The Field Inspection and Documentation of Micropile Works

Allen W. Cadden[1], Donald A. Bruce[2], Jeffrey J. Bean[3]

Abstract

From the time the basic design is complete on any project, the focus must be on finding the most appropriate contractor with adequate resources, and making arrangements to ensure that every pile is installed correctly and in accordance with the design intent. Drawing on experiences from numerous micropile projects, including some of the largest completed in the country, this paper describes the important personnel and documentation systems implemented by owners, designers, and contractors along with some specific tips for large-scale micropile projects.

1. BASIC PRINCIPLES

The successful implementation of any innovative tool takes a combination of good technology and skilled personnel. Staffing a project with the appropriate people from the beginning is critical. This need applies to both the contractor and the engineer. The contractor is typically concerned with production and technical challenges. This means that staffing the project with capable drilling, grouting, engineering, management, and accounting skills is paramount. Since every site is different to some extent, a clear understanding of the likely conditions will allow the contractor to select personnel who have operated in similar conditions. Without having the correct people, the project begins at a disadvantage. The challenges of difficult drilling conditions often result in low production early in projects, and stress on the personnel because of lack of success. These difficulties can lead to poor operational decisions and contractual tensions.

The engineer/designer has similar issues. Usually the experienced senior designer is not available to be on site full time. The inspection personnel must therefore be fully familiar with the construction methods, equipment, geology, and the goals of the design. Often the learning process must be repeated on each new site. It is therefore critical that changing of personnel on site be kept to a minimum since both the knowledge gained of site conditions and installation procedures must be maintained. The changing of people during a project can result in miscommunications and failure to fully or properly implement all tasks.

A typical micropile project may feature one or two drilling machines installing three to four piles per day for two to three months. Such a job may consist of one hundred to three hundred piles an average of fifty feet deep, making the total drilling footage five thousand to fifteen thousand feet. Most engineers and

[1] Principal, Schnabel Engineering, 510 E. Gay Street, West Chester, PA 19380, U.S.A.; telephone 610-696-6066; fax 610-696-7771; email acadden@schnabel-eng.com
[2] President, Geosystems, L.P., P.O. Box 237, Venetia, PA 15367, U.S.A.; telephone 724-942-0570; fax 724-942-1911;
email dabruce@geosystemsbruce.com
[3] General Manager, Layne Christensen Company, 22537 Colemans Mill Road, Ruther Glen, VA 22546, U.S.A.; telephone 804-448-8060; fax 804-448-1771; email jjbean@laynechristensen.com

contractors have been associated with these types of projects wherein the contractor places a seasoned superintendent and possibly an engineer on the site and the engineer may provide an inspector for each machine. The engineer will also record data for drilling and grouting, and verify the contractor's compliance with the specification and the method statement. These projects maintain work schedules of single-shifts for eight to twelve hours per day over five to six days per week. The maintenance of six to eight drill logs per day is by no means an inordinate task. There are frequently problems associated with unanticipated buried obstructions or a pile slightly out of tolerance, but the contractor will move to another footing pending redesign of the former, and contractual resolution of the latter.

Figure 1. Intense micropile construction site, with multiple rigs working 24 hours per day

The dynamics of the project change however when the task is to install one thousand five hundred piles or sixty-five thousand feet in eight weeks as was experienced by the authors in a large project recently. Comparing this actual project to the "typical" smaller project outlined above, two machines working a single-shift became five machines working around the clock six days per week (Figure 1). Three to four piles per day became thirty to forty, and the average daily production exceeded two thousand feet. The contractor's on-site personnel increased from eight or ten people to over fifty, and the engineering oversight increased from two to over ten people.

The same process for setting up the work is employed for both large and small projects, but obviously the number of people involved increases dramatically as does the required level of focus on details. The owner, designer, and contractor must realize this at the onset. This needs to be fully described in the proposal phase and normally is, as the owner wants it clearly demonstrated that the successful offeror has the adequate manpower to handle the work. Often, however, the level of field support from the designer is not so clearly defined until the start of construction, and this can lead to difficulties in staffing and training the inspection personnel on short notice.

