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SPENDING DIMES TO SAVE DOLLARS: THE VALUE OF SPECIALIZED CONSTRUCTION MANAGEMENT ON LARGE TRENCHLESS PROJECTS.

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ABSTRACT

Construction claims on trenchless technology projects are all too frequent. This is especially true on microtunneling and large diameter horizontal directional drilling (HDD) projects where construction sites are often tight, geotechnical information can be limited, and the technologies are constantly pushed to their limits. Because trenchless installations are often high-risk portions of a project, effective construction management on trenchless installations require the collection of data that is not required on open cut projects. Without the collection of this specialized information by knowledgeable construction inspection staff, claims cannot be supported or properly defended against. This paper presents trenchless case histories where construction claims were filed against the Owner. It explains how data collected during specialized construction management was used to evaluate these claims to determine the portions of the claim that had merit and the portions that were inflated. Through these examples, the paper provides guidelines for effective construction management of trenchless construction projects.

Introduction

Many trenchless technology projects involving the new installation of large diameter pipelines carry a large risk component. This is especially true for pipelines larger than 24inches in diameter. One of the primary risks is encountering a differing site condition (DSC) during construction that leads the contractor to file a claim against the owner. Often these claims are a large percentage of the overall bid price and are tremendously costly to resolve for all parties involved. Although the industry is making great strides to help in the evaluation of differing site conditions claims (such as investing in more extensive geotechnical site investigations and developing geotechnical baseline reports for trenchless projects), there remains a large number of trenchless projects on which DSC claims are filed.

Many DSC claims have traditionally focused on encountering obstructions that halt the forward progress of the machine. However, DSC claims that do not involve obstructions are becoming increasingly more common. Instead, these claims are centered on encountering materials that allegedly slowed the contractor's expected production, impacted line and grade, affected machine performance, or caused excessive wear or damage to the machine. Unlike traditional DSC claims, it is not necessary to dig a retrieval shaft to rescue the machine because the machine is typically able to continue to excavate through the native soil. Therefore, it is critically important to understand how machines perform in a variety of ground conditions in order to determine if in fact a differing site condition exists. Proper data collection during construction inspection is the key element in understanding the machine performance, and, therefore, in analyzing a DSC claim.

Inspecting Trenchless Construction

On high-risk trenchless construction projects, it is essential to have knowledgeable construction inspection staff that are on site throughout the entire construction process. The on-site construction inspector should be familiar with the trenchless technique that they are inspecting so that they can record and interpret the construction activities as they are happening, making sure to document any unusual events such as equipment failures, break-downs, slowed production, etc. A knowledgeable, experienced, trenchless construction inspector will be able to collect the important information to interpret the construction activities and determine if a differing site condition was encountered during construction.

It is common for most microtunneling machines to have automated data collection systems that track most machine parameters such as cutterhead torque, jacking force, slurry flow rates and pressures, steering corrections, etc., as well as to have the Contractor be contractually required to manually record these readings and submit them to the Owner/Engineer on a regular basis. However, it is highly recommended that the construction inspector collect independent readings from the control system. The inspector-collected readings serve as backup data in the event that the automated data should be compromised for any reason. In addition, in the event that a claim is filed, the relationship between the Owner and the Contractor can become strained and the transfer of information may be compromised. If the construction inspector has been taking machine parameter readings throughout the drive, the Owner as well as the Contractor will have the same information from which to base the conclusion on the alleged differing site condition.

<u>Case History – Delay Claim</u>

On a 72-inch diameter microtunneling project the microtunneling machine (MTBM) encountered an abandoned PVC monitoring well on a 675 foot drive. The microtunneling machine was able to tunnel through the monitoring well successfully; however, the contractor filed a differing site condition claim stating that encountering the well caused a significant delay. The contractor stated that pieces of the PVC well were shattered by the machine and clogged the slurry lines and pumps. The contractor submitted a claim for lost production for the time required to clear the slurry lines and slurry pumps, resulting in the loss of a half day.

