WORK INSTRUCTIONS FOR ENGINEERS

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OP-029. INTERPRETATION OF CIU TEST

29. INTERPRETATION OF CIU TEST

29.1 INTRODUCTION

The procedure is to determine peak effective friction angle (ϕ') and apparent cohesion (c') from the CIU test (Isotropically Consolidated Undrained Triaxial Test) results.

29.2 DEFINITIONS

- σ_1' = major principal effective stress
- σ_3' = minor principal effective stress
- σ_3 = major principal total stress (Cell Pressure)
- u = pore water pressure

29.3 PROCEDURE

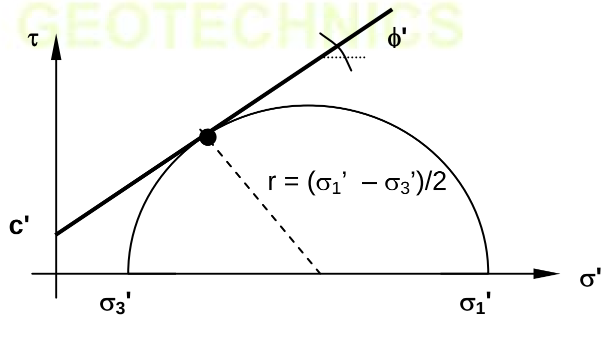
(1) Usually three CIU tests are carried out at different pre-consolidation stresses (σ_3') for an undisturbed sample at a particular depth.

(2) Select a suitable criterion used to define the occurrence of failure of the test samples. The following criteria are commonly used:
- Maximum deviator stress (σ_1' – σ_3'),
- Maximum principal stress ratio (σ_1' / σ_3') – can be used in which the deviator stress continues to increase at large strains.

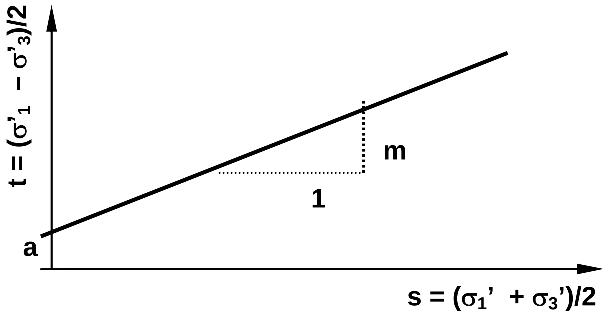
(3) Based on the selected criteria in step (2), obtain the stress points at failure, ie. values of σ_1' and σ_3' when deviator stress or principal stress ratio is maximum, for each test.

(4) If values of σ_1' and σ_3' are not available in the laboratory datasheet, the respective values can be computed as follows:
- Deviator stress (σ_1' – σ_3') = Axial load / Area
- σ_3 = Cell Pressure
- σ_1' = Deviator stress + Cell Pressure – Pore Pressure
- σ_3' = Cell Pressure – Pore Pressure

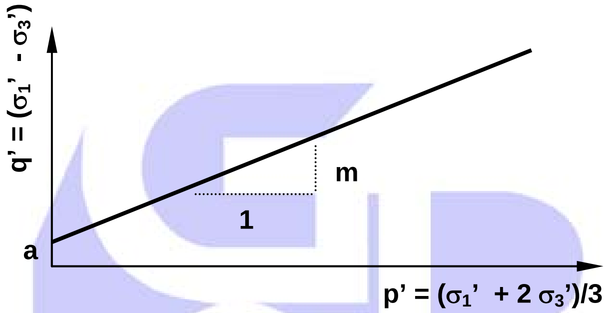
(5) The shear strength parameters (ϕ', c') can be interpreted using effective stress Mohr circle or effective stress path plots (MIT plot or Cambridge plot).
- Mohr circle: τ against σ'



- MIT plot (t-s plot): $(\sigma_1' - \sigma_3')/2$ against $(\sigma_1' + \sigma_3')/2$



