CHAPTER 7: OPEN TRENCH CONSTRUCTION

Figure 7-1: Open trench construction utilizing a modified vee trench.

Excavation

Generally, the contractor will select the method of excavation provided it results in an installation which complies with the project plans, specifications and applicable safety requirements. Any method not in accordance with normally accepted practice must receive prior approval of the engineer.

NCPI offers *Tips for Installing Vitrified Clay Pipe* to ensure contractor success and compliance with best installation practices.

The trench width at the top of the pipe is an important factor affecting structural loading on installed pipe. Any increase in width over the design trench width shown in the specifications or on the plans will increase the backfill load. Should the trench width exceed the specified dimensions, and provision for this condition is not covered in the specifications and plans, the revised method of construction must be reviewed and approved by the engineer.

The trench is generally excavated in the upstream direction. Any variation in this procedure should be at the direction of the engineer. It is important that the line and grade shown on the plans be followed.

Rock Excavation

In rock excavation, the pipe should be bedded with Class I or II material at a minimum depth under the pipe barrel of 6 inches or $B_C/5$ (Pipe outside diameter/ 5), whichever is greater.

Trench Walls

Where ground conditions are such that trench walls may not remain vertical, the contractor may elect to use sloping side walls or to use shoring, sheeting or trench boxes to support the trench wall.

In all cases, the critical dimension is the trench width measured at the top of the pipe (B_d).

Use of Shoring, Sheeting and Trench Box

It may not always be necessary to use shoring, sheeting or trench boxes. The primary concern is for safety and all applicable regulations should be strictly observed. Shoring and sheeting also retains trench width integrity and reduces the risk of cave-in.

Timber sheeting placed in the pipe zone shall be left in place or cut off not lower than the top of the pipe. Pulling timber sheeting creates voids at the sides of the pipe that reduce the side support provided by the soil. Thin steel sheeting may be pulled provided no voids are created and the pipe bedding is not disturbed.

Figure 7-2: *Trench sheeting and spreader bars*

Steel trench boxes are used for trench construction and safety. If possible, the trench box should ride above the top of the pipe, on the bottom of a wider step trench. Narrow backhoe buckets are available to maintain design trench width up to the top of the pipe. In this case, dragging the trench box forward does not interfere with pipe bedding and cannot pull the pipe joints apart.

If the trench box rides below the top of the pipe, care must be taken to protect the integrity of the pipe bedding, particularly when movement of the trench box leaves a void in the pipe bedding. Care must also be taken to ensure that movement of the trench box does not pull the pipe joints apart. A suggested method would be to secure the pipe with a wood cross block, cable and winch at a downstream manhole.

Examples of sheeting, shoring and trench boxes are shown in Figures 7-2, 7-3, and 7-4.

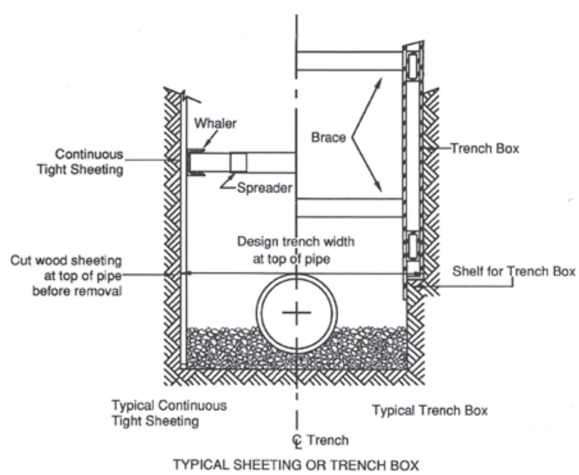

Figure 7-3: *Sheeting or Trench Box*

Foundation Preparation

Trench load design for all pipe is based upon a firm and unyielding foundation. It is essential that the trench bottom remain stable during backfilling, compaction and under all subsequent trench operations.

The foundation is critical to the performance of the entire pipe installation. The foundation must be firm and unyielding as it needs to support the bedding, pipe and backfill as shown in Figure 6-5 on page 6-4.

In cases where the trench bottom is soft and unsuitable to support the pipe, bedding and backfill; removal of material is necessary. Replacement can be accomplished with crushed rock or a woven geotextile fabric or both, to stabilize the foundation. Consult a Geotechnical engineer for other design methods to ensure the foundation can support the load.

