3D1 Geotech Engineering: Soil Classification Lab Report

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Summary

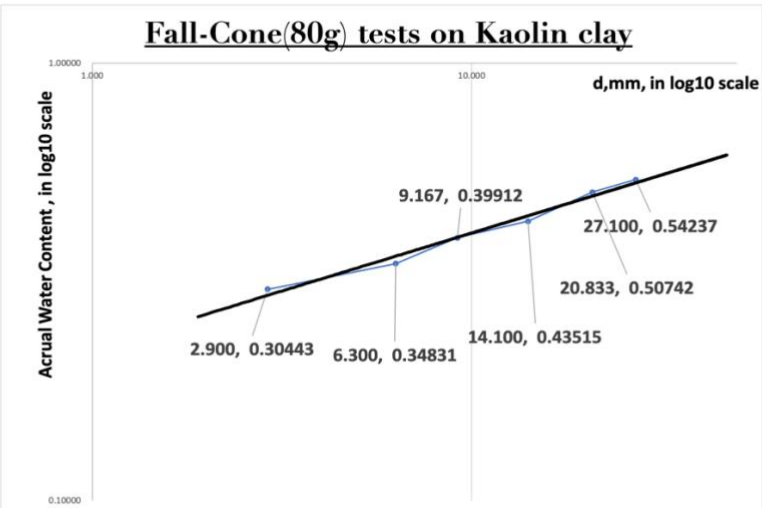
The aim of this experiment is to conduct standardised BS 1377-2:1990 liquid limit and plastic limit on Bentonite clay and Kaolinite clay; and thereby to classify those two types of cohesive soils in terms of the water contents they hold at the limits of their range of plastic behaviour. And from those investigations to determine the basic characteristics of Bentonite and Kaolinite.

Background

Plastic limit W_P, liquid limit W_L (Atterberg limits), are basic measures of the critical water contents of a fine-grained soil (clays and silts). Clays and silts interact with water and thus change sizes and having varying shear strength. And therefore, laboratory tests on W_P and W_L are important in preliminary design stages of any structure to ensure the soil have required engineering properties; such Atterberg limits are also used to distinguish between silt and clay, and between different types of silts and clays.

Batches of Bentonite clays of nominal water contents 110,125,140, 155 and 170% and Kaolinite clay of water contents 35, 40, 45, 50 and 55% are tested for liquid limit W_L with BS 1377-2:1990 standardised cone penetrometer; with Kaolinite clay of water contents ***w*** of 35, 40 and 45% also tested by non-standard 240g cone.