Table 1. Tunneling Activity Duration and Downtime for the 675-foot tunnel drive.

Activities	**Duration (Hours)**	**Average Delay (Hours)**
Average Pipe Connection Times	1.64	0.72
Pipe Connection Without Delay	0.92	
Average Tunneling Times	1.20	0.39
Tunneling Without Delay	0.81	
Downtime Events		
Adjusting MTBM Attitude	1.0	
Booster Pump Connections	1.50	
Booster Pump Problems	1.42	
Computer Problems	1.08	
Survey Equipment	1.50	
Power Pack Problems	25.0	
Coolant Hose Replacement	0.33	
Slurry Water Problems	3.20	
Slurry Line Blockage	2.0	
Hydraulic Problems	14.07	
Jacking Frame Set-Up	1.50	
Difficulties Connecting Pipe	6.0	
Total Downtime Events	58.6	
Total Hours Worked	220	
Percentage of Downtime	26.6%	

The project Owner had retained a specialized construction management team with a microtunneling inspector who had a tremendous amount of microtunneling experience. The inspector had very detailed records of all activities on the drive and was able to prepare a detailed analysis on the construction downtime events. As with almost all microtunneling projects, downtime events make up a significant portion of the overall construction activities. As such, it was important to analyze the downtime associated with clearing the clogged slurry lines and pumps to determine the lost production experienced by the contractor. Using the data collected during construction, the specialized on-site construction inspector was able to generate Table 1 illustrating the contractor's average activity durations and downtime events.

Examination of the daily records showed that on the day that the contractor encountered the PVC monitoring well, they spent a total of 1.25 hours clearing the slurry lines and slurry pumps. However, this activity was done simultaneously with connecting the next pipe for tunneling. Since their average pipe connection time was 1.64 hours, cleaning the slurry lines and pumps did not have an overall impact to their production. In fact, on the day in question, their overall downtime was less then their average project downtime of 27%. When these statistics were presented to the contractor, their claim was dropped.

Case History – DSC Loose Soil Conditions

A differing site condition claim was filed on a microtunneling project that included a 60-inch microtunnel drive in excess of 1,100 feet. The contractor claimed that the soils were accurately described over the first 900 feet of the drive in the geotechnical baseline report, but over the last 200 feet of the drive they encountered "very loose soils." These alleged very loose soils were blamed for a host of difficulties, including steering problems resulting in misalignment of the machine into the retrieval shaft and thus misalignment through the retrieval seal. The contractor blamed the misalignment for the loss of seal at the retrieval shaft and the ensuing retrieval shaft flood. The DSC claim presented to the Owner was over $1.5 Million.

Specialty on-site construction management was provided for the microtunneling on the project. A representative was on site during all microtunneling operations and recorded soil conditions along the entire length of the drive, describing the types of material (cobbles, gravel, sand, silt, etc.) and estimating the relative amounts of each material that were excavated, as seen at the soil separation plant (e.g. 25% gravel, 50% sand, and 25% silt, etc.). In addition, physical evidence of the excavated soil was collected in sample bags and logged every 20 feet along the length of the drive (once per pipe segment) and when materials changed. Representative photographs of the material on the soil separation plant were also taken to supplement the logs. MTBM machine parameters recorded by the microtunneling data acquisition system were collected daily and supplemental data were manually recorded at five foot intervals along the entire microtunnel drive to confirm and supplement those recorded by the data logger. The Contractor was aware of the activities of the specialty construction manager and was required by specification to provide access to the CM for all data collection and measurement.

