The Use of Mini-Horizontal Directional Drilling for Placement of HDPE Pipe in Water Applications

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User-friendly guidelines for the placement of high density polyethylene (HDPE) pipe with mini-horizontal directional drilling equipment have recently been developed by the Plastics Pipe Institute (PPI). Technical Report TR-46, "Guidelines for Use of Mini-Horizontal Directional Drilling for Placement of High Density Polyethylene Pipe," represents a comprehensive set of information that can be used for water applications. The new document is intended to provide information analogous to that provided in ASTM F 1962, "Standard Guide for Use of Maxi-Horizontal Directional Drilling for Placement of Polyethylene Pipe or Conduit Under Obstacles, Including River Crossings," but at a level appropriate for the less complex mini-horizontal directional drilling (mini-HDD) technology and typical project characteristics. The document reflects the latest industry information and also includes new information on HDPE pipe selection methodology.

Figures 1 and 2 illustrate typical mini-horizontal directional drilling (mini-HDD) equipment, and pilot boring and back reaming operations, including placement (pullback) of the product pipe for water applications.

Mini-HDD is typically employed for boring segments less than 600 feet in length, at depths up to 15 feet, and placing pipes up to 12 inches in diameter. In contrast, maximum-horizontal directional drilling (maxi-HDD) technology is capable of accurately boring holes thousands of feet in length, and placing pipes of 48 inches or greater, at depths up to 200 feet. Maxi-HDD machines may weigh as much as 30 tons, or greater, and are appropriate for placing pipes under large rivers and other major obstacles.

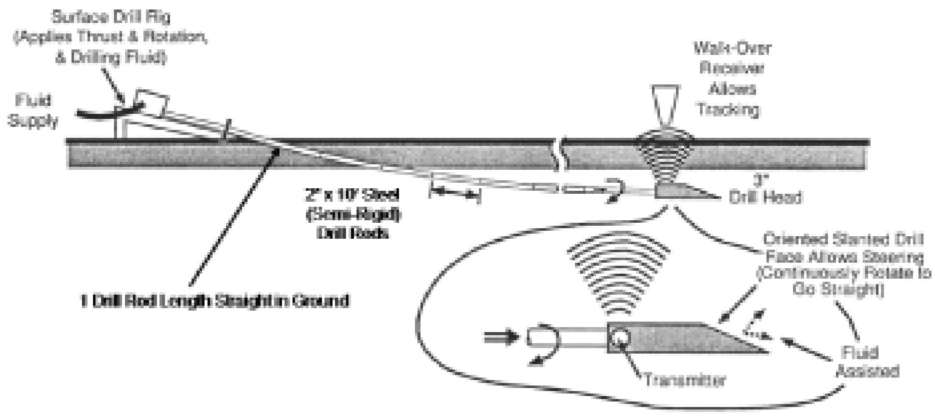

Figure 1 Typical Mini-HDD Equipment and Pilot Boring Process

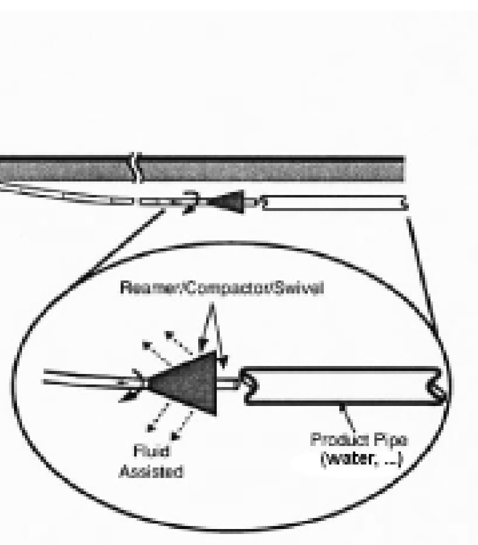

Figure 2 Typical Mini-HDD Back-Reaming and Pipe Pullback Process

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The ASTM F 1962 provides recommended procedures for the placement of HDPE pipe using maxi-HDD. It provides overall guidelines, addressing preliminary site investigation, safety and environmental considerations, regulations and damage prevention, bore path layout and design, implementation, and inspection and site cleanup. One of the significant contributions of the document is the provision of a rational, analytical method for selecting the polyethylene pipe strength based on the estimated installation and post-installation (operational) loads on the polyethylene pipe. The ASTM F 1962 therefore provides a means of determining project feasibility, as well as initial design information.

