Practical 3: Unconfined Compression Test

General

The unconfined compression test (UC test) is to determine the unconfined shear strength, qu. Undrained shear strength is interpreted as the maximum internal resistance of a soil to the applied shear force when it is sheared at constant volume. The test is done by subjecting rapid compressive loading on a cylindrical soil specimen so that no drainage takes place during the shear. Take note there is only vertical load applied on the soil sample which is the major principal stress ($\sigma 1$) and no radial stress , ($\sigma 3$ = zero). Precaution, the unconfined compression test is inappropriate for dry sands or crumbly clays as the materials would fall apart without some land of lateral confinement.

From the Mohr circle, shear strength Su,

$$s_u = c = \frac{q_u}{2}$$

Where:

C = Cohesion

The results obtained from the UC test can be used for various purposes especially for foundation design and earth retaining wall design. Undrained shear strength is used to estimate short-term bearing capacity of fine-grained soils for foundations and estimate the short-term stability of slopes.

Objective

To determine the undrained shear strength (Cu) of find-grained soil.

Standart Reference

British Standard 1377 – Part 7: Shear strength tests (total stress)

ASTM D 2166 - Standard Test Method for Unconfined Compressive Strength of Cohesive Soil

Apparatus

1) Compression device with proving ring

2) Dial gauges

3) Sampling moulds and trimming equipments

Procedure

1) A specimen with 38mm diameter and 76mm height from the sampling moulds is prepared.

2) The specimen in the compression device is carefully placed and centered it on the bottom plate.

3) The device is adjusted so that the upper plate just makes contact with specimen and the load and deformation dials to zero.

4) The load is applied so that the device produces an axial strain at a rate of 0.5% to 2% per minute. The load and deformation dial readings is recorded on the data sheet at every 20 divisions on deformation dial.

5) The load is keep applied until i) the load decreases significantly, or ii) the loadholds constant for four continuous readings, or iii) the deformation exceeds 15% strain.

6) A sketch is drew to depict the sample failure.

7) The test procedures (2) to (6) is repeated for different water content of soil specimen.

Calculation

Own result (for w/c=23.9% and dry density=1.589g/cc

Sample Data

Initial Length, Lo = 76.68mm

Diameter, d = 37.53mm

Initial Area, Ao = πd2 ÷ 4

=3.1416×37.532 ÷4

= 1106.23 mm2 = 1.10623×10-3 m2

Volume, V = Ao × Lo

= 1106.23 × 76.68

= 84826.02 mm3 =84.826cm3

Moist Weight, Ww = 167g

Oven Dried Weight, Wod = 134.8g

Actual Dry Density = Wod ÷ V×103

= 134.8 ÷ 84826.02×10-3

= 1.589g/cc

Actual w/c = (Ww-Wod)/Wod×100%

= (167-134.8)/134.8×100%

= 23.9%

Air Void, e = (V-Vs)/Vs=(84.826-134.8⁄2.65)/(134.8⁄2.65)