To coordinate this for all parties, the first step is to define an organizational chart (Figure 2) clearly indicating personnel, job function, and chain of command. This should be developed during design or at the latest during the construction proposal development so that all parties recognize the level of effort that is expected of them. Résumés for specialty subcontractor individuals should be submitted with their proposal indicating their ability to support the organizational chart. Résumés from key management personnel to craft labor should be requested: operators who run the drills, grouting equipment, and load tests are integral to the project success.

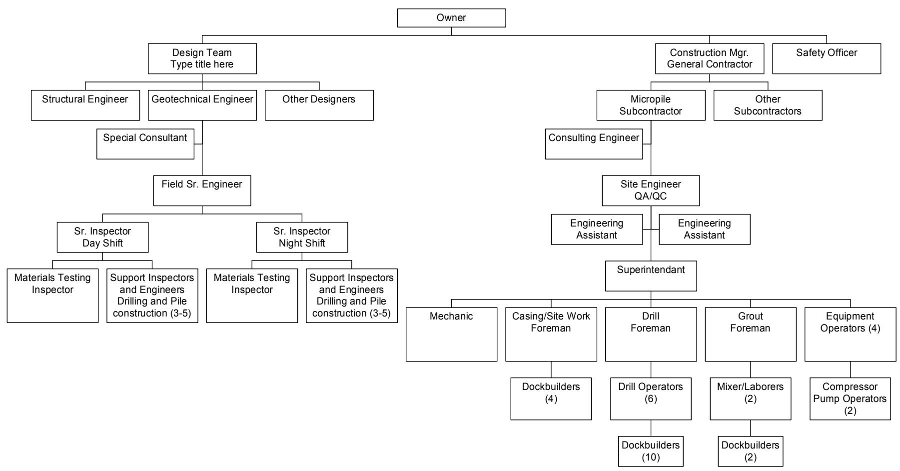

Figure 2. Typical project organization chart for a major project.

In summary, the successful and high quality implementation of a micropile project begins in the field with the selection of properly trained and experienced personnel, and with a clear, logical, and functional organization. This applies equally to the owner's representatives and inspection staff as to the contractor's personnel.

2. THE DUTIES AND RESPONSIBILITIES OF THE CONTRACTOR

2.1 Functions and Duties of the Individuals

On any project, the precise duties and responsibilities of the respective parties must be clearly identified. The following discussion provides a generic view, applicable to a major, fast track project.

The personnel organization chart is the baseline for the project, although it may not be very specific regarding the individual responsibilities of the functions and positions. The following is an outline of the roles envisioned for each of the contractor's personnel:

- Project Manager: has complete responsibility for project and often becomes full-time site manager, and can negotiate with the owner's or construction manager's representative with respect to all aspects of the job. On a very large project, this person probably has senior corporate responsibilities.

- Engineering Design: personnel supporting the project from the contractor's home office or may be from a subconsultant. They will make site visits depending on the level of engineering or design required by the contractor, or the frequency of significant changes.
- Safety Officer: is responsible for contractor's overall compliance with safety procedures. This individual provides on-site support as required. The Safety Officer has authority independent of the Project Manager. He may not be resident.

  Site Engineer: provides project management with operational and technical support; directs QA/QC efforts and sets up testing procedures and schedules; and aids in directing engineering assistants with regard to data collection and entry into spreadsheets and logs.
- Engineering Assistants: support QA/QC efforts. They become the clearinghouse for all contractor-generated data on a daily basis. These data include those from testing, drillers' reports, grouting reports, and surveys. They will interface with inspection personnel in reviewing and preparing as-built data for submission to the owner. They will coordinate survey and layout information and develop as-built drawings.
- Superintendent: directs the work force and ensures quality compliance with specifications; coordinates daily work activities with construction manager and other site contractors; submits daily reports which act as, or supplement, the job diary and contain a description of the day's completed work along with the associated equipment, manpower, and materials consumptions; and inspect material shipments for quality compliance upon delivery.
- Drilling/Grouting/Site Foreman: take direction from the superintendent and assist in completing the daily reports by collecting information from the operators. Their function is to expedite and facilitate the completion of the work.
- Drill Operators and Grout Batch Plant Operators: are the main equipment operators and the heart and soul of the construction operation. After the proposal, submittals, and work plans are all approved, the operators will determine how safely and with what speed and quality the finished product is actually delivered. Equipment operators will provide the logs for the holes to the rig inspector to submit with their reports. Experienced operators are required to maximize production in difficult drilling environments.

