9B-3 Flexible Plastic Pipes

A. Introduction

Flexible pipes are generally considered pipes that will deflect at least 2% of their diameter without any damage. However, most flexible pipes used for utility applications are required to undergo deflections of 20-30% during testing and certification without failing. The key to the performance of a flexible pipe is its ability to deflect without buckling or cracking.

The most common flexible pipes currently in use are High-Density Polyethylene (HDPE) and Poly-vinyl Chloride (PVC). Numerous varieties of each are produced. PVC pipe is used extensively for sanitary sewers and water mains. HDPE pipe is commonly used for subdrains and is also available for storm sewer applications.

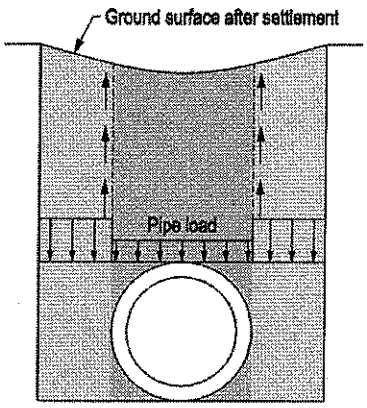
In order to take advantage of the benefits and avoid the limitations of flexible pipes, it is necessary to understand how they perform and how their properties are defined.

B. Soil-pipe interaction

A flexible pipe obtains its load-carrying ability from its flexibility. Just like a rigid pipe, after the installation of a flexible pipe, the trench bedding and backfill materials will settle. However, because the flexible pipe deflects when loaded, the central soil column, directly over the pipe, will settle more than the adjacent soil columns.

As differential settlement occurs between the soil column over the pipe and the soil columns adjacent to the pipe, frictional forces between the soil columns transfer some of the load from the central soil column to the adjacent soil columns (see Figure 1). This reduces the load on the flexible pipe. As the pipe is loaded, the pipe deflects vertically, pushing the sides of the pipe outward toward the sides of the trench. This results in the development of sidewall support from the pipe bedding.

Figure 1: Soil-pipe interaction for flexible pipes



Flexible pipe performance is highly dependent on proper bedding to provide the required sidewall support. A pipe with lateral sidewall support is capable of carrying a significantly larger load than an unsupported pipe. Without sidewall support, some flexible pipes would be crushed by the weight of the backfill above. For this reason, it is imperative that flexible pipes be properly backfilled with high-quality materials.

Given the significance of sidewall support, consideration must be given to the locations where flexible pipes are installed. Flexible pipes should not be used in areas where future adjacent excavations are likely. These excavations could expose or weaken the bedding envelope supporting the pipe.

For additional information on the soil-pipe interaction of flexible pipes, and the method to determine pipe load and predicted deflection, refer to the Uni-Bell PVC Pipe Association's: *Handbook of PVC Pipe: Design and Construction* or the Plastic Pipe Institute's publication: *The Complete Corrugated Polyethylene Pipe Design Manual and Installation Guide.*

C. Pipe design

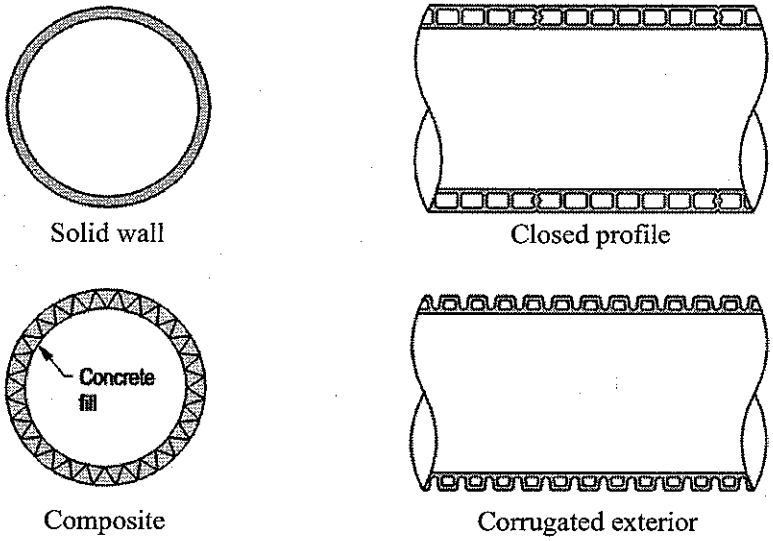
The design of most flexible pipes is based upon pipe stiffness. Pipe stiffness is a term used to describe the resistance of a flexible pipe to deflection when subjected to a load. Pipe stiffness is measured by placing a section of flexible pipe between two flat plates. A load is applied until the pipe is deflected 5% of its diameter. The load at which this occurs is the pipe stiffness. Pipe stiffness is specified in lb/in^2.

In general, pipe stiffness is related to the material properties and wall thickness of the pipe (see Figure 2). For solid walled pipe with a given modulus of elasticity, the ratio of the pipe diameter to its wall thickness (diameter ratio or DR) determines the stiffness of the pipe. Solid walled pipes of different diameters, but with the same DR, all have the same pipe stiffness. To provide a stiffer pipe, the wall thickness is increased (i.e., DR is reduced).

Another way to increase pipe stiffness is to change the shape of the pipe wall. Pipe manufacturers have developed a number of different wall cross-sections that increase or maintain pipe stiffness while using less material per foot of pipe. Closed profile pipe uses an "I"-beam-type cross-section. Composite pipe is a dual-walled pipe with a truss-type structure in the middle and the area filled with lightweight concrete. Flexible pipe is also commonly produced with a corrugated exterior and smooth interior.

Regardless of the wall shape, the generally accepted standard for minimum pipe stiffness is 46 lb/in^2. This corresponds to a PVC pipe with a DR of 35. Pipes with a lower stiffness are also available; however, they should be used with caution in the right-of-way or other areas subject to disturbance for the reasons described in the Section 9B-2, Rigid Pipes. In addition, installing pipes with stiffness lower than 46 lb/in^2 should be done under careful supervision to ensure that the pipe has proper bedding. After installation, these pipes should be tested with a mandrel to ensure deflections do not exceed 5%.

Figure 2: Types of commonly used flexible pipe



1. **PVC.** PVC pipe is used primarily for sanitary sewer mains and service lines. Sanitary sewer installations are generally deep enough that it is unlikely an adjacent excavation will encroach on the pipe bedding envelope. Therefore, the use of PVC for sanitary sewers in the right-of-way is acceptable. However, for shallow installations, consideration should be given to the possibility of adjacent excavations causing damage. If this is likely, an alternate pipe material or a PVC pipe with higher pipe stiffness should be considered.

   For a given class of PVC pipe, pipe stiffness is generally consistent regardless of the diameter. The minimum PVC pipe stiffness allowed in the SUDAS Specifications is 46 lb/in^2.

2. **HDPE.** HDPE pipe has been used extensively as subdrain and as agricultural drain tile. HDPE storm sewer pipe is also available. Unlike PVC pipe, the pipe stiffness for HDPE pipe varies depending on diameter. The stiffness varies from 50 lb/in^2 for a 12-inch pipe down to 17 lb/in^2 for a 48-inch pipe. Due to the relatively shallow depth of bury for most storm sewer pipes and the low pipe stiffness for many diameters, HDPE pipe should not be used as storm sewer within the right-of-way. Use of HDPE pipe outside of the right-of-way should be done with consideration given to depth of bury and potential for future disturbance.

