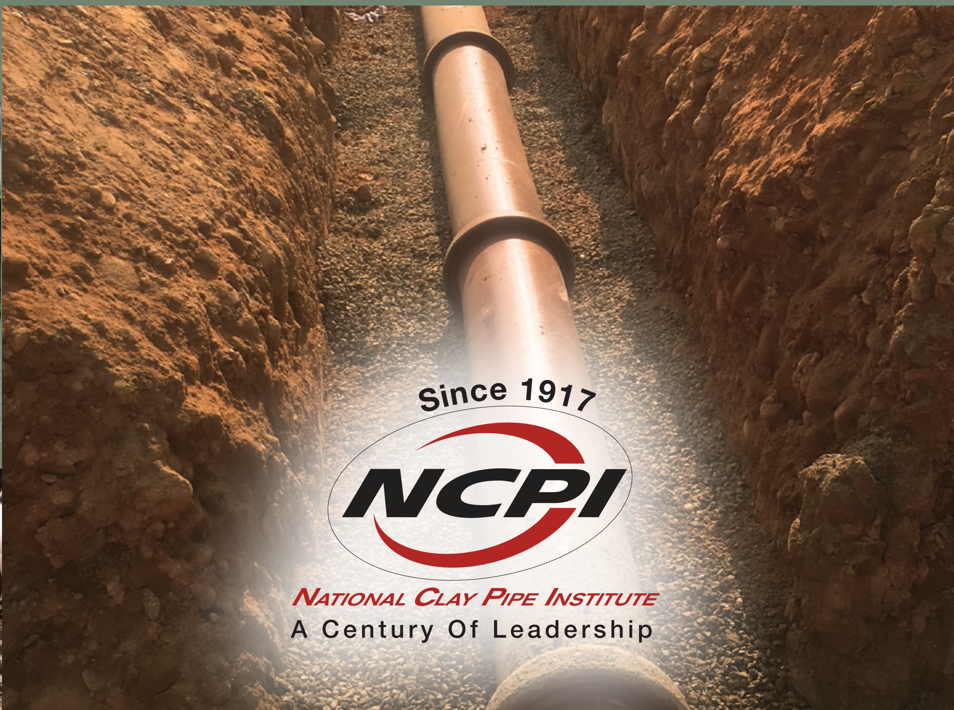
Vitrified Clay Pipe Installation & Inspection Handbook



Since 1917

NCPI

NATIONAL CLAY PIPE INSTITUTE

A Century Of Leadership

Six keys to successful VCP pipeline installation:

Trench Width .... Page 8
Trench width should be measured “dirt-to-dirt” at the top of the pipe barrel (not stopping at the trench box). The trench width should not exceed the design specification.

Foundation.. Page 11
The foundation is the basis on which the entire pipeline is built. A firm and unyielding foundation will ease installation and eliminate problems associated with movement during later phases of construction.

Bedding Classes.. Page 15
Project specifications designate a minimum bedding class requirement to achieve the appropriate factor of safety. Adherence to the minimum bedding class specified is critical to ensure the installation will support the backfill load.

Bell Holes .... Page 25
Bell holes are critical for ensuring that the load is supported by the pipe barrel and for preventing a point load on the bell.

Haunching.. Page 27
Haunching ensures uniform support of the pipe and must be performed before the bedding material is no higher than the quarter point of the pipe barrel.

Compaction... Page 28
Walk behind and hand-held, light compaction equipment can be used in the trench and at cover depths of less than 5'.

VITRIFIED CLAY PIPE
INSTALLATION & INSPECTION HANDBOOK

Vitrified Clay Pipe (VCP)

- Over 5 Billion linear feet of VCP installed in the U.S.
- In service in the U.S. for over 200-years
- THE longest-lasting, most sustainable pipe material

Installation practices encountered throughout the country are many and varied. Those described here are considered sound, although it is recognized that there may be other equally satisfactory methods. Technical data presented are considered reliable, but no guarantee is made or liability assumed.

The recommendations in this Handbook should not be substituted for the judgment of a professional engineer.

Additional information on the installation of clay pipe is found in ASTM C12 *Standard Practice for Installing Vitrified Clay Pipe Lines* and NCPI's *Vitrified Clay Pipe Engineering Manual.*

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Printed in the United States of America.

Table of Contents

CHAPTER 1

PLANNING THE WORK

Scope of Work

The scope of work required for sewer projects is clearly stated in the plans and specifications. Construction Inspectors of a project must interpret these plans and specifications to ensure quality construction, in full compliance with the original designs.

Construction Inspectors verify both workmanship and materials. They must be trained in proper installation techniques for VCP and adhere to project specifications to see that they are fulfilled in every detail. A copy of the plans and specifications must be available at all times.

Each of the following steps in construction must be carefully supervised and inspected and all safety regulations enforced.

- Planning the work
- Pipe specifications & inspection of all construction materials
- Excavation of the trench
- Installation of sheeting or shoring
- Foundation preparation
- Bedding placement under the pipe barrel
- Installation of the pipe
  - – Compression joint assembly
  - – Haunching
- Installation of sewer connections (lateral connections)
- Initial backfill
- Final backfill of the trench
- Inspection and testing before acceptance

Job Records

A field book or project management program is used to record all important events during each day's construction. These notes provide an accurate record of the project. Typical notations in the field book include, but are not limited to:

Figure 1: *Lowering VCP Jacking pipe into the pit*

- Weather conditions
- Equipment used each day and number of people employed
- Time of delivery, quantities, dimensions of items such as sewer pipe, manholes, sand, gravel and crushed rock and other delivery inspection notes
- Time and place of encountered unmarked utility lines or other unexpected obstacles
- Trench width, (from dirt to dirt) measured at the top of the pipe
- Conditions of trench, such as dry, wet, flooded, running sand, gravel or crushed rock
- Location of rock and its volume, especially when its excavation is to be paid for as a separate bid item
- Type of sheeting or shoring used and whether or not it is left in place
- Condition of the trench bottom and its suitability as a firm and unyielding foundation to support the pipe, bedding and backfill
- Haunching method utilized during bedding installation
- Type of equipment and method used to achieve specified compaction of backfill
- Location of connections (These locations should be transferred to "as-built" drawings for future reference)
- Any changes to alignment or pipe size should be documented and recorded in the "as-built" drawings

- Location and description of pipe cradles, pipe encasement and other special work
- Accidents and other unusual events
- Results of test(s) as required by the specifications - Set-up notes, dates, times and witnesses of each acceptance test
- Quantity of work completed each day
- Site visits by suppliers or owners

Working Relationships

Cooperation among the owner, the contractor, the crew, the inspector, the engineer and the material supplier is critical to the success of any project.

If adverse construction conditions are encountered or major deviations from plans and specifications are required, the engineer must be consulted and his recommendations followed. All such changes should be documented and communicated to the team.

NCPI offers training for your construction and inspection team to ensure the success of your project. Contact NCPI or your local manufacturer to schedule training before your project breaks ground.

