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Configurating of Plastic Index and Liquid Limit for calcareous soil

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Abstract

When light soils get moisture there occurs a cohesive force. At extreme low moisture the soil acts as a solid while at high levels the mix flow like a liquid. Atterberg, a Swedish scientist, created a way to define the consistency of such soils with changing moisture concentrations in the early 1900s. At extreme low moisture, the soil acts more like a solid when the moisture content is very low. The behavior of soil can be arbitrarily categorized into four fundamental states: solid, semisolid, plastic, and liquid depending on the moisture concentration. When the moisture content is sufficiently high, the soil and water may flow like a liquid. The shrinkage limit is determined by the percentage of moisture at which a solid becomes a semisolid. The plastic limit and liquid limit are the moisture contents at the transition points from semisolid to plastic and from plastic to liquid, respectively. "The Atterberg Limits" are all such parameters.

Key words: calcareous soil, shrinkage limit, plastic index.

Introduction

Soils and rocks are natural materials. Soil is not a continuous mass and contains solid, liquid, and gaseous phases, and these three phases. Assessment of soils is done by many methods. Phase diagrams, such as those shown in ***Figure*** -1 indicate the relative proportions of solids, water, and air in a soil. The weights or masses of the three components are depicted on the left side of the diagram, while their volumes on the right side.

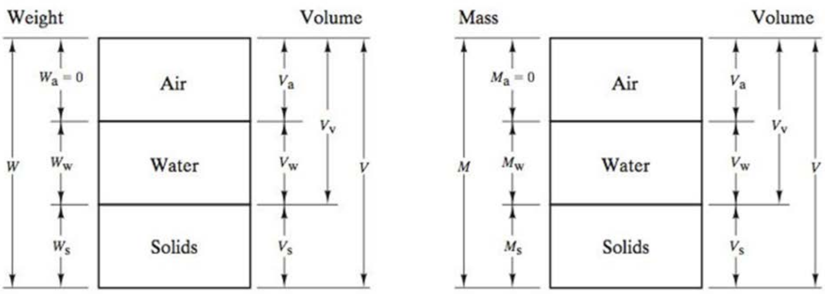

Figure -1: Description of soil. The relative proportions of solids through, water, and air in a soil.

PARTICLE SIZE AND SHAPE

Soil solid has different shapes. Liquid and plastic limits are determined by laboratory tests. Casagrande (1932) stated that plasticity is important by the equation

$$PI = 0.73(LL - 20) \qquad \text{Eqn. (1)}$$

A-line separates the clays from the silts. Clay lies above the *A*-line, and silts lie below it. The information provided in the plasticity chart is important. A line called the *U*-line lies above the *A*-line. The *U*-line is the upper limit of the of the plasticity index to the liquid limit. The equation for the *U*-line can be given as:

$$PI = 0.9(LL - 8) \quad \text{Eqn. (2)}$$

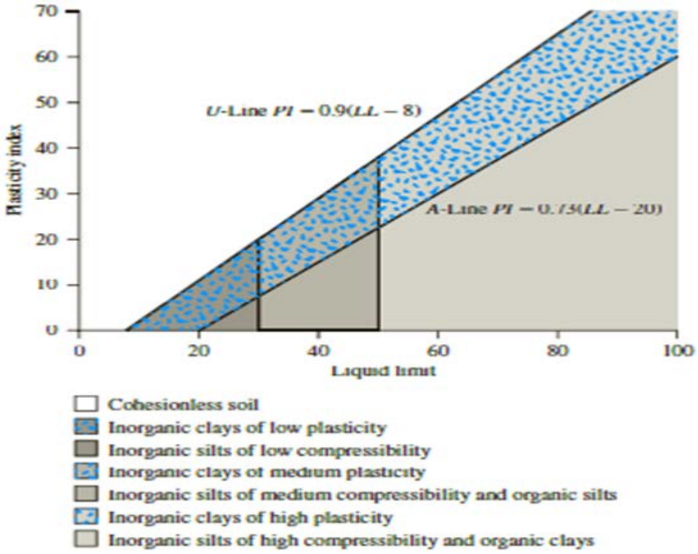

Figure-2 Plasticity chart

Plasticity and the Atterberg Limits

Classification distinguishes between silts and clays. When the consistency of a soil changes from hard and rigid to soft and, clays can be very plastic and silts only slightly plastic.

The Atterberg Limits

Atterberg (1846–1916) developed tests to assess the relationship between moisture and soil. Terzaghi and Casagrande (1930) adapted these tests. The tests include three laboratory tests: the ***liquid***, the ***shrinkage limit*** (SL), and the ***plastic limit*** which are referred to (ASTM D4318 for liquid and plastic limits and D427 for shrinkage limit). The moisture content corresponding to a cone penetration of d = 20 mm is the plastic limit.

Figure -3 illustrates the Cambridge Gault clay's liquid and plastic limit determination as stated by Wroth and Wood (1978). Table -1-a gives the ranges of liquid limit, plastic limit, and activity of some clay minerals (Mitchell, 1976; Skempton, 1953). The plastic limit is the lower limit of the plastic stage of soil.

