Trenchless Construction

Trenchless construction consists of installing pipes (e.g., culverts, utility lines) via “tunneling” under a highway. Trenchless construction should be considered in areas where conventional open-trench construction methods are undesirable (e.g., traffic impacts).

The role of the Geoprofessional for trenchless projects is to:

- Perform the geotechnical investigation
- Evaluate geotechnical conditions for suitability of trenchless construction
- Produce the Geotechnical Design Report (GDR)
- Provide design and contract preparation support
- Provide construction support

The role of the Contractor is:

- Selection of feasible construction methods and equipment. Construction equipment and methods for trenchless methods are evolving and the contractors have knowledge of suitable and available construction methods and equipment for the project and site.
- Estimation of potential pavement settlement profile.
- Evaluation of potential damage to existing facilities.
- Implementation of preventive and/or mitigation measures.
- Monitoring of pavement settlement and the impacts of construction to facilities.

If the geotechnical investigation reveals information that would preclude the use of trenchless construction, the GP must contact the client to discuss if the trenchless method is appropriate.

References

Review these documents before developing projects that include trenchless methods for pipe installation.

- Synthesis of Trenchless Technologies, Virginia Center for Transportation Innovation and Research, VCTIR 15-R16, June 2015
- Trenchless Installation of Conduits Beneath Roadways, NCHRP Synthesis of Highway Practice 242, 1997
- Trenchless Methods for Storm Drain Culvert Renewal/Replacement, Caltrans, May 2018
- Encroachment Permit Manual, Chapter 600 – Utility Permits, 603.6A Trenchless Technologies, Caltrans
Investigation

The purpose of geotechnical investigation for trenchless construction is to provide sufficient information to facilitate selection of an appropriate construction method by the Contractor and reduce uncertainties and risks during construction. The subsurface information is conveyed through the GDR, which includes Boring Records.

The following information is useful for the selection of the trenchless method:

- The presence and depth of gravels, cobbles, boulders, loose sand, soft clay, man-made structures, and utilities
- Soil and rock stratigraphy
- Depth to bedrock
- Rock type, core recovery, Rock Quality Designation (RQD), weathering, hardness, unconfined compressive strength, orientation and spacing of bedding
- Groundwater elevation, groundwater conditions at geologic contacts
- Difficulties encountered during geotechnical investigation, such as loss of drilling fluid, or caving of a drilled hole
- Soil and rock engineering properties, including corrosivity evaluation, particle size distribution, hydraulic conductivity, unit weight, and shear strength
- The presence of expansive or collapsible materials

A typical highway project may include multiple pipes. The site condition at each pipe location may differ while the project budget may be limited and does not allow a comprehensive geotechnical investigation. An accurate interpretation of site geology will be instrumental in the development of an effective investigation program. Walk through, observe, photograph, and gather evidence of the conditions at the job site and surrounding area for information identified in the above items list that may assist in the development of subsurface profile along the pipe alignment. Consider excavating observation trenches on the embankment slopes or native surface to observe, photograph, and gather subsurface information.

Perform at least one boring at each pipe location. For trenchless construction that installs pipes with inside diameters equal to or greater than 30 inches, perform at least two exploratory borings with one boring near each end. For installations that traverse a divided highway, perform an additional boring in the median. Eliminate borings when possible, for example in cases where the geologic conditions are known and/or as-built boring data are available.

Extend the boreholes at least 10 feet below the invert of the pipe, and to a stiff or dense soil layer. In the zone between one diameter above the crown and one diameter below the invert of the pipe, retrieve soil specimens using continuous sampling.

When scheduling subsurface exploration for installation of pipes with diameters equal to or greater than 30 inches, collaborate and coordinate with District Environmental
Analysis, so that District Environmental Analysis can perform soil vapor profiling during drilling. The data obtained from soil vapor profiling is needed as part of submittals to Cal OSHA Mining and Tunneling Unit for the construction of the project.

**Feasibility Study**

Do not perform geotechnical design or analysis for Caltrans trenchless construction projects.

