GEOTECHNICAL INVESTIGATIONS – THE WAY FORWARD

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INTRODUCTION

A thorough geotechnical investigation is a pre-requisite for a reliable, safe and economical foundation design. It is important that whatever is envisaged at the investigation and design stage should translate into construction that is in sync with the design concepts, assumptions and predicted foundation behavior.

Understanding the ground conditions thoroughly for proper foundation design includes the following:

- Knowledge of the local geology and groundwater conditions.
- Information on performance of foundations in the vicinity, data on past-failures, if any.
- Detailed geotechnical investigation to clearly define the soil classification, relevant engineering properties and likely foundation behavior.

Insufficient / sketchy information on any of these counts increases the uncertainty in design. The designer may be constrained to make assumptions which may or may not be valid. As a consequence, the design may be conservative leading to higher foundation cost. On the other hand, there could be situations where the safety of the structure is compromised.

LEVELS OF GEOTECHNICAL INPUT

When work of geotechnical investigation is awarded to an agency, usually budget and time constraints overrule technical considerations on most projects. As a result, the scope is reduced to a minimal level and price consideration supersedes the technical capability of the agency.

But it must be realized that you get what you pay for. There are innumerable instances where saving at the investigation stage translated into high foundation costs and/or failure of foundations. Surprises at construction stage can not only delay the project but also result in increased costs/financial losses.

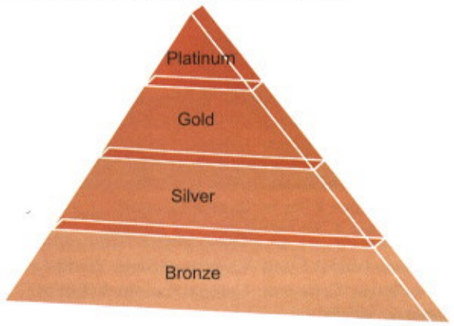
The geotechnical input that the owner / designer gets may be categorized into four levels:

Platinum: Detailed investigation with comprehensive in-situ testing, analysis by experienced expert, reliable site-specific design parameters, advanced design methods, optimized using serviceability criteria, monitoring during construction stage.

Gold: Detailed investigation, analysis done by experienced expert, somewhat site-specific design parameters, advanced design methods, partly optimized.

Silver: Limited boreholes extending beyond planned pile toe / 5-10 m below planned foundation level with SPT and limited laboratory testing, generic design parameters, empirical methods of analysis by experienced engineer, simple / basic design methods, usually over-designed foundations.

Bronze: Shallow boreholes / trial pits, limited or no testing, design parameters guessed / selected by engineer with limited expertise, over-conservative / unsafe / unreliable design.



As one moves up along the pyramid from bronze towards platinum, the factor of ignorance reduces and the reliability of design is enhanced. It also results in reduction in foundation cost and construction time.

POSSIBLE AREAS OF IMPROVEMENT

- Move towards Gold / Platinum level of investigations, particularly for important / major projects. Avoid bronze level investigations.
- The geotechnical investigation program should be tailor-made for the project site, as per site / project requirements.
- Use advanced testing / investigation methods.
  - If using SPT, use automatic trip hammer. Hopefully, SPT will die a peaceful death soon; it is increasingly being discarded as a preferred choice of penetration testing in Europe and USA.
  - Outdated techniques such as trial pits, dynamic cone penetration tests, plate load tests, block vibration tests, etc. should be discontinued.
  - Upgrade to CPT/CPT-u, pressuremeter, dilatometer, vane shear tests (in soft clay), seismic methods, geophysical testing, remote sensing, etc.
  - Use advanced sampling and laboratory testing methods.
- Use results of field instrumentation data for important structures to update design parameters.
- Use advanced analysis methods, softwares for analysis.
- Observational method of design based on field observations and instrumentation should be implemented.

