Chapter 6
Installation

6-1. Introduction

Installation of geotechnical instrumentation, whether during construction of a project or in an existing structure, requires special attention to detail. Faulty installation of instruments not only can lead to erroneous and misleading performance data, but could also affect the integrity of a structure. Methods of installation are dependent on the parameters to be monitored, site conditions, and selected instruments. Therefore, qualified, experienced, and competent personnel are essential if an installation is to be successful. An installation of an instrumentation system is not considered routine; therefore this chapter includes guidelines and recommendations rather than step-by-step procedures.

6-2. Personnel Issues

The purpose of geotechnical instrumentation is to provide accurate and timely data so that performance evaluations of a project can be made by personnel responsible for safety of an embankment dam or levee. The quality and accuracy of the evaluations are highly dependent on proper instrumentation installation. In addition, District and project personnel will be responsible for the maintenance of the instrumentation system (see Chapter 8). Therefore it is highly recommended that in-house personnel perform as much of the actual installation as possible, and that the design and installation of an instrumentation system be the responsibility of the instrumentation program manager (see Chapter 3).

6-3. Contracting Issues

Although in-house expertise is preferred, contracting may be necessary. Work such as trenching, conduit installation, and other site work can be performed by general construction contractors. Drilling contractors require close supervision by a geotechnical engineer during installation. However, a great deal of the work requires an instrumentation specialist (who will usually be the instrumentation program manager) who is familiar with the particular instruments and has a good working knowledge of geotechnical engineering and the local site conditions. If a contractor is to be responsible for the installation of an instrumentation system, the specifications should include the following items:

- Purpose of the geotechnical instrumentation program.
- Responsibilities of the contractor.
- Instrumentation system performance criteria.
- Qualifications of contractor's instrumentation personnel.
- Quality assurance.
- Submittals.
- Scheduling work.
- Storage of instruments.
- Materials (provide a detailed description of all types of instruments included in the contract).
- Factory calibration requirements.
- Pre-installation acceptance tests.
- Installation instructions (provide a detailed step-by-step procedure for the installation of each type of instrument included in the contract).
- Instructions for changed site conditions.
- Field calibration and maintenance requirements.
- Protection of instruments.

6-4. Instrumentation of New Structures

Various options exist when planning installation of an instrumentation system in a new structure. Instrument casing can be installed upward in the embankment as the fill rises. However, it is generally not advisable to extend the casing vertically through the core material of an embankment. Horizontal runs of tubes and cables must not extend horizontally fully through the core (see Figure 6-1d) and must exit the downstream face of the embankment. Vertical runs of tubes and cables can run upward through any zone of the embankment except the core. The installation of vertical runs of tubes and wires through the core of an embankment is not acceptable and must be avoided. Obtaining adequate compaction, due to difficult access around the casing, is very difficult, resulting in the creation of a poorly compacted zone. An alternative to installing an instrument which requires casing is to use an instrument which requires tubes or cables. In addition, the inclusion of instrumentation in an

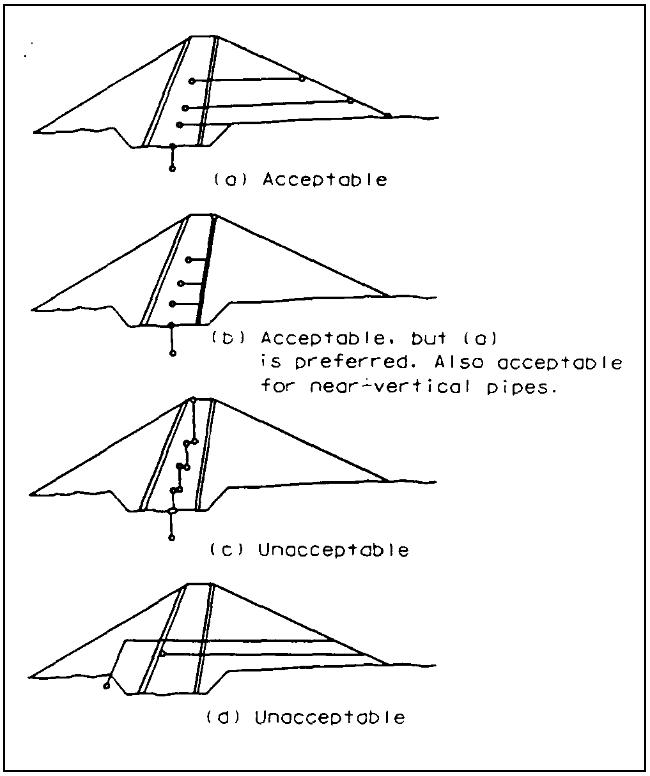

Figure 6-1. Examples of acceptable and unacceptable routings for instrumentation tubes and cables (after Dunnicliff 1988)

