	18	42	1.17	5	117
14-60	0°	RED-BROWN SILTY CLAY	24	18	42	1.17	5	117
14-61	0°	RED-BROWN SILTY CLAY	24	18	42	1.17	5	117
14-62	0°	RED-BROWN SILTY CLAY	24	18	42	1.17	5	117
14-63	0°	RED-BROWN SILTY CLAY	24	18	42	1.17	5	117
14-64	0°	RED-BROWN SILTY CLAY	24	18	42	1.17	5	117
14-65	0°	RED-BROWN SILTY CLAY	24	18	42	1.17	5	117
14-66	0°	RED-BROWN SILTY CLAY	24	18	42	1.17	5	117
14-67	0°	RED-BROWN SILTY CLAY	24	18	42	1.17	5	117
14-68	0°	RED-BROWN SILTY CLAY	24	18	42	1.17	5	117
14-69	0°	RED-BROWN SILTY CLAY	24	18	42	1.17	5	117
14-70	0°	RED-BROWN SILTY CLAY	24	18	42	1.17	5	117
14-71	0°	RED-BROWN SILTY CLAY	24	18	42	1.17	5	117
14-72	0°	RED-BROWN SILTY CLAY	24	18	42	1.17	5	117
14-73	0°	RED-BROWN SILTY CLAY	24	18	42	1.17	5	117
14-74	0°	RED-BROWN SILTY CLAY	24	18	42	1.17	5	117
14-75	0°	RED-BROWN SILTY CLAY	24	18	42	1.17	5	117
14-76	0°	RED-BROWN SILTY CLAY	24	18	42	1.17	5	117
14-77	0°	RED-BROWN SILTY CLAY	24	18	42	1.17	5	117
14-78	0°	RED-BROWN SILTY CLAY	24	18	42	1.17	5	117
14-79	0°	RED-BROWN SILTY CLAY	24	18	42	1.17	5	117
14-80	0°	RED-BROWN SILTY CLAY	24	18	42	1.17	5	117
14-81	0°	RED-BROWN SILTY CLAY	24	18	42	1.17	5	117
14-82	0°	RED-BROWN SILTY CLAY	24	18	42	1.17	5	117
14-83	0°	RED-BROWN SILTY CLAY	24	18	42	1.17	5	117
14-84	0°	RED-BROWN SILTY CLAY	24	18	42	1.17	5	117
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14-87	0°	RED-BROWN SILTY CLAY	24	18	42	1.17	5	117
14-88	0°	RED-BROWN SILTY CLAY	24	18	42	1.17	5	117
14-89	0°	RED-BROWN SILTY CLAY	24	18	42	1.17	5	117
14-90	0°	RED-BROWN SILTY CLAY	24	18	42	1.17	5	117
14-91	0°	RED-BROWN SILTY CLAY	24	18	42	1.17	5	117
14-92	0°	RED-BROWN SILTY CLAY	24	18	42	1.17	5	117
14-93	0°	RED-BROWN SILTY CLAY	24	18	42	1.17	5	117
14-94	0°	RED-BROWN SILTY CLAY	24	18	42	1.17	5	117
14-95	0°	RED-BROWN SILTY CLAY	24	18	42	1.17	5	117
14-96	0°	RED-BROWN SILTY CLAY	24	18	42	1.17	5	117
14-97	0°	RED-BROWN SILTY CLAY	24	18	42	1.17	5	117
14-98	0°	RED-BROWN SILTY CLAY	24	18	42	1.17	5	117
14-99	0°	RED-BROWN SILTY CLAY	24	18	42	1.17	5	117
14-100	0°	RED-BROWN SILTY CLAY	24	18	42	1.17	5	117

