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Influence of Fine Fraction on Shear Parameters and Consolidation Behavior of Tropical Residual Soil

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Abstract

Objectives: Tropical residual soils are widely available in the southern part of India and the construction in this type of soils more challenge issue to the geotechnical engineers to design the structure in the settlement criteria. **Analysis:** Tropical residual soils are in general are regarded as multi component, polyphase, and particulate system with compositional and/ or structural discontinuities. Both index and engineering properties of natural soils primarily depend on mineralogy and percentage of fine fraction. **Findings:** In this paper, eight soil samples are considered for to obtain the influence of the fine fraction on shear parameters and consolidation behavior of tropical residual soils in Tirupati region. Shear strength tests and one-dimensional compression tests have been conducted apart from the classification and identification tests. **Application/ Improvement:** Based on the experimental test results and analysis, it has been found that the percentage fine fraction has a greater significant influence on engineering properties like cohesion, angle of internal friction and compression index of tropical residual soils.

Keywords: Compression Index, Fine Fraction, Shear Parameters, Scanning Electron Microscopy, Tropical Residual Soil

1. Introduction

The engineering properties of geomaterials such as shear strength parameters and compressibility characteristics are boundless importance in the geotechnical engineering for foundation design of buildings, dams, roads, and other infrastructure projects. The engineering properties of soil such as cohesion (c), angle of internal friction (ϕ) and compression index (C_c) are chiefly be influenced by on the particle size distribution, plasticity nature and state of the soil. The advanced laboratory test data availability is very low, or where only poor quality soil samples are available, in such condition a preliminary valuation of the engineering properties can be predicted by using simple index tests of soil.

A painstaking experimental study has been carried out on the soil samples and these samples extracted from different depths from various locations of Tirupati region. The properties of Tirupati regions soil samples represent a widespread of soils normally encountered in this region. Based on the test results and analysis, a relation between the percentage fine fraction and engineering properties like cohesion, angle of internal friction and compression index of soils has been developed to understand the behavior of soil with different percentage of fine fraction and it indicates that greater influence on the engineering properties in tropical zones.

Several researches were carried out on the response of engineering properties of soils with index properties, and evidence of the significant effect of the fine fraction on engineering properties of soil. In the tropical zone, weathering of the parent rock is more intense and occurs to greater depths than elsewhere of residual soils and it's caused by the tropical climatic conditions, such as high changeability temperatures and precipitation. The residual soils engineering behavior is significantly influenced by the evolution of weathering processes, the presence of bonded structures and fabric, and also by the depth of penetration of which will be influenced by the disjointedness in the natural rock. The residual soil availability is more common and it's needed to analysis of for better performance of civil engineering structure on this soil[1].

The researchers carried out the study on residual soil

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to characterize the engineering properties of soil in the residual regions[2-4]. The investigated results are represented the influence of soil structure on the index and engineering properties and mainly on the compressibility behavior[5], and also evaluated effect of the collapsibility behavior of tropical residual soil[6,7].

The majority of laboratory studies are on residual soils are point out that the greater influence of index properties on engineering properties from the testes under triaxial or oedometer conditions. The shear resistance manifests from inter particle friction and which is described in terms of residual friction angle. Based on various attempts has been made to correlate residual friction angle (f_r) with the index properties of residual soil and it's found that the influence[8]. The relation of the f_r value with the clay fraction (CF) and for the given clay, f_r decreases with the liquid limit (w_L) and for a given liquid limit and clay fraction, f_r decreases with increase in normal effective stress[9,10]. A correlation between residual friction angle f_r and the liquid limit has been examined and the correlation have found greater significant influence and a parameter which is a function of liquid limit, plasticity index (w_p) and clay fraction. For residual soils, the researchers proposed correlations of f_r with liquid limit for various ranges of clay fraction[11-13].

The observation found out that the residual friction angle f_r is related to liquid limit, plasticity index and clay fraction, but better correlation has been observed for clay fraction with residual friction angle. These relationships are developed with single variable and empirical formulae for residual friction angle with multi variable soil properties are not available[14]. Recently, the researchers found that the amount of clay mineral may play an important key role in prediction of angle of friction based on index properties of soil[15].

