

2014 UPDATES TO ASTM C12

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ABSTRACT

The ASTM standard C12 “Standard Practice for Installing Vitrified Clay Pipe Lines” gives recommended methods for installing vitrified clay pipe (VCP). C12 was significantly modified for the 2014 version (C12-14). Three of the most notable changes were:

- Use of uncompacted soil for the bedding
- Adoption of uniform soil groups
- Recommended gradation for the bedding soil

The current standard includes several bedding classes for proper support of the pipe with corresponding Load Factors. The Load Factors reflect the amount of support the bedding soil gives to the installation. While the basic trench configurations and Load Factors have not changed, the 2014 version incorporates various improvements including:

- Discontinuation of the concrete arch bedding class
- Adoption of *Uniform Soil Groups for Pipe Installation*
- Recommendation for methods of improving the foundation to provide proper support for the pipe when the foundation is deemed not suitable
- Updates to bedding standards, including:
 - Use of uncompacted soil for the bedding
 - Recommended gradation for bedding soils
 - Specifying the appropriate amounts of fractured faces for Class II soil particles
 - Limiting the maximum soil particle size for bedding and initial backfill materials to 1-inch and 1½-inch particles.
- Requiring shovel slicing of haunch area soil to occur before the bedding height is 0.25 of the outside diameter of the pipe.
- Replacing subjective language with more definitive language
- ASTM specialized standards relating specifically to Controlled Low Strength Materials (CLSM) bedding for VCP

In 1995, C12 became the first pipe installation standard to give CLSM bedding as a viable option. Requirements for flowability when placed, 28 day compressive strength, and set time prior to backfill load are now referenced to the ASTM CLSM

standards. One advantage of using VCP is that it will not float during CLSM installation.

INTRODUCTION

One hundred years ago, in 1915, ASTM C12 was issued. Finally adopted in 1919, this standard has undergone countless revisions since. The standard was significantly modified in 2014 (C12-14).

The 2014 update incorporates the following improved installation requirements and techniques:

- 1- Discontinuation of the concrete arch bedding class.
- 2- Adoption of *Uniform Soil Groups for Pipe Installation*.
- 3- Recommendation for methods of improving the foundation to provide proper support for the pipe when the foundation is deemed not suitable.
- 4- Updates to bedding standards, including:
 - a. Use of uncompacted soil for the portion of the bedding that the pipe is laid on.
 - b. Recommended gradation for bedding soils.
 - c. Specifying the appropriate amounts of fractured faces for Class II soil particles.
 - d. Limiting the maximum soil particle size for bedding and initial backfill materials to 1-inch and 1½-inch particles, depending upon the bedding class.
- 5- Requiring shovel slicing of haunch area soil to occur before the bedding height is 0.25 of the outside diameter of the pipe.
- 6- Replacing subjective language.
- 7- Adopted ASTM standards relating specifically to CLSM.

Trench Cross Section

Figure 1 illustrates the terms that are used throughout this paper and in connection with the changes to the ASTM standard.

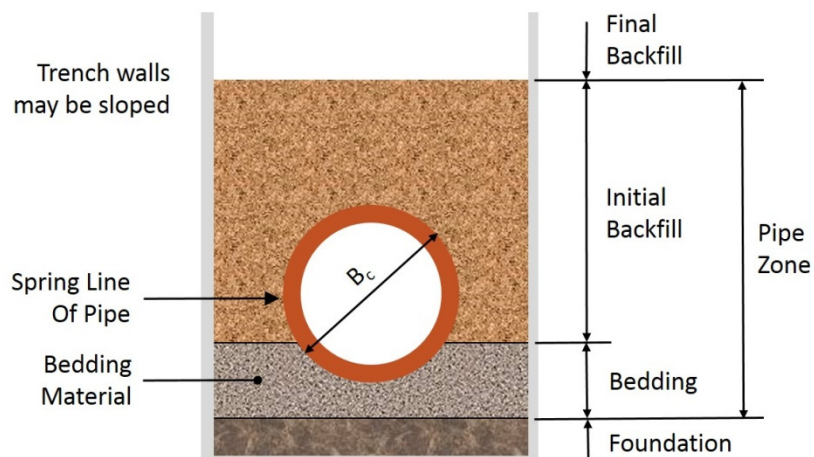


Figure 1: Trench Cross Section Terminology
(Class C shown)

