EVALUATION OF SOIL PARAMETERS BY USING LIGHT CONE PENETROMETER

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ABSTRACT: Conventional investigation methods such as standard penetration test, cone penetration test are fail to identify week deposits like soft clay and designing the foundation without identifying presence of such layer and its strength is risky. Under the conditions stated, a simple field testing equipment required to operate in such deposits and is also to be well suited for projects like road works, simple buildings etc. One such equipment is a light cone penetrometer (LCPT). Tests are done using LCPT at a few sites and resistances are recorded over a depth of 6 m at each locations. Resistances are also measured by conducting standard penetration test at location wherever LCPT was done. Correlation between LCPT and SPT resistances is developed. Simultaneously soil samples are collected from each location of LCPT and tested in laboratory for index properties and parameters such as shear strength, compressibility and field CBR. These soil parameters are correlated with the LCPT resistance individually.

KEYWORDS: Penetrometer test, light cone penetrometer, soil parameters, correlation

1 INTRODUCTION

Field tests plays a major role in sub-surface investigation in assessing strength and compressibility properties of various deposits at a location of a project. There are different methods of investigation, among them penetration tests such as Standard Penetration Test (SPT), Static Cone Penetration Test (SCPT), Cone Penetration Test (CPT) are widely employed in geotechnical investigation in general to assess relative strength of deposits. There are penetrometers with special arrangement ment for measuring in-situ stress, porewater pressure, dynamic properties etc. In overall it can be said that a subsurface investigation is incomplete without a penetration test. It is because not only the relative strength of deposits are known at insitu but also many empirical correlations between penetration resistance and various properties (shear strength parameters, compressibility parameters, over consolidation pressure, swell properties, subgrade modulus etc.) are developed over a period based on numerous field data (Meyerhof, 1956; Ilamparuthi, 1981; Zaki et al., 1990; Aroosa, 2000; Moayed and Naeini, 2006; Ravisharma and Ilamparuthi, 2009; Deepika and Chakravarthi, 2012; Nwobasi and Paul, 2013). Despite well established correlation and lot of improvisation over operation of penetrometers, researchers are working on developing simple device, which can be employed effectively in poor deposits where in undisturbed sampling is next to impossible, thus penetrometers like T-bar penetrometers, ball penetrometer and light cone penetrometer are developed and are put in use. In this study a light cone penetrometer is developed and its operation is standardised. Tests are conducted at four sites by employing LCPT and SPT and the resistances are correlated so as to use the correlations which are based on SPT 'N' values. Soil samples both undisturbed and disturbed samples are collected and tested. The results thus obtained are correlated with LCPT resistances. The details of equipment, operation procedure and correlations developed are presented in this paper.

2 METHODOLOGY

The light cone penetrometer is adopted in the field along with the standard penetration test equipment. Boreholes were drilled in the field by rotary drilling method and standard penetration test were conducted at intermittent depths in the borehole. Tests using light cone penetrometer were conducted around the borehole at a radial distance of 1m. Field tests were also done, to determine the CBR value of the soil at its natural state, at a radial distance of 1m. The resistances recorded in the light cone penetration test were then correlated individually with the resistance measured in the standard penetration test and the field CBR value obtained from the tests. Simultaneously soil samples were collected from the site to determine their shear strength parameters and compressibility characters. These parameters were then correlated individually with the penetration resistance obtained from the light cone penetration test.

3 LIGHT CONE PENETROMETER

The light cone penetrometer used in this study was designed and fabricated by the authors. The components of the light cone penetrometer are cone, detachable driving rods, guide stand, hammer, hammer guide rod and anvil. The dimensions of the components of LCPT are as presented in Table 1.

Table 1 Dimensions of various components of LCPT.

Component	Dimension
Cone	Dia – 25 mm, Apex angle - 30^0
Driving rod	Dia – 20 mm, Length – 500mm
Guide stand	1000 x 600 x 500
Hammer	Weight – 14.5 kg
Hammer guide rod	Dia – 50 mm, Length – 700 mm
Anvil	Dia – 100 mm, Length – 150 mm

Fig 1 Light cone penetrometer

4 PROCEDURE

There is no standard procedure for LCPT test and a procedure is adopted which is explained as follows

At a selected test location, the surface is cleaned and leveled to fix the guide frame assembly. The frame is fixed firmly on to the ground with anchor rods driving through the base plate of the frame. The driving rod is made to pass through the hole of the cross bar which is connecting the frames. The cone is fixed at the bottom of the driving rod and the top of the driving rod is connected to the anvil with the help of adapter. The hammer rod is fixed to the anvil through which the hammer is allowed to fall. The verticality of the driving rod assembly is checked before driving the rod. Fig. 1 shows the operation of LCPT at a site.