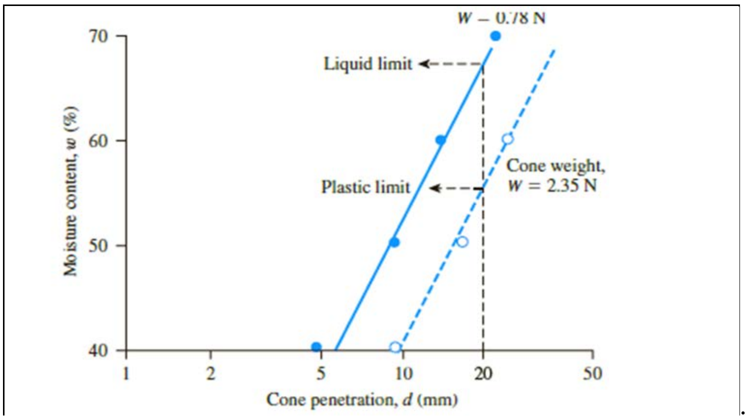

Figure 3: The fall cone test is performed to determine the Cambridge Gault clay's liquid and plastic limits.

Table -1(a, b, c): The Liquid Limit, Plastic Limit, and Activity of Some Clay Minerals at Typical Values

1 (a) Typical Values of Liquid Limit, plastic Limit, and Activity of Some Minerals				1 (b) The plasticity index in a qualitative manner		1 (c) Typical values of shrinkage limit for some clay minerals	
Mineral	Liquid Limit LL	Plastic Limit, PL	Activity, A	PI	Description	Mineral	Shrinkage limit
Kaolinite	35–100	20–40	0.3–0.5	0	Nonplastic	Kaolinite	25–29
Illite	60–120	35–60	0.5–1.2	1–5	Slightly plastic	Illite	15–17
Montmorillonite	100–900	50–100	1.5–7.0	5–10	Low plasticity	Montmorillonite	8.5–15
Halloysite (hydrated)	50–70	40–60	0.1–0.2	10–20	Medium plasticity		
Halloysite (dehydrated)	40–55	30–45	0.4–0.6	20–40	High plasticity		
Attapulgite	150–250	100–125	0.4–1.3	0.4	Very high plasticity		
Allophane	200–250	120–150	0.4–1.3				

The ***liquid limit*** (*LL*) is moisture content where behavior of clay soil changes from ***plastic*** to ***liquid*** . Transition from plastic to liquid is gradual, and the ***shear strength*** of the soil is not actually zero at the liquid limit. Plasticity is the difference between the liquid limit and the plastic limit

$$PI = LL - PL$$

Eqn (3)

The plasticity index was classified qualitatively by Burmister (1949), as indicated in Table 1-b.

The plasticity index is important in classifying fine-grained soils. It is fundamental to the Casagrande plasticity chart, which is currently the basis for the Unified Soil Classification System. The ***plasticity index***, **PI**, or I_P, is a measure of the range of moisture contents that encompasses the plastic state:

$I_P = \omega_L - \omega_P$ Eqn (4)

When light soil is at a moisture between moisture of its liquid and plastic limits, it is in a plastic state. In this state, the soil can be easily molded without cracking or breaking. This property relates to the amount and type of clay in the soil.

A soil sample's natural water content is scaled to the maximum using the liquidity index (LI). It can be estimated as a ratio of the difference between the plastic and liquid limits and the natural water content: Since W is the natural water content, LI=(W-PL)/(LL-PL).

Soils of high clay contents retain this plastic state over a wide range of moisture contents, and thus have high plasticity index. When a light soil is at a moisture content between plastic and shrinkage, they are in semisolid states. In this state, the soil cracks when it deforms.

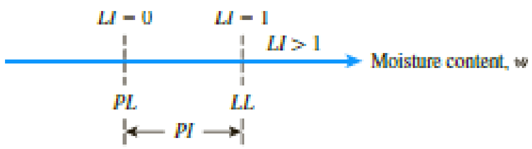

Figure4: L liquidity index

The consistency index (*CI*) indicates 'firmness'. It is calculated as $CI = (L_L - W)/(L_L - P_L)$, where W is the existing water content. Soil at the liquid limit will have a consistency index of 0, while soil at the plastic limit will have a consistency index of 1 and *if* $W > L_L$, CI is negative. That means soil is in a liquid state. Moreover, sum of Liquidity index and Consistency index equal to 1 (one) since w = *in situ* moisture content. If w is equal to the liquid limit, the consistency index is zero. Again, if w = *PL*, then *CI* = 1, as shown in Figure (4).

