Time for Thought

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Summary Geotechnical studies involve the collection of facts, the interpretation of these facts and analysis of the geotechnical model. The importance of accurate factual information is illustrated by project experience and a plea is made for the provision of adequate time to carry out a thorough interpretation of site conditions.

1. INTRODUCTION

As practitioners in geotechnical engineering and engineering geology we are all involved in the assessment of ground conditions for projects large and small. We use a range of techniques to provide this assessment, usually a combination of examination of surface features, subsurface investigations and laboratory testing. The different techniques used are selected to enable identification of the range and distribution of the different materials present to establish the geotechnical model which is then used to assess the existing site conditions and to analyse the effect on these site conditions of the proposed development. The scope of the investigations is frequently affected by site specific topographic and geotechnical constraints, by the time available for the work and by budget restrictions.

The compilation of the geotechnical model involves the determination of a usually limited amount of factual data, accompanied by a considerable amount of interpretation and often extrapolation. This interpretation is based on the data obtained from individual sites, supplemented by general information obtained from regional topographic and geological maps, aerial photographs and geophysical surveys. In most cases the information on surface and near surface site conditions is more complete than information on site conditions at depth where the assessment has to be based on an assumption of the most likely situation. The extent of the interpretation involved is not often appreciated by the non-geotechnical community - for example it appears reasonably common to expect evaluation of a subsurface profile based on 100 mm diameter drillholes at 1000 m spacings.

One factor which is often omitted from the investigation program is the provision of adequate time (and the associated cost) to allow logical consideration of all the information available and assessment of the geotechnical constraints on the project. Although we talk of formulating a geotechnical model based on all the information and then providing an analysis based on this model, too often the investigation program is structured to provide for the field and laboratory work followed immediately by production of a report which is basically a presentation of the results of the earlier work. There does not seem to be an appreciation that it is necessary to consider the data at some length to ensure that the utmost benefit is obtained. As professionals we are taught to think. In many cases it appears that we do not strain our brains too much.

I have been involved in geological and engineering geological investigations in Australia and overseas for more than 40 years and frequently carry out reviews of geotechnical aspects of current and future project development. I would like use one or two examples to illustrate some of the problem areas which I have come across.

2. FACTUAL DATA

The whole assessment process is based on the determination of some factual information. If these facts are incorrect it is probable that the interpretation will also be incorrect. It is important that we ensure the accuracy of our facts and use the correct techniques which would establish these facts.

2.1 Survey

A feature which should be obvious and is often overlooked is the location and elevation of site investigations. In many cases the technical objectives of the investigation seem to obscure the requirement to know where it is. Unfortunately as time goes by we do not appear to be learning.

In the early 1960's I provided ground geological control for a United Nations airborne geophysical survey for minerals near the Western Rift Valley in Uganda. The survey identified a major electromagnetic anomaly near the boundary of a granite mass, a surveyor was sent out to peg the anomaly, a drilling rig was dispatched and a 50 m intersection of high grade copper ore obtained from the first hole. We had a party to celebrate and during the party I mentioned to the surveyor that the site was on the east bank of a river. He said that he had located it on the west bank of the river. Subsequent review showed that the surveyor had sited the hole 15 km from the anomaly, there was no aerial anomaly where the ore was struck and no ore in several holes drilled at the correct location. So much for surveyors and airborne geophysics!

On a recent road project in NSW it was discovered that the interpretation of the rock/soil profile on the selected route was based on a geophysical survey carried out for a former route located some distance away. Not surprisingly the cutting design had to be modified.

Currently I am reviewing a major hydroelectric project in the Philippines. The feasibility study has included a drilling program where the coordinates and elevations are stated "as planned but not as drilled". So far it appears that few of the holes were drilled at the planned locations - some are more than 100 m away and collar elevations range from 40 m above to 40 m below the indicated level. As the holes penetrated an essentially horizontally bedded sequence of rocks there is considerable confusion about the interpretation of subsurface conditions.