While the ASTM F 1962 guidelines are convenient and practical to apply by experienced engineers for a maxi-HDD operation, the corresponding equations and procedures represent relatively complicated formulas, and an extensive tedious methodology, when considering smaller, lower-cost operations associated with typical mini-HDD applications, including those associated with placing a new water distribution line. Nonetheless, some mini-HDD installations may be considered to be relatively critical with respect to the capability of the available drill rig and/or the strength of the product pipe being installed, and for which a relatively convenient, although possibly less precise, design procedure would be desirable. Furthermore, any construction procedure must address basic safety rules, avoid damage to existing facilities, adhere to applicable government regulations, and consider environmental issues. Report TR-46 was therefore developed to serve as an inclusive document, providing practices for placement of HDPE pipe for various applications, using mini-HDD. The document is available via the PPI website at http://plasticpipe.org/pdf/tr-46-hdd-guidelines.pdf.

Report TR-46 reflects the latest industry information and also includes new information not readily available elsewhere. For example, easy-to-understand guidelines are provided for proper drill rig positioning that are consistent with meeting required placement depths and drill rod capabilities, as well as for estimating the relevant forces and effects present during installation, allowing proper selection of the pipe strength.

Report Details

Technical Report TR-46 contains several main chapters or sections, briefly described below.

Scope, Related Industry Standards and Terminology

The TR-46 addresses planning, design, drill rig setup, and installation practices for the placement of polyethylene pipe using mini-HDD equipment. The primary focus is on commonly used high density polyethylene (HDPE) pipe with a material designation code of either PE3608 or PE4710. Information is also provided for pipe of medium density polyethylene (MDPE) PE2406/2708 material. Depending on the diameter, polyethylene pipe may be supplied in continuous lengths on a reel, or by discrete segments, which would typically be fused together in the field. In addition to water supply applications, such pipe may be used for conveying various other fluids (natural gas, oil, etc.), as well as conduits for containing utility cables.

Preliminary Site Investigation

The general feasibility of utilizing mini-HDD technology for placing the proposed pipeline(s) must be determined prior to any proposed construction activities. Such a preliminary investigation is required to gain an understanding of the local characteristics in order to help ensure a cost-effective, efficient and, above all, safe operation. Of particular importance, and as addressed in other sections of the guidelines, is the awareness of existing utilities in the vicinity of the proposed pipeline and the need to maintain minimum specified clearances during the construction process.

Safety and Environmental Considerations

Safety is a primary concern during any activity, including construction utilizing mini-HDD equipment and procedures. Potential safety issues fall into two general categories: (1) those directly related to the setup and operation of the mini-HDD equipment, and (2) those associated with the proper location, identification, and marking procedures intended to avoid contact with, and damage to, existing utilities. This section provides practices to avoid or minimize equipment-related risks during mini-HDD operations. Employees must be trained to prevent injury to themselves during the operation of the equipment and be prepared to mitigate accidents, so electric power and gas line strikes are specifically addressed. Although not considered to be hazardous materials, the proper handling and disposal of drilling fluid is also discussed to avoid possible environmental issues.

Regulations and Damage Prevention

This section addresses the second category of potential safety issues, focusing on procedures to eliminate or reduce hazards associated with damaging existing utilities, such as initial boring or backreaming operations. Recommended practices include: "call before you dig" (811); properly locating and marking existing utilities, as well as exposing such utilities at anticipated crossings with the bore path; avoiding mechanized digging within the required tolerance zone; and the use of subsurface utility engineering, as described in CI/ASCE 38, "Standard Guidelines for the Collection and Depiction of Existing Subsurface Utility Data."

Pipe Design and Selection Considerations/ Bore Path Planning and Drill Rig Setup

These two sections contain new informa-

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tion that is not readily available or in a convenient format elsewhere. This information is discussed in greater detail below.

Implementation

It is beyond the scope of the TR-46 guidelines to provide detailed operational procedures for the various mini-HDD and auxiliary equipment, which are generally available from the manufacturers or other sources. However, proper procedures are described for pilot boring, tracking, steering, reaming and pullback operations, as well as pipe handling and connection, and record keeping.

Completion

Following installation of the pipe, it is necessary to confirm the viability of the new facility, provide a permanent record of the actual placement location, and ensure final site cleanup. In particular, the integrity of the pipes should be appropriately verified, depending upon the application and the owner specifications. For water applications, any mud or debris that may have entered the pipe must be expelled, the pipeline flushed, and the system pressurized and checked for leakage.

Pipe Design and Selection Considerations

Report TR-46 contains a convenient calculation method for the selection of the HDPE pipe strength. The procedure is presented in an easy-to-understand format and appropriate for users with various backgrounds. In particular, the procedure provides a means of selecting the pipe strength to avoid collapse due to hydrostatic pressure at the desired placement depth and to withstand the required pulling loads during installation.