The cone and drive rod assembly is driven into the soil by dropping the hammer on the anvil at the rate of 15blows/minute. The blows required for every 5cm penetration of drive rod and cone assembly is recorded. After every 50mm penetration of drive rod and cone into the soil the anvil and the hammer rod are removed and the length of the drive rod is extended by attaching another graduated rod. The driving rod assembly is driven further depths by attaching the anvil and by dropping the hammer on the anvil. The procedure is repeated till the number of blows required for 50 mm penetration exceeds 20. This condition is exercised to avoid damage to the cone and drive rod assembly. The test can also be terminated if the depth of penetration reaches 6 m. After the test is completed, the driving rod assembly is removed by back hammering technique. The hammer rod and the anvil are detached and the hammer is inserted through the driving rod above which the anvil is fixed for back hammering.

The resistance thus recorded is plotted with depth to know the relative strength of the deposit. The cumulative number of blows for every 30 cm penetration are calculated and plotted in the graph.

5 TEST LOCATIONS AND DETAILS OF TESTS.

The sites selected for conducting field tests are Muttukadu, Poonamalle, Mogappair West and Perumbakkam. SPT tests were conducted at these sites and the soil strata were identified. The soil strata present in Muttukadu, Poonamalle and Mogappair were identified as poorly graded sand of loose to medium dense state. The soil present in Perumbakkam was high plastic clay of soft to medium stiff consistency. The field tests conducted in the sites were SPT, LCPT and CBR tests. At each site one SPT and three LCPT's at a radial distance of 1 m from the SPT location, three field CBR tests and field density tests were conducted. Simultaneously soil samples were collected from the sites and were tested for index, strength and compressibility properties.

6 RESULTS AND DISCUSSION

As stated LCPT was conducted at three locations at each site and the average value was determined for every 50 mm penetration and the values determined over the layers of penetration of 6 m were compared with SPT values recorded. The SPT values recorded are taken as N_{60} and the values are not corrected for overburden since LCPT and SPT are conducted under identical conditions of the deposits. These two values are correlated and relation between them for sand and clay deposits are determined independently. Similarly the resistances of LCPT is correlated with angle of shearing resistance in case of test in sandy soil and correlated with unconfined compression strength in case of test in clayey soil. The correlation established are presented in the subsequent sections.

6.1 Correlation between SPT and LCPT

From the field tests conducted the resistances recorded in the standard penetration tests and the light cone penetration tests in sand strata are plotted in Fig. 2. The correlation between the SPT and the LCPT resistance for sand of loose to medium dense condition is found as,

$$N_{SPT} = 0.446 * N_{LCPT} \quad (1)$$

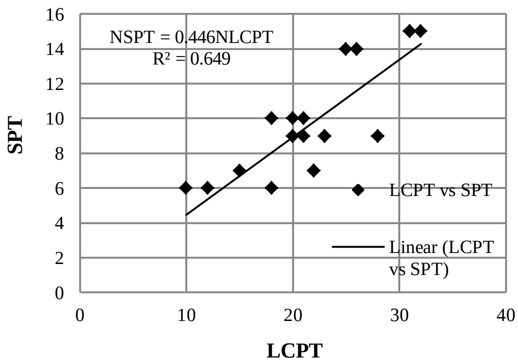

Fig. 2 LCPT resistance vs SPT-N value for sand

Similarly resistances of SPT's and LCPT's recorded in clay deposits are plotted in the Fig. 3 and the correlation obtained between them is given in the following equation.

$$N_{SPT} = 0.55 * N_{LCPT} \quad (2)$$

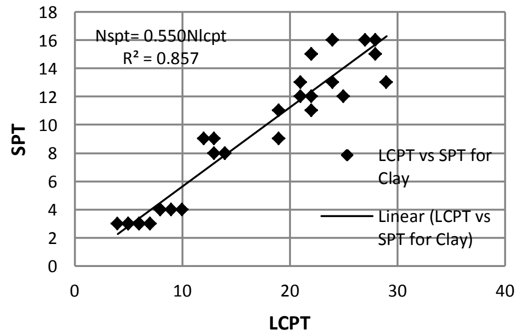

Fig. 3 LCPT resistance vs SPT-N value for clay

6.2 Correlation between LCPT and ∅

Direct shear tests were conducted on the soil samples of sand collected from Muttukadu, Poonamalle and Mogappair, and angle of shearing resistances of sand of respective locations are presented in Table 2 along with average N_{LCPT} values and relative densities. The angle of shearing resistance obtained are 29^o for loose condition of sand, 33^o-34^o for medium dense condition and 36^o for dense condition. The respective N_{LCPT} values are 10 blows, 18 blows and 22 blows. Both N_{LCPT} and ∅ values obtained from direct shear test are related and the relation between them is as given in equation 3.