The recent major project personnel for the contractor all had prior large job experience and were not new to detailed recordkeeping on construction-oriented projects of this nature. On-the-job training of personnel with so many piles to install was not an option. Where such staffing is not feasible, it is imperative that the management and several of the key field supervisory personnel have similar experience and will make time to train each of the remaining personnel on the intricacies of data management on a large project.

2.2 Outside Review and Work Plan

Often the contractor will employ the services of an independent consultant even if the pile design responsibility is the owner's responsibility. This additional peer review is an additional set of eyes for complicated projects. The consultant will review the contractor's work plan, witness test pile installations, actual testing and conduct periodic observation of production work. This independent review will help bridge the gap between the contractor and the owner's technical design and oversight, thus aiding the overall smooth running of the project.

Where the project is for a private entity, there may be some allowance for submittal and document review to begin prior to award, as a part of the best value evaluation by the owner, rather than basing the selection solely on low bid. To complete this, the contractor will submit with his bid a detailed work plan. The work plan is specific as to the types and sourcing of materials and equipment planned for the work. An outline of the proposed installation techniques for drilling and grouting the piles is included along with a man-hour loaded schedule for the project's duration. Furthermore, issues such as spoil management, QA/QC measures, including pile testing procedures and sequence, grout testing and monitoring, material certifications and project recordkeeping should be included in the submittal. All of this information coupled possibly with a detailed personal interview before award affords the owner - and engineer - an opportunity to thoroughly review of the contractor's proposed scope of work and commercial conditions.

2.3 Data Management

2.3.1 Survey and Layout

The contractor may be obliged to employ a licensed surveyor to assist in making sure the piles are correctly located. The surveyor relies on benchmarks provided by the owner to establish control. Each pile is numbered sequentially and a base map is produced. This greatly facilitates pile identification in the field.

A separate spreadsheet is maintained with all of the piles listed by reference number along with their corresponding North and East coordinates, cutoff elevation, and location by building column line references. During the project, pile locations may be changed due to redesign, and the base map must be modified accordingly and updated. The details that may be contained in a management table are shown in Table 1.

Table 1. Information typically included in a pile "management table."

PLANNED CONSTRUCTION	AS-BUILT
Pile Number Location Northing Location Easting Capacity (Working and Ultimate)	Location Northing Location Easting Offset from design location Drilled length Length of soil

PLANNED CONSTRUCTION	AS-BUILT
Planned Length Design Bond Length Pile Reinforcing Details Pile Top Detail	Length of rock Redrill length Bond length Reinforcing installed Grout volume placed Regrouting volume

Pile layout in the field on large and congested sites can be accomplished primarily with GPS. This works well when direct line of sight is not always available due to the number of drills and other construction equipment. Wood stakes with fluorescent orange flags and the pile number written on it are first used to stake locations; however, as the site becomes increasingly trafficked stakes are lost. Metal spikes driven flush into the crushed stone working surface with flagging was used effectively on this recent project.

A different surveyor can be employed by the contractor to provide as-built pile coordinates for each completed pile. These pile locations, along with final cutoff elevation for the casing and bar should be determined within forty-eight hours after a pile is completed. The contractor can then enter this asbuilt data into the spreadsheet containing the design pile coordinates and the offset distance can be calculated. Typically these data are then emailed to the construction manager for submission to the structural engineer for review, and evaluation of whether the actual as-built pile locations are satisfactory. The entire process from obtaining as-built data to the final review by the structural engineer may take about two days. Such quick turnaround of data is imperative when pile caps are to be formed and poured immediately behind pile drilling.

It is preferable to use two independent groups of surveyors for two reasons. One is for quality control purposes as the as-built surveyor is independent of the layout. The second is simply that the workload can be too much for one company to handle: a single company may not possess the resources to handle all of the work on a large, fast-moving project.