Methodology

Fall cone method

The fall cone method is a common way to determine liquid limits in Europe and Asia. (British Standard—BS1377). A semilogarithmic graph can then be plotted with moisture content (w) versus cone penetration d. The plot results in a straight line. The moisture content corresponding to d = 20 mm is the liquid limit. From the flow index can be defined as:

$$I_{FC} = \frac{W_2\,(\%) - W_1\,(\%)}{\log d_2 - \log d_1} \qquad \text{Eqn. (5)}$$

where ω_1, ω_2 = moisture contents at cone penetrations of d_1 and d_2, respectively. As in the case of the percussion cup method (ASTM 4318), attempts have been made to develop the estimation of liquid limit by a one-point method. They are

$$LL = \frac{w}{0.77\,\log d} \qquad \text{Eqn. (6)}$$

$$LL = \frac{w}{0.65+0.175d} \quad \text{Eqn. (7)}$$

Feng (2001) developed a formula between LL, ω, and d as follows:

$$LL = w\left(\frac{20}{d}\right) \quad \text{Eqn. (8)}$$

where w (%) is the moisture content for a cone penetration d (mm) falling between 15 mm to 25 mm. Feng (2001) has given the following correlation between the liquid limits determined according to ASTM D4318 and British Standard BS1377.

$$LL_{(BS)} = 2.6 + 0.94\left[LL_{(ASTM)}\right] \quad \text{Eqn. (9)}$$

Three to four tests at varying moisture contents of soil are conducted, and the corresponding cone penetrations (d) are determined. The moisture content corresponding to a cone penetration of d = 20 mm is the plastic limit. Figure-3 shows the liquid and plastic limit determination of Cambridge Gault clay reported by Wroth and Wood (1978). Table 1-a gives the ranges of liquid limit, plastic limit, and activity. By using Table 1-a which gives the ranges of liquid limit, plastic limit, and activity. Using Table-1 b calculate plastic Index PI, by using the relation

PI= LL- PL *Eqn (10)*

Shrinkage limit tests are performed in the laboratory with a porcelain dish about 44 mm in diameter and about 12.7 mm high. The inside of the dish is coated with petroleum jelly and is then filled completely with wet soil. Excess soil standing above the edge of the dish is struck off with a straightedge. The mass of the wet soil inside the dish is recorded. The soil pat in the dish is then oven-dried. The volume of the oven-dried soil pat is then determined. The shrinkage limit can be determined as, SL = ωi (%)-Δ ω (%), since, ωi = initial moisture content when the soil is placed in the shrinkage limit dish, and Δω= change in moisture content (that is, between the initial moisture content and the moisture content at the shrinkage limit)

Δω (%) = ([(Vi - Vf) ρw])/M2) x 100
Eqn (11)

Since,

V i = initial volume of the wet soil pat (that is, inside volume of the dish, cm^3

V f = volume of the oven-dried soil pat (cm3)

ρ w = density of water (g/cm^3)

Finally, combining Eqs. (6), (7), and (8) gives:

SL= ([(Mi-M2)/M2]) x (100) – ([(Vi-Vf)/M2]) x ρw x (100)) Eqn (12)

Result and discussion

ILLUSTRATIVE APPLICTION FOR DEVELOPING ACTIVITIES

Steps of calculation

1- Calculate Liquid Limit and Plastic Limit for U-line PI = 0.9(LL-8), and A-Line PI = 0.73(LL-20) for Plastic indices shown in Table 2, since as an example, substitute PI=10 in equation of U -line PI=0.9(LL-8). Then 10= 0.9(LL-8), then LL= 9.1111. Repeating this also for A-Line PI=0.73(LL-20). Then 10= 0.73(LL-20), then LL=-0,64888, and so on for all PI shown in table.

2- Plot and draw a chart that x-axis express the Liquid Limit LL and y-axis as Plastic index PI. The chart diagram is illustrated in Figure 5.

3- Plot and draw the data points of soil, and derive the equation of this points by regression analysis which result the equation PI- Soil Line= 07312(LL-8.7329), with R^2=1.

4- Determine and calculate the intersection point of U-Line PI= 0.9(LL-8), and A-Line PI = 0.73(LL-20), which its result is (-43.52941176-46.37647). The method of calculation as follows:

(U Line) = 0.9X(LL-8)

(A Line) = 0.73X(LL-20)

At intersection of U-Line & A-line: 0.9(LL-8) = 0.73(LL-20), Then: 0.9(LL) - 0.73(LL)= (-0.73*20+ 0.9*8)

The resulting Liquid Limit (LL) is -43.52941176. Substituting the resulted LL in any of the two equations it will result that PI = (-46.37647059). then the coordinate intersection point is (-43.52941176 - 46.37647).

5- Calculate and determine the intersection between U-Line and Soil Sample -Line, which their equations are u-Line PI= 0.9X(LL-8), and Soil -Line Pi= 0.7132*LL-8.3729.

At inter section of U-Line & Soil Line Set Eqn. (1), Then: 0.9(LL-8) = 0.7132 (LL-8.3729), Then: 0.9X(LL-8) = 0.7132*LL-8.3729 The resulting Liquid Limit (LL) is -6.27997859. Substituting the resulted LL in any of the two equations it will result that

PI =-12. 85198. Then the coordinate intersection point is (-6.27997859-12.85198).

