Trenchless Technology

Mainak Mouli Panja[1], Aarohi Kumar Munshi[2]

[1]*IIM Calcutta, NF-3 Flat-23, D.H.Road, Joka, Kolkata – 700104 West Bengal*

[2]*CH-25, Near GM Office, Jhingurda Project, Singrauli- 486889 Madhya Pradesh*

ABSTRACT

Trenchless technology stands for subsurface construction works where fewer trenches or no continuous trenches are required to be done. The technology helps in installing, repairing and replacing of water pipes, gas and petroleum pipes, and telecommunication cables without disrupting the traffic, normal lifestyle and has minimal impact on economic activity in congested areas and to the environment. This includes a wide variety of methods, materials, and equipment capable of doing large scale works using Tunnel Boring Machine or even small scale work like laying of pipes with or without the entry of workers. This method is also very useful in seismic prone zone, places with hard rock strata, high ground water level and can be helpful in reducing soil erosion in regions with high rainfall. The method has also proven to be very useful for the army installations. This method will prove to be very economic and time saving and will become a boon to a third world and highly populated country like India.

Keywords: Cathodic protection, pipe renovation, pipe installation, pipe reaming

1. INTRODUCTION

Trenchless technology is the techniques for utility line installation, replacement, rehabilitation, inspection, location and leak detection with minimum excavation from the ground surface (North American Society of Trenchless Technology). It also makes it possible to install the utilities under rivers canals and other obstacles with no disruption of flow and with minimum and no damage to the environment. It can enhance forest roadway culvert applications by minimizing excavation and maybe less costly than conventional open-cut excavation. In this paper the authors present a variety of techniques for installing repairing and replacing of water pipes, gas and petroleum pipes including a wide variety of methods family of equipment and materials for the process. There are various methods of trenchless technologies that may be used, and the type of method chosen is dependent upon the pipe size that needs to installed, the depth it needs to be installed at, the soil conditions of the ground and the overall cost of the method. The authors have found out a problem regarding the corrosion scene in underground metal water pipes.

Trenchless technology has the following advantages:

- Cost: Substantial cost savings are possible. However, even when trenchless methods are more expensive, such technologies are the best.
- Environmental effects: Less soil is disturbed so impacts on adjacent organisms and water bodies can be reduced significantly.
- Disruption to traffic is less.
- Speed of installation: Construction often takes less time, regardless of the road fill depth.
- Safety
- Less engineering: Less surveying, fewer design calculations, and fewer drawings and specifications may be required.

Methods involved in trenchless technology:

- New pipe installation method
- Pipe renovation method
- Pipe replacement method

1. New pipe installation method

1.1 Horizontal Directional Drilling(HDD)/ Directional Boring

This is one of the most widely used continuous trenchless technologies. It is used for the installation of everything from service connections to residential and commercial/institutional buildings, to pipes and cables under roadways and rivers. HDD is used for installing pressure pipes and conduits, where precise grades are not required and are applicable for diameters up to 1200 mm.

The main components of HDD are: a directional drill rig of a size suitable for the job; drill rods linked together to form a drill string to advance the drill bit and for pulling back reamers and products (pipe); a transmitter/receiver for positioning of the location of the drill and product; a tank for mixing and holding drilling fluid; and a pump for circulating the drilling fluid This is in addition to drilling bits, reamers, swivels and pulling heads. The HDD industry divided into 3 major categories.

Type	Diameter[mm]	Depth[m]	Drive length[m]	Typical application
Maxi HDD	600-1200	≤61	≤1800	Rivers and highway crossings
Midi HDD	300-600	≤23	≤270	Rivers and roadway crossings
Mini HDD	50-300	≤4.5	≤180	Telecommunication, power cables and gas lines

1.2 Pipe Ramming

It is a trenchless method of installation for new pipes over, typically, short, shallow distances. This common method has been widely used for installation under railway lines and roadways because it causes little ground movement in comparison to other methods. Most often, the pipe is hammered into the side of an embankment to pass under the obstacle. The pipe is open-ended to allow the soil to move into the pipe rather than compacting it outside the pipe, thus, reducing surface heave and allowing this method to be used at shallow surfaces.

