Installation of Large Diameter Buried Pipes

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I. Introduction and Scope

There is an ongoing need to provide designers, specifiers, engineers, consultants and students an overview and general understanding on the proper installation and rehabilitation of buried municipal and industrial pipelines to provide a long-lasting wastewater and potable water infrastructure that will serve future generations. Most buried pipe relies on interaction with the surrounding soil to carry loads. The properly designed pipe and joining system depends on proper soil support, and therefore proper installation, to provide good structural performance.

The Fiberglass Tank & Pipe Institute was incorporated in 1987 as a non-profit trade association serving the major fiberglass piping, manhole, septic tank, dry wells and oil/water separator manufacturers in the USA. The Institute provides a forum through which industry members can work together effectively toward common goals. This includes coordinating studies, combining resources to provide standard-setting organizations with superior technical data and disseminating information to the government, industry and the public.

This paper is about pipe types, joint types and soil types and how, through good design and installation, they interact to form effective piping-soil systems. The paper describes the basic structural assumptions that designers make on the installation of rigid and flexible pipe in specific soil conditions. Further, the paper describes the stages in pipeline open trench and trenchless construction – excavating the trench, preparing the foundations, placing the bedding, placing and compacting the embedment soil and back fill to design specifications in the construction of new and the rehabilitation of existing sewers and water transmission systems.

II. American Society of Civil Engineers (ASCE)

The American Society of Civil Engineers (ASCE) conducts a Continuing Education program and may be contacted by writing ASCE, 1801 Alexander Bell Drive, Reston, VA 20191-4400 or telephone 1-800 548 2723. The Fiberglass Tank & Pipe Institute shared sponsorship of *The Design and Installation of Buried Pipes* which is the sixth video in the Engineering in Action series and part of the Engineering Applications Video Library. This video is supported by a Resource Book which expands some of the topics and provides useful references for further information. In addition, the Institute is a voting member of additional design and installation practices, namely ASTM D 3839 Standard Practice for Underground Installation of Fiberglass Pipe, and AWWA M-45 Fiberglass Pipe Design Manual.

This paper is modeled after the installation portion of the ASCE video and addresses the following topics:

- *Types of pipe, their materials and pipe joints:* This section distinguishes between pressure and non-pressure pipe, rigid and flexible pipe and an introduction to the types of pipe joints.
- *Site and environmental conditions:* This section discusses variations in site topography that may influence the pipe design. Further, it discusses different types of soil types and densities, their strengths and stiffness.
- *Pipe loading and soil interaction:* This section discusses how to achieve favorable pressure distributions from soil and other loadings by following good installation practices. Further, there is a discussion on pipe bedding and how it affects rigid and flexible pipe performance.
- *Pipe-soil excavation and construction:* This section describes the design of first a foundation layer, next the bedding on which the pipe is placed and the laying of the pipe, then the embedment material placed between the pipe and trench wall and finally the trench backfill.
- *Trenchless construction methods:* Trenchless construction methods for new construction or rehabilitation of existing piping.
- *Pipe joints and joining methods:* This section describes the types of joints and methods by which they are installed.
- *Testing and quality assurance:* This section describes quality control, pipe and joint testing for leaks to ensure the quality of the pipe-soil system.

III. Types of Pipe, Materials and Joining

A. **Rigid Pipe:** Rigid pipe does not deform significantly; it carries loads primarily through inherent strength. When a rigid pipe is overloaded, it cracks. Various forms of concrete, clay and asbestos cement pipe are considered to be rigid. However, differences among types of rigid pipe that includes steel reinforced concrete used to carry tensile loads in low pressure and non-pressure applications.

B. **Flexible Pipe:** Flexible pipe pushes outward against the side fill soil and uses the soil to help carry loads. One definition of flexible pipe is that it can sustain at least a 2% change in diameter without structural damage.

C. **Pipe Materials:**

   a. *Fiberglass Reinforced pipe* may be used for pressure and non-pressure applications. The pipe is manufactured with glass fibers and resin or both and may contain a silica-resin core. It may be wound over an internal mandrel with resin and continuous fibers or chopped fibers or both. Alternatively, it may be centrifugally cast in an external mold.

   b. Smooth wall *steel pip*e may be used for pressurized transmission lines and various coatings and liners may be applied for corrosion protection.

   c. *Corrugated metal pipe* made of steel or aluminum may be used for gravity sewers and culverts with galvanizing the most common corrosion protection.

   d. *Ductile iron pipe* may be used for non-pressure and pressure applications with an interior lining and exterior coating the most common corrosion protection.

   e. *Thermoplastic pipe* may have a solid wall for non-pressure and pressure applications, but when fabricated with a structural wall it is used for gravity waste water applications.

