GEOTECHNICAL INVESTIGATIONS PRACTICE

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ABSTRACT: The most appropriate scope of geotechnical investigation will vary from site to site. The Geotechnical consultant shall develop a scope of investigation that adequately addresses current geotechnical concerns. However, in general, geotechnical investigations shall include test borings or test pits, where bedrock exists at shallow depths. Test boring shall be drilled with equipment suitable for the subsurface conditions. Test boring shall be deep enough to extend below the depth of influence for foundations. For hillside developments, the boring should extend into bedrock or residual soils. Deeper borings may be necessary where fills or landslide deposits are present. Soil sampling should be performed with equipment capable of retrieving undisturbed samples of the materials encountered. The number of test borings or test pits shall be sufficient to adequately characterize subsurface conditions in the area of proposed development. In areas acknowledged to be underlain by or near regional landslides the Geotechnical Consultant shall provide information regarding the extend of the landslide, history of reported damage caused by the landslide, and any available information regarding the current activity of the slide.

INTRODUCTION
Testing agencies and Client/consultant are the main performer of the Soil Investigation which is being carried out as per the code provisions. The stages for Soil Investigation are (1) Testing Schedule & Tender Conditions (2) Field Work (3) Laboratory work and (4) Reporting. In this paper the role of performers and code provision is discussed for each stage of Soil Investigation.

TESTING SCHEDULE & TENDER CONDITIONS
The testing schedule shall be more informative for the design data as well as cost effective. It is very important to decide number of boreholes and depth of investigation. The guideline for which is covered under I S 1892 – 1979 wide clause no 2.3.1 & 2.3.2. In clause 2.3.1 it is mentioned that for compact building site covering an area of about 0.4 Hector, one borehole or trial pit in each corner and one in centre is adequate. The word bore or trial pit is confusing. Trial pit has limitation of depth (Clause 3.3 I S 1892-1979). As per the guideline of clause 2.3.2 the depth of investigation shall be depth of foundation + 1.5 to 2.0 times the width of the footing and in this case trial pit can be considered for the strip foundation only.

Soil exploration should generally be carried out in two stages that is preliminary and detailed but unfortunately the guidelines by BIS is not followed.

The quantity and specifications in the tender shall cover all the requirements for the design of various structures. In large value tenders, where loads are very high and it is mandatory to go for pile as foundation, the specifications are given considering pile foundation only and the data is not available or very limited data is available for shallow foundation for small structures like small pump house, electrical sub-stations, compound wall, machine foundations, pipe supports etc.

Many times the consulting firm / Architect firm has no specialized geotechnical engineer and tenders are floated copying old tender of the reputed consulting firm. In such cases they include the tests which is not required for the project or which is not suitable for the site.

There is an example that the site is not even visually inspected by the consultant and without having preliminary exploration report the tender for the power plant in M P was floated. The tender was with the consideration of soil strata only and on the site there was an exposed rock on 30 % of the plot and for the rest area, rock strata starts from maximum 2.0m depth.

One tender for communication tower for one state where the termination depth for the borehole is N value 50 blows/300 mm penetration. The rates to be quoted are per no of bore hole. As the tender was for the area covering whole state, the depth variation for termination is likely varying from 2.0 m to 10 m and even more in coastal region.

As BIS is silent about the maximum interval for the physical properties to be reported, there is huge difference of interval for reporting physical tests which varies from 1.0 m to more than 10 m. In one tender having total borehole depth 175 m (7 nos x 25 m ) and soil classification was asked for 2 samples per bore hole that is total 14 nos. only. More beauty of the tender is out of 60 nos of undisturbed samples to be collected; only 14 samples are to be selected for FDD, FMC and Specific gravity. Out of many suggestions they have accepted few and did not agree for the test of Specific gravity, FDD and FMC. All other laboratory tests (Unconfined Compressive Strength, Consolidation, Swelling pressure and Triaxial) are also required to be carried out 2 samples per bore hole. If laboratory tests are limited to above what is the requirements of collection of 60 numbers of UDS?

If we read the requirements to be submitted by the contractor, any one fill that it is duty of the consultant to submit the details to client.
Our Bureau of Indian Standard has published following codes for Soil Investigations:

- IS 1888: 1982 Method of Load Test on Soils.
- IS 1892: 1979 Code of Practice for Subsurface Investigation for Foundations
- IS 4453: 1980 Code of Practice for Subsurface Exploration by Pits, Trenches, Drifts and Shafts
- IS 4464: 1985 Code of Practice for Presentation of Drilling Information and Core Description in Foundation Investigation.
- IS 7720: 1991 Criteria for Investigation, Planning and Layout for Barrages and Weirs
- IS 9214: 1979 Method of Determination of Modulus of Sub-grade Reaction (K-value) of Soils in Field.
- IS 10060: 1981 Code of Practice for Subsurface Investigation for Power House Sites
- IS 13746: 1993 Code of practice for geotechnical investigation of offshore jacket structure
- IS 15681: 2006 Geological Exploration by Geophysical Method (Seismic Refraction) - Code of Practice.