=0.66757

Degree of Saturation, Sr = (γs×w)/e

= (2.65×0.239)/0.66757

=0.948

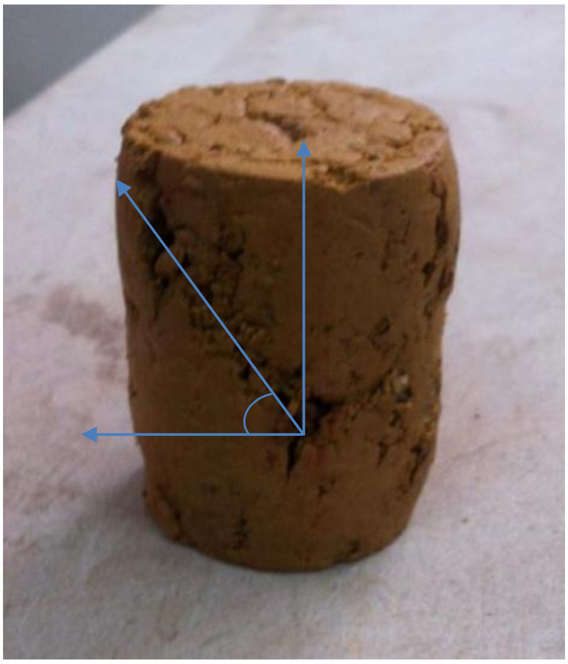
Data Tabulation

Axial Deformation, ΔL [1div=0.01mm]		Axial Force, P [1div=3.924N]		Strain, ε [$\Delta L/L_o$]	Corrected Area,A' (m^2) [$A_o/(1-\varepsilon)$]	Stress, σ (kN/m^2) [P/A']
Div	mm	Div	kN			
0	0.0	0	0.0000	**0.0000**	0.00000	**0.000**
20	0.2	5	0.0196	**0.0026**	0.00111	**17.690**
40	0.4	8	0.0314	**0.0052**	0.00111	**28.229**
60	0.6	11	0.0432	**0.0078**	0.00111	**38.714**
80	0.8	13	0.0510	**0.0104**	0.00112	**45.632**
100	1.0	15	0.0589	**0.0130**	0.00112	**52.514**
120	1.2	17	0.0667	**0.0156**	0.00112	**59.358**
140	1.4	19	0.0746	**0.0183**	0.00113	**66.166**
160	1.6	21	0.0824	**0.0209**	0.00113	**72.936**
180	1.8	23	0.0903	**0.0235**	0.00113	**79.670**
200	2.0	24	0.0942	**0.0261**	0.00114	**82.912**
220	2.2	26	0.1020	**0.0287**	0.00114	**89.580**
240	2.4	27	0.1059	**0.0313**	0.00114	**92.776**
260	2.6	29	0.1138	**0.0339**	0.00115	**99.380**
280	2.8	30	0.1177	**0.0365**	0.00115	**102.529**
300	3.0	31	0.1216	**0.0391**	0.00115	**105.660**
320	3.2	32	0.1256	**0.0417**	0.00115	**108.772**
340	3.4	32	0.1256	**0.0443**	0.00116	**108.476**
360	3.6	33	0.1295	**0.0469**	0.00116	**111.561**
380	3.8	34	0.1334	**0.0496**	0.00116	**114.627**
400	4.0	35	0.1373	**0.0522**	0.00117	**117.675**
420	4.2	36	0.1413	**0.0548**	0.00117	**120.704**
440	4.4	37	0.1452	**0.0574**	0.00117	**123.714**
460	4.6	38	0.1491	**0.0600**	0.00118	**126.706**
480	4.8	39	0.1530	**0.0626**	0.00118	**129.680**
500	5.0	40	0.1570	**0.0652**	0.00118	**132.635**
520	5.2	41	0.1609	**0.0678**	0.00119	**135.571**
540	5.4	42	0.1648	**0.0704**	0.00119	**138.490**
560	5.6	42	0.1648	**0.0730**	0.00119	**138.101**
580	5.8	43	0.1687	**0.0756**	0.00120	**140.991**
600	6.0	44	0.1727	**0.0782**	0.00120	**143.863**
620	6.2	45	0.1766	**0.0809**	0.00120	**146.716**
640	6.4	46	0.1805	**0.0835**	0.00121	**149.551**
660	6.6	47	0.1844	**0.0861**	0.00121	**152.367**
680	6.8	48	0.1884	**0.0887**	0.00121	**155.165**
700	7.0	49	0.1923	**0.0913**	0.00122	**157.944**
720	7.2	49	0.1923	**0.0939**	0.00122	**157.491**
740	7.4	50	0.1962	**0.0965**	0.00122	**160.243**
760	7.6	51	0.2001	**0.0991**	0.00123	**162.976**