Actual Soil Conditions

Four types of soil were encountered in varying amounts along the drive: gravel, sand, silty sand, and clay. Consistent with the geotechnical baseline report (GBR), the soils transitioned from a highly permeable mixture of gravel, sand, and silt over the vast majority of the drive (first 980 feet) to a low-permeability mixture of fine sand and silty sand over the last 82 feet of the reception shaft (with the exception of a 100-foot zone in the middle of the drive where the machine encountered silty sand and clay). Table 2 summarizes the physical evidence and observations collected by the microtunneling inspectors during the drive. For the purpose of discussion, the drive is separated into four distinct sections, characterized by the soil conditions encountered. These sections are listed below.

Table 2 Actual Ground Conditions Encountered on Microtunnel Drive

Length	Pipe Numbers	Material
First 485 feet	Machine and Pipes 1 through 23	Gravel, Sand, and Silty Sand
485-585 feet (100 feet)	Pipes 24 through 28	Clay and Silty Sand
585-980 feet (395 feet)	Pipes 28 through 45 (including the first IJS)	Gravel, Sand Silty, Sand, and Clay
980-1062 feet (82 feet)	Pipes 46 through 52 (including second IJS)	Fine Sand and Silty Sand

Interestingly, the Contractor claimed that the zone in which the DSC existed was within the last 200 feet of the drive; however, the construction inspector noted a distinct change in soil conditions at 82 feet from the reception shaft where gravel was no longer present in the formation. This note was further substantiated by construction photos of the soil separation plant and spoil bin taken during tunneling as shown in Figure 1

Figure 1 Spoil Bin with Significant Gravel (left) Spoil Transitioning to Fine Sand and Silt without Gravel (right)

The Contractor claimed that they were mining through “aggressive, gravely, and cobbley ground” similar to that described in the contract documents until 200 feet before the reception shaft where upon “loose to very loose soils most likely sand, silty sand, and silt” were encountered.

Further Dispelling the Contractor’s DSC Claim

The Contractor then used two machine parameters, head roll and cutterhead torque, to show that that ground conditions were very loose. However, their analysis did not examine other key factors, such as operational practices, that dictated machine performance. The following paragraphs examine head roll and cutterhead torque in conjunction with machine drive speed and operation. When these factors are considered, the machine parameters conclusively show that the soils in the last 200 feet were not loose, but were in fact dense.

Head Roll

The microtunneling machine consists of a cutterhead attached to a hydraulic motor located in a cylindrical shell that houses equipment required to operate the MTBM. The hydraulic motor is capable of turning the cutterhead in a clockwise or counterclockwise direction. Because of an unbalanced torque imparted by the rotating cutterhead, the machine has the tendency to roll in the opposite direction of cutterhead rotation.

Machine operators alternate the rotation of the cutterhead between clockwise and counterclockwise to keep the machine from rolling too far beyond centerline, typically three degrees. The machine data logger records the head roll. A positive head roll is consistent with clockwise head roll while a negative head roll is consistent with counterclockwise head roll.

When an operator observes rotation of the machine or head roll, the cutterhead is stopped and then rotated in the reverse direction to correct the roll. The process of alternating clockwise and counterclockwise rotation is continued throughout the entire drive if head roll is experienced. The magnitude of the negative or positive head roll can be controlled by the operator, as the only way to change the head roll is for the operator to stop the cutterhead and reverse its direction of rotation.

In very loose soils the machine may not respond to the change in rotation of the cutterhead due to a lack of soil resistance on the machine to counter-balance the torque created by the rotating wheel. For example, in very loose soils the machine will not respond when the cutterhead is turning in the clockwise direction and may still exhibit a positive head roll.

The Contractor claimed that it was evident that the MTBM encountered very loose soil conditions at STA 117+64 because the machine "began rolling clockwise." The report contends that the operators continued to advance the MTBM "slowly and carefully" to STA 116+46. They further stated that the clockwise head roll "continued despite the operators reversing the rotation of the cutterhead which was considered an alarming trend indicative of very loose ground that provided virtually no resistance to the rotation of the MTBM cutterhead." Upon examination of the records taken by the construction inspector (the Contractor had not forwarded their own records to the Owner) it was found that these statements were factually incorrect and that the machine had responded to changes in cutterhead rotation.