Bedding Classes – Class D, C, B, and Crushed Stone Encasement

The previous standard included several bedding classes for proper support of the pipe with corresponding load factors. The currently recognized bedding classes are shown in Figure 2. The load factors reflect the amount of support the bedding soil gives to the installation (pipe bearing strength X load factor = field supporting strength). While the basic trench configurations and load factors have not changed, the references to type of soil used in the various areas have changed to use uniform soil group nomenclature. The soil groups are defined in Table 1 on page 4.

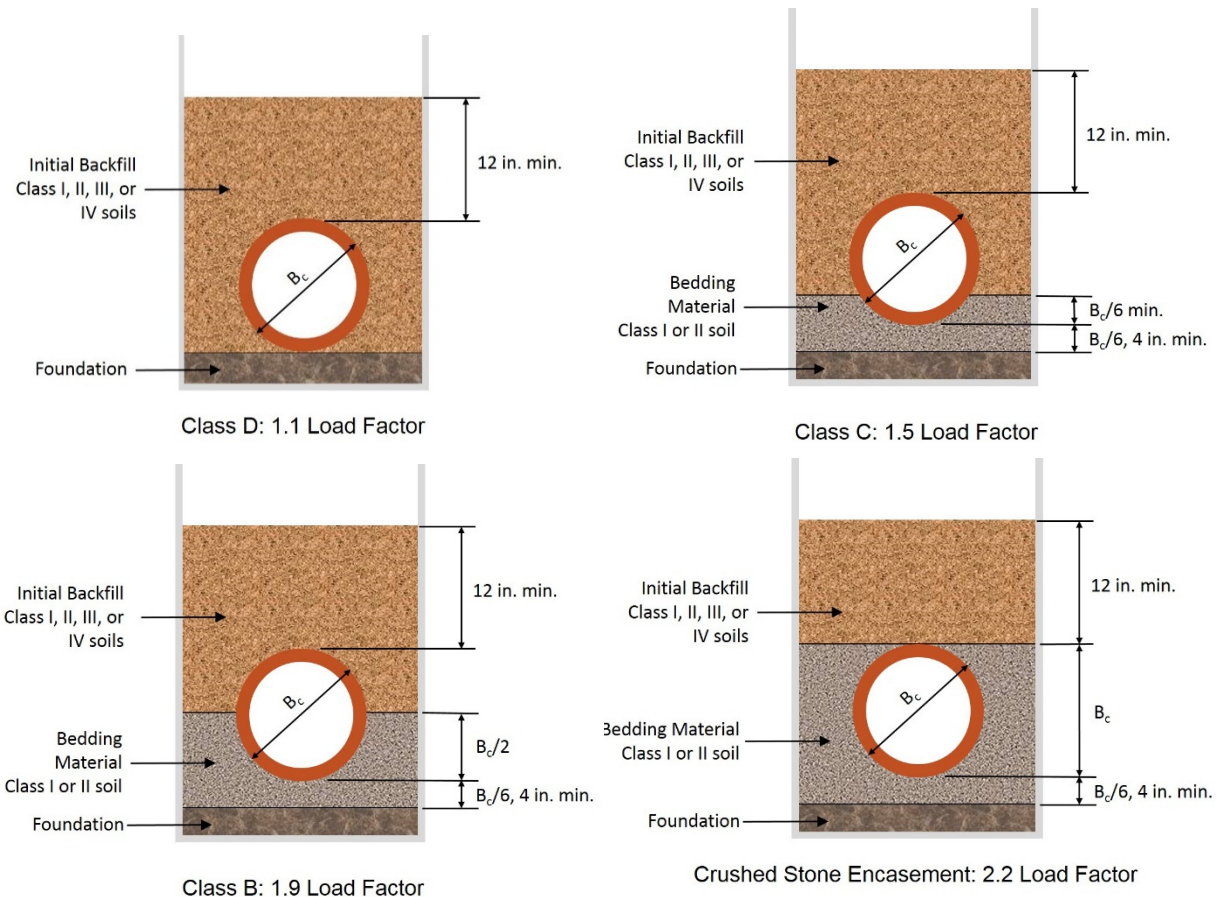


Figure 2: VCP Bedding Classes Class D through Crushed Stone Encasement

DISCONTINUED USE OF CLASS A – CONCRETE ARCH

Until the 2008 version of C12, Class A bedding was defined using two installation details, a concrete cradle and a concrete arch. The Class A concrete arch is no longer recommended and older specifications that include this option should be updated. The concrete arch was discontinued because any settlement of the bedding soil beneath the arch had the potential to increase the load on the pipe. Additionally, the settlement could result in a point load at the contact of the concrete arch on the top of the pipe. ASTM C12 continues to recognize two viable concrete bedding classes, concrete cradle and full concrete encasement.

UNIFORM SOIL GROUPS

The soil groups used in each bedding class are defined in Table 1. The soils are grouped according to strength required for pipe support (Howard 2009). This table has been incorporated into many ASTM standards and AWWA manuals and is now included in C12.

The additional soil requirements for VCP installations, such as gradation and particle angularity were added.

Uniform Soil Groups for Pipe Installation¹		
Soil Class	Definition	USCS Symbols
Class I²	Crushed Rock <ul style="list-style-type: none"> - 100% passing 1-1/2 in. (38 mm) sieve - \leq 15% passing #4 sieve - \leq 25% passing 3/8 in. (9.5 mm) sieve - \leq 12% passing #200 sieve 	