780	7.8	51	0.2001	**0.1017**	0.00123	**162.504**
800	8.0	52	0.2040	**0.1043**	0.00124	**165.209**
820	8.2	53	0.2080	**0.1069**	0.00124	**167.896**
840	8.4	54	0.2119	**0.1095**	0.00124	**170.564**
860	8.6	54	0.2119	**0.1122**	0.00125	**170.064**
880	8.8	55	0.2158	**0.1148**	0.00125	**172.705**
900	9.0	56	0.2197	**0.1174**	0.00125	**175.327**
920	9.2	56	0.2197	**0.1200**	0.00126	**174.809**
940	9.4	57	0.2237	**0.1226**	0.00126	**177.403**
960	9.6	58	0.2276	**0.1252**	0.00126	**179.979**
980	9.8	58	0.2276	**0.1278**	0.00127	**179.442**
1000	10.0	59	0.2315	**0.1304**	0.00127	**181.990**
1020	10.2	59	0.2315	**0.1330**	0.00128	**181.444**
1040	10.4	60	0.2354	**0.1356**	0.00128	**183.964**
1060	10.6	60	0.2354	**0.1382**	0.00128	**183.409**
1080	10.8	61	0.2394	**0.1408**	0.00129	**185.902**
1100	11.0	61	0.2394	**0.1435**	0.00129	**185.337**
1120	11.2	62	0.2433	**0.1461**	0.00130	**187.802**
1140	11.4	62	0.2433	**0.1487**	0.00130	**187.228**
1160	11.6	63	0.2472	**0.1513**	0.00130	**189.665**
1180	11.8	63	0.2472	**0.1539**	0.00131	**189.082**
1200	12.0	64	0.2511	**0.1565**	0.00131	**191.492**
1220	12.2	65	0.2551	**0.1591**	0.00132	**193.882**
1240	12.4	65	0.2551	**0.1617**	0.00132	**193.281**
1260	12.6	66	0.2590	**0.1643**	0.00132	**195.644**
1280	12.8	66	0.2590	**0.1669**	0.00133	**195.033**
1300	13.0	67	0.2629	**0.1695**	0.00133	**197.368**
1320	13.2	67	0.2629	**0.1721**	0.00134	**196.749**
1340	13.4	67	0.2629	**0.1748**	0.00134	**196.129**
1360	13.6	67	0.2629	**0.1774**	0.00134	**195.509**