Minimum Wall Thickness Based upon Depth

The HDPE pipe strength is directly related to the wall thickness as specified by its dimension ratio (DR), defined as the ratio of pipe diameter to wall thickness. The TR-46 guidelines indicate that essentially all the commonly used wall thicknesses for HDPE pipe (i.e., DR 7.3 to DR 17) would be sufficiently strong for depths to approximately 15 feet—the typical limit for mini-HDD installations. Thinner walled pipe, such as DR 21, are normally not used but may be adequate for very shallow depths, such as 7 feet or less, depending on the ability to withstand expected surface loads. For depths greater than 15 feet, very thin wall HDPE or MDPE pipe, or special situations, the adequacy of the product for the application should be verified using the supplementary information provided in the document. In some cases, such as very thin-walled pipe and/or relatively large depths, special practices or precautions not typically employed during mini-HDD installations may be required. For example, filling the pipe with water during pullback simultaneously reduces the net external hydrostatic pressure during (and following) installation and the buoyant weight of the pipe, resulting in reduced pull loads.

Table 1 Safe Pull Tension (lbs), HDPE (PE3608) Pipe, 1 Hour – IPS Sizes

Nominal Size	Pipe Diameter to Thickness Ratio (DR)						
	7.3	9	11	13.5	15.5	17	21*
2-in.	2,998	2,505	2,096	1,739	1,530	1,404	1,085
3-in.	6,511	5,439	4,551	3,777	3,324	3,049	2,356
4-in.	10,762	8,991	7,524	6,244	5,494	5,040	3,895
6-in.	23,327	19,488	16,307	13,533	11,909	10,924	8,442
8-in.	38,399	32,080	26,844	22,278	19,603	17,982	13,897
12-in.	86,398	72,180	60,398	50,125	44,108	40,461	31,268

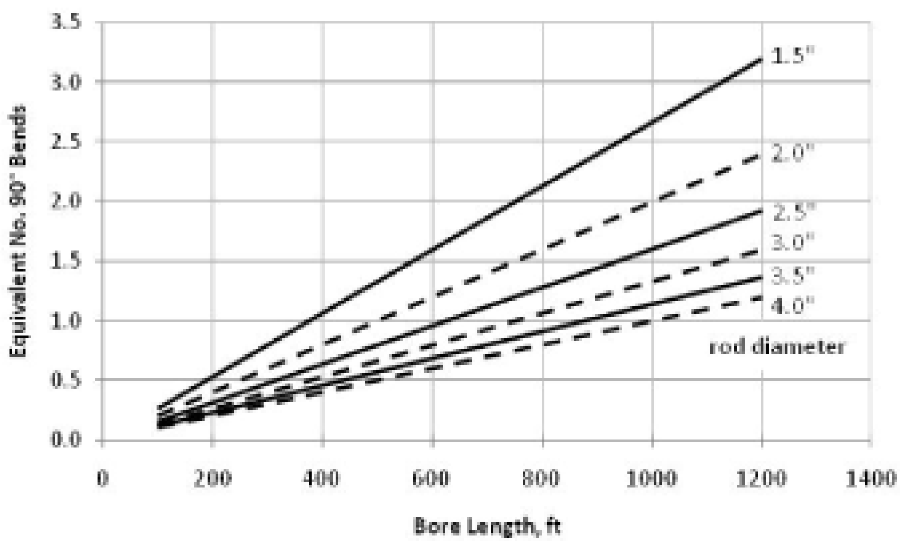

Figure 3: Unplanned Curvature, n_2

Minimum Wall Thickness Based upon Pulling Load

Table 1 provides the "safe pull tension" for HDPE (PE3608) pipe as a function of pipe (nominal) diameter and wall thickness (DR value). These values are conservative, and are intended to account for the cumulative load duration on the pipe and avoid non-recoverable viscoelastic deformation, as well as provide a degree of margin to account for inherent uncertainty in determining the pull load. This is difficult to predict, regardless of the procedure used for such calculations (Slavin and Petroff, 2010). For MDPE pipe, the tabulated values must be adjusted by a factor of approximately 0.80 and, for PE4710 material pipe, increased by a factor of approximately 1.05.