The investigation results found that the characterizing of engineering properties of soil and analyzing their spatial pattern has a key role in dealing of soils for different land uses. The difficulty and in some cases the high cost of attaining the soil strength indices has led to many researchers looking for correlations with simply measured the index properties of soil[16-18]. Several empirical procedures have been developed over the decades to forecast the shear strength of soils, particularly for unsaturated soils.

The sample disturbance of soil also influence based on the percentage fine fraction and it has been founded that the study on the consolidation characteristics of compression paths (i.e., void ratio verses effective stress), it is the ratio of compression index before yield and after yield stress regimes under Oedometer test loading conditions. However, the compressibility needs analyze the test results of residual soils to understand the compression response and to evaluate the sample disturbance for comprehensive understanding of the behavior under loading for to solve a practical problems of soil[19-21].

2. Materials and Methods

2.1 Introduction

The residual soil is collected from the Tirupati region of Andhra Pradesh, India for the purpose of present investigation and the experimental study are carried out on tropical residual soils.

2.2 Experimental Investigation

The experimental study is wisely planned for analysis and fine content influence assessment to understand the engineering properties of tropical residual soils. The experimental work involves, to determine the basic and engineering properties of soil such as undrained shear strength and consolidation behavior. All the soil sample tests in this present study are conducted based on the provisions of stipulated in Bureau of Indian Standards.

2.3 Soils Tested

The present investigation purpose of soil has been obtained from the Tirupati region surroundings. The details of point locations of sampling are 1. Mullapudi, 2. Yogimallavaram Residential Area, 3. Industrial Development Park, Gajula Mandyam, 4. Fire Station Building at Nagari, 5. Besides Thiruchanur by-pass road, Tiruchanur, 6. Renigunta Road, 7 & 8. Nadavalur.

2.3.1 Collection of Samples

The soil samples have been collected from the site with necessary care for to maintain the natural condition and same transported to the laboratory (Fig:1). All the soil samples were air-dried and stored in air tight containers for the purpose further experimental study.

2.3.2 Properties of Soils

2.3.2.1 Basic Properties of Soils

The tested soil properties are considered in the present investigation and are reported in table 1. Based on the report, seven soils represents the Clayey Sand and one is Clay with Intermediate compressibility. The particle size analysis for eight the soil samples are presented in figure 2 and from the figure that particle size analysis curves are large variation with fine content stretching from 28.6% to 68% and hence its represents the wide range of soil in this region. The liquid limit and plastic limit values range from 47.5% to 85.0% and 14% to 26% respectively and its represents the wide range of soils. The Scanning Electron Microscopy test have been conducted for the all samples for to understand the basic visual behavior of sample in site condition and it's shown in figure 3.

Figure 1. Soil sample collection in the site.

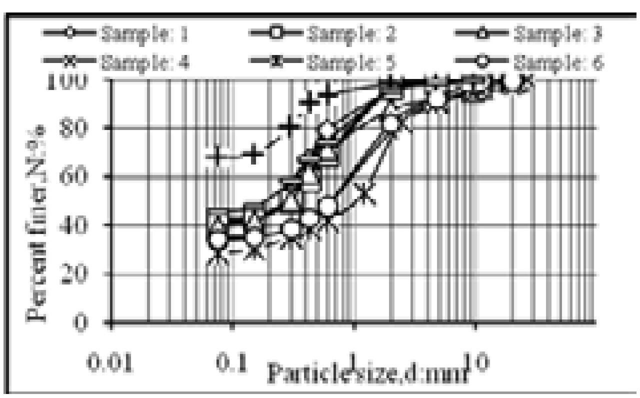

Figure 2. Grain size distribution curves for the combination of all samples.

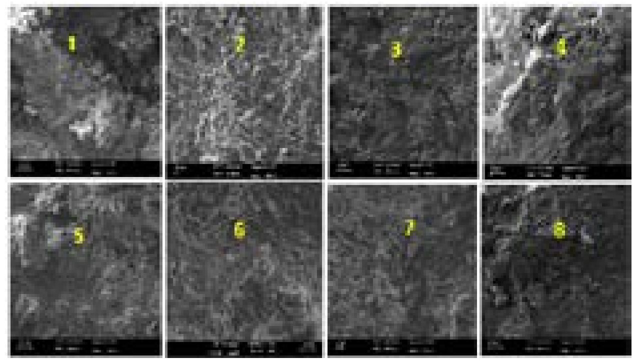

Figure 3. SEM photograph of all eight soil samples.