- Cambridge plot (q-p plot): $(\sigma_1' - \sigma_3')$ against $(\sigma_1' + 2\,\sigma_3')/3$

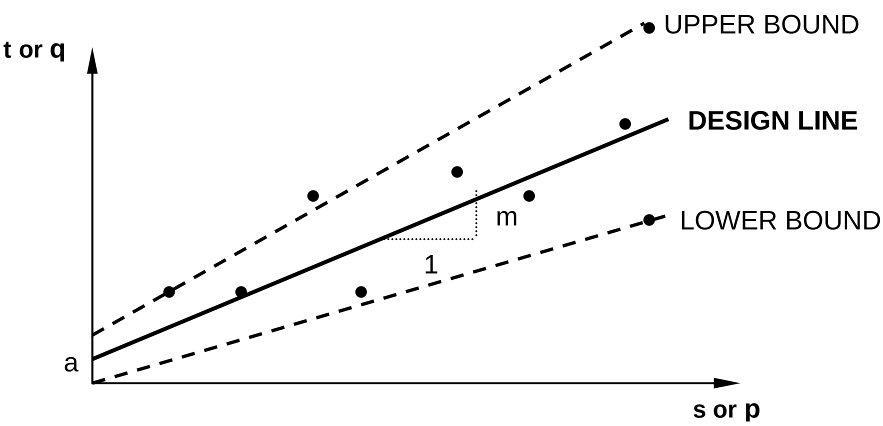


(6) Select type of the plot to be employed, ie. **MIT plot or Cambridge Plot**. Compute coordinates (*x,y*) for all the stress points obtained in step (5), depends on the type of plot.
- For MIT plot: *x*-value is $(\sigma_1' + \sigma_3')/2$ and *y*-value is $(\sigma_1' - \sigma_3')/2$.
- For Cambridge plot: *x*-value is $(\sigma_1' + 2\,\sigma_3')/3$ and *y*-value is $(\sigma_1' - \sigma_3')$.

(7) To establish more representative parameters for similar soil type at a site, plot all the points in a single graph. Plot only the points without showing a line. **Important: The x-axis and y-axis in the graph should be plotted with same scale (1:1).**

(8) From scatter points, draw the upper bound line and lower bound line. For lower bound, y-axis intercept (a) is normally taken as 0.

(9) Draw a design line, which is considered as a moderately conservative line (best fitted line, or a line below about 2/3 of total nos. of points).



(10) Calculate the gradient (m) and y-axis intercept (a) of the design line.

(11) Use the following equations to calculate values of ϕ' and c':

a) t-s Plot / MIT Plot
- $\phi' = \sin^{-1} m$ … Eq. (1)
- $c' = a / (\cos \phi')$ … Eq. (2)

b) q-p Plot / Cambridge Plot
- $m = 6 \sin \phi' / (3 - \sin \phi')$ … Eq. (3)
- $c' = a \tan \phi'/m$ … Eq. (4)

29.4 WORKED EXAMPLE

i. *'Maximum stress ratio'* is used as failure criteria in this example.

ii. Referring to sample datasheet in Appendix A, a stress point at failure (σ_1', σ_3') is obtained, in which its principal stress ratio is maximum.

Maximum $\sigma_1' / \sigma_3' = 3.101$

$\sigma_1' = 172.71$ kN/m^2

$\sigma_3' = 55.7$ kN/m^2

iii. Repeat step (ii) for other set of CIU test results.

