Bearing and liquefaction evaluation of mixed soils

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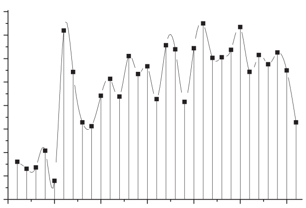

ABSTRACT

This research work deals with assessment of soil mixtures behavior prepared from different types of soils. The characterization of 31 soil mixtures in loose condition were conducted by direct shear, standard compaction for obtaining optimum moisture content (OMC), wet sieve analysis, plastic limit and liquid limit testing. This technique was evaluated to analyze and overcome the soft soil foundation problem as well as liquefaction mitigation, improvement of subsoil and structure stability and providing suitable construction site.

KEYWORDS

Soil mixing, soil behavior, OMC, bearing capacity, liquefaction.

RESUMEN

Este trabajo de investigación se ocupa de evaluar el comportamiento de muestras de mezclas preparadas a partir de diferentes tipos de suelos. La caracterización de 31 mezclas de suelo en condiciones sueltas fueron llevadas a cabo mediante pruebas de corte directo, compactación estándar para obtener el contenido de agua óptimo (OMC), granulometría en húmedo y límites plástico y líquido. Este trabajo tiene el propósito de resolver el problema de la cimentación en suelo suave así como mitigar la licuefacción, mejorando la estabilidad del subsuelo y de la estructura, proporcionando un sitio de construcción adecuado.

PALABRAS CLAVE

Mezcla de suelo, comportamiento de suelos, OMC, capacidad de desplazamiento, licuefacción.

INTRODUCTION

A structure under dynamic and static forces could be stable enough in absence of geo-technical problems. Good bearing capacity is an important characteristic of any soil for reducing damages upon structure, in the case of an earthquake. If this parameter is weak, then soil mixing technique could be an option for keeping structure out of great danger. This method is useful for achieving safe bearing capacity before any construction activity.

During the design of foundation, the designer should take into consideration mechanical properties of soil to evaluate field conditions.[1] Soil strength depends on cohesion, c, angle of friction, tan φ, or both combined. Mahmoud and Abdrabbo[2] presented an experimental study concerning a method for improving the bearing capacity of strip footing resting on sand sub-grades employing vertical non-extensible reinforcement. The test results indicated that this type of reinforcement increases the bearing capacity of sub-grades and modifies the load–displacement behavior of the footing.

Study of bearing capacity of footing under eccentric or eccentric – load has been carried out by Meyerhof;[3-5] Prakash[6,7] and Houlsby[8] determined the vertical bearing capacity of a limited number of cones on clay. Martin[9] extended this analysis to 1296 combinations of cone angle, footing embedment, roughness factor and increases of undrained shear strength with depth.[10] Junhwan Lee and Rodrigo Salgado[11] conducted a research work on estimation of limit unit bearing capacity q_{bL} of axially loaded circular footings on sands based on cone penetration test cone resistance qc is examined and conventionally checked of the bearing capacity limit state using the bearing capacity equation requires calculation of Ng and thus an estimate of angle of fraction (Φ).[11]

The main objective of this research is to evaluate mixed soil characteristics as per soil mineralogy and morphology and applied them in development of new mixed soil. characterization of 31 soil mixed samples of sand, gravel and different types of soils was carried out. Laboratory tests were conducted for determining properties of mixed soil and calculate mixtures of safe bearing capacity. This investigation allows identifying site soil mixtures for increasing soil foundation bearing capacity.

METHODOLOGY AND EXPERIMENTS

The experiments were conducted following the method of direct shear test in the Geo-technical Engineering Laboratory of S. J. College of Engineering in Mysore. In these experiments, several samples were prepared to improve red soil (plastic soil) properties by mixing with sand, gravels and non-plastic soils. Liquid limit, plastic limit, wet sieve analysis, standard compaction and direct shear tests were employed to characterize the behavior of the mixtures in the laboratory.

Calculation of safe bearing capacity of the soil mixtures was made using the Terzaghi calculation method, cohesion, angle of friction, moisture and unitary weight, given that they are the main factors of soil foundation characteristics, for finding the best bearing capacity of soil foundation. Materials used for each sample are show in the table I. In A square footing of 1.5 m depth and 2.5 m * 2.5 m was taken for calculation of safe bearing capacity.