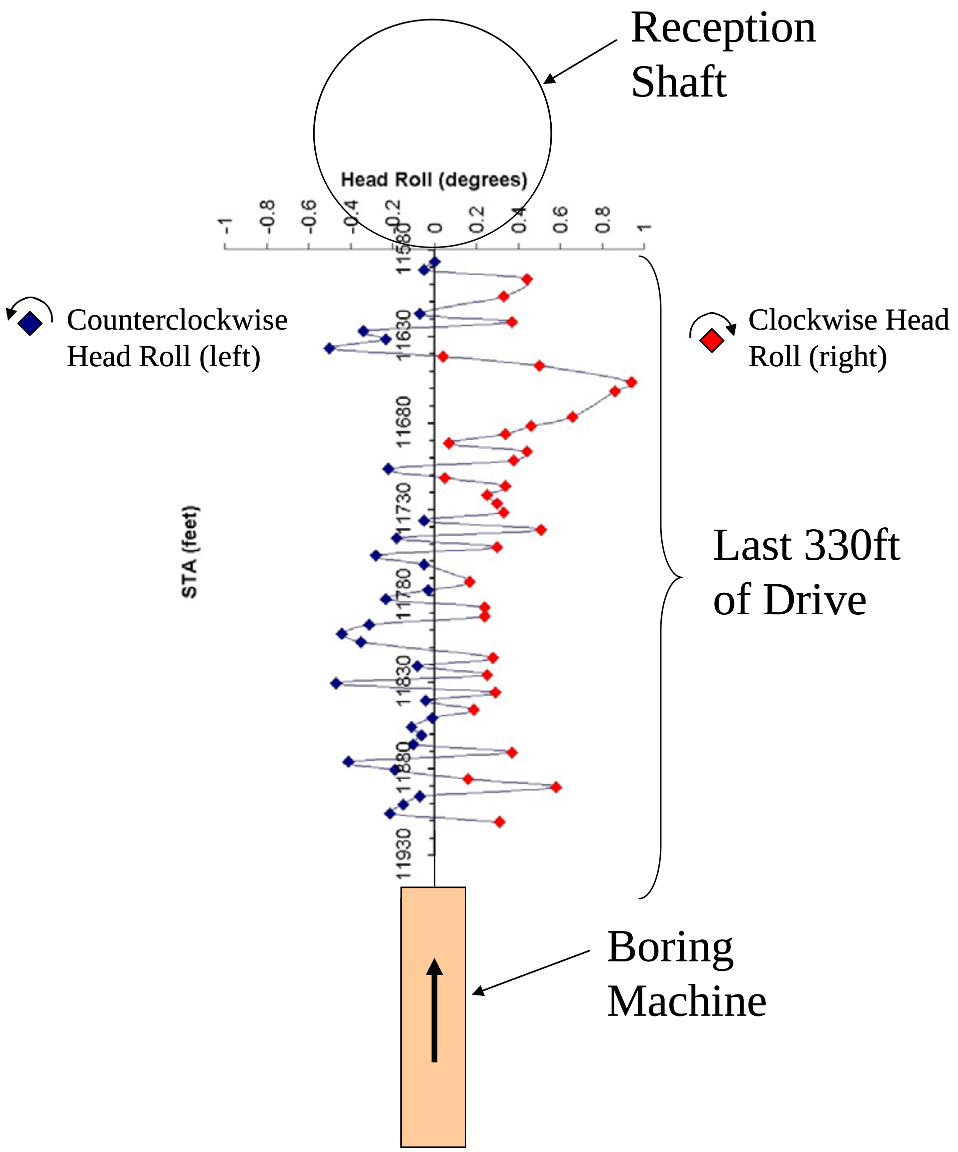

Figure 2 Cutterhead roll over the last 330 feet of the microtunnel drive.