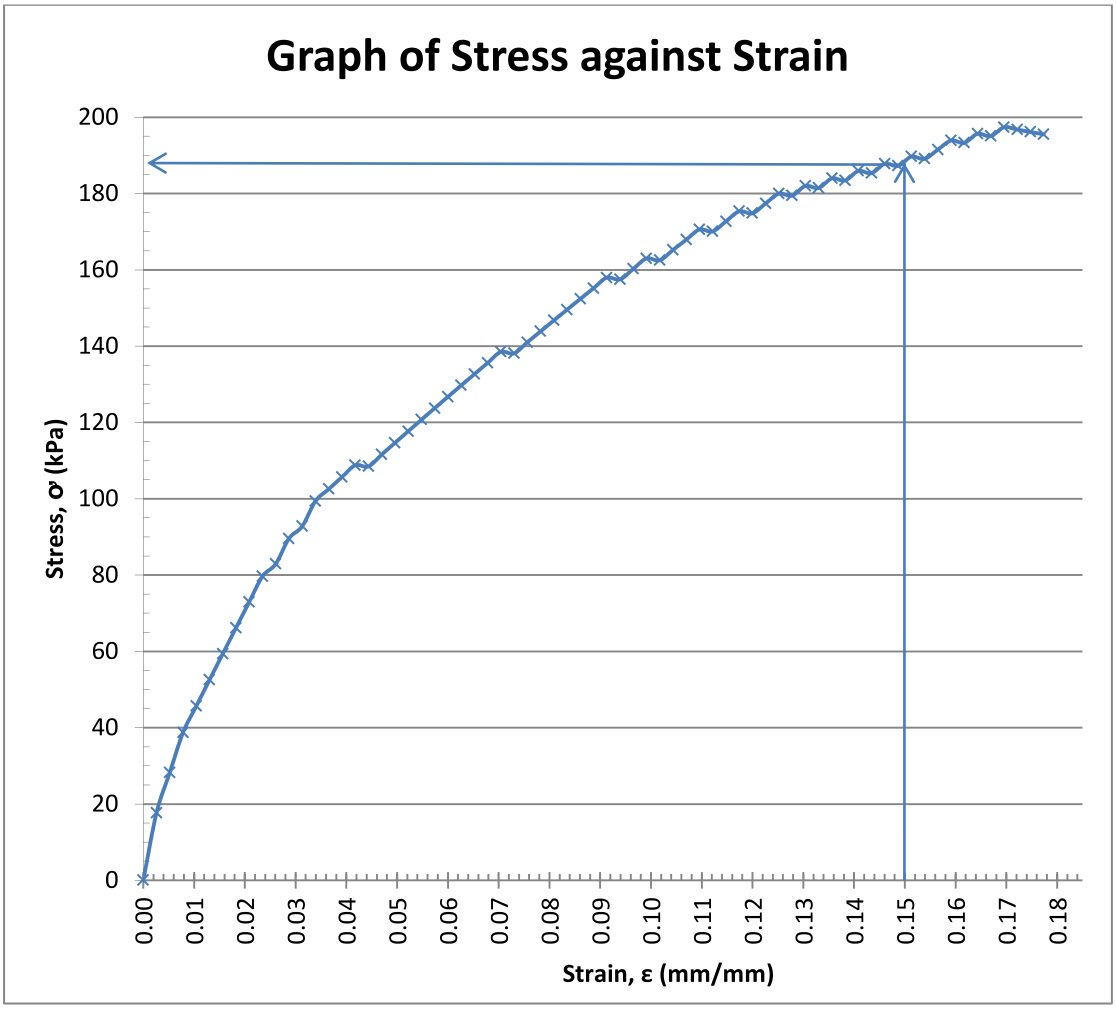
Failure Mode

The angle of failure plane occurred at 63° to the horizontal.



Test Results Plotting

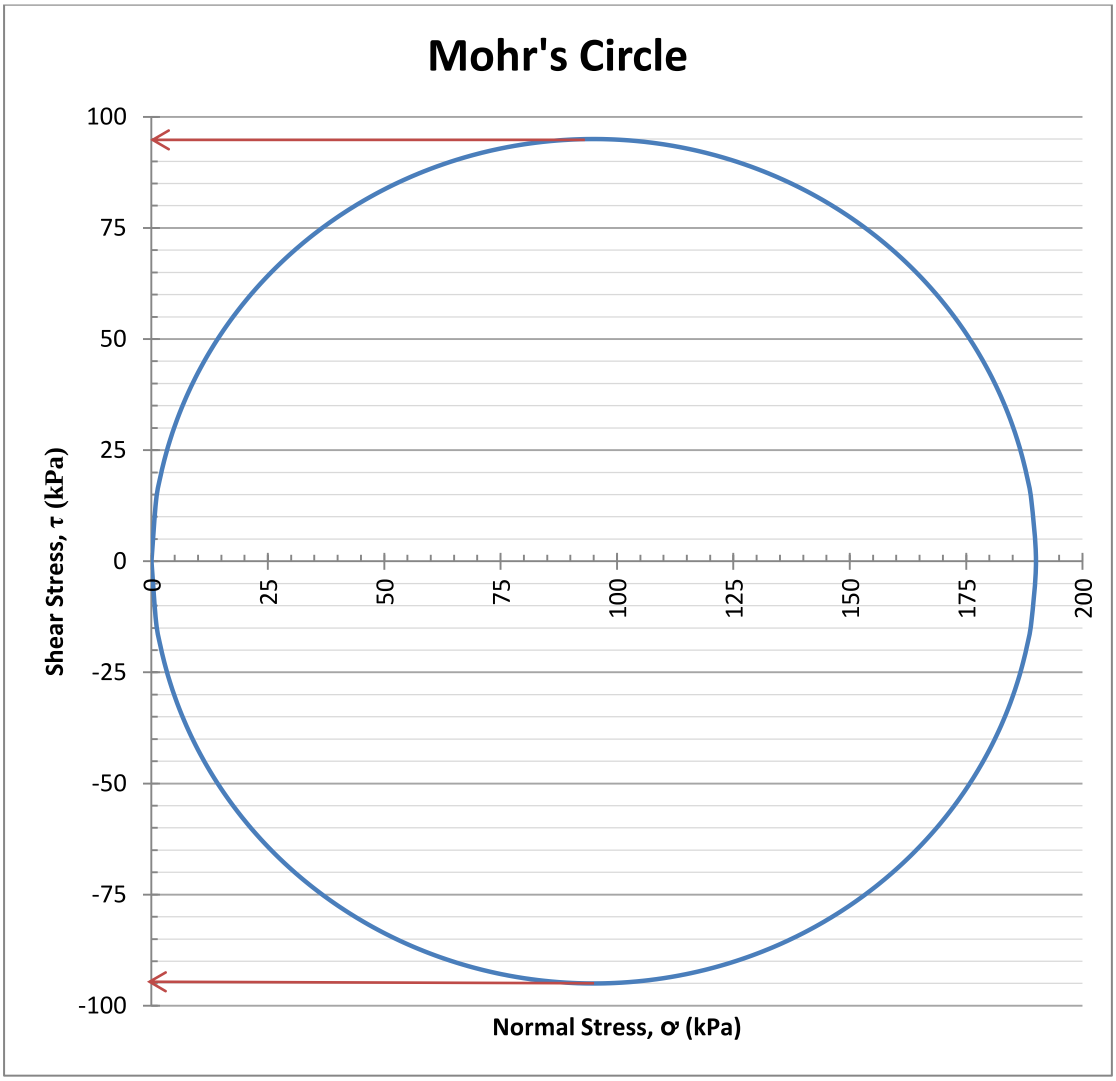
Graph of stress against strain



The unconfined compressive strength (q_u) of the fine-grained soil can be obtained from the graph of stress against strain. While the load per unit area at 15% axial strain,

q_u = 188 kPa

Mohr’s circle of the soil in specimen



From the graph, the maximum undrained shear strength is 95kPa.

