

PRE-CONSTRUCTION DRILLABILITY ASSESSMENT FOR HORIZONTAL DIRECTIONAL DRILLING IN ROCK

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Abstract

This paper presents concepts that evolved through a research project sponsored by the Pipeline Research Council International (PRCI). The objective of the project was to investigate methods for the reduction of claims for extra compensation associated with horizontally directionally drilled (HDD) pipeline installations in rock. These claims result from HDD contractors' allegations that rock properties experienced during construction are significantly different from the properties on which the contractors' bids were based. The paper provides information and recommendations that improve exploration and testing methods for assessing the drillability of rock to be encountered on HDD pipeline installations. It is anticipated that these improvements will lead to a better understanding of rock drillability which will in turn lead to more accurate bid prices and more effective drilling plans, thereby reducing claims for extra compensation. The paper also addresses contractual and risk management considerations and alternate dispute resolution.

PRCI Project Description

The mission of the PRCI (www.prci.com) is to develop and disseminate technology that enables energy pipeline companies around the world to provide safe, reliable, environmentally compatible, and cost-effective service. In fulfillment of this mission, the PRCI engaged J. D. Hair & Associates, Inc. to undertake a research project with the objective of reducing claims for extra compensation associated with HDD pipeline installations in rock. The four primary tasks undertaken in this project are listed below.

1. Survey the HDD Industry and selected pipeline system owners to identify existing practices and summarize experience.
2. Conduct a literature search and obtain technical papers applicable to assessing the drillability of rock.
3. Describe modifications to existing practices, if any, which may achieve the desired solution.
4. Describe and prepare cost estimates for research projects and field trials that can be carried out to enhance existing exploration and testing methods.

This paper presents concepts associated with the third task, primarily a proposed recommended practice for conducting subsurface investigations for HDD installations.

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Proposed Recommended Practice for Subsurface Investigation

A proposed recommended practice covering subsurface investigations for HDD installations is presented in the following paragraphs. This recommended practice is presented as a starting point for review and discussion within the HDD Industry and associated engineering community. Individual practitioners or technical organizations may adopt all, or some, of this recommended practice in accordance with their own experience and professional judgment. It is anticipated that the practices recommended herein will evolve and be modified as the HDD Industry evolves.

Scope

This recommended practice covers subsurface investigations for major pipeline installations installed by HDD. Generally speaking, major pipeline installations are greater than 500 feet in length and involve pipe with a nominal diameter of at least 6 inches. They are installed by medium to large HDD drilling rigs.

HDD is a trenchless excavation method that is accomplished in three phases. The first phase consists of drilling a small diameter pilot hole along a designed directional path. The second phase consists of enlarging the pilot hole to a diameter suitable for installation of the pipeline. The third phase consists of pulling the pipeline into the enlarged hole. HDD is accomplished using a specialized horizontal drilling rig with ancillary tools and equipment.

This recommended practice is not meant to replace sound engineering judgment. HDD installations are complicated civil engineering works and their design should only be undertaken by experienced professional engineers.

Geotechnical Characterization Profile

An appropriately conducted subsurface investigation for an HDD pipeline installation will allow the production of a “Geotechnical Characterization Profile” (GCP). The purpose of a GCP is to provide a set of baseline conditions that can be used for two primary tasks: 1) to estimate the effort and cost involved with an HDD installation; and 2) to determine whether the actual conditions encountered differ from the baseline conditions. It is similar in function to a Geotechnical Baseline Report as described in the ASCE’s *Geotechnical Baseline Reports for Underground Construction*, but it is intended to be a much more concise document structured for use specifically with an HDD installation.

A GCP has contractual and commercial implications. While it is typically based on measured data, it is not a presentation of measured data, hence the term “Characterization”. Measured geotechnical data should be presented in a Geotechnical Data Report (GDR).