Figure 2: *Inspectors are a vital link between specification and construction.*

CHAPTER 2

PIPE SPECIFICATIONS & INSPECTION

Pipe Specifications

The engineer's plans and specifications describe the materials, methods and scope of work to be performed. These specifications frequently refer to standards established by recognized professional organizations which serve as excellent supplements to procedures contained in the contract specifications.

The design documents must specify the standards for all pipe materials. Established standards serve to clarify the minimum performance standards the pipe must meet in order to appropriately serve the remaining design parameters.

Pipe material specifications change project design considerations, so pipe materials cannot be treated as interchangeable.

Pipe Inspection

VCP (Vitrified Clay Pipe) is inspected and measured for compliance with quality standards at the factory. It should be inspected at the point of delivery and again immediately prior to installation. Rejected pipe shall not be marked or defaced in any manner. The supplier must be notified immediately of the reason(s) for rejection.

ASTM Standards

Those concerned with pipe installation should be familiar with the latest revision of regional construction specifications and the following American Society for Testing and Materials (ASTM) Specifications:

C12 *Standard Practice for Installing Vitrified Clay Pipe Lines*

C301 *Standard Test Methods for Vitrified Clay Pipe*

C425 *Standard Specification for Compression Joints for Vitrified Clay Pipe and Fittings*

C700 *Standard Specification for Vitrified Clay Pipe; Extra Strength, Standard Strength and Perforated*

C828 *Standard Test Method for Low-Pressure Air Test of Vitrified Clay Pipe Lines*

C896 *Standard Terminology Relating to Clay Products*

C923 *Standard Specification for Resilient Connectors Between Reinforced Concrete Manhole Structures, Pipes and Laterals*

C1091 *Standard Test Method for Hydrostatic Infiltration Testing of Vitrified Clay Pipe Lines*

C1208/1208M
Standard Specification for Vitrified Clay Pipe and Joints for Use in Jacking, Sliplining, Pipe Bursting and Tunnels

CHAPTER 3

TRENCH EXCAVATION

Excavation

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.

Excavated trenches should be straight, to the required grade with the width (measured at the top of the pipe) held to a minimum. Adequate room for proper haunching should be considered during design.

Line and Grade

In most cases, the engineer establishes line and grade and places grade stakes and/or other reference markers to show station and depth of pipe invert. The contractor works from these markers to dig the trench at the specified location and depth.

Figure 3: *A common pipe laser in use*

A laser is commonly used to establish alignment of pipe and grade of trench bottom, bedding materials and pipe invert.

The laser sends a straight beam of laser light from a unit which has been positioned for proper line and grade to a target with predetermined reference marks.

Figure 4: *Laser target used to confirm final alignment.*

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 excavated trench width (dirt to dirt) measured at the top of the pipe (see Specified Width iIllustrations in Figure 5). The trench width at the top of the pipe must not exceed the specified width as shown on the design drawings. Even a small increase in trench width causes a large increase in loading. For example, if a 2'0" trench width is increased only 6", the backfill load is increased by about 50%.

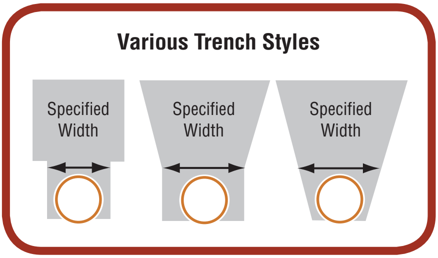

***Figure 5:** No matter which trench style is used, trench width as measured from dirt to dirt at the top of the pipe is critical.*

In deep cuts, a narrow step-trench or sub-trench may be excavated after a wider trench is used above the level of the top of the pipe. A vee or modified vee trench may also be used. In all cases, the specified trench width at the top of the pipe must not be exceeded without written approval.

Sheeting, Shoring and Moveable Trench Boxes

It may not always be necessary to use shoring, sheeting or trench boxes. The primary concerns are for personnel safety and strict observation of all applicable regulations. Shoring and sheeting also retains trench width integrity and reduces the risk of cave-ins.

***Figure 6:** Trench sheeting and spreader bars*

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 and haunch areas are not disturbed.

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.

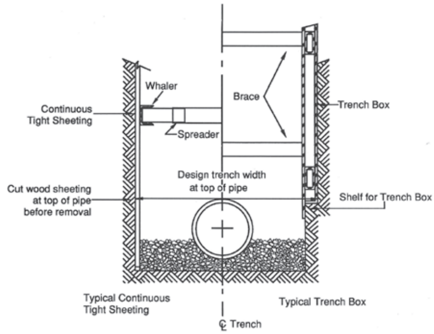

Figure 7: *Trench sheeting and spreader bars*

If the trench box rides below the top of the pipe, care must be taken to protect the integrity of the pipe bedding and haunch areas, 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.

Dewatering

Water must be removed from the trench prior to establishment of a firm and unyielding foundation and before placement and final grading of the bedding under the pipe barrel.

The trench must be kept dry during all phases of pipe installation.

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 8).

Several well points can be joined together so that one pump can handle a group of points.

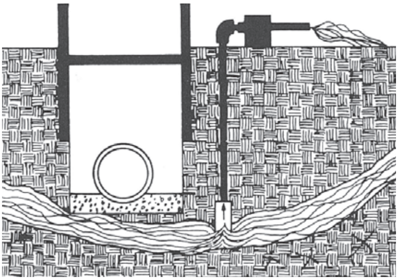

Figure 8: *Lowering the ground water table with well points*

CHAPTER 4

FOUNDATION & BEDDING CLASSES

The construction inspector is responsible for ensuring that the class of bedding specified is actually provided.

Foundation

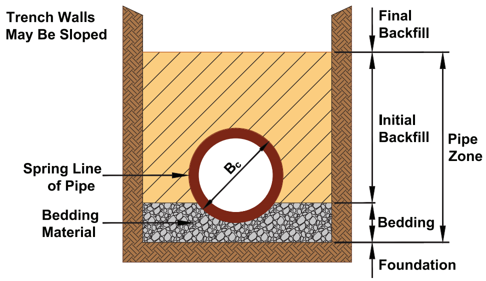

Figure 9: *Trench Cross Section (Class C shown)*

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. This foundation provides uniform longitudinal support to minimize differential movement of the pipeline.

Stable uniform support for the pipe 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, backfill, and compactive efforts.

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 an unstable trench bottom is encountered, it is necessary to over-excavate and create a firm and unyielding foundation. Replacement with native materials, crushed rock, gravel, slag or coral are commonly used to build a foundation capable of properly supporting the bedding, pipe, backfill and compactive efforts.

When necessary, these materials can be combined with a geotextile, or the geotextile can be used in place of those materials to stabilize the trench bottom. The over-excavation as well as whether geotextile is necessary to stabilize the trench bottom, will vary according to the field conditions encountered. Consult a geotechnical engineer for other design methods to ensure the foundation can support the load.