2.3.2 Pile Installation Data

The specifications, contractor's method statement submittal, and test program are typically merged together to form a baseline for subsequent production pile installation. Grout quality and consistency is typically indicated by specific gravity testing (when fluid, prior to placement) and by cubes, for later strength testing. A batch plant set on electronic load cells accurately measures cement and water by weight for every batch of cement mixed. Grout testing may be performed by personnel from an independent local laboratory working under the direction of the design engineer, or can be conducted by the contractor himself.

Data collection at the pile location becomes a collaborative effort between the contractor, engineer, and independent materials testing laboratory. A dedicated inspector on each drill can accurately record the work and collect geotechnical data during drilling. The basic principles of Measurement While Drilling (MWD) should be applied focusing on quantitative measures such as rate of penetration, as well as material descriptions inferred from drill performance or cuttings (Bruce, 2003). Based on this, the inspector can provide instruction to the driller as to where to terminate overburden casings and rock socket drilling in an owner-controlled pile design project. The contractor provides a basic drill log of the hole with associated casing lengths and reinforcing bar.

The grouting records collected separately is then married to the drilling log at the end of each day to complete each micropile log.

The timely upkeep and maintenance of the pile construction as-built data is a task that must be implemented (Table 2) at the beginning and maintained daily. The contractor's site engineer collects the drillers' reports and grouting reports daily, and the data are entered into an as-built spreadsheet. The owner's engineer will usually complete a duplicate from the data collected by the inspectors. The contractor and engineer must verify quantities daily to maintain accurate documentation for both parties. The consensus spreadsheet should be submitted to the construction manager weekly.

2.3.3 Pile Corrections

There are sometimes circumstances where pile construction does not meet the standard of quality required. For example, tooling and/or casing may become lodged in the hole, or grouting problems may occur or installation may become impossible or impractical due to a differing site condition. Occasionally, a pile may just have been located incorrectly or installed to the wrong depth. The key is to review site processes when errors do occur so that such errors or non-compliances are not repeated. Redesign may allow the use of a "wrong" pile by modifying a pile cap or installation of a "sister" pile as a supplemental element. The rate of defective piles is normally less than 1% with, of course, the goal being zero.

3. THE DUTIES AND RESPONSIBILITIES OF THE OWNER'S ENGINEER

The organization chart (Figure 2) depicts the level of effort for a large project for the engineering/design side. Recognizing that the engineer has a basic need for data collection and recordkeeping is only a step in the documentation effort. The overall goal of the engineer's representative on site is that of confirming the assumptions made during design, and verifying that the owner is receiving the product for which he contracted.

Similar to the roles defined for the contractor's personnel, the following is a brief description of the roles for the owner's field representatives:

Sr. Engineer: must have a complete understanding of the geologic conditions and assumptions, the pile design requirements, expectations for drilling conditions and rig performance, grouting process, and an overall awareness for the unexpected. The Senior Engineer has complete responsibility to manage the field staff, make field judgment calls that do not change the basis of design, review all documentation, and report to the Engineer of Record.

