Designing a Successful Trenchless Underground Construction Project

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1. Introduction:

Water is an increasingly concern in our nation, according to the 2008 Construction Outlook Second Quarter report. Aging infrastructure, population growth and net migration are fueling demand for new and replacement construction, especially in the Sunbelt and Rustbelt regions. Yet despite an expected decrease in federal and state revenues and a downturn in non-residential construction, water supply and sewage and waste disposal construction is expected to increase significantly by 2009.

Once again the construction industry will be charged with having to do more with less. Less skilled workers, smaller budgets, tighter deadlines, and increasing environmental restrictions, making the demand for construction professionals educated in trenchless methodology even more critical than ever before.

"Designing a Successful Trenchless Underground Construction Project" thoroughly examines each phase of a safe and successful trenchless installation and/or renewal project. Arvid Veidmark, a veteran in trenchless construction, discusses how to implement and utilize the latest technology and methodology to limit disruptions, reduce costs, minimize design changes, and eliminate environmental issues - a must for planners, managers, engineers and any other professionals tackling the challenges of replacing aging infrastructures in declining economic conditions.

Through this paper, professionals will gain a greater understanding of modern trenchless methods, allowing them to create better developed designs for pipeline replacement and renewal. They will improve quality control through the specification of new technology and implementation of critical subsurface engineering processes, and most importantly they will be better equipped to evaluate and manage construction costs throughout a project.

2. Design Considerations:

Several key factors directly influence the design of a new or refurbished utility infrasture:

- **Location-** the environmental impact on the surrounding area most often determines whether it is to be an open cut or trenchless installation. Although cost is always a factor, most designers agree circumstances where traffic disturbance or detour is unavoidable, regardless of the method used, open cut is the most cost effective solution. Where a bore crosses a major thoroughfare, rail road track or waterway, trenchless is the most suitable option. The location will also determine the length of the bore and the method used depending on access, surface conflicts, and whether or not it is a residential or commercial property.

- **Soil Conditions**-For underground construction it is necessary to know the actual soil stratification at the site. Depending on the depth of the installation, soil samples may be obtained for appropriate laboratory tests. To avid flooding during installation, it is also important to observe surface drainage to and from the site and determine depth of bedrock.

- **Utility to be installed**-The type of utility will determine the size and type of carrier line, (DIP, PVC, HDPE), gravity and pressure, slope, size of casing and wall thickness required. The utility also determines if spacers or skids are employed or if grout versus chip is used to fill the annualar space.

- **Length of bore-**The size and depth of the bore pit is dependant on the length of the bore as well as shore boxes and sheet piling requirements.

- **Existing conflicts**-Verification of existing utility conflicts diretly affect the design of the intended bore. Other factors such as whether the conflict can be relocated, removed or deactivated are also major influences. Trenchless construction projects require that the contractor be given a record of potential conflicts including as-builts, although they should not be relied upon. Additonal research is necessary and usually conducted by the contractor to positively locate and expose existing utilities where running parallel less than 10 ft (at specified intervals, dependent on proximity and type of utility) or where crossing the bore path of the project. Subsurface utility engineering (S.U.E.) is a highly recommended method of confirming subsurface utility locations utlizing GPR and vacuum excavating techniques. It also involves managing risk, utility mapping, and the assurance of quality.

3. Trenchless Methods:

Horizontal Auger Boring: Most often involves the installation of steel casing under freeways, canals and rail road tracks. The auger simultaneously jacks a steel casing from a drive pit through the earth while removing the spoils inside the casing. Bores range in diameter from 8”-72”. After installation of the casing (which supports the soil around it) a pipe is installed and the annular space is filled with chip or grout.

BMTA: Used for applications where line and grade are critical. The cutting head is individually powered. The boring machine provides the BMTA with thrust and auger spoil removal. They range in size from 42” – 96” and are well suited for soft ground steel cased bores.

Small Boring Unit (SBU): A small diameter cutter head and thrust bearing assembly that extends the capabilities of the auger boring machine and can easily cut through hard rock faster than any other method available. SBU range in size from 24" – 72", install drives up to 500', and can bore through rock 4,000 – 25,000 psi. SBU in many cases eliminates the need for hand tunnel.

Hand Tunnel: The simplest form of soil excavation using picks, shovels, or pneumatic hand-held tools. Standard bores are up to 600' with pipe sizes ranging from 36" – 144". Typical soil applications include dry clay, wet clay, dry sand, and dry silt. Hand tunnels require a tunnel shaft.

Horizontal Directional Drilling (HDD): Mainly used for installation of pressure pipelines and cable conduit (PVC, HDPE or Steel). Typical bores can use up to 24" conduit and be as long as 800'. Longer bores can be done with special equipment. HDD has the ability to track and steer using a two stage process. No pit required.

Tunnel Boring Machine (TBM): Equipped with hydraulic or electrically driven rotary cutter heads or disc cutter. Cut soil is forced inside shield through slits in cutter head as the shield is advanced. Provide much improved face stability during soil excavation. TBM is most suitable for non-cohesive soils below water table.