   In addition to pipe deflection, HDPE pipe must also be analyzed for several additional failure modes. These include wall thrust, buckling pressure, bending stress, and bending strain. In general, the limits on the depth of bury for HDPE pipe is not due to deflection, but wall thrust.

   One of HDPE pipe's material properties is its tendency to creep, or permanently deform when stressed beyond a certain level for an extended time. If the wall thrust stresses at the springline of the pipe are high enough, the sidewall of the pipe can undergo permanent deformation. Wall thrust failures occur as rippling, buckling, or cracking at the springline of the pipe.

D. Flexible pipe bedding

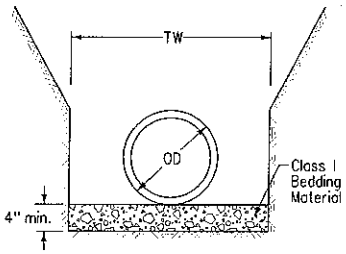
For most gravity installations with flexible pipe, granular bedding material is recommended. Suitable granular bedding material is self-compacting when placed in the trench. This ensures proper pipe support is provided in the area below the springline, where it is difficult to provide mechanical compaction. The bedding below the springline is critical for providing proper sidewall support for flexible pipes.

Granular bedding should be extended to the top of the pipe for storm sewers (Bedding Class F-2), and to 1 foot over the top of the pipe for sanitary sewer installations (Bedding Class F-3). The additional granular bedding material in this area protects the pipe from impact and movement during final trench backfill. In excavations where trench boxes are used, care must be taken to prevent disturbance of the pipe and bedding material when moving the trench box.

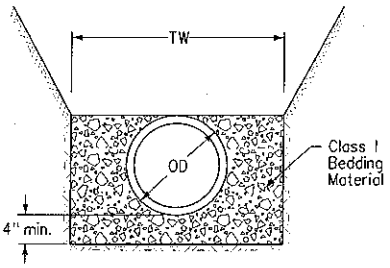
For gravity pipe installations using ductile iron pipe or other flexible water main materials, granular bedding material may not be required along the sides of the pipe, due to the additional pipe strength provided by these products. For these applications, granular bedding is only required under the pipe (Bedding Class F-1) to assist in achieving the proper grade and alignment.

Figure 3 illustrates the standard bedding classes for flexible pipe installations. Refer to Section 9B-4, Ductile Iron Pipe, for bedding types for flexible pressure pipe (AWWA C900 / C905).

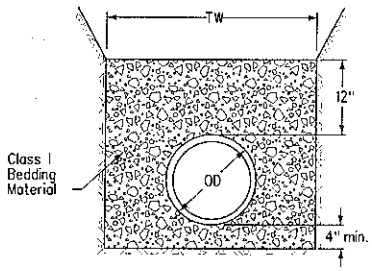
Figure 3: Flexible pipe bedding types



Class F-1



Class F-2



Class F-3

E. Trench width

1. **Minimum.** Unlike rigid pipe, the load on a flexible pipe does not increase as trench width increases. While trench width does not affect the pipe load, it must be wide enough to properly place and compact the bedding material in the haunch and primary backfill areas of the pipe. Generally this is considered to be 1.25 times the outside diameter of the pipe plus 12 inches, or the outside diameter of the pipe plus 18 inches, whichever is greater.

2. **Poor soils.** As mentioned earlier in this section, a critical requirement for flexible pipe performance is sidewall support. In a typical installation, the thrust forces from the sidewall of the deflecting pipe are transferred through the granular bedding material to the trench walls. As these forces pass through the rock envelope, they are distributed over a larger area, reducing the pressure against the trench walls. The crushed stone bedding has a higher bearing capacity, or modulus of soil reaction, than the adjacent soil, allowing it to carry greater loads than the surrounding soil without deformation.

   In a typical installation, the granular bedding material reduces the pressure against the trench walls to an acceptable level. However, for installations with poor soil conditions, the in-situ soils may not provide adequate lateral support with a standard trench and pipe bedding. Examples of poor soil conditions include poorly compacted fill with a SPT blow count of five or less, peat, muck, or highly expansive soils. In these situations, additional trench width may be required. A wider trench, and thus a wider rock envelope, allows the thrust forces from the pipe sidewall to be distributed over an even larger area on the trench wall. By increasing the bearing area, the pressure on the trench wall can be reduced to a level that the in-situ soil can support. For conditions with poor soils, increasing the minimum trench width to two times the outside diameter of the pipe is recommended.

F. Pressure pipe

Using flexible pipes for pressure applications such as water main or sanitary sewer force mains is also common. Unlike flexible pipes for gravity flow applications, pressure pipes are classified based upon the pressure rating of the pipe, rather than the pipe stiffness.

Flexible pressure pipes typically have a significantly thicker wall than gravity flow pipes. As such, the inherent stiffness of the pipe is also significantly greater. For example, C900, DR 18 pipe has an equivalent pipe stiffness of 360 lb/in^2.

Because of the increased pipe stiffness and relatively shallow depth of bury, bedding requirements for PVC water mains and force mains are less critical than flexible gravity pipe. Native soil can be used for bedding many PVC water main or force main installations. Likewise, the concern of adjacent excavations disturbing the pipes sidewall support is not an issue with PVC pressure pipes. Refer to Section 9B-4, Ductile Iron Pipe, for typical pressure pipe installations.

TRENCH AND BACKFILL

PART 1 - GENERAL

1.01 SECTION INCLUDES

A. Trench excavation for pipe systems, manholes, intakes and other structures.

B. Trench bedding and foundation stabilization.

C. Pipe and structure placement and backfill.

1.02 DESCRIPTION OF WORK

A. Perform all excavations required to complete the work shown on the plans.

B. Prepare trench excavations and shoring for new work, and install the utility lines, structures, and system components, including bedding and foundation stabilization.

C. Complete specified backfill operation.

D. Reference is made to the Iowa Department of Transportation English Standard Specifications for Highway and Bridge Construction, Series 2001 and all current General Supplemental Specifications and Materials Instructional Memorandum by the term "Iowa DOT Specifications" and/or "Iowa DOT I.M."

1.03 SUBMITTALS

A. Submit under provisions of Division 1.

B. Samples, granular bedding material: submit 10-pound samples of each type, if required.

C. Samples, granular backfill material: submit 10-pound samples, if required.

D. Gradation reports for fill materials and bedding materials.

E. Results of Proctor and In-Place Density Tests on backfill.

F. Contractor will provide Material Certifications to the Jurisdictional Engineer.

1.04 SUBSTITUTIONS

A. Use only materials conforming to these specifications unless permitted otherwise by Jurisdictional Engineer.

B. Obtain approval of Jurisdictional Engineer for all substitutions prior to use.

1.05 DELIVERY, STORAGE, AND HANDLING

A. Deliver only materials that fully conform to these specifications or for which submittals have been provided to Jurisdictional Engineer and approved for use.

B. Store delivered materials and excavated materials in locations that will not interfere with operations and minimize environmental damage.

