GEOTECHNICAL EXPLORATION: COST AND TIME OPTIMIZED PROGRAMME FOR RELIABLE PREDICTION OF SBC, SBP, ABC & DEPTH OF FOUNDATION

By:

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Introduction:

Though significant progress has been made in accepting importance of geotechnical exploration in past 2 decades by planners, designers and National Building Code, there are many aspects such as generalized tender documents, needs to be updated. The soils, being heterogeneous, anisotropic, sensitive to environmental changes and sampling technology, the extrapolated design foundation parameters including depth of foundation could be, a) over conservative, b) unsafe in some cases and c) unwise from cost of exploration / benefit to design ratio. There are instances where application of exploration disproved realities regarding stability for stable built structures when exploration was unknown. (e.g. Forts, Palaces, Taj etc., SBC 10T/m2, Liquefactions? - Forensic analysis) The teachers, principally well versed with theory, would like to learn from success and failures experienced.

Professional Problems on exploration:

Opinion poll of users, mostly structural engineers, builders, planners, regarding exploration can be summarized as:

- Very expensive,
- Time consuming,
- Doubtful, degree of credibility of the recommendation as judged from local observations or similar nearby projects,
- Interpretation is subjective and variable

There is wide spread belief that
"Art of foundation engineering (Pre 1950) was safer, economical and less time consuming" (Desai, 1996).

This, in our opinion, is due to
a) limited role of geotechnical engineers in exploration,
b) absence of specific structural data / problem, and
c) scanty details of site environment (present / proposed).

The lack of feedback of final design, performance of structure over years and professional transparency has throttled progress in Ground Engineering & Foundation Engineering.

Crisis in Ground Engineering:

The crisis can be attributed to:

- Lack of qualified devoted professionals in practice,
- Poor control over tools, samplers & field test without keeping specific problems in view,
- The practice of taking arbitrary or topo decision on foundation and referring it for expert opinion,
- Codes for guiding design parameters are non existing or vague or outdated. e.g. permissible differential settlement, interpretation of SPT, DCPT, CPT etc.

The crisis in geotechnical profession is caused by one or more contributes listed below:

Fresh Engineers:

Last decade of 20th century saw large demand for fresh graduates and post graduates in field of Geotechnical engineering. The employer recruited them as experts. Activity of such experts in public/private/government/academic sectors may lead to crisis in soil engineering. The situation is similar to 1958 crisis in Europe (Henry Lossier, 1958). An engineer, on large job, eager to practice theories just learnt, finds essential facts concealed in tables, graphs, field and laboratory notes representing a tropical jungle. Such deposits are inevitable with large number of drillings and samplings by number of agencies. Bulky volumes of data is a must for clients satisfaction for his investment.

Experts:

"Theory can only be used as a guide for judgement".
Capacity for judgement is acquired by years of field contact - feedback of actions and reactions of soil behavior. Both the judgement and experience mends and sharpen tools of interpretations. Calibration of predictions by the feedback generates confidence and increase capacity to take calculated risk for cost and time optimizations. Terzaghi (1959) rightly stated: "Expertness required innate qualifications and desire over which we have no control". Engineers in field practiced soil engineering without basic knowledge of subject and majority of scholars practiced as consultants with little interaction with soils in field & laboratory. This type of environment deepened crisis further.

For projects of thousands of crores every year, expected turnover runs to Tens of crores for exploration. With reputed few exploration agencies available in country, the scenario is critical. The high profit margin and shortage of agencies brought out mushroom growth of small drilling firms as soil explorers. They are ill equipped, non professional and have little interest in what they do.

Consulting Engineers:

Using exaggerated limitations and knowledge of Geotechnical engineering, consultants developed a "Topo culture". They pre-decided foundation for structures based on worst subsoil condition elsewhere. It is this over-safe, uneconomical design which consulting firms generate. Still numbers of problems emerge during execution and it consumes time and contractual deviations. The limited exploration in general multiplied crisis of confidence.

Equipment industry:

The instruments are available but the crisis is created by practically little service after sales by manufactures or their agents.

Professional Ethics:

Lastly activities of few professionals, with hardly any ethics, have used knowledge (abused) to prove non-technical or arbitrary decisions by misquoting literature or wrong interpretations. They have as experts, filed affidavits in courts etc to be corrected by counter litigation and arbitration. Increasing such trends of claims for damages or ordering demolitions etc using soil reports, unless arrested, can damage profession.