PILE NO.	DESC.	PROPOSED NORTH	PROPOSED EAST	PROPOSED CASE ELEV.	PROPOSED BAR ELEV.	AS-BUILT NORTH	AS-BUILT EAST	AS-BUILT CASE ELEV.	AS-BUILT BAR ELEV.	DIFFERENCE BAR STICKUP	DIFFERENCE N-DIFF	DIFFERENCE E-DIFF	DIFFERENCE TOTAL DIFF	DIFFERENCE BAR DIST.	DIFFERENCE CASE DIST.
1125	H36	5375.9500	4085.8400	239.50	241.50	5376.08	4085.70	239.67	241.53	1.86	-0.13	0.14	0.19	0.03	0.17
1126	H36	5377.9000	4090.4400	239.50	241.50	5378.07	4090.61	239.55	241.58	2.03	-0.17	-0.17	0.24	0.08	0.05
1127	H36	5370.9900	4085.2200	239.50	241.50	5371.25	4085.14	239.52	241.59	2.07	-0.26	0.08	0.27	0.09	0.02
1128	H36	5372.9400	4089.8300	239.50	241.50	5373.21	4089.76	239.55	241.51	1.96	-0.27	0.05	0.27	0.01	0.05
1129	H36	5366.0300	4084.6100	239.50	241.50	5366.12	4084.54	239.54	241.55	2.01	-0.09	0.07	0.11	0.05	0.04
1130	H36	5367.9800	4089.2200	239.50	241.50	5368.10	4089.12	239.54	241.59	2.05	-0.12	0.10	0.16	0.09	0.04
1131	H36	5369.9300	4093.8200	239.50	241.50	5369.99	4093.80	239.54	241.56	2.02	-0.06	0.02	0.06	0.06	0.04
1132	H37	5347.1700	4097.8600	241.00	243.00	5347.19	4097.81	241.02	243.05	2.03	-0.02	0.05	0.05	0.05	0.02
1133	H37	5350.1800	4093.8700	241.00	243.00	5350.29	4093.91	240.99	243.03	2.04	-0.11	-0.04	0.12	0.03	-0.01
1134	H37	5352.1400	4098.4700	241.00	243.00	5352.24	4098.68	240.91	243.07	2.16	-0.10	-0.21	0.23	0.07	-0.09
1135	H38	5327.1000	4098.4900	238.50	240.50	5327.20	4098.65	238.52	240.51	1.99	-0.10	-0.16	0.19	0.01	0.02
1136	H38	5329.0600	4103.1000	238.50	240.50	5329.02	4103.07	238.53	240.49	1.96	0.04	0.03	0.05	-0.01	0.03
1137	H38	5330.9400	4107.5500	238.50	240.50	5330.99	4107.55	238.55	240.50	1.95	-0.05	0.00	0.05	0.00	0.05
1138	H38	5332.9000	4112.1500	238.50	240.50	5332.95	4111.94	238.51	240.54	2.03	-0.05	0.21	0.22	0.04	0.01
1139	H38	5322.6500	4100.3800	238.50	240.50	5322.66	4100.39	238.55	240.53	1.98	-0.01	-0.01	0.01	0.03	0.05
1140	H38	5324.6100	4104.9800	238.50	240.50	5324.66	4104.83	238.52	240.56	2.04	-0.05	0.15	0.16	0.06	0.02
1141	H38	5326.4900	4109.4300	238.50	240.50	5326.57	4109.43	238.51	240.55	2.04	-0.08	0.00	0.08	0.05	0.01
1142	H38	5328.4500	4114.0400	238.50	240.50	5328.62	4113.95	238.50	240.53	2.03	-0.17	0.09	0.19	0.03	0.00
1143	H39	5302.9800	4116.6000	241.00	243.00	5303.09	4116.87	240.94	243.07	2.13	-0.11	-0.27	0.29	0.07	-0.06
1144	H39	5305.9900	4112.6100	241.00	243.00	5305.86	4112.43	240.96	243.05	2.09	0.13	0.18	0.22	0.05	-0.04

Table 2. As-built survey table

Senior Inspector: leader of the field crew and is responsible for ensuring adequate training and understanding of the particular tasks that the individual inspectors are assigned is in place; provides response to minor clarification or interpretation of items such as adequate bond material; collects daily field records and ensures completeness and accuracy before turning the paperwork over to the Senior Engineer for review.

- Inspectors: independent data collection and documentation of field activities and as-built conditions for every foundation element, must understand the design and construction expectations for the task being monitored.

The representatives in the field serve as eyes and ears for the more senior designers in the office. As such, they must have the ability to understand the design, site assumptions, and construction process. With a small project, this ability is typically carried in one person. On a large project, this can be a sizeable cadre of personnel, which adds complication of personnel, data, and paperwork management to the duties of the senior representatives.

Often, the most experienced field inspection personnel may not possess the variety of skills necessary to understand design, construction, schedule and personnel management, recordkeeping, and organization. Careful selection is required to identify those with sufficient skills to fill the positions in the organization chart. Improper selection often creates significant difficulties as designers and replacement personnel have to back track and recreate records from sketchy notes.

