Liquid and Plastic Limits Evaluation of Mixed Soil Matrices

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Abstract – To improvement of soil characteristics for maintaining its allowable load sustainability, deformation and stability understanding of soils nature in creation of model by mixing soil technique is first requirement at design of soil foundation. In this investigation 31 mixed soil model were developed, and effect of liquid limit and plastic limit in controlling soil bearing capacity under loose and compacted condition evaluated, and to achieve soil behavior SEM and XRD results of any of soils have been used, the result revealed soil plasticity has direct correlation with soil bearing capacity, stability and deformation, and these characteristics could be controlled if percentage of mixed soil accurate is selected or soil mineralogy and morphology controlled.

Keyword: Soil Characteristics, Soil Deformation, Soil Improvement

1. Introduction

The liquid limit of a soil is the moisture content, expressed as a percentage of the mass of the oven-dried soil, at the boundary between the liquid and plastic states. The moisture content at this boundary is arbitrari1y defined as the liquid limit and is the moisture content at a consistency as determined by means of the standard liquid limit apparatus [1]. It is too important in civil engineering awareness of soil science for seismic mitigation of structure placed on soil foundation consists of soft soil.

The composition of any soil is an important factor which influences many soil properties, such as shear strength, liquid limit (Ll), plastic limit (Pl) etc [2]. There have been more than one hundred sets of direct shear tests conducted on soils composed of four reference clay minerals and various combinations of them in Columbia University Clay Mineral Standards Project [3]. Researches in unsaturated soil mechanics considerably developed in the past decades, through the simultaneous development of experimental investigations and theoretical analyses [4]. Several authors have also studied strip foundations but reinforced with different materials such as steel bars [5-7], steel grids [8-9], geo-textile [10] and geo-grids [11-12], and also they studied the behavior of circular footing on confined sand [13]. Study of bearing capacity of footing without reinforcement under eccentric inclined loads by many researchers has been carried out [14-18]. In this paper behavior of 31 soils mixed models, consists of sand, gravels and soils Investigated to identify correlation between liquid and plastic limit and soil behavior in the soil mixing method.

2. Methodology and Experiments

The experiments are conducted in S. J. College of Engineering, Mysore to evaluate mixed soil characteristics. In the present experiments, several models have been developed to improve red soil (plastic soil) by mixing with sand, gravels and non-plastic soils. In this investigation liquid limit, plastic limit, standard compaction test, XRD, SEM and direct shear test have been employed to characterize accurate behavior of models in the laboratory. Calculation of safe bearing capacity of any mixed soils are done using the Terzaghi calculation method, and cohesive (C), angle of friction(Φ), moisture and unit weight of the mixed soils are considered. Materials have been used for creation of model illustrated in the table 1. All models have assumed depth of 1.5 m and widths 2.5 m * 2.5 m for square footing in calculation of safe bearing capacity. Table 1 indicated mixed soil models of all soil types, the real soil characteristics were considered to assess soil foundation improvement by performing laboratory tests thorough the interpreting of the test results, this should be required for any earthwork design. Formulas for calculation of safe bearing capacity, suggested by Terzaghi, are the following:

1) $q_f = 1.3C\,N_c + \gamma D N_q + 0.4\,\gamma B N_\gamma$
2) $q_{nf} = q_f - q_{nf} = qf\text{-}\gamma D$
3) $q_s = (qnf/F) + \gamma D$

Also N_q, N_c and N_γ are the general bearing capacity factors and depending upon 1) Depth of footing, 2) Shape of footing, 3) Φ, have been used from suggestion by the Terzaghi [19]. The liquid limit and plastic limit of 31 mixed soils models contrasted with the bearing capacity, cohesiveness, and angle of friction, optimum moisture content and unit weight.

