A METHOD TO PREDICT REALISTIC SPT RESISTANCE OF EXPANSIVE CH SOILS BASED ON DCPT

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ABSTRACT: The standard exploration programme aims at bore log with SPT and undisturbed samples at interval of depth 2 m. As soil profile is unknown, SPT test, normally recommended for non cohesive soil deposits, is often the only data available to predict shear and compressibility of wet clays in common practice, of soil exploration data. The state of art of test, codes and interpretations are presented by Desai, M. D. [1]. The data is presented as penetration resistance of SP sampler or cone as N_SPT and N_c blows/30cm. Over burden correction is only for non-cohesive deposits. The authors have always adopted DCPT (Part I) as quick, cheap test for all sites. The data of investigation for 29 no of sites around South Gujarat, having top expansive CH soils upto the depth of 8 is analysed. It brought out a unique correlation of N_C/NSPT with depth. N_C by DCPT for any depth is used to discard unusual low N_SPT observed by pre-wetting by driller, drilling method and practices by operators. At depth of foundation and 2 m below, estimated N_SPT could be derived to obtain realistic N_SPT values. A case study illustrates that pile/raft foundation recommended could be reverted to shallow foundation for a project by such checks.

INTRODUCTION

Normal soil exploration for shallow foundations as per codes, adopts alternate standards penetration test (SPT) and undisturbed sampling at 1.5 to 2.0 m interval. The international society of SMFE TC-16 [2] provided guidelines for SPT for global uniformity. Though SPT test is recommended for non-cohesive soils which cannot be sampled in insitu state, in exploration reports, large number of tests have been reported in cohesive soil.

The empirical correlations practiced by geotechnical engineers, and related state of art of the test, equipment and interpretation are established by Desai, M.D. [1]. In absence of data as no UD sample was collected where SPT is performed, lower N_SPT is interpreted to obtain shear, compressibility parameters to assess safe bearing capacity, CBR and safe bearing pressure etc. The data is adopted to evolve stability analysis or design of ground improvement of foundations in cohesive soils, when no other direct or indirect data are available.

The data of exploration provides significant information varying from 0 to 100 %. The authors have adopted parallel DCPT test (Part I) for all sites to cross check soil strata. DCPT is interpreted by state of practice Desai, M.D. [1].

The SPT records frictional resistance of a metal tube against soil insitu disturbed by per-drilling (watering), release of stress and drilling operations in addition to human factors operating manual operations. DCPT test has no bore and records resistance to shear of the soil continuously. It suffers adhesion on road at deeper depths. In expansive desiccated top clays, it is less disturbed by operations and human factors.

INSITU SPT – DCPT TEST

Both test standards IS: 2131 [3], 4968 (Part I) [4] ISSMFE TC-16 recommended reference test [2] have been discussed in detail by Desai M. D. [1].

For generalized specifications of alternative SPT and UDS at 1.5 m interval for all site and soils, may provided significant data varying from 0 to 100%. The codal and test book interpretations of tests gives wide range and at the same times extremely conservative. The SPT tests in cohesive soils are also corrected for surcharge pressure by many investigation reports which is illogical.

The practiced interpretation for saturated soils (> 80%) is summarized as under.

<table>
<thead>
<tr>
<th>N_SPT blows/30cm</th>
<th>Consistency</th>
<th>C_u (kPa)</th>
<th>E_s (kPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - 2</td>
<td>Soft</td>
<td>18</td>
<td>1000</td>
</tr>
<tr>
<td>2 - 4</td>
<td>Firm</td>
<td>18 – 36</td>
<td>1000 - 2000</td>
</tr>
<tr>
<td>4 - 7</td>
<td>Stiff</td>
<td>36 – 72</td>
<td>1500 - 3500</td>
</tr>
<tr>
<td>7 - 15</td>
<td>Very stiff</td>
<td>72 – 150</td>
<td>7000 - 15000</td>
</tr>
<tr>
<td>&gt;15</td>
<td>Very hard</td>
<td>&gt;150</td>
<td>-</td>
</tr>
</tbody>
</table>

The N_SPT for CH expansive clays is sensitive to structure (desiccated/stratified/dispersed), moisture content, technique & tools for drilling, etc. For N_SPT in such clays (0-4m) driller has attitude of adding water before chiseling. In absence of supervision adopting lesser drops for manual test is common increasing N_SPT. The water added with structure and expansive nature of soil has variable impact on SPT and C_u obtained on UDS samples collected from such bores. Alluvial layered clays shored lower C_u and stiff clays compressed samples showed higher C_u. It is well known that C_u is very sensitive to moisture content of UD samples.
Desai M. D., Tailor R. M. & Desai N. H.