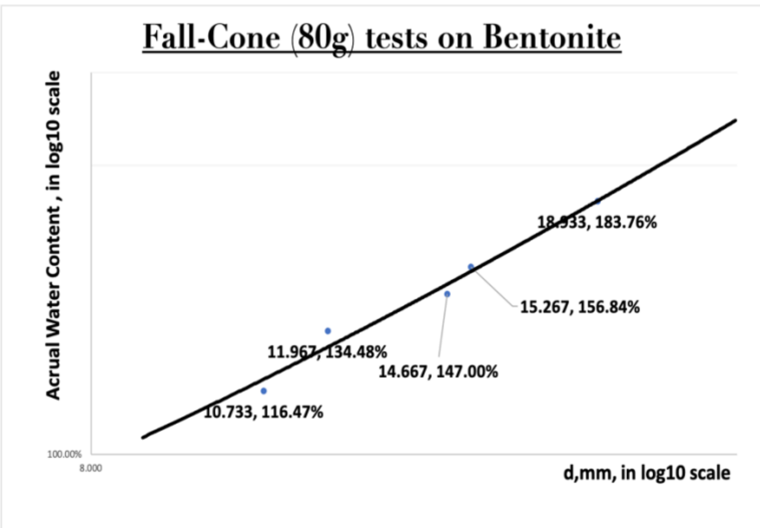
Result

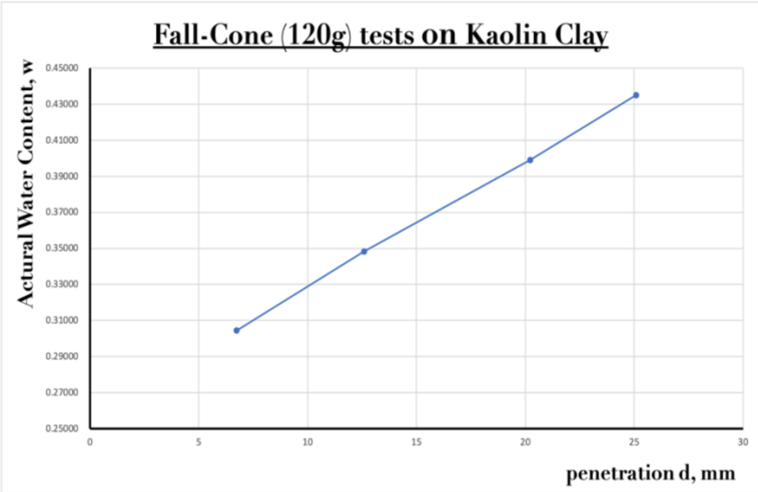


By calculating the corresponding water contents ***w*** at penetration ***d***=20mm on the trendline:

$W_{L,\text{Kaolinite}} = 0.4913$

$W_{L,\text{Bentonite}} = 1.9212$





By averaging actual water contents ***w*** of 5 Bentonite samples and 4 Kaolin samples, it resulted:

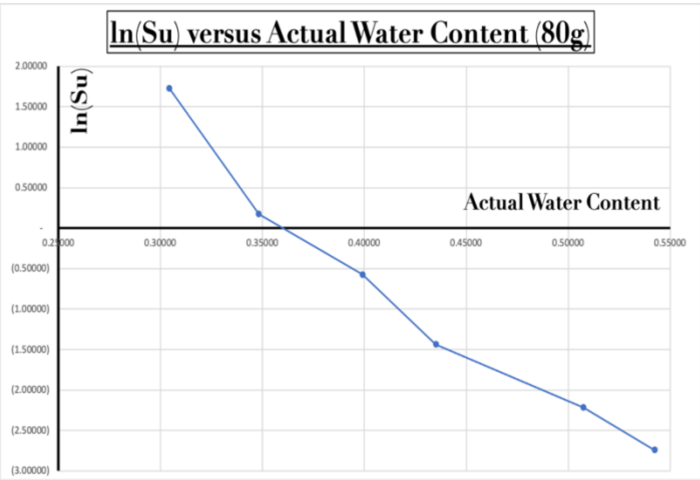
$W_{P,\text{Kaolinite}}$ = 29.99%

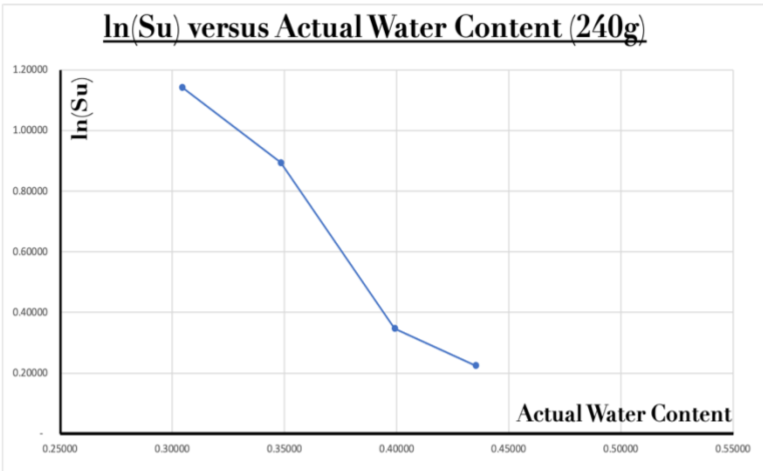
$W_{P,\text{Bentonite}}$= 44.38%

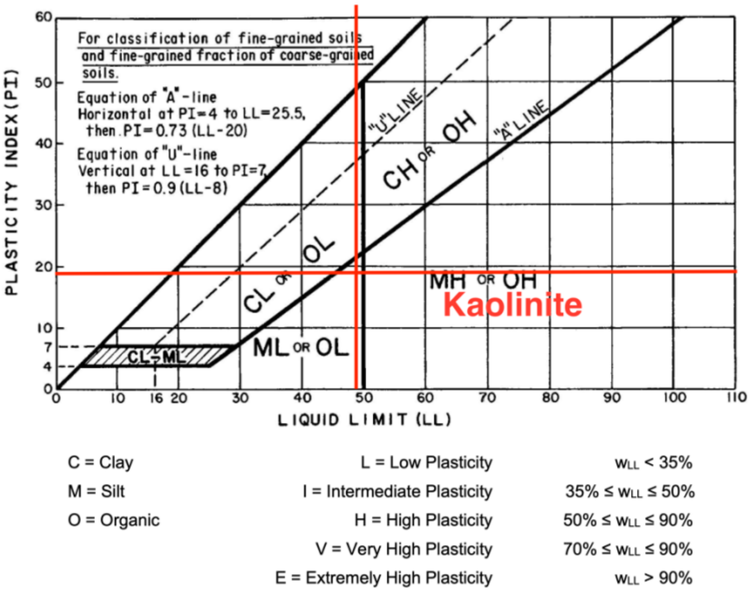
Plasticity index, I_P=W_L-W_P

$I_{P,\text{Kaolinite}}$ = 0.1914

$I_{P,\text{Bentonite}}$= 1.4774







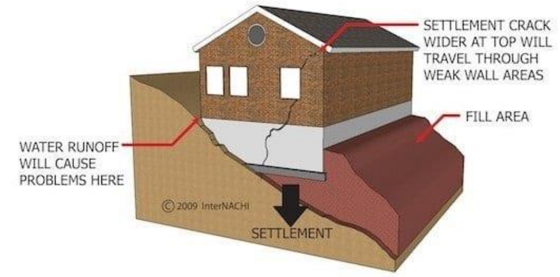
It can be plotted on the graph that Kaolinite is below the "A" Line ($I_{P,\text{Kaolinite}}$19.14<21.26), and therefore Kaolinite is classified as ML (Low Plasticity Silt).
Bentonite is not within the range of the graph, but it can be calculated (165.71>$I_{P,\text{Bentonite}}$ 147.74>125.65) that, Bentonite is in between the "A" Line and the "U" Line, therefore Bentonite is classified as CH (High Plasticity Clay).

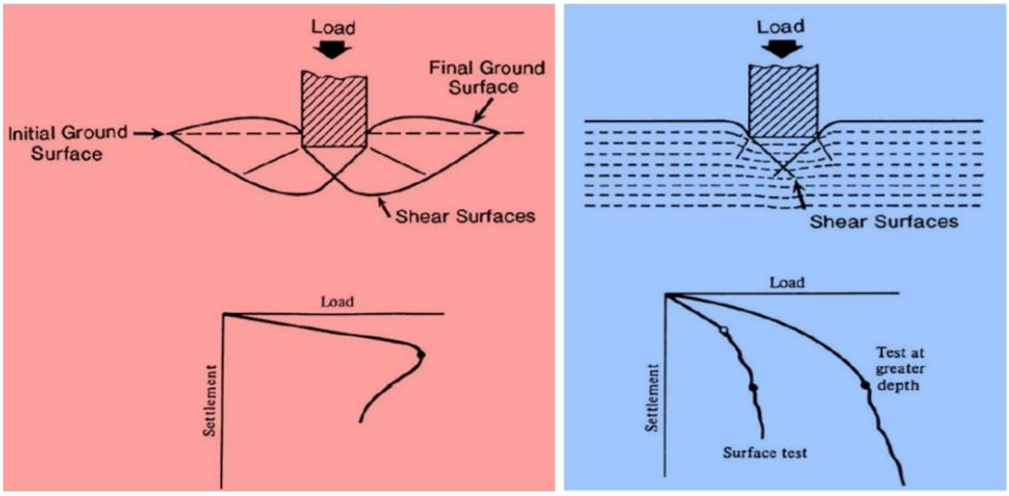
Undrained shear strength ***Su***, of the clay is potentially 1 at the liquid limit.