The following codes are indirectly useful to decide investigation scheme as it gives information for the requirement of data for the design.

- IS 9556: 1980 Code of Practice for design and construction of Diaphragm wall.

**FIELD TESTING**

The second phase of investigation is Field testing. It is very important that the field work shall be carried out under the supervision of Geotechnical Engineer and here most of the agencies are lacking. The tests commonly conducted are conducting Standard Penetration Test and collecting undisturbed samples for the laboratory tests at regular interval. Other tests conducted in boreholes are Field Vane Shear test, field permeability Test, Pressure-meter test etc. As thumb rule SPT and UDS are taken alternate at maximum interval of 1.5 m. As per clause 3.3 of I S 1892, the undisturbed samples are obtained by driving sharp edge thin wall tube in to ground by light hammering or pressure. As per clause 4.3.4 of I S 2132, the sampling tube shall be pushed in to the soil by a continuous and rapid motion. Note from the same clause says “in case of equipment for SPT is used for driving the sampling tube, then the length of penetration shall be limited to 50 blows”. As the limit is of 50 blows irrespective of dia. of tube, one has to use lower diameter tube at deeper depth with increase in resistance. Now the two code provisions are contradicting. Are 50 blows can be considered as light hammering? or lowering by hammering can be considered as continuous and rapid motion?

There are two criteria going against collection of UDS from hard strata:

1. The wall thickness of tube due to area ratio specified in I S 11594 is not strong enough to withstand the force and tube edges are bend and
2. Will Sample be undisturbed after 50 blows of hammering? The friction generated between wall of tube and soil is so high (even using 38 mm tube size) that collection with light hammering is not possible and SPT hammer is being used for the driving. Can the sample be Undisturbed in this case? It is observed in some tenders that for the cohesive strata having SPT values more than 30 blows, UDS shall be replace by SPT. BIS / Experts should discuss the issue and come to the final conclusion.

The second issue is sometimes the consultant suggest that SPT test shall be extended for the penetration from 450 mm to 600 mm and SPT value shall be considered for 300 mm to 600 mm penetration value. As far as I S 2131 is concern, this is non-confirmative. If we use the spit sampler as per I S 9640, the penetration depth available is 508 mm of body + 50 mm of head that is only 558 mm and in this case the sample shall be compressed and we shall definitely get the higher value. (In this depth calculation some seating depth due to wt. of sampler + rod + hammer is not considered).

In I S 2131 note under clause 2.1.1 is completely ignored by many, most of us which is very harmful at the time of interpretation and recommendation. The note read as: The stiffness of the drill rod used for testing influences the N value obtained by means of the test. A light rod ‘whips’ under the blows of the hammer. The drill rod shall preferably have stiffness equal to A-rod (41.3 mm outer diameter). For depths of exploration more than 10 m, special precautions shall be taken to keep the rod vertical by using centering spacers and/or by using stiffer rods to minimize the whipping effect. Spacers may be provided at every 10 m, or more frequently, if necessary.

In IS 1888: 1982, wide forward (clause 0.3 & 0.4) the limitations of the tests are elaborated very specific. In partially cohesive soil and loose to medium cohesionless soil, we shall not get the clear ultimate Bearing Capacity from stress v/s settlement graph. Clause 5.2 suggests plotting the graph on Log-Log scale keeping settlement as abscissa against corresponding load intensity as ordinate. The graph will give us two straight lines and intersection of which is yield point of the soil. The confusion is that, what should be factor of safety to arrive the Safe Bearing Capacity? We recommend the factor of safety between 1.5 on yield stress.

The common important points missed by agencies are:

1. Exact location and elevation of testing point. (In medium to small projects).
2. Use of centering spacers while conducting SPT test beyond 10.0 m depth.
3. Condition of head and shoe of spit spoon sampler.
4. Proper cleaning of bore using mud drilling method or rotary drilling.
5. In non-cohesive strata below water table, some times Sand blowing occurs which is not observed or ignored.
6. Fall of SPT hammer is not maintained uniform.
7. The equipments to be used in field tests shall be calibrated frequently.
8. In plate load and pile load tests, load shall be maintained uniform till next increment. The load increment criteria shall be followed.
9. Pressure meter test in rock is carried out after few days of the drilling and predrilled bore is over size.
10. Leakage in hydraulic system of field equipment.
11. UDS tubes shall be lightly oiled from inside/outside or both as per site condition.
12. Condition of head for thin wall sampler.
13. Sealing, transportation and preservation of UDS tube.
14. Depth of penetration of field vane below bottom of the bore.
15. Rate of rotation to be maintained during field vane shear test.
16. During the field vane shear test, observation of remolded strength shall be taken.
17. During the field vane shear test, observation with dummy rod shall also be taken.
18. Boring Guide is not being used in DCPT.