MIT PLOT

iv. The stress points obtained in steps (ii) and (iii) are plotted in **MIT plot**, as shown in Figure A1. The plot includes the stress points from CIU tests for the undisturbed samples at different boreholes. Coordinates (x_i, y_i) are computed, for example by using the values in step (ii):

$x_1 = (\sigma_1' + \sigma_3')/2 = 114.505$ kN/m^2

$y_1 = (\sigma_1' - \sigma_3')/2 = 58.505$ kN/m^2

v. The upper bound and lower bound lines are first drawn on the plot and then a design line is also drawn, as shown in Figure A1.

vi. The gradient (m) and y-axis intercept (a) of the design line are calculated as follows:

$$m = \frac{52 - 5}{100} = 0.47$$

$$a = 5 kN/m^2$$

vii. The values of ϕ' and c' are computed using Eq. (1) and (2):

$$\phi' = \sin^{-1} m = \sin^{-1}(0.47) = 28°$$

$$c' = \frac{a}{\cos \phi'} = \frac{5}{\cos 28} \approx 6 kN/m^2$$

CAMBRIDGE PLOT

viii. The stress points obtained in steps (ii) and (iii) are plotted in **Cambridge plot**, as shown in Figure A2. Coordinates (x_i, y_i) are computed, for example by using the values in step (ii):

$x_1 = (\sigma_1' + 2\sigma_3')/3 = 94.7$ kN/m^2

$y_1 = (\sigma_1' - \sigma_3') = 117$ kN/m^2

ix. The gradient (m) and y-axis intercept (a) of the design line are calculated as follows:

$$m = \frac{122 - 12}{100} = 1.1$$

$$a = 12 kN/m^2$$

x. The values of ϕ' and c' are computed using Eq. (3) and (4):

$$\phi' = \sin^{-1}[3(1.1)/(6 + 1.1)] = 28°$$

$$c' = \frac{12 \tan 28°}{1.1} \approx 6 kN/m^2$$

∴ ***ϕ' = 28°, c' = 6 kN/m^2 are adopted as design values.***

HOLE No.	:	BH-2A	SPECIMEN No.		:	1
SAMPLE No.	:	MZ-3	INITIAL HEIGHT OF SPECIMEN (cm)		:	14.000
DEPTH (m)	:	9.00-10.00	INITIAL DIAMETER OF SPECIMEN (cm)		:	7.000
DATE OF TEST	:	16-08-2000	SPECIMEN HEIGHT AFTER CONS. (cm)		:	13.749
TEST No.	:	-	SPECIMEN AREA AFTER CONS. (sq.cm)		:	37.118
TYPE OF TEST	:	CIU (Single Stage)	WET MASS (g)		:	997.56
CELL PRES. (kN/sq.m)	:	90	DRY MASS (g)		:	823.65
BACK PRES. (kN/sq.m)	:	200	PROVING RING CONSTANT (kN/div.)		:	0.0079