Figure 7-4: *Trench Box within the pipe zone*

For trench bottoms above the water table, a general rule-of-thumb is that the foundation is firm and unyielding if a person can walk on the foundation without sinking into the soil or feeling it move underfoot. For trench bottoms below the water table, a Standard Penetration Test should be conducted in accordance with ASTM D1586 *Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils* before construction. An "N" value of 10 or higher is used to consider the foundation firm (for details on SPT, see *Pipeline Installation 2.0*, Howard 2015).

When unstable or rocky trench bottoms are encountered, it will be necessary to over excavate and restore the trench bottom to a firm and unyielding foundation with selected materials capable of properly supporting the pipe. Select native materials, crushed stone, gravel, slag, coral or other granular materials are commonly used for this purpose. The amount of granular material necessary to stabilize the trench bottom will vary according to the field conditions encountered. See additional information on page 6-4.

Figure 7-5: *Constructing a bell hole during pipe laying*

Pipe Installation

Care should be taken in storage, handling and installation to avoid damage to the pipe and joint surface. Consult your pipe manufacturer for further information.

A visual inspection of the pipe just prior to installation should be performed by the installer.

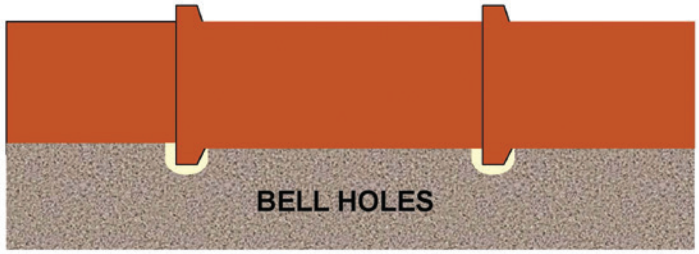

Figure 7-6: Bell hole illustration; the pipe barrel supports the trench load

Pipe are generally installed with the bells pointing upgrade. The pipe barrel must rest firmly and evenly on the trench bottom or bedding material to support the trench load. Bell or coupling holes must be dug to ensure the pipe barrel and not the bells nor couplings support the trench load as shown in Figures 7-5 and 7-6. See *Bell or Coupling Holes* section starting on page 6-7 for further information. If a trench box is used and within the limits of the pipe zone, re-excavation of the bell hole may be necessary on the last pipe laid if filled with bedding material during box advancement. The pipe shall be installed to the design line and grade. The pipe is then installed using a laser or gradeliner.

For additional information on installation and techniques, refer to ASTM C12 *Standard Practice for Installing Vitrified Clay Pipe Lines* and the *NCPI Installation & Inspection Handbook*.

Pipe Joining

Compression joints should be assembled in strict accordance with the manufacturer's recommendations.

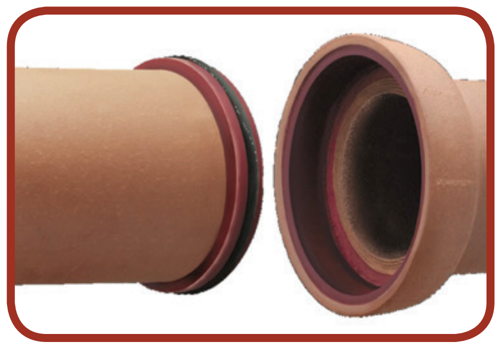

Figure 7-7: VCP flexible compression joint

Particular care should be taken to keep foreign materials from interfering with proper joint assembly. The mating surfaces of the joint should be wiped clean and lubricated prior to assembly following the manufacturer's recommendations.

All compression joints are manufactured in accordance with ASTM C425 *Compression Joints for Vitrified Clay Pipe and Fittings*.