Talks of using the art of foundation over scientific approach of Geotechnical engineering should not be taken lightly. All post - Terzaghi efforts will go waste, if serious attempt to tackle the crisis is not perused by the profession.

Real Experts:

In earth work and foundation engineering, a novice enters tropical jungle of data. His hopes, to obtain readymade (Text Book) solutions to problems using theory and tutorials learnt in class, will soon vanish. He is soon frustrated. Only one with inquisitive mind, dares to plunge into the jungle with a bush knife (knowledge). He gets the taste of soil mechanics in action. He soon will realize that it will take years of welding his knife to attain competency. Latter in practice he may rise to expertness, not necessarily successful (Terzaghi, 1959).

Habits of (a) observations, (b) analysis of causes and feedback of performance, (c) renouncing old convictions and (d) evolving appropriate new realistic models, will reduce gap between theoretical and actual behaviour. It is a continuous process. This requires initiative, imagination, dedication, resourcefulness and thorough knowledge of basics of soil mechanics. In quick buck spinning world surrounding, personals with such qualifications will be few. These few experts cannot cope up with work in time.

Terzaghi (1959) correctly stated, "Soil mechanics will not consistently serve its purpose until profession realize that it is supplement to and not substitute for common sense combined with knowledge acquired by experience. "Engineer must get used to the idea that he has to use his brains and judgement all the time even if he knows theory by heart."

Failures, if analysed recorded unbiased, are more valuable than success.

Exploration data for project:

The back bone of Geotechnical Engineering, is soil exploration. It forms the basis for decision which influences cost, time to execute and safety of projects. General complaints against exploration of soil as **foundation materials are:**

(a) Very expensive, (b) Time consuming,

(c) Poor in reliability, (d) Interpretation is personal and hence variable.

Bulkiness of generalized explorations records are inevitable for projects involving earthwork, roads, large industrial plots etc. Part of bulkiness is considered essential to satisfy the owner to justify large investment. "Percentage significant information may range from 0 % to close to 100% depending on the qualifications of man who planned sub soil exploration. Even excellent records, undigested and un-condensed, cannot serve useful purpose. This task requires weeks and months of efforts, for which most of the cases had little time and personal" (Terzaghi, 1959). Time lag between collection of data and use by the designer, leads to serve contamination. Crisis of confidence in profession, is an easy excuse to defend one's inability to digest. The analysis for reliability of data requires time and experience based judgments. The field layman's classifications to laboratory tests and performance of structures around, presents many contradictions. Pruning of the data or rechecking, though obligatory, is rarely done.

Laboratory CH soil could be insitu layered clay and sand strata or expansive clay below water table which has different insitu behavior. Even white / yellow clays could be expansive. The range of shear and compressibility parameters, based on standard investigation specifications, irrespective of subsoil, creates more confusion unless redundant or irrelevant results are discarded. Drainage conditions of tri-axial, SPT, density from UDS or SPT, vane shear in layered or moist sandy clay etc. needs closer expert scrutiny. Expansive potential, in a soil report do not mean sub soil needs treatment, if subsoil is below water table or has equilibrium moisture. Swelling potentials has misguided designers to treat even swollen deposits, or deep moist deposits with no access for moisture.

Also simplified universal standard specifications for exploration and consultancy evolved, by firms, may not provide safe parameters for given site & soil conditions for problem analysed. Thus bulk redundant data above and below the stressed zone, though useless, is inevitable. The Table - 1 & 2 shows, practice, cost, time needed for exploration of medium to large projects in generalized all purpose explorations.

Table: 1 – Specifications and explorations cost for Typical Project Site.

Procedure	Pit hole by Augur, shell, wash boring
Extent	Every node of 60 m grid in vast area. 4 corners and one center of large Building. For closely spaced structure maximum depth 4.5 x B or 1.5 x L. For B = 3 m explore 14 m. (Thumb-rule depth of exploration 3 m per amount of load equivalent to one storey) For Raft one or two 20 to 30 m deep bores for weak layers if any at depth or to rock.
Types	C = 0 Soil SPT at 1.5 m interval in stress zone. (Ns – P0' - Ns' – Rd – Ø – E - qp40) Ø = 0 Soil UDS @ 1.5 m interval in stress zone, 20 % points replace by insitu vane shear tests if soil is soft, sensitive. UDS for stiff desiccated clay (Ns > 25) are not reliable. C - Ø soil suitable combination of above to obtain critical parameters (Table 2) Disturbed samples of each layer 6 to 8 per bore
Exploration for 14,000 sq.m	5 bores, B = 3 m, Df = 2m, depth of exploration 10 m, 4 bores, 10 m deep – One 15 m bore, 55 m of drilling, 2545 m3 of soil represented by 1 m drilling