The role of the Geoprofessional is to advise and discuss with clients if the findings from geotechnical investigation indicated the use of trenchless methods can be problematic, less practical, or more expensive, and the option of open trench should be considered instead. The scenarios that favor open trench option include, installation in highway section with low annual average traffic volume, installation near the pavement, subsurface conditions are not favorable for trenchless methods, or no space for equipment set up immediately outside of the highway. Open trench construction will require traffic management, such as super-closure, one-way traffic control, staged construction, and/or traffic diversion.

**Reporting**

The following should be included in the GDR for trenchless construction. For general content requirements refer to the GDR module in the Caltrans Geotechnical Manual.

**Geotechnical Conditions**

For pipe installations that require boring diameters of 30 inches or greater, in addition to the required information in this section, provide a summary of the information obtained from geotechnical investigation that addresses Cal OSHA requirements as described below so that the District can compile and submit the required information.

According to Cal OSHA Mining and Tunneling Unit [Underground Classification Requirements](#), “for all tunnels, … all pipejacking, and boring projects 30 inches or greater in diameter must be Classified by the Mining and Tunneling Unit before bidding.” For Cal OSHA to classify the excavation, the submittal of following information, among others, is required:

“4. One copy of any geological information and/or soils reports that are proximate to, or representative of, the conditions existing at the site of the underground construction work, especially as they relate to the presence of flammable gases and hydrocarbons.”
Recommendations

It is the responsibility of the Contractor to determine the most suitable and available construction means and methods for the project and site. It is also the responsibility of the Contractor to evaluate possible damage to facilities, such as pavement settlement, implement preventive and mitigation measures, and monitor impacts to facilities during construction. Therefore, do not provide design recommendations relating to construction methods.

PS&E Package Development

Work with the Districts to:

- Verify that the project Special Provisions have incorporated the *Trenchless Construction nSSP* posted on the Geotechnical Services website.
- Coordinate with the Districts and the owner of the Trenchless Construction nSSP for any revisions needed from the Districts.

Geotechnical Tasks during Construction

Coordinate with the Resident Engineer and request for review of the following submittals according to project Special Provisions:

- Shop drawings
- Daily construction records
- Post-construction records

Attend the Pre-Construction Meeting and discuss:

- Shop drawings and the proposed construction method
- Mitigation plans for both during and after construction

If requested by the Resident Engineer, provide technical support.
Commonly used Trenchless Methods

The following list presents commonly used trenchless methods and brief descriptions of each method:

- Horizontal Directional Drilling
- Microtunneling
- Pipe Jacking
- Pipe Jacking / Open Shield Pipe Jacking
- Earth Pressure Balance Machine (EPBM) Pipe Jacking
- Pipe Ramming
- Guided Pipe Ramming
- Pilot Tube Method
- Auger Boring
- Guided Boring
- Intermediate Jacking Station
- Hand Tunneling
Horizontal Directional Drilling

Horizontal Directional Drilling (HDD), also known as directional boring, is a method of installing pipes underground using a steerable arc-drilling rig. The bore path can be monitored and adjusted according to the location of the proposed utility or obstacles that are encountered. HDD is a three-phase process:

1. Pilot hole: A drill bit tool creates a pilot hole approximately 1 to 5 in in diameter from the entry to the receiving locations at an angle of 5 to 30 degrees from the ground surface.

2. Reaming: Enlarging the hole by approximately 50% and prepares it for the pipe placement. A reamer tool replaces the drill bit and is pulled back or pushed forward by the HDD machinery to expand the pilot hole. Multiple passes with the reamer may occur during construction.

3. Pipe pullback: The product pipe is attached to the reamer and pulled through the HDD borehole into place.

Drilling fluid is used to suspend and remove soil cuttings. It is also used to stabilize the hole, reduce friction, cool and lubricate the drill bit, and control soil pressures below the surface. Typically, drilling fluid consists of a mixture of water, bentonite, soda ash, and chemicals that assist in preventing swelling. The slurries most used are bentonite-based.

