The geotechnical consultant

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Introduction

Geotechnics, or geomechanics, is that branch of engineering which relates directly to the ground: its natural behavior, the way it responds to artificially-changed conditions and the way it interacts with man-made structures.

Geotechnical input is required for most civil, structural and mining engineering projects, and yet the ground is highly variable and its behavior difficult to predict. This presents the geotechnical consultant with problems of imprecision and uncertainty which are unfamiliar to many of his, or her, colleagues in allied technical disciplines, and are not often appreciated by the layman.

To address the implications of this, the following paper has been prepared by members of the Sydney Group of the Australian Geomechanics Society.

It is hoped that it will clarify the public perception of the geotechnical consultant, place in perspective the services which can be supplied, explain why most geotechnical work has to pass through a number of basic stages, and provide useful advice on briefing, engagement and professional liability.

With technological advancement, our ability to predict the way in which the ground behaves in a wide range of circumstances has improved enormously over the last 20 or 30 years.

There is every reason to assume this process will continue in future with resulting financial benefits to the community as a whole, and an increased confidence among engineers and clients alike that the ground-related aspects of their projects can be dealt with effectively.

Geotechnical consultants

Many engineers have a limited understanding of geotechnical principles, since they have to apply them only rarely during their professional lives. As a result, geotechnical specialists have an important part to play in the planning, design and construction of most projects.

Geotechnical consultants come from a range of backgrounds including soil mechanics, rock mechanics, engineering geology and hydrogeology. Singly, or as a team of professionals they can investigate a site and provide advice on probable ground behavior under a specific set of circumstances. Geotechnical consultants need a good general knowledge of engineering principles, mining and civil construction methods, so they can communicate effectively with their colleagues and clients. They work in private consulting practice, in large contracting organisations and in government authorities and generally hold university degrees in civil engineering or engineering geology. Many also hold more specialised postgraduate qualifications. Even so, relevant experience is of paramount importance and can only be gained "on the job".

Briefing and selecting a geotechnical consultant

Many misunderstandings and problems arise through inadequate briefing of geotechnical consultants and poor communications during the work. It is not realistic to require that an investigation should find out "everything"

about a site. Neither is it reasonable to instruct that specific holes should be drilled at specific locations to specific depths.

When briefing a geotechnical consultant, it is appropriate to:

- Describe clearly the project and define performance requirements, including structural loads, levels, tolerable ground movements, flow rates and other relevant criteria
- Seek the consultant's advice on the type of investigation that is needed, the amount of field and laboratory work, the overall time scale and the scope of the final report
- Request a written proposal setting out the services to be provided and an estimate of total costs and fees
- Provide all available survey and underground services information and inform the consultant of any restrictions which may be placed on his work.

The brief for a geotechnical investigation should always be flexible. Since so much depends on what is actually encountered on the site there must be scope to modify the program should conditions be different from those anticipated. Failure to incorporate this flexibility can result in a loss of quality, with potentially serious consequences if difficult ground conditions are encountered later.

Consultant selection based on cost alone, without a detailed brief and without any attention being paid to the proposed scope of work, will normally result in the consultant who proposes to undertake the smallest amount of work being appointed, that is, the fewest boreholes, least testing and least effort being put into understanding the site. This inevitably increases the risk of unexpected difficulties arising as the project progresses with a consequent risk of increased costs. When such costs occur they are frequently many times the saving on the geotechnical investigation.

For larger and, particularly, more complex jobs it is reasonable to obtain proposals from more than one consultant. This gives an opportunity for innovation in investigation method, but it is in the interests of the project that selection should be based first on technical merit and on cost only when two proposals appear to be equally sound. Under these circumstances it is appropriate to notify all consultants ahead of time, that they are in competition and preferably with whom.

It is always advisable to ask for a record of the firm's relevant experience and for details of key personnel who are likely to work on the job. This information should be considered alongside the technical and financial proposal when making an appointment.

Geotechnical investigation

To give more than general advice a geotechnical consultant normally has to undertake an investigation to gather specific information about the site within which development is proposed. The steps in an investigation may include some or all of the following, depending on the availability of information and the development requirements:

1. Form a model of the anticipated site geology from published information, field exposures, the regional setting and, in some cases, remote sensing data
2. From the known project requirements, select those matters which require definition such as excavation characteristics, foundation capacity, settlement behavior and overall stability
3. Confirm or modify the geotechnical model by exploratory drilling, excavation and perhaps the use of geophysical techniques
4. Obtain values for the engineering properties of the materials onsite and the groundwater regime from insitu and laboratory tests and observations.

Sampling and testing of the ground disturbs its natural properties, so interpretation of test results requires care and experience. Advances in insitu and laboratory testing are helping to overcome this problem. Even so, the most sophisticated, modern techniques, which tend to be too expensive for routine engineering work, are not totally reliable.

Site investigation is, however, the key to understanding most geotechnical problems. the scope and nature of the investigation and analysis required will depend on the characteristics of both the site and the proposed development. The advice of an experience geotechnical professional should be sought on these matters, since he will usually be in a better position to know local ground conditions and problems and the relative costs of different investigation methods. He will also ensure that investigation is directly relevant to the project in hand.

Holes which are drilled without reference to both the project and the site geology will often be of limited value, so planning is a critical stage in the investigation process. On larger, or more complex, projects it is often cost-effective to stage field work, so that general conditions on site are understood first and, later, more specific investigation is undertaken as the requirements of the project become better defined.