Most of the key elements important to the engineer are exactly the same as those identified above for the contractor. This is a good scenario because the contract is setup based on the contractor achieving the key elements of the project, those that are fundamental to the design intent and details. Some related considerations are:

- The pile numbering scheme established at the beginning of the project should be easily recognized by all field and office personnel since everyone will have to communicate in the numbering language throughout the project. These numbers should be logical based on site and building layout (e.g., start at a corner and work clockwise or utilize the architect's column numbering scheme in some form). This logic will allow everyone to quickly find the location on a plan, or to visualize the site remotely from the head office when issues arise in the field.
- Survey references are critical; these must be protected and accurate. Efforts spent at the beginning of the project to make these as accurate and permanent as possible are invaluable. They must also be accessible throughout the project.
- All drilling processes require careful observation and recording. With micropile installation, this is the key element for the confirmation of geologic conditions. The equipment used is very powerful and will penetrate quickly through most geologic conditions. As such, it take experience on the part of the inspector to understand how the drill and tooling works, what controls the driller exerts on the advancement process, and what valuable feedback the ground can provide. A control pile program should be completed where the inspection personnel can witness installation of piles and gain an understanding of the process as it compares to results depicted in nearby test boring logs. Subsequently, load testing of some of these piles will be used to confirm these observations and establish the baseline drilling program for the project.

- The grout is mixed on site. Although the mix is usually relatively simple (i.e., just cement and water), minor variations can have a significant impact on the placement process or performance of the pile. Micropile construction requires a stable cement-based grout. When the grout is too viscous, it is difficult to pump. When it has an excessive w:c ratio the strength is compromised, and bleeding and shrinkage of the grout increases. Simple tests, primarily the Baroid mud balance, and often the flow cone (Chuaqui and Bruce, 2003), are the best methods for confirming the quality of the grout before it is paced in a pile. Obviously, the compressive strength tests are not available until well after the pile is constructed and on a fast track project, often the pile cap is in place before strength testing is complete. Furthermore, experience with cement grouts has shown that the compressive strength tests do more to confirm the ability of the technician to make cubes than they serve as a reliable quality control tool.
- Field documentation is the key to relaying the information back to the designers in the office. Most engineers have standard forms for recordkeeping. It is prudent to review these forms and modify them if needed so that all of the required project specific information will be recorded. Field personnel should be obliged to fill in all lines on every form provided, every day, since they are often tempted to skip areas they feel are unnecessary. This will result in a loss of data and inability to thoroughly understand the project upon later review. A standard form with unnecessary blanks warrants modification, however.
- Summary documents should also be efficient. Where spreadsheets are created to manage large amounts of data, efforts should be made to set these up so that the information is easily entered and compared to key metrics. Metrics are often related to design issues, but should also consider contracting issues between the owner and the contractor. Often, fields can be set up with conditional formatting to provide flags when data fall out of an acceptable range. This will make the review of the information more efficient (Table 3).
- The role of the designer and field inspection staff is clearly not restricted to data collection. Their experience and understanding of the project engineering issues can help identify problems before they happen and prevent errors in reinforcement placement, grouting, or layout from occurring. The understanding and attention to detail coupled with some available free time to observe conditions between recordkeeping events can be an asset to the contractor's personnel who are often under extreme pressure to meet schedule and prevent damage to equipment, and who may be tired and less attentive at times.

The flow of data and confirmation of information between the field inspection staff and the contractor was described in Section 2.3 above. This must occur in real time so that the inspection reports can be delivered to the engineer for review. A regular reporting or summary should be provided then from the engineer to the owner and possibly the construction manager. This serves two purposes. First, it is a verification tool for the owner when reviewing contractor submittals and pay requests. Second, it is a tool for the engineer to ensure that there is a timely review of the information. The timing of these reports should be established at the beginning of the project based on these two needs.