Table 1 Mixed soil models [19]

Sl. No	% of Red Soil	% of Sand	% of Gravel 4.75 mm	% of Gravel 2 mm	% of Black Soil	% of Gray Soil	% of Dark Brown Soil	% of Yellow Soil	% of Light Brown Soil
1	100	0	0	0	0	0	0	0	0
2	55	45	0	0	0	0	0	0	0
3	55	0	45	0	0	0	0	0	0
4	55	0	0	45	0	0	0	0	0
5	55	15	15	15	0	0	0	0	0
6	55	0	0	0	45	0	0	0	0
7	55	0	0	0	0	45	0	0	0
8	55	0	0	0	0	0	45	0	0
9	55	0	0	0	0	0	0	45	0
10	90	0	0	0	2	2	2	2	2
11	80	0	0	0	4	4	4	4	4
12	70	0	0	0	6	6	6	6	6
13	60	0	0	0	8	8	8	8	8
14	50	0	0	0	10	10	10	10	10
15	70	0	0	0	10	10	10	0	0
16	70	0	0	0	10	10	0	10	0
17	70	0	0	0	10	10	0	0	10
18	70	0	0	0	10	0	10	10	0
19	70	0	0	0	10	0	10	0	10
20	70	0	0	0	10	0	0	10	10
21	70	0	0	0	15	15	0	0	0
22	70	0	0	0	15	0	15	0	0
23	70	0	0	0	0	0	0	15	15
24	70	0	0	0	15	0	0	15	0
25	70	0	0	0	15	0	0	0	15
26	70	0	0	0	0	15	15	0	0
27	70	0	0	0	0	15	0	15	0
28	70	0	0	0	0	15	0	0	15
29	70	0	0	0	0	0	15	15	0
30	70	0	0	0	0	0	15	0	15
31	55	0	0	0	0	0	0	0	45

3. Results and Discussion

The results of liquid limit (Ll) and plastic limit (Pl) of 31 mixed soil types were evaluated. The red soil, mixed soil type 3 (consists of 55% of red soil and 45% of gravel 4.75 mm) and mixed soil type 4 (consists of 55% of red soil and 45% of gravel 2 mm) have exhibited high plasticity and mixed soil type 6 (consists of 55% red and 45% of black soils), mixed soil type 7 (consists of 55% red and 45% of gray soils) and mixed soil type 9 (consists of 55% red and 45% of yellow soils) exhibited low plasticity (table 2). Only the red soil has considerable amount of clay minerals, it shown in its mineralogy, where as the remaining other soils have meager concentrations. The red soil has exhibited relatively high plasticity where as the remaining soils exhibited very low plasticity. From figures 1-3 and table 3-4 as per soils morphology, mineralogy and laboratory experiments observed in maximum level of liquid limit and plastic limit, highest level of bearing capacity appeared but this phenomena is not occur for minimum of bearing capacity, the bearing capacity has non linear correlation with liquid limit and plastic limit. A soil characteristic is controlled liquid limit and plastic limit, saturated soil is changed all its properties and could not be easy predict exactly soil future behavior without scientific investigation. Percentage of red plastic soil in the model played main role in the level of liquid limit and plastic limit. Employee of non plastic in creation of model reduces liquid limit and plastic limit. The factors like angle of friction, unit weight and moisture content along with cohesiveness affected on the bearing capacity and liquid limit and plastic limit simultaneously, but it is not constant for all.

Table 2 liquid and plastic limits of 31 mixed soil models

Liquid limit (%)	Plastic limit (%)	Liquid limit (%)	Plastic limit (%)	Liquid limit (%)	Plastic limit (%)	Liquid limit (%)	Plastic limit (%)
Model 1		Model 2		Model 3		Model 4	
32.37	17.785	20.4	11.2	32.37	17.785	32.37	17.785
Model 5		Model 6		Model 7		Model 8	
29.74	16.34	16.94	9.3	15.09	8.29	23.34	12.82
Model 9		Model 10		Model 11		Model 12	
15.14	8.31	29.5	16.209	27.1	14.89	25.06	13.77
Model 13		Model 14		Model 15		Model 16	
23.3	12.8	21.78	11.97	26.01	14.23	24.53	13.47
Model 17		Model 18		Model 19		Model 20	
25.39	13.95	26.02	14.299	26.99	14.83	25.4	13.96
Model 21		Model 22		Model 23		Model 24	
24.74	13.59	27.1	14.89	25.39	13.95	24.76	13.61
Model 25		Model 26		Model 27		Model 28	
26.07	14.32	26.83	14.74	24.09	13.24	25.36	13.94
Model 29		Model 30		Model 31			
26.32	14.46	27.84	15.3	19.14	10.51		