C. Grade and shape stockpiles for drainage and protect adjacent areas from runoff. Provide erosion control around stockpiles.

D. Remove unsuitable and excess materials from the site.

1.06 SCHEDULING AND CONFLICTS

A. Construction Sequence :

1. Attend a preconstruction meeting if required by Jurisdictional Engineer.

2. Submit plan for construction sequence and schedule prior to commencing construction.

B. Conflict Avoidance:

1. Expose possible conflicts in advance of construction, such as utility lines and drainage structures. Verify elevations and locations of each and verify clearance for proposed construction.

2. Complete other elements of the work that can affect line and grade in advance of other open cut construction unless noted on the plans.

3. Notify Jurisdictional Engineer of conflicts discovered or changes needed to accommodate unknown or changed conditions.

1.07 SPECIAL REQUIREMENTS

A. Stop Work: Stop work and notify Jurisdictional Engineer immediately if contaminated soils, historical artifacts, or other environmental or historic items are encountered.

B. Use of Explosives: Submit detailed plans outlining all proposed blasting operations, locations, methods, and use of mats and other safety measures to the Jurisdictional Engineer.

1. Obtain written approval before using explosives.

2. Use personnel experienced with explosives.

C. Conform to local, state, and federal requirements.

D. Abandoned Utilities: Remove and dispose of abandoned utility lines including gas mains, water mains, sewer mains, telephone conduits, service lines, etc. required to complete the work. Said work shall be incidental to the project unless otherwise specified.

1.08 MEASUREMENT FOR PAYMENT

All measurements for payments will be made by the Jurisdictional Engineer or authorized representative.

A. General: No separate payment will be made for unclassified excavation. Include trenching, bedding, placing backfill, compaction, and dewatering in the costs in the unit bid for all pipe and structures, except as follows:

1. Rock Excavation: Rock, if encountered and verified by the Jurisdictional Engineer, will be measured and paid for by the cubic yard removed from the excavation, or will be paid for by change order unless otherwise provided for in the contract documents.

2. Over-excavation and trench bottom stabilization:

a. Measure quantity in tons of stabilization material placed in the over-excavation. Over-excavation is incidental.

b. Payment will be made for over-excavation, stabilization material, and placement based on the unit price per ton of stabilizing material

3. Unsuitable Backfill:

a. Where excavated material is found to be unsuitable for backfill and cannot be made suitable in the opinion of Jurisdictional Engineer, measurement of replacement material furnished by the Contractor from outside the project limits will be by cubic yards, including furnishing, transporting, and installing. Payment will be made at the unit bid price per cubic yard or by change order.

b. Except for over-excavation, removal of unsuitable soil is incidental to unclassified excavation.

c. Suitable backfill replacement material located within the project limits will not be measured and paid separately.

B. Open Cut Casing and Carrier Pipe Installation: Measurement will be for the length of properly installed casing, measured along the centerline of the casing. Payment will be made for both the carrier pipe and casing pipe as a combined single bid unit for the appropriate method of installation.

C. Incidental Items: Unless otherwise specified in the contract documents, the following items will be included in the unit price for open cut casing and carrier pipe installations: guides, fillers, levels, backfill, and other appurtenances necessary to perform specified function.

D. Culvert Excavation: Unless specified in the contract documents, include excavation for culverts in the unit bid price for all pipe and structures. If required by the contract documents, culvert excavation will be measured and paid according to Class 20 Excavation in Iowa DOT 2402.

E. Over-Excavation not for Stabilization And Repair Of Same: No payment will be made.

F. Structure Removal: The Jurisdictional Engineer will count the quantity of structures to be removed including each manhole and inlet removed according to the plans and will be paid by the number removed.

G. Surfacing Removal and Replacement: Unless otherwise specified in the contract documents include all temporary or permanent surface removals and replacements for both granular and hard surfaces for streets, drives, and sidewalks in the unit prices for all pipe and structures.

H. Abandoned Utilities: Remove and dispose of abandoned utilities encountered within the work zone This work is incidental.

I. Compaction Testing: All contractor-provided services associated with compaction testing are incidental to the pipe installation.

PART 2 - PRODUCTS

2.01 EXCAVATED MATERIALS

A. Unclassified Excavation: Excavation of all materials encountered, except rock and over-excavation.

B. Rock Excavation: Boulders or sedimentary deposits that cannot be removed without continuous use of pneumatic tools or blasting.

C. Over-excavation: Excavation of soil or rock in trenches below the pipe zone, see Figure 3010.1.

D. Suitable Excavated Materials For Backfill:

1. Soil, clay, silt, sand, and gravel with moisture content suitable to achieve required compaction. ASTM D 2321, Class II through IVA (see 3010. 2.01. E).

2. Fine-grained soils according to ASTM D 2321 Class IVB (inorganic) (see 3010. 2.01. E) may be used in the final backfill upon approval of the Jurisdictional Engineer.

3. Adjust moisture content of excessively wet, but otherwise acceptable, material by spreading, turning, aerating, and otherwise working material as necessary to achieve required moisture range.

4. Adjust moisture content of excessively dry, but otherwise acceptable material by adding water, then turning, mixing, and otherwise blending the water uniformly throughout the material until the required moisture range is achieved.

5. Lime or fly ash may be added to soils to produce a suitable backfill material. Uniformly mix soil and additive. Determine Standard Proctor maximum density and optimum moisture content of the modified material. Amount of additive applied is subject to Jurisdictional Engineer's approval.

E. Non-Manufactured (Excavated) Backfill Materials: (See Sections 3010, 2.03 and 2.04 for manufactured backfill)

Class	Type	Soil Group Symbol D 2487	Description	Percentage Passing Sieve Sizes			Atterberg Limits		Coefficients	
				1½ in. (40 mm)	No. 4 (4.75 mm)	No. 200 (0.075 mm)	LL	PI	Uniformity C_u	Curvature C_c
II	Coarse-Grained Soils, clean	GW	Well-graded gravels and gravel-sand mixtures; little or no fines	100%	‹50% of "Course Fraction"	‹5%	Non Plastic		›4	1 to 3
		GP	Poorly-graded gravels and gravel-sand mixtures; little or no fines.						‹4	‹1 or ›3
		SW	Well-graded sands and gravelly sands; little or no fines.		›50% of "Coarse Fraction"				›6	1 to 3
		SP	Poorly-graded sands and gravelly sands; little or no fines.						‹6	‹1 or ›3
	Coarse-Grained Soils, borderline clean to w/fines	e.g. GW-GC, SP-SM	Sands and gravels which are borderline between clean and with fines.	100%	Varies	5% to 12%	Non Plastic		Same as for GW, GP, SW and SP	
III	Coarse-Grained Soils, with Fines	GM	Silty gravels, gravel-sand-silt mixtures.	100%	‹50% of "Coarse Fraction"	12% to 50%		‹4 or ‹"A" Line		
		GC	Clayey gravels, gravel-sand-clay mixtures.					‹7 and ›"A" Line		
		SM	Silty sands, sand-silt mixtures.		›50% of "Coarse Fraction"			›4 or ‹"A" Line		
		SC	Clayey sands, sand-clay mixtures.					›7 and ›"A" Line		
IVA	Fine-Grained Soils (inorganic)	ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands, silts with slight plasticity.	100%	100%	›50%	‹50	‹4 or ‹"A" Line		
		CL	Inorganic clays of low to medium plasticity, gravely clays, sandy clays, silty clay, lean clays.					›7 and ›"A" Line		
IVB (1)	Fine-Grained Soils (inorganic)	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.	100%	100%	›50%	›50	‹"A" Line		
		CH	Inorganic clays of high plasticity, fat clays.					›"A" Line		
V	Organic Soils (Unsuitable for backfill)	OL	Organic silts and organic silty clays of low plasticity.	100%	100%	›50%	‹50	‹4 or ‹"A" Line		
		OH	Organic Clays of Medium to high plasticity, organic silts.			/td>	›50	‹"A" Line		
	Highly Organic (Unsuitable for backfill)	PT	Peat and other high organic soils.							