Subsurface survey is also important. Investigations for an underground power station constructed in Papua New Guinea in the 1960's intersected what were interpreted to be several massive shear zones. Following review of the data the power station was moved and re-oriented. When the excavation of the machine hall was carried out it was found that the investigation holes had been deflected along narrow shear zones, there were no major shears and none of the holes had passed through the power station area. Accurate borehole survey would have saved a lot of worry and redesign.

2.2 Material Types

The assessment of site conditions is affected by the material type present and recognition of this material is often left to junior or unqualified staff. This can lead to major problems.

I carried out a review in the 1980's of a major project in the Northern Territory where for more than 20 years geotechnical and geophysical investigations had been unsuccessfully directed at the location of cavities in limestone foundations. Examination of the core and local outcrops confirmed that the rock was in fact sandstone - a bottle of acid would have saved a lot of money.

Investigations in the 1960's for a tunnel line indicated the presence of several igneous dykes. A magnetic survey along the tunnel suggested that 80% was highly magnetic. This contributed to some mis-interpretation until it was shown that in fact the dyke rock was less magnetic than the indurated siltstone country rock.

2.3 Rock Mass Defects

The engineering performance of a rock mass is commonly controlled by the nature, frequency and orientation of rock mass defects. Where these are determined from surface outcrop the information is usually reliable, but information from core logs must be treated with caution.
Drilling for a major cutting on a roads project in NSW in the 1980's appears to have induced a considerable number of drill breaks. The average spacing of fractures recorded in the logs were about 100 mm. Logging of the cutting after excavation identified seven natural defects over a height of nearly 40 m.

Analysis of core defect orientation on another road project in NSW was based on an assumption of granite foliation which was vertical and striking north-south. Remapping of outcrops showed that the foliation ranged by more than 30 degrees both in strike and dip. A revised analysis produced a significantly different defect orientation which was confirmed on excavation.

The current project in the Philippines is also affected by drill breaks. The recovered drill core is fragmented near to 30 m high cliffs in massive sandstone.

2.4 Rock Mass Permeability

In many major projects the permeability of the rock mass is a critical input to design. It is important that the testing program and techniques are suited to the problem.

In the studies during the 1970's of the foundations for the uranium tailings dams in the Northern Territory it was important to determine absolute values of leakage. This involved modification of the standard "packer" test to accommodate low pressures and very low flows. These techniques were further modified during the studies in the 1980's to assess the potential leakage from the water supply reservoirs on the South Coast of NSW into coal mines.

It is common to water test down-stage with a single-packer. The use of a double packer can introduce uncertainty. For example the several hundred tests carried out with a double packer in the project in the Philippines gave values which ranged from 8 to 12 Lugeons regardless of rock type and condition with a gradual decrease in permeability with depth. This indicates that the bottom packer is probably not operating properly. The permeability figures are obviously nonsense, but have been accepted by the design consultant and have been the subject of statistical analysis!

A current tunnel project in NSW has water inflow which appears to be related to substance rather than defect permeability. High rates of flow result from a large exposed surface area rather than high permeability. The usual field permeability tests are not designed to address this situation.

2.6 Groundwater

The importance of groundwater in most civil and mining engineering projects cannot be overstressed. Water inflows, leakage, dewatering and slope stability are all affected by groundwater levels. Although most reports include some information on water levels, in my experience many are incomplete and inconclusive. Records are often spasmodic and restricted to the period of investigation. The fluctuation in groundwater level and pore pressures as a result of a major rainfall event can significantly project performance. This aspect cannot be evaluated until sufficient records are obtained.

3. INTERPRETATION

Having got our facts right we then have to use them and any other relevant information to interpret the situation between the known points. In this interpretation we have to use our background knowledge of natural materials, their method of formation and engineering properties. Uniformity is the exception rather than the rule! The interpretation should consider all possible alternatives - lateral thinking is useful in this situation.