- Accuracy: Varies pending on operator skills
- Pipe: 2- to 48-inch diameter (OD); Steel, HDPE, PVC, Clay, and fiber glass pipe (FRP)
- Typical length: < 6,000 feet
- Suitable: Clay, cohesionless sand/silt
- Unsuitable: Soils containing more than 50% gravel or loose soils, and rock sizes more than 3 inch in diameter
Microtunneling

Microtunneling requires significant ground excavation to construct launching and receiving shafts at the entry and exit points. It requires hydraulic jacking system, closed-loop slurry system, slurry separation unit to remove the soil from the slurry mixture, lubrication system to lubricate the exterior of the pipe string, laser guidance system, crane to hoist pipe sections into the jacking shaft, and control room. Microtunneling Boring Machine (MTBM) is advanced by overcutting the soil by 0.5 in.

- Accuracy: ± 2 inches
- Pipe: 24- to 102-inch diameter (OD); Steel, RCP, VCP, HOBAS®
- Typical length: < 1,500 feet
- Suitable: Loose to very dense sand, soft to hard clay/silt, rock; high groundwater ok
- Unsuitable: Running/flowing groundwater, very loose/loose sand, very soft and soft clay/silt, boulder, hard rock, mixed face condition
Pipe Jacking

Pipe jacking is a trenchless method for installing a pipe through the ground from a drive shaft to a reception shaft. The pipe is propelled by jacks located in the drive shaft. The jacking force is transmitted through the pipe to the face of the pipe jacking excavation.

- **Accuracy:** ± 2 inches
- **Pipe:** 42- to 132-inch diameter (OD); Steel, RCP, fiber glass pipes with high accuracy
- **Typical length:** < 1000 feet
- **Suitable:** Uniform soil free from boulders & cobbles
- **Unsuitable:** Loose sandy soils with high groundwater inflows
- **Construction:** Manual or mechanical soil excavation; Intermediate jacking stations for long pipelines
Pipe Jacking/Open Shield Pipe Jacking

Referred to as “jack and bore”, pipejacking is a system for directly installing pipes behind a shield, with or without a powered excavation head by hydraulic jacking from a launch shaft such that the pipes form a continuous string in the ground. The installation process requires a jacking frame and thrust block in the launch shaft to provide forward thrust. Installation involves a cyclic process of loading the pipe onto the cradle behind the shield, jacking the pipe forward into the ground while simultaneously excavating the soil, retracting the jacks, and repeating the process until the shield reaches the reception shaft.

- **Accuracy:** ± 2 inches
- **Pipe:** 48- to 168-inch diameter (OD); Steel, RCP, VCP, HOBAS
- **Typical length:** < 1,000 feet
- **Suitable:** Stable cohesive soil above groundwater
- **Unsuitable:** Loose or soft soils with groundwater above the invert
Earth Pressure Balance Machine Pipe Jacking

Earth Pressure Balance Machine (EPBM) Pipe Jacking is a person-controlled, guided, pipe jacking method that provides continuous face support. The method is similar to Microtunneling, but for larger diameter pipes. EPBM pipejacking uses mechanical pressure applied to the face to counterbalance the earth and groundwater pressures. Spoil is mixed with soil conditioners which prevent sticking of clays to the machinery and reduce groundwater inflows. The conditioned soil is transported from the face by a tightly fitting auger system to muck carts which transport the spoils to the jacking shaft for removal.

- Accuracy: ±1 to 2 inches
- Pipe: 54- to 144-inch diameter (OD); Steel, RCCP, RCP, HOBAS
- Typical length: < 1,000 ft
- Suitable: Clay, silt with groundwater at or below crown
- Unsuitable: Sand, gravel, cobbles and/or boulders with high groundwater
Pipe Ramming

Pipe ramming is a non-steerable installation method for driving an open-ended steel casing using a pneumatic hammer. Because of the energy involved with each blow, a mandrel must precede the driven pipe. Like the jacking process, the hammering process requires the removal of displaced soil and material as the pipe moves into the embankment.