For all the samples, real soil characteristics were considered to assess soil foundation improvement by performing laboratory tests thorough the interpreting of the test results. This procedure should be required for any groundwork design.

Formulas for calculation of safe bearing capacity, suggested by Terzaghi, are presented below:

1) $q_f = 1.3C\,N_c + \gamma DNq + 0.4\,\gamma BN_\gamma$

2) $q_{nf} = q_f - q_{nf} = q_f - \gamma D$

3) $q_s = (q_{nf}/F) + \gamma D$

Also N_q, N_c and N_γ are the general bearing capacity factors which depend on 1) depth of footing, 2) shape of footing, 3) Φ, (was used from suggestion by the Terzaghi calculation method).[12] The safety factor applied to the bearing capacity formula is recommended to be no smaller than 3.0.

RESULTS AND DISCUSSION

For determining soil morphological characteristics the method of wet sieve analysis was employed. Among all soils, red and black had the best and linear distribution of particles (figure 1 and table II).

Test of liquid limit and plastic limit indicated that black, green, yellow, dark brown and light brown soils are not plastic and the red soil is the only one with plastic propieties. Results of liquid and plastic limits are show in table III, and IV aswell as figure 2. Red soil has liquid

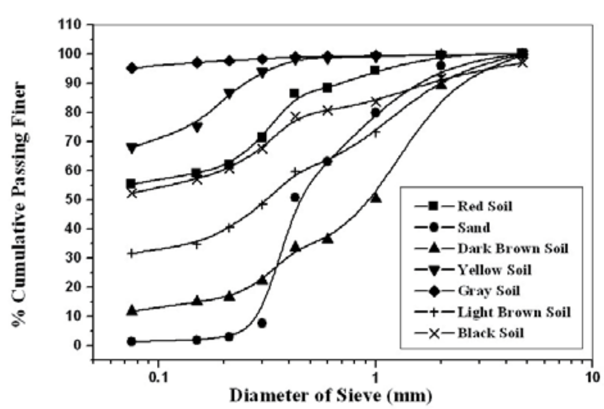

Fig. 1. Result of sieve analysis of soils.

Table I. Soil mixtures.

S1. No	% of red soil	% of sand	% of gravel 4.75 mm	% of gravel 2 mm	% of black soil	% of green 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	150	0	15
31	55	0	0	0	0	0	0	0	45

Table II. Results of sieve analysis of soils (PF= Passing Finer).

S1. No	Diameter of sieve	PF of red soil (%)	PF of sand (%)	PF of dark brown soil (%)	PF of yellow soil (%)	PF of green soil (%)	PF of light brown soil (%)	PF of black soil (%)
1	4.75	100	100	99.59	100	100	100	96.94
2	2	99.58	96	89.10	99.6	99.6	92.6	91.83
3	1	94.16	79.8	50.15	99	99.4	76	83.66
4	0.6	88.12	63.2	36.23	98.6	99	63.2	80.59
5	0.425	86.24	50.6	33.40	98.2	98.8	59.6	78.55
6	0.3	71.24	7.6	22.10	93.8	98.2	48.2	67.52
7	0.212	61.86	2.8	16.45	86.8	97.6	40.4	60.77
8	0.150	58.94	1.8	14.84	75.2	97	34.6	56.88
9	0.075	55.40	1.2	11.61	68	95.2	31.6	52.19
10	Received	0	0	0	0	0	0	0

limit of 32.7 % and plastic limit of 17.785 %. Due to plasticity of red soil, it was selected for evaluation and eventual improvement as construction and sub soil material.[12]

Result showed that green soil is made of finer particles among all soils. In dry (0% moisture), maximum and minimum bearing capacity are 1595.69(KN/m^2) and 136.64 (KN/m^2) respectively in samples 5 and 23. In OMC condition maximum bearing capacity (454.31 KN/m^2) is in sample 3, and minimum-bearing capacity (75.95 KN/m^2) is in samples 27. Maximum and minimum OMC are in samples 21 and 5 respectively (figure 3). Table V-VI and figure 4 -7 illustrated γ, Φ, C, and S.B.C of all models in 0% and OMC moisture content. Mineralogy is more important in the wich to soil mix than soil morphology.

