5-0 INSTALLATION

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BUYER/USER IS RESPONSIBLE FOR SERVICEABILITY OF THE PRODUCT IN ANY GIVEN APPLICATION. SELLER IS NOT RESPONSIBLE FOR INJURY OR DAMAGE RESULTING FROM IMPROPER INSTALLATION, NONCOMPLIANCE WITH THESE GUIDELINES FOR INSTALLATION OF PRODUCT, OR USE OUTSIDE THE GUIDELINES SET FORTH HEREIN.

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5-1 OVERVIEW OF INSTALLATION CONSIDERATIONS

Installation of Hancor polyethylene pipe is in most respects very much like that of any quality pipe installation. The strength of a pipe system shall be considered a combination of the pipe itself and the backfill envelope. Proper construction maximizes the drainage capabilities designed into the pipe by maintaining alignment and load-carrying ability.

Recommendations for proper backfill and installation for Hancor products are based primarily on the requirements of ASTM D2321 "Recommended Practice for Underground Installation of Flexible Thermoplastic Sewer Pipe". This handbook is not intended to replace standard industry or project specifications, but to provide guidance based on our experience, research and recommendations for proper product performance.

The elements regarding backfill that are addressed in this section are as follows:

Proper backfill material selection - A variety of materials can be used as structural backfill with the final decision, many times, based on what is most available locally. Native soil may be an appropriate material providing it meets the basic criteria established in this section.

Proper backfill compaction - Compaction forces out air and moisture to provide a more stable structure. Minimum compaction levels are based on the material characteristics and the design load; some situations may require the use of mechanical compactor while others require simply tamping the material to eliminate voids.

Proper backfill structure - An adequate quantity of structural backfill is necessary to ensure adequate support. Undisturbed native soil from a trench wall often provides additional support. Typical trench dimensions and the effect of the trench wall are discussed in this section.

In addition, this section discusses job-site handling, trench construction and pipe installation for Hancor products, compaction methods, and several specialized installation considerations.

Federal regulations covering safety for construction are published in the Safety and Health Regulations for Construction under the Department of Labor, Occupational Safety and Health Administration (OSHA). These regulations define practices, which must be followed.

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5-2 PRE-INSTALLATION STORAGE AND HANDLING

Polyethylene pipe is lightweight and easy to use. While no special care is needed in handling and installation a few precautions should be set forth.

- Follow all applicable safety regulations when handling pipe.
- The pipe shall not be dropped from the delivery truck into an open trench, or onto uneven surfaces.
- Avoid dragging or striking the pipe against another pipe or object.
- Avoid dragging the pipe across the ground.
- Do not drive over the pipe prior to installation.
- Inspect the pipe and joining systems before installation.

Many of Hancor's drainage products are available palletized allowing for convenient transporting and orderly storage. If the products were not received on a pallet, the pipe should be carefully stacked. One method commonly used is to secure the bottom lengths of pipe together side-by-side, or use stop blocks, and then place additional pipe on top. Where pipe is stock piled, the total pile height shall not exceed 5-feet and the pipe must be adequately restrained to prevent pile collapse. Do not walk on stock piled pipe. Additional handling and storage information is available upon request.

Ambient temperature extremes do not affect the strength or handling characteristics of polyethylene pipe. Cold temperatures can affect the impact resistance of some thermoplastics, although polyethylene remains highly impact resistant even in sub-zero conditions. In-house quality checks demonstrate that the impact resistance at zero degrees F (-18C) is many times that required by specification. Additionally, hot weather, especially when coupled with direct sunlight, will raise the pipe temperature, but will not significantly affect handling or installation behavior.

Depending on the product, either carbon black or titanium dioxide is added to the polyethylene to protect against ultraviolet light; unprotected plastic can become less impact resistant over time. Such additives are required by the specification and protect the pipe during storage periods at the manufacturing facility and at the job site. Ultraviolet light is no longer an issue after installation.

Long-term exposure to ultraviolet light causes slightly different results. The additive, either carbon black or titanium dioxide, protects the pipe for several years, after which the impact strength of the exposed layer, generally 0.001-inch (0.03mm), is significantly reduced. This damaged layer then functions in shielding the remainder of the pipe wall from any

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further damage. There are HDPE culverts, currently under observation, that were installed in 1974. The culverts have retained nearly all of their original strength characteristics and support strong evidence of continued service.

5-3 LINE AND GRADE

Storm drain pipe systems are designed to provide hydraulic capacity based on pipe size and slope. The alignment or line of the pipe is the horizontal location of the pipe while the grade is the vertical slope of the pipe. In order for a storm drain system to function as designed, it is important to install the pipe to the proper line and grade.

