TRANSMISSION & DISTRIBUTION WORLD

Thermal Grouts Go the Distance

New formulations enable contractor to fill the annulus between 30-inch casing and internal conduits feeding downtown Austin.

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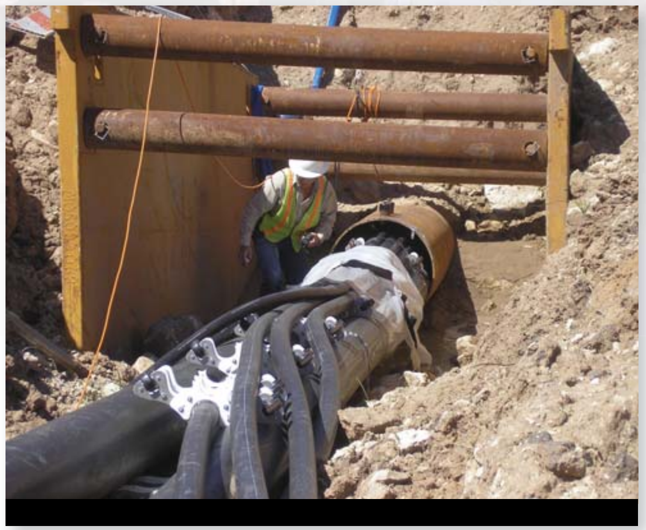
MOST UTILITIES USE HORIZONTAL BORING OR PIPE JACKING TO PLACE LARGE-DIAMETER STEEL OR POLYETHYLENE CASINGS UNDER ROADWAYS. Utility services can then be run through the various sizes of conduits placed within the casings. But when electrical cables are placed within these conduits, challenges can escalate. Because heat is generated within underground cables, the annulus between the casing and the internal ducts must be filled with a thermally conducting grout to help dissipate the heat. And these grouts must not only have superior thermal properties, but they also must have proper flow characteristics and heat of hydration characteristics. The challenges are compounded as pumping lengths are increased.



Superintendent Chris Tobias performs a final inspection in preparation for bulkheading the casing.

A SPECIAL CHALLENGE

Something special happened last summer that has resulted in grouting technologies taking a major leap forward. Austin Energy and the City of Austin, Texas, U.S., were upgrading city services in the downtown area and hired Jacobs Civil (Dallas, Texas) to come up with an engineering solution to run feeder cables and sewer mains to the Davenport suburb of Austin. Horizontal boring techniques were required to traverse a 4000-ft (1220-m) segment of the route. This was to be accomplished with two separate 2000-ft (610-m) bores. One leg of the bore was to traverse under the Austin Country Club, with the second leg of the bore going under Lake Austin and alongside Highway 360.

The project designer had anticipated filling the annulus between a 30-inch (76-cm) steel casing and the 14 internal conduits and mains with grout. The casing contained:

- Two 12-inch (30-cm) wastewater mains

At the east end of the project and looking west across the Austin Country Club, 30-inch casing runs 2000 ft underground to the left side of the bridge, and from there, 2000 ft under Lake Austin and behind the hill on the right side of the bridge. Maximum depth of casing is about 60 ft.

GROUT FORMULATIONS

Grout installers prefer not to use any type of aggregate (even fine sand) in grouts because of the possibility of segregation and the potential for higher pumping pressures. To address these concerns, a ground silica flour (93% passing the No. 200 sieve) was used in the mix for the Austin Energy project.

Component	lb/cu yd	kg/cu m
Cement	850 to 1445	504 to 858
Fly ash	0 to 685	0 to 406
Silica flour	650 to 825	386 to 490
Water	800 to 950	475 to 564
Resulting slurry density	2970 to 3240	1764 to 1925

The typical component materials of the grout consisted of silica flour Type 1 Portland cement, Class F fly ash (not used in the final mix design) and a super plasticizer (10-Esl Sika Admixtures). Several trial mixes were prepared using various proportions of these components to yield homogenous slurries. The slurries were mixed thoroughly for about 10 minutes using a laboratory-type mixer.

