A Tool for Continuous On-Site Monitoring During Grouting of Post-Tensioning Tendons

by Dr. Andrea J. Schokker, University of Minnesota Duluth, and Jacob A. Bray, New Hudson Facades

This article describes the innovative use of an in-line density meter, a tool common to the chemical and food industries, to provide continuous information of the density of the grout during pumping. This tool can provide a significant indicator of post-tensioning (PT) grout quality as it enters and exits the ducts.

Background

For decades, PT grout has been successfully used to provide a highly alkaline and dense barrier for corrosion protection of PT strand in tendons while also bonding the tendons with the surrounding structure (in the case of internal tendons). Significant advancements have been made in material quality and the training of installers; however, notable quality issues, primarily related to bleed and soft grout, continue to be of concern. Overwatering of grout is the most significant factor related to poor field performance of PT grout. The prepackaged materials commonly used for grouting of PT tendons are tested within specific water ranges to achieve the desired performance. Therefore, it is critical to ensure that the grout placed in the tendon is within the same water range as the grout that was prequalified through testing. Overwatering can be caused by water in the tendons, water in the grouting line, or the addition of too much water to the mixture. Too much water may sometimes be added in an effort to have a less-dense mixture that is easier to pump, or an operator might make a measurement error. No matter the cause, the consequence of overwatering can be a compromised corrosion protective system.

According to the *Specification for Grouting of Post-Tensioned Structures*,[1] density measurements of the grout must be taken with the mud balance device at the inlet and the outlet of the tendon one time per day.[2] The mud balance is a straightforward test, but it has drawbacks:

- A discrete sample may not be representative of the rest of the grout, particularly if water is being picked up in the lines or tendon.
- If water is added after the initial mud balance testing, the change in density will not be recorded.
- There is potential for operator error, particularly with grouts that gel quickly and plug the weep hole in the mud balance device.

Given these limitations of the mud balance test, the use of an in-line meter to continuously measure density could significantly improve the monitoring of grout quality. The meter is used commonly in industrial settings and is specified for slurry materials. It doesn't need to be calibrated, but it can be checked at any time by running water through it because water has a known density.

Test Plan

As described in detail in the *PTI Journal*,[3] a study sponsored by the Post-Tensioning Institute was conducted to evaluate the feasibility of using a commercially available in-line meter to monitor PT grouting. A schematic of the test setup is shown in **Fig. 1**. For this study, the Krohne OPTIMASS 1400C S25 Coriolis flow meter was selected. The density meter includes a digital readout as well as a data acquisition system that stores density and temperature measurements on a micro SD card for later analysis.

The test program included a comparison of data from the in-line meter and the current density measurement tool, the mud balance. Although data variation is expected, it is important to have confidence that the in-line meter values are consistent with the range of values obtained from existing practice. A wide range of grout densities was tested to provide a spread of data for comparison. Testing used two prepackaged grouts. The initial water contents were at the manufacturer's recommended value; then water was added in increments up to a value that was 65% over the maximum

Figure 1. In-line Coriolis-based flow meter measures grout density and temperature between grout plant and tendon inlet. Figure: Andrea J. Schokker, reprinted from *PTI Journal* with permission.

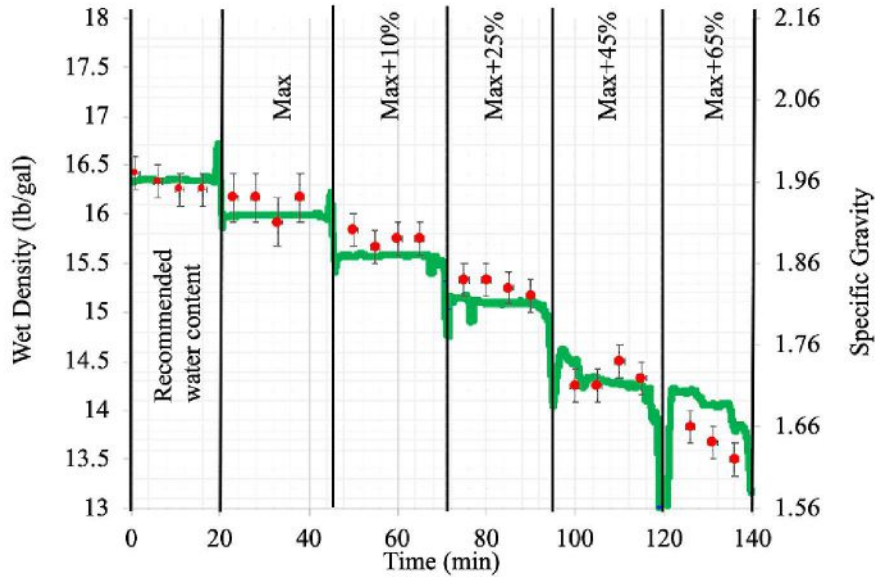

Figure 2. Comparison of continuous in-line Coriolis-based flow meter and individual mud balance density results for test with a single grout. In-line density meter data are in green, and mud balance data are in red. Figure: Andrea J. Schokker, adapted from *PTI Journal* with permission.

given by the manufacturer. Overwatering was done during testing to verify the performance of the device. However, it is important to note that, when used in the field, grouts should *never* have a water content above the maximum value stated by the manufacturer. Overwatered grouts can lead to significant bleed issues.