Rising underground water is a factor, which decreases soil-bearing capacity. In such situation (sample 16), with 10% of green soil could be chosen as the best option. Soils with fine particles, in OMC condition leduce bearing capacity and this sample is suitable if liquefaction mitigation is needed. But in sample 27 and 21 witch consist of more than 15% green soil in OMC condition, no bearing capacity is observed, it is due to green soil mineralogy and morphology, in preparation of sample could be resistent to liquefaction wich is the first thing taht should be consider is soil mineralogy and morphology.

It could be deduced that in design of a soil mixed for liquefaction mitigation requires proper fine material and gives positive correlation with bearing capacity. Sand is more vulnerable for liquefaction due to saturation what result from its weak cohesion. Black soil also is vulnerable to liquefaction because it to decreases its cohesion in OMC condition. sample 3 made up of good interlock particle and sample

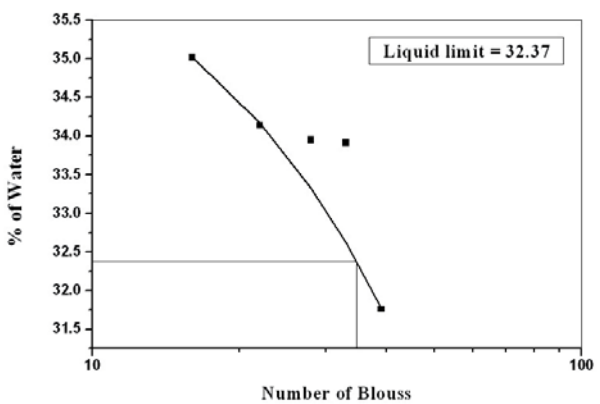

Fig. 2. Liquid limit of red soil.

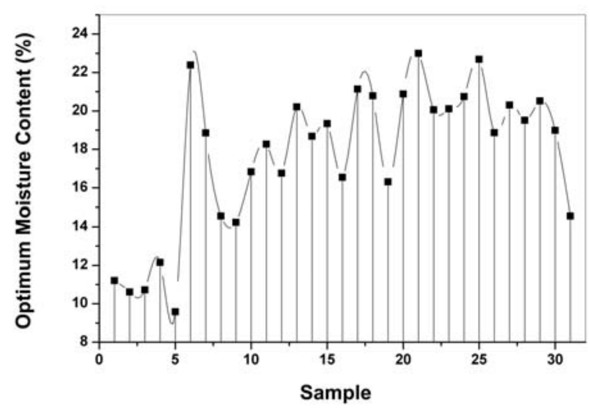

Fig. 3. Optimum moisture content *Vs* sample No.

Table III. Liquid limit of red soil.

S1. No	Reading number	Cup number	Weight of wet sample (g)	Weight of dry sample (g)	Weight of cup (g)	Weight of dry soil (g)	Weight of water (g)	% of water
1	16	75	39.7	35.43	23.24	12.19	4.27	35.02
2	22	41	37.6	34.11	23.89	10.22	3.49	34.14
3	28	103	34.92	32	23.4	8.6	2.92	33.85
4	33	61	37.7	33.83	22.42	11.41	3.87	33.91
5	39	1	51.14	48.24	39.11	9.13	2.9	33.76

Table IV. Liquid plastic of red soil.

S1. No	Cup number	Weight of wet sample (g)	Weight of dry sample (g)	Weight of cup (g)	Weight of water (g)	Weight of dry soil (g)	% of water	Average % of water
1	86	25.75	25.2	22.68	0.46	2.61	17.62	17.785
2	7	39.55	39.55	36.66	0.44	2.45	17.95	17.785
Plastic limit of red soil is 17.785%								

10 consists of all five soils particles, in loose OMC condition. They show similar result, but sample 3 would be better option from economic point of view. Underground water decreases the angle of friction of soil. It takes place due to reduction of friction between soil particles. When red soil is mixed with sand in loose OMC situation, due to sand morphology characteristics, model maintains good interlock between particles and eventually shows less decrease in the angle of friction.

All factors described above are important when the building structure is heavy with possibility of concentrated loading and the ground on which it rest show poor bearing capacity of soil or is affected by natural phenomena like rising water table.[13]

The foundation should also be designed and constructed to maintain or promote constant moisture in the soils. For example, the foundation should be constructed following the wet season.[14] The interaction between the coarse and fine grain matrices affects the overall mechanical behavior of the mixture of these soils.[15]

The liquefaction potential of a soil mass during an earthquake is dependent on both seismic and soil parameters.[16] If in civil engineering more attention is applied to the soil mineralogy by use of advance experimental such as SEM and XRD and XRF then in future by understanding of better soil behavior and composition could access more stability of soil foundation as well as structure.