Table 3 Experiments Results [19]

Sl. No	Model No	OMC (%)	γ (KN/m^3)	Φ Degree	C (KN/m^2)	S. B. C (KN/m^2)
1	1	11.2	21.94	38	21	2036.22
2	2	10.61	21.83	39	12	1926.51
3	3	10.72	23.46	39	46	3334.44
4	4	12.15	23.82	36	28	1833.97
5	5	9.58	23.02	40	8	2060.95
6	6	22.39	20.09	32	20	888.70
7	7	18.86	20.95	32	26	1026.83
8	8	14.56	23.35	18	44	427.74
9	9	14.23	20.96	30	28	718.00
10	10	16.83	21.61	36	22	1567.43
11	11	18.27	21.56	15	47	349.69
12	12	16.76	21.07	22	49	608.36
13	13	20.21	21.83	21	33	431.67
14	14	18.68	21.179	27	38	786.91
15	15	19.34	20.96	29	8.5	487.99
16	16	16.55	20.31	31	22	834.95
17	17	21.14	21.18	20	27	341.94
18	18	20.79	21.18	20	23	311.26
19	19	16.31	20.96	33.5	12	879.86
20	20	20.88	20.96	24	23	439.56
21	21	23.00	21.5	23	10	287.22
22	22	20.06	22.05	23	32	503.18
23	23	20.11	21.07	23	22	398.52
24	24	20.75	20.41	19	22	280.01
25	25	22.69	20.748	22	16	310.33
26	26	18.87	21.72	21	28	389.32
27	27	20.31	21.94	24	26	479.81
28	28	19.51	21.72	17.5	28	298.58
29	29	20.52	22.59	17	9	170.00
30	30	18.99	22.47	18	24	286.20
31	31	14.56	21.61	28	26	700.05

Table 4 Minerals of Soil Sample Experiment [20]

Sl. No	Soil Name	Minerals in the soil sample
1	Red soil	quartz, illite, muscovite, saponite, sauconite and carbonate- fluorapatite
2	Black soil	quartz, pyrophyllite, carbonate- fluorapatite and orthochamosite
3	Yellow soil	quartz, brucite, clinochlore and sandoite
4	Light brown soil	quartz and carbonate
5	Dark brown soil	nacrite, odinite, amesite, chamosite and biotite
6	Green soil	quartz, cancrisilite, chamosite, orthochamosite and brucite