Figure 2 clearly shows alternating head roll of the machine during the last 330 feet of the drive, consistent with operator induced cutterhead rotation reversals. For example, at STA 117+64, the machine displayed a negative (counterclockwise) head roll. Over the next five (5) feet of drive distance the cutterhead was rotated in the opposite direction and the machine responded by rolling clockwise until a positive (clockwise) head roll was indicated. Then, over the next five (5) feet of drive distance, the cutterhead rotation was again reversed and the machine rolled counterclockwise until a negative (counterclockwise) head roll was indicated. The information collected by the on-site construction inspector clearly showed that the machine roll data did not support the DSC claim of a loose soil condition over the last 200 feet of the drive.

Cutterhead Torque

During tunneling, the torque required to turn the cutterhead was measured and recorded. The torque reading indicates the amount of effort required to turn the cutterhead. If there is a large amount of resistance or pressure on the cutterhead, the effort to turn the cutterhead will be great and the torque reading will be high. In turn, if there is little resistance on the cutterhead, the effort required to turn the cutterhead will be low and the torque reading will be low.

Torque can be controlled by the operator by adjusting the speed of tunneling. If the operator is pushing very fast into the soil, the resistance against the face of the machine is great and it will require more effort to rotate the cutterhead, resulting in a high torque reading. However, if the operator slows the speed of the machine, the resistance on the face is lower and the torque reading will go down. Therefore, it is extremely important to analyze the changes of machine speed in conjunction with the changes in torque.

The only time that the torque reading is indicative of the soil type is when the machine is operated at a constant speed. If the torque drops, indicating less pressure on the head, while the machine is moving at a constant speed, the operator knows that the soil has changed and the machine has moved into a material that puts less resistance on the cutterhead. Conversely, if the torque increases, the operator knows that the machine has moved into a material that exerts higher resistance on the face of the machine.

To support the Contractor's claim they stated that "very loose soils were evidenced in a loss of MTBM torque at the face." They further stated that "torque rapidly fell to near 50 bar while the normal operating range for torque is between 90 to 150 bar." Figure 3shows the torque over the last 140 feet of the drive containing notes relating to soil conditions and operational speed of the machine.