From calculation:

cu = qu/2

= 188÷2

= 94kPa

Group Results (different water content and dry density)

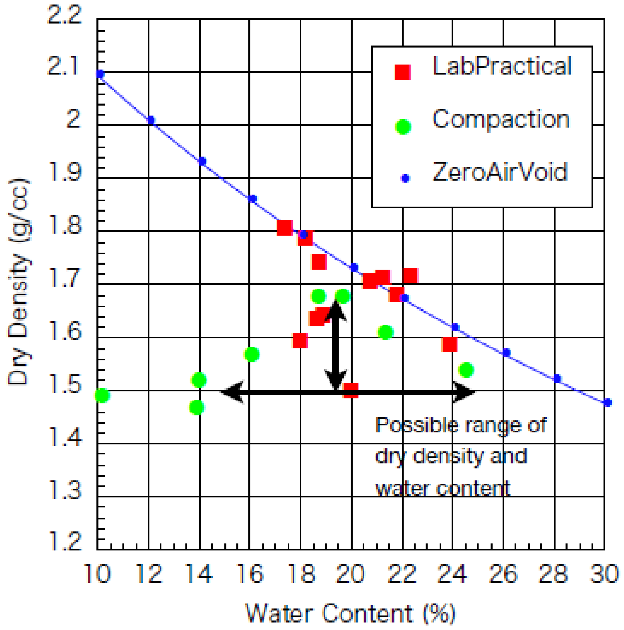
Preliminary results of Unconfined compression test for different w/c content and dry density.

Group	w/c	Dry Density	q_u (kPa)	Sr
3011	17.4	1.807	913	0.988
3012	18.2	1.788	787	1.00
3021	21.8	1.683	207	1.01
3022	20.00	1.500	329	0.691
3031	18.00	1.593	557	0.719
3032	23.9	1.589	190	0.948
3041	18.9	1.642	130	0.816
3042	18.64	1.638	560	0.800
2011	22.34	1.717	125	1.09
2012	20.75	1.708	286	0.997
2021	18.74	1.744	629	1
2022	21.25	1.715	79	1.03

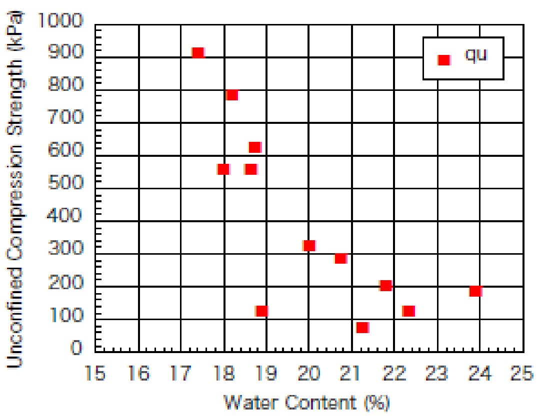
The compaction test results for the different w/c content and dry density under the same compactive effort.

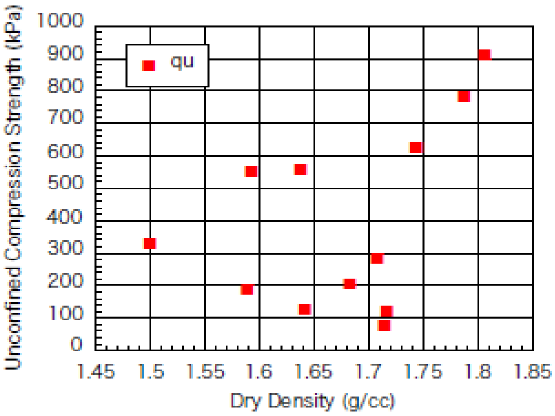
Compaction Test Results	
w/c (%)	Dry Density
10.16	1.49
13.87	1.47
13.97	1.52
16.06	1.57
18.68	1.68
19.63	1.68
21.33	1.61
24.5	1.54

Graph of the relationship of dry density and water content from compaction test, the unconfined compression test result, and the zero air-void line.