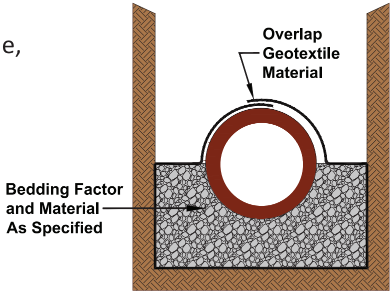

Figure 10: *Controlling migration of bedding material with Geotextile*

When using Class I or II bedding materials (see Uniform Soil Groups Table on page 43), loss of pipe support can occur when both of the following conditions are present:

1. Fine-grained native soils (as described in ASTM D2487) at the foundation level and/or within the pipe zone, AND

2. A rapidly fluctuating water table within the pipe zone.

In this environment, to prevent loss of pipe support, a geotextile encapsulation of the Class I or II bedding material is needed (see Figure 10). For additional information, see the Geotextile section on page 23 of this handbook or the *Vitrified Clay Pipe Engineering Manual*.

If a foundation stabilization support method is being used, any change to this method must be made at the next manhole connection.

Bedding and Materials

Allowable Bedding Material & Initial Backfill per Bedding Class					
Bedding Class	Allowable Bedding Material			Allowable Initial Backfill	
	Soil Class (Table 3)	Gradation	Size	Soil Class (Table 3)	Particle Size
Class D	N/A	N/A	N/A	I, II, III or IV	1"
Class C	I or II		1"	I, II, III or IV	1½"
Class B	I or II	- 100% passing a 1" sieve - 40 – 60% passing a 3/4" sieve - 0 – 25% passing a 3/8" sieve	1"	I, II, III or IV	1½"
Crushed Stone Encasement	I or II		1"	I, II, III or IV	1½"
CLSM	I or II		1"	I, II, III or IV	1½"
Concrete Cradle	N/A	N/A	N/A	I, II, III or IV	1½"

Table 1: *Allowable Bedding Material and Initial Backfill per Bedding Class (from ASTM C12)*

The pipe may be laid on a flat trench bottom of suitable undisturbed native material (Class D Bedding) or, in the case of over-excavating, on a restored flat trench bottom. In either case, the bottom of the entire pipe barrel shall have a continuous and uniform line bearing support.

If any foundation support method is being utilized by the installer, any change to this method must be made at the next manhole connection.

Bell or coupling holes must be dug so that the load is entirely supported by the pipe barrel, not the pipe bell. **The bell or coupling must not support any portion of the load.** The holes should be no larger than necessary to make sure that the pipe barrel is resting firmly and evenly on the trench bottom or bedding material. When properly installed, there should be room to slide a hand around the lower half of the bell or coupling.

When an imported bedding material is used (Class C, B and Encasement Bedding Classes), the bottom of the trench should be over-excavated. The depth of the material below the bottom of the pipe should be at least one-sixth of the outside diameter of the pipe (B_C), but in no case less than 4 inches. The portion of the bedding directly beneath the pipe barrel and above the foundation **should not be compacted** for Class B or Crushed Stone Encasement.

At this point the contractor can make a quick, simple check of the elevation of the bedding material using the laser. This minimizes the need for further grading when the pipe is installed.

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.

Load Factors

The load a pipe can support varies according to the class of bedding.

The engineering specifications will define a bedding class. The engineer uses a “load factor” based on a designated type of bedding to compute the load bearing capacity of the pipe. The field supporting strength consists of the strength of the pipe itself increased by the support of the particular bedding. For example, the load factor for Class C bedding is 1.5 which means the field supporting strength is 50% greater than the specified pipe strength.

The engineer has selected the bedding class and associated “load factor” to meet the calculated trench load. This is why the contractor and inspector must make sure that the design trench width is maintained and that the bedding class is achieved according to the engineer’s specifications. Remember, the pipe strength and the specified bedding class work together to support the trench load.

Bedding Classes

Class D Bedding, Load Factor = 1.1

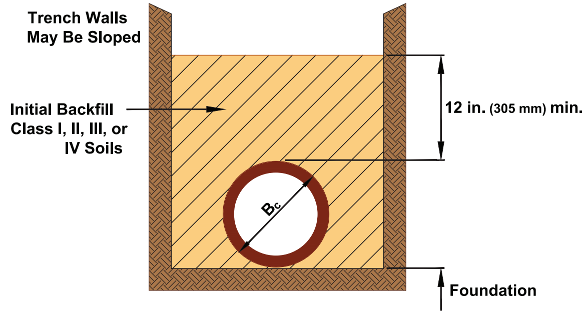

Figure 11: *Class D Bedding – Load Factor = 1.1*

The pipe shall be placed on a foundation with bell holes provided. The bottom of the entire pipe barrel shall have continuous and uniform bearing support.

The initial backfill shall be either Class I, II, III, or IV soil having a maximum particle size of 1 inch. Refer to the Uniform Soil Groups table in the reference section of this handbook for specific information about soil classes.

Class C Bedding, Load Factor = 1.5

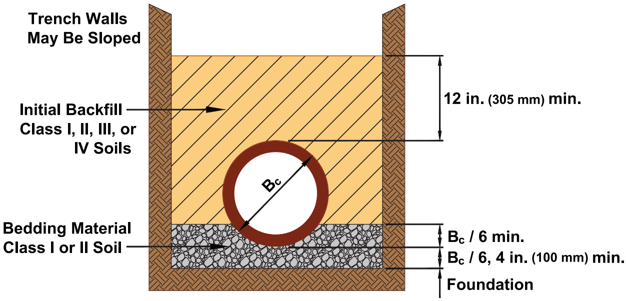

Figure 12: *Class C Bedding – Load Factor = 1.5*

The pipe shall be bedded (with bell holes provided) in Class I or Class II soil having a maximum particle size of 1 inch. Refer to the Uniform Soil Groups table in the reference section of this handbook for specific information about soil classes.

Sand is suitable as a bedding material in a total sand environment but may be unsuitable where high and rapidly changing water tables are present in the pipe zone. It may also be undesirable in a trench cut by blasting or in trenches through clay type soil. Regardless of the trench condition or bedding class, the maximum load factor for sand bedding is 1.5.

The bedding shall have a minimum thickness beneath the pipe of 4 inches or one-sixth of the outside diameter of the pipe (B_C), whichever is greater (see Table 2 on page 42), and shall extend up the haunches of the pipe one-sixth of the outside diameter of the pipe. The bedding material shall be carefully placed and sliced into the haunches of the pipe with a shovel or other suitable tool.

The initial backfill shall be of selected material either Class I, II, III, or IV having a maximum particle size of 1½ inches.