The fluidity of each mix was measured in accordance with the ASTM C 939 "Flow Cone Method." For each mix, a set of samples was prepared in 3-inch by 6-inch (8-cm by 15-cm) test molds to determine the fluid density and to measure the thermal resistivity.

Various mixes were considered in the following ranges using locally available materials. Depending on the mix, proportions of the materials ranged as listed in the table.

The flow rates of grouts are determined using a flow cone containing 1725 ml of material flowing through a 0.5-inch (1.27-cm) opening as specified in ASTM C 939. The faster the cone empties, the quicker the grout will flow. Flow rates of 25 sec to 40 sec were achieved, and the final selected mix had one of the faster flow rates.

The resulting mixes had effective thermal resistivities that varied from 65 cm-°C/W to 75 cm-°C/W, which more than met the thermal requirements of the grout. Super plasticizers, in varying amounts, were used to aid in the flow of the grouts.

- Six 3-inch (8-cm) conduits containing 12.4-kV distribution circuits
- Two 3-inch and four 2-inch (5-cm) conduits for grout.

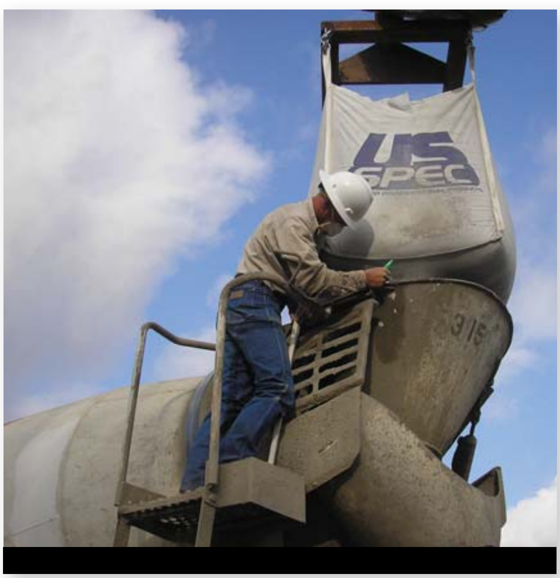
Pumping the grout proved to be one of the most difficult aspects of the job. The spacers (typically in 5-ft [1.5-m] intervals) used to keep conduits in the desired configuration have small openings and thus are highly resistant to grout being pumped.

The installation project required approximately 180 cu yd (138 cu m) of specialty thermal grout be pumped at distances up to 1000 ft (305 m) in each of the pipelines.

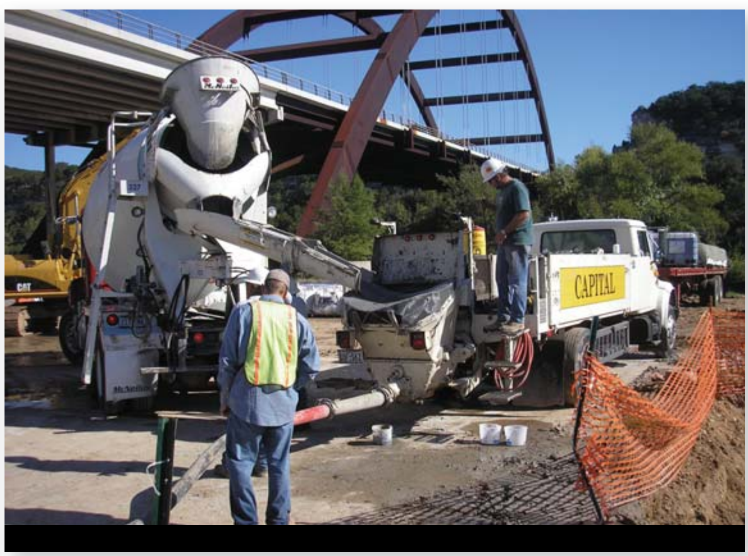
ADVANCED GROUTING TECHNOLOGIES.