Recording of field data must be accurate. It should be realised, however, that even the best field report is a subjective interpretation of the facts which comprise only the samples recovered, the numerical results of tests and observations such as drill performance, or water levels at specific times.

Field staff should be able to notice when conditions are different from those anticipated, or when the finding appear to be inconsistent. Such circumstances may demand a modification of the investigation program. To react to this requires a professional understanding of the consequences for the project as a whole. It is not something that should be left to the drilling contractor, unless he has appropriate engineering qualifications and is also aware of the details of the job.

Even the most intensive and well-managed investigation samples only a small percentage of the total site. There will always be the potential for unforeseen geological factors to emerge later as "problems" when features not met in borcholes become apparent.

Data and analysis

Assessment of geotechnical data involves interpretation of the geology in relation to field and laboratory test results. Data is not always consistent so judgement and experience have to be exercised in deriving an appropriate geotechnical model for analysis.

The mathematical tools at our disposal are not perfect, but generally more precise than the quality of our site investigation data. Where data is unreliable, even the most sophisticated analysis is likely to give the wrong answer. Choosing an appropriate analytical technique, given the quality of the available data and the required accuracy of the final answers, is a matter for experienced professional judgement.

Reporting and design

The geotechnical report should cover all aspects required by the brief. It will not normally attempt to design civil or structural works, but should provide sufficient advice and parameters for design engineers to do so.

Regardless of the adequacy of the report, engineering

design is often greatly assisted by experienced geotechnical input. This will reduce the risk of inappropriate solutions being selected and can streamline the overall design process considerably.

Some clients believe that once the geotechnical report has been presented any further geotechnical involvement should be unnecessary. In most cases, this is not so: interaction between the geotechnical consultant and the designers will often lead to better solutions being adopted than the alternatives which might otherwise have been considered. This is where cost savings can frequently be made.

Discussion of alternatives is normally part of the design process and discussion is generally more effective if people with different expertise participate. To reduce the possibility of subsequent contractual problems, such discussions should be sufficiently formal for the matters discussed to be recorded.

Tendering

Preparation of tender documents follows design. In addition to writing the site investigation reports, the geotechnical consultant is often the best person to define terms, procedures and quantities if no standard specification, or method of measurement, is being used.

A contractor will normally benefit by seeking geotechnical advice while preparing his tender, just as a client for a project with complex ground works will benefit from tender assessment by a geotechnical consultant. In either case, there is less chance of inappropriate techniques being adopted to deal with the particular ground conditions of the site. For the same reason it is often beneficial for a geotechnical consultant to be involved in precontract discussions with tenderers, since it is only at that time that the contractor's assumptions can be discussed in an atmosphere free from prejudice.

Construction

Construction, to the geotechnical consultant, is the last stage of investigation and need not be too late to influence design, or choice of construction methods, if an appropriately flexible contractual situation exists.

Excavation is frequently undertaken which produces large exposures of the site geology for the first time. The consultant's presence on site at this stage will enable design assumptions to be verified and assist with overcoming unexpected geotechnical problems, if they arise.

Geotechnical consultants are often asked to "certify" that the works will "perform satisfactorily", "be suitable for a particular purpose" or some similarly worded requirement.

This form of certification amounts to a warranty for which consultants are not insured. It is not, therefore, in the clients interests to require such certification. The consultant can, however, certify that work has been carried out generally in accordance with the design intent, or that testing has been carried out in accordance with the specified standards.

Performance monitoring is to be encouraged whenever possible, since it provides a check on the satisfactory behavior of the works as they are built, and because it warns of construction problems before they get out of hand and provides data which can be invaluable for other projects in the same area.

This interpretation of the facts is least often available to geotechnical consultants and yet is invaluable data if it can be obtained.

Limitations and risks

The accuracy of geotechnical engineering advice is limited by geological variations, sampling and testing difficulties, theoretical uncertainties about behavior and the amount of data that can be collected given a project's budgetary constraints. All of these lead to the possibility that actual conditions and behavior encountered may differ from those anticipated.

Risks can be reduced with more intensive and higher quality work, but never completely eliminated. The "risks" in his regard are generally those relating to construction costs, or reduced performance of a structure, rather than to overall stability or to life and limb, even though these situations can unfortunately arise.

It is in the client's interest that advice should not be overly conservative. Good advice, often leading to significant cost savings, can be given provided the potential limitations are accepted by all concerned and the risks are knowingly shared by those with financial interests in the particular project. Contractual arrangements which recognise the inherent uncertainties in geotechnical engineering and allow for adjustment to cope with variable conditions should be aimed for. If unexpected conditions are met on a site, immediate involvement of the geotechnical consultant will help to achieve a satisfactory solution to the problem.

The engineering profession as a whole is conscious of the conflicts imposed by owners who seek minimum costs of construction, but are ready to sue at the instant something goes wrong. It is appropriate that "risk tolerance" should be discussed with the geotechnical consultant as part of the initial briefing – this will enable the budget for the site investigation to be balanced against risk expectations.

Conclusion

Competent geotechnical input can provide significant cost savings during the course of a project, both at the feasibility and design stage, and during construction. The preparation of reliable and comprehensive site information will increase contractor confidence and reduce the risk of construction claims.

There needs to be recognition of the fact that geotechnical engineering is not an exact science and that a site investigation report cannot be a guarantee of trouble-free construction. Risks will, however, be very much reduced by engagement of competent, experienced personnel and a budget appropriate to the scale of work and the anticipated difficulties of the site conditions.

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