Class B Bedding, Load Factor = 1.9

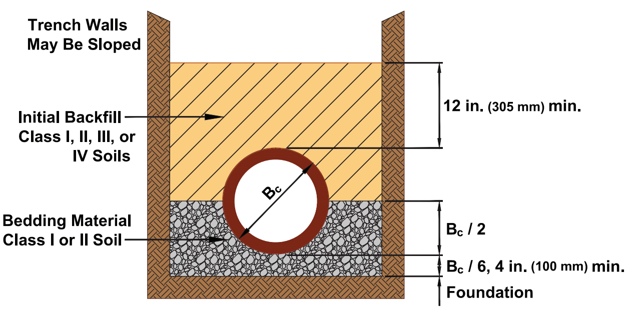

Figure 13: *Class B Bedding – Load Factor = 1.9*

The pipe shall be bedded in Class I or Class II soil with bell holes provided. Refer to Table 1 on page 13, for maximum particle size and gradation.

The bedding shall have a minimum thickness beneath the pipe of 4 inches or one-sixth of the outside diameter of the pipe (B_C), whichever is greater (see Table 2 on page 42), and shall extend up the haunches of the pipe to the springline. The portion of the bedding directly beneath the pipe and above the foundation **should not be compacted.** The bedding material shall be carefully placed and sliced into the haunches of the pipe with a shovel or other suitable tool. Initial shovel slicing should be performed before the bedding is no higher than the quarter point of the pipe diameter. Shovel-slicing the bedding material into the haunches of the pipe is required to achieve the 1.9 load factor.

The initial backfill shall be either Class I, II, III or Class IV having a maximum particle size of 1½ inch.

Crushed Stone Encasement Bedding, Load Factor = 2.2

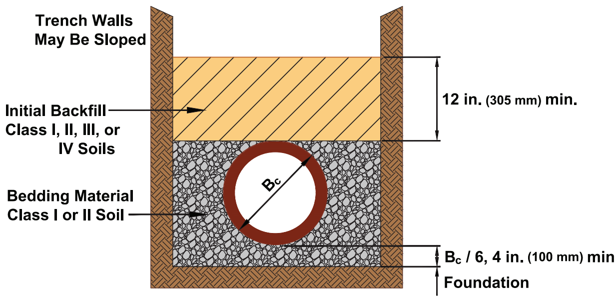

Figure 14: *Crushed Stone Encasement Bedding – Load Factor = 2.2*

The pipe shall be bedded in Class I or Class II soil with bell holes provided. Refer to Table 1 on page 13, for maximum particle size and gradation.

The bedding shall have a minimum thickness beneath the pipe of 4 inches or one-sixth of the outside diameter of the pipe (B_C), whichever is greater (see Table 2 on page 42), and shall extend upward to a horizontal plane at the top of the pipe barrel. The portion of the bedding directly beneath the pipe and above the foundation **should not be compacted**. The bedding material shall be carefully placed and sliced into the haunches of the pipe with a shovel or other suitable tool. Initial shovel slicing should be performed before the bedding is no higher than the quarter point of the pipe diameter. Shovel-slicing the bedding material into the haunches of the pipe is required to achieve the 2.2 load factor.

The bedding material shall extend to the specified trench width and upward to the top of the pipe barrel following removal of any trench sheeting or boxes.

The initial backfill shall be either Class I, II, III or IV having a maximum particle size of 1½ inches.

Controlled Low Strength Material (CLSM) Bedding, Load Factor = 2.8

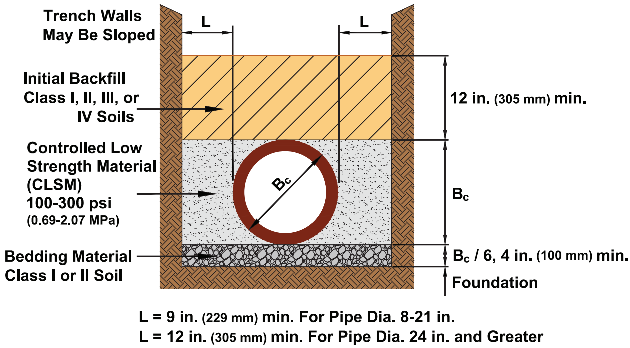

Figure 15: *Controlled Low Strength Material (CLSM) Bedding – Load Factor = 2.8*

The pipe shall be bedded on Class I or Class II soil with bell holes provided. Refer to Table 1 on page 13, for maximum particle size and gradation.

The bedding shall have a minimum thickness beneath the pipe of 4 inches or one-sixth of the outside diameter of the pipe (B_C), whichever is greater (see Table 2 on page 42).

Figure 16: *Measuring the spread diameter to determine flowability prior to placement*

For pipe diameters 8 to 21 inches, CLSM shall extend a minimum of 9 inches on each side of the pipe barrel. For pipe diameters 24 inches and larger, CLSM shall extend a minimum of 12 inches on each side of the pipe barrel.

Testing for flow consistency should be conducted in accordance with ASTM D6103 /D6103M *Standard Test Method for Flow Consistency of Controlled Low Strength Material (CLSM)*. When placed, CLSM shall have a measured spread of 7 – 9 inches. A typical result is shown in Figure 16.

The 28-day compressive strength shall be 100 to 300 psi as determined by ASTM D4832 *Standard Test Method for Preparation and Testing of Controlled Low Strength Material (CLSM) Test Cylinders.*

CLSM shall be directed to the top of the pipe to flow down equally on both sides to prevent misalignment. Place CLSM to the top of the pipe barrel.

Initial backfill shall only commence after a 500 psi minimum penetrometer reading is achieved as determined by ASTM C403/C403M *Standard Test Method for Time of Setting of Concrete Mixtures by Penetration Resistance.* The penetrometer shall have a maximum load capability of 700 psi and have a 1 square inch by 1 inch long cylinder foot attached to a ¼-inch diameter pin as shown in Figure 17. The initial backfill shall be either Class I, II, III, or IV having a maximum particle size of 1½ inches. The fill can be completed in a single pour to the top of the pipe or it can be done in two or more lifts if desired.

Figure 17: *A pocket penetrometer can be used to determine CLSM strength prior to backfill*

When CLSM is properly placed at the top of the pipe, no installations have resulted in flotation. CLSM must be directed to flow equally on both sides of the pipe to prevent misalignment and flotation.

NCPI conducted tests to define the optimal mix for CLSM used in gravity sewer applications with vitrified clay pipe. Varying percentages of ⅜-inch coarse aggregate, accelerator and entrained air were tested. The primary goal was to determine a mix design that would yield the fastest cure time over a maximum of six hours based on penetration resistance readings using a penetrometer.