A GCP should clearly show anticipated subsurface conditions. Subsurface conditions do not have to be encountered or measured in a boring to be anticipated. The purpose of the GCP is to set down baseline assumptions in order to impose consistency on the way the engineer, owner, and contractor comprehend the subsurface conditions. A GCP should be prepared by knowledgeable engineers with experience in geotechnical surveys, HDD installation techniques and costs, and

construction contracts. It should be constructed taking into account risk and allocation of risk.

A GCP should be presented graphically, preferably on the HDD installation design plan & profile drawing. General subsurface formations should be delineated using the horizontal and vertical control system on which the drilled path design is based. In this context, the term “formation” is defined as any unit of bedrock or overburden with homogenous HDD engineering properties. A tolerance for formation delineation may be called out, but should not be so large as to defeat the purpose of formation delineation. A GCP need only cover the subsurface region to be drilled. Regions falling outside of the drilled path tolerances will not be encountered and need not be characterized.

Overburden soils should be classified according to the Unified Soil Classification System as described in ASTM D 2487, *Classification of Soils for Engineering Purposes*. Soil descriptions in accordance with ASTM D 2488, *Description and Identification of Soils (Visual-Manual Procedure)* may also be used. Where the soils fall outside of the Unified Soil Classification System, such as with man made fill, descriptive text should be used on the GCP. Descriptive text should also be used in formations where erratic or anomalous obstacles may be encountered, such as a formation composed of glacial till containing random boulders.

An interface formation between bedrock and overburden should be defined and described. The interface will often consist of weathered and fractured rock. The GCP should not present an unrealistic condition where fine grained overburden transitions into competent bedrock.

Distinct bedrock formations, if any, should be delineated and the anticipated range of rock properties called out.

General Geologic Review

The first step in a subsurface investigation for an HDD pipeline installation should be a general geologic review. This review should consider the geologic mechanisms that created the subsurface geologic profile through which the pipeline will be installed. Understanding geologic mechanisms leads to an understanding of the types of subsurface conditions that are possible and probable. For example, a crossing of the Mississippi River in South Louisiana will penetrate alluvial deposits consisting of silts, sands, gravels, and clays. Bedrock is known not to be present and glacial activity did not extend to this region. Therefore, concerns with rock properties and glacial till may be dismissed.

A general geologic review also involves examining existing data to determine what conditions have been encountered on other projects in the vicinity of the installation. Existing data may be available from other HDD installations or construction projects involving deep foundations or excavation (ASCE 2005, p. 8). Measured or report quality data need not be available. The designer need only have enough confidence in the information to prepare a GCP, or specify a subsurface exploration program that will provide data required for GCP preparation. For example, numerous HDD crossings have been installed beneath the Houston Ship Channel. Additional subsurface exploration is not generally required to prepare a GCP with the appropriate range of soil classifications. When viewed from the

perspective of HDD installation, the subsurface conditions beneath the coastal plane surrounding Houston are consistent and predictable.

A contrary example is presented by the Harlem River on the northeastern side of Manhattan Island. Bedrock and overburden elevation and composition are highly variable over short distances. A significant subsurface exploration program is required provide the data necessary to prepare a reasonable GCP.

Subsurface Exploration

The primary component of a subsurface exploration is an exploratory boring program to collect soil and/or rock samples for classification and laboratory analysis. The number, location, and depth of exploratory borings should be designed taking into account site-specific conditions including the results of a general geologic review, the availability of access, and cost relative to the incremental data acquired (ASCE 2005, p. 8) (AGA 1995, p. 30).

Non-intrusive exploratory methods (geophysical methods) may be employed to augment exploratory borings and assist in producing a GCP. However, because of the need for physical samples for testing and borings for correlation of geophysical methods, exploratory borings are expected to remain the cornerstone of any HDD subsurface exploration (AGA 1995, p. 30).

General guidelines for design of an HDD exploratory boring program are as follows.

Exploratory Boring Location and Spacing

Borings should not be located on the drilled path centerline to reduce the possibility of drilling fluid inadvertently surfacing through a completed boring during installation (ASCE 2005, p. 8). If space allows, borings should be offset a minimum of 50 feet from the centerline. Borings should be placed near, and bracket if possible, anticipated locations of formation transition (ASCE 2005, p. 8).