DIAL GAUGE READING x0.001cm	STRAIN (%)	AREA (sq.cm)	PROVING RING READING	AXIAL LOAD (kN)	DEVIATOR STRESS (kN/sq.m)	PORE PRESSUR READING (kN/sq.m)	PORE PRESSUR CHANGE (kN/sq.m)	SIGMA 3 BAR (kN/sq.m)	SIGMA 1 BAR (kN/sq.m)	P (kN/sq.m)	P BAR (kN/sq.m)	Q BAR (kN/sq.m)	PRINCIPAL STRESS RATIO
0	0.00	37.118	0.0	0.000	0.000	200	0	90.000	90.000	90.000	90.000	0.000	1.000
5	0.04	37.132	9.5	0.075	20.212	202.8	2.8	87.200	107.412	100.106	97.306	10.106	1.232
10	0.07	37.146	18.4	0.145	39.133	205.7	5.7	84.300	123.433	109.566	103.866	19.566	1.464
15	0.11	37.159	24.6	0.194	52.300	208.4	8.4	81.600	133.900	116.150	107.750	26.150	1.641
20	0.15	37.173	28.6	0.226	60.781	211.1	11.1	78.900	139.681	120.391	109.291	30.391	1.770
25	0.18	37.186	33.2	0.262	70.532	213.2	13.2	76.800	147.332	125.266	112.066	35.266	1.918
30	0.22	37.200	36.0	0.284	76.452	215.1	15.1	74.900	151.352	128.226	113.126	38.226	2.021
35	0.25	37.213	38.6	0.305	81.944	217	17	73.000	154.944	130.972	113.972	40.972	2.123
40	0.29	37.227	41.3	0.326	87.644	218.6	18.6	71.400	159.044	133.822	115.222	43.822	2.220
45	0.33	37.240	43.6	0.344	92.491	220.4	20.4	69.600	162.091	136.246	115.846	46.246	2.329
50	0.36	37.254	45.0	0.356	95.426	222.4	22.4	67.600	163.026	137.713	115.313	47.713	2.412
60	0.44	37.281	46.6	0.368	98.747	224.3	24.3	65.700	164.447	139.373	115.073	49.373	2.503
70	0.51	37.308	48.2	0.381	102.063	226.3	26.3	63.700	165.763	141.031	114.731	51.031	2.602
80	0.58	37.336	49.1	0.388	103.892	228.1	28.1	61.900	165.792	141.946	113.846	51.946	2.678
90	0.65	37.363	50.0	0.395	105.719	229.2	29.2	60.800	166.519	142.860	113.660	52.860	2.739
100	0.73	37.390	50.8	0.401	107.332	230.4	30.4	59.600	166.932	143.666	113.266	53.666	2.801
125	0.91	37.459	52.6	0.416	110.932	231.8	31.8	58.200	169.132	145.466	113.666	55.466	2.906
150	1.09	37.528	53.7	0.424	113.044	232.8	32.8	57.200	170.244	146.522	113.722	56.522	2.976
175	1.27	37.597	54.5	0.431	114.517	233.6	33.6	56.400	170.917	147.259	113.659	57.259	3.030
200	1.45	37.666	55.0	0.435	115.355	233.8	33.8	56.200	171.555	147.677	113.877	57.677	3.053
225	1.64	37.736	55.7	0.440	116.586	234	34	56.000	172.586	148.293	114.293	58.293	3.082
250	1.82	37.806	55.9	0.442	116.810	234.2	34.2	55.800	172.610	148.405	114.205	58.405	3.093
275	2.00	37.876	56.1	0.443	117.011	234.3	34.3	55.700	172.711	148.505	114.205	58.505	3.101
300	2.18	37.946	56.3	0.445	117.210	234	34	56.000	173.210	148.605	114.605	50.605	3.093
325	2.36	38.017	56.4	0.446	117.200	233.7	33.7	56.300	173.500	148.600	114.900	58.600	3.082
350	2.55	38.088	56.5	0.446	117.189	233.3	33.3	56.700	173.889	148.594	115.294	50.594	3.067
375	2.73	38.159	56.6	0.447	117.177	233	33	57.000	174.177	148.589	115.589	58.589	3.056
400	2.91	38.231	56.7	0.448	117.165	232.5	32.5	57.500	174.665	148.582	116.082	58.582	3.038
450	3.27	38.374	56.8	0.449	116.932	231.6	31.6	58.400	175.332	148.466	116.866	58.466	3.002
500	3.64	38.519	56.9	0.450	116.697	230.8	30.8	59.200	175.897	148.349	117.549	58.349	2.971
550	4.00	38.665	57.0	0.450	116.461	230	30	60.000	176.461	148.231	118.231	58.231	2.941
600	4.36	38.812	57.1	0.451	116.224	229.5	29.5	60.500	176.724	148.112	118.612	58.112	2.921
650	4.73	38.960	57.2	0.452	115.985	228.5	28.5	61.500	177.485	147.992	119.492	57.992	2.886
700	5.09	39.110	57.3	0.453	115.744	227.8	27.8	62.200	177.944	147.872	120.072	57.872	2.861
750	5.45	39.260	57.4	0.453	115.502	227	27	63.000	178.502	147.751	120.751	57.751	2.833
800	5.82	39.412	57.5	0.454	115.258	226.3	26.3	63.700	178.958	147.629	121.329	57.629	2.809
850	6.18	39.564	57.6	0.455	115.012	225.5	25.5	64.500	179.512	147.506	122.006	57.506	2.783
900	6.55	39.718	57.7	0.456	114.766	224.6	24.6	65.400	180.166	147.383	122.783	57.383	2.755
950	6.91	39.874	57.8	0.457	114.517	223.8	23.8	66.200	180.717	147.259	123.450	57.259	2.730
1000	7.27	40.030	57.8	0.457	114.070	222.9	22.9	67.100	181.170	147.035	124.135	57.035	2.700
1100	8.00	40.346	57.8	0.457	113.175	221.2	21.2	68.800	181.975	146.587	125.387	56.587	2.645
1200	8.73	40.668	57.8	0.457	112.280	219.8	19.8	70.200	182.480	146.140	126.340	56.140	2.599
1300	9.46	40.995	57.8	0.457	111.386	218.2	18.2	71.800	183.186	145.693	127.493	55.693	2.551
1400	10.18	41.326	57.8	0.457	110.491	216.7	16.7	73.300	183.791	145.245	128.545	55.245	2.507