Pipe Bursting: Used to upsize the capacity of LP gas, water, and sewer pipelines that range from ¾" - 54" OD. Bursting tool is inserted into existing pipe and pushed or pulled through.
Viability depends on environmental impact, type of host, type of replacement, soil conditions, depth/Length of pipe.

- Pneumatic or Static process used depending on type of host and replacement pipe.
    - Pneumatic = non-fracturable (steel/ductile iron)
    - Static = fracturable pipe (clay/cast iron

Pipe Ramming: Is mainly used for installation of utilities for road and railroad crossings. Two stage technique for installing casing from a bore pit to a reception pit. Works best in sandy, rocky soils. Pipe diameters range from 6" and up. There is no limit on linear feet.

Micro Tunneling: Uses a remotely controlled MTBM combined with the pipe jacking technique to directly install product pipelines underground in a single pass. Can install pipe from 12" to 12' diameter. Is a cost effective solution when faced with unstable soil conditions and work below the groundwater level.

Pilot Tube Boring: PTMT is an alternative to conventional microtunneling. Combines accuracy of microtunnelling, steering mechanism of directional drill, and spoil removal system of auger bore. Employs auger and guidance system, using camera mounted theodolite and target with electric light emitting diodes (LEDs) to secure high accuracy in line and grade.

4. Case Study: Auger Boring Challenges In The Virgin Islands

Project: Saint Croix is an island in the Caribbean Sea, and a county and constituent district of the United States Virgin Islands (USVI), an unincorporated territory of the United States. It is the largest of the U.S. Virgin Islands, being 28 by 7 miles (45 by 11 km) and hosts one of the world's largest and most modern oil refineries.

Aging Pipelines & 20' high dike

Construction of the 45,000 barrels per day (BPD) refinery began in October of 1966. Substantial expansion occurred in the period 1966 to 1974 to increase the refinery's capacity and making it the largest refinery in the world at that time:

Aging Pipelines

Heavy oil upgrading capacity was gradually added beginning in 1981 eventually increasing the refinery's capacity to 485,000 barrels per day BPD.

To accommodate the original 2,000+ acre facilities on the south shore of St. Croix, a ¼ mile of wetlands was dredged and contained by a 120' long x 20' high dike that eventually became home to a service road, power and fire lines, and four major fuel lines that connected the refinery to adjacent holding tanks.

Many years and four major hurricanes later, two of four fuel lines had to be shut down due to leaks. At a cost of $800,000 per day in lost revenue, immediate upgrades were required.

Design Considerations: Lack of as-builts and supporting documentation for the original facility and containment areas proved an immediate challenge. Although it was well known that a 30" fire line, a 12" water line, and a 12000 KV electric line existed in the area of the newly proposed pipelines, their exact location and depth was unknown. Initial soil investigation revealed moderate clay and coral at 15-ft. however, soil conditions beyond that point were also unknown.

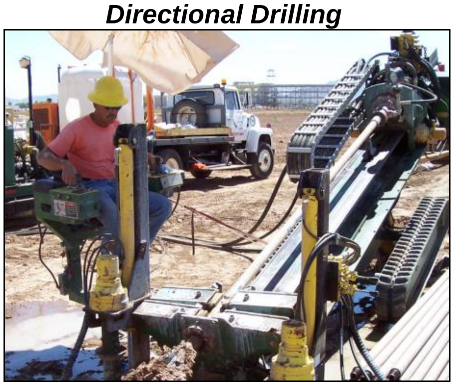
Methods Considered	Advantages	Disadvantages
HDD	None	None
Hand Tunnel	Line and Grade Accuracy	Not allowed due to Safety Rules
Auger	Speed	Drift of casing
Pipe Ramming	No voids	2 steps to install, vibration, noise

To minimize the cost and risks associated with this project, horizontal auger bore was selected as the most suitable method. Four 120' auger bores to install (2) 30" OD steel casings and (2) 48" OD steel casings were required.

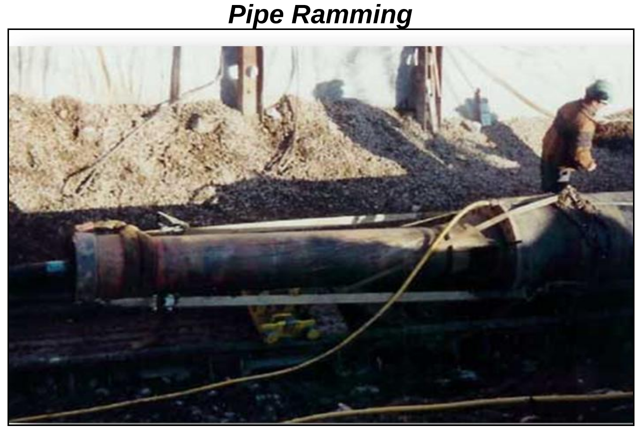
Hand Tunnel

Auger Bore

Directional Drilling



Pipe Ramming



Installation Challenges: Construction began in early October, 2007. The first of the two bores to install 48" OD steel casing failed. Extreme weather had stripped the binding material from the outer layer of coral causing the loose material it to cave in. Dropping a foot below grade, a second bore successfully cleared the loose material but became bound in dense sticky clay at approximately 60ft. Water was pumped in and around the auger to loosen the clay and allow the auger to glide for another 40 ft. Once again the auger encountered the outer layer of coral as it exited the dike making turning the auger impractical. It was then shut down and used as a jacking device for the remaining 20 ft. successfully avoiding an overflow oil drain that was discovered during the installation