The following simplified equation has been developed for the purpose of estimating the pull load during mini-HDD installations of polyethylene pipe:

Tension (lbs) = [Bore Length (ft) x Buoyant Weight (lbs/ft) x (1/3)] x $(1.6)^n$

The buoyant weight may be conveniently determined as:

Buoyant Weight (lbs/ft) = ½ [Pipe Outer Diameter (in.)] ^{2} ***– Pipe Weight (lbs/ft)***

The term n is equal to the number (including fractions) of effective 90° bends due to cumulative route curvature, where $n = n_1 + n_2$. The quantity n1 is the number of planned (deliberate) 90° route bends, and n_2 is the number of effective route bends resulting from typical path corrections and route curvature during the pilot boring operation, for which the following guideline is suggested:

n_2 ***= [Bore Length (ft) / 500 ft] x [2-in / Rod Diameter (in.)]***

The quantity n_2 is shown in Figure 3 for various rod diameters.

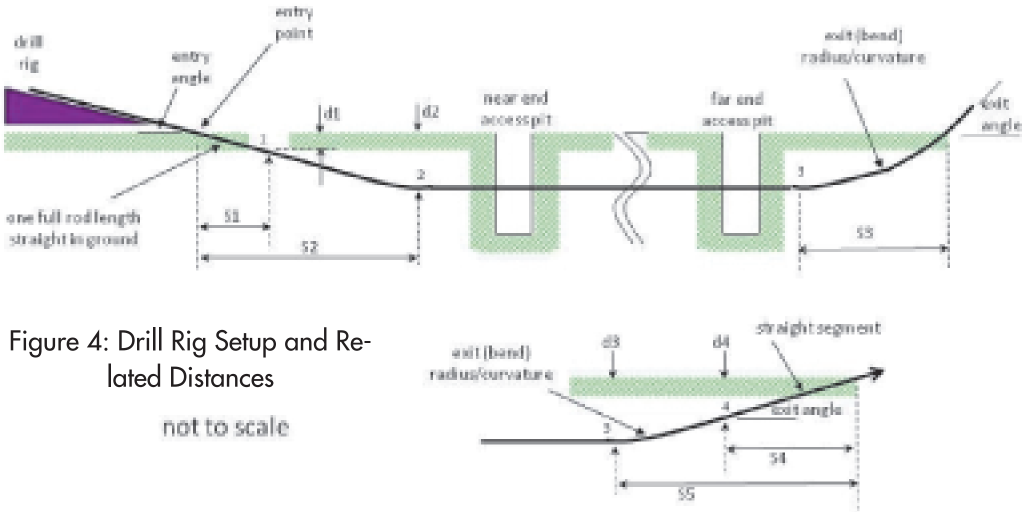

Figure 4: Drill Rig Setup and Related Distances

not to scale

For a specified pipe diameter, the procedure for selecting an appropriate pipe strength (DR value) consists of comparing the estimated pull load to the strengths in Table 1. This procedure is similar, but much less complicated, than that incorporated in ASTM F 1962 for the more sophisticated maxi-HDD installations. The present mini-HDD calculations will generally result in considerably shorter placement distances than those corresponding to the design methodology provided in ASTM F 1962, which may result in possible pullback distances of several thousand feet. Mini-HDD installations suffer relative to those performed using typical maxi-HDD technology due to the lesser degree of control (e.g., greater cumulative route curvature) and the desire to forego the use of anti-buoyancy techniques, such as inserting water into the pipe during pullback to reduce buoyant weight and significantly reduce required pull loads.

In general, the preceding formulas and methodology are recommended for estimating pull loads for mini-HDD installations. Other methods for determining pulling loads are typically based on well-controlled maxi-HDD installations and not representative of actual mini-HDD applications with respect to anticipated pull loads.

Bore Path Planning and Drill Rig Setup

In comparison to maxi-HDD installations, for which the design of the bore path is typically performed by experienced engineers or organizations, the contractor using mini-HDD is generally responsible for cost-effectively accomplishing this task. Thus, TR-46 provides user-friendly drill rig setup and bore path planning information consistent with meeting the requirements of the project owner, including geographic constraints and placement depth. The ability to satisfy the overall requirements depends on the bending characteristics of the steel drill rods and the drill rig setup parameters.

Figure 4 illustrates a typical mini-HDD bore vertical profile trajectory, including occasional pits along the route. These pits may be required for pipe splicing, completing lateral connections, or exposing existing utilities. The

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pits may also be useful for collecting drilling fluid from the boring or reaming operations. The bending capability and length of the drill rods, and their entry angle to ground surface, will determine the minimum depth achievable at the beginning of the bore path.