(1) See Section 3010, 2.01, F, 2 for restrictive use.

F. Unsuitable Material: Remove unsuitable materials from the site, including, but not limited to, the following:

1. Rock with gradation not meeting the stated gradation for stabilization material.
2. Individual stones or concrete chunks larger than 6 inches, and averaging more than one per each cubic foot of soil.
3. Frozen materials.
4. Stumps, logs, branches, and brush.
5. Trash, metal, or construction waste.
6. Soil in clumps or clods larger than 6 inches, and without sufficient fine materials to fill voids during placement.
7. Unsuitable soils, as defined in Section 2010, 2.03, excluding material used as topsoil.
8. Class V Material (ASTM D 2321), as defined in Section 3010, 2.08.
9. Environmentally-contaminated soils.

G. Replacement of Unsuitable Soils:

1. If the excavated material is determined by the Jurisdictional Engineer to be unsuitable and cannot be conditioned so that it

becomes suitable, furnish all necessary backfill material.

2. Remove and dispose of unsuitable material from the site.

2.02 STABILIZATION (FOUNDATION) MATERIALS

A. Clean 2-1/2 inch crushed stone or crushed Portland Cement Concrete (PCC) material, with the following gradation:

Sieve	Percent Passing
2-1/2"	100
2"	90 to 100
1-1/2"	35 to 70
1"	0 to 20
1/2"	0 to 5

B. Jurisdictional Engineer may authorize a change in gradation subject to materials available locally at time of construction. Subject to the Jurisdictional Engineer's approval, crushed concrete may be used if it is within plus or minus 5% of the gradation for each size of material.

2.03 CLASS I GRANULAR BEDDING AND BACKFILL MATERIAL (Storm Sewers and Sanitary Sewers)

A. Use gravel or crushed stone for granular bedding, complying with the following gradation:

Sieve	Percent Passing
1 1/2"	100
1"	95 to 100
1/2"	25 to 60
No. 4	0 to 10
No. 8	0 to 5

Note: Jurisdictional Engineer may authorize the use of crushed PCC, for pipe sizes up to 12 inches, or a change in gradation subject to materials available locally at time of construction.

B. Use aggregates having a percentage of wear, Grading A or B, not exceeding 50%, determined according to AASHTO T 96.

C. Compaction: See Section 3010, 3.06.

2.04 CLASS II BACKFILL MATERIAL (Storm Sewers, Sanitary Sewers, and Water Mains)

A. Class II material is manufactured and non-manufactured open graded (clean) or dense graded (clean) processed aggregate, clean manufactured sand, or coarse grained natural soils (clean) with little or no fines.

B. Class II material is non-plastic soil less than 1-1/2 inches in size and consists of the following:

SOIL TYPE	DESCRIPTION OF MATERIAL CLASSIFICATION	REMARKS SECTION
GW	Well-graded gravels and gravel-sand mixtures, little or no fines. 50% or more retained on No. 4 sieve. More than 95% retained on No. 200 sieve. Clean.	Where hydraulic gradient exists check gradation to minimize migration. Clean groups suitable for use as drainage blanket and underdrain.
GP	Poorly graded gravels and gravel sand mixtures, little or no fines. 50% or more retained on No. 4 sieve. More than 95% retained on No. 200 sieve. Clean.	
SW	Well-graded sands and gravelly sands, little or no fines. More than 50% passes No. 4 sieve. More than 95% retained on No. 200 sieve. Clean.	
SP	Poorly graded sands and gravelly sands, little or no fines. More than 50% passes No. 4 sieve. More than 95% retained on No. 200 sieve. Clean.	

C. Compaction: See Section 3010, 3.06.

D. Class II material may be specified in the contract documents by the Jurisdictional Engineer between the pipe embedment zone and the top 2 feet of final backfill when the trench is under the pavement.

2.05 CLASS III BACKFILL MATERIAL (Storm Sewer, Sanitary Sewer, and Water Mains)

A. Class III material is natural coarse-grained soils with fines.

B. Class III material follows Section 3010.2.01, G and consists of the following:

SOIL TYPE	DESCRIPTION OF MATERIAL CLASSIFICATION	REMARKS SECTION
GM	Silty gravels, gravel-sand-silt mixtures. 50% or more retained on No. 4 sieve. More than 50% retained on No. 200 sieve.	Do not use where water condition in trench may cause instability.
GC	Clayey gravels, gravel-sand-clay mixtures. 50% or more retained on No. 4 sieve. More than 50% retained on No. 200 sieve.	
SM	Silty sands, sand-silt mixtures. More than 50% passes No. 4 sieve. More than 50% retained on No. 200 sieve.	
	Clayey sands, sand-clay mixtures. More than 50% passes No. 4	

SC	sieve. More than 50% retained on No. 200 sieve.	

C. Compaction: See Section 3010, 3.06.

2.06 CLASS IVA BACKFILL MATERIAL (Storm Sewer, Sanitary Sewer and Water Mains)

A. Class IVA material is natural fine grained inorganic soils.

B. Class IVA material follows Section 3010, 2.01, G and consists of the following:

SOIL TYPE	DESCRIPTION OF MATERIAL CLASSIFICATION	REMARKS SECTION
ML	Inorganic silts, very fine sands, rockflous, silty or clayey fine sands. Liquid limit 50% or less. 50% or more passes No. 200 sieve.	Obtain geotechnical evaluation of proposed material. May not be suitable under deep fills, surface applied wheel loads, and under heavy vibratory compactors and tampers. Do not use where water conditions in trench may cause instability.
CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays. Liquid limit 50% or less. 50% or more passes No. 200 sieve.	

C. Compaction: See Section 3010, 3.06.

D. Suitable only in dry trench conditions.

2.07 CLASS IVB BACKFILL MATERIAL (Storm Sewer, Sanitary Sewer, and Water Mains)

A. Class IVB material is natural fine-grained inorganic (high elastic silts and plastic clays - fat clay) with a liquid limit greater than 50%.

B. Class IVB material follows Section 3010, 2.01 and consists of the following:

SOIL TYPE	DESCRIPTION OF MATERIAL CLASSIFICATION	REMARKS SECTION
MH	Inorganic silts, micaceous or diatomaceous fine sands or silts, elastic silts. Liquid limit greater than 50%. 50% or more passes No. 200 sieve.	Not to be used in pipe embedment zone.
CH	Inorganic clays of high plasticity, fat clays. Liquid limit greater than 50%. 50% or more passes No. 200 sieve.	