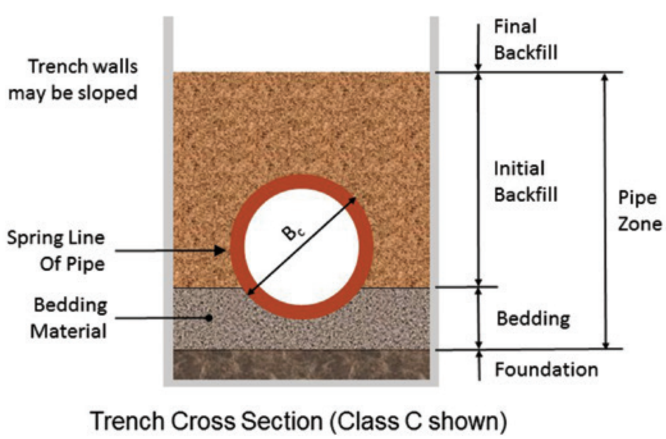

Figure 7-8: Trench Cross Section

Pipe Bedding

The bedding or backfill materials shall be sliced into the haunch areas of the pipe with a shovel or other hand tool to fill the voids in this area. (See haunch support discussion on pages 6-6 to 6-9.)

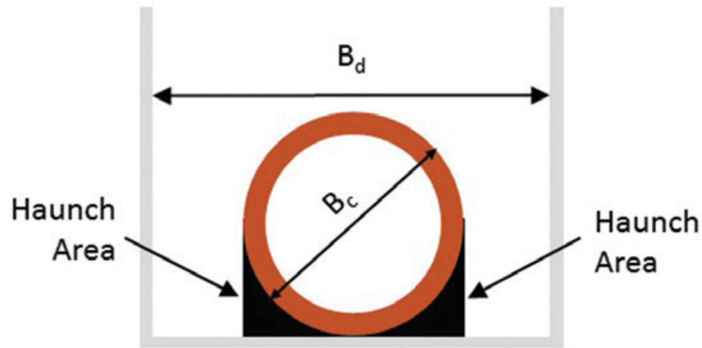

Figure 7-9: *TERMINOLOGY*
B_c = the outside diameter of the pipe.
B_d = the design trench width measured at the horizontal plane at the top of the pipe barrel.

Initial Backfill

Initial backfilling takes place after the pipe has been installed according to the engineering specifications.

The initial backfill extends from top of the bedding material, up the sides of the pipe, to a level 12 inches over the top of the pipe. The initial backfill should be carefully placed as soon as possible to protect the sewer line.

Final Backfill

The final backfill extends from the initial backfill to the top of the trench. Final backfill shall be placed in lifts or stages not to exceed 10 feet when using water consolidation or as required by designated methods of mechanical compaction. Final backfill shall have no rock or stones having a dimension larger than 6 inches within 2 feet of the top of the initial backfill. Selected backfill material may be required for the top foot or more as specified by the engineer.

Figure 7-10: *Shovel slicing the pipe haunches*

Compaction

Compaction of the backfill material is usually required to prevent settlement of the ground surface or to support paving or structures. In areas where support of the pavement over a trench is required, compaction of part or all of the backfill material may be specified. When it is necessary to achieve a high degree of compaction, it may be advisable for the design engineer or contractor to consult a geotechnical engineer.

Trench backfill specifications generally require mechanical compaction in layers, referred to as lifts, but may allow compaction using water. Most soil materials may be compacted by mechanical means in lifts. However, it is necessary to determine if the field moisture content is in the optimum moisture range in order to obtain the desired compaction with normal compactive effort.

Cohesive soils (Class III or IV) are best compacted using pressure, impact, or kneading. Cohesionless soils (Class I or II) are best compacted using vibration. Water settling methods such as flooding, ponding, jetting, or puddling may reduce the soil volume but do not result in very high densities. Amster Howard, in the book *Pipeline Installation 2.0*, describes the various methods of compaction, appropriate equipment, and testing procedures applicable for different types of soils. See www.pipeline-installation.com for more information.

Figure 7-11: *Hoe mounted sheepsfoot roller compacting final backfill*

To achieve the specified compaction with the lowest risk and cost, the correct selection of compaction equipment and methods are necessary. Depending upon the soil type and compaction requirements, wide choices of compaction equipment are available.

Extreme care should be taken when using heavy mechanical compaction equipment. There should be a minimum of 5 feet of cover over the top of the pipe before any heavy mechanical compaction equipment is employed. This will tend to reduce dangerous impact loads on the pipeline. Walk behind and hand held light compaction equipment within the trench can be used at cover depths less than 5 feet.

The selection and use of suitable compaction equipment must be made with care so that the pipe will not be disturbed or damaged. A pavement breaking type of falling weight “stomper” or drop hammer, should never be used for compacting, even with a substantial cover over the pipe. These impact devices can damage the pipe and/or force it out of alignment.

