Reasons for Monitoring Performance with Geotechnical Instrumentation

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Construction of civil engineering facilities must deal with many unknowns and limited data. This is especially true for those projects in urban areas that involve construction on or in soil and rock. We are working in materials with properties that can change instantly and significantly from one point to the next. These changes may result from the actions of nature in laying down the earth, from prior activities of man on the site, or from actions of the contractor as he works with the site. Further complications may come from uncertainties in the loads that the new facility must withstand during construction and operation. These uncertainties combine to produce substantial uncertainty about how the completed facility will perform throughout its life.

Compounding the importance of these uncertain conditions are the potentially large consequences of unexpected performance by the facility. Unexpected performance may adversely impact the project, neighbouring structures and utilities, and people. Unexpected performance may delay the project, increase its cost, and lead to lengthy and expensive litigations.

Table 1 summarizes the principle technical reasons for recommending a geotechnical monitoring program for a project. Each of these is discussed below in the context of today's practice of geotechnical engineering. In general, a common feature of these technical reasons is that monitoring programs save money.

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Table 1. Reasons for monitoring performance

1.	Enabling use of the observational method.
2.	Indicate impending failure.
3.	Reveal unknowns.
4.	Assess contractor's means and methods.
5.	Minimize damage to adjacent structures.
6.	Devise remedial measures to fix problems.
7.	Improve performance.
8.	Advance state-of-knowledge.
9.	Document performance for assessing damages.
10.	Inform stakeholders.
11.	Satisfy regulators.
12.	Reduce litigation.
13.	Show that everything is ok.

Enabling use of the Observational Method

Monitoring provides us with quantitative information on actual performance. We compare the measured performance with the predicted or expected performance. Differences indicate the effects of uncertainties in our design. We need to evaluate those differences to determine what they indicate for future performance. If the anticipated future performance is unacceptable, we look for changes, modifications, and remediation that can be made to alter the future performance. This process, defined as the "Observational Method," was brilliantly described by Dr. Peck in his Rankine Lecture (Peck, 1969).

For example, an embankment might be placed over a soft soil stratum by constructing it in stages. Placed all at once, the embankment would cause a foundation failure. Placing the embankment in stages with time between each stage allows the soft soil to strengthen by consolidation between each stage. Instruments to measure movements and pore water pressures could be used to determine when enough consolidation of the clay has occurred that the next stage of fill can be safely added. A delicate balance may be sought between adding the next stage as quickly as possible to minimize construction time but not so quickly that a stability failure is created.

Indicate Impending Failure

Geotechnical facilities can fail with catastrophic consequences to life and property. Such failures may be the result of excessive loads, design errors, construction deficiencies, unknown or different conditions, deterioration, operational errors or intentional action. Geotechnical monitoring has been widely used to detect the onset of failure in dams, slopes, embankments and excavations. Such monitoring may have different purposes. It may be to issue a warning to evacuate people and move equipment. It may be to initiate action to forestall the failure. It may provide feedback when causing an intentional failure, such as for a mining operation or a field test.

Reveal Unknowns

Geotechnical engineers constantly work with unknowns. Sometimes these unknowns can cause a catastrophic failure that destroys the entire project, takes lives, or ruins careers. Other times they cause delays, which increasingly lead to expensive claims for "differing site conditions".

The foundations of the geotechnical

discipline were built on the use of field measurements to reveal unknowns during construction and head off disaster. In fact, it can be argued that the driving force that led to the development of most of the instrumentation we use today was a need to measure something to reveal unknowns.

Use of procedures which reveal unknown conditions as early as possible and engage remedial work as soon as possible leads to lowest project cost. A good geotechnical monitoring program is vital to this approach. The alternative of delay, denial, and blame almost always costs more. Additional costs come from the expenses incurred to determine who pays the added cost.

Assess Contractor's Means and Methods

The outcome of some geotechnical projects depends on the means and methods of the contractor, and geotechnical monitoring is used to determine whether the contractor's means and methods meet the specified performance requirements.