C. Compaction: See Section 3010, 3.06.

D. When approved by the Jurisdictional engineer, Class IVB material may be used as final trench backfill in a dry trench.

E. Do not use in the pipe embedment zone.

2.08 CLASS V BACKFILL MATERIAL (Topsoil)

A. Class V Material is natural highly organic soils with a liquid limit of greater than 50%. See Section 3010, 2.01

B. Use Class V Material only as topsoil outside of the pavement, unless otherwise specified or allowed by the Jurisdictional Engineer.

C. Do not use Class V Material shall not be used in the pipe embedment zone.

2.09 BEDDING AND BACKFILL MATERIALS FOR PIPE CULVERTS

A. Bedding:

1. Use minimum Type C embedment (see Figure 3010.1).

2. Install water stop or curtain wall at culvert inlet, as specified in the contract documents.

B. Backfill Material:

1. Use all suitable material excavated for pipe culvert work, as specified in Section 3010, 2.01 for backfill material.

2. Dry suitable material that has excessive moisture prior to placement.

3. Remove unsuitable material, as specified in Section 3010, 2.01, from the project site.

2.10 BEDDING AND BACKFILL MATERIALS FOR SUBDRAINS

A. Drainable Bedding and Backfill Materials Include:

1. Porous backfill material.

2. Pea gravel.

3. Use as shown on the plans or on the detailed drawings.

B. Porous Backfill Material: Crushed stone or gravel with the following gradation.

~~4. Crushed stone or gravel with the following gradation:~~

Sieve	Percent Passing
3/4"	100
1/2"	95 to 100
3/8"	50 to 100
No. 4	0 to 50
No. 8	0 to 8

Iowa DOT Gradation No. 29.

C. Coarse Aggregate: Use Stabilization Materials, per Section 3010.

D. Pea Gravel: Use commercially available pea gravel.

E. Impervious Bedding: Use least permeable on-site materials.

F. Engineering Fabric: Use Iowa DOT 4196.

2.11 SPECIAL PIPE EMBEDMENT MATERIAL

A. Concrete Supports: Where specified in the contract documents, construct concrete support systems according to Figures 3010.2, 3010.3, 3010.4, 3010.5, 3010.6, and 3010.7.

B. Concrete Bedding, Arch, or Encasement:

1. Concrete: commercial, 4,000 psi compressive strength.
2. Unreinforced, unless otherwise shown on the plans.
3. Minimum concrete thickness: 6 inches or as shown on the plans.

C. Flowable Mortar:

1. Approximate quantities per cubic yard:
   - a. Cement 100 pounds
   - b. Fly ash 300 pounds
   - c. Fine aggregate 2,600 pounds
   - d. Water, approximate 70 gallons
2. Compressive strength at 28 days; 100 psi to 200 psi.

D. Controlled Low Strength Material (CLSM):

1. Approximate quantities per cubic yard:
   - a. Cement 50 pounds
   - b. Fly ash 250 pounds
   - c. Fine aggregate 2910 pounds
   - d. Water, approximate 60 gallons
2. Compressive strength at 28 days 50 psi.

2.12 CASING PIPE WITH CARRIER PIPE: See Section 3020, 2.01, 2.02, 2.03, and 2.04.

PART 3 - EXECUTION

3.01 PREPARATION

A. When natural soils for Class II, III, and IV backfill material is required as specified in Figure 3010.1, provide written certification from a testing laboratory that the material meets the class specified if so requested by the Jurisdictional Engineer.

B. Locate, mark, and protect existing utilities and facilities in the work area.

C. Provide access to utility service locations, such as valves, manholes, and utility poles.

D. Identify owners of utilities on or near the site, and notify them of operations to occur.

E. Protect existing facilities and landscaping features, or replace as shown on the plans.

F. Protect bench marks, control points, and land survey monuments, or replace at Contractor's expense.

3.02 TRENCH EXCAVATION

A. Notify the Jurisdictional Engineer prior to the start of excavation activities.

B. Remove and stockpile the top 8 inches of topsoil for subsequent reuse.

C. Place excavated material away from trench. Grade spoil piles to drain. Do not allow spoil piles to obstruct drainage.

D. Remove rock, rubbish, boulders, debris, and other unsuitable materials at least 6 inches below; and on each side of the pipe. Restore grade using soil suitable for backfill.

E. Correct unauthorized excavation at no cost to Jurisdiction, using bedding or stabilization materials.

F. Provide protective fences and barricades around open excavations, appropriate to the surrounding area.

G. Provide weight tickets for stabilization material to the Jurisdictional Engineer at the time of delivery.

H. Provide safety fence around open excavations.

I. Trench Excavation for Sanitary Sewers, Storm Sewers, Water Mains, and Pipe Culverts:

1. Maximum and minimum pipe trench width: See Figure 3010.1.

2. Flat trench bottom, conduit bearing directly on trench bottom (not applicable for rock excavation) for water main pipe only with bell hole shaping:

a. Shape trench bottom to support pipe around 1/4 of perimeter for the full length of the pipe barrel.

b. Provide bell holes.

3.Trench bottom, conduit supported by bedding material:

a. Excavate trench as shown on the detailed drawings.

b. Install bedding material to support the full length of the pipe barrel.

4. Trench depth:

a. See Figures 3010.1.

b. For those material types not shown in Figure 3010.1, the maximum height of bury will be 20 feet. Installations greater than 20 feet require submittal of licensed professional engineer trench design and certification.

5. Conform all trench operations to current OSHA regulations.

J. Structure Excavation:

1. For concrete structures and parts of structures without footings, 18 inches outside the horizontal projection of the structure.

2. For concrete structures with footings, 18 inches outside the footings.

3. For anchor rods, 12 inches on each side of the rod.

4. For buried anchors, the face of the buried anchor on one side and 24 inches outside the buried anchor on the other face.

3.03 ROCK OR UNSTABLE SOILS IN TRENCH BOTTOM

A. Notify the Jurisdictional Engineer prior to over-excavation.

B. Jurisdictional Engineer will determine the need for trench bottom stabilization prior to installation of pipes and structures.

C. See Figure 3010.1 for over-excavation of rock and wet or soft foundations.

D. Provide weight tickets for the stabilization material to the Jurisdictional Engineer at the time of delivery.

3.04 SHEETING, SHORING, AND BRACING

A. Conform sheeting and bracing of all excavations to the latest state and federal regulations governing safety of workers in the construction industry.

B. Leave in place all temporary sheeting below 2 feet over top of pipe unless sheeting removal plan is approved by Jurisdictional Engineer. Conform all trench operations to current OSHA regulations.

C. Move trench boxes carefully to avoid excavated wall displacement or damage.

D. When necessary or required, install adequate sheeting and bracing to prevent ground movement that may cause damage or settlement to adjacent structures, pipelines, and utilities.

E. Any damage due to settlement because of failure to use sheeting, because of inadequate bracing, or through negligence or fault of the Contractor in any other manner, shall be repaired at the Contractor's expense.

F. For sides of trenches in unsuitable, loose, or soft material, shore, sheet, brace, slope, or otherwise support by means of sufficient strength to protect employees working within them.

