Geotechnical Instrumentation

Geotechnical instrumentation is used to obtain surface and subsurface data for geotechnical projects. The collected data can be used to characterize site conditions, verify design assumptions, monitor conditions during construction or provide long-term performance data for earth-related structures. The need and benefit of geotechnical instrumentation should be evaluated by the geoprofessional to quantify uncertainties that are associated with the nature of soils, rocks, and groundwater.

Caltrans Geotechnical Instrumentation Branch (GIB) provides services to plan, install, monitor, collect, and report geotechnical instrumentation data to meet project objectives. The geoprofessional is encouraged to request GIB involvement as early as possible so that proper and reliable instrumentation can be selected, costs can be better estimated, and funding allocated.

Geoprofessionals in the Office of Geotechnical Design West may also contact their Branch D (Geotechnical Support Branch) for instrumentation service.

The references at the end of this module provide detailed information on the technical components of geotechnical instrumentation.

Services Available

Instrumentation services provided include groundwater level/pressure monitoring, percolation/infiltration testing, deformation/displacement monitoring, load/stress monitoring, long-term automated remote monitoring, other auxiliary instruments, and design and construction support. The GIB will also assist in obtaining consultant instrumentation services, if necessary.

Groundwater Monitoring

GIB uses water level dip meters, portable programmable digital sensors (such as Levelogger), or vibrating wire piezometer sensors for groundwater monitoring. A dip meter is often used to the read water level manually in open standpipe piezometers. A portable Levelogger can be installed stand-alone in standpipe piezometers and easily be moved from one job site to another. The Leveloggers can also be used for percolation/infiltration testing. Data collected automatically by programmable Leveloggers can be easily downloaded on site or remotely. Vibrating wire piezometer sensors are used mostly in automated remote monitoring stations with dataloggers. The dataloggers are available in both single-channel and multiple-channel and are protected in weather-proof enclosures.

Deformation/Displacement Monitoring

Slope inclinometers (SI), sometimes coupled with Time Domain Reflectometry (TDR) cables, are commonly used to locate landslide slip planes and monitor subsurface movements of landslides, embankments, abutments, etc. Extensometers, tilt meters, crack meters, and beam sensors monitor displacements on the ground surface, rock masses, underground openings, bridges, and retaining structures.

Load/Stress Monitoring

GIB provides load/stress monitoring by reading strain gauges or elasto-magnetic force sensors installed by contractors on soil nails or ground anchors to monitor performance of load bearing elements. Earth pressure cells, either embedded in soil mass or in contact with a structure, can be used to measure the total stresses on foundation soils to verify the design assumptions.

Automated Monitoring Station and Remote Data Retrieval

Automated continuous monitoring and remote data retrieval is used for large-scale long-term monitoring projects. GIB uses automated dataloggers and cellular modems or Digital Subscriber Line (DSL) Ethernet connections to provide real-time data to the geoprofessional.

Auxiliary Instrumentation Service

GIB provides downhole camera surveys of SI and piezometers. If there is concern about quality of installation or a problem with data collected, a downhole camera survey can be conducted to visually inspect the installation to determine if issues exist.

Design and Construction Support

The GIB will provide oversight for Caltrans Construction in the placement and monitoring of geotechnical instrumentation for specification compliance and quality assurance.

Contract Service Support

Other instruments or monitoring methods not available from the GIB may be found at the Geotechnical Instrumentation Reference Manual of FHWA (Publication No. NHI-98-034). For those services, GIB will assist the geoprofessional in their procurement of contract support by:

- Providing technical specifications for construction contracts
- Assisting in the selection of appropriate instrumentation methods and devices
- Developing instrument specifications

- Getting price quotations from vendors
- Assisting in field installation, data collection, and reduction
- Assuming the monitoring responsibilities after contractor's completion of contracted instrumentation work

The project geoprofessional is responsible for completing all required Task Orders and/or contract procurement paperwork for consultant services.

Requesting Services

The Geotechnical Instrumentation Service Request Forms are available online. There are four forms available for downloading:

- *Slope Inclinometer Test Request*
- *TDR Test Request*
- *In-Situ Test Request*
- *Field Instrumentation Request*

The *In-Situ Test Request* can be modified for groundwater level/pressure monitoring, percolation/infiltration test, and other customized instrumentation projects.