1.3 Auger Boring (Case Boring/Jack & Bore)

The auger boring process employs an auger boring machine to rotate a series of connected continuous flight augers (auger chain) positioned within a casing pipe and fitted to a cutter head at the front of the casing. The rotating cutter head, which is slightly larger in diameter than the casing pipe, excavates the soil in front of the casing. The soil is transported back to the machine via the helical auger chain. At the original entry point the soil is removed by hand or machine. The auger boring machine advances along a track, which is aligned to drive the casing pipe on the designed installation line. Once the machine reaches the end of the track arrangement, the auger chain is disconnected from the machine and the machine is moved back to the original starting point on the track where a new casing segment is welded to the existing casing pipe, and a new auger length (chain) is connected to the machine and to the existing chain/cutter head. The excavation and thrust process is repeated until the planned bore is completed.

1.4 Slurry Horizontal Rotary Boring

It is a technique which creates a horizontal bore hole from a drive shaft to a reception shaft using a rotary drill bit and drill tubing. The drilling fluid (slurry, bentonite, water or air pressure) is used to facilitate the drilling process by keeping the drilling bit clean through spoil removal. At the beginning an unsupported hole is produced and the pipe installed afterwards.

1.5 Water Jetting

The excavation method relies on a high speed jet of water to liquefy soil and aid in spoil removal. A special nozzle is attached to the end of a solid rod and extended forward into the bore hole. It is a simple method and does not require sophisticated equipment; however, it does not provide good control over bore hole size. The other main disadvantages are large quantities of water required to carry out excavation and consequently large amounts of spoil removal which may cause surface ground settlement (U.S. Army Corps of Engineers, 1999)

1.6 Tunnelling

Tunnelling process needs an entry and exit pit . It involves four main steps, (1) soil excavation, (2) spoil removal, (3) segmental pipe installation, and (4) alignment control. Soil excavation can be carried out by any excavation method, including hand mining, open-face mechanical excavation, or any tunnel boring machines. The available space dictates the appropriate spoil removal (such as slurry systems, vacuum extraction systems, belt and chain conveyors, etc.

1.7 Micro tunnelling

This process uses a remotely controlled Micro-tunnel Boring Machine (MTBM) combined with the pipe jacking technique to directly install product pipelines underground in a single pass. The term micro-tunnelling applies to remotely controlled, steerable, controlled excavation tunnelling methods for pipelines of 3 400 mm diameter or less and usually for lengths up to 460 m . The spoil is removed from the cutting head within the new pipeline which is advanced by pipe jacking. This process avoids the need to have long stretches of open trench for pipe laying. Thus this method reduces extreme disruption to the community during construction. Spoil may be removed by auger, slurry conversion or vacuum extraction.

2. PIPE RENOVATION METHOD

Pipe renovation is the rehabilitation of existing pipe insitu without replacement. This method can be used for deteriorating pipe or leaking pipe.

2.1. Structural Methods

2.1.1. Slip lining

It involves the insertion of a new pipe into an existing pipe. A new pipe with an outside diameter smaller than the inside diameter of the host pipe is either pulled or pushed into the host pipe. Slip lining may be continuous or segmental. After the new pipe has been installed, the annular space between the new and host pipe is grouted. Grout may serve only to restrain the new pipe and transfer load from the existing pipe. The grout may cause the new and host pipe to act as a composite, increasing the pipe’s ring stiffness and its resistance to external hydrostatic loads.

2.1.2. Cured-in-Place Piping (CIPP)

This process involves inserting a new polyester pipe into the deteriorated host pipe and curing it in place. It can be used on pipe ranging from 100 mm to 2700 mm. The liners are impregnated with a polymer resin, which when cured will form a close fitting liner pipe within the host pipe. The liner may be designed with sufficient thickness when cured to sustain the loads imposed by external groundwater and internal service pressure, and by soil and traffic acting on the pipe.