Grouting has evolved into a sophisticated element of construction. Grout technicians are often required to have professional training and, under some circumstances, certifications. The testing of grouts is a trial-and-error event. Just because a cement is labeled Type I, II or III does not guarantee its behavior will be the same when added to chemical admixtures or even aggregate. Each type of cement is a blend of chemicals, and the variation between cements can be substantial. Grouting is part science, part art. Still, accurate testing, planning and execution of grouting should follow a standard procedure.

Mears/HDD, LLC (Rosebush, Michigan, U.S.) served as the general contractor for this project and installed the 2000-ft lengths of 30-inch steel casing. Conduits were installed with locating spacers, supplied by Underground Devices (Northbrook, Illinois, U.S.), every 5 ft. The conduits and spacers were



Chris Tobias empties a 2000-lb "supersack" of blended dry grout materials into a ready-mix truck.



The ground-zero staging area for mixing grout and for initial pumping into both casings. Pumping also was performed at the highway end of one of the casings and at the Austin Country Club.

located and tested within the casings prior to placing the grout.

GROUT PUMPING

A grouting subcontractor who had committed to tackling the project during the prebid phase backed out after the project had been awarded. Inquiries to local contractors to take on the grout-pumping phase of the project were unsuccessful. Their responses were mostly: "This cannot be done," "I'll pass" or "Call someone else." When the search went national, Constellation Group, LLC of Baltimore, Maryland, U.S. (not affiliated with Constellation Energy) was found and ultimately selected for the job.

Section of pipeline (note 3-inch grout lines).

Bulkhead is shown and grouting is completed.

GROUT FORMULATIONS

Geotherm Inc. (Chandler, Arizona, U.S.), a firm that specializes in developing thermal backfills for underground applications, had already been engaged to determine the thermal characteristics of subsurface soil and to design the specialty grout that would have a thermal resistivity of 80 cm-°C/W or lower. Geotherm had considered several formulations and settled on several possible formulations to meet the following parameters:

- Low thermal resistivity, with rho less than 80 cm-°C/W
- Low viscosity, flow rate or time of efflux of less than 40 sec in a standard-flow cone, so it would flow around all the nooks and crannies and spacers at low pumping pressures
- Low heat of hydration, as high cure temperatures could soften high-density polyethylene (HDPE) conduits, resulting in deformation or collapse
- Long set times, because it would take all day to mix and place 50 cu yd (38 cu m) of grout
- Homogenous with no mix segregation
- Low shrinkage, to ensure complete filling of the annulus with no residual air pockets.

Constellation Group selected the mix design that was most suitable for pumping. Water-reducing admixtures from Sika Corp. (Lyndhurst, New Jersey, U.S.), as well as a stabilizer to improve flow and control bleed, separation and set time, were tested. Quantities were adjusted until desired flow properties (at 26 sec, considerably lower than the initial specification of 40 sec, using a ASTM C 939 flow cone) were obtained.

At this point, it was not known whether the thermal characteristics had been altered by the addition of the admixtures and stabilizer. Samples were sent to Geotherm facilities for thermal testing. Results came back showing that the desired resistivities of less than 80 cm-°C/W had been maintained.

Therefore, Constellation Group was ready to pump. Only one question remained: Would Constellation Group be able to pump this grout 1000 ft?

Austin Energy's project specifications required that a full-scale mock-up be performed. The crew installed a 50-ft (15-m)-long section of 30-inch casing (with conduits and spacers placed inside). Then, 1000 ft of 3-inch HDPE SDR11 grout pipe was laid out on the ground.

With perhaps 35 to 40 individuals witnessing, the crew mixed 7 cu yd (5 cu m) of grout on-site. Initial on-site testing indicated the grout was a little too dry (which would result in higher pumping pressures), so 10 gallons (45 liters) of water were added. Further tests showed the grout to have the proper consistency. Mixing on-site was required because of the distance from the nearest ready-mix plant and the need for the specialized mix design.