In the absence of controlling site-specific conditions, boring spacing may range between 500 and 2,000 feet longitudinal to the drilled path. Spacing offset from the drilled path should be between 50 and 100 feet and borings should be placed on both sides of the drilled path.

Actual boring locations should be surveyed so that the horizontal and vertical position of the boring will be known. Boring locations should be referenced to the same horizontal and vertical control system used in the drilled path design.

Exploratory Boring Depth

Borings should penetrate to an elevation below the depth of the proposed drilled path to provide information for design modifications as well as anticipated drilling deviations (ASCE 2005, p. 8). In the absence controlling site-specific conditions, all borings should penetrate to an elevation 60 feet below the lowest elevation of the obstacle being crossed. In the case of a waterway, this would be 60 feet below the deepest point.

Sampling Interval and Technique

Sampling interval and technique should be set to accurately describe subsurface material characteristics taking into account site-specific conditions. Split spoon samples should be taken in overburden at five-foot depth intervals in accordance with ASTM D 1586, *Standard Test Method for Penetration Test and Split Barrel Sampling of Soils*. Thin wall tube samples taken in accordance with ASTM D 1587, *Standard Practice for Thin-Walled Tube Sampling of Soils for Geotechnical Purposes*, may also be taken if deemed beneficial in clay. Bedrock should be continuously cored in accordance with ASTM D 2113, *Standard Practice for Rock Core and Sampling of Rock for Site Investigation*, to the maximum depth of the boring. (ASCE 2005, p. 9) (AGA 1995, p. 31).

Exploratory Boring Abandonment

Steps for abandoning exploratory borings in accordance with local government regulations must be undertaken. In the absence of local regulations and at a minimum, borings should be backfilled in a manner that will reduce the possibility of drilling fluid migration along the borehole during subsequent HDD operations. A mixture containing cement grout and a bentonite product to promote expansion is recommended. Borehole drilled spoil may be incorporated into the backfill mixture if considered beneficial. The upper 5 feet of land borings should be backfilled with the surrounding soil and the surface graded smooth (ASCE 2005, p. 9).

Laboratory Tests

A laboratory testing program for an HDD subsurface investigation has two functions: 1) to provide data necessary for soil classification in accordance with ASTM D 2487, and 2) to provide data that may be used by contractors to assess drillability and prepare a drilling cost estimate.

For fine-grained soils and sands (SW through OH), data required for classification is all that is needed. These soils can generally be drilled with a jetting assembly. Standard Penetration Test values obtained during sampling will provide an indication of the relative density or consistency of the soil (Terzaghi and Peck 1967, p. 341, p. 347).

For coarse-grained soils (GC through GW), more detailed data should be provided. Sieve analyses (ASTM D-422) should be run with results plotted on a grain size chart. This provides a more detailed indication of the character of the soil.

For bedrock, percent recovery and Rock Quality Designation (RQD) values obtained during coring should be provided. Density should be measured and provided. Applicable laboratory tests are listed below.

- Unconfined Compressive Strength (ASTM D 2938) While unconfined compressive strength is not a direct indicator of drillability, it is a commonly run test and has been historically used in the HDD Industry to assess drillability.

- Mohs Hardness Mohs hardness values are subject to substantial variation, but they provide a reasonable indication of hardness and can be obtained using a relatively inexpensive and commonly run test.
- Cerchar Abrasivity The Cerchar Abrasivity Test has not been generally used in the HDD Industry.
- Splitting Tensile Strength (Brazilian Tensile Strength) (ASTM D 3967) The Splitting Tensile Strength Test has not been generally used in the HDD Industry.

Development of methods for assessing drillability of bedrock is ongoing. The tests listed above provide data that may be used in existing methods, or in developing new methods. Different data requirements should be anticipated as analytical methods specific to the HDD Industry evolve.