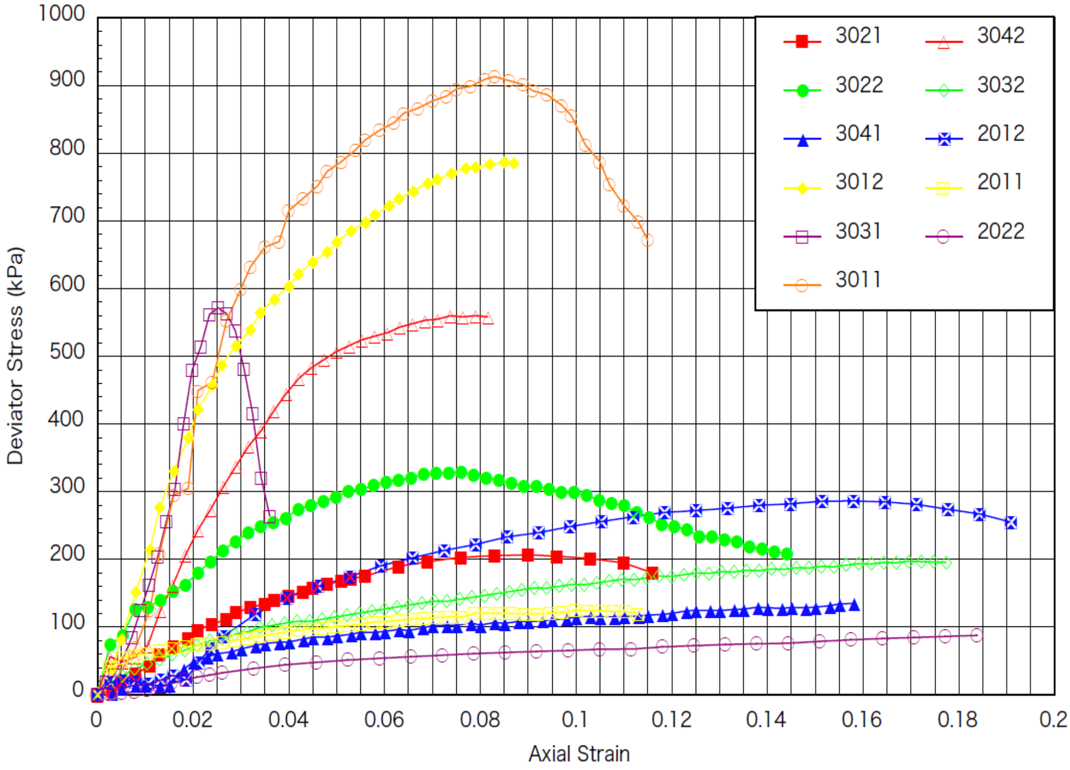


The graph of unconfined compression strength, qu against water content and against dry density respectively.





Graph of stress against strain with different w/c content and dry density



Discussion

From the graph of stress against strain , when the load per unit area at 15% axial strain, it gives qu = 188kPa. Thus, unconfined compressive strength of the fine-grained soil is 188kPa. The undrained shear strength is given by,

$$\mathbf{c}\mathrm{u} = \frac{\boldsymbol{\sigma}1}{2} = \frac{\mathbf{q}u}{2} = \frac{188}{2} = 94\mathrm{kPa}$$

The Mohr's Coulomb failure criterion is used to determine the failure criterion of soils. According to Mohr's Coulomb theory, the relationship between the normal stress on any plane and the shearing strength exists on the plane is assumed to be linear,

$s = c + \sigma \tan \phi$

where,

c= apparent cohesion

ϕ= angle of shearing resistance

For unconfined compression test,

$$\sigma 1 = 2c \tan(45° + \frac{\phi}{2})$$

$$\alpha = 45° + \frac{\phi}{2}$$

When ϕ=0 (saturated soil),

$$\alpha = 45°$$

The actual angle of failure plane however occurs at 63° instead of 45°. This is due to the assumption of ϕ=0 which means the specimen is fully compacted with zero air void. This is impossible to be achieved and hence the deviation of 18°for the theoretical and actual angle of failure plane.

Group results

The table below shows an overall results for unconfined compressive strength of each specimen with different water content and dry density.