Discussion

Atterberg limit tests can be used as a guideline to indicate the likelihood of a ground base to consolidate (ground settlement) when under load. For example, if the soil water content is

close to its Liquid Limit W_L around an excavated space (such as for tunnels, basements or shafts), a lot of ground settlement (downward movement of the ground) can be expected if a structure is built above; and for soil with water content close to its Plastic Limit $W_P$the opposite is true.
Therefore, we can recognise a weak bearing soil through the Atterberg limit tests.





A general shear failure (Left, red) occurs for soils that are in a dense or hard state. (e.g., a heavily compacted clay with water content ***w*** below plastic limit I_P, therefore is brittle)
A punching shear failure (Right, blue) occurs for soils that are in a loose or soft state. (e.g., a highly plastic clay with high water content ***w*** close to its liquid limit I_L)

Atterberg limits aren't suitable for natural clayey soils which contain modest proportions of coarse sand and gravel. Because cohesionless (free-running type) coarse soils such as gravel and sands are classified by particle size analysis by using a nest of sieves. (coarse sand and gravel solids do not stick together, whose strength mainly depends on friction between solid particles)

Appendix

Water contents

Kaolin

nominal wc	Container	Empty weight	Weight with wet soil	Weight with dry soil	evaporated water weight	Actual Water Content	ln(Su) (80g)	ln(Su) (240g)
Powder								
30%	b8	2.6	28.78	22.67	6.11	0.30443	1.72788	1.14177
35%	G2	2.61	3.81	3.5	0.31	0.34831	0.17620	0.89451
40%	G7	2.59	5.78	4.87	0.91	0.39912	(0.57385)	0.34689
45%	C7	2.6	9.46	7.38	2.08	0.43515	(1.43505)	0.22541
50%	G5	2.61	7.69	5.98	1.71	0.50742	(2.21581)	
55%	D4	2.59	18.97	13.21	5.76	0.54237	(2.74177)	
60%								
65%								

Bentonite

nominal w.c.	Container	Empty weight	Weight with wet soil	Weight with dry soil	actual water content	
Powder						
110	B6	2.59	4.43	3.44	0.99	116.47%
125	A8	2.62	4.66	3.49	1.17	134.48%
140	C1	2.59	10.42	5.76	4.66	147.00%
155	H1	2.61	7.49	4.51	2.98	156.84%
170	B4	2.61	8.69 ?		#VALUE!	#VALUE!
180	E3	2.6	5.92	3.77	2.15	183.76%

Bentonite PL samples

1	C8	2.61	5.69	4.74	0.95	44.60%
2	G9	2.62	4.52	3.92	0.6	46.15%
3	D7	2.66	3.89	3.51	0.38	44.71%
4	C6	2.6	5.06	4.28	0.78	46.43%
5	H7	2.6	5.35 ?		#VALUE!	#VALUE!
6	A7	2.59	4.13	3.69	0.44	40.00%

Kaolin PL samples

1	D1	2.58	5.46	4.81	0.65	29.15%
2	H9	2.62	4.73	4.24	0.49	30.25%
3	E1	2.6	8.33	6.99	1.34	30.52%
4	D2	2.67	5.05	4.5	0.55	30.05%

Fall cone 80g

penetration in mm

test no	1	2	3	avg
	2.7	2.8	3.2	2.900
	6	6.3	6.6	6.300
	9.8	8.2	9.5	9.167
	15.2	14.3	12.8	14.100
	19.5	20.6	22.4	20.833
	30	26.2	25.1	27.100
	10.8	10.9	10.5	10.733
	12.2	12.2	11.5	11.967
	14.9	14.4	14.7	14.667
	16.2	15.4	14.2	15.267
	17.2	16.8	16.8	16.933
	19.6	18.4	18.8	18.933

Fall cone 240

1	2	3	avg
6.9	6.7	6.6	6.733333
12.3	12.5	13	12.6
20.2	19.8	20.7	20.23333
25.2	24.8	25.3	25.1