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Instrumentation for Embankments

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On many highway embankment construction projects, geotechnical instrumentation is an essential tool for monitoring the performance of the foundation and the embankment. This is especially the case if some type of special foundation treatment is employed (Chapter 6) or special soil deposits (Chapter 9) are encountered. The instrumentation and monitoring program is primarily used to alert geotechnical and construction engineers to soil behavior or construction problems different from those anticipated in design. For instance, adverse soil behavior may call for a reduction in the rate of embankment construction. Alternatively, encountering soil behavior much better than that assumed in design may allow increased construction loading rates, steeper embankment slopes, and elimination or reduction of recommended special foundation treatments. Instrumentation is useful for determining the rate of strength gain and degree of consolidation of the foundation soils. It can also indicate conditions of impending failure.

This chapter is intended to provide construction personnel with an overview of geotechnical instrumentation and an appreciation of its importance to the overall success of the embankment construction. Depending on the project, department practice, and contractual arrangements, the instrumentation may be installed by the contractor or a specialty subcontractor. In this case, field personnel will be responsible for inspecting the installation of the instruments. In all projects, field personnel are responsible for monitoring the contractor's operations so that the instru-

mentation, which is expensive and important, is properly protected during construction. On many projects, construction engineers and technicians are required to periodically read the instruments and to report the values to the appropriate project supervisor or geotechnical engineer. This is a very important responsibility, and it must be done diligently and carefully.

OVERVIEW OF GEOTECHNICAL INSTRUMENTATION

Information on Instrumentation

The notes for the FHWA training course on geotechnical instrumentation (Dunnicliff and Sellers 1980) are probably the best overall reference on the subject for highway construction. Dunnicliff (1982) gives a useful summary of the training course notes. Hanna (1985), Dunnicliff (1988), and Wilson and Mikkelsen (1978) have written good general references on geotechnical instrumentation.

When Is Instrumentation Used?

Instrumentation is used under the following circumstances:

- When a foundation failure could be expensive, life threatening, or damaging to adjacent property;
- When the design dictates waiting periods or controlled rates of loading;
- When new methods of foundation treatment or unusual embankment materials are being used;
- When the embankment is expected to settle greater than 2 ft; or
- When information gained by instrumenting the first sections of a large project that is being designed and constructed sequentially can be used to improve the design of subsequent sections.

Instrumentation Selection and Location

Selection of the specific types and numbers of instruments and their locations is done by the geotechnical engineer who designed the embankment and/or its foundation. A number of considerations influence these design decisions, but these considerations are not routinely communicated to project engineers or field personnel. This is unfortunate because

the more construction personnel know about the instruments and their purpose, the fewer problems there are likely to be with the installation and operation of the instruments, and the more reliable will be the measurements. Above all, good, frequent communication must be maintained between the geotechnical engineer and construction personnel. One way to ensure proper communication is for the geotechnical engineer to periodically visit the project site to discuss progress and review what to do at critical times during construction. The construction personnel should not hesitate to contact the geotechnical engineer if they have questions concerning any aspect of the instrumentation program.

Locations of the instruments will be indicated on the plans. In many instances instrumentation will be in the way of construction activities, or plans may call for instruments or readout devices to be placed in locations obviously hazardous to the instruments or equipment. The field engineer should consult with the soils engineer about relocating such items before they are installed. In most cases, soils engineers would rather have data from a less desirable location than no data at all, so changing the proposed location of instruments in the field is usually not a problem.

All instruments and readouts should be clearly marked or flagged when they are installed. Such marking cannot be overdone. The contractor's foremen, equipment operators, and laborers should be well aware of the location of the instrumentation and its importance to the project.

Instrument Types

Generally for embankment construction, measurements of pore pressures (using piezometers), vertical movements (using settlement platforms, Sondex tubes, and heave stakes), and horizontal movements (using inclinometers and survey stakes) are most commonly used. Other parameters such as earth pressure, soil strains, dynamic properties, and the like may occasionally be required.

There are numerous types of geotechnical instrumentation available, and each has its own advantages and limitations. Information on the specific instruments to be used on a project may be found in the references in the section on Information on Instrumentation or from a geotechnical engineer.

CONSTRUCTION MONITORING

It is often the responsibility of the construction engineer's staff to read the instruments. Soils engineers should make provisions for instructing and

familiarizing construction personnel with the instrumentation and explain the purpose of the instrumentation program, how the information will be used, how to read the instruments, how often they need to be read, and what to do with the readings. Presentation and interpretation of the measurements are the geotechnical engineer's responsibility; rarely are field personnel involved in this aspect of instrumentation.

Rules of Data Acquisition

The following rules should be adhered to in the acquisition of data:

1. Read all the instruments at approximately the same time of day on each day they are scheduled to be read.
2. Try to take readings when construction is not in progress. Read all of the instruments in the morning before construction starts, and/or at the end of the day after it has stopped.
3. Obtain complete and accurate information about the construction operations at the time of the readings. Examples are fill height, changes in visible water surfaces (rivers, excavations, dewatering, and the like), and any nearby construction operations. Note the weather conditions at the time of the readings.
4. Pay special attention to readings that are different from previous readings. Do not omit or ignore any readings, no matter how inaccurate they may seem. Substantial differences may indicate a reading error, instrument or readout malfunction, or the need for rapid remedial action. Double-check and record the value, and inform the geotechnical engineer immediately.

Frequency of Readings

Establishing the frequency of readings is the geotechnical engineer's responsibility. It will depend on the project, how rapidly settlement is taking place, or whether stability is critical. In general, readings will range from several times a day to one to three times a week during embankment construction, and perhaps one to four times a month during waiting periods or after the embankment is complete. Geotechnical specialists may initially specify more frequent readings than are really necessary and then adjust the schedule after interpreting the first few sets of data. If consecutive readings show no changes, the time between readings may be extended. If there are large differences, the frequency of readings may be increased. It should be emphasized that if impending failure is indicated

by the instruments, corrective action must be taken immediately, and instrumentation readings, data reduction, and interpretation done almost continually during such a time. Close coordination between field personnel and the geotechnical engineer is essential in such cases.

REFERENCES

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