6- Figure 5 illustrates the result of Plastic index and Liquid Limit chart of Soil sample and U-Line and A-line, which it is noticed that it lies between them.

7- As illustrated in table 3: it is noticed that S-oil Line lies between U-PI Line and A-Line.

Conclusion of Shrinkage Limit:

1- Calculate and plot the Plastic Index and Liquid Limit for every record A-Line PI=0.73(LL-20) and U-Line PI=0.9(LL-8).

2- Plot also the soil data (PI and LL).

3- Calculate and determine the intersection point of U-Line and A-Line.

4- The intersection point between the soil data line and a straight line, which intersects the liquid limit axis at a location that denotes an approximation of the shrinkage limit (SL), as shown in the diagram below.

5- To determine the Shrinkage limit graphically, Join the point of intersection to intersection of soil data line with a straight line, which intersection the liquid limit axis at a point that indicate the Shrinkage Limit (SL) approximate estimate.

Table 2. Given data of soil required to calculate and determine Shrinkage Limit (SL) of the soil.

Sample No.	(Sand)	(Silt)	(Clay)	Texture	Liquid limit % (LL)	Plastic limit % (LL)	Plasticity Index (PI)	Shrinkage limit (SL)	Plasticity Index (PI)
1	53.2	26.9	19.9	Sandy Clay	37.86	19.23	18.63	10.07	18.632
2	53.2	26.9	19.9	Sandy Clay	37.86	19.23	18.63	10.07	18.632
3	62.6	19	18.4	Sandy Clay	36.86	18.95	17.92	9.75	17.917
4	65.6	14.5	19.9	Sandy Clay	37.04	19	18.05	9.81	18.047
5	62.6	15.8	21.6	Sandy Clay Loam	37.68	19.18	18.5	10.01	18.502
6	43.8	34.6	21.6	Loam	38.96	19.55	19.41	10.41	19.413
7	46.9	30	23.1	Loam	39.05	19.57	19.48	10.44	19.478
8	56.3	25.3	18.4	Sandy Clay	37.32	19.08	18.24	9.89	18.242
9	53.2	25.2	21.6	Sandy Clay Loam	38.32	19.36	18.96	10.21	18.957
10	50	25.4	24.6	Sandy Clay Loam	39.05	19.57	19.48	10.44	19.478
11	56.3	25.3	18.4	Sandy Loam	37.32	19.08	18.24	9.89	18.242
12	59.5	22.1	18.4	Sandy Loam	37.04	19	18.05	9.81	18.047
13	65.9	14.2	19.9	Sandy Loam	37.04	19	18.05	9.81	18.047
14	68.9	12.7	18.4	Sandy Loam	36.41	18.82	17.59	9.61	17.592
15	75.4	6.2	18.4	Sandy Loam	36.04	18.71	17.33	9.49	17.331
16	70.5	11.1	18.4	Sandy Loam	36.04	18.71	17.33	9.49	17.331
17	51.5	25.4	23.1	Sandy Loam	38.78	19.5	19.28	10.35	19.283
18	54.8	23.6	21.6	Sandy Loam	38.23	19.34	18.89	10.18	18.892
19	62.6	17.5	19.9	Sandy Loam	37.23	19.05	18.18	9.87	18.177
20	73.7	7.9	18.4	Sandy Loam	36.13	18.74	17.39	9.52	17.396
21	56.3	22.1	21.6	Sandy Clay Loam	38.05	19.29	18.76	10.12	18.762
22	53.2	25.2	21.6	Sandy Clay Loam	38.32	19.36	18.96	10.21	18.957
23	68.9	12.7	18.4	Sandy Loam	36.41	18.82	17.59	9.61	17.592
24	68.9	12.7	18.4	Sandy Loam	36.41	18.82	17.59	9.61	17.592
25	75.4	7.8	16.8	Sandy Loam	35.58	18.58	17	9.35	17.006
26	75.4	7.8	16.8	Sandy Loam	35.58	18.58	17	9.35	17.006
27	68.9	12.7	18.4	Sandy Loam	36.41	18.82	17.59	9.61	17.592
28	72.1	11.1	16.8	Sandy Loam	35.77	18.63	17.13	9.41	17.136
29	59.5	22.1	18.4	Sandy Loam	37.04	19	18.05	9.81	18.047
30	54.8	25.3	19.9	Sandy Loam	37.77	19.21	18.57	10.04	18.567
31	59.5	20.6	19.9	Sandy Loam	37.5	19.13	18.37	9.95	18.372
32	65.9	12.5	21.6	Sandy Clay Loam	37.41	19.1	18.31	9.92	18.307
33	56.3	17.4	26.3	Sandy Clay Loam	39.05	19.57	19.48	10.44	19.478
34	53.2	25.2	21.6	Sandy Clay Loam	38.32	19.36	18.96	10.21	18.957
35	56.3	22.1	21.6	Sandy Clay Loam	38.05	19.29	18.76	10.12	18.762
36	59.5	22.1	18.4	Sandy Loam	37.04	19	18.05	9.81	18.047
37	59.5	22.1	18.4	Sandy Loam	37.04	19	18.05	9.81	18.047

