A STUDY ON CONSTRUCTION ASPECTS OF HDD

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A STUDY ON CONSTRUCTION ASPECTS OF HDD

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CERTIFICATE

This is to certify that the work contained in this thesis titled "A study on Construction Aspects of HDD" has been carried out by Arun Varghese under my supervision and has not been submitted elsewhere for a degree.

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ABSTRACT

Horizontal directional drilling is versatile form of utility construction and has seen enormous growth in the last decade as it offers a clear alternative to conventional methods. Drilling is conducted in both the vertical and horizontal direction and can be steered within; dependent upon subsurface conditions. HDD can install utilities from 1 to 48 inch diameter and up to 6000 feet in length. The construction process along with drill bits, reamers and pipeline materials discussed in this project. The advantage of cost reduction and environmental, social and time benefits will be examined. This document provides best practices and recommended procedures for the investigation, planning and construction procedure of an HDD installation for pipeline construction.

NOMENCLATURE

1. Do - Outside diameter
2. Di – Inside diameter
3. T – Wall thickness
4. I – Moment of inertia
5. Wt – Weight of pipe in air
6. As- Cross sectional area of pipe
7. R – Radius of curvature
8. E – Modulus of elasticity
9. μ_d – Co-efficient of drag
10. d_m – Mud density
11. HDD – Horizontal Directional Drilling
12. HDPE – High density poly ethylene

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CHAPTER 1

INTRODUCTION

Horizontal directional drilling (HDD) has emerged as a preferred crossing method in many situations for the installation of oil and gas pipelines as well as other utilities under watercourses, roads, rail lines, steep slopes and other obstacles. This technology has been enthusiastically embraced by proponents- contractors and regulators as a potentially low impact construction technique in many cases. however, the suitability of the HDD method must be evaluated and Compared to more traditional open-trench construction techniques in order to ensure that an appropriate: technique is chosen for the conditions and concerns present at a particular crossing Recognition of the advantages, limitations and potential risks of HDD is all important step in this evaluation.

The successful design and construction of an HDD is the result of a team effort combining the skills of the regulatory group, owner, Engineering consultant, Environmental consultant, inspection services and the specialist HDD contractor. Success in this endeavor is measured in more than the successful pull back of the prebuilt pipeline drag section. It is the completion of the project for a reasonable cost with minimal environmental impact and in a manner that allows the contractor to make a fair profit. These should be the goals in any type of project including an HDD installation. It is important to realize that an HDD may represent the critical path on the overall project schedule. In addition an HDD may have the highest risk of failure of any activities on a project. Therefore, all aspects of planning, design and construction for an HDD need to be assigned a high priority or importance value clue to their potential effect on the overall project.

CHAPTER 2

LITERATURE REVIEW

(2.1) Description of HDD:

Horizontal directional drilling is a trenchless construction method utilizing equipment and techniques from horizontal oil well drilling technology and conventional road boring. HDD construction is used to install Petroleum pipelines (Steel or plastic), fiber optic and electric cables, and water and waste water pipelines where conventional open trench construction is not feasible or will cause adverse disturbances to environmental features, land use or physical obstacles.

HDD technology is used in many situations, including, the following:

Lake crossings;

Wetland crossings;

Canal and watercourse crossings;

Valley crossings;

Sensitive wildlife habitat;

Road and railway crossings.

HDD installation involves four main steps:

1. Pre-site planning;
2. Drilling a pilot hole;
3. Expanding the pilot hole by reaming; and
4. Pull back of pre-fabricated pipe.

The following summarizes the main activities that take place during each phase of an HDD. Drilling of the Pilot hole and pipe string pull hack are illustrated on.

(2.1.1) Pre-Site Planning:

A determination is made as to whether an HDD is technically and geotechnical feasible by studying existing geological data and conducting field investigations to assess the subsurface conditions and characteristics likely to be encountered during the drill. If an HDD is determined to be feasible, a drill path is designed to meet the requirements of the crossing and appropriate drill entry and exit locations are selected An allowance is made in the design of the drill path fur any potential changes in the obstacle (i.e., stream migration or cutoff development) to be drilled under and the drill entry and exit points are refined.

(2.1.2) Drilling the Pilot Hole:

An HDD drill rig and supporting equipment are set-up at the drill entry location determined during the pre-site planning phase, A pilot hole is drilled along the predetermined drill path. Periodic readings from a probe situated close to the drill bit are used to determine the horizontal and vertical coordinates along the pilot hole in relation to the initial entry point; the pilot hole, path may also be tracked using a surface monitoring system that determines the down hole probe location by taking measurements from a surface point. Drilling fluid is injected under pressure ahead of the drill bit to provide hydraulic power to the down hole mud motor (if used), transport drill cuttings to the surface, clean buildup on the drill bit, cool the drill bit, reduce the friction between the drill and bore wall, and stabilize the bore hole.

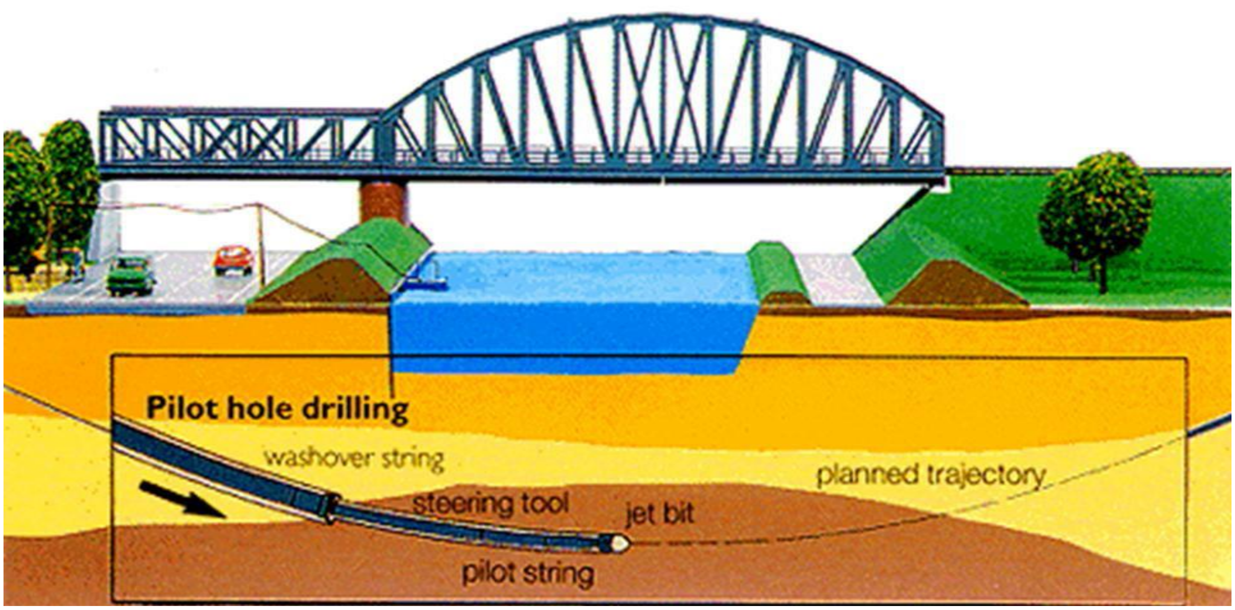

Fig source: waterworld.com

Fig 1: Drilling the pilot hole

(2.1.3) Reaming of the Pilot Hole:

The down hole assembly is removed from the drill string upon breaking the ground surface at the exit location and is replaced with a back reamer: The drill string is pulled back through the bore hole and the back reamer enlarges the diameter of the drill hole; The reamer may be pulled from the pipe side of the HDD crossing if additional passes with the reamer are required to achieve the desired bore hole diameter; and The reaming stage may not be necessary during HDDs for small diameter pipelines where the bore hole created by the pilot hole drill is of adequate size to pull back the pipe string.