2.3.2.2 Shear parameters of Soils

An attempt has been made to determine the shear parameters of soils under consideration. The values of the shear parameters depend on the drainage conditions as simulating in field conditions. The laboratory triaxial test under the condition of un-drained shear has been conducted on the all soil samples in the in-situ state. The stress-strain response for all the soil samples for confining pressure of 50 kPa is found to be lower than the confining pressure of 100 kPa. The change in deviator stress may be attributed to change in void ratio affected due to internal drainage occurring on the account of partial degree of saturation. The maximum deviator stress ranges from 120 kPa to 300 kPa depends on variations in structural arrangement of particles, particle groups and the relative effect of fine fraction on the strength behavior.

Compressibility behavior:

The compressibility behavior of soil is the major important engineering properties and it symbolizes the volume changes with under loading condition; the behavior representing the magnitude of settlement under the increases with the effective stress. The in-situ compression most often takes place under the one-dimensional consolidation, and it is simulated by Oedometer tests. It is performed for eight soil samples under the undisturbed condition in this present study. The sensible care has been excised to retain basic constituents of the soil and the in-situ state. The test samples have been saturated under 5 kPa normal effective stress with duration of 24 hours to attain almost the state of saturations. The consolidation behavior of all eight soil samples effective stress-void ratio curves are presented in figure 4.

Based on the consolidation test results, the void ratio verses effective stress curve are represented initially rigid response up to a particular effective stress value and shows a greater gradation of compression beyond this effective stress value. The same compressibility behavior is noticed with respect to the tested eight soil samples.

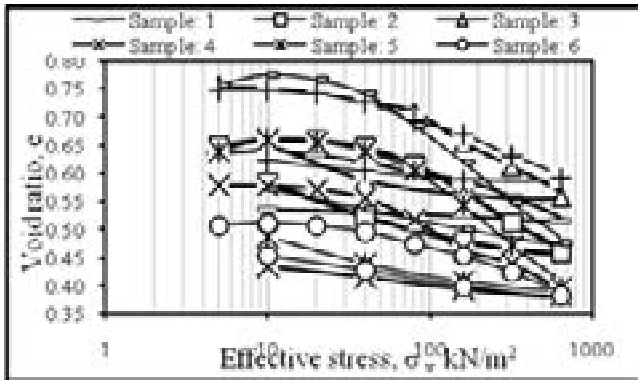

Figure 4. One-dimensional consolidation curves for the combination of all the soil samples.

3. Results and Discussion

3.1 Introduction

The main object of detailed experimental investigation to propose of obtaining the relations between the percentage fraction and engineering properties of shear strength and consolidation behavior of soil. The analysis results are presented in the following section.

3.2 Shear Strength Parameters Verses Percentage Fine Fraction

The structural strength of soil is primarily depends on the function of shear behavior. The soil failure generally occurs due to "shearing behavior" along the internal surface within the soil particles. The shear strength of the soil is represent based on angle of internal friction and cohesion and its ability to resist sliding along internal surfaces within the soil mass. The angle of internal friction of the soil primarily depends upon density, particle size analysis, particles shape, surface texture, and the moisture content. The shear strength behavior is directly related to the applied normal force acting between the particles of soil.

Based on the importance of shear strength parameters, an attempt has been made to find out the relation between percentage fine fraction (FF) and the angle of internal friction (ϕ) is shown in figure 5, with a correlation of 0.909 and the corresponding equation is as follows,

$$\phi = -0.5614FF + 41.074 \tag{1}$$

The relation may be noticed that the increase of fine fraction decreases the angle of internal friction.

Another attempt has been made to find out the relation between the cohesion (c) and fine fraction (FF) is shown in figure 6, with a correlation of 0.9325 and the corresponding equation is as follows,