Procedures

The project geoprofessional is encouraged to contact the GIB Branch Chief early in the planning stage to discuss and define the instrumentation goals. GIB will assist in formulating the most appropriate and cost effective instrumentation scheme. GIB will also determine whether the instrumentation work can be done by GIB staff or by consultant.

If GIB will perform the service, the project geoprofessional must complete the appropriate request form and retain the supervisor signature. The request, a site vicinity map and general site plan, should then be emailed to GIB Branch Chief. The site plan should show the instrument identifications (IDs), proposed instrumentation locations, and significant site features. The GIB engineer will review the request and discuss the scope of work with the project geoprofessional and finalize the instrumentation plan.

The project geoprofessional is responsible for ensuring the readiness of the project, including but not limited to, obtaining permits, traffic control, or other site-specific preparations. Additionally, where instrumentation requires borehole drilling, such as TDR, SI, or piezometers, the project geoprofessional is responsible for coordinating with Drilling Services to install such devices.

The GIB is responsible for testing, installing, and maintaining the instruments, implementing a quality control program during installation, and monitoring. The GIB is

responsible for collecting, reviewing, reporting, and maintaining the data collected.

General Practice of In-House Instrumentation

Initial readings are taken as soon as possible once the instruments are installed and stabilized based on the GIB's recommendations. Because most instrumentation data are referenced to initial data, collecting reliable initial data to establish a baseline is essential.

A data collection schedule will be set based on construction activity, the rate at which the readings change, and the requirements of data interpretation. The project geoprofessional may modify the monitoring schedule according to the data collected, engineering judgment, and whether resources are available.

Processing and Presentation of Monitoring Results

GIB's monitoring process includes the following steps:

- Collection of raw data
- Screening of raw data
- Data reduction and calculations
- Plotting of data
- Interpretation of data
- Report preparation

Among the steps listed above, data reduction, calculations, and interpretation of data are the most human-intensive activity, and no technique is currently available for automatic interpretation. Thus, interpretation should be performed by geoprofessionals who are familiar with the monitoring program, its construction procedure, and details of instrument installation. They should especially be capable of exercising good engineering judgment.

Interpretation of instrumentation data is an ongoing process. Initial interpretations will be tentative, dependent on collection of more data. Initial interpretations may change as a better understanding of the actual behavior is developed. Assessment of the performance of an individual instrument often requires a study of data over a longer period of time.

Various types of plots can be produced including routine plots of data versus time, plots to assist with predictions, plots for comparing observed and predicted behavior, plots for comparison of measurements and observations, and plots to examine cause and effect relationship. Selection of plots must be made on a case-by-case basis by the project geoprofessional, with the purpose of the instrumentation program clearly in mind.

Standards for Monitoring Reports

After data has been interpreted, the GIB will provide an interim monitoring report to the project geoprofessional. Reporting will be on a regular schedule as specified by the project geoprofessional and will include the following:

- Summary plots
- A brief commentary, noting all significant changes since the previous interim monitoring report
- Recommended action pertaining to the monitoring program or data interpretation

Upon completion of the monitoring work the GIB will provide a final report to summarize the results of the monitoring program and to provide any recommendations to geotechnical designers. The final report will include:

- A description of the project and reasons for using geotechnical instrumentation
- Relevant project design and construction information
- Summary of the monitoring plan
- Descriptions of instruments and readout units
- Plans and cross-sections indicating instrument IDs and locations
- Instrument installation procedures
- Procedures for data collection, processing, presentation, and interpretation
- Observed behavior, including summary plots and factors that influence measured data
- Analysis of observed behavior, including comparisons between measured and predicted, a discussion of significant changes and probable causes, or comparisons with published literatures, etc.
- Discussions and recommendations based on the monitoring results

References

1. Geotechnical Instrumentation for Monitoring Field Performance, John Dunnicliff, 1998.
2. Geotechnical Instrumentation Reference Manual, NHI Course No. 13241 - Module 11, FHWA Publication No. HI-98-034, October 1998.
3. Use of Inclinometers for Geotechnical Instrumentation on Transportation Projects, Transportation Research Board, Circular No. E-C129, October 2008.
4. Time Domain Reflectometry for Monitoring Slope Movements, University of Wyoming, FHWA-WY-06/03F, August 2006.