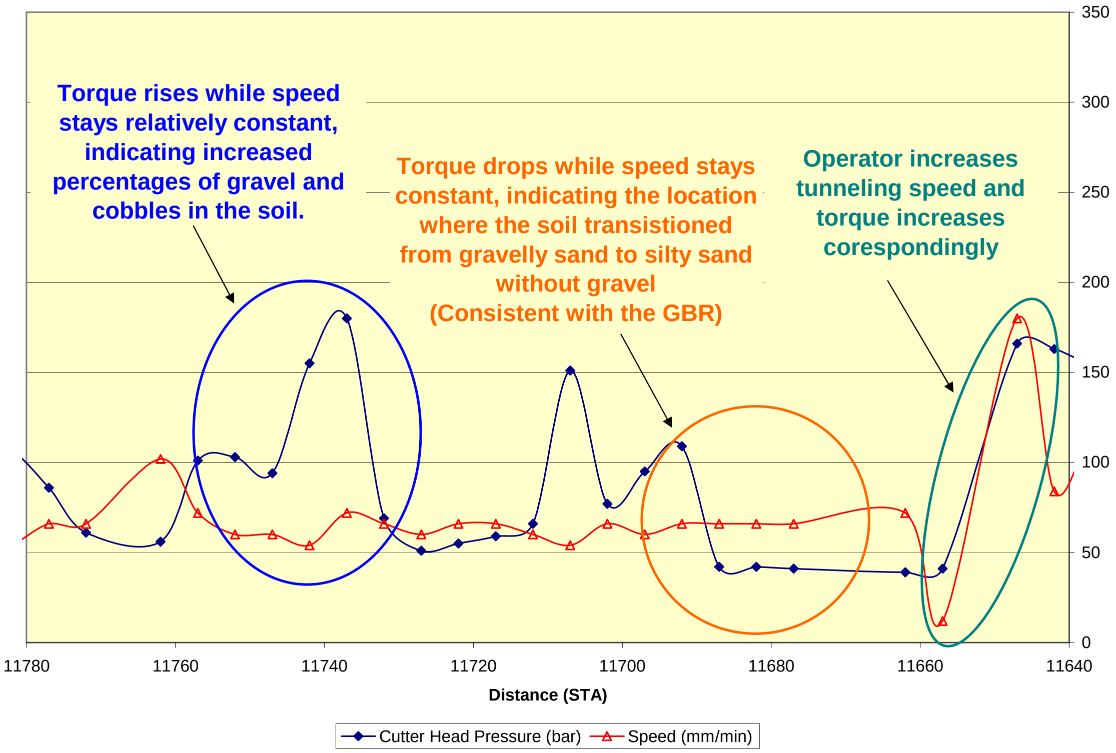

Figure 3 Annotated Torque Graph showing last 140 feet of Microtunnel Drive

In fact, at STA 117+64 the torque was increasing while the speed was remaining relatively constant. Between STA 117+32 and STA 116+86 the torque alternated between high and low as the MTBM most likely passed through a transitional zone of some gravelly soil and some sandy soil. At STA 116+86 the torque did drop rapidly; however, this location corresponds to the contact where the MTBM proceeded into uniform silty sand without gravel. This contact where gravel was no longer encountered corresponds with the description of soils presented in the GBR and the soil samples collected by the on-site inspector. As the machine passed from the gravelly soil, where it was required to crush rock to make progress, into a soil where no crushing was necessary, the torque would be expected to drop, especially if the operator did not increase speed. This reduction in torque is clearly illustrated in the Figure 3.. Then at STA 116+57 the speed was markedly increased to 180 mm/min and the torque increased correspondingly.

Figure 4 is a graph of the torque readings throughout the distance of the alleged DSC (the last 200 feet of the drive). It is important to note that the torque readings remained relatively high from STA 116+57 to the end of the drive. Had the soil conditions been very loose as the Contractor contended, the torque readings would have fallen and the operator would not have been able to sustain the high torque , even with marked increases in speed. The torque readings across the last 200 feet of the drive clearly indicate that the soil was not very loose as stated by the Contractor.

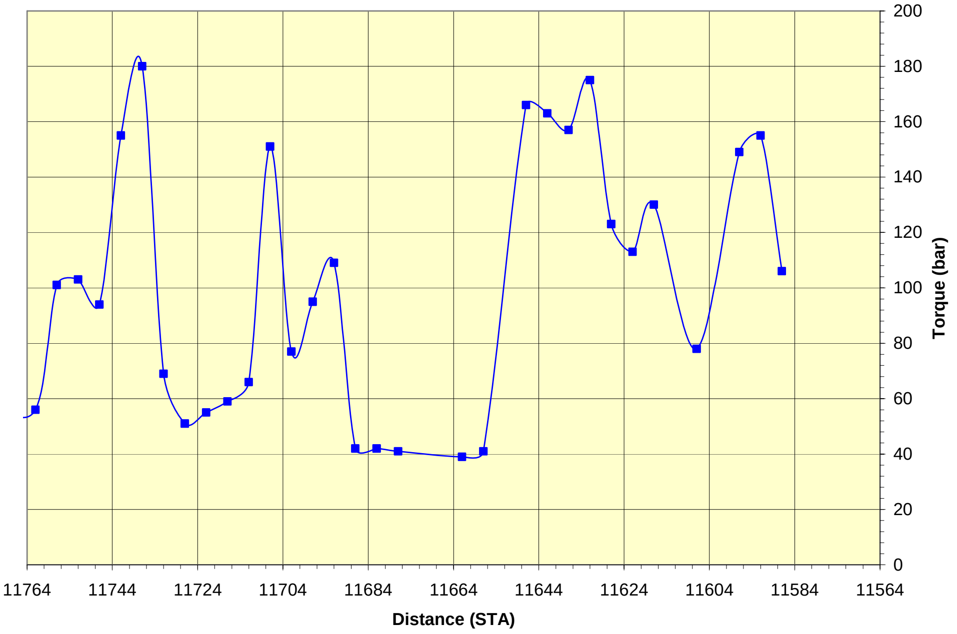

Figure 4 Torque over the last 200 feet of the drive (alleged DSC zone)