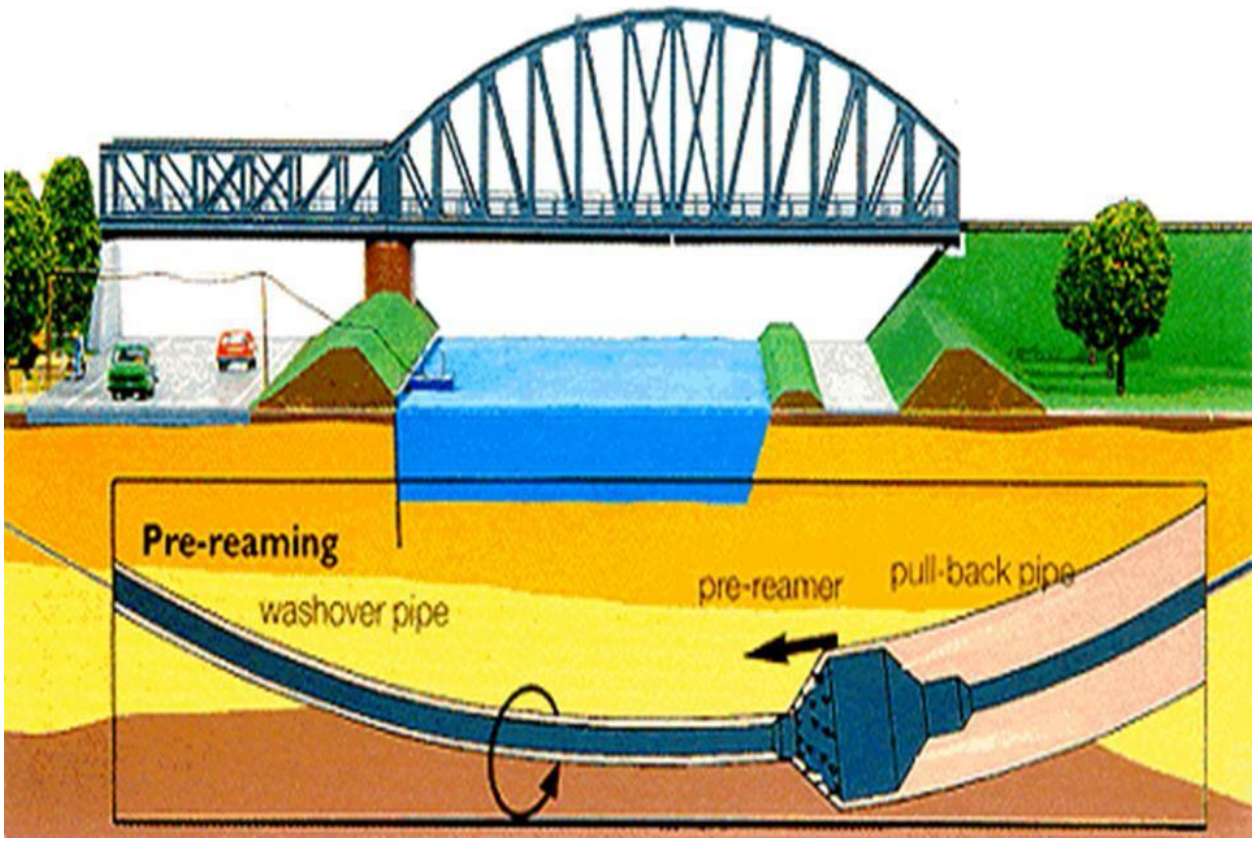

Fig Source: waterworld.com

Fig 2: Reaming of the pilot hole

(2.1.4) Pipe String Pull back:

Pipe is welded into a pipe string or drag section, that is slightly longer than the length of the drill, on the exit side of the bore hole. The pipe is typically coated with a corrosion and abrasion resistant covering, and is commonly hydrostatically pretested to ensure pipeline integrity. The pipe string is pulled over rollers into the exit hole and the pullback continues until the entire pipe string has been pulled into the bore hole. The external coating of the pipe string visible at the entry point is inspected for damage upon completion of the pull back. An internal inspection of the pipe string is performed to identify any damage done to the pipeline during the pull back. Upon successful pull back of the pipe string, the drilling equipment is dismantled and demobilized. The pipe string is connected to the conventionally laid pipeline and work areas are reclaimed with the rest of the pipeline right-of-way.