$$c = 0.7952FF + 11.692 \tag{2}$$

Table 1. Soil Properties

Sl. No:	Description	Values (Sample)							
		1	2	3	4	5	6	7	8
		Depth at, m							
		2	2.8	2.1	3	2.4	2.3	1.7	2.5
1.	Gravel, G (%)	1.40	1.40	7.90	10.15	9.10	7.60	0.30	1.30
2.	Sand, S (%)	58.10	56.70	52.20	54.35	62.30	57.90	31.70	53.00
3.	Silt+Clay, (M+C) (%)	40.50	41.90	39.85	35.50	28.60	34.50	68.00	45.70
4.	Liquid Limit, wL (%)	58	59.5	68	69.5	85	68.7	47.5	56
5.	Plastic Limit, wP (%)	15	20	14	24	26	23	14	16
6.	Plasticity Index, IP (%)	43	39.5	54	45.5	59	45.7	33.5	40
7.	Indian Standard Classification	SC	SC	SC	SC	SC	SC	CI	SC
8.	Shear Strength Parameters								
	Angle of internal friction, ϕ in degrees	18	17	18.5	22	27	23	5	11
	Cohesion, c in kPa	45	47	45	39	31	38	63	52
9.	Compressibility Characteristics								
	Compression Index at post yield, Cc_2	0.176	0.173	0.160	0.189	0.220	0.180	0.107	0.163
	Compression Index at pre-yield, Cc_1	0.033	0.015	0.042	0.010	0.027	0.011	0.038	0.056

It may be noticed that the linear relation between the cohesion and the percentage fine fraction.

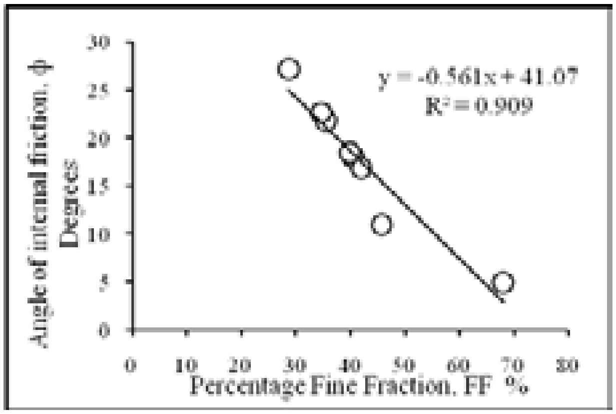

Figure 5. Percentage fine fraction verses angle of internal friction.

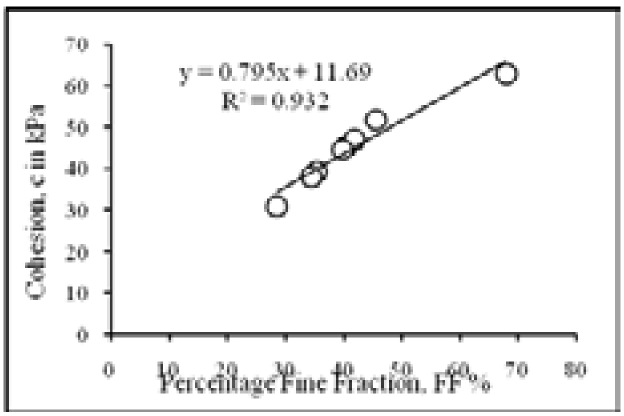

Figure 6. Relation between percentage fine fraction and cohesion.

3.3 Compressibility Characteristics Verses Percentage Fine Fraction

3.3.1 Compressibility Characteristics

The compressibility behavior observed based on the analysis of test results and it is represented in table 2, it is point out that the percentage of initial compression with given effective stress is 6% to 10% with relate to the end compression for eight tested samples in this present study. Based on the investigation the effective stress up to at 40 kPa is more affective on soil and at it is respond like a rigid behavior and after that linearly increased with loading (soil state i.e., void ratio changes).With the unloading condition, the recompression index of soil decreased effectively 4.03% to 20% with compare to the final compression for eight soil samples. The percentage of compression with effective stress intervals are as shown in figure 7 and the comparative percentage of consolidation for eight samples are represented in figure 8.

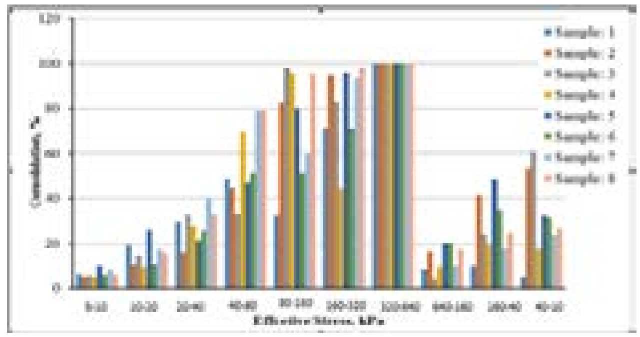

Figure 7. Effective stress verses Consolidation for all soil samples.