Sample No.	(Sand)	(Silt)	(Clay)	Texture	Liquid limit % (LL)	Plastic limit % (LL)	Plasticity Index (PI)	Shrinkage limit (SL)	Plasticity Index (PI)
38	53.2	26.9	19.9	Sandy Loam	37.86	19.23	18.63	10.07	18.632
39	64.2	17.4	18.4	Sandy Loam	36.77	18.92	17.85	9.72	17.852
40	68.9	12.7	18.4	Sandy Loam	36.41	18.82	17.59	9.61	17.592
41	58.5	24.7	16.8	Sandy Loam	36.68	18.89	17.79	9.69	17.787
42	66.5	16.7	16.8	Sandy Loam	36.13	18.74	17.39	9.52	17.396
43	45.8	29.6	24.6	Loam	39.42	19.68	19.74	10.55	19.738
44	63.3	15.1	21.6	Sandy Clay Loam	37.59	19.16	18.44	9.98	18.437
45	44.5	35.6	19.9	Loam	38.41	19.39	19.02	10.24	19.023
46	63.3	19.9	16.8	Sandy Loam	36.31	18.79	17.52	9.58	17.527
47	63.3	19.9	16.8	Sandy Loam	36.31	18.79	17.52	9.58	17.527
48	69.7	13.5	16.8	Sandy Loam	35.95	18.68	17.26	9.47	17.266
49	48.9	32.7	18.4	Loam	37.77	19.21	18.57	10.04	18.567
50	63.3	19.9	16.8	Sandy Loam	36.31	18.79	17.52	9.58	17.527
51	57	26.2	16.8	Sandy Loam	36.77	18.92	17.85	9.72	17.852
52	66.5	16.7	16.8	Sandy Loam	36.13	18.74	17.39	9.52	17.396
53	41.1	40.5	18.4	Loam	38.32	19.36	18.96	10.21	18.957
54	63.3	19.9	16.8	Sandy Loam	36.31	18.79	17.52	9.58	17.527
55	72.7	10.5	16.8	Sandy Loam	35.77	18.63	17.13	9.41	17.136
56	72.7	10.5	16.8	Sandy Loam	35.77	18.63	17.13	9.41	17.136
57	45.8	26.3	27.9	Sandy Clay Loam	40.05	19.86	20.19	10.75	20.193
58	66.5	16.7	16.8	Sandy Loam	36.13	18.74	17.39	9.52	17.396
59	63.3	19.9	16.8	Sandy Loam	36.31	18.79	17.52	9.58	17.527
60	45.8	34.3	19.9	Clay	38.41	19.39	19.02	10.24	19.023
61	51.53	15.86	32.62	Sandy Clay Loam	40.51	19.99	20.52	10.89	20.519
62	50.03	7.17	42.8	Sandy Clay	41.97	20.41	21.56	11.35	21.559
63	65.39	15.28	19.34	Sandy Loam	36.95	18.97	17.98	9.78	17.982
64	60.28	20.88	18.84	Sandy Loam	37.14	19.02	18.11	9.84	18.112
65	37.43	17.92	44.66	Clay	42.97	20.7	22.27	11.66	22.275
66	65.38	3.15	31.47	Sandy Clay Loam	39.42	19.68	19.74	10.55	19.738
67	51.5	11.22	37.29	Sandy Clay	41.15	20.18	20.97	11.09	20.974
Sample No.	(Sand)	(Silt)	(Clay)	Texture	Liquid limit % (LL)	Plastic limit % (LL)	Plasticity Index (PI)	Shrinkage limit (SL)	Plasticity Index (PI)
68	54.57	11.07	34.36	Sandy Clay Loam	40.51	19.99	20.52	10.89	20.519
69	49.57	14.37	36.06	Sandy Clay	41.15	20.18	20.97	11.09	20.974
70	67.65	10.85	21.5	Sandy Clay Loam	37.32	19.08	18.24	9.89	18.242
71	59.23	22.33	18.44	Sandy Loam	37.14	19.02	18.11	9.84	18.112
72	49.15	18.56	32.29	Sandy Clay Loam	40.6	20.02	20.58	10.92	20.584
73	53.44	1.86	44.7	Sandy Clay	41.97	20.41	21.56	11.35	21.559
74	55.28	21.87	22.85	Sandy Clay Loam	38.41	19.39	19.02	10.24	19.023