D. Pipe Joining: The integrity of joints is essential to pipe performance. There are a number of pipe joining techniques, most of which require skill and experience. Pipe manufacturers provide detailed procedures for joint assembly and hands-on training.

a. *Gasketed joints* are push-on joints and are used with most pipe systems. The gasket may be located around the spigot end of the pipe, in a groove in the bell end of the pipe or in a groove inside a coupling joint.

b. Other joints include mechanical couplings, adhesive bonding, fiberglass overlays, heat fusion of polyolefin pipe, welding of steel pipe and flanges when making pipe-to-valve connections.

IV. Site and Environmental Conditions

A. Site Evaluation: Long-term performance of pipelines can be affected by natural and human-created site conditions. An evaluation of the site conditions may include:

- Land contours which will affect pipe alignment
- Areas of rock that will make installation more difficult
- Unstable soils that could cause long term settlement
- Water-table levels and fluctuation
- Presence of other buried services
- Seismic activity requiring special design

V. Pipe-Soil System

A. Soil Characteristics: In a pipe-soil system, the most important properties of the soil are strength and stiffness. Thus, soil type and density are important properties for naturally occurring and backfill materials.

B. Native Soil: Native soil types are identified under several classification systems. One of the most common is the Unified Soil Classification System (USCS, or ASTM D 2487). Soil types from soil borings along the pipeline route are classified in the USCS system using two letter symbols. The first letter represents one of the four basic soil classifications: G for gravel, S for sand, C for clay and M for silt. The second letter describes the particle size distribution: W for graded, P for poorly graded, L for low plasticity and H for high plasticity.

C. Backfill Soil: Backfill soil, if grouped into three broad groups, has relatively consistent properties:

- Clean cohesion-less gravels and sands provide the best pipe support, especially when compacted. Cohesion-less means that the particles do not stick together when dry and their strength is not affected by water.
- Clays and silt provide the least support for pipe, especially when not compacted. Clays form hard clods when dry and are soft when wet. Silts are non-plastic and have a flour texture when dry. Both clays and silts are difficult to compact when wet or dry.
- Natural mixtures of gravel, sand, clay or silt may provide good backfill depending on the proper amount of sand and gravel.

D. Soil Density: Soil density is a key indication of soil strength and stiffness and is measured in mass per unit volume (e. g., pounds per cubic foot). Soil density is determined in the laboratory by a test called the “Proctor” and is reported as a % of standard proctor (ASTM D 698).

VI. Pipe-Soil System Construction

A. **Trench Excavation:** Trenches must be excavated so that the side walls remain stable and a movable trench box may be needed to provide a safe working area to prevent the sides from caving. It is a good practice to excavate just ahead of installation to prevent trench destabilizing. The space between the trench wall and pipe should be wide enough to allow placement and compaction of backfill in the haunch zone and compaction of backfill at the side of the pipe.

B. **Trench Foundations:** A foundation layer may be required if the trench bottom is unstable or contains organic or low density material. Bedding supports the pipe, distributes the load on the bottom and should be specified for gravity lines. If the native soil is to form the trench foundation, it must provide stable uniform support for the pipe. Geotextiles or georgics are sometime used to reinforce unstable soils or to separate bedding and backfill from native soils.

C. **Embedment:** Placing and compacting the embedment soil in accordance with specifications is the most important stage of installation. The type of embedment soil and the degree of compaction should be specified in the design.

   Compaction methods include:

   - Smooth-drum or pneumatic-tired rollers compact soil by applying pressure.
   - Impact tampers which compact the soil in specified lifts.
   - Sheepsfoot rollers knead soil soils and break up earth clods.
   - Vibrating rollers or plates shake particles shifting them into denser formation.

VII. Trenchless Technology

Trenchless construction technology methods include the new construction (or replacement) of piping and the renewal (i. e., renovation or rehabilitation) of existing piping. Following is a discussion that describes the difference between installing or renewing pipe underground without digging a trench for large diameter fluid carrying pipe in sizes ranging from 6 inches up to 156 inches (13 feet).