Machine Response to Steering Correction

In addition to the arguments made by the Contractor, the data collected by the specialty construction inspection team was able to further reveal information regarding the density of the soil in the last 200 feet of the drive. The density of the soil encountered by the machine dictates how responsive the microtunneling machine will be to steering and directional changes. Denser soil provides greater resistances to steering corrections than looser soil. Therefore, the machine responds to steering corrections much more rapidly in dense soil than in loose soil. In very loose soil it may not be possible to steer the machine due to inadequate resistance provided by the very loose soil. When steering corrections are made in very loose soils the MTBM continues along its current path until it reaches material with sufficient resistance to allow the machine to “push off of the soil” and move in the corrective direction (one can liken this to steering a ship). Because steering corrections in very loose soils are very difficult, “saw toothed” patterns of alternating left and right deviations from design line and up and down deviations from design grade cannot be attained. Rather, in very loose soils, steering corrections are very gradual and typically occur over a long drive length.

On this microtunnel drive, the microtunneling machine was able to maintain the as-built line and grade to within two inches horizontally and vertically of the design alignment. (NOTE: Specifications allowed deviations up to three inches). On typical microtunneling projects, this amount of deviation is considered very good over a 1,000-foot drive.

The Contractor’s claim stated that “during the final push, steering was difficult and erratic, and the operators were fighting both to keep the MTBM from diving (deviating from established grade) and on established line.” Steering data collected during tunneling does not support this statement. The microtunneling operators were able to steer the MTBM in an aggressive saw toothed pattern as shown in Figure 5.