Table V. Experimental results when soil is in loose 0 % moisture condition.

S1 No	Sample No	Zero % moisture content	γ (KN/m³)	Φ degrees	C (KN/m²)	S.B.C. (KN/m²)
1	1	0	11.808	38	0	701.55
2	2	0	12.54	35	10	699.82
3	3	0	13.93	36.5	14	1082.95
4	4	0	12.71	42	0	1522.62
5	5	0	13.32	42	0	1595.69
6	6	0	11.5	37	12	972.18
7	7	0	12.11	36	0	529.09
8	8	0	13.26	32	0	329.73
9	9	0	11.38	35	0	407.78
10	10	0	10.29	37	4	656.88
11	11	0	10.9	36	0	476.22
12	12	0	12.35	33	0	344.46
13	13	0	11.5	35	0	412.08
14	14	0	12.72	36	0	555.74
15	15	0	11.5	35	0	412.08
16	16	0	11.93	33	0	332.75
17	17	0	12	35	0	430.00
18	18	0	12.11	37	0	624.23
19	19	0	11.02	35	0	394.88
20	20	0	11.51	31	12	464.86
21	21	0	12.42	35	0	445.05
22	22	0	11.81	35	8	623.57
23	23	0	13.32	34.5	0	136.64
24	24	0	11.51	33	0	321.03
25	25	0	12.72	34	0	393.26
26	26	0	1405	34	0	434.38
27	27	0	12.11	32.5	0	319.45
28	28	0	12.72	37	0	655.67
29	29	0	12.72	34	6	530.02
30	30	0	13.02	35.5	0	517.70
31	31	0	11.2	37	0	577.32

Table VI. Experimental results when soil is in loose OMC condition.

S1. No	Sample No	Optimum moisture content	γ (KN/m³)	Φ degrees	C (KN/m²)	S.B.C. (KN/m²)
1	1	11.2	10.8	27	10	279.61
2	2	10.61	10.29	33.5	0	302.58
3	3	10.72	14.4	23	34	454.31
4	4	12.15	13.61	32	4	416.26
5	5	9.58	13.32	27	16	392.42
6	6	22.39	11.35	24	6	171.96
7	7	18.86	11.62	31	4	324.93
8	8	14.56	14.41	20	10	157.56
9	9	14.23	11.08	28.5	10	326.59
10	10	16.83	10.11	32	10	445.97
11	11	18.27	10.6	25	8	199.20
12	12	16.76	11.8	20	24	243.72
13	13	20.21	12.23	17	14.5	142.12
14	14	18.68	11.2	21	14	178.69
15	15	19.34	11.5	21	10	166.03
16	16	16.55	9.99	23.5	20	291.38
17	17	21.14	11.27	18	19	191.16
18	18	20.79	12.89	13	20	145.73
19	19	16.31	10.05	26.5	8	230.78
20	20	20.88	10.29	25	18	304.68
21	21	23.00	10.9	22	20.5	271.31
22	22	20.06	10.23	21	15	198.43
23	23	20.11	11.08	12	22	140.26
24	24	20.75	9.69	28.5	7	260.23
25	25	22.69	9.99	18	11	129.50
26	26	18.87	10.9	22.5	8	165.55
27	27	20.31	10.72	19.5	2	75.95
28	28	19.51	10.9	21	14	194.95
29	29	20.52	10.72	15	16	132.95
30	30	18.99	10.9	18	14	154.96
31	31	14.56	11.2	26	2	336.07

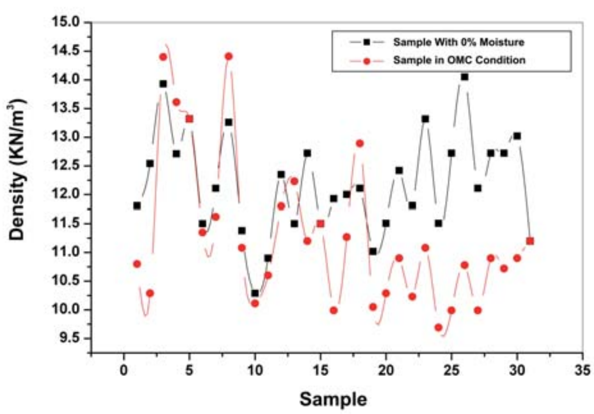

Fig. 4. Density (KN/m³) *vs.* sample.