Generally, no special practices are required to maintain line and grade, however, certain installation techniques can greatly increase the system performance and rate of installation.

Alignment is established by a field survey. Once the trench is excavated on line, the pipe bedding shall be placed to proper thickness. The top of the bedding shall be adjusted to allow for the difference between the plan invert (flowline) and pipe profile wall thickness. To determine the dimension to be subtracted from the pipe inverts indicated on the plans when checking bedding elevations measure the distance from the interior side of the liner to the crown of the corrugation.

5-4 TRENCH EXCAVATION

The width of the trench depends on the pipe diameter, backfill material, and the method of compaction. Trenches that are too narrow will not allow for proper pipe installation, whereas trenches that are overly wide are unnecessarily costly. As a practical matter, standard bucket sizes may also factor into the decision. The design engineer may modify the trench widths based on an evaluation of the competency of the in-situ materials, the quality and compaction level of the backfill, the design loads and the compaction equipment to be used. In lieu of the engineer's recommendations or governing agency specifications, the following trench widths are suggested.

Minimum trench widths are as shown in Table 5-1.

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Table 5-1

Minimum Trench Widths

Nominal Pipe Diameter, in. (mm)	Minimum Trench in. (m)	Nominal Pipe Diameter, in. (mm)	Minimum Trench in. (m)
4 (100)	21 (0.5)	24 (600)	48 (1.2)
6 (150)	23 (0.6)	30 (750)	56 (1.4)
8 (200)	26 (0.7)	36 (900)	64 (1.6)
10 (250)	28 (0.7)	42 (1050)	72 (1.8)
12 (300)	30 (0.8)	48 (1200)	80 (2.0)
15 (375)	34 (0.9)	54 (1350)	88 (2.2)
18 (450)	39 (1.0)	60 (1500)	96 (2.4)

These minimum trench widths are necessary for suitable in-situ soils. These widths generally allow for backfill material to flow on either side of the pipe and permit many types of compaction equipment. If the width is not sufficiently wide for the materials and methods proposed, a wider trench allowing for proper installation shall be constructed. Six to eight inches (0.15 - 0.20m) on either side of the pipe is about the minimum acceptable trench width allowed when compaction equipment is not required.

In very poor native soils (for example; peat, muck, or highly expansive soils), a wider trench width will be required. This wider trench width shall be based on an evaluation of the in-situ soil, and the design and construction loads.

Trench widths for smaller diameter pipe are often determined by the bucket size available for the excavator, and in many cases can exceed twice the nominal pipe diameter. From an economical point of view, it's best to keep the trench width in perspective with the pipe diameter.

One common misconception is that wide trenches are necessary for flexible pipe. Wide trenches are not only costly to excavate and fill with backfill material; they can actually detract from the structural integrity of the pipe/backfill system in many cases. Years of consolidation create a very stable soil environment. The desire is to destroy as little of that stability as necessary when digging the trench. Stable trench walls actually enhance the structural integrity of the system when the trench is relatively narrow. Overly wide trenches also require more backfill material and more compaction which may not form a structure as stable as the undisturbed native material.

The depth of the trench is dictated by the geography of the site and the pipe slope required. However, if an adequate foundation for the pipe is not available at the desired depth, additional excavation will be needed. Rock outcroppings, muck, and other unsuitable materials do not provide proper support. They shall be removed and replaced with suitable granular material. Refer also to Figure 5-1.

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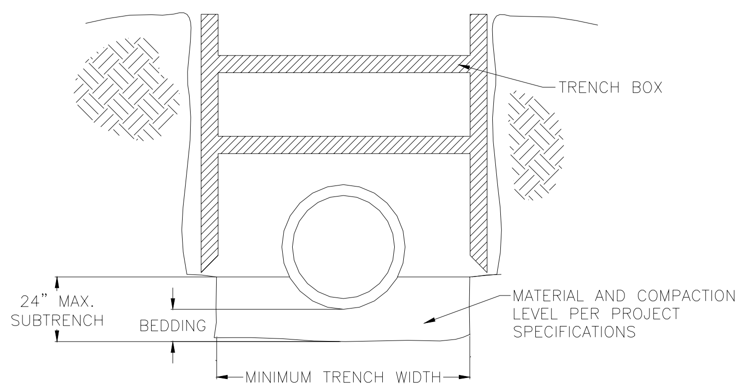
Trenching shall be completed in existing soils with sidewalls reasonably vertical to the top of the pipe. For positive projection embankment installations, the embankment material shall be placed and compacted to a minimum of one (1') foot above the pipe and the trench excavated into the embankment. When excavation depths or soil conditions require shoring or use of a trench box, the bottom of the shoring or trench box shall be placed no lower than the top of the pipe. This prevents disruption of the backfill envelope when removing the shoring or trench box. Dragging the trench box shall only be done if it does not damage the pipe or disrupt the backfill, otherwise, the box shall be lifted vertically into its new position. If this practice cannot be followed, consideration should be given to leaving the shoring in place. The most effective way to maintain a sound system is to provide a 'sub trench' within which to place the pipe and backfill. For safety, the bottom of the trench box should not be greater than 24" above the bottom of the trench. For more information on the use of trench boxes, refer to Technical Note 5.01: *Recommended Use for Trench Boxes*.