2.1.3. Woven hose lining epoxy bonded

This method uses flat fibre reinforced polyethylene hoses from 150 mm to 500 mm, where it can sustain internal pressure up to 40 bars, (ISST, 2013). The woven hose is inserted at the inlet of the rehabilitated pipe and pulled using a winch at the outlet. Inflation takes place after securing the liner to the host pipe until it contacts its wall for bonding.

2.2 Non-Structural methods

2.2.1. Shotcrete and cement mortar lining

This process involves pneumatically spraying concrete or mortar onto the inside of the host pipe. The wet liner on the inside of the pipe will cure, harden and seal the pipe. This technique is popular in relining of culverts and has become an all-inclusive term for both wet and dry concrete spraying processes. For smaller diameter pipe applications, cement mortar lining is used to protect pipe interiors from corrosion. The pipes must first be cleaned thoroughly with high pressure washers, then, in small diameter (no man-entry) pressure pipes, a thin layer of cement mortar is sprayed on using a rotating-head spray machine. The mortar is either fed through hoses from the surface, or in larger pipe applications, the mortar mix is often fed from a down-hole hopper. The speed that the spray machine is pulled through the host pipe determines the thickness of the coating. The spray application is followed by towelling, which is typically carried out by either rotating a spatula fitted to the spay machine or by a tubular shield sized to the internal diameter of the coating, which is pulled through the pipe behind the spray machine.

2.2.2. Epoxy/Polyurethane lining

Both epoxy and polyurethane lining provide corrosion protection and enhanced flow characteristics in small diameter metallic host pipes and leak protection in large pipe diameters. Like the cement mortar lining, the host pipe has to be cleaned and dry prior both coating application. Fast curing time, relative to the cement mortar, is the main advantage of the Epoxy and Polyurethane liners, 16 hours and 2 hours respectively.

3. PIPE REPLACEMENT METHOD

3.1 Controlled Line and Grade (CLG) System

This is a pipe replacement method with the ability to correct sags, humps or misalignments in existing pipelines. A steel rod string, a series of short, steel rods coupled together, is inserted through the existing pipe, for the entire length of the replacement section. After the rod string is precisely aligned to the desired line and grade between the insertion and reception pit it is anchored in tension (pre-tensioned). Then light cement slurry is pumped in to fill the old pipeline and any open voids around it. Once the cement slurry is cured (between 4 hours to24 hours), a bursting head and a replacement pipe are attached to one end of the rod string. The rod is then pulled out towing the new pipe behind it. A bentonite may be used for lubrication to reduce the friction against the new pile and thereby reducing the pulling force required.

3.2 Pipe bursting

An existing pipe is replaced size-for-size or up-sized with a new pipe using the existing alignment (In-Line Replacement).The technique is the most cost effective when there are few lateral connections, when the old pipe is structurally deteriorated, and when additional capacity (larger diameter pipe) is needed. It fractures a pipe and displaces the fragments outwards while a new pipe is drawn in to replace the old pipe. Typical pipe bursting involves the insertion of a conically shaped tool (bursting head) into the old pipe. The head fractures the old pipe and forces its fragments into the surrounding soil. At the same time, a new pipe is pulled or pushed in behind the bursting head. The base of the bursting head is larger than the inside diameter of the old pipe (50 mm to 100 mm) larger than the old pipe to cause the fracturing and slightly larger than the outside diameter of the new pipe, to reduce friction on the new pipe and to provide space for manoeuvring the pipe. The rear of the bursting head is connected to the new pipe, while its front end is connected to a cable or pulling rod. The bursting head and the new pipe are launched from the insertion pit, and the cable or pulling rod is pulled from the reception pit.

Pipe suitable for Pipe Bursting are typically made of brittle materials, such as vitrified clay, cast iron, plain concrete, asbestos, or some plastics. Reinforced Concrete Pipe (RCP) can also be successfully replaced if it is not heavily reinforced or if it is substantially deteriorated. Ductile iron and steel pipes are not suitable for pipe bursting, and can only be replaced with pipe splitting.

The most favourable ground conditions for Pipe Bursting are soils that can be High Density Polyethylene (HDPE) and Medium Density Polyethylene (MDPE) pipes are the most common replacement pipe materials. Other types of replacement pipe include cast iron pipe, vitrified clay pipe, and reinforced concrete pipe.