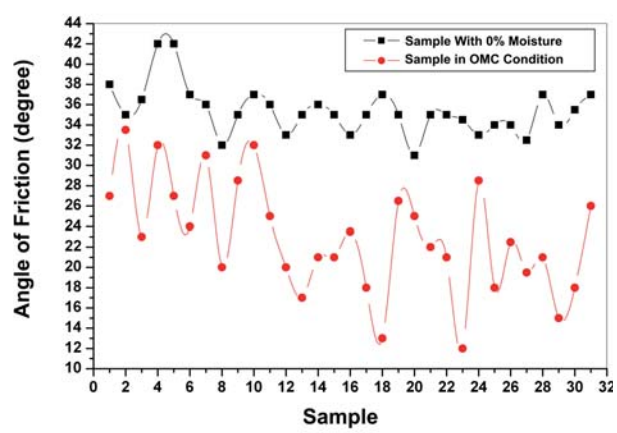

Fig. 5. Angle of friction *vs.* sample.

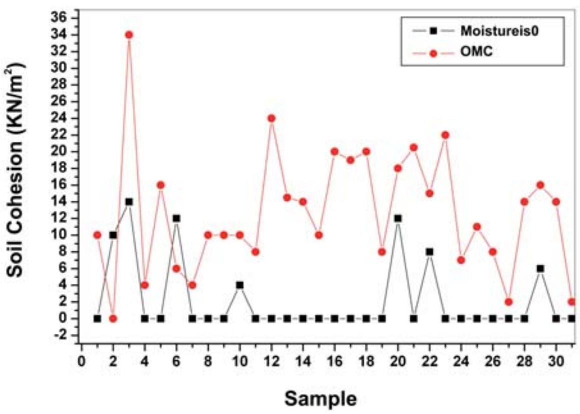

Fig. 6. Soil cohesion *vs.* sample.

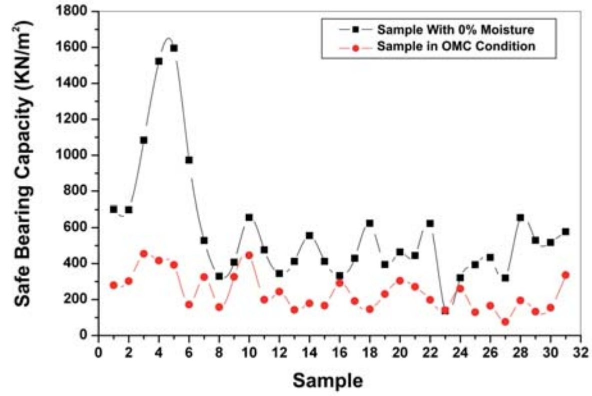

Fig. 7. Safe bearing capacity *vs.* sample.

CONCLUTION

Proper selection of mixtures made of suitable material could significantly improve soil bearing capacity.

Rising underground water is a factor involved in decreasing soil-bearing capacity and it has less effect on a model with proper soil combination.

It is possible for liquefaction mitigation to employ the soil mixing method. In design of soil mixing for liquefaction mitigation, finer material mixtures in model have positive correlation with soil bearing capacity.

Soil mixing technique could seriously improve the ability of soil resistance if it is faces shear failure.

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NOMENCLATURE

Φ (Degree) =Angle of Friction
C (KN/m^2) =Cohesive of Soil
OMC (%) =Optimum Moisture Content
SBC (KN/m^2)=Safe Bearing Capacity
γ (KN/m^3) =Unit Weight
q_f (KN/m^2) =Ultimate Bearing Capacity
q_{nf} (KN/m^2) =Net Ultimate Bearing Capacity
q_s (KN/m^2) = Safe Bearing capacity
N_c = General Bearing Capacity Factor
N_q = General Bearing Capacity Factor
N_γ = General Bearing Capacity Factor
B (Meter) = Width of the Foundation
D (Meter) = Depth of Foundation
F =Factor of Safety =3

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