APPENDIX A SAMPLE DATASHEET

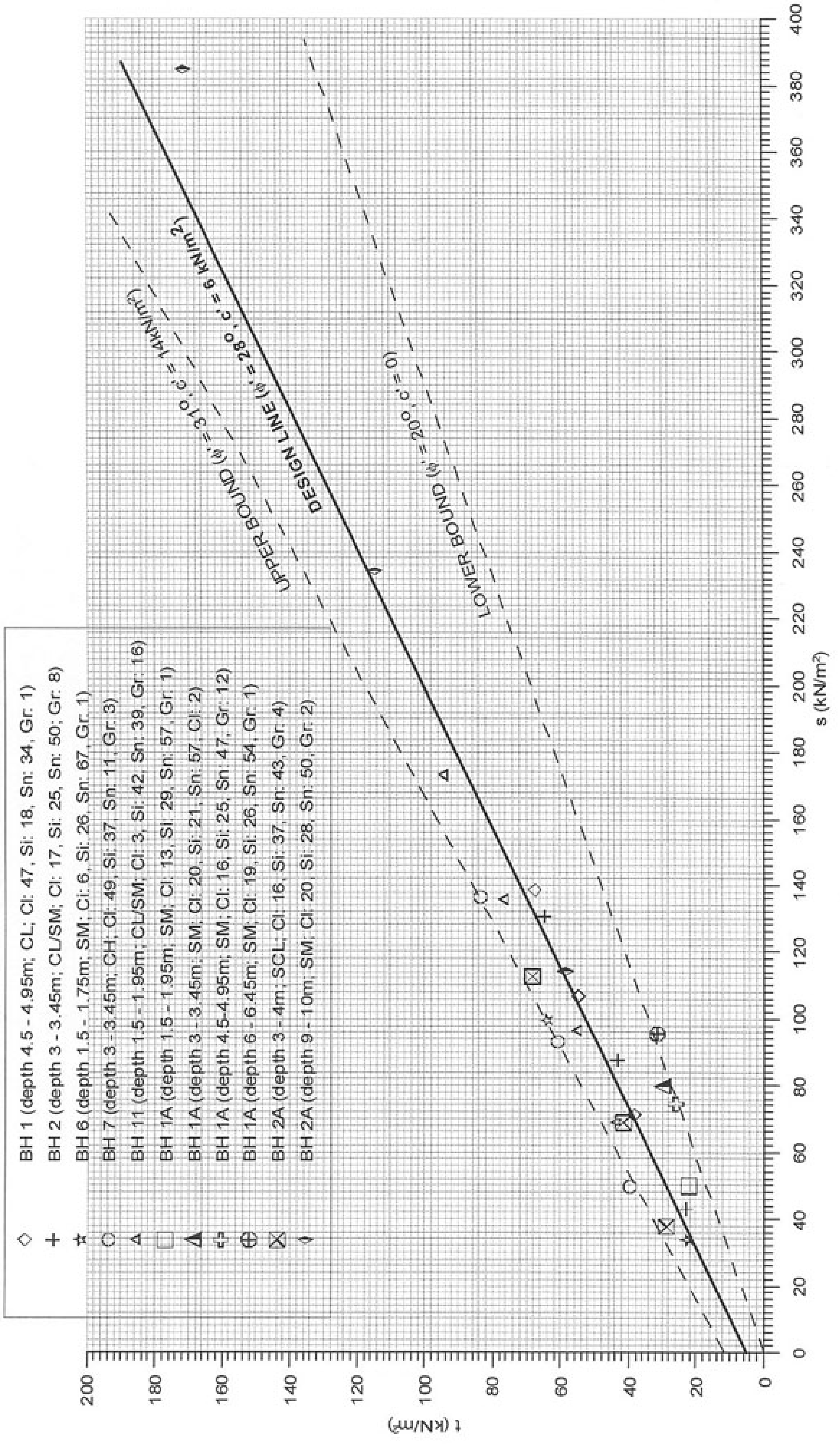


