Impact of Different Non-Plastic Fines Contents on Undrained Shear Strength Behavior of Soil

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ABSTRACT
The flow failures of the alluvial sandy ground cause catastrophic damage such as tilting of structures, floating up of structures, permanent later displacement of ground. In order to quantify the tendency of flow characteristics of sandy soils, a simple and reliable concept of steady state strength approach has been used. To evaluate the same, total ten tests are conducted with relative density varying as 30% and 45% and for same effective consolidation pressure of 120kPa. It was observed that with increase in equivalent granular state parameter the residual shear strength reduces till threshold fines content and later on increases.

KEYWORDS: Non plastic fines, threshold fines content, undrained shear strength

INTRODUCTION
Past research has debated the effect of non-plastic silt content on liquefaction potential of sand. Many studies suggested that liquefaction resistance increases with increase in silt content (Seed et al.1983,1985; Tokimastu and Yoshimi 1983; Salgado et al. 2000; Polito and Martin 2001). However, other studies concluded that potential for contractive behavior is based on the deposition state either loose or dense (Lade and Yamamuro 1997; Kuerbis 1989; Zlatovic and Ishihara 1997). The focus of this study was to study the determination of equivalent granular state parameter and its effect on the residual shear strength of the soil. Systematic variation in fines content (0%, 5%, 15%, 25% and 30%) and densities (low and medium) were used to determine how each affects the liquefaction potential of sandy silt.

EXPERIMENTAL INVESTIGATION
SAMPLE TESTED
Clean sand

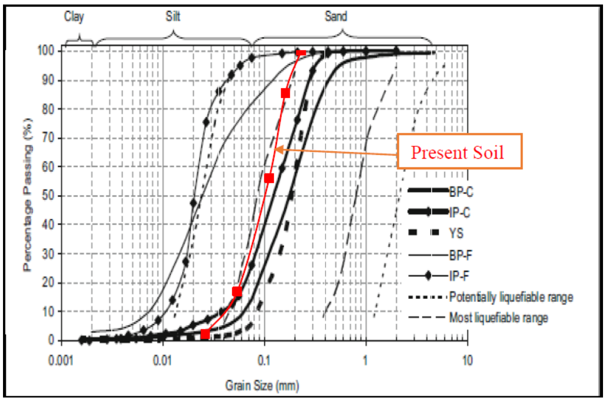

Figure 1. Grain size distribution curve for clean sand used in the proposed research work along with grain size distribution of soils susceptible to liquefaction proposed by Tsuchida (1970)

Clean silt
Grain size distribution or the percentage of various sizes of soil grains present in given dry soil sample, is an important soil grain property. The sieve analysis procedure is confirming to IS 2720 Part 4 using hydrometer. Grain size distribution curve of the silt used for testing is as shown in Figure 2.

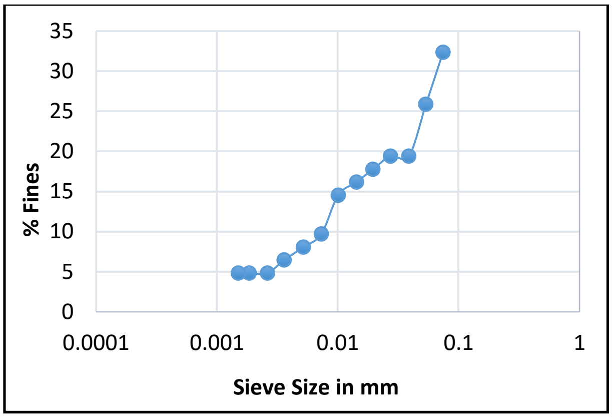

Figure 2. Grain Size Distribution curve for clean silt used in the Proposed Research Work

Determination of Maximum density (γ_{max}) and Minimum density (γ_{min}) of sand and silt respectively

The maximum and minimum density has been computed by a procedure confirming to IS 2720 Part 14. Using these values, e_{max} and e_{min} are calculated

$RelativeDensity$ (%)= $((e_{max} - e)/(e_{max} - e_{min}))$ x100 **……………………………….......*eq (1.)***.