75	22.02	70.62	7.36	Silt Loam	34.95	18.4	16.55	9.15	16.551
76	45.53	18.19	36.27	Sandy Clay	41.42	20.25	21.17	11.18	21.169
77	69.49	11.61	18.9	Sandy Loam	36.59	18.87	17.72	9.67	17.722
78	58.1	14.03	27.87	Sandy Clay Loam	39.23	19.63	19.61	10.49	19.608
79	61.44	10.06	28.49	Sandy Clay Loam	39.14	19.6	19.54	10.46	19.543
80	55.04	7.58	37.39	Sandy Clay	40.97	20.12	20.84	11.03	20.844
81	79.88	7.19	12.92	Sandy Loam	33.94	18.11	15.83	8.84	15.835
82	53.24	7.17	39.58	Sandy Clay	41.33	20.23	21.1	11.15	21.104
83	35.66	37.25	27.09	Clay Loam	40.6	20.02	20.58	10.92	20.584
84	49.04	11.58	39.38	Sandy Clay	41.6	20.31	21.3	11.23	21.299
85	63.87	8.54	27.59	Sandy Clay Loam	38.87	19.52	19.35	10.38	19.348
86	62.35	13.61	24.04	Sandy Clay Loam	38.23	19.34	18.89	10.18	18.892
87	55.59	12.42	31.98	Sandy Clay Loam	40.14	19.89	20.26	10.78	20.258
88	50.05	34.33	15.62	Loam	36.86	18.95	17.92	9.75	17.917
89	72.27	0.91	26.82	Sandy Clay Loam	38.14	19.31	18.83	10.15	18.827
90	47.77	8.34	43.89	Sandy Clay	42.24	20.49	21.75	11.43	21.754
91	48.63	10.31	41.06	Sandy Clay	41.88	20.39	21.49	11.32	21.494
92	56.16	16.99	26.85	Sandy Clay Loam	39.23	19.63	19.61	10.49	19.608
93	67.35	27.45	5.2	Sandy Loam	30.2	17.04	13.17	7.67	13.169
94	52.42	13.25	34.33	Sandy Loam	40.69	20.05	20.65	10.95	20.649
95	33.14	61.42	5.44	Silt Loam	32.67	17.74	14.92	8.44	14.925
96	60.06	24.8	15.14	Sandy Loam	36.04	18.71	17.33	9.49	17.331
97	62.31	12.68	25.01	Sandy Clay Loam	38.41	19.39	19.02	10.24	19.023
98	43.73	12.72	43.55	Clay	42.42	20.54	21.88	11.49	21.884

Sample No.	(Sand)	(Silt)	(Clay)	Texture	Liquid limit % (LL)	Plastic limit % (LL)	Plasticity Index (PI)	Shrinkage limit (SL)	Plasticity Index (PI)
99	55.84	20	24.16	Sandy Clay Loam	38.69	19.47	19.22	10.32	19.218
100	63.63	9.05	27.32	Sandy Clay Loam	38.78	19.5	19.28	10.35	19.283
101	57.72	31.13	11.14	Sandy Loam	34.67	18.32	16.35	9.07	16.356
102	60.2	12.39	27.41	Sandy Clay Loam	39.05	19.57	19.48	10.44	19.478
103	45.01	17	37.99	Sandy Clay	41.7	20.33	21.36	11.26	21.364
104	58.26	23.37	18.37	Sandy Loam	37.14	19.02	18.11	9.84	18.112
105	59.81	14.52	25.67	Sandy Clay Loam	38.69	19.47	19.22	10.32	19.218
106	62.3	8.61	29.08	Sandy Clay Loam	39.23	19.63	19.61	10.49	19.608
107	75.18	11.44	13.38	Sandy Loam	34.4	18.24	16.16	8.98	16.161
108	58.09	25.17	16.73	Sandy Loam	36.68	18.89	17.79	9.69	17.787
109	73.07	17.82	9.11	Sandy Loam	32.58	17.72	14.86	8.41	14.860

Table 3: Result of Calculation for Liquid Limit, Plastic Limit and Plasticity Index (PI).

SN	Liquid Limit (LL)	Plastic Limit, (PL)	Plastic Index (PI)	U-Line PI = 0.9(LL-8)	A-Line PI = 0.73(LL-20)	U-Line PI = 0.9(LL-8) (developed)	A-Line PI = 0.73(LL-20) (developed)	Soil Sample PI (developed)	Soil Sample PI (fitted)
Intersection point 0f U-line and A-line	-43.5294				-46.3765	-46.3765			-39.4181
1	37.865	19.234	18.631	26.878	13.041	26.878	13.041	18.632	18.632
2	37.865	19.234	18.631	26.878	13.041	26.878	13.041	18.632	18.632
3	36.862	18.946	17.915	25.975	12.309	25.975	12.309	17.917	17.917
4	37.044	18.999	18.045	26.140	12.442	26.140	12.442	18.047	18.047
5	37.682	19.182	18.501	26.714	12.908	26.714	12.908	18.502	18.502
6	38.959	19.548	19.411	27.863	13.840	27.863	13.840	19.413	19.413
7	39.050	19.574	19.476	27.945	13.907	27.945	13.907	19.478	19.478
8	37.318	19.077	18.240	26.386	12.642	26.386	12.642	18.242	18.242
9	38.321	19.365	18.956	27.289	13.374	27.289	13.374	18.957	18.957
10	39.050	19.574	19.476	27.945	13.907	27.945	13.907	19.478	19.478
11	37.318	19.077	18.240			26.386	12.642	18.242	18.242
12	37.044	18.999	18.045			26.140	12.442	18.047	18.047
13	37.044	18.999	18.045			26.140	12.442	18.047	18.047
14	36.406	18.816	17.590			25.565	11.976	17.592	17.592
15	36.041	18.711	17.330			25.237	11.710	17.331	17.331
16	36.041	18.711	17.330			25.237	11.710	17.331	17.331
17	38.777	19.496	19.281			27.699	13.707	19.283	19.283
18	38.230	19.339	18.891			27.207	13.308	18.892	18.892
19	37.226	19.051	18.175			26.304	12.575	18.177	18.177
20	36.132	18.737	17.395			25.319	11.776	17.396	17.396
21	38.047	19.286	18.761			27.042	13.174	18.762	18.762
22	38.321	19.365	18.956			27.289	13.374	18.957	18.957
23	36.406	18.816	17.590			25.565	11.976	17.592	17.592
24	36.406	18.816	17.590			25.565	11.976	17.592	17.592
25	35.585	18.580	17.005			24.826	11.377	17.006	17.006
26	35.585	18.580	17.005			24.826	11.377	17.006	17.006
27	36.406	18.816	17.590			25.565	11.976	17.592	17.592