Grout testing involved mixing a batch in a commercial high-shear grout plant at the manufacturer's recommended water content, transferring the grout to the holding/agitator tank, and pumping it through a hose connected to the meter and then back into the holding tank. The grout was continuously recirculated for approximately 25 minutes. Mud balance tests were performed at 5-minute intervals during recirculation of the grout. After 25 minutes, additional water was added to the grout with a short remixing time. Test measurements were repeated for each water level.

Results and Discussion

Raw data from the in-line meter is easily exported to spreadsheet software for analysis and graphing. **Figure 2** shows plots of the in-line meter data (data points are so close together that they appear as the green line in the plot) as well as the results from the mud balance test. Mud balance data are shown in red with a bar indicating the amount of data spread between all readings taken at a given water content. The figure shows correlation between the mud balance test results and the in-line density meter readings, with distinct changes in density as water is added. The short downward spike of the in-line meter data between each water content change is due to a brief shutoff of the pump as the grout was transferred to the mixer and then back to the holding tank. As is shown in the figure, density changes are relatively small for significant changes in water content. The mud balance test has accuracy limitations in these ranges, and these limitations can be compounded by operator error or by acquiring a sample that is not representative of the batch. The in-line density meter provides accurate results and continuous monitoring of the grout as it is pumped into the tendon. **Figure 3** shows the temperature readings of the same grout mixture during pumping. Temperature data are captured by the in-line meter at the same time as each density reading.

Summary and Recommendations

In this test, the in-line density meter (based on the Coriolis principle) showed clear potential for use in the field pumping of PT grout. Both the density and temperature data provide an electronic record of grouting from start to finish. Issues related to grout consistency (poor mixing and clumping), water trapped in the hose or pump piping, and other inconsistencies can be captured in data from the in-line meter. The use of an additional meter at the outlet would provide indications of water or debris that might be trapped in the tendon duct.

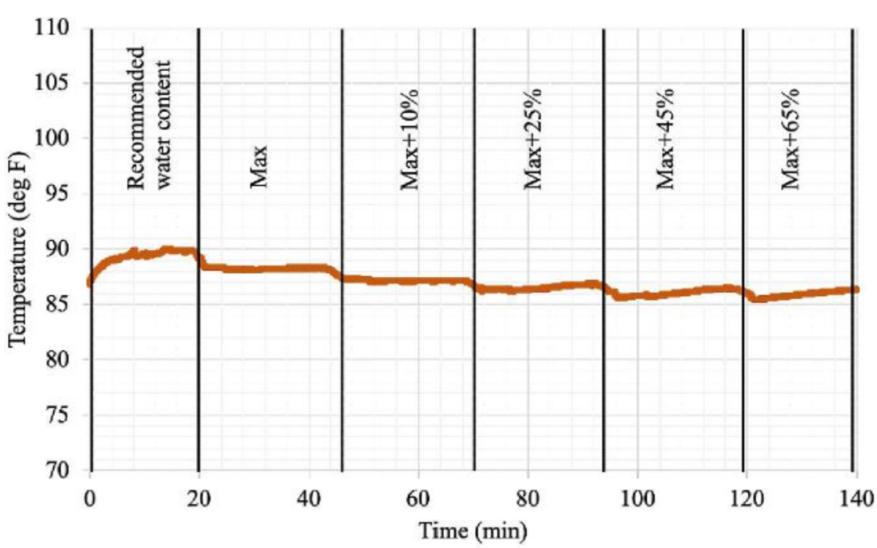

Figure 3. Temperature readings from in-line Coriolis-based flow meter corresponding to grout density results shown in Fig. 2. Figure: Andrea J. Schokker, adapted from *PTI Journal* with permission.

References

1. Post-Tensioning Institute (PTI). 2012. *Specification for Grouting of Post-Tensioned Structures (PTI M55.1-12) with Addendum #1 (June 2013)*, 3rd ed. Farmington Hills, MI: PTI.
2. American Petroleum Institute (API). 2015. *ANSI/API Specification 10A: Specification for Cements and Material for Well Cementing*. Washington, DC: API.
3. Bray, J.A., and A.J. Schokker. 2019. "In-Line Monitoring of Grout Density During Pumping." *PTI Journal* 15(1): 5-9.

Dr. Andrea J.Schokker is a professor of civil engineering at the University of Minnesota Duluth. Jacob A. Bray is an engineer with New Hudson Facades in Mendota Heights, Minn.