Class II³	Clean, Coarse Grained Soils <ul style="list-style-type: none"> - Any soil beginning with one of these symbols (can contain up to 12% fines) - Uniform fines 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 <ul style="list-style-type: none"> - Any soil beginning with one of these symbols 	GM, GC, SM, SC
	Sandy or Gravelly Fine Grained Soils <ul style="list-style-type: none"> - Any soil beginning with one of these symbols, with \geq 30% retained on #200 sieve 	ML, CL
Class IV	Fine-Grained Soils <ul style="list-style-type: none"> - Any soil beginning with one of these symbols, with $<$ 30% retained on a #200 sieve 	ML, CL
Class V⁴	Fine-Grained Soils, Organic Soils <ul style="list-style-type: none"> - 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 1: Uniform Soil Groups for Pipe Installation

FOUNDATION

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 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.

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 supports the load.

The native material in the trench bottom must be capable of excavation to a uniform undisturbed flat bottom for a Class D installation. If the trench is over-excavated, the trench bottom should be brought back to grade with the required bedding material.

BEDDING

Uncompacted Bedding

A layer of uncompacted bedding beneath the pipe is now included for Class B and Crushed Stone Encasement. The weight of the pipe, the fluids in the pipe, and the backfill help the pipe settle into the uncompacted layer and create a small bedding angle for support. This settlement also mobilizes the strength of the haunch support. The use of uncompacted bedding is an acceptable and recognized technique as evidenced by its inclusion in many ASTM standards and AWWA manuals.

Accordingly the following statement was added to Section 9 “Bedding” under Construction Techniques:

- 9.2 The portion of the bedding directly beneath the pipe and above the foundation should not be compacted for Class B and Crushed Stone Encasement.

Gradation

The bedding soil shall be cohesionless soils, Class I or Class II. The gradation for Class I and Class II soil for Class C bedding shall have a maximum particle size of 1 in. (25 mm).