SN	Liquid Limit (LL)	Plastic Limit, (PL)	Plastic Index (PI)	U-Line PI = 0.9(LL-8)	A-Line PI = 0.73(LL-20)	U-Line PI = 0.9(LL-8) (developed)	A-Line PI = 0.73(LL-20) (developed)	Soil Sample PI (developed)	Soil Sample PI (fitted)
Intersection point 0f U-line and A-line	-43.5294				-46.3765	-46.3765			-39.4181
28	35.767	18.632	17.135			24.990	11.510	17.136	17.136
29	37.044	18.999	18.045			26.140	12.442	18.047	18.047
30	37.774	19.208	18.566			26.796	12.975	18.567	18.567
31	37.500	19.130	18.371			26.550	12.775	18.372	18.372
32	37.409	19.103	18.305			26.468	12.708	18.307	18.307
33	39.050	19.574	19.476			27.945	13.907	19.478	19.478
34	38.321	19.365	18.956			27.289	13.374	18.957	18.957
35	38.047	19.286	18.761			27.042	13.174	18.762	18.762
36	37.044	18.999	18.045			26.140	12.442	18.047	18.047
37	37.044	18.999	18.045			26.140	12.442	18.047	18.047
38	37.865	19.234	18.631			26.878	13.041	18.632	18.632
39	36.770	18.920	17.850			25.893	12.242	17.852	17.852
40	36.406	18.816	17.590			25.565	11.976	17.592	17.592
41	36.679	18.894	17.785			25.811	12.176	17.787	17.787
42	36.132	18.737	17.395			25.319	11.776	17.396	17.396
43	39.415	19.679	19.736			28.274	14.173	19.738	19.738
44	37.591	19.156	18.436			26.632	12.842	18.437	18.437
45	38.412	19.391	19.021			27.371	13.441	19.023	19.023
46	36.314	18.789	17.525			25.483	11.910	17.527	17.527
47	36.314	18.789	17.525			25.483	11.910	17.527	17.527
48	35.950	18.685	17.265			25.155	11.643	17.266	17.266
49	37.774	19.208	18.566			26.796	12.975	18.567	18.567
50	36.314	18.789	17.525			25.483	11.910	17.527	17.527
51	36.770	18.920	17.850			25.893	12.242	17.852	17.852
52	36.132	18.737	17.395			25.319	11.776	17.396	17.396
53	38.321	19.365	18.956			27.289	13.374	18.957	18.957
54	36.314	18.789	17.525			25.483	11.910	17.527	17.527
55	35.767	18.632	17.135			24.990	11.510	17.136	17.136
56	35.767	18.632	17.135			24.990	11.510	17.136	17.136