Project requirements may be in the form of a performance specification where the contractor is required to provide the design and complete the construction. Maintaining the stability of the bottom of a deep excavation against uplift is one example. The specifications might require that the contractor maintain a minimum factor of safety against bottom heave due to uplift of at least 1.1. Piezometers installed to measure pore water pressures beneath the excavation would indicate whether the contractor is meeting this important requirement.

Minimize Damage to Adjacent Structures

Geotechnical construction may affect adjacent property with undesirable results. Expensive repairs, bad relations and protracted litigation can result.

Movement of the ground outside a supported excavation is one example. The specifications might require the contractor to provide an excavation support system that limits horizontal and vertical movements outside the excavation to a specified amount, so that adjacent structures are not damaged by the work. Geotechnical instrumentation to measure vertical and horizontal movement outside the support system is used to determine whether the contractor meets this requirement. In doing this, we save the costs to fix the actual damages. In addition, we may avoid or greatly reduce the costs that come from inflated claims and protracted litigation resulting from the alleged damages. Such savings can be of great significance, especially in urban areas.

Devise Remedial Methods to Fix Problems

Things sometimes go wrong in geotechnical construction that must be fixed. Finding the best fix requires understanding what went wrong. Data from geotechnical monitoring can help engineers to determine what caused the problem. Then a remedial action can be devised that addresses the specific cause rather than masks the symptoms.

Improve Performance

Modern concepts of business management stress continual improvement and the need for measurements to gauge success. A common saw in business practice is "that which is measured improves, while things not measured eventually fail." The mere process of measuring performance coupled with normal human behavior leads to improved performance.

The underground construction industry is searching for ways to improve their operations to produce facilities that perform better and cost less. Like other business processes, improvement can only be assessed by measurement. Geotechnical monitoring programs can play a central role in providing these measurements.

Advance State-of-Knowledge

Many of the advances in the theories of geotechnical engineering have their roots in data from geotechnical monitoring on full-scale projects. The data give us insight into how things are performing and about causal relationships. Historically, a significant amount of geotechnical instrumentation was used as part of a research effort to improve our state of knowledge. Much of this was paid for by governmental agencies with a mission to improve practice. The result has been a substantial improvement in our understanding of how various foundation systems, excavation methods and ground improvement processes work and don't work.

Document Performance for Assessing Damages

Claims for damages by third parties represent one of the substantial risks encountered in geotechnical projects. Some claims may include charges for damages unrelated to the construction. Others may be inflated, such as a claim for major loss when only minor architectural damage has occurred.

Data from geotechnical monitoring can help establish the validity of such claims. For example, if the instrumentation shows that an adjacent building has not moved during construction, it becomes more difficult for the owner to claim that cracks in the building resulted from the construction activity.

Inform Stakeholders

Construction in developed areas may affect numerous parties, all of whom seek a role in controlling the adverse impacts of the project. People tend to fear construction impacts and anticipate the worst outcomes. Data from geotechnical monitoring can provide solid evidence of the true construction impacts. It can provide powerful responses to the questions and fears of stakeholders.

Satisfy Regulators

Some facilities must be instrumented to meet the requirements of specific regulations, usually to help protect public safety or the environment.

Reduce Litigation

Data from geotechnical monitoring can be a powerful deterrent to litigation. Contractors may claim differing site conditions. Abutters may claim for damages caused by construction. Owners may claim poor performance of the completed facility. Where subsurface conditions are involved, data from a good geotechnical monitoring program may provide powerful evidence to help reach a fair resolution of such claims.

Show that Everything is OK

Increasingly we use geotechnical monitoring programs to demonstrate the actual performance is within the bounds anticipated by the designers. The presumption is there will be no surprises or unexpected consequences to cost and schedule, and that unexpected behaviour can be identified early enough to maintain control of the project cost and schedule.

In this use, data from a geotechnical monitoring program helps maintain the various parties' confidence in the performance of the work and frees them to focus on other issues. Increasingly, owners desire performance monitoring systems that are comprehensive and robust but with instant reporting as simple as a green light to indicate that everything is in an acceptable state.

References

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