Pipe bursting methods:

3.2.1 Pipe splitting

3.2.2 Pneumatic pipe bursting

3.2.3 Hydraulic expansion

3.2.4 Static bursting

3.3 Pipe implosion and crushing

This System is similar to a bursting one in which it crushes the pipe while pulling through the replacement. In this the old pipe is crushed inwards and then old pipe fragments are pushed outward by the bursting tool. The replacement pipe is dragged in behind the bursting head. The pipe implosion tool (bursting tool) consists of two parts: a crushing head. The cylindrically shaped crushing head is slightly larger than the existing pipe and has steel blades extending in a radial shape from the centre. The head fractures the old pipe and pushes the pipe fragments inwards into the old pipe space. The second part is the steel cone which follows forcing the crushed pipe fragments and soil outwards and pulls in the new replacement pipe . The implosion method cannot be used to replace metallic or thermoplastic pipes.

3.4 Pipe eating/ reaming

This method differs from a bursting operation. The crushed fragments of pipe mixed with soil are vacuumed out, as slurry, through the new pipe and out of the space. This method is remotely controlled. The cutting head may be laser guided to a different alignment, “eating” segments of the old pipe as well as the soil.

A Pipe reaming operation is similar to the pipe eating technique in that it involves crushing the old pipe and mixing the pipe fragments and soil into a slurry, which is then pumped back to the surface for disposal. This option is often more suitable in harder, more compacted soils and rock. With pipe reaming, a drill rig pulls the cutting/reaming head through the existing pipe, crushing it into pieces while pulling the new pipe into place. The reamer teeth pulverize the pipe in a cutting and flow process, rather than compacting and splitting the pipe. Drilling fluid is used to decrease friction, to hold the hole/tunnel open and to suspend pipe fragments and soil particles. The pipe and soil fragments and waste material flow with the drilling fluids to a reception pit where this slurry is pumped out with a vacuum mud collection truck.

Problem Statement

Corrosion is regarded as one of the major threats to metal pipes lying underneath the ground level carrying water. The low value of water leading to corrosion reduces the service life to a great extent. The authors of this project have found out that the conventional methods of renovating of pipelines have proven to be a limitation in some cases.

Case 1

An old pipeline running between the Agumbe Ghat area (Udupi, Karnataka) has corroded completely and needs urgent attention. But the pipe runs through the conserved national park area and the natural environment, flora, fauna can’t be disturbed.

Case 2

A water carrying pipe with very less diameter runs through a very sensitive area where conventional methods of pipe renovation are not possible.

Solutions

2. Galvanic method

The solution to all this problems can be solved by a method called *Cathodic protection* . This method involves the introduction of a different electrical circuit into the pipe. Some cathodic protection systems operate as shown in Fig.1, by introducing a sacrificial anode into the pipe. A **sacrificial anode** is a piece of very active metal (usually zinc or magnesium) which is more galvanically active than any other metal in the system. The sacrificial anode will be the only metal corroded, and even previously active anodes on the pipe wall will become cathodes and will thus be protected. Since the sacrificial anodes slowly corrode away, they must be replaced at intervals and maintenance required on the protection system. This method will ensure that the metal pipe is not corrode and instead the sacrificial anode is used up and can be replaced periodically.

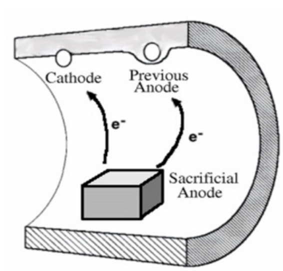

Fig.1

2. Impressed current cathodic protection (ICCP)

Alternatively, some cathodic protection systems involve the introduction of an external direct current source, known as a **rectifier**. The rectifier creates a very strong anode since it is constantly producing electrons (an electric current.) This turns the rest of the pipe into a cathode, which prevents any corrosion in the pipe. To complete the circuit, the pipe must be connected back to the rectifier. Direct current cathodic protection systems have been developed which are fully automatic and will compensate for any changes without operator control.

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