Figure 5-1
Typical Sub Trench Installation



5-5 BACKFILL ENVELOPE CONSTRUCTION

Backfill construction shall be evaluated as part of the structural design of polyethylene pipe like it is for other pipe materials. ASTM D2321 serves as the basis for installation recommendations in trafficked installations. Acceptable backfill materials and construction methods are very similar or, in many cases, identical to those required for other types of pipe material.

The primary purpose of the backfill envelope is to provide long-term support to the pipe. In a properly constructed backfill envelope, the loads are distributed across the crown of the pipe to the material along the sides and then to the pipe bedding and foundation. This load arching effect reduces the total load applied to the pipe.

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The load that a flexible pipe will carry is related to the backfill envelope construction. The load-carrying ability of a pipe/backfill system will be determined by a combination of the backfill material, the level of compaction, and the placement of the backfill material. However, the type of application may also influence what type of backfill is required. These and other related issues are discussed in subsequent paragraphs in this section.

BACKFILL MATERIAL

Material selection is the first and most important step to creating a structurally sound backfill envelope. In general, backfill material should be of an aggregate nature, able to be compacted, if necessary, into a structurally sound structure. A variety of materials, including some native soils, meet these requirements.

Backfill offers passive resistance, termed the “modulus of soil reaction”. The modulus of soil reaction is determined by a combination of the material and the amount of compaction. The type of material (sand, gravel, clay, etc.) and compaction level (standard Proctor density) determine overall strength of the backfill. Some research indicates that other factors, such as the beneficial effects of trench walls, may add to the conservancy of the backfill strength, although those relationships are often neglected. (This information assumes the trench walls are at least as strong as the backfill material.)

The strength of the backfill can be described using different parameters. One way is by describing it in terms of the modulus of soil reaction (E’), which is an empirical value developed by the Bureau of Reclamation to calculate deflection. Another parameter used to describe backfill strength is the secant constrained soil modulus (M_S). Values for M_S and E’ are discussed further in the Structures chapter of this handbook.

Hancor recommends soil types and compactions as shown in Table 5-2 and 5-3 in installations involving AASHTO H-25 or HS-25 loads under minimum cover conditions or in deep installations. Shallow, non-trafficked installations may not require this level of backfill quality, but any modifications should be discussed with Hancor engineers prior to establishing backfill criteria on a particular project. Installations involving higher loads sometimes require a higher soil strength; Hancor engineers can also provide additional guidance on backfill requirements in these situations.

As discussed in the Structures section of this handbook, it is the combination of the type of material and compaction level that will determine the soil strength. When a variety of options will work in a particular installation, the final decision can depend on what is most available locally in order to keep the cost of the installation to a minimum. Native soil may be specified when it meets the requirements of Table 5-2 and 5-3. Using native soil eliminates the cost of imported backfill material and the effort spent grading or hauling the excavated material off site. If

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the native material is not acceptable, then appropriate material will need to be brought in.

Controlled Low Strength Material (CLSM) or flowable fill is another, more specialized, type of backfill material that is increasing in use throughout the country. This material is essentially very low strength concrete that is poured around the pipe. With CLSM or flowable fill, trench width can be reduced to a minimum of the outside diameter of the pipe plus 12-inches and the E' of the native material must be at least 1000 psi. Although the structural integrity of flowable fill is excellent, it will misalign or float the pipe unless precautions, such as weighting the pipe or pouring the flowable fill in layers, are taken. Conventional compacted granular material creates structurally sound backfill that is easier to use and often less expensive to install. For more information on the use of CLSM refer to Technical Note 5.02: *Use of CLSM as Backfill Material for HDPE Pipe.*

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Table 5-2
Classes of Embedment and Backfill Materials

