CHAPTER 4

FOUNDATION & BEDDING CLASSES

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

Foundation

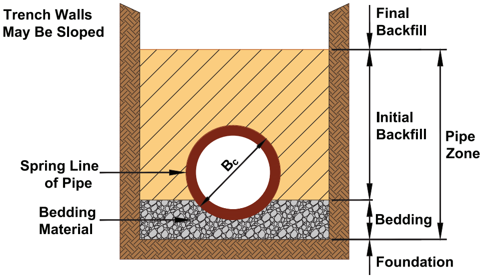

Figure 9: *Trench Cross Section (Class C shown)*

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.

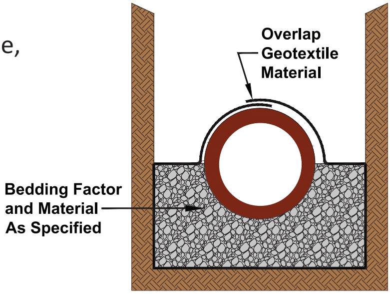

Figure 10: *Controlling migration of bedding material with Geotextile*

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 ¾" sieve - 0 – 25% passing a ⅜" 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

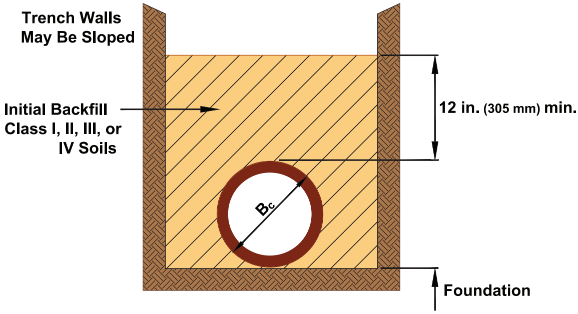

Figure 11: *Class D Bedding – Load Factor = 1.1*

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

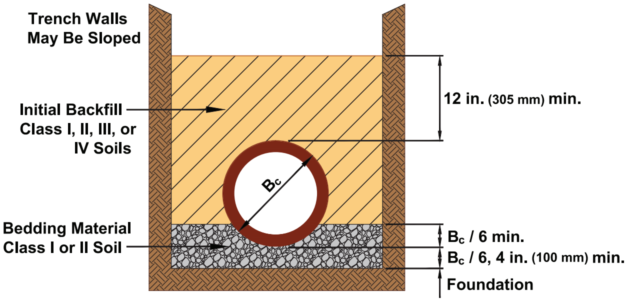

Figure 12: *Class C Bedding – Load Factor = 1.5*

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

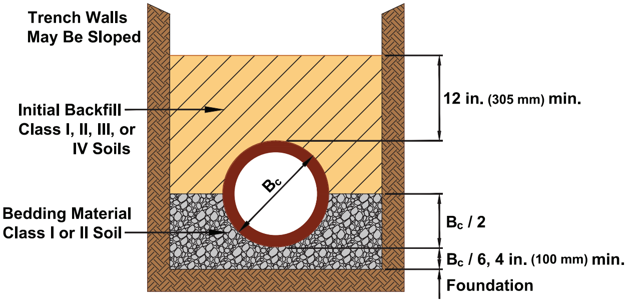

Figure 13: *Class B Bedding – Load Factor = 1.9*

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

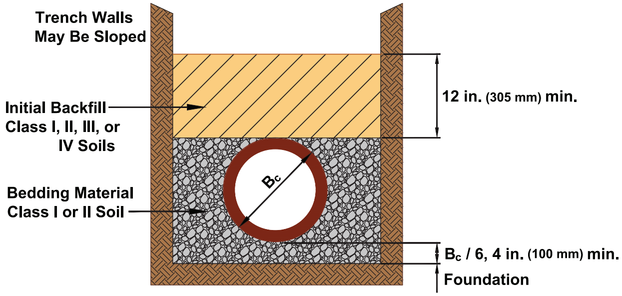

Figure 14: *Crushed Stone Encasement Bedding – Load Factor = 2.2*

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

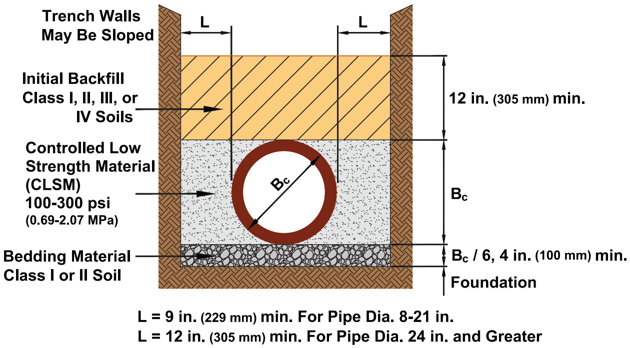

Figure 15: *Controlled Low Strength Material (CLSM) Bedding – Load Factor = 2.8*

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 3⁄8-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

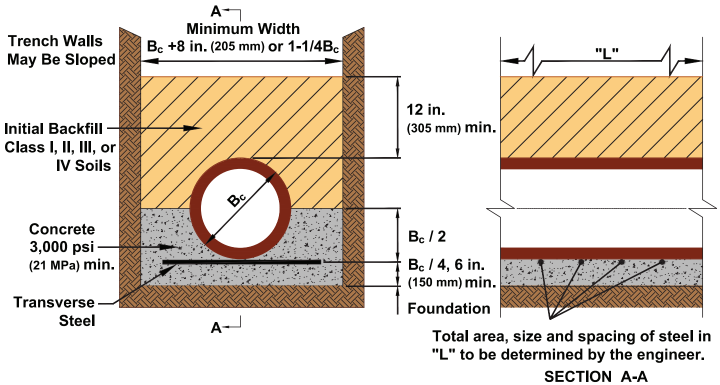

Figure 18: *Concrete Cradle Bedding – Load Factor = 3.4*

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

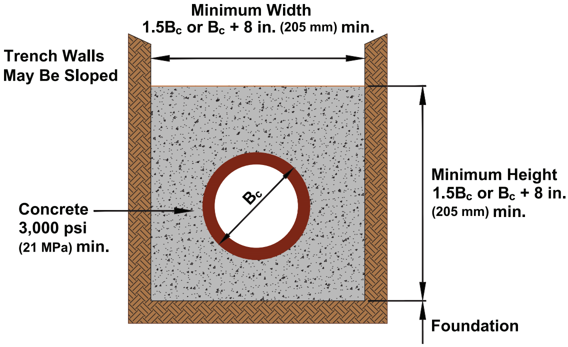

Figure 19: *Full Concrete Encasement*

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.

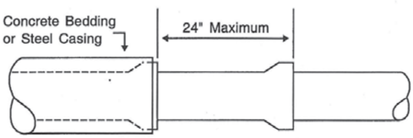

Figure 21: *Field Transition Joints*

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).