The foundation must remain firm and unyielding during all backfill and compactive efforts. Testing should be performed at the beginning of every project to ensure the compactive method utilized does not damage the pipeline.

Dewatering

Water must be removed from the trench prior to establishment of a firm and unyielding foundation. The trench must be kept dry during all phases of pipe installation.

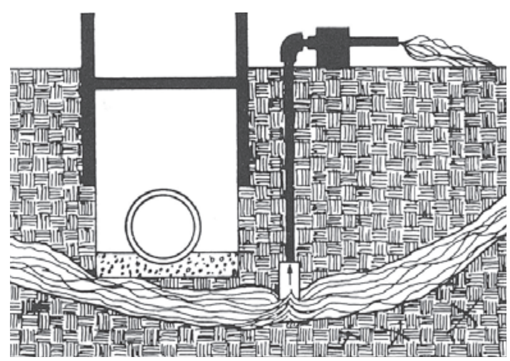

Figure 7-12: *Lowering the ground water table with well points*

- The ground water table can be lowered with well points wherever soil conditions permit. They must be located at intervals dictated by soil properties and placed reasonably close to the trench walls. They should be sunk to a depth below the elevation of the trench bottom (see Figure 7-12).
- In some cases the trench dewatering system may consist of a geotextile in addition to open graded crushed rock. Fine sands in a fluctuating water table environment are vulnerable to foundation problems and may require a geotextile encapsulation of the drain.

Geotextile

Crushed rock or other coarse aggregate is recommended and used as a bedding material to improve the load bearing capacity of pipe. Thicker layers of these materials have been employed to stabilize the base of the trench. Loss of pipe support can occur when open-graded materials are used on sites with fine grained material (as described in ASTM D2487) at the base of the trench and with a water table which can fluctuate rapidly in the pipe zone. This is believed to be caused by water moving rapidly through the fines to the coarse material and carrying the fine-grained soils with it. To prevent movement of the fine grained soils into the voids of the open-graded bedding material, the material should be encapsulated in a geotextile material. Overlaps should be provided and care must be taken to prevent entry into the crushed rock or aggregate base.

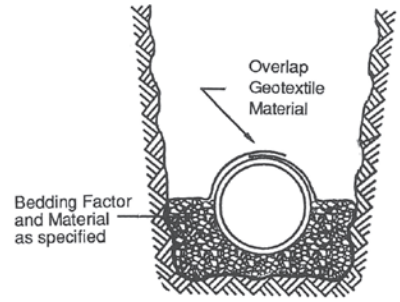

Figure 7-13: Controlling migration of bedding material with Geotextile.

CLSM bedding material is another option when fine grained soil conditions exist with a fluctuating water table. Using CLSM bedding would eliminate the threat of these materials migrating and therefore, a geotextile would not be needed.

Service Connections

In main line and lateral sewer construction, it is important to assure proper embedment, backfill and compaction of the construction materials which support and surround all Wye's or Tee's used for service connections. Some cities use Tee's instead of Wye's since there is an insignificant difference in turbulence of flow between Wye and Tee connections to small and intermediate diameter main line sewers.

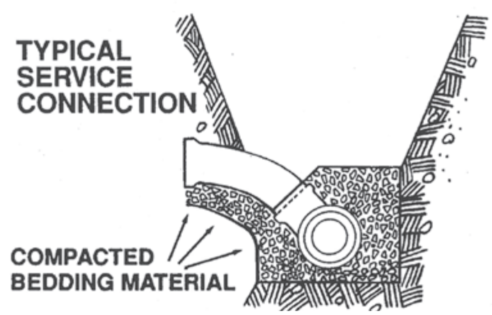

Figure 7-14: Typical Service Connection

Field Verification

After installation, backfill and compaction, the sewer shall be tested for integrity by a method specified or approved by the engineer; see Chapter 11 for applicable methods. It is recommended that testing be performed when the first manhole-to-manhole pipeline is installed, backfilled, and compacted prior to paving and periodically as the installation progresses. This will ensure both the trench design and installation methods are appropriate for the field conditions.

Figure 7-15: Pulling a trench box within the limits of the pipe zone.