ASTM D2321[1] Class	ASTM D2321[1] Description	ASTM D2487 Notation	ASTM D2487 Description	AASHTO M43 Notation	Min. Compaction Required (Std. Proctor Density %)[3]	ASTM D2321[1] Percentage Passing Sieve Sizes: 1 ½ in. (40mm)	No. 4 (4.75mm)	No. 200 (0.075mm)	Atterberg Limits: LL	PI	Coefficients: Uniformity Cu	Curvature Cc
IA[4]	Open-graded, clean manufactured aggregates	N/A	Angular crushed stone or rock, crushed gravel, crushed slag; large voids with little or no fines	5 56	Dumped to Slight	100%	≤10%	<5%	Non Plastic		N/A	
IB	Dense-graded, clean manufactured, processed aggregates	N/A	Angular crushed stone or other Class IA material and stone/sand mixtures with gradations selected to minimize migration of adjacent soils; little or no fines			100%	≤50%	<5%	Non Plastic			
II	Clean, coarse-grained soils	GW	Well-graded gravel, gravel-sand mixtures; little or no fines	57 6 67	Moderate (85%)	100%	<50% of “Coarse Fraction”	<5%	Non Plastic		>4	1 to 3
		GP	Poorly-graded gravels, gravel-sand mixtures; little or no fines								<4	<1 or >3
		SW	Well-graded sands, gravelly sands; little or no fines				>50% of “Coarse Fraction”				>6	1 to 3
		SP	Poorly-graded sands, gravelly sands; little or no fines								<6	<1 or >3
	Coarse-Grained Soils, borderline clean to w/fines	GW-GC, SP-SM	Sands and gravels which are borderline between clean and with fines	N/A		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	Gravel & sand with <10% fines	Moderate to High (90%)	100%	<50% of “Coarse Fraction”	12% to 50%	N/A	<4 or <“A” Line	N/A	
		GC	Clayey gravels, gravel-sand-clay mixtures							<7 & >“A” Line		
		SM	Silty sands, sand-silt mixtures				>50% of “Coarse Fraction”			>4 or <“A” Line		
		SC	Clayey sands, sand-clay mixtures							>7 & >“A” Line		
IVA[2]	Inorganic fine-grained soils	ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands, silts with slight plasticity	N/A	N/R	100%	100%	>50%	<50	<4 or <“A” Line	N/A	
		CL	Inorganic clays of low to medium plasticity; gravelly, sandy, or silty clays; lean clays	N/A						>7 & >“A” Line		
IVB	Inorganic fine-grained soils	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts	N/A	N/R	100%	100%	>50%	>50	<“A” Line	N/A	
		CH	Inorganic clays of high plasticity, fat clays	N/A						>“A” Line		
V	Organic soils or Highly organic soils	OL	Organic silts and organic silty clays of low plasticity	N/A	N/R	100%	100%	>50%	<50	<4 or <“A” Line	N/A	
		OH	Organic clays of medium to high plasticity, organic silts	N/A					>50	<“A” Line		
		PT	Peat and other high organic soils	N/A								

Notes:
1) Refer to ASTM D2321 for more complete soil descriptions.
2) Class IVA material has limited applications and can be difficult to place and compact; use ONLY with the approval of a soil expert. Contact Hancor for additional information regarding suitability of this backfill material.
3) N/R indicates that use of this material and/or compaction level is not recommended by ASTM D2321 for the backfill envelope.
4) When using open-graded material, additional precaution must be taken to reduce or eliminate the risk of migration of fines from adjacent material. Refer to ASTM D2321 for more complete information.

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BACKFILL PLACEMENT

Storm sewers are sometimes placed on foundations that settle and shift in a non-uniform manner. Fortunately, flexible pipe can accommodate many of these changes without detrimental effects. The best construction practices, however, involve placing the pipe on a firm foundation for maximum performance and structural integrity throughout the design life.

In some cases it may be necessary to perform subsurface evaluations of the soil conditions where muck, rock, or other unsuitable conditions are suspected. Zones of soft material, such as muck, allow the pipe to settle, potentially affecting the structural integrity and hydraulic characteristics of the system. Rock and rock protrusions apply point loads where they contact the pipe that can affect the hydraulics or structural integrity of the system. It is recommended that unsuitable foundation material be excavated before installation of the pipe proceeds. Where a rock or unyielding or soft foundation is present, the design engineer or a geotechnical engineer shall be consulted to determine the extent to which the undesirable material is to be excavated.

If no undesirable foundation material is found, a minimum of 4- to 6-inches (0.1 - 0.15m) of bedding shall be placed and compacted on the foundation to equalize load distributions along the invert of the pipe. (Refer to Figure 5-2 for a pictorial description of backfill terminology.)