Where $e= G \times \gamma_w \gamma_d$ -1

Where γ_w= Density of water (9.81 kN/m^3)

Using these relations and basic equations in Soil Mechanics, the quantity of sand required to fill the known volume is calculated. Also quantity of water is calculated. And the required relative density is achieved. Table 1. Show the properties of clean sand and Table 2. Show properties of clean silt.

Table 1.Properties of clean sand

Properties Of Sand	Value	IS Code
γ_{max}	18.12 kN/m^3	IS : 2720 (Part 14)-1983
γ_{min}	15.34 kN/m^3	IS : 2720 (Part 14)-1983
G	2.67	IS : 2720 (Part 3/sec 1)-1980
e_{max}	0.8093	IS : 2720 (Part 14)-1983
e_{min}	0.5725	IS : 2720 (Part 14)-1983
D_{50}	0.28 mm	IS : 2720 (Part 4)-1985
C_u	2.56	IS : 2720 (Part 4)-1985
C_c	1	IS : 2720 (Part 4)-1985

Table 2. Properties of silt

Properties Of Sand	Value	IS Code
γ_{max}	15.17 kN/m^3	IS : 2720 (Part 14)-1983
γ_{min}	11.91 kN/m^3	IS : 2720 (Part 14)-1983
G	2.67	IS : 2720 (Part 3/sec 1)-1980
e_{max}	1.1070	IS : 2720 (Part 14)-1983
e_{min}	0.6547	IS : 2720 (Part 14)-1983
D_{50}	0.02mm	IS : 2720 (Part 4)-1985
C_u	1.6	IS : 2720 (Part 4)-1985
C_c	0.056	IS : 2720 (Part 4)-1985
LFC	27.07	H. K Dash & T.G.Sitharam

INSTRUMENTATION

For any experimental work instrumentation has become an integral part now-a-day.. To study the initiation of liquefaction using this equipment one transducer, Linearly varying Deformation Transducer (LVDT) and load cell are used. Transducer is used to measure pore water pressure, LVDT to measure axial strain and load cell to apply axial load. Capacity of pore pressure transducer is with least count 0.1 kPa, capacity of LVDT is 10 mm with least count of 0.1 mm & capacity of load cell is 15 kN.

Pore pressure transducer is used to measure the pore water pressure

LVDT is mounted on the triaxial cell as to measure axial deformation.

The air water system comprises of two cylindrical chambers with balloon arrangement, one used to apply confining pressure to simulate field condition and other used to saturate the specimen so as to simulate the liquefied soil. Capacity of each chamber is 1000kPa with least count 1kPa.

Vacuum Pump is used to remove the air voids present in between soil particles after soil is reconstituted.

TESTING PROGRAM

Test was planned with moist tamping method for size 75mm x 150 mm and fines varying before and after 'Threshold Fines Content'. Detailed testing program is given in Table 3.

TESTING PROCEDURE

Initially a weighed amount of soil is determined from relative density , then it is mixed with five percent of water. The split mould along with a membrane is placed on the triaxial base. The mould is filled with approximately same amount of soil with fixed amount of blows. After the mould is completely filled with soil, its end is made water tight using O-rings. After the specimen is prepared it is subjected to vacuum to avoid the disturbances during further process. Now, the spilt mould is removed and the density of the specimen is ensured by measuring the height of the specimen. The triaxial cell is placed over the specimen. The cell is completely filled with water by means of a motor and if there is no leakage detected than carbon-di-oxide is supplied to accelerate the saturation rate of the specimen. By simultaneous application of confining pressure and back pressure, the specimen is saturated till 100%. The 100% saturation is measured by using Skempton's Pore pressure parameter (B value) defined as ratio of change in confining pressure to the change in the pore pressure. The B value greater than 0.96 indicated the specimen is 100% saturated.

The specimen is isotropically consolidated at an effective stress of 120kPa. Now, the specimen is sheared at a constant rate of 0.01 %/min, this is minimum possible strain at which there is uniform dissipation of pore water pressure. The LVDT is mounted on the cell to measure the deformation during shear. The readings are recorded till a visual failure pattern of specimen.