Absence of need for bore, watering for drilling and evaluation of shear resistance of soil insitu in DCPT test makes test relatively less affected by operations and testing.

Evaluation of $E_s$ for Saturated cohesive Soils is given by:
For Normally consolidated clays = 500 $N_{SPT}$ kPa
For Over-consolidated /desiccated clay = 1000 $N_{SPT}$ kPa

SOIL PROFILE
The south Gujarat region has top 7 – 8 m deep CH expansive clays. They could be alluvial (stratified) marine and residual as well in east & south part. Some of the typical properties are:
- Clay + silt > 70%,
- Clay % 20 to 40 %,
- LL = 50 to 65 %,
- PI = 25 to 30,
- Field Density $= 1.5 \pm 0.1$ g/cc,
- Water content 23 to 26 %, occasionally 30 to 36 %,
- OMC = 22 %,
- MDD = 1400 kg/m$^3$,
- $C_u = 50$ to 150 kPa,
- $\Phi_u = 10^\circ$ to 15$^\circ$,
- $N_{SPT} = 2$ blows/30cm

GWL is beyond 8 m except in 4 cases of more than 29 sites spread in south Gujarat. The environmentally it has average 1000 mm rainfall and high temperature of 35$^\circ$ to 40$^\circ$ C in summer. Drainage is poor. The excavations observed presented inconsistency with UCC and results on remoulded shear test in laboratory.

SPT – DCPT TEST DATA
For 29 different sites in 100 km x 30 km of area, same agencies drilled, conducted, SPT, DCPT. The human factor was more or less same. This data of explorations was tabulated to derive:

1. Depth Vs $N_{SPT}$ blows/30cm
2. Depth Vs $N_c$ blows/30cm
3. Depth Vs $N_c/N_{SPT}$ ratio

For all sites Fig. 1, 2 and 3 presents the data and correlation equations are derived:

- $N_c$ blows/30cm = $3 + 2.6Z$ [For lower bound ($R^2 = 0.95$) and $Z$ in m]
- $N_c$ blows/30cm = $5 + 2.6Z$ [For upper bound ($R^2 = 0.95$) and $Z$ in m]

1

- $N_c = 1 + 2.4Z$ for 0 to 4 m range of $Z$
- $N_c = 7 + 1.5Z$ for 4 to 10 m range of $Z$

2

- Ratio $N_c/N_s = 1.26\ln(Z) + 0.8$ [$R^2 = 0.99$, $Z$ is depth below G.L. in m and range is 1to7m maximum]

3
A method to predict realistic SPT resistance of expansive CH soils based on DCPT

The designer adopted $N_s = 5$ by extrapolation and net SBC for footings at depth of 3 m was 100 kPa. This was so low SBC that raft or deep piles were recommended by report.

Using work presented, $N_s$ cannot be less than 11 by Fig. 1 and gave min $N_s = 8$ and net SBC 160 kPa. The footings were feasible for same site and a confirmatory load test was advised by authors.

Thus the approach proposed has following direct uses:
1. Provide logical system to discard and revise inconsistent higher/lower values observed at sites by formation and test procedure lapses.
2. Logical extrapolation of wide range between two tests for a desired depth of foundation can be obtained.
3. Provide check by using Fig. 3 for continuous evaluation of DCPT.
4. Possible evaluation of critical depth of environmental weathering or desiccations of the top crust of soil in high temperature heavy rain fall area. (Fig. 3)
5. Provide data base of similar deposits in country to generalize the uniform approach of digesting raw data of exploration.

CONCLUSIONS
The region with deep cohesive expansive soils, desiccated environmentally, presents low SPT values due to water added by driller. The UDS in such bore is swollen and do not represent insitu structure.

To overcome this study of large scale data brought out unique correction of dynamic cone (50 mm) $N_C/N_s$ with depth for south Gujarat area covering residual, marine and alluvial CH soils. Study of similar data bank in other regions can provide more universal correlation for code of practice.

The authors discarded SPT and shear test data of soil reports by checking the predicted $N_s$ value using DCPT test. In number of cases footing could be planned when raft was recommended by normal codal practice. Even for stability analysis $C_u$ was estimated by above approach. Based on foundation cost and time saving and need of designer 1m x 1m size model load tests have been advised for confirmation.

Site where $N_s$ has to be extrapolated for foundation depth, the study suggest minimum value of $N_{SPT}$ cross checked by DCPT and $N_C$ value using evolved $N_C/N_S$ ratio with depth correlation.

REFERENCES
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