A. **Renewal of existing piping:** Renewal of existing piping involves one of two methods to be determined after conducting an assessment of the structural condition and degree of inflow/infiltration exposure.

   a. *Renovation* is the first option if the existing piping is found to be structurally sound. Then the objective is to reduce inflow/infiltration by injection or sealing techniques to repair limited damage. However, often the host pipe has structurally deteriorated (i. e., missing pieces/cracked joints in masonry piping, hydrogen sulfide corrosion of concrete piping or corrosion of steel piping) and “rehabilitation” is necessary.

   b. *Rehabilitation* measures restore the pipeline’s structural condition while still operating the original “host” pipe. Construction techniques may include slip-lining with a new pipe; interior lining with cements or installing cured in-place liners plus other techniques. This paper is limited to trenchless pipe replacement using slip-lining and pipe jacking methods.

VIII. Trenchless Technology Methods

Following are certain trenchless technology methods described in ascending order, with small diameter methods listed first:

A. New Pipeline Construction or Replacement

a. **Auger Boring:** This is a trenchless construction method used to install a casing by hydraulically pushing the pipe through the ground and removing the spoil through the pipe using an auger. This method is limited to amenable soil conditions, relatively short distances and relatively small diameter piping (e. g., 24 inches).

b. **Direction Drilling:** This is a trenchless construction method that employs a directional drill to bore a horizontal tunnel (e. g., 2,200 feet in length and up to 36 inches in diameter). The tunnel is then reamed to remove the spoil and may be filled with bentonite slurry to maintain tunnel stability. The pipeline is assembled aboveground, pulled or pushed into the tunnel and anchored.

c. **Micro Tunneling and Pipe Jacking:** This is a trenchless piping construction method that pushes the pipe into place (i.e., pipe jacking) behind a micro tunnel boring machine that is remotely controlled. The boring machine is connected to the head of the pipe that follows the slightly oversized tunnel as it is drilled. The minimum diameter is 12 inches, which is limited by the available machines. The practical maximum internal diameter is 84 inches.

d. **Utility Tunneling and Carrier Pipe:** This construction method involves excavating the ground at the leading edge of a shield or boring machine and erecting a lining system from within the excavated space. The minimum size is approximately 48 inches in diameter, which is the size required to allow personnel access to erect a liner from inside the opening. The lined tunnel acts as a host for the installation of the carrier pipe system which is grouted in place.

B. Pipeline Renewal Technologies

a. **Slip-lining:** This is a construction method used to insert a new pipeline inside an existing host pipeline. Although slip-lining reduces the inside diameter of the pipe, the reduced inflow and infiltration combined with the smooth interior of plastic or fiberglass slip-lining materials increase the hydraulic flow. A typical construction method involves digging insertion pits (e. g., 10 feet wide and up to 25 feet long) over the existing pipeline at approximately 600 to over 1,200 foot intervals. Workers enter the pits and remove the top of the existing pipe. After cleaning buckets are pulled through the line, sections of the slip liner are lowered and either pulled or pushed into place. Final installation may include pumping a grout between the host pipe and slip- liner if the structural integrity of the host pipe is in question.

b. **Pipe Bursting**: Pipe bursting tools are used in slip-lining to provide access in collapsed or narrow sections of the host pipe and if the pipe diameter is being increased.

C. Typical Applications

Following are typical applications for new, replacement or rehabilitation of 2 through 102-inch diameter piping systems:

- Storm-water
- Industrial Effluents
- Sewer Interceptors
- Sewer Lines
- Force Mains
- Water Supply
- Salt Water Lines

IX. Quality Assurance

Inspections: Inspection begins with the pipe manufacturer checking the materials they receive and bench testing the pipe after manufacture (i.e., Quality Control). Inspection continues during the entire installation. Pipe sizes and class must be checked against the laying diagram or specification drawings. Pipe, gaskets and fittings should be inspected for damage during transportation and during on-site storage. Once installed, the pipe must be inspected and tested before the line is accepted. Pressure lines can be tested by pressurizing water at operating levels or higher. Gravity systems can be tested by using low-pressure air, low-pressure water and vacuum or if ground water is infiltrating into the pipe. These and other tests assure the quality of the pipe-soil system (i.e., QAQC).

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References

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4. Trenchless Technology (June 1996) article “What is Trenchless Technology Anyway?”
5. American Society of Civil Engineers ASCE , Design and Installation of Buried Pipe