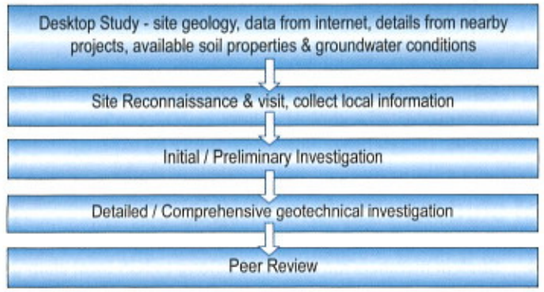
SELECTION OF THE INVESTIGATION AGENCY

Selection of agency based on L-1 price criterion not only discourages technical enterprise and innovation but also encourages malpractices. While no common criteria can be implemented by all organizations, each organization should identify a selection processes that gives due weightage to technical competence and experience while eliminating poor work-quality / mediocrity.

There is need for treating the soil investigation agency as a consultant and not a contractor. An experienced consultant can add value to the project if he is involved right from the initial planning to the construction stage. Since soil is a natural material with inherent variations, obtaining realistic data and reviewing the results during construction can provide vital inputs in enhancing the reliability of design and construction.

SCOPE OF INVESTIGATION AND SEQUENCE OF ACTIVITIES

The decision on scope required should be finalized after proper inputs from a geotechnical engineer based on a desktop study and site reconnaissance. On important projects, an initial / preliminary investigation may be used to work out the scope required for a detailed investigation program. Peer review by a recognized expert can add value to the study. These steps are explained in the flowchart below:

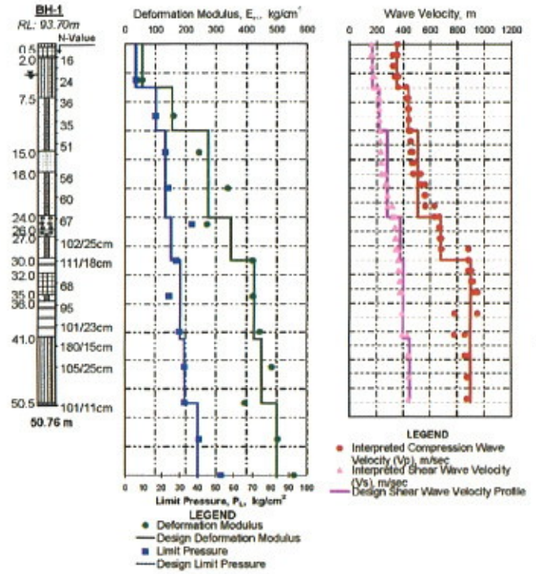


SOME EXAMPLES

Overhead Tank at Gwalior: At the site of an overhead tank at Gwalior, a loose heterogeneous fill of boulders and stones was present to about 6-7 m depth. Two bronze-level investigations had been done without proper appreciation of the ground conditions. The first one included boreholes which were terminated upon meeting refusal to SPT at the ground level. The second investigation included plate load test (30x30 cm size test plate) on the boulders yielded very high bearing capacity.

To better assess the foundation conditions, a gold-level investigation was done which included deep boreholes penetrating into the natural soils below the boulder-fill and comprehensive laboratory testing. The data was effectively used to evaluate the safe bearing pressure for raft foundation for the overhead tank.

Multi-storeyed Building at Noida: For a 60-storeyed building coming up in Noida, the owner had got a silver-level investigation done consisting of boreholes to 30-40 m depth. To better assess the soil characteristics and to obtain more realistic / representative soil parameters for design of the piled-raft, a platinum-level investigation was carried out that included deep borehole to 50 m depth, pressuremeter tests and cross-hole seismic tests. The data was effectively used to develop design parameters for better assessment of liquefaction potential, evaluation of pile capacities, etc.



The involvement of the geotechnical engineer investigation did not stop after the investigation was done but carried on to the construction phase. Static and dynamic pile load tests on test piles and working piles were followed up with low-strain integrity testing, and concrete coring to assess the quality of the pile concrete. The data generated was effectively used to interpret safe pile capacities and correlate with soil data so as to redesign the foundation system as per actual condition of the pile integrity. Thus, an overall assessment of the geotechnical and structural safety of the foundation system ensured that the foundation system behaved as per the design.

CONCLUDING REMARKS

In the end, nothing can replace good engineering judgment and "feel of the soil" of an experienced geotechnical engineer. This should be backed up with a thorough and detailed geotechnical investigation to clearly assess site-specific design parameters and proper analysis for a reliable and safe foundation system.