The gradation for Class I and Class II soil for Class B bedding, Crushed Stone Encasement, and CLSM bedding shall be as follows:

- 100% passing a 1 in. (25 mm) sieve
- 40-60% passing a 3/4 in. (19 mm) sieve
- 0-25% passing a 3/8 in. (9.5 mm) sieve

Particle Shape

Class II soils shall have a minimum of one fractured face. For Class B, Crushed Stone Encasement, and CLSM installations where high and/ or changing water tables are present, the composition of materials shall be as follows:

- 100% of the material shall have at least one fractured face,
- 85% of the material shall have at least two fractured faces,
- 65% of the material shall have at least three fractured faces.

The percent of fractured faces should be determined in accordance with ASTM D5821. Because the particles are 100% fractured, Class I material is considered to be more stable and provides better support than Class II material that may have some rounded edges.

HAUNCHING

Proper haunch support (Figure 3) is necessary for the achievement of the load factor and thus, the structural integrity of the pipe. Lack of proper haunch support is one of the most common causes of any pipeline failure.

Haunch support depends on three factors:

1. Proper compaction of the bedding materials in the pipe haunches
2. Mobilization of the bedding within the limits of the haunch area
3. Bell or coupling holes/ pipe barrel uniform support

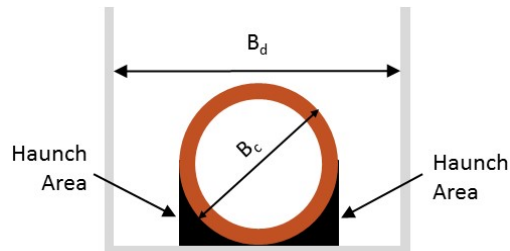


Figure 3: Pipe Haunch Areas

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.

Compaction Of Haunch Soil

Compaction of the soil in the haunch area significantly increases the support for the pipe. Gravels and crushed rock dumped into a trench beside the pipe result in minimum densities of the soil, which is about 80-85% of their maximum density. Compacting the soil to about 95% (ASTM D4253 *Standard Test Methods for Maximum Index Density and Unit Weight of Soils Using a Vibratory Table*) can increase the stiffness (modulus) of the soil 300 to 600% (Howard 2015).

All bedding material shall be shovel-sliced so the material fills the haunch area and supports the pipe to the limits shown in the trench diagrams.

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. To be the most effective, and to meet the requirements of C12, shovel slicing should be done before the bedding is no higher than the quarter point of the pipe, as illustrated in Figure 4. Shovel-slicing the bedding material into the haunches of the pipe is essential if the total load factor of the bedding class is to be realized. Appropriate shovel slicing technique is demonstrated in Figure 5.

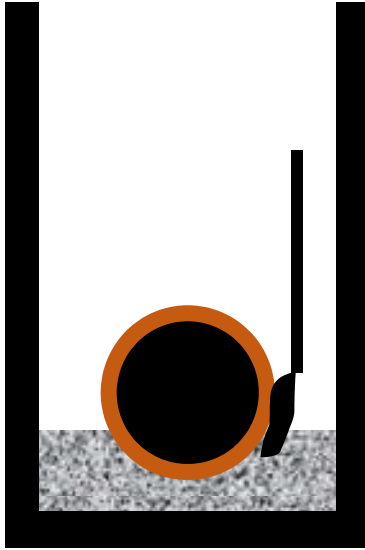


Figure 4: Initial haunching should be performed before the bedding is no higher than the quarter point of the pipe diameter.



Figure 5: Shovel-slicing the bedding material into the haunches of the pipe is essential.

Increased Haunch Support By Soil Mobilization

Haunch support for pipe can be effectively actuated by providing an uncompacted bedding for the pipe. The weight of the pipe, fluid in the pipe, and the backfill soil over the pipe help push the pipe into the uncompacted material creating a small cradle. Since uncompacted bedding under the pipe has a low stiffness, minor pipe settlement will mobilize the haunch soil support. Compacted haunch material is not as effective if the pipe is resting on compacted bedding above the foundation. The compacted soil simply acts as a filler. However, if the pipe is raised during compaction of the haunch soil, then the haunch support can be mobilized similar to uncompacted bedding. Uncompacted bedding material is specified directly beneath the pipe and above the foundation for both Class B and Crushed Stone Encasement classes in the current C12.