Fast Set Mix Design for CLSM

Cement: 188 pounds (type I/II or II/V)

Fine aggregate: 75% - 80% (by weight)

Coarse aggregate: 25% - 20% (by weight)

Water: Water necessary to obtain Flowability (7"- 9" spread diameter)

Accelerator: 4% (as a percent of cement)

Air entrainment: 15% - 20%

Flowability: 8-inch, +/- 1 inch spread diameter (3-inch diameter by 6-inch long cylinder, per ASTM D6103)

Concrete Cradle Bedding, Load Factor = 3.4

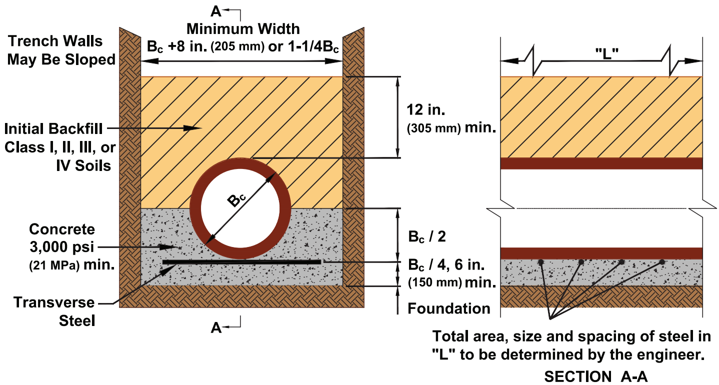

Figure 18: Concrete Cradle Bedding – Load Factor = 3.4

The pipe shall be bedded in a cradle of reinforced concrete having a thickness under the barrel of at least 6 inches or one-fourth of the outside diameter of the pipe (B_c) whichever is greater, and extending up the haunches to a height of at least one-half the outside diameter of the pipe. The cradle width shall be at least equal to the outside diameter of the pipe plus 4 inches on each side or 1.25 times the outside diameter of the pipe, whichever is greater. If the trench width is greater than either of these dimensions, concrete may be placed to full trench width.

The initial backfill shall be either Class I, II, III, or IV having a maximum particle size of 1½ inches.

The load factor for concrete cradle bedding is 3.4 for reinforced concrete with p = 0.4%, where p is the percentage of the area of transverse steel to the area of concrete at the bottom of the pipe barrel as shown in Section A-A of Figure 18.

Full Concrete Encasement

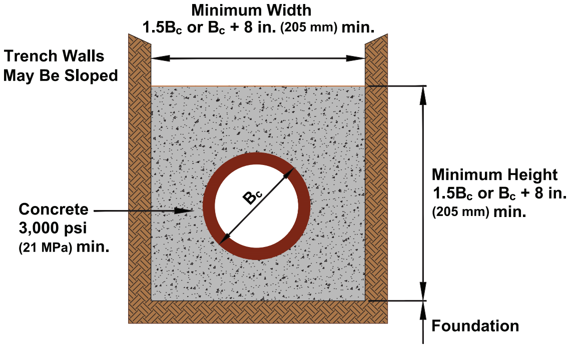

Figure 19: *Full Concrete Encasement*

There are specific sites where concrete encasement may be desirable. Concrete encasement shall completely surround the pipe and shall have a minimum thickness, at any point, of 4 inches or one-fourth of the outside diameter of the pipe (B_c), whichever is greater.

The encasement shall be designed by the engineer to suit the specific use.

The use of concrete cradle or full encasement class bedding permits the pipe to support substantially higher backfill loads. A vibrator or stinger must be used when concrete is placed to ensure consolidation of the material in the pipe haunches. The trench must not be backfilled before the concrete has gained sufficient strength to support the backfill load. Backfill should not proceed until the concrete has attained adequate compressive strength.

Concrete Construction Joints

When using concrete as a component of a pipe bedding system, consideration should be given to the use of construction joints to maintain pipeline flexibility. For concrete cradle and full encasement installations, a construction joint is needed. These joints shall be aligned with the face of the socket (end of the pipe bell).

Figure 20: *EPS foam blocks used in a full encasement installation.*

Expanded polystyrene (EPS) foam blocks and sheets, mastic, plywood or various other means have been utilized to direct the fracture of the concrete beam.

Field Transitions Joints

Where construction of the line changes from concrete bedding to another bedding class, the concrete shall terminate at the face of the bell to provide flexibility and prevent shear fracture. In locations where the bedding material type changes or when pipe is transitioned from inside a casing to a conventional trench within a manhole run, consideration should be given to differential settlement (similar to connections at manholes; see Chapter 7). In all cases, shorts or stub pieces of 24-inches or less can be used to provide this flexibility.

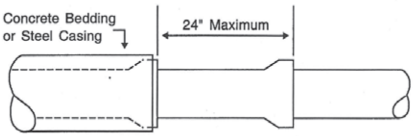

Figure 21: *Field Transition Joints*

Where construction of the line changes from jacking pipe to bell and spigot or plain end coupling pipe (different type joint designs), shorts or stub pieces with rubber couplings can be utilized to make the transition between pipe types.

Geotextile

Class I or II bedding materials (see Uniform Soil Groups Table on page 43) are specified for Class C, B, Encasement and CLSM bedding classes to improve the load bearing capacity of the pipe. Thicker layers of these materials have also been employed to stabilize the base of the trench. When using Class I or II bedding materials, loss of pipe support can occur when both of the following conditions are present:

1. Fine-grained native soils (as described in ASTM D2487) at the foundation level and/or within the pipe zone, AND

2. A rapidly fluctuating water table within the pipe zone.

This loss of pipe support is 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 Class I or II bedding material, the bedding should be encapsulated in a geotextile. Overlaps should be provided and care must be taken to prevent entry into these voids (see Figure 10 on page 12).

CHAPTER 5

PIPE INSTALLATION

Pipe Handling

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 22: *Constructing a bell hole during pipe laying*

Bell or Coupling Holes

Pipe are generally installed with the bells pointing upgrade. Bell or coupling holes must be carefully excavated so that the bells or couplings support no part of the load. The pipe barrel is designed to support the trench load and must rest firmly and evenly on the trench bottom or bedding material. Bell or coupling holes must be dug to ensure the pipe barrel and not the bells or couplings support the trench load as shown in Figure 23.

When properly installed, there should be room to slide a hand around the lower half of the bell or coupling before the next pipe is installed.

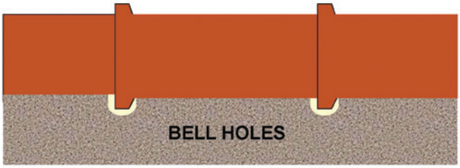

Figure 23: *Bell hole illustration; the pipe barrel supports the trench load*

If a trench box is used within the limits of the pipe zone, re-excavation of the bell hole may be necessary on the last pipe laid if the bell hole is filled with bedding material during box advancement.

Pipe Joining

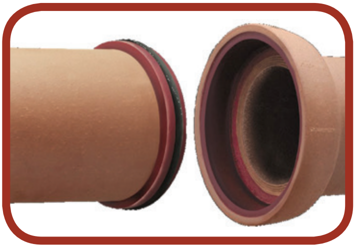

Figure 24: *VCP flexible compression joint*

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

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.*

Lubricate both joint surfaces, line up the bell and spigot and shove the pipe together with a steady pressure. Pipe should be in straight alignment during assembly.