G. Where excavations are made with vertical sides that require supporting, use sufficient strength for sheeting and bracing to sustain the sides of the excavations and to prevent movement that could in any way injure the work, or adjacent structures, or diminish the working space sufficiently to delay the work.

H. Select sheeting and bracing material of sufficient dimensions and strength to adequately support the sides of trenches and excavations, which will not split when driving, and will be free of imperfections that may impair its strength or durability.

I. Drive sheeting to true alignment and ensure contact of adjacent pieces.

J. In wet excavation, use grooved sheeting to prevent passage of soil. Fill any voids between sheeting and face of excavation with suitable material.

K. Do not remove sheeting and bracing before the completion of the work, unless otherwise directed by the Jurisdictional Engineer.

L. For sheeting left in place, cut off 18 inches for clearance below the bottom of the pavement in streets/highways and 18 inches below the original ground surface, unless otherwise required by the contract documents or the Jurisdictional Engineer. Leave in place all temporary sheeting below 2 feet over top of pipe, unless a sheeting removal plan is approved by Jurisdictional Engineer.

3.05 DEWATERING

A. Do all work in dry conditions; do not install pipes on excessively wet soil.

B. Perform the dewatering operation according to the dewatering plan submitted to the Jurisdictional Engineer. Dewatering operations may be modified from the plan for actual field conditions, with approval of the Jurisdictional Engineer.

C. Adequate dewatering is the Contractor's responsibility unless otherwise stated in the contract documents.

D. Install dewatering system appropriate for the soil conditions.

E. Maintain water levels sufficiently below the bottom of trench excavation (typically 2 feet) to prevent upward seepage.

F. Provide for handling water encountered during construction:

1. Prevent surface water from flowing into excavation. Remove water as it accumulates.

2. Do not use sanitary sewers for disposal of trench water. Discharging water into storm sewers requires Jurisdictional Engineer's approval.

3. Do not discharge water onto adjacent property without property owner's approval.

4. Maintain and control water discharge as necessary to prevent a safety hazard for vehicular and pedestrian traffic.

5. Direct water discharge shall be directed away from electrical facilities or equipment and intersections.

6. Use noise and fume reducing dewatering equipment to minimize disturbance.

7. Provide at least two operating pumps for each trench opened in wet ground, and at the same time shall have one pump in reserve.

G. Place backfill in trenches prior to stopping dewatering operations.

H. Protect trench water discharge points from erosion.

I. Operate dewatering systems to prevent damage to adjoining structures and facilities.

J. Monitor adjoining structures and facilities during dewatering operations. Cease dewatering operations and notify the Jurisdictional Engineer if damage is observed.

3.06 PIPE INSTALLATION

Refer to Figures 3010.1 to 3010.9, as appropriate, for the installation. Use only the types of materials shown for each position within the trench, for the given groundwater conditions, for the compaction to be provided, and for the type of pipe being installed.

A. Pipe Bedding:

1. Shape pipe bed to evenly support pipe at the proper line and grade, with full contact under the bottom of the pipe.

2. Install pipe and system components.

3. Place bedding simultaneously on both sides of the pipe. Correct any pipe displacements before proceeding.

4. Place bedding in lifts no greater than 6 inches thick, ~~and~~ consolidate, and moderately compact.

5. Concrete encasement: Install where shown on the plans.

6. If required in the contract documents or if approved by the Jurisdictional Engineer, flowable mortar or controlled low strength material may be used in lieu of other bedding material types.

7. Secure pipe against displacement or flotation prior to placing flowable mortar or concrete encasement.

B. Haunch Support:

1. Place granular haunch material in lifts no greater than 6 inches thick, ~~and~~ consolidate, and moderately compact by slicing with a shovel or using other approved techniques.

2. If required in the contract documents, or if approved by the Jurisdictional Engineer, concrete, flowable mortar, or controlled low strength material may be used instead of other haunch material types. Secure pipe against displacement or flotation prior to placing flowable mortar, controlled low strength material, or concrete encasement.

C. Primary and Secondary Backfill (Pipe Cover):

1. Place pipe cover material in 6-inch lifts ~~and compact to densities required according to class of material. Figure 3010.1 (sheet 1)~~. Compact Class I and II (cohesionless) materials to a minimum of 65% Relative Density. Compact Class III and IVA (cohesive) materials to a minimum of 95% or maximum Standard Proctor Density.

2. If required in the contract documents or if approved by the Jurisdictional Engineer, flowable mortar or controlled low strength material may be used in lieu of other cover material types. Secure pipe against displacement or flotation prior to placing flowable mortar or concrete encasement.

3. Special pipe support: If required, provide special pipe support as shown on the plans (See Figures 3010.4 to 3010.6).

D. Final Trench Backfill:

1. Place backfill in the trench immediately after recording locations of connections and appurtenances or at Jurisdictional Engineer's direction.

2. Place backfill adjacent to structures immediately after concrete has reached design strength and connecting work has been completed.

3. Allow no more than 100 feet of trench to be open overnight or when work is not in progress except as provided on the plans.

4. Place suitable excavated backfill:

a. Carefully place backfill over top of pipe and around structures.

b. Compact as required.

5. Compaction:

a. Within street right-of-way, compact each lift to ~~at least~~ a minimum of 65% Relative Density for Class I and II (cohesionless) materials and a minimum of **95% of maximum Standard Proctor Density** for Class III and IVA (cohesive) materials~~, otherwise compact to at least 90%~~.

b. Outside of the street right-of-way, compact to a minimum of 50% Relative Density for Class I and II (cohesionless) materials and a minimum of 90% of maximum Standard Proctor Density for Class III and IVA (cohesive) materials.

~~b~~c. In areas more than 3 feet below pavement structure, place backfill in lifts no thicker than 8 inches.

~~c~~d. In areas less than 3 feet below pavement structure, place backfill in lifts no thicker than 6 inches. Terminate backfill at 8 inches below finish grade in areas to remain unpaved, and to subgrade elevation in areas to be paved. Place 8 inches of topsoil in unpaved areas.

~~d~~e. When crossing under levees, railroads, and State or Federal highways, comply with the compaction requirements of these jurisdictions, if more stringent than these requirements.

~~e~~f. For Vitrified Clay Pipe (VCP), keep all heavy compaction equipment 5 feet above the top of the pipe. In the area less than 5 feet, use hand held compactors. Do not allow the compactor to come in contact with the pipe.

6. Moisture Range: Obtain required compaction within a soil moisture range of optimum moisture to 4% above optimum moisture content.

7. Dispose of surplus and unsuitable materials.

8. Hydraulic compaction (flooding with water) is not allowed unless authorized by the Jurisdictional Engineer.

E. Casing Pipe: Place bedding and backfill materials for casing pipe the same as for a rigid gravity flow pipe.

3.07 PIPE INSTALLATION IN CONSTRUCTED EMBANKMENTS

Install all pipes in trenches according to Section 3010, 3.06. When allowed by the contract documents, pipes may be constructed in embankments as follows:

A. Placing Pipe Sections: (See Section 4020, 3.03)

B. Place Backfill for Pipes:

1. Thoroughly tamp backfill under and around the pipe and in layers not to exceed 8 inches for the full length and width of the pipe.