It is common practice to include in contract documents only the factual data obtained on a project to avoid any potential for misleading information as the basis for a contractual claim. Apart from the problems of incorrect facts mentioned above I believe that in many situations it is preferable to provide the interpretation of the site conditions which has been adopted for design as this model should have had the benefit of considered input during the whole period of investigation. The contractor has to independently carry out this assessment during the relatively short tender period - and also submit a fixed price for construction.

It is often difficult to convince clients of the extent and reliability of the interpretation. On one building project in NSW in the 1980's a series of test pits over a sloping site identified a stepped sandstone profile. The sections provided to the designer included a "dashed" interpretation of the rock/soil contact between test pits with the explanation that it referred to an inferred location. Despite these comments the foundation design was rigidly based on this interpretation and the contract based on the indicated profile as factual.

It is important to recognise that the regional geology can provide fundamental input to the interpretation. The initial geological work in the 1960's at Liddell Power Station in the Hunter Valley, NSW recognised several faults with significant throws which affected site conditions in the intake canal. These faults were interpreted as normal faults until on review it was recognised that the area is close to the Hunter Thrust - the major compressional fault on the northern side of the valley. Reinterpretation of the faults as thrust faults clarified the geological situation.

It appears that problems of reservoir leakage in a current project in Thailand also result from a failure to recognise a thrust fault - in this case providing a leakage path through karst limestone under quartzite.

Sometimes even with the best of information the interpretation can be wrong - at Eraring Power Station in NSW frequent drill holes on the intake canal indicated a low dip of the strata to the west. When the canal was excavated it was found that the strata was horizontal with a series of parallel faults with a downthrow to the west.

The value of aerial photographs in the interpretation of site conditions cannot be overestimated, particularly if it is practicable to confirm the conditions on the ground. A regional study for alternative tailings dam sites at Ok Tedi in the 1980's revealed that in areas of total tropical forest cover it was possible to identify the distribution of rock types, rock structure and areas of recent and slope failure. This required intensive and repeated study of the photographs accompanied by visits to representative areas - fortunately by helicopter.

Another project where aerial photographs proved invaluable was the investigation for the Alice Springs to Darwin gas pipeline which crosses about 200 km of karst limestone. Photogeology and site visits - again by helicopter - indicated that cavern formation was concentrated at areas of intersection of regional joint sets. Some modification of the route avoided these areas.

Where similar conditions exist over a wide area it is sometimes possible to understand the problem and its causes. The landslide study of the TAZARA railway in Tanzania involved about 80 landslides which affected the line over a distance of about 50 km in deeply weathered granite. These landslides proved to be some of many thousands which are present in this region and systematic observation both on the ground and on aerial photographs was able to identify the full range of progressive development from an erosional feature to a rotational failure. The field investigations were able to define the geometry and material properties but the understanding of the mechanism of failure was founded on a considerable period of observation and thought.

4. MOST MEMORABLE PROJECT

I have been asked to describe my most memorable project. There have been many large and small in lots of different places and with different memories. Some have had spectacular scenery - a couple of projects in Nepal spring to mind. Some have been in pleasant surroundings - in Fiji and the Solomon Islands; others have left a mixed impression - hot, wet and full of insects. One thing I have discovered is that the jungle in most places is similar.

I consider that my most memorable project has to be the TAZARA landslide study. My involvement with this project lasted from 1981 to 1989. It covered a fascinating problem in an area of geological and geomorphological interest. We initially visited Tanzania during a period of depression as a result of extreme socialist policies - as the study progressed living conditions improved. To reach the project area we had to traverse one of Africa's largest game parks - full of elephants, wildebeest and lions - all free. During the study I had the opportunity of working closely with some of the leading geotechnical engineers and engineering geologists in this country including Robin Fell, Bruce Walker, Max Ervin, Fred Baynes and Paul Wallis. It has been the opportunity to join with them through the process of the investigation, analysis of site conditions and the design of the remedial works and also their companionship under sometimes adverse conditions which has made this project most memorable.