For small diameter pipe, joint assembly can be done by hand or with a bar as an aid. When using a bar, care should be taken not to damage the lip of the bell or coupling. A wood block may be used to cushion the bar pressure.

For larger sizes, a nylon sling, cable, or other approved device used to lower the pipe can be used as an aid in the assembly of the compression joint.

Care must be taken to ensure that the joint is completely assembled.

Bedding and Haunching

After laying the pipe, the bedding material is placed to the height specified by the class of bedding.

The bedding or initial backfill should be shovel sliced in the "haunches" of the pipe to fill the voids and consolidate the material in this area. This assures uniform support of the pipe barrel and achieves the required load factor. Shovel slicing should be done when the bedding material is no higher than about one-fourth of the pipe diameter.

Shovel-slicing the bedding material in the haunch areas is critical. It takes little time, maintains grade, eliminates voids beneath the pipe and in the haunch areas, consolidates the bedding, and adds little or nothing to the cost of the installation.

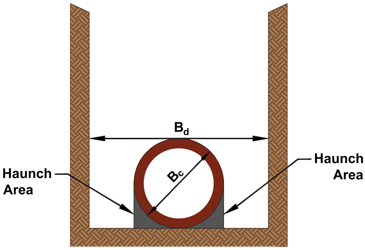

Figure 25: *Terminology*

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.

Figure 26: *Shovel slicing the pipe haunches*

Shovel slicing is required to achieve the desired load factor.

Good haunch support:

- Significantly increases the load carrying capacity of buried pipe
- Requires compacting the soil in the haunch area using a shovel, spade, or other suitable tool
- Can be attained by using CLSM (flowable fill) with the proper flowability

- Is not attained by dumping gravels and crushed rock beside the pipe
- Can be aided by pipe settling into uncompacted bedding to mobilize the strength of the haunch soil

Initial Backfill

The initial backfill is then carefully placed to a minimum height of 12" above the top of the pipe. This is done to maintain pipe alignment and protect the pipe from damage during final backfilling. The initial backfill should be free from large material and conform to Allowable Bedding Material & Initial Backfill per Bedding Class table in the reference section.

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 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.

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, in order to obtain the desired compaction with normal effort, the field moisture content of the soil needs to be optimal.

Cohesive soils (Class III, IV, V) 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. In the book *Pipeline Installation 2.0*, Amster Howard 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 27: *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.

Compaction Abuse

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 compaction method utilized does not damage the pipeline.

The selection and use of suitable compaction equipment must be made with care so that the pipe will not be disturbed or damaged.

Figure 28: *Close-up shot of a sheepsfoot roller*

CHAPTER 6

LATERALS & SPECIAL FEATURES

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.

No matter which style of service connection is specified, it is critical that all lateral service connections observe the same standards as the mainline installation for embedment, backfill, and compaction of the construction materials.

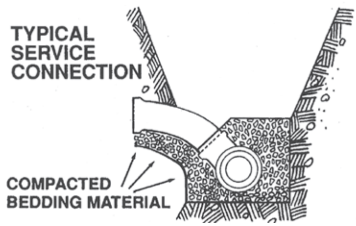

Figure 29: *Typical Service Connection*

Pipe Fittings

Special attention should be given to compaction under the fitting spurs/branches to avoid shear failure through backfill load.

Where vertical risers cannot be avoided, special construction methods are required and should be evaluated by the design engineer.

Tapping for Service Connections

Connection of a service lateral to a sewer main can be accomplished by the use of various available tap saddle kits or tee fittings. All tap saddle kits and tee fittings require core drilling a hole in the sewer main (see Figure 30).

Figure 30: *Tapping a new sewer main for a service connection*

Excavation of Laterals

Pipe trenches should be dug with the same care required for main lines. Trenches should be straight, to the required grade with width held to a minimum, while allowing adequate room for haunching.

Where the soil is sufficiently firm to provide a solid foundation for the pipe, the trench bottom should provide uniform support for the barrel of the pipe. Bell or coupling holes must be dug at the proper intervals so that the barrel of the pipe supports the weight.

Care should be taken to excavate no deeper than necessary, unless there is a supply of angular crushed stone or other suitable coarse material available to bring the trench bottom to grade and provide uniform support for the barrel of the pipe. Rock or other unyielding material, which is encountered, should be removed. The pipe foundation should be free of all lumps and irregularities.

Where the bottom of the trench is either of rock or an unstable material, it is necessary to excavate below grade and backfill to grade with angular crushed rock or similar material.

Installation

Each section of pipe should be installed to a specified line and grade. Pipe are generally installed with bells or couplings upgrade.

As the installation progresses, the interior of the pipe should be cleared of all dirt and foreign material. The trench should be kept as dry as possible while the pipe is being installed. The specific manufacturer's recommendations should be carefully followed.

Figure 31: *Two services constructed in the same trench excavation*

Backfill

Normally the excavated earth is satisfactory for backfilling purposes. The trench should be backfilled as soon as inspection is completed. To protect the line from lateral movement, the bedding and backfill should be carefully placed around and above the top of the pipe.

Stoppers

In cases where fittings or stub-outs will not be connected immediately, a suitable stopper with compatible jointing should be securely placed in the fitting. If a low-pressure air test is performed, stoppers must be braced externally.

CHAPTER 7

CONNECTING TO MANHOLES & OTHER STRUCTURES

Manholes shall be installed on an unyielding foundation. Where the pipeline connects to a manhole or other structure, protection from differential settlement must be provided. A bell and spigot joint with a factory applied gasket or plain-end pipe joined with rubber compression couplings will provide the needed flexibility and water-tightness. Two points of flexibility should be used within 36 inches of each manhole connection. This can be accomplished by using:

1. two short lengths (stubs of 24 inches or less) or
2. one short length and one flexible manhole connector

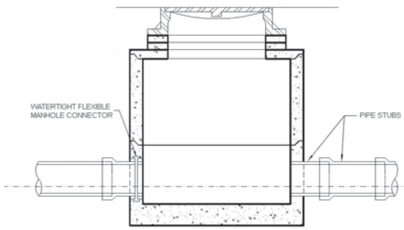

Figure 32: *Two points of flexibility should be provided within 36 inches of a structure.*

Acceptable points of flexibility shall be a factory-applied joint (per ASTM C425), an elastomeric compression coupling (per ASTM C425), or a flexible manhole connection (per ASTM C923 *Standard Specification for Resilient Connectors Between Reinforced Concrete Manhole Structures, Pipes, and Laterals*). Each connection shall be considered a single point of flexibility.

Figure 33: *Two points of flexibility at this manhole are provided by the flexible manhole connector and the flexible compression joint on the short length of pipe.*

If a manhole connector is utilized as one of the points of flexibility, it is important that the pipe is centered in the connector and the tightening clamp is torqued per the manufacturer's instructions. Mortar or grout should never be placed between the pipe and the wall of the concrete structure.

ASTM C923 requires axial flexibility of 7^{o} in any direction. The use of mortar in this area or not centering the pipe will limit the ability of the connector to compensate for differential settlement via axial flexibility. If a filler is required, the product used must remain flexible.