PILE PROGRAM PROJECT 40-0082 - AS-BUILT PRODUCTION PILES DATA																	
Micropile #	Row Name	Pile Type	Existing Ground Elevation (FT)	Casing Cut-Off Elevation (FT)	Date Drilled	Actual Depth from Ground Level (FT)	Length from BOH to Cut-off Elevation (FT)	Cased Shaft Depth (FT)	Rock Socket Depth (FT)	Till Socket Depth (FT)	Date Grouted	Bar Size (#)	"Actual" Grout In Pile (CF)	Batch Plant Mixed (CF)	Theoretical Volume (CF)	110% Theoretical Volume (CF)	Extra Grout Placed (CF)
171	R42	1	238.5	240.5	6/14	63.0	64.5	54.5	10.0		6/15	18	32.0	36.0	23.3	25.7	6.3
168	R41	1	238.6	240.5	6/14	67.0	63.4	53.4	10.0		6/15	18	26.4	26.4	22.9	25.2	1.2
174	R43	1	238.7	240.5	6/15	76.5	77.8	54.8	23.0		6/15	18	30.0	30.0	27.6	30.4	
177	R44	1	238.7	240.5	6/15	67.0	68.3	57.3	11.0		6/15	18	26.0	28.4	24.7	27.2	
180	R45	1	238.4	240.5	6/15	98.0	99.6	65.1	34.5		6/15	18	41.6	45.6	35.1	38.6	3.0
170	R41	1	238.5	240.5	6/16	68.5	65.5	55.5	10.0		6/16	18	36.8	36.8	23.7	26.1	10.7
173	R42	1	238.6	240.5	6/16	83.0	84.4	54.4	30.0		6/16	18	35.5	35.5	29.7	32.7	2.8
176	R43	1	238.5	240.5	6/16	63.0	64.5	53.5	11.0		6/16	18	26.6	27.6	23.3	25.6	1.0
183	R46	1	239.2	240.5	6/17	89.0	89.8	78.8	11.0		6/17	18	36.0	36.0	32.6	35.9	0.1
179	R44	1	238.5	240.5	6/17	95.0	96.5	64.5	32.0		6/17	18	45.6	45.6	34.1	37.5	8.1
182	R45	1	238.7	240.5	6/17	81.0	82.3	72.3	10.0		6/17	18	33.6	33.6	29.9	32.9	0.7
621	N41	1	239.5	241.0	6/17	35.0	36.5	26.5	10.0		6/17	18	15.6	15.6	13.0	14.3	1.3
616	N42	1	239.8	241.0	6/18	47.0	48.2	21.2	27.0		6/18	18	24.7	25.2	16.5	18.2	6.5
611	N43	1	240.2	241.0	6/18	40.0	40.8	26.8	14.0		6/18	18	20.7	19.2	14.4	15.8	4.9
608	N44	1	240.1	241.0	6/18	34.5	33.4	23.4	10.0		6/18	18	15.0	19.2	11.9	13.0	2.0
601	N45	1	240.1	241.0	6/18	77.0	77.9	37.9	40.0		6/18	18	45.2	45.2	26.9	29.5	15.7
186	R47	1	238.9	240.5	6/18	72.0	73.1	39.1	34.0		6/18	18	28.1	37.2	25.4	27.9	0.2

Table 3. Typical pile data summary spreadsheet

4. PROJECT STARTUP

There is typically a "ramp-up" phase during which the contractor, engineer, construction manager, and owner are individually and together field commissioning their respective systems. This allows valuable time to debug procedures such as the testing, sampling, production, data collection and reporting, and inspection. The construction manager in particular must allow time for his personnel to become acquainted with the specialty nature of micropile installation especially when they are providing concurrent work services which may interfere with the micropile operation, e.g., site excavation and access, utility relocation, water, electric, and lay down restrictions.

Often projects call for several "disposable" piles, successful piles load tested prior to production pile construction. On projects with particularly tight schedules, it is frequently agreed that production pile installation may start in areas of the site where a single load test has been successfully completed. This permits the production work to start sooner and with fewer men and pieces of equipment. This also permits all of the parties to develop a familiarity with the work and to refine procedures during this "honeymoon" phase. Furthermore, the crews and inspectors can become comfortable with the particular geologic condition and the drilling and grouting parameters, before moving into other areas where construction procedures may need to be varied as each representative load test is completed. As a result, the contractor is able to accelerate by working with a smaller crew on single shifts. Later, when more intense work begins, the production curve can be expected to be much steeper than what might have normally been expected by starting with full crews in multiple variable conditions.