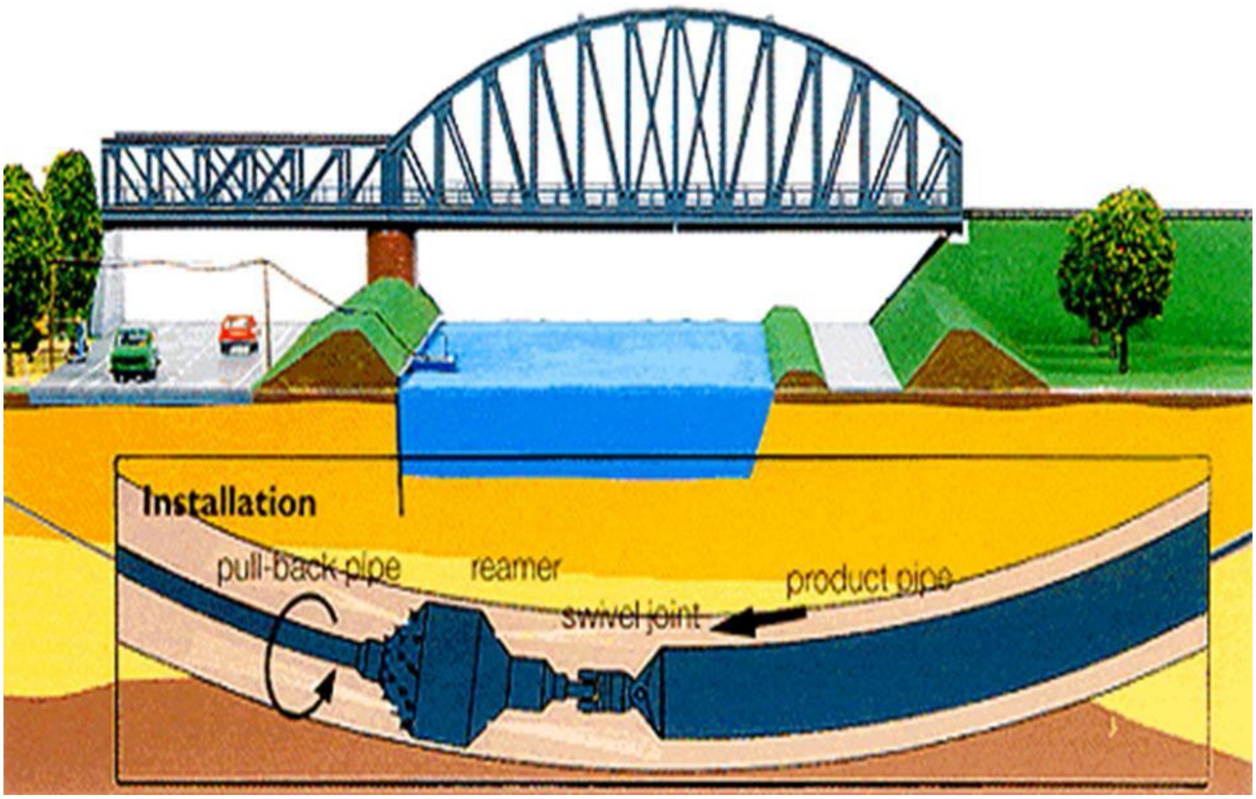

Fig source: waterworld.com

Fig 3: Pipe strings pull back

(2.2) Factors influencing HDD as the Preferred Crossing Method:

The decision to install an HDD crossing at a specific location is the result of a process that addresses the following issues like:

(2.2.1) Pipeline Route Selection:

The selection of a preferred crossing location based on an overland pipeline routing assessment should also consider the method of crossing, alignment and access for the HDD construction. The pipeline routing should allow for layout areas, entry/exit pads, access routes, and minimal points of inflection in the design drill path and the pipe string layout area.

(2.2.2) Crossing Location Selection:

The selection of the crossing should be undertaken in conjunction with the route selection to allow the following:

- Flexibility in using various crossing methods, especially if the HDD fails and an alternative crossing technique is required
- Flexibility to use various accesses or vehicle crossing methods
- Flexibility in refining the exact crossing location in the event that constraints prevent certain alignments.

(2.2.3) Crossing Method Selection:

In selecting a pipeline crossing method many factors must be taken into consideration. These include, among others:

- Pipeline diameter
- Project schedule
- Watercourse crossing width, depth and flow
- Environmental sensitivity and associated constraints
- Geotechnical concerns
- Substrate composition
- Hydrological data

- Costs of the various alternatives
- Navigation
- Amount of working space
- Regulatory requirements and conditions including timing constraints
- Equipment availability
- Contractor expertise
- Downstream water users
- Landowner and community issues
- Engineering constraints
- Construction season.

The selection of a crossing method is an exercise in striking, a balance among the considerations listed above to derive the most practical solution. The method that is preferred is usually that which is geotechnical feasible and offers the required level of environmental protection for the lowest cost. Selection of an HDD crossing when other methods are more cost effective, technically feasible and offer sufficient environmental protection may be inappropriate. If an HDD is the strongly preferred method by regulators and this method is considered to have a low likelihood of success or is otherwise impractical, the regulators should be provided detailed information on the crossing method selection process and the rationale for the rejection of the HDD method.

(2.2.4) Other Selection Issues:

Assuming that HDD has been selected as the preferred crossing method, the following other selection issues must be evaluated.

(2.2.4.1) Access:

Pipeline routing and drilling execution planning should consider that access to both sides of the drill will be required during the HDD construction process. If adequate access to the crossing cannot be provided on both sides of the watercourse and the watercourse is suitable for the installation of a crossing structure, a temporary crossing structure may need to be installed for vehicle and equipment traffic. As with the selection of the crossing method, selection of the vehicle crossing technique also involves striking a balance between many of the same considerations listed above for crossing method selection to derive the most practical solution. The technique that is preferred is usually one which offers the required level of environmental protection for the lowest cost. Access will also be required:

- To a water Source during the installation of the HDD
- For monitoring of the drill path
- During clean-up operations in the event of a drilling fluid release to surface.

Sediment and erosion control protection plans may be warranted to ensure that access creation or use do not result in adverse effects.

(2.2.4.2) Drill Entry and Exit Site Selection

The selection of the drill entry and exit locations will need to consider the following:

- The terrain must be cleared leveled and suitable for the work (sites with negligible longitudinal or side slopes are preferred)
- Entry and exit location should be of sufficient size and configuration to undertake the work safely : this should include consideration of
- Drill rig entry and points (note that generally the entry point should ideally be at an equal or lower elevation than the exit point)
- Rig size and layout requirements
- Pipe lay down area or false night-of-way (note that a straight approach to the exitpoint is preferred to avoid the need for false right-of-way)

(2.2.4.3) No Drill Zone:

A No Drill Zone can be identified that addresses geotechnical issues and concerns at the proposed crossing site. As defined by the -geotechnical engineer, the No Drill Zone is the upper limit of potential drill paths between specified entry and exit locations, intended to ensure that the bore is maintained within geological materials suitable for an HDD while providing sufficient cover to mitigate potential inadvertent return concerns. As detailed in next section, definition of the No Drill Zone for a proposed HDD crossing is influenced by a number of factors, including:

- Crossing area terrain conditions, in terms of the difference in elevation between entry and exit locations and along the HDD alignment, that determine, in large part, the minimum recommended depth of cover
- Subsurface soil and bedrock stratigraphic conditions, and the suitability of the various units for directional drilling
- River engineering considerations, including depth of scour during the design flood event and potential for bank/meander migration and cut oft development

The presence of active, inactive and potential landslide features, and other geotechnical “problem” areas, which should be avoided by the design drill path. All potential drill paths should be designed to pass outside of the No Drill Zone. While the No Drill Zone is typically defined in terms of geotechnical considerations, it may also be influenced by environmental and socio economic concerns, such as wildlife concerns, rare plant occurrences, social resources (e.g. land use) and Cultural resources (e.g., archaeological sites) etc. Specific studies may be necessary to identify the presence of these environmental and cultural features. Relocation of the entry and/or exit point, thereby altering the length of the design drill path, may provide a means of mitigating some of these non-geotechnical concerns.

(2.2.4.4) Water Source:

The availability of a water supply to the HDD site should also be considered during the planning stage of the project, Water will be required for the following:

- Initial drilling fluid make-up
- Additional drilling fluid as the drill progresses.
- Replacement fluid for drilling fluid escaping into the formation due to seepage or hydraulic fracture
- Pretesting, where warranted, of the pipe string.

Hydraulic fractures can greatly increase the water requirements during an HDD project. Water can be pumped from a water body to the drill site or hauled to storage tanks onsite.

Factors to be considered in selecting a water supply are:

- Access to the water body
- Flow restrictions
- Regulatory approval
- Construction schedule (i.e., air temperature, anticipated stream flow/volume and water quality).
- Physical limitations such as the distance or elevation of the entry point from the water body.