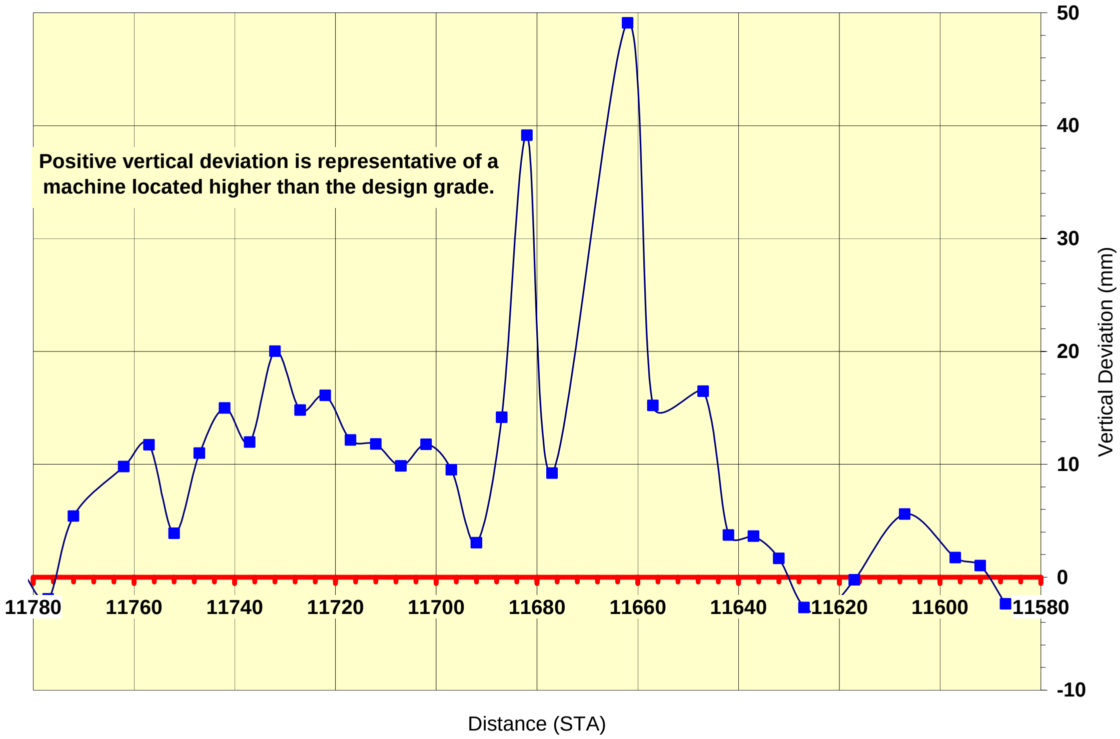

Figure 5 Vertical deviations of the microtunneling machine over last 200 feet.

The ability to steer the machine in a saw toothed pattern, as shown in this graph of vertical deviation clearly indicates that the soil encountered was dense. If very loose soils were actually encountered, these directional changes would not have occurred and the graph would show no sharp or abrupt reversals in direction. Hence, the physical evidence does not support the argument presented by the Contractor that the soil encountered between STA 117+64 and 115+81 was very loose.

Invaluable Data Otherwise Unavailable

Although the construction inspection staff was collecting the records from the data acquisition system throughout the drive, the data critical to the claim was not transmitted to the Owner. The tunnel hit the reception shaft at 3 a.m. after what had been an extremely long shift. The tunnel operator, with no objection from anyone on site, elected to shut down operations and agreed to transmit the data to the inspector on the next day of construction. However, the data was never transmitted to the Owner. As a result, the only information about machine parameters that the Owner had in their possession was that taken by the construction inspector. The machine parameter data i.e. torque readings, roll readings, machine advance rates, rotational direction of the cutterhead, etc. proved to be invaluable when evaluating the claim. Without the specialized construction management, the Owner would not have had any information from which to evaluate the claim.

Claim Resolution

The DSC claim was carefully evaluated by the Owner in light of the information collected by the construction inspector, and the Owner concluded that a differing site condition did not exist. The Contractor continued to pursue the claim and both parties agreed to participate in non-binding mediation in an attempt to resolve the issues associated with the claim. During the mediation process it became evident that although the Contractor did experience problems associated with the retrieval of the microtunneling machine, the difficulties were not a result of a differing site condition or loose soil conditions at the reception shaft.

As is often the case with mediation, the resulting settlement was not entirely beneficial to either party. However, in the end the Owner paid less than half of the Contractor's original claim. The reduction was based largely on the evidence gleaned from data collected by the on-site microtunneling inspector. In the final analysis, the amount of money spent by the Owner on specialized construction inspection and claim review for this project totaled less than 5% of the contractor's original claim. Additionally, the difference between the original claim amount and the final settlement (or the amount that the Owner saved by using the specialized CM data to disprove the Contractor's claim) was more than ten times the amount spent on specialized construction management services.

Conclusion

Having the proper construction inspection staff on a high-risk trenchless technology project is very important to the overall success of the project. Without knowledgeable, experienced people recording the construction events and machine parameters it is difficult, if not impossible, to properly evaluate construction claims and determine their validity. Just as the included examples showed that the Contractors did not have valid claims against the Owner, collection of the appropriate data will also show when there is, and when there is not, a valid differing site condition claim. This information is equally valuable when a DSC is encountered and Owners are required to go to Public Boards or meetings to show the need to provide additional compensation to the Contractor beyond what was provided in the bid price. The extra cost associated with hiring a firm that specializes in trenchless construction management is a small up-front investment towards lowering the overall amount paid on trenchless construction claims. Owners and Engineers should carefully consider the value of having experienced construction inspection staff on these high risk projects to protect the upper ceiling cost of the overall project.