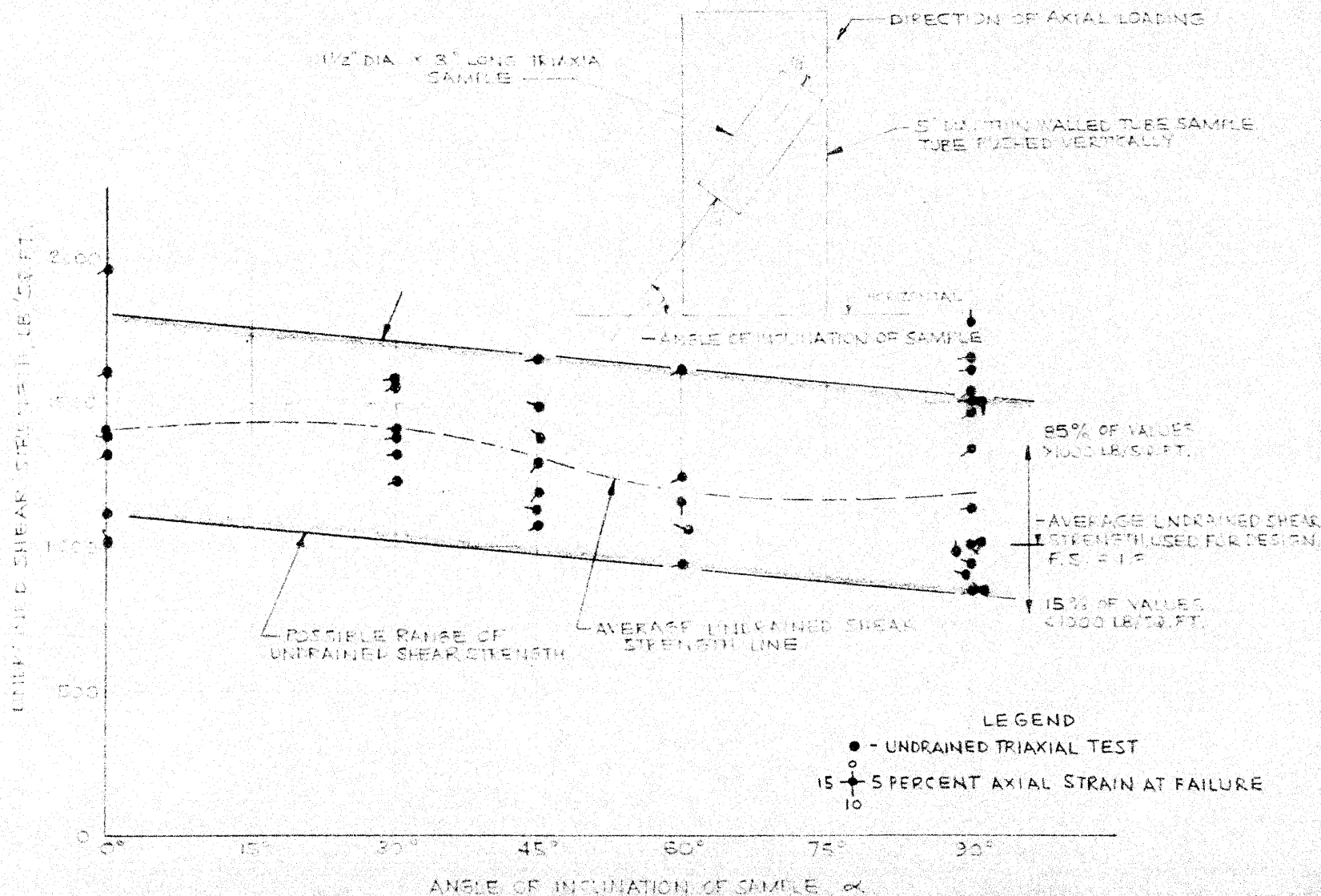
DEFECTS IN NEGATIVE DUE TO  
CONDITION OF ORIGINAL DOCUMENT



DICTIONAL SHEAR STRENGTH CHARACTERISTICS  
OF IRREGULARLY LAYERED SILTY CLAY STRATUM

MASSIVE PORTION

FIGURE C-16



AVERAGE AXIAL STRAIN AT FAILURE 14 %  
AVERAGE TOTAL UNIT WEIGHT 129 LB/CU. FT.