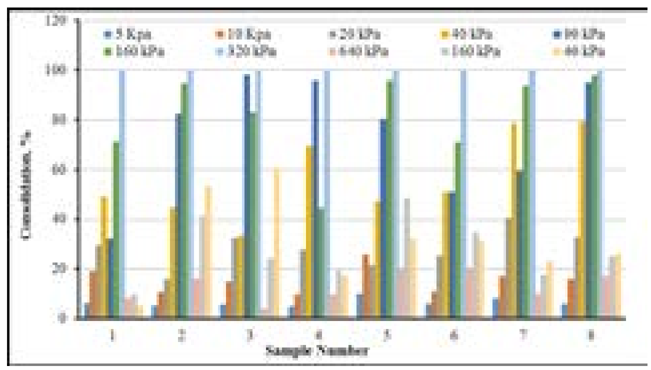

Figure 8. Consolidation behavior of all samples.

Based on the importance of compression index for to evaluate settlement analysis of soil, an attempt has been made to find out the relation between percentages of fine fraction (FF) and compressibility index (Cc) and it is shown in figure 9.

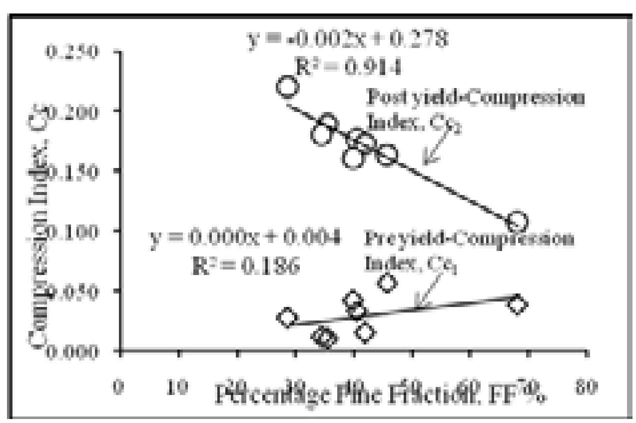

Figure 9. The relation between percentage fine fraction and compression index.

Table 2. Consolidation behavior at different loading

Sl. No:	Effective Stress Intervals, kPa	Sample No:							
		1	2	3	4	5	6	7	8
		Consolidation, %							
1.	**Loading:** 5-10	6.37	5.33	5.81	5.10	10.00	6.10	8.10	6.20
2.	10-20	19.12	10.65	14.84	9.72	25.86	10.91	17.02	15.85
3.	20-40	29.48	15.98	32.58	27.78	21.65	25.45	40.43	32.93
4.	40-80	49.00	44.76	33.23	69.44	47.13	50.91	78.72	79.27
5.	80-160	32.27	82.46	98.39	95.83	80.46	50.91	59.57	95.12
6.	160-320	71.31	94.71	82.90	44.44	95.98	70.91	93.62	102.44
7.	320-640	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
8.	**Unloading:** 640-160	8.37	16.27	4.03	9.72	20.00	20.00	10.00	17.07
9.	160-40	9.96	41.37	24.19	19.44	48.66	34.76	17.51	25.00
10.	40-20	5.38	53.37	60.48	17.36	32.28	31.45	23.40	26.22

Based on the analysis of soil, it is indicated the influence of the fine fraction is more on the compression index at post yield (Cc2) with the compare to the compression index at pre yield (Cc1) as shown in figure 9. With increases the fine fraction content the post yield compression index is decreasing and pre compression index is mildly increases. The fine fraction content and post yield compression correlation is obtained as 0.9144 and the corresponding equation is as follows,

$$Cc_2 = -0.0026FF + 0.2786 \quad (3)$$

4. Conclusion

Based on test the results and analysis, it has been indicated that the percentage fine fraction content has a significant influence on the soil engineering properties such as shear strength and parameters and consolidation characteristics. With increases of percentage of fine fraction the angle of internal friction is decreases and the linear relation is founded between the cohesion and the percentage fine fraction. The influence of the fine fraction is more on the post yield compression index (Cc2) with the compare to the pre yield compression index (Cc1). To increase with the fine fraction the post yield compression index is decreasing and pre compression index is mildly increased. These empirical correlations may be useful for primary and micro level investigation of residual soils in the tropical zone.

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