CHAPTER 8

TESTING INSTALLED LINES

Acceptance testing is the process of formalizing acceptance of a completed pipeline. Methods commonly used are, Low-Pressure Air Testing, CCTV Inspection and Hydrostatic Infiltration Testing. Common practice is to test each section from manhole to manhole after it is backfilled. NCPI recommends the low-pressure air test as the preferred method of acceptance testing because it is not a subjective test.

The first section of any sewer project should be tested immediately upon completion to ensure that the installation procedure will produce the results required by the specifications.

Experience demonstrates that continual testing as a job progresses improves adherence to good job site practices, increases contractor productivity and ensures compliance with engineering plans.

All acceptance tests must be performed by qualified personnel. These tests should be witnessed by the inspector or engineer's representative.

Low-Pressure Air Testing

This is the preferred and most commonly-used post-installation testing method because there is no room for interpretation. The low-pressure air test is unforgiving, it is not a subjective test.

When the measured water table is 5 ft. or less above the pipe barrel at the midpoint of the test section, a low-pressure air test is an accurate method of testing a sewer line for acceptance (for 5 ft. or greater see "Hydrostatic Infiltration Testing" on page 39).

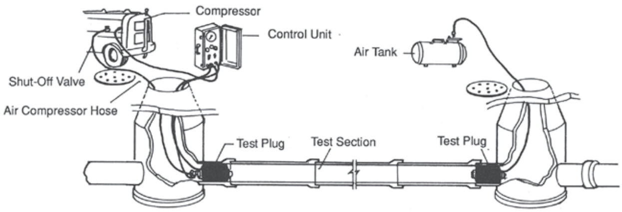

Figure 34: *Line Acceptance Testing*

Acceptance or failure of a line is determined by a specific drop in air pressure over a specified length of time (see *Low-Pressure Air Test for Sanitary Sewers* booklet, available online).

Test Procedure

Clean the sewer line by flushing before testing to wet the pipe surface and clean out any debris. Plug all pipe outlets to establish the required test pressure. All stoppers in laterals should be braced.

Figure 35: *Test Plug*

ASTM C828 *Standard Test Method for Low-Pressure Air Test of Vitrified Clay Pipe Lines* describes the procedure for air testing sewer lines. Air test tables found in the NCPI *Low-Pressure Air Test for Sanitary Sewers* are derived from ASTM C828.

The pressure-holding time is based on an average holding pressure of 3 psi gauge or a drop from 3.5 psi to 2.5 psi.

Add air until the internal air pressure of the sewer line is approximately 4.0 psi gauge. After an internal pressure of approximately 4.0 psi is obtained, allow time for the air pressure to stabilize. The pressure will normally show some drop until the temperature of the air in the test section stabilizes.

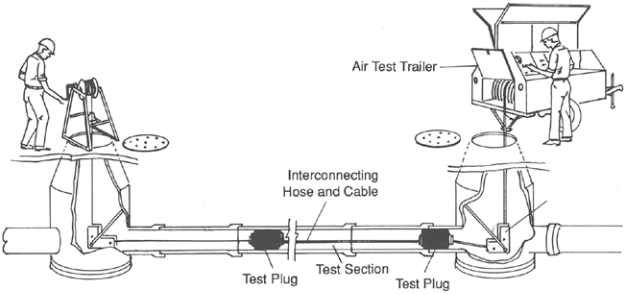

Figure 36: *Segmental Air Testing*

When the pressure has stabilized above the 3.5 psi gauge reading, reduce the pressure to 3.5 psi to start the test. Record the drop in pressure for the test time. If the pressure does not drop more than 1.0 psi during the test time, the line is presumed to have passed. It is not necessary to continue the test for the total time when it is clearly evident that the rate of air loss is less than the allowable.

This procedure can be used as a presumptive test, which enables the installer to determine the acceptability of the line before backfill and subsequent construction activities.

Safety During Testing

The air test can be dangerous if a line is improperly prepared due to improper training, a lack of understanding or carelessness.

Calculate the amount of back pressure the plug must withstand and be certain the plug being used is designed to withstand this pressure. Always use a pressure gauge and regulator when inflating a sewer plug. Under-inflated plugs will not be able to withstand the required back pressure. Over-inflated plugs can rupture causing possible damage and injury.

It is extremely important to install and brace the various plugs to prevent blowouts. A force of 250 Lbf is exerted on an 8-inch plug by an internal pipe pressure of 5 psi. The sudden expulsion of a poorly installed plug, or of a plug that is partially deflated before the pipe pressure is released, can be dangerous.

As a safety precaution, pressurizing equipment should include a regulator or relief valve set at 10 psi to avoid over pressurizing and damaging an otherwise acceptable line. No one shall be allowed in the manholes during testing.

CCTV Inspection

The high-quality video, images and reports CCTV camera systems produce have led to wide-spread adoption. As an investigative tool, these CCTV systems are unmatched in enabling operators to highlight concerns and more importantly the reports create a historical record of the condition of the pipe at the time of final acceptance. This visual record has become an important reason for many agencies to require CCTV inspection as part of the final acceptance testing on newly installed pipelines. This visual record has become a useful tool in the overall accessment of the collection system.

It is essential that CCTV operators receive ongoing training on the equipment, condition assessment methods and characteristics of the pipe material evaluated to minimize errors. Unintentional, incorrect observation(s) are not only unproductive but can also be quite expensive. There have been cases in which dig-ups were conducted only to discover the assessment did not match actual pipe conditions, or they were far less significant than originally indicated. For this reason, NCPI recommends the low-pressure air test as the preferred method of acceptance testing.

See the NCPI document *A Guide to Analyzing CCTV Inspection* (available online).

Hydrostatic Infiltration Testing

When the measured water table is 5 ft. or greater above the pipe barrel at the midpoint of the test section, infiltration testing is the preferred and least expensive method of acceptance testing. The infiltration test measures the ground water entering the pipeline. Manholes should be tested independent of the sewer line.

ASTM C1091 *Standard Test Method for Hydrostatic Infiltration Testing of Vitrified Clay Pipe Lines* describes the procedure for Infiltration Testing and allowable rate of infiltration.

If water is present in the line, isolate the section of pipeline being tested from the upstream side. Discontinue pumping of ground water for a minimum of 24 hours prior to testing. Determine the infiltration flow rate in the sewer line at the furthest downstream point of the section being tested.

It is necessary to collect and measure the infiltration over a period of time. A convenient collection time is one hour. This measurement can be converted to gallons per hour and to gallons per inch diameter per mile, per day and compared to the specified standard.

Water infiltration may be collected by using a dam at the invert of the pipe, using a flow-through plug or other convenient method.

The set up in Figure 37 is recommended to achieve this result. After the infiltration for the pipe is determined, the lower plug in the upstream manhole can be removed and the combined infiltration from the pipeline and the manhole can be measured. The manhole infiltration is calculated by simply subtracting the pipeline infiltration from the combined pipeline and manhole infiltration. Other procedures for infiltration testing may be equally satisfactory.