AVERAGE LIQUID LIMIT 36 %  
AVERAGE PLASTICITY INDEX 19  
AVERAGE IN SITU WATER CONTENT 21 %

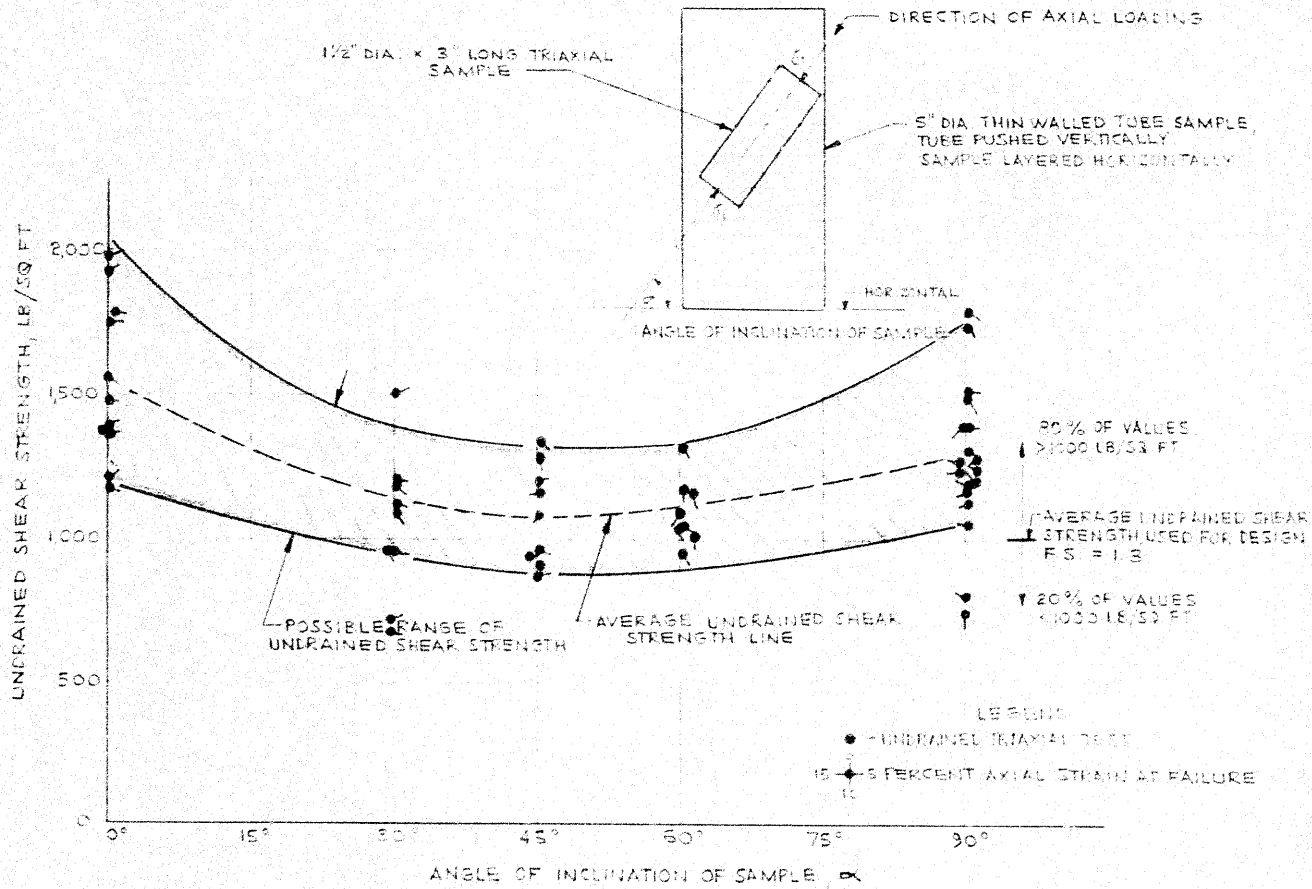
GOLDER & ASSOCIATES

Made by  
CHKD  
Appd. *[Signature]*

DIRECTIONAL SHEAR STRENGTH CHARACTERISTICS  
OF IRREGULARLY LAYERED SILTY CLAY STRATUM.  
[LAYERED PORTION]

21-15-3

FIGURE C-17



AVERAGE AXIAL STRAIN AT FAILURE 3 %  
AVERAGE TOTAL UNIT WEIGHT 116 LB/CU FT

AVERAGE LIQUID LIMIT 65 %  
AVERAGE PLASTICITY INDEX 34  
AVERAGE IN SITU WATER CONTENT 36%

GOLDER & ASSOCIATES

Modd. Acc.  
CHKD. Appd. 17