2. Place backfill and thoroughly tamp around and over the pipe for its full length.

3. Extend the completed embankment on both sides of the pipe from the original ground line to at least 1 foot above the top of the pipe with a slope as shown in the contract documents. Construct the embankment over the pipe with a width no less than the outside diameter of the pipe and centered over the pipe. If necessary to accommodate construction traffic, increase the height of fill to the nominal diameter of the pipe or 3 feet, whichever is greater.

4. When pipe are laid wholly or partly in a trench, granular backfill material may be required for backfill. Compact the remainder of the fill to at least 1 foot above the top of the pipe with slopes as outlined above.

5. If the trench has been cut wide enough to permit use of a roller, after the pipe is bedded, thoroughly tamp the backfill material under and alongside the pipe with a mechanical tamper to the mid-height elevation of the pipe.

6. The contract documents may require placement of culvert pipe with moisture control. When not required, place roadway pipe after construction of an embankment by methods that will produce results equivalent to those required for construction of the embankment, except that moisture determinations will be waived for placing backfill completed within 48 hours after excavation.

7. In addition to the normal backfill material requirements, when directed by the Jurisdictional Engineer, build such approach fills to provide a roadway 10 feet in width over the pipe with grades no steeper than 10%.

3.08 STRUCTURE BEDDING

A. Bedding for Structures Bearing on Undisturbed Soils:

1. Shape the bottom to accurate grade and size.

2. Remove loose material, large clods, stones, and foreign materials.

3. In unstable soils or rock conditions see Section 3010, 3.03 for stabilization requirements. Follow bedding requirements as shown in Figure 3010.1.

B. Bedding for Structures Bearing on Bedding Material:

1. Over excavate to minimum of 8 inches or as specified in the contract documents.

2. Place bedding material for structures according to the contract documents and with the material and control specified in Figure 3010.1.

3.09 STRUCTURE BACKFILL

A. Removal of Forms and Falsework: See Section 6010, 3.06.

B. Placement of Backfill: Place backfill after structure concrete has reached at least 80% of the design strength and connecting work has been completed, unless otherwise specified. Determine strengths under comparable conditions. If strength is not determined, place backfill after 14 days.

C. Backfill Against Walls and Around Structures:

1. Where backfill is required on both sides of a concrete wall and around all sides of monolithic structures, proceed with filling operations simultaneously on all sides of walls and structures so the fill is kept at approximately the same elevation at all times. Consider concrete box, arch, and circular culvert monolithic structures.

2. Compact the 3 feet closest to all walls or wing faces by pneumatic or hand tampers only.

D. Placing Backfill with Excavated Material:

Unless otherwise specified, see Section 3010, 3.06, D for suitable excavated materials for backfill.

3.10 OPEN CUT CASING PIPE INSTALLATION

A. Casing Pipe: Install casing pipe according to Section 3010, 3.01 to 3.07, as appropriate.

B. Carrier Pipe: Install carrier pipe according to Section 3020, 3.05.

3.11 FIELD QUALITY CONTROL

A. References:

1. ASTM C 136; Standard Method for Sieve Analysis of Fine and Coarse Aggregates.

2. ASTM D 698; Standard Test Methods for Moisture-Density Relations of Soils and Soil-Aggregate Moisture Using 5.5 pounds (4.54 kg) Rammer and 12 inch (305 mm) Drop. (Standard Proctor Method)

3. ASTM D 1556; Standard test Method for Density and Unit Weight of Soil in Place by the Sand-Cone Method.

4. ASTM D 2216; Standard Test Method for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass.

5. ASTM D 2922 and D 3017; Test Methods for Density of Soil and Soil-Aggregate in Place and Water Content of Soil and Rock by Nuclear Methods (Shallow Depth).

6. ASTM D 4253 and D 4254, Test Methods for Maximum Index Density of Soils using a Vibratory Table and Minimum Index Density of Soils and Calculation of Relative Density.

B. Compaction Testing: Provide compaction testing of backfill, using the services of an independent testing laboratory approved by the Jurisdictional Engineer, unless testing is provided by Jurisdictional Engineer.

C. Schedule Testing: Notify Jurisdictional Engineer when work is prepared for testing.

D. Soil Testing:

1. Cohesive soils: Determine moisture-density relationships by ASTM D 698 (Standard Proctor). Perform at least one test for each type of cohesive soil used.

2. Cohesive soils: Determine in-place density and moisture content using ASTM D 1556 (sand-cone method) and D 2216 or ASTM D 2922 and D 3017 (nuclear).

3. Non-cohesive soils: Determine maximum and minimum index density and calculate relative density using ASTM D 4253 and D 4254 (cohesionless soils).

4. Gradation: Test according to with ASTM C 136.

E. Testing Frequency and Locations: Perform testing of the final trench backfill, beginning at a depth of 2 feet above the top of the pipe, as follows:

1. Contractor provided:

a. Make one test per each 2 vertical feet of consolidated fill at each street crossing.

b. Make one test per each 2 vertical feet of consolidated fill for each 200 horizontal feet of trench.

c. Additional testing may be required by Jurisdictional Engineer if non-compliance or a change in conditions occur.

d. Coordinate the timing of testing with the Jurisdictional Engineer.

e. The Jurisdictional Engineer will determine the location of testing.

f. If necessary, excavate to the depth and size of as required by the Jurisdictional Engineer to allow compaction tests. Place backfill and recompact.

2. Owner Provided:

a. Coordinate the timing of testing with the Jurisdictional Engineer.