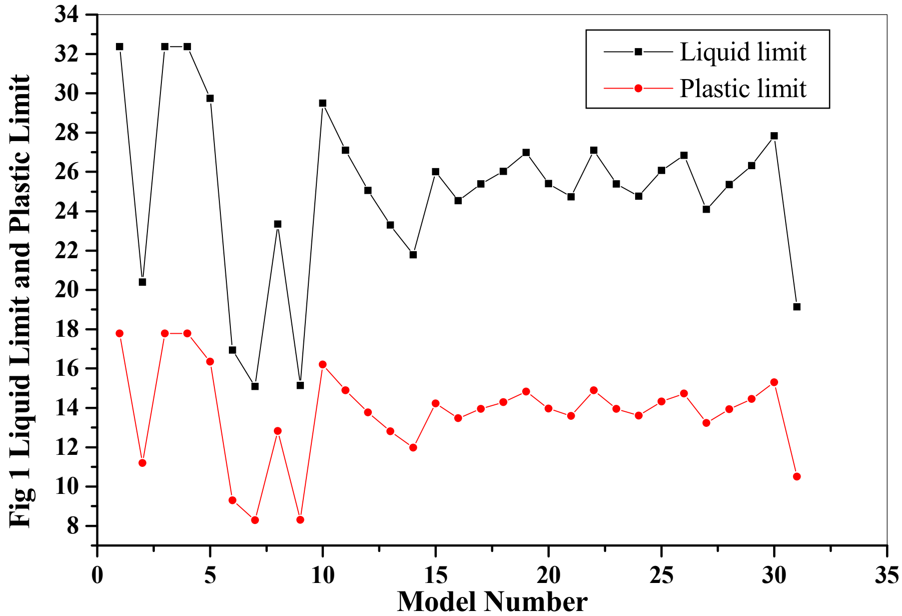

Fig 1 result of liquid limit and plastic limit

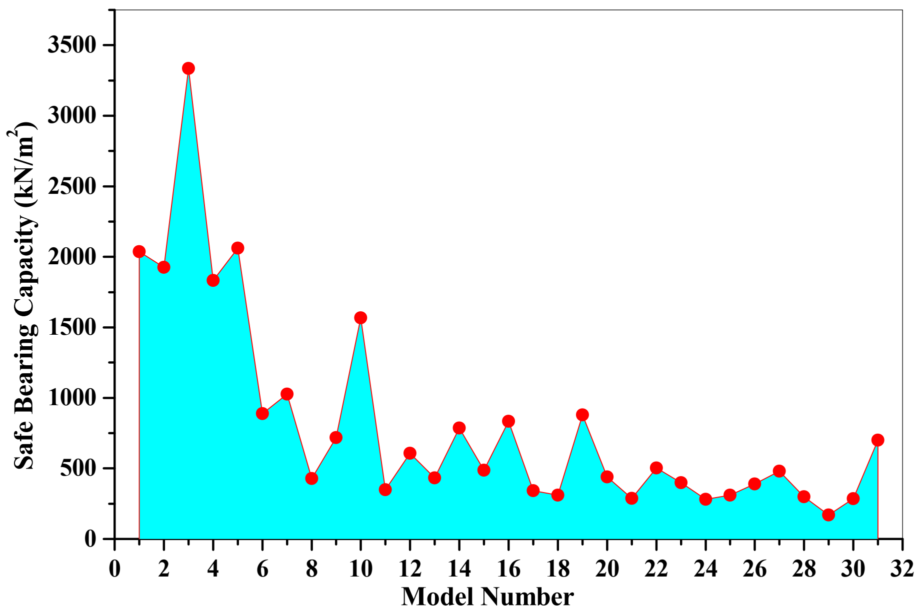

Fig 3 Result of Safe Bearing Capacity (kN/m^2) Vs Model No

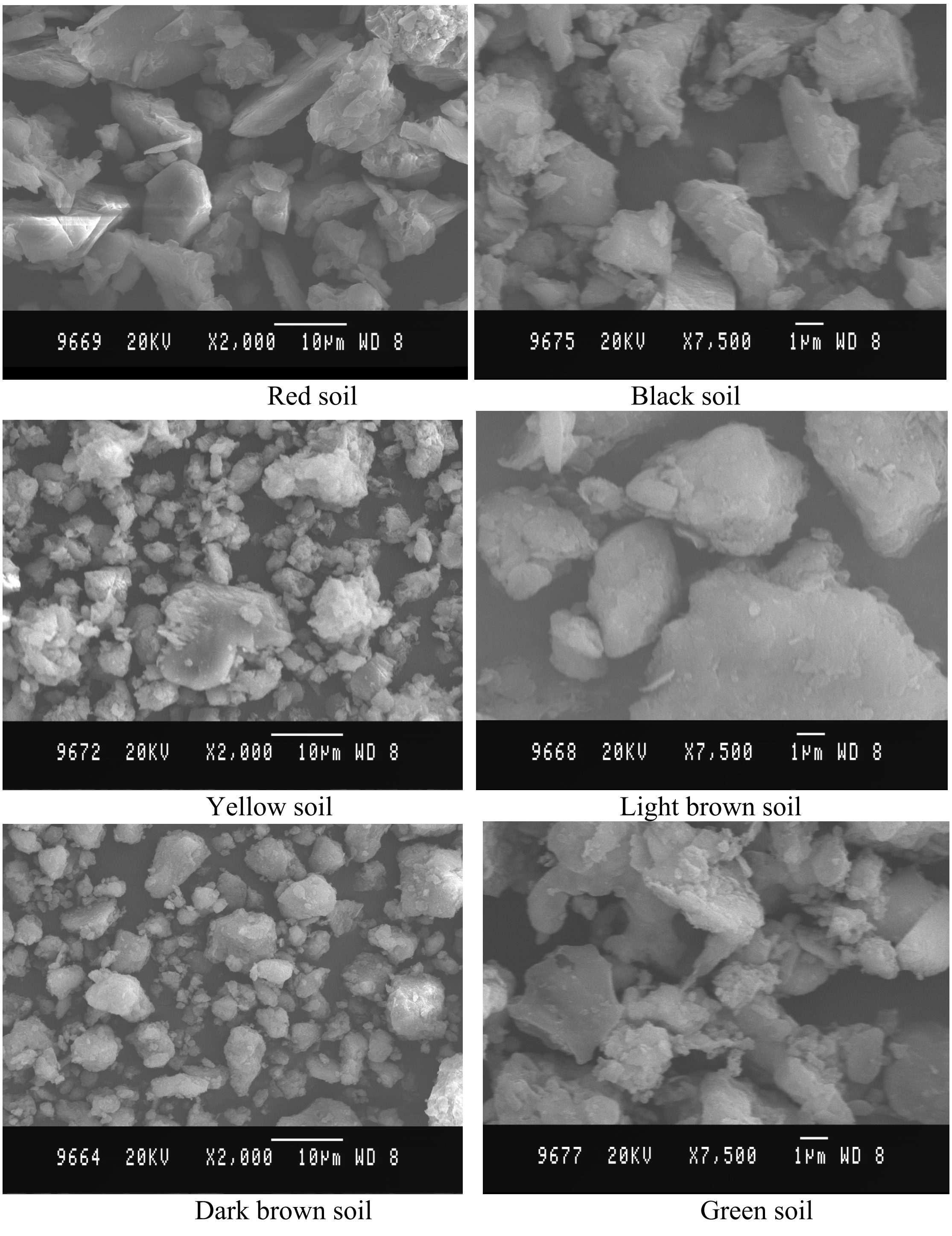

Fig.2. SEM photos of six soil samples [20]

4. Conclusion

The results of XRD and SEM indicated the percentage of red plastic soil in the model played main role in the level of liquid limit and plastic limit it is due to soil mineralogy and morphology. The bearing capacity has linear correlation with liquid and plastic limits if other factors not effected to that. There is possibility in control of soil foundation load acceptability by maintaining of soil liquid limit and plastic limit in mixed soil model under compacted condition.

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NOMENCLATURE

Φ [°]	= Friction Angle
C [kN/m2]	= Soil Cohesivity
OMC %	= Optimum Moisture Content %
SBC [kN/m2]	= Safe Bearing Capacity
γ [kN/m3]	= Unit Weight
q_f [kN/m2]	= Ultimate Bearing Capacity
q_{nf} [kN/m2]	= Net Ultimate Bearing Capacity
q_s [kN/m2]	= Safe Bearing capacity
N_c	= General Bearing Capacity Factor
N_q	= General Bearing Capacity Factor
N_γ	= General Bearing Capacity Factor
B [m]	= Foundation Width
D [m]	= Foundation Depth
F	= Safety Factor = 3
Ll	=Liquid limit (%)
Pl	=Plastic limit (%)