In order to achieve a specified depth at a particular point at the beginning of a pilot bore operation, the front of the drill rig must be located an appropriate distance rearward from the point of interest. Knowledge of such minimum setback requirements is important with respect to verifying that there is sufficient space available to properly perform the mini-HDD operation. For example, point 1 (Figure 4) is located directly along the entry path of the drill rod, where the resulting bore path is inclined at the entry angle, and the setback distance corresponding to reaching the depth d1 is designated as S1. This represents the minimal setback distance for achieving a specified depth, independent of the orientation of the bore path, which is not level at that point.

Beyond point 1, the drill rods are steered such that the bore path trajectory becomes level at point 2, corresponding to a depth d2 and setback distance S2. For the same depth of interest, the distance S2 is significantly greater than S1. The greater distance is required to allow the drill rods to establish an upward curvature consistent with achieving a horizontal orientation. The S2 setback distance depends on both the entry angle and rod characteristics. Due to the limited bending capability of the rods, as well as the recommendation that the first drill rod be placed in the ground without any curvature or steering (see Figure 1), there is a minimum depth, designated as $(d2)_{min}$, at which the trajectory is able to become level.

The setback distances S1 and S2 are a function of the depth, d1 or d2, respectively, as shown in Figure 5, for a representative 10-foot-long drill rod, with a minimum bend radius or curvature of 100 feet. The minimum depth $(d2)_{min}$ is identified by the minimum depth plotted for the S2 curves. As an example, for an entry angle of 15°, a depth d1 of 72 inches will be achieved at a setback distance S1 of approximately 22 feet. In comparison, a setback distance S2 of at least 35 feet is required to reach the same depth d2 at a level trajectory. Figure 5 also indicates that this entry angle and drill rod combination is not consistent with achieving a level trajectory at depths shallower than approximately 72 inches. If it is necessary to become level at a shallower depth, a lower entry angle and/or drill rod with a smaller allowable bend radius would be required.

Information regarding other significant dimensions, including required horizontal distance for surface rise, and for drill rods for different characteristics, is also provided in a similar format.

Conclusions

This new document is intended to provide information analogous to that provided in ASTM F 1962 for maxi-HDD projects, but at a level appropriate for the less complex mini-HDD technology. Although the TR-46 guidelines are primarily described with respect to mini-HDD operations, guidelines for the use of midi-HDD machines and associated practices may be obtained from the present TR-46 document, and/or ASTM F 1962, depending upon the particular application and the judgment of the contractor or engineer.

References

- ASTM F 1962, "Standard Guide for Use of Maxi-Horizontal Directional Drilling for Placement of Polyethylene Pipe or Conduit Under Obstacles, Including River Crossings," American Society for Testing and Materials.
- CI/ASCE 38, "Standard Guidelines for the Collection and Depiction of Existing Subsurface Utility Data," American Society of Civil Engineers.
- Slavin, L.M and Petroff, L., 2010. "Discussion of ASTM F 1962 or 'How are the Pulling Load Formulas Derived and How are they Used ?'," NO-DIG 2010, North American Society for Trenchless Technology.

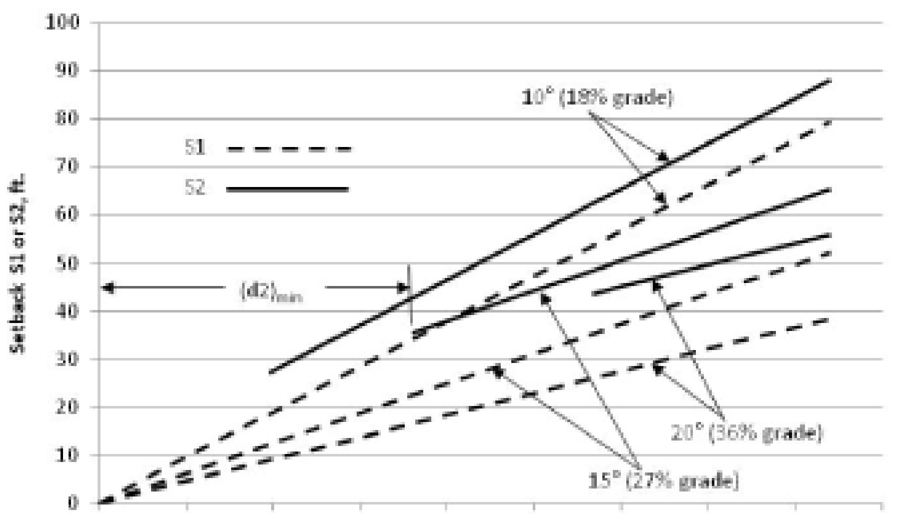

Figure 5: Drill Rig Minimum Setback Distance Drill Rods:
10 Feet Long, 100 Feet Radius of Curvature