Table 3. Testing Program

Sr. No.	Name of Test	Fines Content	Relative Density	Voids Ratio	Effective Stress
1	M-00	0%	30%	0.7382	120 kPa
2			45 %	0.7072	120 kPa
3	M-05	5%	30%	0.6769	120 kPa
4			45 %	0.6461	120 kPa
5	M-15	15%	30%	0.6141	120 kPa
6			45 %	0.5761	120 kPa
7	M-25	25%	30%	0.5951	120 kPa
8			45 %	0.5569	120 kPa
9	M-30	30%	30%	0.6389	120 kPa
10			45 %	0.5987	120 kPa

RESULTS AND DISCUSSION

4.3 Determination of undrained shear strength of the sand with varying fines content.

The concept given by Castro and Polous,1985 (Figure 13.) was used to determine the undrained shear strength of the silty sand.

$S_{su} = q_s \cos \Phi_s$ …………………………………. ***eq (2.)***

$\sin \Phi_s = q_s /(\sigma'_{3s} + q_s)$………………………......***eq (3.)***

$q_s = (\sigma'_{1s} - \sigma'_{3s})/2$……………………………….……***eq (4.)***

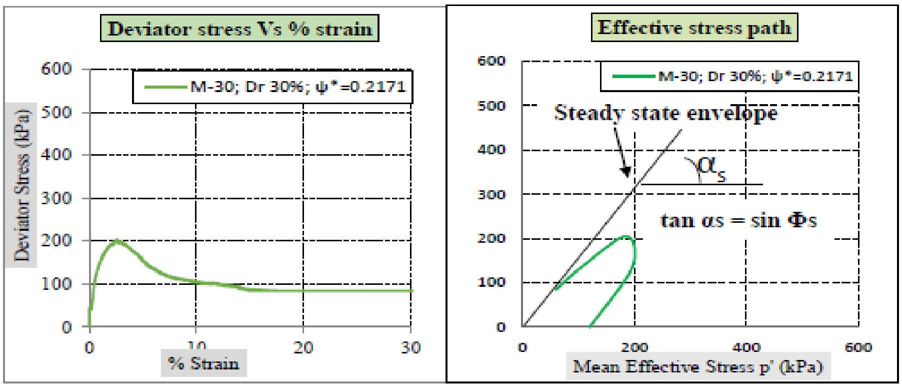

Figure 3. Determination of internal angle of friction (Φ_s)

Table 4. Undrained shear strength of sand silt mixture for RD =30%

Fines content (%)	α_s	φ_s	Ψ*	Ssu (kPa)
0	41	60.37	0.02	123.11
5	42	64.21	0.057	40.78
15	43	68.83	0.121	28.89
25	44	74.94	0.367	5.59
30	43	71.61	0.23	13.38

Table 5. Undrained shear strength of sand silt mixture for RD 45%

Fines content (%)	α_s	φ_s	Ψ*	Ssu (kPa)
0	41	57.07	0.02	138.7
5	42	60.37	0.057	55.61
15	43	64.21	0. 058	42.85
25	44	68.83	0.09	21.66
30	43	66.39	0.052	42.67

Undrained shear strength and relative density

As relative density increases the natural voids ratio decreases and due to close packing of the soil mixture, the undrained shear strength increases. Figure 4, shows that with increase in relative density from 30% to 45% the shear strength increases for all fines content. The residual shear strength of clean sand is maximum as compared to sand with varying fines content.

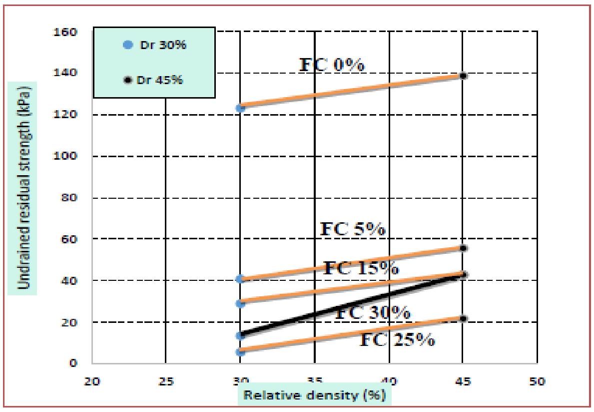

Figure 4. Undrained Residual Strength Vs. Relative Density

CONCLUSIONS

The undrained residual strength increases with increase in relative density.

The strength of silty sand up to 25% fines content is less than that of clean sand. It means that the strength of soil is weakened with increase in fines content upto 25%.

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