(2.3) Engineering Design Considerations:

Various factors to be considered before doing a HDD crossing are:

(2.3.1) Geotechnical Study

The most important aspect of a HDD crossing is the degree of effort taken to study the geotechnical aspects of the planned crossing. A comprehensive assessment of the underground conditions such as soil type, rock type, and their location relative to the planned drill crossing is required in order to properly design the crossing and ensure its success. Air photos, topographical maps, geological maps, previous job histories (road cuts, bridges, and other crossings), hydrology, and geological analysis are some of the tools used to study the intended crossing. Typically vertical exploration holes are made to retrieve core samples which are used to assess the extent and depth of varying underground conditions.1 It is important that the depth of the exploration holes is at least 10-15m below the intended drill path and that a sufficient number of holes are made to adequately define the underground conditions.

(2.3.2) Design of Drill Path:

The design of the drill path should consider all of the information gathered from the crossing area. The physical limitations of the site as well as geotechnical, environmental (fish. wildlife. vegetation, land use, cultural and hydrological information should be considered in the preparation of the drill path design.

(2.3.3) Limits of Curvature

The design of the drill path and selection of pipe must consider the following:

- The radius of the curves in the drill path.
- The exit and entry angle.
- The radius of the arc of the drill path should consider the diameter of the pipe to be installed.

The diameter of the pipe to be installed in meters multiplied by 1200; or The pipe diameter in inches multiplied by 100 to obtain a radius of curvature in feet. This formula is used of the ensure a conservative radius of curvature that will allow for the easy installation of the pipe and minimize the bending stress on the pipe. If the pipe is smaller than the drill string, the larger pipe size shall be used in the minimum radius calculations. This will ensure that the drill pipe will not be overstressed and the drill can proceed as planned. In most applications, the radius of curvature will not be lower than 250 m.

(2.3.4) Depth of Cover:

Depth of cover requirements are dependent upon a number of factors such as subsurface conditions, type of drilling equipment, mud pressure (which is a function of the mud pump capacity) and the difference in elevation between the entry and exit points. Depth of cover is a factor used in the development of the No Drill Zone in above section and should be determined by the HDD project team.

(2.3.5) Alignment:

Angles in the easement/right-of-way alignment adjacent to an HDD crossing should be minimized. If difficulties are encountered during an HDD, it may be necessary to increase the drill length. Therefore, the entry and/or exit points would need to be moved farther back from the location being crossed. The approach alignment to the HDD crossing needs to allow for the potential need for lengthening of the crossing.

(2.3.6) Right-of-Way:

The drill path should be aligned to lie within the right-of-way boundaries. If this is not feasible, new right-of-way must be acquired at a prior to commencement of the HDD. Temporary workspace is typically required at a crossing above and beyond that necessary for conventional pipeline construction. The pipe string will require additional workspace and, where the alignment on the exit side is not straight, additional workspace, typically referred to as false right-of-way, and may be required. This area should be of sufficient length and width to allow the pipe to be welded up and tested along the full length of the pipe string. It is highly recommended that the pipe string be fabricated in one complete section since any stoppage in pulling of the pipe string adds significant risk to the success of the project.

(2.3.7) Land Issues:

The land issues listed below should be considered during the planning phase of an HDD project;

- Landowner consultation during the routing, and crossing selection process, and when determining a water source for drilling activities.
- Landowner consultation when determining access to the water source.
- Landowner consultation to avoid Conflict with land use practices (e.g., drill in pasture when cattle have been rotated to another pasture or during the winter to avoid the crop year).
- Informing the landowner of HDD processes and applications to avoid potential issues.
- Landowner consent for access across lands not on the right-of-way for monitoring purpose and potential reclamation of inadvertent returns.
- Spills on the entry side and the pipe side of the drill may require reclamation and remediation as well as compensation to landowner and compensation for any habitats lost.
- Trespass off the right-of-way due to inadequate marking of designated work areas or inadequate location or amount of workspace.

(2.3.8) Casing:

Contractors often use a short section of casing that is 'dug in' at the start of construction. This casing is intended to prevent inadvertent near-surface returns, and allows for easy monitoring of drilling mud return levels. However, where unconsolidated deposits represent a risk of inadvertent returns on the entry side, the casing may need to be more extensive. The casing can either be driven in with a large hydraulic hammer or possibly, in softer soils, pushed in with the drill rig.

Casing should be of sufficient length to seal into a suitable competent formation such as bedrock or cohesive stiff clay. The casing diameter should be greater than the final reaming pass to ensure down hole tools can easily enter the bottom of the casing throughout the entire drilling operation and pull back. It is preferable to remove any casing at the end of the crossing construction since it will shield the pipeline within the crossing from cathodic protection.

(2.3.9) Coating

(2.3.9.1) Anti corrosion

An anti-corrosion coating is applied to the pipeline, including any sections to be used for a HDD crossing. The anticorrosion coating is used in conjunction with cathodic protection to provide a corrosion protection system for the steel line pipe. In most cases the anti-corrosion coating has been designed to have some degree of flexibility, impactresistance, good adhesion to the steel substrate, some degree of moisture permeation resistance, and compatibility with the cathodic protection system. The anti-corrosion coating system is applied in a coating plant using an industry standard such as CSA Z245.20- 98.6 Where as a number of coatings will meet the necessary requirements to provide external corrosion protection for the pipeline, they do not necessarily have the mechanical properties to withstand the rigors of a HDD crossing.

(2.3.9.2) Antiabrasion

A variety of anti-abrasion coatings have been developed specifically to protect the anticorrosion coating from mechanical damage. In addition to gouge and wear resistance, it is important to have good adhesion between the anticorrosion coating and the anti-abrasion coating. Flexibility and impact resistance are less of a concern as the pipe is not bent to any significant degree and the coating is not subjected to the same degree of potential impact damage as that encountered by the main line in an open ditch installation. These coating systems and methods for testing their properties will be discussed in more detail later in this project.

(2.4) Construction Considerations:

(2.4.1) Workspace Requirements:

Workspace for an HDD may require clearing and grading, depending on the entry and exit sites selected for the drill. Since the drill entry location or entry side accommodatesthe drill rig and supporting equipment, the entry side location requires satisfactory accessas well as stable ground conditions to support heavy equipment. Equipment typically found on the entry side of a HDD includes:

The rig unit;

Power unit and generators;

Drill pipe rack and drill pipe;

Water pump;

Drill mud supply;

Drill mud mixing tank;

Drill mud pump; and

Mud handling and cleaning system.

Since the drill exit side is the location for the fabrication of the pipe string as well as where the pipe string is inserted into the bore hole, the workspace required is typicallylonger to accommodate the pipe string and may require extra temporary workspaceoutside of the right-of-way known as “false right-of-way”.

Equipment typically found on the exit or pipe side of the HDD includes:

Exit mud containment tanks/pits;

Cuttings settlement tanks/pits;

Pipe racks and product pipe;

Rollers and pipeline handling equipment;

Side booms and other heavy equipment; and

Pipelines, welding.

Coating and testing equipment.

(2.4.2) Site Preparation:

1. Prior to any alterations to work-site, Contractor shall photograph or video tape entire work area. One copy of which shall be given to CLIENT/TPIA representative and one copy to remain with Contractor for a period of following the completion of the project.