If uniformly graded gravel is loosely placed or dumped beside a pipe it will typically leave a void in the haunch area. This will reliably result in a decreased load factor no matter the bedding class. The gravel has an angle of repose, which is the angle of the slope of the material when dumped into a pile. Gravel with fractured faces will have a steeper angle than gravel with rounded edges. Figure 6 illustrates what happens when crushed rock with an angle of repose of 39 degrees is dumped beside a 36-in pipe with a 44-in outside diameter.

Testing was conducted in 2013 to confirm the theory illustrated in Figure 6 (Boschert and Howard, 2014). Figure 7 is a photo from that research project. It clearly illustrates the reality of the haunch void. The photo was taken after the crushed rock had been dumped into a trench beside a 36-in pipe. Daylight can be seen on the other end of the pipe revealing a void running along the full length of the pipe in this lower haunch area. A video taken during this testing clearly demonstrates the mechanism of the formation of a void in this area. This video is available for viewing on the NCPI YouTube channel.

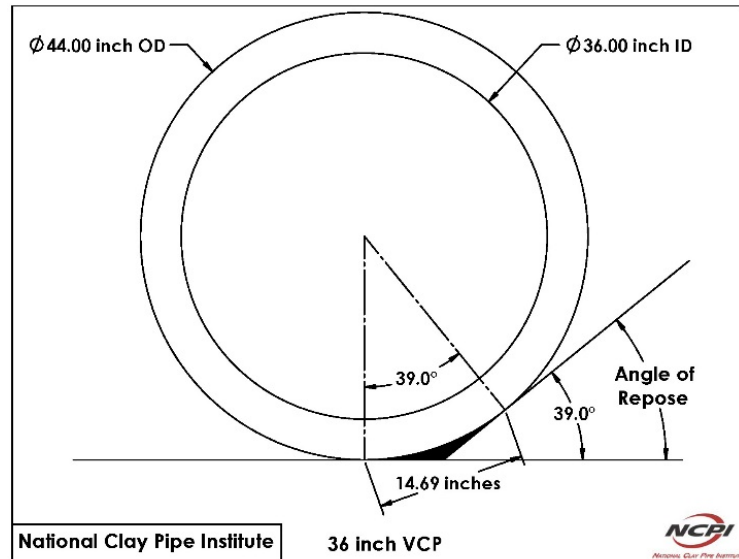


Figure 6: Illustration of the 14.69" void space (shaded black) left in the haunches of a 44-in OD pipe when the bedding material angle of repose is 39 degrees and dumped alongside the pipe.

Good haunch support:

1. Significantly increases the load carrying capacity of buried pipe.
2. Requires compacting the soil in the haunch area, or using CLSM.
3. **Is not attained by dumping gravels and crushed rock beside the pipe.**
4. Can be attained by pipe settling into uncompacted bedding to mobilize the strength of the haunch soil.



Figure 7: In testing, daylight was visible on the other end of a 7.0' pipe section.

INITIAL BACKFILL

The initial backfill is the material placed from the top of the bedding to 12 inches above the top of the pipe. The soil can be Class I, II, III, or IV. Local materials may be used when the required load factor for the trench design can be achieved.

For initial backfill, bedding Class D installations require a maximum particle size of 1 inch while the other bedding classes require a maximum particle size of 1½ inches. This reduced particle size in the Class D bedding detail is a result of the initial backfill beginning at the bottom of pipe and thus encompassing the pipe haunches. With Class D, many native materials taken from the trench will provide suitable support for clay pipe and may be the most cost efficient method of installation.

