COMPLEX SUCCESS
Coping with difficult ground in Florida
Interview with Shahram Siavash, business development manager, geotechnical engineering

Geotechnical monitoring in tunnelling and underground projects provides data that helps engineers and contractors in every stage of a project. Instruments are used to characterize initial site conditions, verify design assumptions and to monitor the effects of construction. Each project presents a unique set of critical parameters, and the designer must identify those parameters and select instruments to measure them.

**Pore-water pressure**: This parameter helps establish initial site conditions; predict slope stability; design and build for lateral earth pressures and monitor the effectiveness of drainage schemes.

**Standpipe piezometers**: Sometimes referred to as an open-hydraulic piezometer or a Casagrande piezometer, it consists of a porous water-intake element connected to a riser pipe. Water enters the riser pipe through the intake element, which is normally sealed in the borehole at a specified depth. As pore-water pressure increases or decreases, the water level inside the standpipe rises or falls. Readings are usually obtained with a water level indicator, which provides a depth-to-water measurement.

**Vibrating wire piezometers**: These instruments consist of a tensioned steel wire, one end of which is anchored and the other end fixed to a diaphragm. The diaphragm deflects in response to applied pore water pressure, changing the tension in the wire and its resonant frequency. They are typically used for continuous and long-term pore pressure monitoring, specifically in fine-grained soils where the use of conventional standpipe piezometers is not recommended.

**Lateral Deformation**: Measurements of this parameter evaluate the stability of slopes; monitor deformation of laterally loaded pile; monitor the magnitude and rate of movements in rock masses; check for ground movement that may affect adjacent buildings; and determine the need and timing for corrective measures.

**Traversing probe inclinometer**: One of the most commonly used for monitoring lateral subsurface deformations. Consisting of a portable wheeled probe, graduated control cable, and a portable readout, the operator makes a survey of the borehole, taking tilt readings at intervals, from the bottom to the top. The resulting data provides a detailed profile of the casing. If ground movement occurs, subsequent surveys will reveal changes in the profile, which can be plotted to determine the magnitude, depth, direction, and rate.

**Vertical deformation**: Measurements help verify soil consolidation is proceeding as predicted; monitor heave in floor of excavation; monitor settlement due to ground loss or heave outside of excavation; monitor for settlements that may damage buildings or service connections and determine the need and timing for corrective measures. Important instruments to measure vertical deformation are: Settlement Cells (to monitor a single, subsurface point); Settlement Extensometers (to monitor large settlements in soft ground below fills); MultiPoint Rod Extensometers (provide high resolution multipoint measurements of vertical deformation) and Horizontal Inclinometers.

**An automatic data acquisition system** may be required when there is a need for real-time monitoring and automatic alarms; sensors are located at a remote site or in a location that prevents easy access; there are too many sensors for timely manual readings; or qualified technicians are not available.

**WHAT ARE THE MOST IMPORTANT PARAMETERS TO MONITOR?**

Soil and groundwater pressure at the tunnel face during EPBM tunnelling, face displacement during open SEM tunnelling, ground convergence and swelling, soil pressure at certain depths, pore pressure, horizontal ground deformations, vertical ground movements at surface or in various depths (settlement), load in anchored elements, strain in compressed or tensioned structural elements, structural deformations (buildings, utilities, bridges), construction-induced vibrations, and groundwater levels near the dewatered areas during tunnelling.

**WHAT ARE COMMON LOCATIONS FOR INSTRUMENTS?**

At tunnel face, on the perimeter of the tunnel, on the ground surface, at various depths above the tunnel, on the adjacent structures and buildings, in the launch and extraction shafts where the tunnel meets the excavation, on support of excavation elements such as tie-backs, struts, and piles, on utilities (water-mains, sewers), on existing building cracks, and adjacent to the sources of vibration.

**WHAT ARE THE FREQUENCIES OF DATA ACQUISITION?**

Frequencies vary depending on the importance of the parameter that is being monitored and the construction stage. Usually, the highest frequencies are during active tunnelling and after completion of a section, the frequencies can be reduced and continued for a defined period as a confirmatory measure. While some parameters, such as ground surface or building movements, may require at least one round of reading during the tunnelling shift, some parameters may require more frequent or even continuous monitoring using automatic data loggers or remote data acquisition systems.

**Agree or disagree?**

Let us know what your experience has taught you. Or let us know what topic should be included in future Rules of Thumb columns. editor@tunnelsandtunnelling.com