$$\emptyset(deg) = \sqrt{20 * N_{LCPT}} + 15^o \quad (3)$$

Where, ϕ = angle of shearing resistance of sand

Table 2 Variation of ϕ value with N_{LCPT}

N_{LCPT}	Relative density	Φ(°)	Equation (3)
10	Loose	29	29.10
17	Medium	33	330
19	Medium	34	34.50
22	Dense	36	35.90

The ∅-values thus obtained from the equation 3 compares well with the value obtained from direct shear test for loose and medium dense condition of sand.

6.3 Correlation between LCPT and C_u

The natural moisture content of the samples are varied between 33% and 42%.The undrained cohesion value of the clay of Perumbakkam is found to vary between 29 kN/m^2 to 39 kN/m^2. The higher value is for the clay sample with lower moisture content where in N_{LCPT} equal to 18 blows.

The undrained cohesion values thus obtained are related with N_{LCPT} values and following empirical relation is obtained.

$$C_u = 0.033 * N_{LCPT} * P_a \quad (4)$$

where, N_{LCPT} = number of blows for 30cm penetration, C_u = undrained cohesion and P_a = atmospheric pressure (≅100 kN/m^2). The value of C_u obtained from the equation 4 is compared with experimental values as well as Terzaghi's recommendation based on SPT value in Table 3.

The C_u values obtained by the empirical relation (equation 4) compares reasonably with the experimental values as well as with the values obtained from the relation suggested by Terzaghi.

Table 3 Comparison of C_u values.

N_{LCPT}	Undrained Cohesion (Cu) kN/m2		
	Experiment	**Equation (4)**	**Terzaghi (based on N value)**
12	38.8	39.6	41.2
12	36.2	39.6	41.2
10	28.7	33	34.3
10	31.1	33	34.3

6.4 Correlation between LCPT and Compressibility Character

The compressibility characteristics of clay samples collected from the field were determined by conducting consolidation tests in the laboratory. It is well known that the compressibility of clay soil depends on content of clay fractions and its plasticity, therefore a correlation between coefficient of volume change (m_v), plasticity index and N_{LCPT} as in equation (5) is formed, which is an identical equation as suggested by Stroud (1975) except that the above equation (5) relates the m_v with N_{LCPT} instead of SPT 'N'. From the equation multiplication factor f is determined using experimental m_v value and field N_{LCPT} value and the values thus determined are plotted in Fig. 4. The curve follows the trend of Stroud (1975)

$$f = \frac{1}{(m_v * N_{LCPT} * P_a)} \quad (5)$$

where, f = multiplication factor, m_v = coefficient of volume change and P_a = 100 kN/m^2.

6.5 Correlation between LCPT Resistance and Field CBR Value

The strength of the subgrade soil was determined by conducting field CBR test as per IS 2720-1970. The surcharge load applied 100 N. It was found that the CBR value varied marginally with the LCPT resistance. The field CBR values are then plotted against the LCPT resistance in Fig 5. The correlation is obtained by curve fitting technique in equation 6.

$$CBR = 1.59 * (N_{LCPT})^{0.375} \quad (6)$$

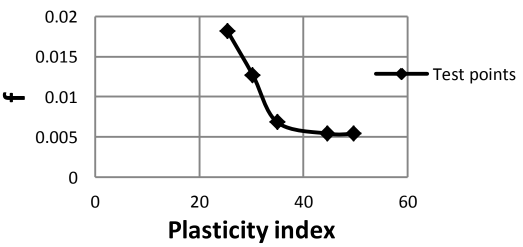

Fig. 4 Correlation between LCPT resistance and coefficient of volume change

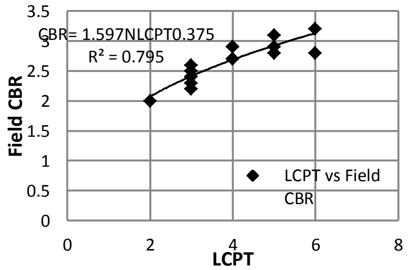

Fig. 5 LCPT vs field CBR

7 CONCLUSION

LCPT and SPT resistances recorded with depths showed almost similar trend irrespective of nature of deposit, however the LCPT resistances are higher than SPT resistances recorded irrespective of the type of deposit. The resistances of LCPT are correlated with SPT 'N' values and strength parameters of sand and clay. The empirical relations obtained are presented. However these relations need further examination by conducting tests at more locations.

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