- **Accuracy:** ±24 to 60 inches
- **Pipe:** 8- to 144-inch diameter (OD); Steel
- **Typical length:** < 300 feet
- **Suitable:** Medium dense sand/gravel, soft to stiff clay, with low groundwater
- **Unsuitable:** Rock/sand with high groundwater
- **Construction:** Low settlement/heave risk; Noisy due to pipe ramming
Guided Pipe Ramming

Guided pipe ramming is a hybrid trenchless technique which can increase the achievable accuracy of the pipe ramming method. The hybrid involves the use of the pilot tube method, pipe ramming, and sometimes auger boring. The following are the processes for Guided Pipe Ramming:

- Installation of a pilot bore by a pilot tube machine from launch area to exit side
- Removal of the guidance head
- Special adapter attached to pilot tubes & hammer, driving the pipes

- **Accuracy:** ±0.5 inches over 300 feet
- **Pipe:** 8- to 144-inch diameter (OD); Steel
- **Typical length:** < 300 feet
- **Suitable:** Medium dense sand/gravel, soft to stiff clay, with low groundwater
- **Unsuitable:** Rock/sand with high groundwater
- **Construction:** Better accuracy than pipe ramming; Pilot tube left in ground
Pilot Tube Method

A two/three stage process for accurately installing pipes by use of a guided pilot tube, followed by upsizing to install the product pipe. After the jacking/reception shafts are in place, the machine is set in place (desired grade, height, line). The pilot tube is guided by camera mounted theodolite and monitor. The pilot bore slanted face displaces the soil, not excavating, thus advancing to the desired location. The pilot bore is enlarged by auger casings which remove the excavated soil in Jacking shaft, and pilot tube is removed from reception shaft. Finally, the product pipe is jacked into place while auger casings are removed from the reception shaft.

- **Accuracy:** ±0.5 inches
- **Pipe:** 4- to 48-inch diameter (OD); Steel, RCP, HOBAS®, Vitrified Clay pipe
- **Typical length:** < 400 feet
- **Suitable:** Loose to medium dense Sand/Silty Sand, Soft to medium stiff clay/silt
- **Unsuitable:** Groundwater level above the pipe and very dense sand
Auger Boring

Technique to form a cased bore from a drive pit to a reception pit. Auger boring rig in the drive pit with its rotating head excavating soil. Spoil is removed back to the drive shaft. After each casing section has been installed, the auger boring rig retracts, and a new section of casing/augers are attached to continue excavation.

- Accuracy: ±12 to 60 inches
- Pipe: 8- to 96-inch diameter (OD); Steel
- Typical length: < 400 feet
- Suitable: Medium to very dense sand /silty clayey gravel, firm to hard clay
- Unsuitable: Rock with high groundwater
- Construction: Decreased length with increased diameter; May be used in conjunction with small boring unit in rock; Possible to withdraw auger to remove obstructions
Guided Boring

Adding auger boring to pilot tube enables longer/larger installations due to added power. A pilot bore is designed, constructed and left in place by use of pilot tube from the launch area to exit side. The guidance head is removed, but pilot tube left in place. The auger machine is attached to the pilot tubes, and by help of special adaptor and a regular auger boring sequence commences along the path of completed bore.

- Accuracy: ±0.5 inches over 500 feet
- Pipe: 8- to 96-inch diameter (OD); Steel
- Typical length: < 400 feet
- Suitable: Medium dense to dense sand, firm to very stiff clay, soft/medium strength rock
- Unsuitable: Rock with high groundwater
- Construction: Possible to withdraw auger to remove obstructions

Intermediate Jacking Stations (IJS)

Cylindrical steel jackets with integrated hydraulic cylinders that are installed during pipe jacking at defined distances apart in the pipe string. These divide the entire pipe string into individual sections, thus reducing the required jacking force on the jacking frame in the launch shaft and enabling very long pipe jacking stretches. IJS can be used with any pipejacking method that allows personnel entry.
Hand Tunneling

Hand tunneling, also called conventional tunneling or hand mining, is typically done using shovels and pneumatic hand tools to excavate the soil or rock. Supports made of wood or metal are then installed to keep the tunnel from collapsing.

Hand tunneling is adaptable and flexible when encountering unexpected conditions such as buried utilities or unknown or difficult soil conditions. Hand tunneling can be used in combination with other trenchless tunneling methods when hard rock, boulders, or other obstructions are encountered. Drilling and blasting are sometimes required to remove large boulders from the excavation path which the boring equipment cannot handle.

For shorter tunnels, hand tunneling can be more economical than using a tunnel boring machine.

With hand tunneling, the workers require enough space in which to excavate the soil. The usual minimum size of pipe that can be installed using hand tunneling is 48 inches.