In the absence controlling site-specific conditions, applicable laboratory testing should be performed on samples from all borings with an approximate vertical spacing of 5 feet. Test results will vary. Multiple samples should be tested to discern the range of values applicable to the formations through which the drilled path will pass.

Geotechnical Data Report

A Geotechnical Data Report (GDR) that presents all of the factual subsurface information gathered for use in design and construction of the HDD installation should be prepared. The GDR should include the following components (ASCE 1997, p. 20).

- a general geologic review;
- a description of the subsurface exploration program;
- a description of the laboratory testing program;
- the logs of all borings and/or test pits; and
- the results of all field and laboratory testing.

The GDR should be provided to contractors for their review and use in preparing a drilling cost estimate. However, the contractual baseline for the drilling cost estimate is presented on the Geotechnical Characterization Profile (GCP). From a contractual standpoint, the GCP should take precedence over the GDR.

Contract Forms

Typically, HDD installations are undertaken under “fixed-price contracts” with the contractor in the position of an “independent contractor”. A fixed-price contract is one in which the owner agrees to pay the contractor a predetermined price for the work regardless of any increases in the contractor’s costs to produce the work (Black 1999, p. 321). An independent contractor is one who is engaged to undertake a specific project but is left free to determine the means and methods for accomplishing the project (Black 1999, p. 774). Prices for HDD installations under fixed price contracts are generally lump sums or unit rates for production (i.e., per foot of pipe installed).

Most HDD Contracts are considered to be “no hole, no pay”. “No hole, no pay” is an HDD Industry term meaning no payment will be made to the contractor if the crossing is not completed in accordance with the plans and specifications. The plans and specifications are structured to control the final characteristics and quality of the pipeline crossing, not the independent contractor’s means and methods employed in installing the crossing.

It is unusual, but not unheard of, for HDD installations to be undertaken using a “daywork contract”. A daywork contract is one in which the contractor is paid a fixed amount per day, or some other unit of time, for providing and operating an HDD drilling spread in accordance with the owner’s requirements. Payment is based on the passage of time regardless of whether or not a pipeline crossing is completed (AGA 1995, p. 77).

Contract forms are not standard. Owners generally develop contract forms in-house. Contract conditions can be negotiated for specific projects and contracts incorporating features of both fixed price and daywork contracts have been employed.

Risk

Risk is defined as the possibility of loss (Black 1999, p. 1328). Risk cannot be eliminated on an HDD installation. It must be managed. To be managed, HDD risk must be understood. Categorizing risk aids in understanding risk.

Risk on an HDD project may be divided into two broad categories, surface and subsurface. Surface risk involves typical events such as weather delays, regulatory delays, and consumable price increases. These risks are well understood and managed and need not be discussed. Subsurface risk involves losses that result from occurrences downhole such as delays associated with rock drillability.

Subsurface Risk

Subsurface risk may be further divided into two categories, unknown conditions and unknown reactions.

Unknown conditions risk results from the fact that subsurface investigation methods do not allow, within practical economic limits, the detailed definition of every formation through which an HDD installation will pass (AGA 1995, p. 78). For example, bedrock may be indicated at varying elevations in a series of borings spaced 500 feet apart. It may seem logical to “connect the dots” of bedrock elevation in each boring with a straight line and thus define the location of bedrock. In fact, significant peaks and troughs may be present between the borings. The straight line interpolation may be totally inaccurate. The complete contour of the bedrock is essentially unknown.

Unknown reactions risk results from the fact that the performance of drilling tools in various formations may be unpredictable. For example, a drilled path may be designed to penetrate bedrock. Properties of the bedrock may be accurately determined from laboratory testing. Nevertheless, the penetration rate of a particular bit on a particular motor may be unknown. Drilling progress may be slower than estimated even though the bedrock location and properties have not varied.

Differing Site Conditions

Owners have traditionally felt that both categories of subsurface risk were assumed by contractors in a fixed price contract and it was the contractors' responsibility to bid projects with enough contingency included to offset this risk (AGA 1995, p. 78). This belief can be summed up in the expression "You bid it – you build it" (ASCE 1997, p. 13).