Group	w/c	Dry Density	q_u (kPa)	Sr
3011	17.4	1.807	913	0.988
3012	18.2	1.788	787	1.00
3021	21.8	1.683	207	1.01
3022	20.00	1.500	329	0.691
3031	18.00	1.593	557	0.719
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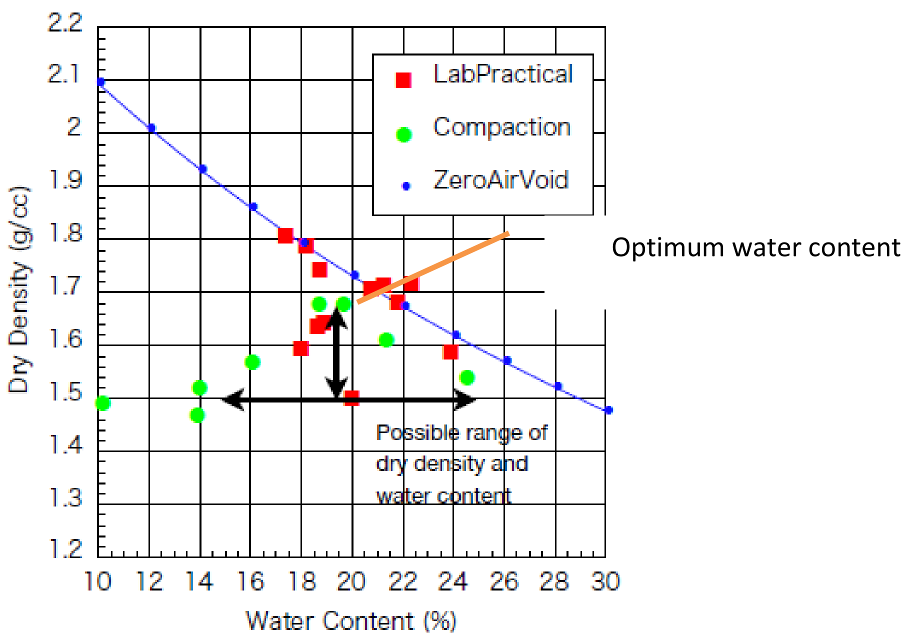
2011	22.34	1.717	125	1.09
2012	20.75	1.708	286	0.997
2021	18.74	1.744	629	1
2022	21.25	1.715	79	1.03

The compaction test is to determine the maximum dry density that can be achieved for a given soil when compacted with standard amount of compactive effort. When a series of soil samples with different water content are compacted , the peak indicates the maximum dry density and the maximum dry density gives optimum water content. The highest green dot which is the maximum dry density(1.68g/cc) occurs at an optimum water content of 19.16%.



In real world engineering practice, the minimum allowable dry density must be at least 90% of the theoretical maximum dry density. Hence for the compacted fill with the soils tested must have achieved at least dry density of 1.5g/cc and the maximum value of 1.68g/cc. Correspondingly, the water content ranged between 15 to 25% approximately.

With the reference of compaction test results , only certain groups such as 3031, 3022,3041, 3042 achieve the acceptable range of water content and dry density .

Compaction Test Results	
w/c (%)	Dry Density
10.16	1.49
13.87	1.47
13.97	1.52
16.06	1.57
18.68	1.68
19.63	1.68
21.33	1.61
24.5	1.54

Group	**3022**	**3031**	**3041**	**3042**
Water Content (%)	20	18	18.9	18.64
Dry Density (g/cc)	1.500	1.593	1.642	1.638
q_u (kPa)	329	557	130	560
Degree of Saturation, Sr	0.691	0.719	0.816	0.800

Precautions have to be taken during the unconfined compression test. Extra be careful while cutting the soil sample, cut the soil sample to the desire length gently to prevent the soil sample from cracking. During the trimming process, make sure the degree of smoothness of the surface of the soil sample is even. Uneven smoothness will affect effect of compaction.

Conclusion

For our own results, the unconfined compressive strength,q_u is 188kPa and undrained shear strength, c_u is 94kPa when water content is 23.9%, dry density is 1.589g/cc, and degree of saturation is 0.948. The angle of failure plane is 63°.Meanwhile for group results, the design unconfined compressive strength, q_u is 560kPa with optimum water content of 18.64% and optimum dry density of 1.638g/cc.

References

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3. Undrained and drained shear strength. Retrieved October 22, 2002. Retrieved from http://www.scribd.com/doc/25011305/Undrained-and-Drained-Shear-Strength