2. Contractor shall abide by the common ground alliance, best practices version 1.0 or most recent, unless exceptions are specifically agreed to by CLIENT. Once the locate service has field marked all utilities, the contractor shall verify each utility (including any service laterals, i.e. water, sewer, cable, gas, electric, phone etc) and those within each paved area. Verification may be performed utilizing ground Penetrating Radar, hand dig, or vacuum excavation. Prior to initiating drilling, the contractor shall record on the drawing both the horizontal and vertical location of the utilities off of a predetermined baseline. The Contractor shall utilize the Ground Penetrating Radar over the projected bore path whether utilities are located in the horizontal drill pathway or not, in order to reduce the opportunity of conflicting with any unforeseen obstructions.

3. Work site shall be graded and filled to provide a level working area. No alternations beyond what is required for operations are to be made. Contractor shall confine all activities to designated work areas.

4. Following drilling operations. Contractor will de-mobilize equipment and restore the work-site to original condition. All excavation will be backfilled and compacted to 95‘% of original density (at a minimum).

(2.4.3) Equipment requirements:

The directional drilling equipment shall consists of a directional drilling rig of sufficient capacity to perform the bore and pullback the pipe, a drilling fluid mixing, delivery and recovery system of sufficient capacity to successfully complete the drill, a drilling fluid recycling system to remove solids from the drilling fluid so that the fluid can be re-used, a guidance system to accurately guide boring operations, a vacuum truck of sufficient capacity to handle the drilling fluid volume, trained and competent personal to operate the system. All equipment shall be in good, safety operating condition with sufficient supplies, materials and spare parts on hand to maintain the system in good working order for the duration of this project.

(2.4.3.1) Drilling Rig:

The directional drilling machine shall consist of a power system to rotate, push and pull hollow drill pipe into the ground at a variable angle while delivering a pressurized fluid mixture to a guidable drill (bore) head. The power system shall be self-contained with sufficient pressure and volume to power drilling operations. Hydraulic system shall be free of leaks. Rig shall have a system to monitor and record maximum pull-back pressure during pull-back operations. The rig shall be grounded during drilling and pull-back operations. There shall be a system to detect electrical current from the drilling string and an audible alarm which automatically sounds when an electrical current is detected.

Types and Sizes of Rigs:

The size of HDD rigs can vary substantially. This range in sizes should be considered when planning and developing specifications for all HDD project. In general, rigs are sized according to their available pull force and rotary torque that can be applied to the drill stem and pipe string. The following are samples of rig sizes and the respective ranges of projects that can be completed.

Torque Length of Drill Diameter of Pipe

0-54,000 Nm up to 200 m up to 168.3 mm

54,000-108,500 Nm up to 400 m up to 273.1 mm

108,500-217,000 Nm up to 500 m up to 323.9 mm

217,000 Nm+Nm over 500 m over 323.9 mm

Note: Nm= Newton meters.

The capabilities of each rig should be assessed for each project. The assessment of rig capabilities should take into account the possibility that formations or other subsurface materials may be encountered that could cause difficulties with the HDD project.

(2.5) Installation Methods for HDD of Pipe:

(2.5.1) Cartridge Method:

The cartridge method involves connecting the joints during installation, one at a time, and is preferred in locations where rights of way (ROWs) or easements are limited. Ductile Iron pipe restrained joint systems can be quickly assembled as the drill string is retracted, During pull-back the joint assembly normally requires little more time than it takes to disassemble the drill stem sections and store them on the rack. Hits installation method requires significantly less space or right-of-way than the assembled-line method.

Fig source: apollotrenchless.com

Fig 4: Cartridge method

(2.5.2) Assembled-Line Method:

The assembled-line method involves stringing out the connected pipe on the ground prior to pull-back. With this method it is necessary to have substantial space available to pre string the pipe above ground (generally on rollers) in direct alignment with the end of the drill path. These is normally the only option for welded-steel and fused-joint polyethylene pipe due to the significant time required position and properly welds or fuse individual pipe sections.

Fig source: apollotrenchless.com

Fig 5: Assembled Line Method

(2.6)Step by Step Procedure for a HDD Installation:

HDD is a trenchless construction method that involves drilling small pilot hole, using technology that allows the drill to be steered and tracked from the surface. The pilot bore is launched from the surface at an angle between 8 and 20 degrees to the horizontal, and transitions to horizontal as-the required depth is reached. A bore path of very gradual curvature or near-straight alignment is normally followed to minimize friction and to stay within the allowable joint deflection and the allowable curve radius for the pipe. This minimizes the chance of getting the pipeline “hung up” in the soil or damaging the pipe. The pilot hole is enlarged (usually approximately1.5 times the largest outside diameter of the new pipe) by pulling back increasing larger reamers, or reaming heads, from the pipe insertion point to the rig side.

To achieve the appropriate bore path size it may be necessary to perform several reaming operations. Generally, all reaming procedures prior to the actual product installation are referred to as pre-reams, and the final ream to the product pipe is attached is referred to a, the back ream. After the pre-reams, the pulling head and connecting product pipe attached to the reamer using a swivel, a device that isolates the product pipe from the rotation of the HDD drill pipe. The product pipe is then pulled behind the final reamer back through the horizontal directional drill path to the exit pit on the rig side.

(2.6.1) Pilot Hole:

The pilot hole shall he drilled along the path shown on the plans and profile drawings or as directed by the client/TPIA Representative in the field. Unless approved otherwise by CLIENT, the pilot-hole tolerance shall be as follows:

(2.6.2) Elevation:

As shown on the plan.

(2.6.3) Alignment:

+5 feet and within 3 feet of right-of-way or easement boundary.

(2.6.4) Curve Radius:

The pilot hole radius shall be no less than 80% of the maximum bending radius as recommended by the pipe manufacturer of the pipe being installed. In no case shall the bending radius be less than 30 pipe diameters, unless approved otherwise by CLIENT/TPIA.

(2.6.5) Entry Point Location:

The exact pilot hole entry point shall be within +5 feet of the location shown on the drawing or as directed by the CLIENT/TPIA Representative in the field.

(2.6.6) Exit Point Location:

The exit point location shall be within +5 feet of the location shown on the drawing or as directed by the CLIENT/TPIA Representative in the held.

(2.6.7) Limitations on Depth:

If not noted on the plans, 6" steel pipe and smaller shall be installed with a depth of 3 to 5 feet and 8-steel pipe thru 12" pipe shall be installed with a depth of 3 to 6 feet unless it is required to install the pipe deeper due to utility conflicts. Steel pipe larger than 12" shall be specifically designed by the engineer and approved by CLIENT/TPIA. Where utilities cross under DOT roads, the depth of cover shall comply with applicable DOT permit.

(2.6.8) Water Main and Non-Water Main Separation Requirements:

The minimum separation requirements between steel water main and a non-water main shall be as outlined as per the standard procedure.

(2.6.9) Reaming process:

The general “rule of thumb” is to ream the drill hole to 1.5 times the outside diameter including coating and insulation of the pipe to be installed. This diameter will generally provide for an adequate allowance for the installation of the pipe. The multiplier may be reduced for large pipe diameters (>36”/914 mm O.D.) The number of reaming passes that will be determined by the hardness of the material being reamed and the ability to remove cuttings from the hole.