Loose Coral

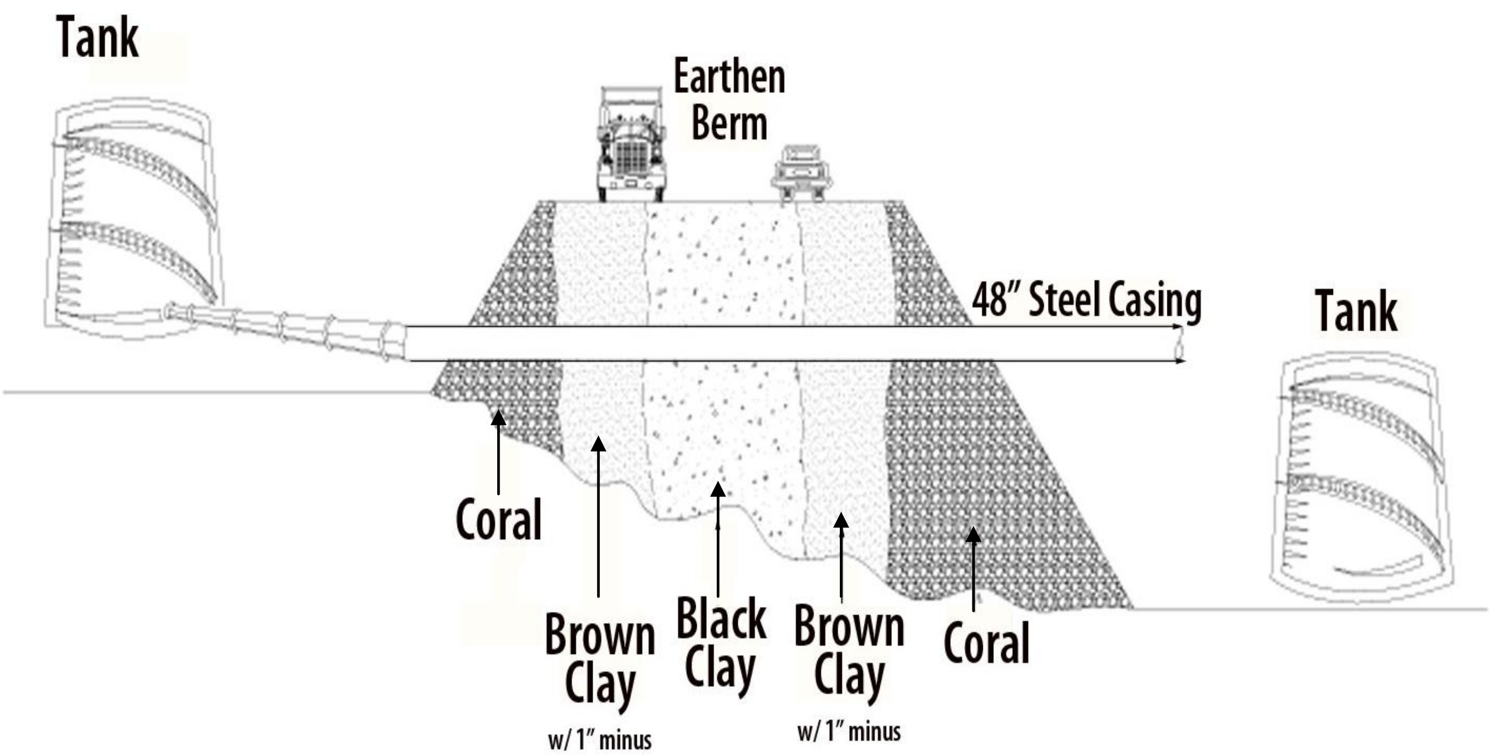


Illustration of layers of soil

With little room to maneuver, and little time to spare, each of the three remaining casings were installed successfully and the project was completed in mid October 2007, amazingly eight days ahead of schedule.

New Fuel Lines Side A

New Fuel Lines Side B

Auger Bore

5. **Conclusion:** Although the lack of as-builts did prove detrimental initially, we were able to employ a combination of innovation, technology, and experience that resulted in success. As demonstrated on this project, the lack of as-builts and documentation will be the initial hurdle for any project. An excellent set of as-builts can save much time and money for an owner and contractor, helping them to make more informed decisions and reduce risk. It is common for changes to be made during construction. What becomes the challenge is making sure those changes are reflected in the as-built records..

   According to the Federal Highway Administration every dollar spent on subsurface utility engineering, over $4.00 is saved during the construction process.

   This project is a prime example of why it is so important for engineers and other construction professionals to familiarize themselves with and implement S.U.E. practices on every underground installation project, especially large diameter installations in which undocumented conflicts are a routine occurrence.