LABORATORY TESTING
Set equations against the left margin of the column and the common mistake done while performing laboratory tests are:

1. Criteria for min. wt. to be taken for particle size analysis is not observed and max. wt. on sieve size to be retained is not observed/known.
2. Clayey samples are not soaked before Atterburg’s limit tests.
3. For moisture content test (it included LL & PL also as we measure moisture content) balance shall be sufficient sensitive to get the accuracy of 0.04 % of sample wt. Hence using balance of 0.01 gms accuracy, min. wt. of sample required is 25 gms. This is not maintained mostly in plastic limit test. There is some controversy in IS specifications in diff. codes. As per IS 2720 Part 2, min. wt. to be taken shall be 25 gms as per above, where as IS 2720 P 5 clause 7.4.2 says the plastic limit shall be determined for at least three portions of the soil passing 425-micron IS Sieve. The average of the results calculated to the nearest whole number shall be reported as the plastic limit of the soil. Earlier in clause 7.3 it is mentioned to take about 8 gms of sample of ball to be prepared for rolling. So actually 3 samples shall be prepared and combined moisture content moisture shall be result of Plastic Limit.
4. In shrinkage limit test, the wet pet shall be allowed to dry in air till the color of sample change from dark to light before it is placed in oven for drying.
5. In Specific Gravity test, sample soaking, applying heating/vacuum, cooling to room temp. is important. Two tests are to be carried out and variation in result should be within 0.03, else the test shall be repeated.
6. The extraction of sample from UDS should in upward direction or in horizontal direction in case of 38 mm dia. sample but should never be in downward direction. It matters much in soft clay samples, silty fine samples, sea bed samples etc. Never drive the smaller tube inside the bigger tube.
7. While performing compaction test as per IS 2720 Part 7 or 8, after 3 / 5 layer compaction sample height in the collar is not maintained less than 6 mm.
8. While performing compaction test, for the clayey soil, soaking is required before testing else there can be error of even 20 % in MDD is possible. (For without soaking sample MDD will be more & OMC will be less than the actual values).
9. Specific Gravity value considered for the Hydrometer test shall be for the sample passing 75 micron sieve. If constant temp. water bath is not used, the room temp. during test shall not have diff. of more than 8° C.
10. For consolidation test loading increment shall be left until the end of primary consolidation is indicated on square root of time plot. In every case, the same increment duration shall be used for all load increments.
11. Tri-axial test shall be performed after consolidation test as value of pre-consolidation pressure is useful in selecting the range of lateral pressure.
12. For UCS and tri-axial shear test, least count for load measuring equipment is not maintained as per the respective I S codes. Similarly least count for Cell pressure measurement is also to be maintained.
13. In box shear test there an amendment in clause 6.1.2. Value δ/3 is now replaced by δ/6. One, who is following only SP-36 Part I, should note that there is printing mistake in equation. Now with the amendment δ shall be replaced by δ/6.
14. During Box shear test, after applying normal stress, the upper part of the shear box is to be raised by 1 mm to leave the gap between two parts of shear box. This is neglected and hence friction between the two metal boxes is added to the value.

REPORTING
Reporting is not just to summaries the result of test but inclusive of recommendation for type of foundation, special care to be taken in design and or construction etc. While reporting, the following data is essential.

- Location Plan and elevation of test point.
- The type of structure and type of loading.
- Finished ground level.
- Structural requirement of foundation level.
- Water table at present and estimate for the future increase or decrease. Water level fluctuation due to tide in tidal zone.
- Flood level in the area.
- Max. load on structure / column and load in nearby structure / column for the diff. settlement.
- Scouring depth or hydraulic data in case of bridge structure for river etc.

The report shall include in general,
1. Location plan and elevation of test points.
2. Graph and table of each test results.
3. Sample calculation of result.
4. Safe Bearing capacity calculation.
5. Settlement calculation.
6. Recommendation of Allowable Bearing Capacity for required depth for specified size and shape of footing.
7. Photograph for the important and specialized field test.
8. Special care to be taken while designing or construction.