Once these procedures are in place, providing the owner with a product of acceptable quality becomes simply 1) locating the pile correctly, 2) drilling the pile according to the established procedures and collecting the data, 3) placing the correct lengths and amounts of materials, and 4) correcting any problems if one of the first three are not met. Significant effort should be placed on establishing baseline controls, tracking the production data, and comparing it back to the baselines to assure all processes are in compliance.

5. THE VALUE OF COMMUNICATION AS A QUALITY TOOL

This paper refers in depth to recordkeeping and data management on a micropile project. Large projects or small, this is a key issue and the first step in overall project communications. Wherever possible, this information should be freely shared and confirmed between parties on a regular basis. Conflicting data discovered late in the project are often difficult to reconcile, and can become a severe point of contention between parties often affecting payment requests.

A second component to the required communication flow on a project is regular meetings. These should occur on several levels. At the highest level, a senior representative from the owner, construction manager, contractor, and engineer should meet regularly (say weekly) to review the overall progress of the project, plan future work, discuss issues that may not be clear for future work, and issues outstanding from completed work. Below this level, regular communication should occur involving daily data review. A third level is within each group (engineer, construction manager, and contractor) where the field personnel are briefed on plans for future work, issues that may be occurring in the data collection and reconciliation, and any changes in design and construction processes. There will also be other meetings including contractual discussions, safety training, or technical training. All of these improve communication, build knowledge and trust, and can help make the project flow more smoothly. In all these communication tools there is absolutely no place for cynicism, hidden agendas, or misleading or incorrect information. Meetings should be held in accordance with the set of "meeting rules" displayed in most corporate offices. All meetings must be accurately documented, and these minutes agreed and accepted by all parties on a regular and prompt basis.

6. FINAL REMARKS

Successful completion of a project requires total commitment and effort from all the parties involved. Where very large and fast track projects are attempted, the cooperation, focus, skill and perseverance of everyone will be put to the test. Several points must be remembered on projects such as this:

- A high level of effort is warranted at the beginning of the project to set it up correctly, provide adequate staffing, establishing recordkeeping procedures, and determining chain of command and documentation flow. All of this effort and more will pay huge dividends in a large, fast-moving project.
- Wherever possible, having a "ramp-up" period, where work starts slowly, is effective at optimizing the procedures of all parties, and will improve subsequent efficiency.
- Quick turnaround is required for the review of information exchanged (as-built data and field problems.) If a timely review of information is not intended, then the data should not be requested. For complicated projects, the owner must provide on site structural engineering and possibly other decision-making personnel.
- Daily progress meetings between the construction manager, contractor, engineer, testing lab, and other subcontractors are integral to pile work and must be held to coordinate efforts and limit downtime during working shifts.
- Two survey companies provide good checks and balances at different times on the same project.
- Specialty design consultant representation for the contractor can help resolve conflicts over design and construction issues with the engineer and owner.
- Persistent extended shifts (overtime) impact the efficiency of all parties thus causing documentation errors and will adversely affect safety. This must be recognized and regular time off must be allotted even in the most intense project circumstances.

REFERENCES

Chuaqui, M. and Bruce, D.A.. (2003). "Mix Design and Quality Control Procedures for High Mobility Cement Based Grouts." *Grouting and Ground Treatment*, Proceedings of the Third International Conference, Geotechnical Special Publication No. 120. Edited by L.F. Johnsen, D.A. Bruce, and M.J. Byle, American Society of Civil Engineers, New Orleans, LA, February 10-12, pp. 1153-1168.

Bruce, D.A. (2003). "The Basics of Drilling for Specialty Geotechnical Construction Processes." Grouting and Ground Treatment, Proceedings of the Third International Conference, Geotechnical Special Publication No. 120. Edited by L.F. Johnsen, D.A. Bruce, and M.J. Byle, American Society of Civil Engineers, New Orleans, LA, February 10-12, pp. 752-771.