FIGURE A1 t-s Plot

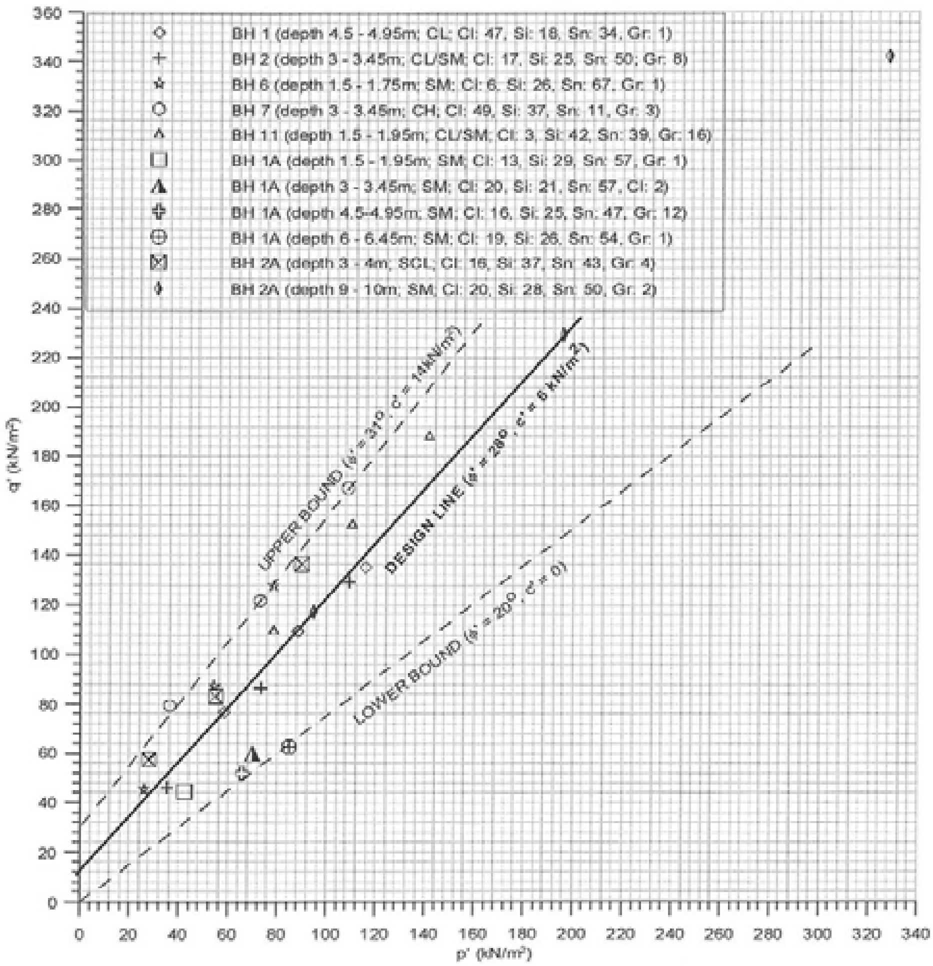


FIGURE A2 q-p Plot