Consider product pipe and reamer diameter requirements:

Product Diameter Reamer Diameter

<8” Product+4”

8”to24” Product *1.5

>24” Product +12”

(2.6.10) Pull Back:

After successfully reaming bore hole to the required diameter, Contractor will pull the pipe through the bore hole. In front of the pipe will be a swivel and reamer to compact bore hole walls. Once pull-back operations have commenced, operations must continue without interruption until pipe is completely pulled into bore hole. During pull-back operations Contractor will not apply more than the maximum safe pipe pull pressure at any time. Maximum allowable tensile force imposed on the pull section shall be equal to 80% of the pipe manufacturer’s safety pull (or tensile) strength.

1. Torsional stress shall be minimized by using a swivel to connect a pull section to reaming assembly.

2. The pullback section of the pipeline shall be supported during pullback operations so that it moves freely and the pipe is not damaged.

3. External pressure shall be minimized during installation of the pullback section in the reamed hole. Damaged pipe resulting from external pressure shall be replaced at no cost to the CLIENT/TPIA.

4. Buoyancy modification shall be at the discretion of the Contractor and shall be approved by the CLIENT/PTIA Representative. The Contractor shall be responsible for any damage to the pull section resulting from such modifications.

5. In the event that pipe becomes stuck. Contractor will cease pulling operations to allow any potential hydro-lock to subside and will commence pulling operations. If pipe remains stuck, Contractor will notify CLIENT/TPIA Representative. CLIENT Representative and Contractor will discuss options and then work will proceed accordingly.

6. Contractor shall provide a break-away link between the swivel and the pipe or a combination swivel and break link. Break-away link shall be rated at 80% of pipe manufacturer's safe pull (tensile) strength. Break pins shall be color coded for easy identification. Contractor shall provide rated break-away link for each material and pipe size(s) for the project.

(2.6.11) Buoyancy Control:

When a drag section is pulled back through the bore, the buoyant weight of the pipe as well as the resulting drag forces between the pipe (pipe coatings) and the walls of the bore will act as resisting forces. The drag force can be severe enough to damage pipe coatings as well as collapse the pipe. Therefore, it is important to determine during the planning phase whether buoyancy control is needed. If buoyancy control is necessary (i.e., for some long and large diameter drills), a buoyancy control plan needs to be implemented.

Typically, buoyancy control is applied by adding water to the drag section during the pull back phase.

(2.7) Monitoring and Documentation of HDD Construction:

Monitoring and reporting are critical during an HDD since they provide a log of activities during the process to:

- Provide early identification of issues
- Make appropriate changes
- Provide a basis for mitigation
- Provide a record of decisions and actions to demonstrate due diligence.

It is important to ensure that sufficient records are maintained before, during and after construction to support subsequent reports prepared to satisfy contractor, owner or government reporting requirements. This should include detailed notes and photographs of al l areas monitored.

The following monitoring and reporting activities should be reviewed for appropriateness for the size and complexity of the HDD crossing;

- Inspector daily records - a day-to-day account of the entire construction of the project
- Steering report
- Drilling fluid volume balance report
- Drilling fluid parameters
- Drilling fluid additives list
- Annular pressure modeling and reporting
- Turbidity monitoring report
- Surface monitoring report
- Pull force monitoring
- Inadvertent return report.

(2.8) Work site restoration:

1. Access pits and excavation shall be backfield with suitable material, and in a method approved by the owner's Engineer/Inspector.

2. The disturbed grass-surface area shall be top soiled, seeded, fertilized, mulched and anchored according the owner's specification for construction, Slopes steeper than 1- on-3, shall be sodded. If a final site restoration is not completed within 5 days after completion of the

operation, the installation of temporary soil erosion and sedimentation control measures shall be required.

3. Upon completion of the work, the contractors shall remove and properly dispose of all excess materials and equipment from the work site.

4. The permit, including the surety requirements, shall remain in effect for a minimum of one year after completing the work to monitor for settlements of the pavements and or slope.

CHAPTER 3

RISK CONSIDERATION AND LIMITATION

Risk Considerations:

As with all construction techniques, a degree of risk and unpredictability is associated with the use of H DD applications. It is recommended that a project team be assembled early in the planning and design process in order to identify and assess potential risk, as well as develop plans to-minimize the risks. Although HDD projects vary widely in complexity, most encounter site-specific characteristics that differ from previous projects. The project team may be composed of the proponent: engineering, geotechnical and environmental consultants; the HDD contractor and the pipeline contractor. Close consultation with regulators and land authorities can assist in the acquisition of initial approvals as well as ensure that alternate plans can be readily implemented if insurmountable problems arise. Risk can generally be divided into three types: regulatory risks: construction risks: and operations risks.

Here we will discuss only construction and operation risks.

(3.1) Construction Risk

Success of an HDD installation is dependent upon the ability of the project team to minimize the causes of failure. Tile risks associated with each crossing will vary according to many factors. These include but are not limited to:

- Inadequate planning
- Lack of contingency planning
- Inexperienced field personnel
- Overestimation by the contractor in the firm’s abilities
- Insufficient quantity and size of equipment onsite
- Inadequate knowledge of subsurface conditions.

Construction risk on a project can be minimized by ensuring that sufficient planning is conducted and an adequate geotechnical investigation is carried out. Another means of addressing risk on a project is through the type of contract that is used in next section.

(3.2) Operations Risk:

The risks associated with an HDD installation during operations are generally considerable less than those of a traditional trenched crossing. In particular, the risk of the following problems is minimized or eliminated:

- Maintenance of disturbed banks or stream bed
- Exposure of pipe during peak flow events or due to ice scour
- Damage of pipe due to anchors or other third party activities.

Increased risks include:

- Pipe is inaccessible for repairs due to depth of cover
- Corrosion due to undetected damage to pipe coating
- Subsidence at entry and exit points
- Visual leak detection is not possible.

(3.3) Environmental Considerations:

HDD crossings are often undertaken to minimize the adverse environmental effects at watercourse crossings. Nevertheless, an HDD does not guarantee that all adverse environmental effects will be prevented. Common adverse effects are the result of: Inadvertent returns of drilling fluids into the aquatic, terrestrial or social/cultural environments; and, to a lesser extent, Disturbance of soils, vegetation, wildlife and social/cultural elements arising, from either construction of drill sites, exit areas- access roads and temporary vehicle crossings, or the HDD activity.

(3.3.1) Environmental Protection Plan:

An environmental protection plan (EPP) should be developed by the owner to address mitigate measures to be implemented during execution of the H DD. Environmental protection planning should cover all aspects of the execution of the HDD including land, water and access needs.

The EPP should address the following aspects and be closely linked to the drilling execution plan:

- Notification and approvals
- Identification of environmental exclusion areas to be incorporated into No Drill Zones
- Environmental and social timing constraints
- Equipment inspection and servicing
- Clearing and grading of HDD sites and access
- Erosion and sediment controls
- Monitoring.

In addition to having an EPP, it is essential to have qualified onsite to enact the plan, to handle deviations to the plan and to report events properly to the authorities. Having an environmental specialties or biologist onsite to liaise directly with the DFO habitat biologist or other similar authority can prove useful. Effective communication of unintended events and subsequent mitigation action to the authorities may reduce delays or unwarranted enforcement actions contingency planning, e.g., inadvertent returns, and reclamation.