The initial backfill does not need to be compacted, especially over the top of the pipe. However, the final backfill may need to be compacted under roads, parking lots, etc. In that case, the initial backfill helps to serve as a padding over the top of the pipe.

CONTROLLED LOW STRENGTH MATERIAL (CLSM) BEDDING

In 1995 C12 became the first pipe installation standard to include CLSM bedding as a viable option. The accepted standard as practiced since that time is shown in Figure 8. Requirements for flowability when placed, 28-day compressive strength, and set time prior to backfill load are now specified in the standard.

For CLSM installations, the pipe shall be bedded on Class I or Class II soil. The bedding shall be placed on a firm and unyielding trench bottom and shall have a minimum thickness beneath the pipe of one-sixth of the outside pipe diameter, but not less than 4 in.

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

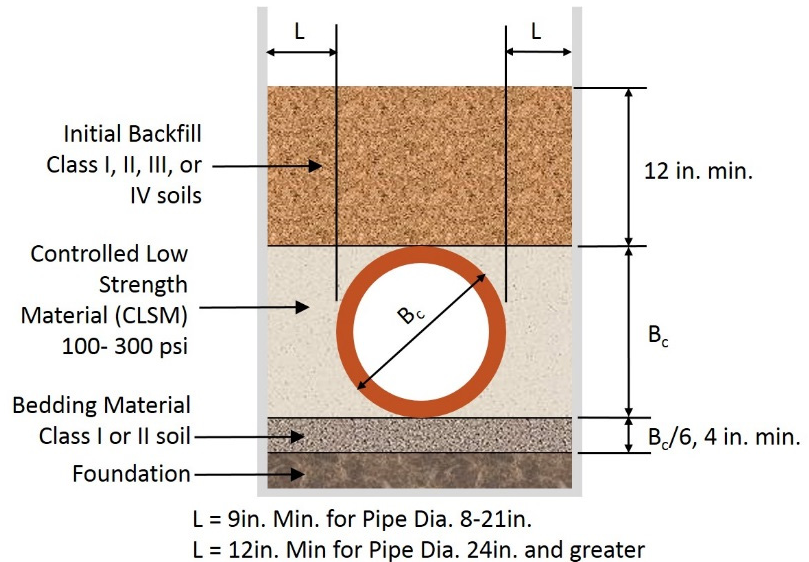


Figure 8: Controlled Low Strength Material (CLSM) Bedding: Load Factor 2.8



Figure 9: Measuring the spread diameter to determine flowability prior to placement.

Testing for flow consistency should be conducted in accordance with ASTM D6103. When placed, CLSM shall have a measured spread of 7 – 9 inches. A typical test result is shown in Figure 9.

The 28-day compressive strength shall be 100 to 300 psi as determined by Test Method ASTM D4832.

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 Test Method C403/C403M. The penetrometer shall have a maximum load capability of 700 psi and have a 1.0 square inch by 1-inch long cylinder foot attached to a ¼-in diameter pin, as shown in Figure 10. The initial backfill shall be either Class I, II, III, or IV having a maximum particle size of 1½ in (38 mm).



Figure 10: A pocket penetrometer can be used to determine CLSM strength prior to backfill.

The fill can be made in a single pour to the top of the pipe or it can be made in two or more lifts if desired. No

field installations using CLSM have resulted in flotation of clay pipe. However, buoyancy calculations done using the Archimedes' Principle (that a body wholly or partly immersed in a fluid is buoyed up with a force equal to the weight of the fluid displaced by the body) indicate that the pipe should have floated. Further research to date supports the theory that clay pipe does not float because CLSM acts as a Bingham fluid. A Bingham fluid, also known as a Bingham plastic, is a viscoplastic material that resists movement at low values of shear stress in the fluid. Buoyancy forces generate shear stress in the CLSM. If the stress applied by the buoyant force does not exceed the shear yield stress of the CLSM, the pipe will not float.