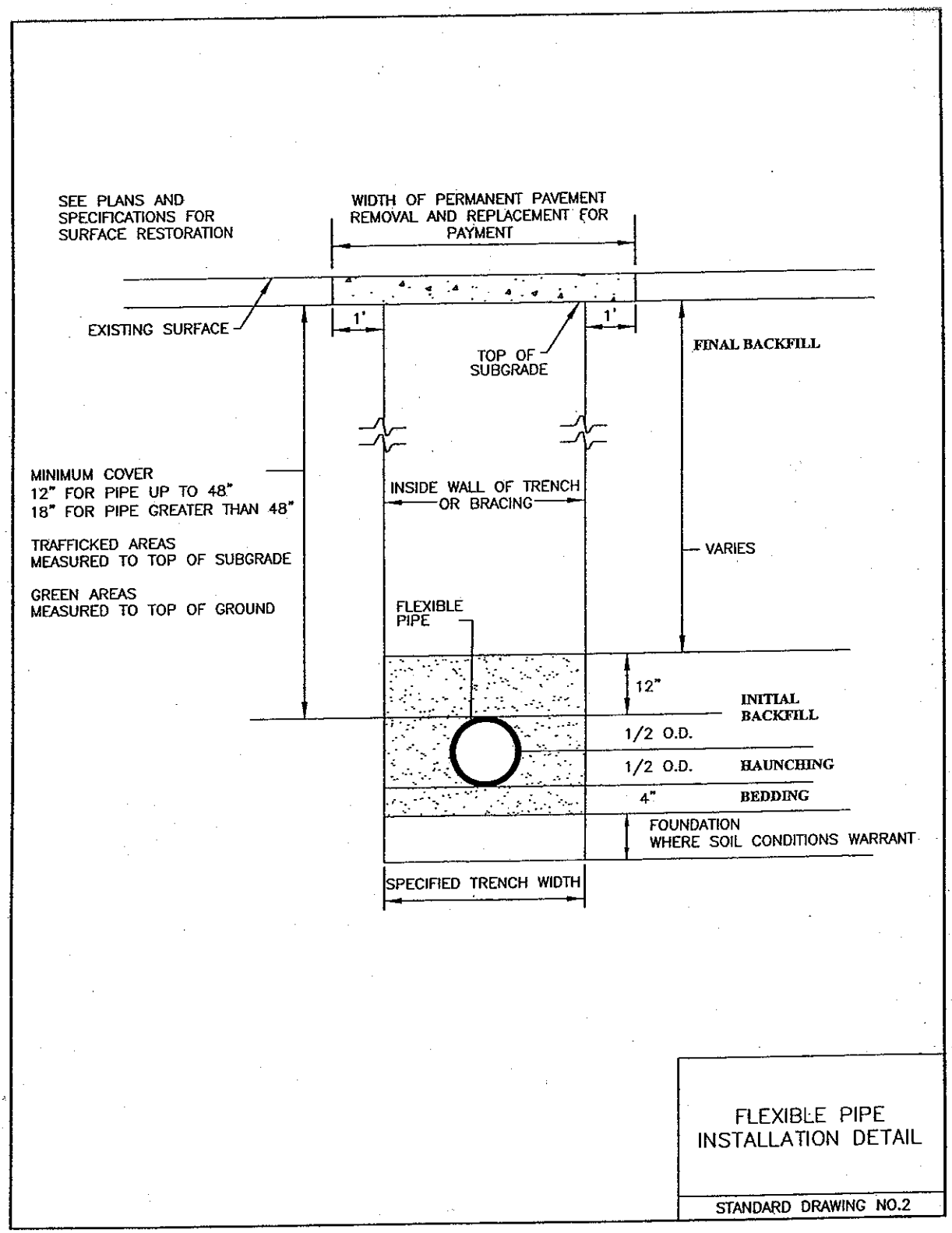
b. The Jurisdictional Engineer will determine the location of testing.

c. Test frequency will not exceed one test per each 2 vertical feet of consolidated fill for each 200 horizontal feet of trench.

F. Test Failure: Rework, recompact, and retest as necessary until specific compaction is achieved in all areas of the trench.

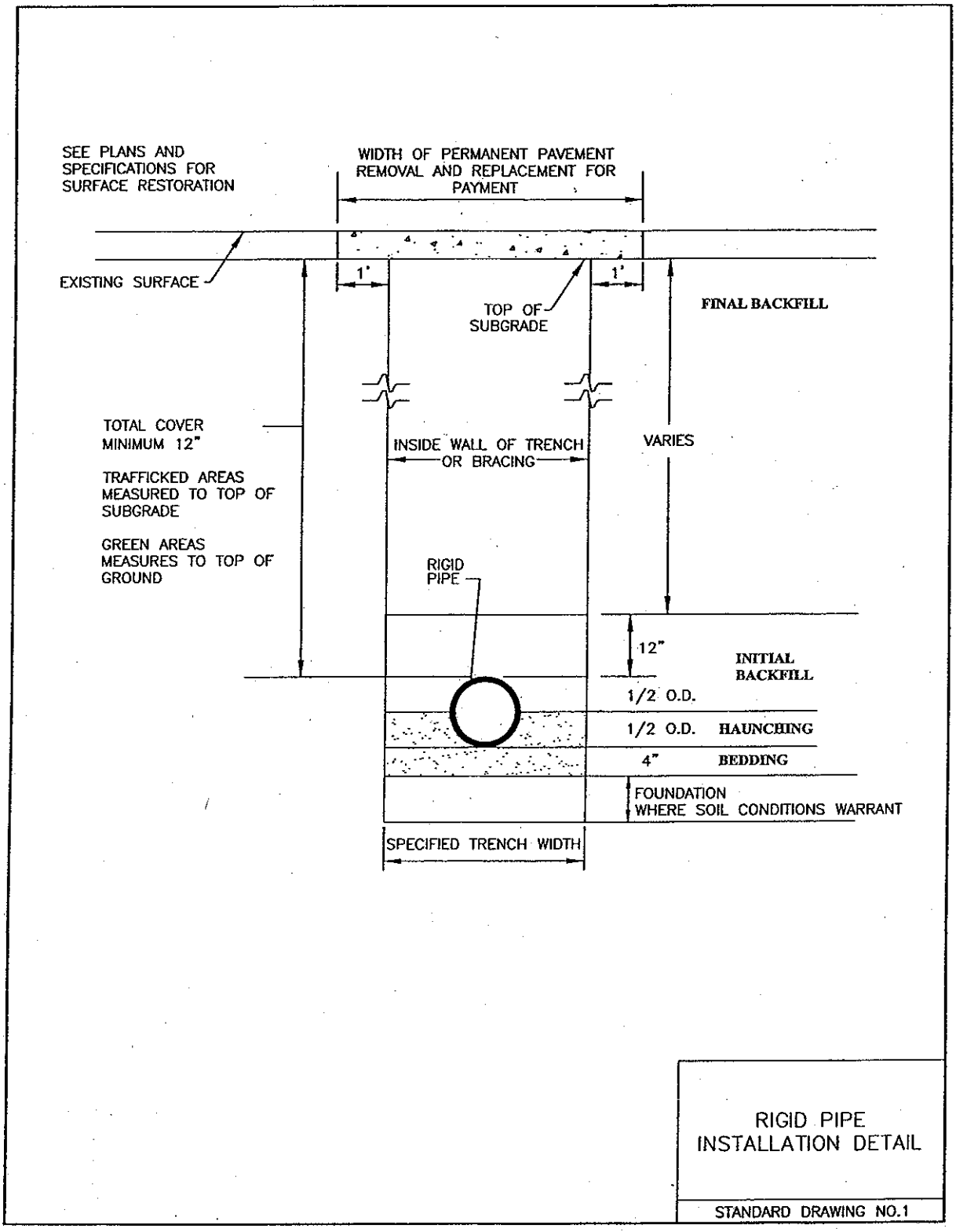
G. Retesting: In event of failed tests, Jurisdictional Engineer may require retesting as deemed necessary. Costs of such retesting shall be paid by the Contractor, at no additional cost to the owner.

END OF SECTION



FLEXIBLE PIPE INSTALLATION DETAIL

STANDARD DRAWING NO.2


SEE PLANS AND SPECIFICATIONS FOR SURFACE RESTORATION
WIDTH OF PERMANENT PAVEMENT REMOVAL AND REPLACEMENT FOR PAYMENT
EXISTING SURFACE
1'
1'
TOP OF SUBGRADE
FINAL BACKFILL
TOTAL COVER MINIMUM 12"
TRAFFICKED AREAS MEASURED TO TOP OF SUBGRADE
GREEN AREAS MEASURES TO TOP OF GROUND
INSIDE WALL OF TRENCH OR BRACING
VARIES
RIGID PIPE
12"
INITIAL BACKFILL
1/2 O.D.
1/2 O.D. HAUNCHING
4" BEDDING
FOUNDATION WHERE SOIL CONDITIONS WARRANT
SPECIFIED TRENCH WIDTH
RIGID PIPE INSTALLATION DETAIL
STANDARD DRAWING NO.1