(3.4) Contingency Plans:

A site-specific contingency plan should be prepared by the project team for each HDD. A well designed contingency plan should address the following:

- Equipment and personnel needs for containment and clean-up.
- Emergency response procedures.
- Plans for continuance of drilling or alternative plan.
- Time lines of acceptable response and notification.
- Clean-up methods and plans.
- Regulatory and stakeholder contacts.
- Monitoring plans
- Disposal plans.

(3.5) Selection of Alternatives:

Alternatives that may be available to allow continued use of an HDD method following an initial failure include:

Down hole cementing to either seal off the problem zone for redrilling or seal off a large portion of the existing bore hole to a point where a new drill path (generally at a lower elevation) call be attempted; note that if reaming is necessary this method may not be successful since any reaming will remove localized cementing. A new drill can be attempted at a steeper entry angle in an attempt to get below the problem area

• The drill can be moved and an attempt made to redrill from a new location (the revised drill path should be reviewed and revised accordingly prior to drilling); and

• The feasibility of conventional (i.e., trenched) crossing methods should be considered if the drill fails; Consult the appropriate protect staff as well as regulatory authorities.

(3.6) Clean-up and Remediation:

An important decision may be required when developing plans to clean-up an inadvertent release of drilling mud. The decision can involve determination of, whether not clean-up and reclamation of a site will incur greater adverse effects oil the environment than leaving the mud *in situ* and allow natural processes to reclaim the area. In some situations, a combination of minimal intervention and letting nature take its course can also be appropriate (e.g., re-establishing a channel in a blocked wetland while leaving the wetland to reclaim itself). The determination as to whether to clean-up or not must be made in conjunction with appropriate regulatory and land authorities. In many cases, this decision will be contrary to traditional practices and must be made after thorough examination of the advantages of each.

Clean-up of Returns:

The impacts from ‘clean-up activities in sensitive environments are dependent upon the level of activity and equipment required to remove the residual drilling mud, terrain and aquatic conditions and season.

Containment:

Several containment measures are commonly used for the uncontrolled release of inadvertent returns (Table 3). The measure(s) chosen to be used depend upon;

- The anticipated volume to be contained
- Existing access to the site
- Environmental sensitivity of the area contaminated and adjacent areas
- Soil and weather conditions.

Clean-up:

It is important for the owner, contractor, appropriate environmental specialist(s), if warranted, and appropriate regulatory agency to discuss the clean-up goals for a site subjected to an inadvertent release of drilling fluids prior to commencement of cleanup activities. If a net gain is not anticipated as a result of clean-up, alternative measures may need to be implemented.

(3.7) Limitations of HDD:

The soil mixed with heavy boulders is very difficult to make a bore hole and pull a pipe string because nobody can drill through boulders and make a constant bore. The boulders may move to anywhere to upstream, downstream or to both sides. The movement of the bolders may stop the reamers at reaming for a bore hole or the pipe string will be choke up due to the movement of bolders. In the fine sand conditions the hole may collapse at the time of reaming or pipe string puling time. It may cause the failure of HDD. In India the available capacity is maximum 600 tonnes. It can pull 18" diameter pipe upto 4.5km and 24" diameter pipe uptp 2.5km safely. And if it is HDPE 18" pipe it can be pulled upt 7km and for 24" upto 5km. All pulling length may vary and it depends upon profile drawing and design calculation.

CHAPTER 4

ECONOMIC CONSIDERATION

(4.1) Potential Economic Advantages of HDD:

The development of guidance systems specifically for HDD use has made HDD technology increasingly efficient and, productive. Experience acquired by HDD contractors and operators during the early period of HDD use has resulted in more competent operating directional equipment as well as more knowledgeable contractors. There are several potential economic advantages of employing, HDD construction techniques as opposed to conventional pipeline installation techniques including:

- Increased use of HDD technology has resulted in associated equipment and labour costs being spread over multiple projects, making individual projects more affordable
- High installation performance
- No additional expense arising from closed streets, irrigation canals or railways
- Minimal to non-existent reclamation costs to the obstacle crossed since surface disruption along the alignment drilled is minimized (inadvertent drilling mud release still requires mitigation)
- The need for removal, restoration, monitoring, maintenance mud other long-term costs associated with trench settlement is eliminated through the use of HDD crossings
- Road cuts, which are expensive to restore, are minimized
- HDDs are possible year-round (instream timing restrictions may apply to conventional construction methods)
- HDD can be faster than conventional crossing methods.

(4.2) Costs of HDD

The costs associated with an HDD are influenced by;

- Location
- Access
- Environmental setting

- Geological characteristics
- Obstacle to be crossed
- Required rig size to complete the drill
- Total length of the drill
- Pipe diameter(s) to be installed.

The types of costs associated with HDDs, as with any construction activity, are direct costs, indirect costs and potential risks to the public. Operating and maintenance costs of completed projects should also be considered for HDD Projects.

(4.2.1) Direct Costs and Benefits of HDD Applications:

Direct costs are readily identified within the scope of a project and are paid for directly from the budget of a project (i.e., the cost of the project itself). Considerable direct costs are often associated with conventional pipeline construction installation methods. Common costs related to conventional construction methods include:

- Excavating equipment required for trenching
- Labour
- Topsoil and spoil handling
- Backfill costs
- Reclamation and restoration costs.

Where conventional construction impacts traffic volumes, water bodies or environmentally sensitive areas, direct costs are often substantially increased. HDD technology can be used to avoid environmentally sensitive areas, areas of large traffic volumes and water bodies, and minimizes the requirements for moving and handling large quantities of topsoil, spoil and backfill. Consequently, there are often some costs saving advantages over conventional installation techniques. In addition, the costs of using trenchless technology do not increase with depth of cover as dramatically as with conventional construction methods, thereby reducing overall costs.

(4.2.2) Indirect Costs and Benefits of HDD Applications:

Indirect costs are tangible and intangible costs which cannot be included in the project costs. Indirect costs accumulated by the proponent on n project depend upon the work site and the issues present or encountered. Factors affecting indirect costs include:

- Traffic obstruction
- Road damage
- Environmental damage
- Air and noise pollution
- Project delay's
- Social costs.

With the potential to reduce the approval period and construction duration, and as old or reduce overall disturbance, HDD applications appeal to indirect cost reduction by minimizing interference with community activities and operations, and adverse environmental effects. Air and noise pollution may also be minimized due to the often reduced installation time. Traffic obstruction and road damage are avoided, since the roads are not affected on the surface by construction. Safely issues and costs associated with HDD applications may also be less that those related to conventional construction techniques (i.e., open excavation), and fewer people are required onsite of HDDs, reducing the chancing the chance of injury in the workplace.

(4.3) Comparison over other trenchless construction methods and Open-Cut construction method:

HDD offers several advantages when compared to other trenchless, construction methods:

- Complicated crossings can be quickly and economically accomplished with a great degree of accuracy since it is possible to monitor and control the drilling operation
- Sufficient depth can be accomplished to avoid other utilities
- In river crossing applications, danger of river bed erosion and possible damage from river traffic is eliminated.
- Requires only a small construction footprint.

(4.3.1)Comparison over Open-Cut construction methods:

On the basis of the following points HDD can be compared with open-cut construction methods.