Test	Tests			Remarks
	Per Bore	Total	Per Layer	
SPT	06	30	07	@ 1.5m interval
Undisturbed samples	05	25	06	@ 1.5m interval
In situ Vane	01	05	2.5	Only for top 2 layers
Classification	06	30	07	Standard tests
Special Classification	02	10	05	DFI, Swell Potential, % clay, SI etc. for top 2 layers
Structure	05	25	06	Density, moisture
Tri-axial shear	02	10	2.5	On selected UDS
U C C	01	05	02	Sat. cohesive soil top 2 layers
Odeometer	02	10	2.5	—
OMC – MDD - CBR	Total 10 to 15 Tests per project			
Cost estimate	Field and laboratory work: Rs. 25,000/- + Mobilization (Varies) Rs. 10,000/- + Report Rs 5,000/- i.e. Rs 8,000/- per bore or 0.2 to 0.3 Rs per m3 of soil explored			
Time	Normally 2 to 4 months with One team & set of kits			

Table: 2 – Practice of field exploration

No	Project	Drilling	SPT			U D Samples		
			Depth per test (m)	Per bore	Per Layer	Depth Per sample (m)	Per bore	Per Layer
01	IBP CO. Ltd.,Hazira	180	02	15	22	02	15	22.5
02	Searle (I) Ltd., Ankleshwar	100	1.6	06	15	1.7	0.6	15
03	Cynides and Chem., Olpad	40	1.6	12.5	6.0	10	02	01
04	ONGC Gandhar	855	1.7	11	83	4.3	4.5	50
05	ONGC Hazira Phase – II	260	1.4	11.8	47.5	4.3	3.8	15
06	Rajula, Bhavnagar	60	04	42	42.5	03	05	05
07	Petro-Chem, Auraya (UP)	1410	02	11	116	4.3	05	81
Range in practice		40-1400	1.4-02	11-15	15-83	02-10	04-06	05-08
Approximate quantity desires by IS Code		Min. 55	1.8	06	07	2.2	05	06

- In limited cases UDS is replaced by insitu vane lest (2 tests per bore).
- 20% projects have prescribed cyclical load tests 2 nos. for design of machine foundations, liquefaction.
- Even for vast area 83 results of SPT or 81 UDS per layer and 15 shear-odeometer tests per layer are bound to consume time and cost.
- The range of parameters will be, for a jungle of data, very wide.
- For shallow foundations stress zone soil data will be scanty. With Large nos. of tests at depths beyond stressed zone are redundant. For deep foundation, data of top layers are rarely useful

Interpretation:

The exploration records must ultimately provide:

1. Zoning of area in plan & model profile of soil for each zone showing critical stratification.

2. Location of water table, profile, flood levels if any.

3. Engineering properties of soil stratifications namely classification, plasticity, consistency, density (relative density for non cohesive soils), water content, shear parameters with appropriate drainage, compressibility, permeability, CBR etc. Basic field, lab data, scrutinized & digested by judgment.(not minimum parameters)

4. Type of structure, depth at which foundation is feasible, stress zone, parameters.

5. SBC, SBP for permissible settlement and ABP, special problems for shallow foundation – footings, Raft for static & transit load such as swelling/ shrinkage, liquefaction etc.

6. Preliminary design report:
   There are no standard interpretations in codes. There are text books adopting over conservative local interpretations. Two books in references (Desai M.D.) have brought out anomalies in performance and predictions.

7. Compile available preliminary data of type of structure, minimum depth of foundation desired by use or flood, permissible settlement & differential settlement, shallow or deep foundations required for approximate loads, breakup of loadings DL, LL, seismic / wind combination for settlement &shear analysis.

8. Recommended approach:
   IS code is guide and not rule. The local conditions, needs and specific studies requires application of mind, common sense and judgment based on local experience. This will provide time and cost optimized programme to provide more reliable data for design of shallow foundation. The planning must eliminate redundant, doubtful data based on casual observation not confirmed by tests to mislead designer. A site & project specification exploration is economical in totality quicker and safer.

“ The part 2 of this article will appear in the next issue”