In the early years of HDD development and application this contracting philosophy was satisfactory. Projects were installed mainly in the alluvial soils of the United States Gulf Coast. Subsurface conditions were consistent and predictable. Competition among contractors was not such that margins were reduced to levels with very limited capacity to absorb risk.

That is no longer the case. HDD installations have been completed in just about every conceivable subsurface condition. As HDD has become the "conventional" method of installing pipeline crossings, more contractors have entered the business and bids are more competitive. Claims for extra compensation based on the theory of Differing Site Conditions (DSC) are not unusual.

DSC clauses are commonly included in contracts that involve subsurface construction (ASCE 1997, p. 13). A typical DSC clause prepared by the Engineers Joint Contract Documents Committee is presented below (EJCDC 1983, pp. 10-11).

4.2.3. *Report of Differing Conditions:* If CONTRACTOR believes that:

4.2.3.1. any technical data of which CONTRACTOR is entitled to rely as provided in paragraphs 4.2.1 and 4.2.2 is inaccurate, or

4.2.3.2. any physical condition uncovered or revealed at the site differs materially from that indicated, reflected or referred to in the Contract Documents,

CONTRACTOR shall, promptly after becoming aware thereof and before performing any Work in connection therewith (except in an emergency as permitted by paragraph 6.22), notify OWNER and ENGINEER in writing about the inaccuracy or difference.

4.2.4 *ENGINEER's Review:* ENGINEER will promptly review the pertinent conditions, determine the necessity of obtaining additional explorations or tests with respect thereto and advise OWNER in writing (with a copy to CONTRACTOR) of ENGINEER's findings and conclusions.

4.2.5 *Possible Document Change:* If ENGINEER concludes that there is a material error in the Contract Documents or that because of newly discovered conditions a change in the Contract Documents is required, a Work Directive Change or a

Change Order will be used as provided in Article 10 to reflect and document the consequences of the inaccuracy or difference.

4.2.6 Possible Price and Time Adjustments: In each such case, an increase or decrease in the Contract Price or an extension or shortening of the Contract Time, or any combination thereof, will be allowable to the extent that they are attributable to any such inaccuracy or difference. If OWNER and CONTRACTOR are unable to agree as to the amount or length thereof, a claim may be made therefore as provided in Articles 11 and 12.

This type of contract condition has evolved over several decades to provide a contractual basis for relief to contractors when site conditions are encountered that are more adverse than those indicated in the contract documents. The objective of including a DSC clause is to remove unknown subsurface condition risk from the contractor and thereby reduce the contingency portion of bid prices (ASCE 1997, p. 12).

Alternative Dispute Resolution

Methods for conducting subsurface investigations, integrating the results of these investigations into construction documents, and analyzing risk associated with HDD installations have been presented in this paper. Application of these methods will reduce claims for extra compensation on HDD installations and streamline the claims process when extra compensation is merited. Nevertheless, disputes on construction contracts are inevitable. This is especially true for HDD installations with the work carried out below the surface where actual conditions are difficult to verify. Therefore, a method for efficiently and effectively resolving disputes is beneficial. The Dispute Resolution Board (DRB) process presents such a method.

The DRB process has proven to be a successful method for avoiding and resolving claims and disputes since it was first employed in 1975. Simply put, a DRB is a board (typically three members) of impartial and knowledgeable professionals formed at the beginning of a project to be familiar with the details of the project, encourage dispute avoidance, and assist in the resolution of disputes for the duration of the project (DRBF 2007).

A DRB provides significant advantages over litigation or arbitration. DRB action is quick, in most cases while the project is ongoing, and carried out by technically knowledgeable professionals. The cost of the process will be less than an adversarial process carried out in court by lawyers. The actual value of a claim may also be less since analysis and action are taken close to the point in time when a loss is experienced. This allows the magnitude of a loss to either the owner or contractor to be minimized by modifying practices in the field or abandoning practices that are not technically feasible.

References

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