TABLE 2 ADDED TO C12

Table 2 was added to C12-14 to summarize the soil requirements for the various bedding classes and serve as a quick reference. It summarizes the type of allowable soil, maximum particle size, and gradation requirements for the bedding and initial backfill materials as discussed in detail in the Bedding section of this paper.

Allowable Bedding Material and Initial Backfill per Bedding Class					
Bedding Class	Allowable Bedding Material			Allowable Initial Backfill	
	Class (Table 1)	Gradation	Particle Size	Class (Table 1)	Particle Size
Class D	N/A	N/A	N/A	I, II, III or IV	1" (25mm)
Class C	I or II		1" (25 mm)	I, II, III or IV	1½" (38 mm)
Class B	I or II	- 100% passing a 1" (25 mm) sieve	1" (25 mm)	I, II, III or IV	1½" (38 mm)
Crushed Stone Encasement	I or II	- 40 - 60% passing a ¾" (19 mm) sieve	1" (25 mm)	I, II, III or IV	1½" (38 mm)
CLSM	I or II	- 0 - 25% passing a 3/8" (9.5 mm) sieve	1" (25 mm)	I, II, III or IV	1½" (38 mm)
Cradle	N/A	N/A	N/A	I, II, III or IV	

Table 2: Allowable Bedding Material and Initial Backfill per Bedding Class

ONGOING AND FUTURE RESEARCH

The ‘Importance of Haunching’ project of 2013 was conducted to determine the difference in haunch soil relative density when dumped alongside the pipe as compared to sliced directly into pipe haunch using a shovel. In these experiments, shovel slicing in the haunch increased the support for the pipe about tenfold as compared to dumped without slicing. A continuation of this project is under way using the saturation and vibration method for haunch compaction of both Class I and Class II soils. Additionally, the use of native soils as the aggregate/soil in CLSM mixtures will be examined.

SUMMARY

The latest version of the “*Standard Practice for Installing Vitrified Clay Pipe Lines*”, C12-14, reflects current technology and language to aid the designer, specification writer, contractor and inspector in delivering a successful installation. The changes include:

- Discontinuation of the concrete arch bedding class
- Adoption of *Uniform Soil Groups for Pipe Installation*
- Recommendation for methods of improving the foundation to provide proper support for the pipe when the foundation is deemed not suitable
- Updates to bedding standards, including:
 - Use of uncompacted soil for the bedding

- Recommended gradation for bedding soils
- Specifying the appropriate amounts of fractured faces for Class II soil particles
- Limiting the maximum soil particle size for bedding and initial backfill materials to 1-inch and 1½-inch particles.
- Requiring shovel slicing of haunch area soil to occur before the bedding height is 0.25 of the outside diameter of the pipe.
- Replacing subjective language with more definitive language
- ASTM specialized standards relating specifically to CLSM bedding for VCP

A table was added that summarizes the type of allowable soil, maximum particle size, and gradation requirements for the bedding and initial backfill materials.

For more information on any of these standards and recommended installation practices, see the latest edition of the National Clay Pipe Institute's *Vitrified Clay Pipe Engineering Manual* (2015), currently available on the website at ncpi.org.

REFERENCES

- ASTM C 12 *Standard Practice for Installing Vitrified Clay Pipe Lines*
- ASTM C 403 *Standard Test Method for Time of Setting of Concrete Mixtures by Penetration Resistance*
- ASTM D 4253 *Standard Test Methods for Maximum Index Density and Unit Weight of Soils Using a Vibratory Table*
- ASTM D 4832 *Test Method for Preparation and Testing of Controlled Low Strength Material (CLSM) Test Cylinders*
- ASTM D 5821 *Standard Test Method for Determining the Percentage of Fractured Particles in Coarse Aggregate*
- ASTM D 6103 *Standard Test Method for Flow Consistency of Controlled Low Strength Material (CLSM)*
- ASTM D 7382 *Test Method for Dry Density of Granular Soils Using a Vibratory Hammer*
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