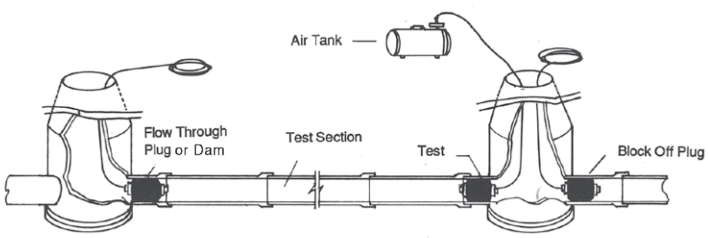

Figure 37: *Recommended set up for Infiltration Testing*

CHAPTER 9

TRENCHLESS INSTALLATIONS USING VITRIFIED CLAY JACKING PIPE

Clay pipe has high compressive strength to resist considerable jacking forces and possesses the needed abrasion resistance to prevent external damage as the pipe is pushed through the surrounding ground.

Figure 38: *Jacking pipes staged at the launch pit on a pilot tube project utilizing a powered cutter head.*

Additionally, clay pipe has the chemical resistance for longevity and tight joints to prevent leakage. Special low-profile joints are designed to facilitate trenchless installation. ASTM C1208/C1208M *Vitrified Clay Pipe and Joints for Use in Jacking, Sliplining, Pipe Bursting and Tunnels*, is the first ASTM standard specification explicitly developed for vitrified clay jacking pipe.

For details on the trenchless installation methods of pilot tube guided boring, slurry microtunneling, and static pipe bursting, see Chapter 8 of the NCPI's *Vitrified Clay Pipe Engineering Manual.*

It is important to us that your project is successful. To ensure that success, please contact NCPI early in your design and planning phase.

Reference Section

Allowable Bedding Material & Initial Backfill per Bedding Class					
Bedding Class	Allowable Bedding Material			Allowable Initial Backfill	
	Soil Class (Table 3)	Gradation	Size	Soil Class (Table 3)	Particle Size
Class D	N/A	N/A	N/A	I, II, III or IV	1"
Class C	I or II		1"	I, II, III or IV	1½"
Class B	I or II	- 100% passing a 1" sieve - 40 – 60% passing a 3/4" sieve - 0 – 25% passing a 3/8" sieve	1"	I, II, III or IV	1½"
Crushed Stone Encasement	I or II		1"	I, II, III or IV	1½"
CLSM	I or II		1"	I, II, III or IV	1½"
Concrete Cradle	N/A	N/A	N/A	I, II, III or IV	1½"

Table 1: *(As presented on page 12) Allowable Bedding Material and Initial Backfill per Bedding Class (from ASTM C12)*

Bedding Thickness Under Barrel (B_C/6 or 4" Minimum) Class C, B, Encasement and CLSM Bedding Classes		
Pipe Size	**Outside Diameter (B_C)** (Varies by Manufacturer)	**Bedding Required***
4"	5" to 5.3"	**4"**
6"	7.5" to 8"	
8"	9.7" to 10"	
10"	12.1" to 12.9"	
12"	14.5" to 15"	
15"	18" to 18.7"	
18"	21.8" to 22.5"	
21"	25.5" to 25.8"	**4¼ "**
24"	28.9" to 29.8"	**5"**
27"	32.7" to 33.7"	**5½"**
30"	36" to 37.5"	**6¼"**
33"	39" to 39.5"	**6½"**
36"	43" to 44"	**7¼"**
39"	46" to 47"	**7¾"**
42"	50" to 51"	**8½"**
* values are rounded up to the nearest ¼"		

Table 2: *B_C/6 or 4" minimum (from ASTM C12)*

Uniform Soil Groups for Pipe Installation from ASTM C12[1]		
Soil Class	**Definition**	**Symbols**
Class I[2]	**Crushed Rock** 100% passing 1-1/2 in. sieve, </= 15% passing #4 sieve, </= 25% passing 3/8 in. sieve, </= 12% passing #200 sieve	
Class II[3]	**Clean, Coarse Grained Soils** Or any soil beginning with one of these symbols (can contain up to 12% fines) Uniform fine sands (SP) with more than 50% passing a #100 sieve should be treated as Class III material	GW, GP, SW, SP
Class III	**Coarse Grained Soils With Fines** Or any soil beginning with one of these symbols	GM, GC, SM, SC
	Sandy or Gravelly Fine Grained Soils Or any soil beginning with one of these symbols, with >/= 30% retained on #200 sieve	ML, CL
Class IV	**Fine-Grained Soils** Or any soil beginning with one of these symbols, with < 30% retained on a #200 sieve	ML, CL
Class V[4]	**Fine-Grained Soils, Organic Soils** High compressibility silts and clays, organic soil	MH, CH, OL, OH, Pt

1 Soil Classification descriptions and symbols are in accordance with ASTM D2487 and ASTM D2488
2 For Class I, all particle faces shall be fractured.
3 Materials such as broken coral, shells, slag, and recycled concrete (with less than 12% passing a #200 sieve) should be treated as Class II soils.
4 Class V soil is not suitable for use as a bedding or initial backfill material.

Table 3: *Uniform Soil Groups for Pipe Installation (from ASTM C12)*

Our Member Companies

For specific questions about your project, please contact your pipe supplier.

LOGAN
Today's Clay Pipe
loganclaypipe.com
800-848-2141

GLADDING, McBEAN
gladdingmcbean.com
800-776-1133

NO-DIG
no-dig-pipe.com
740-385-2184

MISSION
mission clay products LLC
missionclay.com
951-277-4600

building products company llc
buildingproductscompany.com
602-269-8314

Design – Installation – Inspection – Maintenance

NCPI offers the tools and training to ensure successful project design and installation. Vitrified clay pipelines, properly designed and installed, will serve the community indefinitely.

- **NCPI Toolbox Online**
  (Leastcost, Hyflow & Trench Load programs)
- **National Clay Pipe Institute YouTube Channel**
  Available videos range from manufacture of VCP to open trench and trenchless installations, bedding with CLSM made using native soil and haunching research, to name just a few.
- **NCPI's *Vitrified Clay Pipe Engineering Manual***
  An exhaustive reference manual
- **Educational Workshops**
  NCPI offers a variety of workshops to engineers, designers, contractors, installers, inspectors, operations and maintenance personnel. We want to ensure the success of your project. Workshops qualify for PDH credits.

For more information, or to schedule your workshop, contact your pipe supplier or call the NCPI office at 262-742-2904.

The National Clay Pipe Institute represents the clay pipe industry to sewer system decision makers. We offer the unique perspective, history and knowledge of the longest-serving and longest-lasting pipe product available.

For additional information on installation and techniques, refer to ASTM C12 *Standard Practice for Installing Vitrified Clay Pipe Lines.*

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