1. Three of the nine cost factors considered indicated open cut to be slightly cheaper than HDD. The averages of the respondents indicate that contractors spend approximately nine percent more on equipment operational costs for HDD than open cut. Material costs more also found to be nearly three percent higher. The engineering service costs on a project are generally expected to be similar for HDD as open cut.

2. The following table indicates that HDD has a significant reduction on the environmental factors. Dust pollution oil an open cut project was found to be almost three times the impact than on an HDD project. Travel effect on the public, effect on business sales, and the impact on the ecological system have considerable advantages when HDD is utilized- It should be noted that HDD scored higher for removal of waste materials. This is due in large part to the fact that it can be difficult to find waste sites that accept drilling fluid. On open cut projects; however, if soils are removed, disposal of waste materials is usually non-problematic.

3. The next table, which indicates that having a detailed understanding of the soil conditions, is much more critical for HDD. Also, having, the proper information and quantity of existing utilities in the construction area is as important for open cut as it is for HDD. As would be expected, the ground water table and the weather conditions are much more critical oil an open cut project. The impact of surface obstructions for open cut is much important however buried obstructions such as timber and concrete have a greater importance for HDD. Safety issues for both types of construction were surprisingly similar, even though HDD was expected to have a lower rating due to a significant reduction of open trenching and reduction of fatalities.

(4.4) Advantages

- Significantly reduced construction time:

With the elimination of costly and time-consuming excavation and restoration associated with open trenching, installations can be performed in less time. Additionally, the mobility and quick times of the directional drill reduce costs as well.

- Saves expensive or historic landscapes and structures:

Directional drilling minimizes the need to remove expensive landscaping or endanger historic structures with excavation.

- Eliminates unsightly excavation and trenching activity:

Conventional trenching, operations require many pieces of equipment, all of which contribute to noise and sight pollution on site, as well as litter the environment with spoil pipes and trenches. Only the drill, with a minimal amount of support equipment, is required on horizontal directional drilling projects - and trenches are eliminated.

- Reduced impact on residents and business around construction site:

There is no need to close roads or redirect traffic around the construction site, thus maintaining normal traffic patterns and access to business and residential property.

- Reduction in long-term costs associates with settlements:

Installations utilizing directional drilling reduce and in some cases eliminate settlements above the new pipe or conduit. This is particularly advantageous when installations are conducted beneath roads, highways, rail lines and foundations.

- Minimum disruption to road, rail and other service users.
- Minimum reinstatement costs.

CHAPTER 5

CASE STUDY

Chitrapuzha River Crossing

Outside Diameter, Do - 609.7mm

Inside diameter, Di - 587.5mm

Wall thickness, T - 11.1mm

Moment of inertia, I - 0.0009 m^4 (Calculated)

Weight of pipe in air, Wt -163.93Kg/m

Cross section of pipe, As - 0.3465/m^2

Modulus of Elasticity, E - $2*10^{11}$ N/m^2

Radius of Curvature, R (Assumed) – 1250 m

Co-efficient of drag, μ_d – 239N/m^2

Mud density, d_m -1280 Kg/m^3

Proposed length, L -120m

Entry angle – 5degree

Exit angle -4 degree

Hydro test Pressure, P - 90Kg/cm^2 = 8.82 N/mm^2

Design Pressure, p -14Kg/cm^2= 1.37 N/mm^2

Weight of drill pipe (9.6m length) – 35Kg

Rig pull back capacity – 35 ton

Co-efficient of friction between soil and pipe, μ- 0.2

Maximum longitudinal stress during installation

- Buoyancy of steel pipe in down hole:

  $= \pi/4*Do^2*$ Density of drilling fluid

  $= .785*.6097^2*1280$ (Density of drilling fluid= 1280 Kg/m^3)

  Wb=372.85 Kg/m

- Total weight of steel pipe in down hole:

  =(Weight of pipe)-(Buoyancy of pipe in down hole)

  = 163.93-372.85

  = -208.92 Kg/m

- Buoyancy Force:

  = µF*N

  =µ(Buoyancy factor* Proposed length) * g (Where g=9.81,µ=0.2)

  =0.2*(208.92*120)*9.81

  =49188.12 N

- Bending moment :

= EI/R

$$= \frac{2*10^{11}*0.0009}{1250} \quad (I = \pi(Do^4-Di^4)/64)$$

= 144000 Nm

Pulling Force Calculation

- Due to Buoyancy force:

F_1= μF*N

= μ(Buoyancy factor * Proposed length) * N

= 0.2*(208.92*120)*9.81

= 49188.12 N

- Due to curvature:

$$F_2 = \frac{4\mu * \text{Bending moment}}{.5 * 2\pi/360(\text{Q entry} * \text{R} + \text{Q exit} * \text{R})}$$

$$= \frac{4 * .2 * 144000}{0.5 * 2 * 3.14/360(5 * 1250 + 4 * 1250)}$$

= 1174 N

- Due to cohesion:

F_3= μ_d*π/2*Do*L

= 239*1.57*0.609*120

27421.80 N

- Pulling force :

=F_1+F_2+F_3

=49188.12+1174+27421.80

=77783.12N

- Considering safety factor, drill pipe & Reamer weight

= 1.5 * pulling force + drill pipe weight + Reamer weight

= 1.5* 77783.12+700+750

=118124.68 N

= 118124.68/ (9.81*1000) = 12.04 ton

35 ton rig is safe

Stress Calculations

- Allowable Stress :

S= 95% of SMYS

= 0.95*52000

= 49400 psi = 49400/145.037

= 340.60 N/mm^2 (Conversion factor=145.037)

- Bending Stress :

= ED/2R

$$= \frac{200000*609.7}{2*1250000}$$ (Every units in mm)

= 48.77 N/mm^2

- Tensile Stress

$$= \frac{\text{Pulling Force}}{\text{Cross sectional area}}$$

$$= \frac{78723.68}{0.346*1000000}$$ (Area in mm^2)

=0.22 N/mm^2

- Longitudinal stress during installation

Allowable stress > Tensile stress + bending Stress

340.6> 0.22+48.77

340.6>48.99 N/mm^2

Which is very much lower than allowable stress, thus safe

Maximum Equivalent Stress during Final Hydrostatic Test

- Hydro test pressure :

=PD/2t

$$= \frac{8.82*609.7}{2*11.1}$$

= 242.23 N/mm^2

Bending Stress = 48.77 N/mm^2

- Post Installation

  Allowable Stress > Bending Stress + Hydrotest stress

  340.6> 48.77+242.23

  340.52> 291 N/mm^2

  This is very much less than allowable stress, thus safe

CONCLUSION

(5.2) Conclusion:

Horizontal Directional Drilling is a useful tool that is available for the installation of Pipeline crossings across Rivers, Canals, Railways, Roads, and Sewers etc., given the correct conditions.

By the design calculation, we seen that the pipeline used in this project can withstand the all type of stresses, which act on pipe section during construction and operation period. It is important to realize that an HDD may represent the critical on the overall project schedule. In addition, an HDD may have the highest risk of failure risk of failure of any activities on a project. Therefore, all aspect, of planning, design and construction for an HDD need to be assigned a high priority or importance value to their potential effect on the overall project.

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