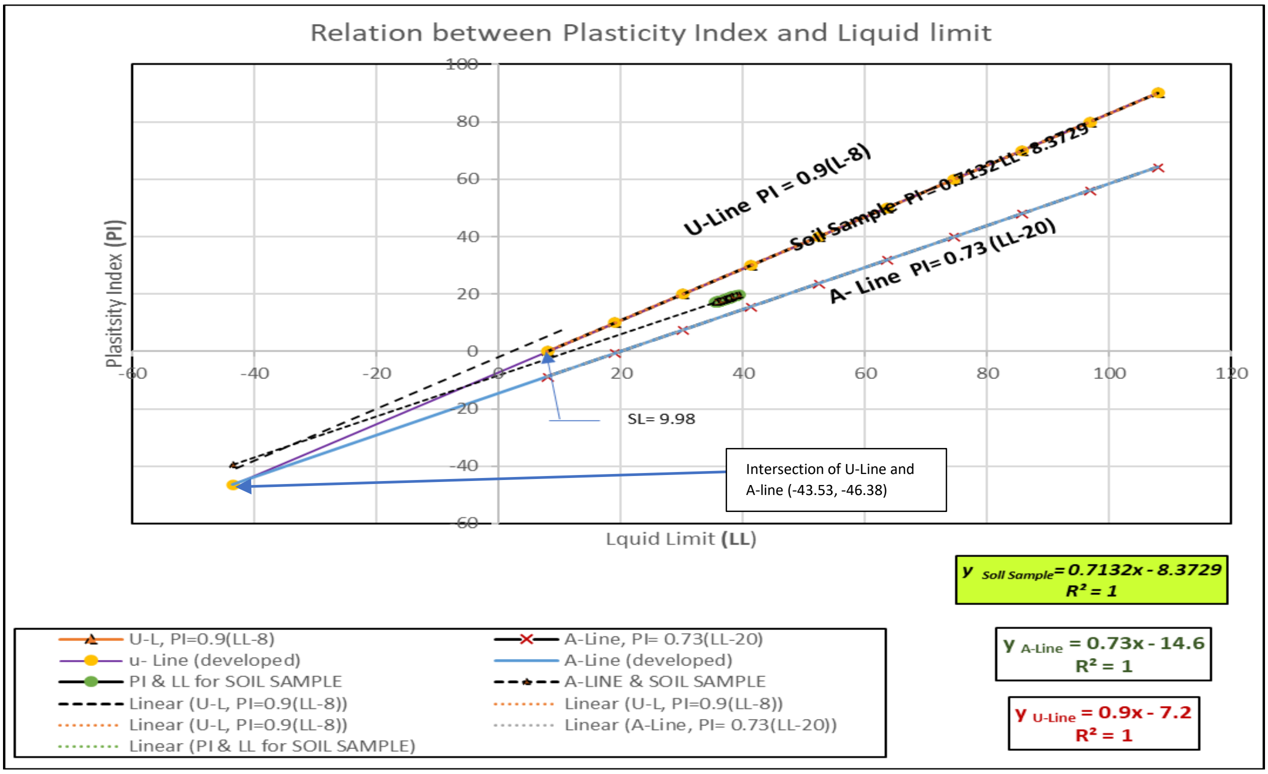

Figure 5: Relation between Plasticity Index and liquid Limit

References

American Society for Testing and Materials (2014). Annual Book of ASTM Standards, Sec. 4,4.08, West Conshohocken, Pa.,USA.

Burmister, D. M. (1949). Principles and techniques of soil identification, (1949). Proceedings, Annual Highway Research Board Meeting, National Research Council, Washington, DC, USA

Casagrande, A. (1932). Research of Atterberg Limits of Soils. Public Roads. 8::21–136.

Feng, T. W. (2001). A Linear log *d* 2 log w Model for determination of Consistency Limits of Soils,.Canadian Geotechnical Journal, 38(6):1335-1342. Fundamentals of Soil Behavior, Wiley,NY,USA

Skempton, A. W. (1953). The Colloidal Activity of Clays, Proceedings, *3rd Intl. Conf. on Soil Mechanics and Foundation Engineering, London 1:57-61*.

Sowers, G. F. (1979). Introductory Soil Mechanics and Foundations: Geotechnical Engineering, Macmillan, NY, USA.

Sridharan, A., Nagaraj, H. B., and Prakash, K. (1999). Determination of the plasticity Index from Flow Indexp, (1976)., ASTM, 22 (2)):175–181.

Wroth, C. P., and Wood, D. M. (1978). Correlation of Index Properties with Some Basic Engineering *Properties* of Soils. *Canadian Geotechnical Journal*, 15((2): 137–14.

تكوين مؤشر اللدونة والحد السائل للتربة الجيرية

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عندما تمتص التربة الخفيفة الرطوبة، تحدث قوة تماسك. في حالة الرطوبة المنخفضة للغاية ،تعمل التربة كمادة صلبة بينما في المستويات العالية من الرطوبة تتدفق عجينة التربة مثل السائل. في أوائل القرن العشرين ابتكر العالم السويدي أتيربيرج طريقة لتحديد توافق هذه التربة مع تغير تركيزات الرطوبة. في حالة الرطوبة المنخفضة للغاية، تعمل التربة مثل مادة صلبة عندما يكون محتوى الرطوبة منخفضًا جدًا. يمكن تصنيف سلوك التربة بشكل تعسفي إلى أربع حالات أساسية: صلبة، وشبه صلبة، وبلاستيكية، وسائلة اعتمادًا على تركيز الرطوبة. عندما يكون محتوى الرطوبة مرتفعًا بدرجة كافية، قد تتدفق التربة والماء مثل السائل. يتم تحديد حد الانكماش بنسبة الرطوبة التي يصبح عندها مادة صلبة شبه صلبة. حد اللدونه وحد السائل هما محتويات الرطوبة عند نقاط الانتقال من نصف صلب إلى لدن ومن لدن إلى سائل، على التوالي. "حدود أتيربيرج" هي جميع هذه المعايير.