embankment construction will, almost inevitably, cause delays and require a general contractor to pay special attention to details and provide protection when working around an instrument that is being installed. Scheduling of cable installation must be coordinated with other activities to avoid damage to cables by construction equipment. Instruments should be sufficiently protected and located with highly visible survey stakes and flagging.

6-5. Instrumentation of Existing Structures

Surface installations, retrofits, or replacements of nonembedded sensors do not generally create installation difficulties. However, drilling may be the only option available when the installation or replacement of a subsurface instrument is necessary in an existing structure. Great care must be taken when selecting a drilling method to be used in an existing embankment. Water or air pressure used during drilling of a borehole can damage the embankment by hydrofracturing. A hydrofracture is a crack, shear plane, seepage path, and/or other detrimental condition that can develop during the drilling process. Impervious cores are especially susceptible to damage and extreme care must be used in drilling in these zones. For this reason, the practice of drilling in embankments or foundations using air (including air with foam) is prohibited per ER 1110-2-1807. A summary of drilling methods is included in Appendix B.

6-6. Drilling Fluids

There are two purposes for using drilling fluids when performing a boring: first, to have a medium through which the drill cuttings are moved from the cutting head at the bottom of the boring to the top; second, to stabilize the sidewalls of the boring from collapse. The viscosity of the drilling fluid can be thickened as necessary to prevent collapse. The drilling fluid adheres to the sidewalls and creates a residual skim coat. The standard bentonite mud is an unacceptable drilling fluid for piezometers because it seals the soil and inhibits piezometric response. Biodegradable mud composed of an organic polymer is acceptable as a drilling fluid because it reverts back to water through enzyme breakdown, leaving no residue. The selection of a drilling fluid must be made with the compatibility of the installed instrument in mind. If there is any possibility of collapse of the walls of the boring, drilling fluid should not be used. Casing is often the preferred method for support.

6-7. General Installation Procedures

Instruments are often installed in boreholes located in either abutments or embankments. Many of the instruments installed in boreholes have minimum and maximum diameter requirements. Drilling specifications should clearly spell out required diameters, depths, alignments, drilling and sampling requirements, instrument requirements, construction details, and special requirements. The information provided below is suggested guidance for instrumentation installation. Each system to be installed should be evaluated on a case-by-case basis. It is the responsibility of the instrumentation program manager or geotechnical engineer to write detailed procedures for the installation of an instrument. When deformations are expected to occur, special considerations are often required so that pipes, tubes, and wires are not damaged as deformation occurs.

a. Planning. Prior to the actual installation of the instrumentation, time should be invested in planning the installation. Planning includes preparation of site-specific detailed step-by-step installation procedures and of a list of required materials and installation tools, preparation of an installation schedule, and coordination of installation with other parties. Additionally, the lead time necessary for the procurement of the instruments should be investigated. Many instruments are manufactured when ordered, and large orders may require significant lead time before delivery to the site. Installation of instrumentation may require support from utility companies (electricity or telephone) which may require long lead time before service is available. Possible road closures while cables cross routes of access may be necessary. The routes which will be used for pulling instrument cables through conduits should be decided. Other ongoing operations or construction activities may impact on the planning of an installation. The necessity for automation (see Chapter 5) must have previously been addressed, since cable runs may change to match hardware limitations and using radio for communication may be less expensive than hardwire options.

b. Pre-installation acceptance tests. When the instruments are received at the site, instrumentation personnel should perform pre-installation acceptance tests to ensure that the instruments and readout units are functioning properly. Where electrical components are irretrievable and must function below the water table, consideration must be given to pressure-testing of instruments for leaks. Pre-installation acceptance tests should include relevant items from the following list:

- Examine factory calibration data to verify completeness (factory calibration and documentation should be specified).

- Examine manufacturer's quality assurance inspection check list to verify completeness (quality assurance procedures and documentation should be specified).

