A top TIP

George Piscsalko of Pile Dynamics and Dr Klaus Meinhard of Porr Bau talk about the innovative application of Thermal Integrity Profiling (TIP) during jet grouting

Thermal Wire cable installed in completed jet-grouted column

Jet grouting is a ground-improvement technique used to increase the bearing capacity of weak, unstable or liquefiable soils. It is effective for most soil types and is useful in all climate conditions.

It is performed by first drilling to the design depth using small-diameter drilling rods and then injecting grout or lime-ash slurry into the subsoil, under pressure and with high-velocity jets. The fluids injected at high velocity cause the soil structure to break down (or erode, which is why jet grouting is said to be an erosion-based system) and mix with the slurry grout material.

Small grouting nozzles direct the grout horizontally into the soil so that as the drill rod is slowly rotated and raised, grouted soil-cement columns are formed. As the grout column expands and solidifies, the subsoil is consolidated and stabilised. Jet-grouting construction techniques include high-pressure injection of grout only, of air and grout, or of an air, water and grout combination. Each has specific qualities and is implemented depending on the application and type of soil.

"All diameter predictions correlated well with the actual measured diameters"

The process of soil improvement through jet grouting is performed without the possibility of any visual inspection throughout the entire installation process. This makes quality control quite challenging: it is difficult to know with certainty the final diameter along the length of the jet-grouted column.

The Tempjet system

Porr Bau, a Vienna contractor that is part of one of Austria's largest construction companies, the PORR Group, has developed a system for using temperature measurements in jet-grouted columns to determine their diameter: Tempjet.

Pile Dynamics, Inc. (PDI) has partnered with Porr Bau to utilise PDI's Thermal Integrity Profiler (TIP) system with Thermal Wire brand cables to measure the temperature at the centre of jet-grouted columns.

Thermal Wire cables feature a digital temperature sensor every 305mm (12in), and have been in use in quality control of drilled shafts as well as augered cast-in-place (ACIP) and continuous flight augered (CFA) piles. Thermal Wire cables are ruggedly constructed to withstand embedment in a concrete structure and can be installed either prior to casting (typically done for drilled shafts) or after casting (for ACIP/CFA piles as well as jet-grouted columns).

In the jet-grouting application, Thermal Wire cables are installed through the drill rod immediately on completion of the jet-grouted column (Figure 1). A Thermal Acquisition Port (TAP, part of the TIP system) is connected to the Thermal Wire cables shortly after their installation and temperature measurements from all sensors are collected and stored every 10 minutes throughout the grout-curing process.

The measured temperatures are then transferred from the TAP to the TIP main unit, where further analysis is performed with the Tempjet software.

The Tempjet software compares the measured temperature history with results from a numerical simulation of the thermo-chemical phenomenon of grout curing. The temperature history is a function of the jet-grout column's diameter, of the cement content of the grout mix, and of the thermal and chemical properties of the grout and surrounding soil.

Given known soil and grout properties, Tempjet simulates a temperature profile as a function of an assumed jet column shape and cement content.

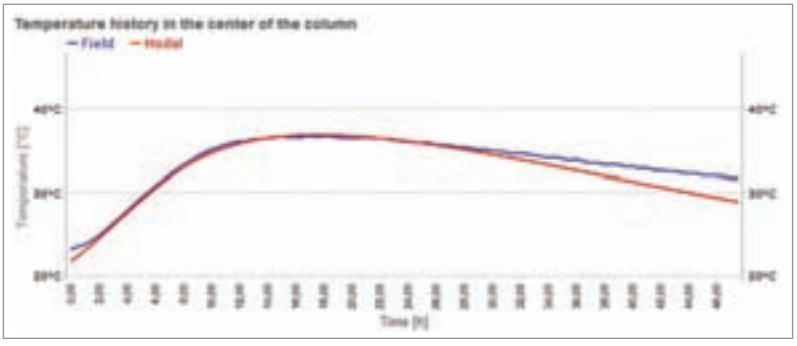
These two variables, column diameter (shape) and cement content, have distinctly different effects on the shape of the measured temperature history: the cement content affects the heating period at the beginning of the hydration (curing) process, while the jet-grout column's diameter mainly influences the decrease of the temperature during the cooling period.

For each combination of shape and cement content, Tempjet simulates a unique temperature history and this is compared with the one measured in the field. The software then refines its cement content and column shape assumptions until differences in the measured and simulated temperature histories are sufficiently small, at which point the program outputs the predicted diameter and cement content.

Success in the field

The Tempjet method of identifying the diameter and cement content of jet-grouted columns has been applied to more than 300 columns at various construction sites throughout Europe.

The jet-grouted columns at each site were installed using the local standard practice and were not altered for these tests. The diameters for many of these tests were verified with excavation or alternative methods. All diameter predictions correlated well with the actual measured diameters. ♦



Tempjet software output: measured temperature histories (temperature versus time) in a jet-grouted column. Each line indicates the temperature history measured by one sensor

For more information: www.tempjet.com/about_en.ft. A thorough discussion of the software is found in Meinhard, K, Lackner, R and Adam, D 'Temperature measurements to determine the diameter of jet-grouted columns', Proceedings, 11th International Conference on Geotechnical Challenges in Urban Regeneration, May 26-28, 2010, London, UK. At the time of publication of that paper the application described in this article was still in development; therefore field temperature measurements were obtained by a different process.