Reliable Post Grouting Techniques to Improve Shaft End-Bearing

Design methods and QA/QC procedures to improve the reliability of post grouting techniques

WHAT IS THE NEED?

Post-grouting of drilled shafts has been shown to increase the capacity and stiffness of drilled shafts, resulting in substantial cost savings. The technology has failed to gain widespread acceptance in the U.S., however, due to questions of reliability. Current design procedures are empirically based on a small number of projects. The relative contribution of various improvement mechanisms is unknown.

Needed is a theoretical framework from which to assess potential improvement mechanisms. This framework would also include use of various measurements that are either routinely collected during post grouting operations or could be in the future. These measurements could then be used to verify performance of post-grouted drilled shafts (PGDS) and improve reliability. Ultimately, guidance on PGDS construction practice and the use of various instrumentation methods is required.

WHAT ARE WE DOING?

A research project was initiated that includes the following components:

• Developing LRFD resistance factors for PGDS based on field tests reported in literature.
• Large-scale laboratory testing to better quantify the stiffening of shaft tip response resulting from post grouting.
• Developing a computational tool for predicting PGDS performance.
• Performing a field-testing program consisting of the construction of 13 drilled shafts. Multiple measurements during the post grouting process will be evaluated in terms of their effectiveness in improving reliability. Four of the shafts will be load tested before and after post grouting.
Preparing a guidance document that prescribes the recommended design process including methods for PGDS capacity prediction, construction measurements and interpretation, and acceptance criteria.

Taking advantage of industry donations of materials and services, the project was amended to include evaluation of different shaft integrity testing techniques including thermal profiling methods. Four shafts were constructed with intentional defects that will allow the effectiveness of different methods to be directly compared. Several devices for evaluation of bottom of shaft cleanliness and dimensional profiling will also be compared.

**WHAT IS OUR GOAL?**

The goal of this research is to develop design and construction guidance of PGDS, including detailed QA/QC procedures that include use of in shaft instrumentation. Guidance will include detailed recommendations on use of instrumentation, interpretation of results, and acceptance criteria. Design guidance will also include LRFD resistance factors for PGDS. Project objectives were extended to include evaluation of new thermal profiling techniques for assessing shaft integrity.

**WHAT IS THE BENEFIT?**

Post grouting of drilled shafts will allow foundation designers to more fully utilize end-bearing in their shaft design. When drilled shaft construction requires use of drilling fluid to stabilize the hole, it is common for end-bearing to be completely ignored due to concerns about poor shaft quality near the shaft tip. Even when shafts are constructed in dry holes, the engineer must account for several inches of displacement to occur before end-bearing is fully mobilized. Post-grouting shafts will mitigate quality concerns near the shaft tip and will mobilize end-bearing resistance with less deflection. Since end-bearing is often a large component of total shaft resistance, including it in drilled shaft design will allow for shorter, less expensive foundations.

Drilled shafts often incur defects during construction. These defects are usually caused by insufficiently cleaned hole bottoms, sloughing soil during concrete placement, or allowing concrete to fall through the drilling slurry. In order to identify possible defects, shafts are constructed with multiple inspection pipes. After construction, Caltrans technicians travel to the site and perform one or two types of testing, gamma–gamma logging, using a Cesium-137 source, or cross-hole sonic testing. In recent years a new method, thermal integrity profiling (TIP), has gained wider adoption. Using concrete hydration as a heat source, multiple strands of temperature sensors allow the identification of cool spots, suggesting a possible defect. The advantage of TIP is that the temperature data collection can be performed by construction personnel, saving Caltrans the time and expense of having technicians travel to the job site. The comparative testing performed in this project will provide Caltrans the critical information needed to determine what role, if any, TIP should play in Caltrans shaft inspection procedures.

**WHAT IS THE PROGRESS TO DATE?**

Thirteen drilled shafts were constructed at a test-site 20-miles north of Sacramento during December 2018, and January 2019. Thermal profiling measurements were taken in each shaft along with gamma-gamma logging and cross-hole sonic testing. In February 2019, twelve shafts were pressure grouted at their tip using one of three grouting systems: sleeve-port, flat jack, or RIM Cell. In late February four of the shafts were static load-tested.
IMAGES

Image 1: Mike Muchard (Applied Foundation Testing) 2015 FHWA PGDS workshop presentation, Oakland CA.

Image 2: RIM Cell test shaft

Image 3: Sleeve-port system

Image 4: TIP wires for thermal measurement

Image 5: Drilled shaft construction

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