- Check cable length.

- Check tag numbers on instrument and cable.

- Check, by comparing with procurement documents, that the model, dimensions, materials, product performance criteria, etc. are correct.

- Bend cable back and forth at point of connection to the instrument while reading the instrument to verify connection integrity.

- Check water pressure or humidity test components as appropriate for the service entity to identify leaks.

- Verify that instrument reading as required compares favorably with factory reading.

- Perform resistance and insulation testing, in accordance with criteria provided by the instrument manufacturer.

- Verify that all components fit together in the correct configuration.

- Check all components for signs of damage in transit.

- Check that quantities received correspond to quantities ordered.

Results of the tests should be documented and include the following items:

- Project name.

- Instrument type and number.

- Identification of any testing or readout equipment used during testing.

- Personnel responsible for testing.

- Date and time of testing.

- Measurement and observations made during testing, as listed above.

- Test results, pass or fail.

c. Installation documentation. In addition to recording pre-installation information, a record of installation should be documented and include the following items:

- Project name.

- Contract name and number.

- Instrument type and number, including readout unit.

- Planned location, orientation, depth, length, and backfill volume data.

- Personnel responsible for installation.

- Plant and equipment used, including diameter and depth of any drill casings or augers used.

- Method of trenching and backfilling.

- Date and time of start and completion.

- Measurements or readings required during installation to ensure that all previous steps have been followed correctly.

- A log of subsurface data indicating the elevations of strata changes encountered in the borehole.

- A determination if the strata at the transducer location was or was not that anticipated in the instrumentation plan.

- Type of backfill used.

- As-built location, orientation, depth, length, and backfill volume data.

- Three-dimension schematic of utility runs to instrument, locating all junction boxes (buried and surface access).

- Results of post-installation acceptance test (see below).

- Weather conditions at the time of installation.

- Miscellaneous notes, including problems encountered, delays, unusual features of the installation, and details of any events that may have a bearing on instrument behavior.

d. Post-installation acceptance test. Upon completion of the instrument installation, installation personnel should demonstrate that the instrument was correctly installed and is functioning properly. The details of the test will depend on the type of instrument, and all possible quality checks should be made. A series of readings should be made (minimum of three) during a short span of time to demonstrate that the instrument reading can be repeated. The installation may have an effect on the parameter which is to be measured and the instrument should be allowed to stabilize and the acceptance test repeated. The details of the test should be included with the installation report.

e. Care and handling. To ensure satisfactory performance of an instrument, it should be protected from the elements prior to installation. The manufacturers will usually describe conditions which are unsuitable for their devices. All instruments should be kept free from dirt and dust. Some instruments or their cables degrade in direct sunlight. Some instruments are sensitive to electric or magnetic fields. Others should be protected from extreme temperatures, humidity, water, shock, and/or chemical precipitates. All instruments should be handled carefully. Cables and tubes should be protected from nicking, bending, and kinking.

6-8. Installation Procedures for Piezometers in Boreholes

Installation of a piezometer in a borehole is not a routine process. Many factors must be considered if the piezometer is to function properly.

a. Example of detailed issues when planning installation. As an example of the thought process that is necessary when preparing detailed installation procedures, the following questions should be answered when selecting a method for installing a piezometer in a borehole in soil: (adapted from Dunnicliff 1988)

(1) What are the soil types?

(2) Is sufficient lead time necessary for procuring special piezometers?

(3) Are there artesian conditions?

(4) Are there excess pore water pressures?

(5) What drilling methods are available?

(6) What skill/care/experience is available among personnel who will be responsible for installations?

(7) How much vertical compression will occur in the soil above the instrument?

(8) Are soil samples required?

(9) How can the borehole be supported?

(10) How much time is available between completion of installation and the need to establish zero readings?

(11) What are the requirements of response time?

(12) What borehole diameter will be used?

(13) How will the casing or augers be prepared, cleaned, backfilled, and/or pulled?

(14) Is a sounding hammer required?

(15) What type of bentonite will be used?

(16) What is the required waiting time for swell?

(17) Is a swelling retardant needed? If yes, what method will be used?

(18) Where will the seals be located?

(19) What will be the required depths of the seals?

(20) Will centralizers be required?