THERMAL GROUT CONSIDERATIONS

All specialized grouts must take into consideration many factors for a practical mix design (rheology). For thermal grouts, the following are just some needed characteristics for a successful project:

- *Air entraining agent*. Although the use of an air-entraining agent lowers the slurry density significantly and improves pumpability, it increases the thermal resistivity significantly. Thus, it should not be used in any thermal grout.
- *Total volume*. The actual volume of slurry pumped must be verified with the calculated volume to ensure the casing is filled completely and void free.
- *Bleed water and shrinkage*. The grout contains a fairly high quantity of water and thus some shrinkage and bleed water will be noticed. After about 24 hours, additional grout should be pumped to fill in the shrinkage volume. This is noticeable at the top ends of the casing.
- *Pumping pressure*. This is a complex function of the slurry density, distance to be pumped, total wall friction, restrictions such as spacers and rate of pumping among other factors. A limiting factor will be the maximum allowable pressure the conduits and other components in the casing can withstand before deformation or crushing. The contractor should keep records of the rate of pumping, pumping pressures and the total volume of the grout installed.
- *Hydrostatic pressure*. Slurry density is typically in the neighborhood of 118 pcf (1800 kg/cu m). This means that each foot of slurry height will develop a pressure of about 0.8 psi (5.5 kPa). If the lowest point of the casing is, say, about 100 ft (30 m) below grade (below the open end of the casing), the pressure at this lowest point will be about 80 psi (550 kPa). This pressure, if higher than the safe operating pressure of the conduits, will result in deformation or cracking of the conduits if they are not filled with water, and sealed and pressurized.
- *Capping*. Once the annular space is completely filled with the slurry, it is suggested that the open ends of the casing be capped (plugged) with high-strength, nonshrink concrete. This will prevent any moisture loss, and as long as the slurry remains at the set moisture content in hardened state, its thermal resistivity will not change.
- *Heat of hydration*. The use of fly ash and super plasticizer helps retard the setting time and lower the heat of hydration. Some slurries contain fairly high quantities of cement, so heat of hydration may be a concern. If not addressed, the temperature rise may soften and deform or collapse polyvinyl chloride or high-density polyethylene conduits. The contractor may consider filling the conduits completely with water and even pressurizing them to mitigate this problem. In the worst case, water can be circulated at a slow rate for a period of about 48 hours to ensure that the ambient temperature rise is kept well within the limits of the softening of conduits.

The pumping of grout commenced. The mixture was successfully pumped through the 1000 ft of 3-inch grout pipe and then through the 50-ft trial length of pipeline without exceeding allowable pressure limits. Subsequent tests showed that the grout exiting the system had maintained a thermal resistivity under 80 cm-°C/W, indicating that segregation of the thermal grout had not occurred.

A SUCCESSFUL FILL

Calculations indicated that it would take 180 cu yd to fill each of the two pipelines now in place. The pours went smoothly as planned. Each batch of grout, usually ranging from 6 cu yd (5 cu m) to 7 cu yd, was tested in the field for flow characteristics (using a standard ASTM C 939 cone), for specific gravity (using a mud balance) and for initial temperature (using a digital thermometer). Each piece of test equipment had been calibrated prior to use. It should be noted that some grout batches had to be adjusted because they were found to be slightly out of tolerance when first mixed. Field conditions vary and personnel mistakes can happen, which is why there should be continuous monitoring. Records were kept of each batch. Independent inspectors made regular unannounced visits to take samples as well.

So, to answer the question, "Can long-distance thermal grouting be done?" The answer is an emphatic yes! The City of Austin now has another feed supplying electricity into the city. And, tests and samples indicate that all the grout met the specifications.

With proper design, planning and execution, and based on the experience gained, this type of grouting can be used at greater distances, giving our industry another option to provide longer underground power circuits. TDW

Guy Dickes is a repair and grouting specialist with the Constellation Group, LLC. He has worked on dams, in nuclear power plants and in refineries. He also has designed equipment for bridge erection and construction instrumentation. Dickes is a qualified specialist in post-tensioned bridge grouting and enjoys solving the "can't-be-done" problems and helping contractors self-perform difficult tasks.
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