(21) Which method of installation is most appropriate?

b. Selection and placement of sand filters. The filter material to be placed around an open standpipe piezometer must be designed to meet filter criteria with respect to the screen and to the gradation of the soil layer in which it is being installed. Filter material for all types of piezometers should be generally clean from fines and not restrict the response of the instrument. Filter material can be placed by pouring the material in the top of the boring or tremied into place. If the material is poured from the top, it should be saturated with water and poured slowly to avoid bridging in the annular cavity of the boring. If the tremie method is used, water should be used to flush the material through the tremie pipe. The tremie pipe is gradually raised as the material builds up in the hole. A sounding hammer (Dunnicliff 1988) should be used to verify depths of placement.

c. Selection and placement of seals. Seals are needed above (and below if necessary) filter zones to ensure that representative readings are collected from single soil stratum. The seal should be constructed of bentonite. A method of compressing slightly moist bentonite into pellets was developed in the Sixties. However, the pellets bridge easily within the casing if they are poured through fluid. Bentonite now exists in the form of angular gravel. This is usually a pit-run graded material, which does not start to hydrate and swell as quickly as compressed bentonite pellets, and if poured slowly, falls to the bottom of the borehole without bridging. If a soil stratum is to be sealed off below the location of a piezometer, great care must be taken with the bentonite to avoid making contact against the sidewalls at the location of the sand filter by using casing. Installation of the bentonite in powdered or slurry form should not be allowed as these methods will coat the casing on the way down and possibly foul the filter below.

d. Multiple-stage piezometers. Multiple-stage piezometers (more than one piezometer in a borehole) are generally not recommended due to the possibility of vertical flow of water between sealed zones. If multiple-stage piezometers are necessary, extreme care must be taken when installing the bentonite seals and the number of stages should be limited to two.

e. Lengths of screens in embankments. Screens are normally minimal in length and situated in aquifers in order to measure the actual pore pressure. In an embankment, the magnitude of pore pressure may be less important than noticing that changes are occurring over the long-term life of a project. If these conditions exist, it may be necessary to install screens of much greater lengths, as indicators of changing conditions.

6-9. Installation Procedures for Other Instruments

Many of the same or similar questions must be answered (see paragraph 6-8*a*) when developing installation procedures for other types of instruments. Manufacturers of inclinometers and borehole extensometers normally supply good instructions for the installation of the downhole components. However, care must always be taken since variable site conditions might alter these procedures. Additional information can be found in Dunnicliff (1988).

6-10. Backfilling Boreholes

Various materials may be used to backfill a borehole. Grout, granular fills such as sand and pea gravel, and bentonite gravel may be used. Grout has the advantage that it readily fills all the void spaces. However, grout should not be used if it will bleed off into the surrounding ground, and in this situation a pregrouting step may be appropriate. Grouting guidance is available in EM 1110-2-3506 and Driscoll (1986). Grout mixes should be tested to determine appropriate ratios of water, cement, bentonite, and sand (rarely used) that will ensure good performance between the instrument and the surrounding soil or rock.

6-11. Protective Housings

Each installed instrument must be protected with a protective housing that is provided with a vented locking cap. Protective housings should be grouted into place not only to secure the cap but also to prevent surface water from flowing into the instrument. Unfortunately, instrument housings protruding above the ground are often a target for vandals. In extreme cases or in roadways, an instrument may be flush-mounted with the surface, and surrounded with a gate box similar to those used by utility companies. The drawbacks of this method are that the boxes are hard to find with a snow covering and drainage must be considered so that surface water does not flow down the instrument.

6-12. Documentation

After completion of the installation of all instruments, the following documents should be bound and placed in a report:

- Description of instruments, readout units, and automation equipment.
- Plans and sections sufficient to show instrument numbers and locations.
- Appropriate surface and subsurface stratigraphic and geotechnical data.
- Instrument calibration and maintenance procedures.
- Instrument installation procedures.
- Instrumentation and/or automation documentation from manufacturers, including calibration data and warranty information.
- Pre-installation acceptance test documents.
- Post-installation acceptance tests.
- Instrument installation reports.
- A list of suggested spare parts needed for repair or maintenance.
- Procedures for data collection and processing.
- Names, addresses, and phone numbers of maintenance/repair sources.

It is recommended that at least two copies of the documentation be prepared. One should be maintained on file at the project site. The other should be filed in the District office.