A stable and uniform bedding shall be provided for the pipe and any protruding features of its joints and/or fittings. The middle of the bedding equal to 1/3 of the pipe O.D. should be loosely placed, with the remainder compacted to a minimum of 90% standard proctor density. Class I, II, and III materials are suitable for use as bedding. Note: Where using open-graded material (IA for example) in any fill zone, additional precaution must be taken to reduce or eliminate the risk of migration of fines form adjacent material. Precautionary steps could include the use of geotextile between the varying fill materials, gradation selection to prevent the migration of fines, or other precautionary measures. Refer to ASTM D2321 for more complete information.

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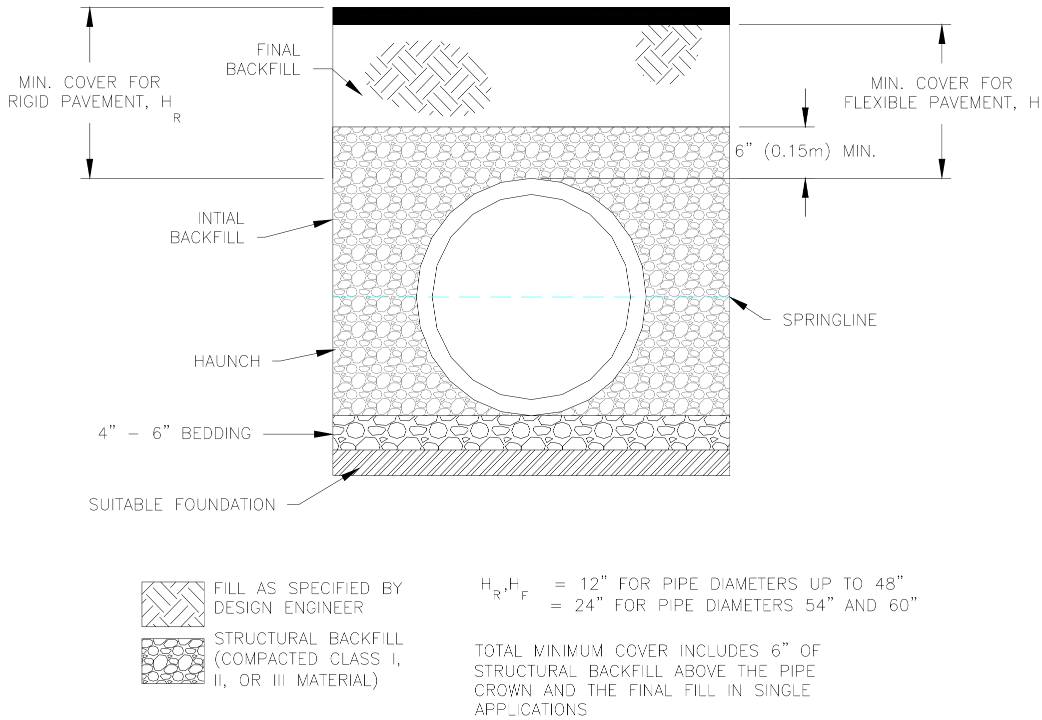
Figure 5-2
Typical Backfill Structure



The next layer of backfill, the haunching, is the most important since it is this layer that provides the pipe with support against the soil and traffic loadings. Class I, II, and III materials are suitable for use in the haunches. Haunching shall be placed in lifts of 4- to 6-inches (0.10 - 0.15m) and compacted in accordance with Table 5-2. Tamp to achieve the specified compaction, or shovel into the area, eliminating voids, if the material doesn't require compaction. Construction of each lift should be repeated up to the spring line.

Initial backfill extends from the spring line to a minimum of six inches (0.15m) above the crown of the pipe. This area of the backfill anchors the pipe and ensures that loads are distributed as evenly as possible into the haunching. The same material used in the haunching should be used for the initial backfill. Where differing materials are used, backfill material size should be selected as to prevent migration of fines or a geosynthetic shall be used to separate the backfill zones. Additionally, it is crucial to obtain similar backfill strength between fill zones if differing materials are used. Where varying soil strengths exist, structural performance of the overall system may be compromised; therefore using the same material as was used in the haunch area for the initial backfill is recommended. When using a material that requires compaction it is important not to use mechanical compaction equipment directly on the pipe itself. Class I, II, and III materials are suitable for use as initial backfill. Initial backfill shall be placed in lifts of 4- to 6-inches (0.10 - 0.15m) and compacted in accordance with Table 5-2. Tamp to achieve the specified compaction, or shovel into the area, eliminating voids, if the material doesn't require

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compaction. Construction of each lift should be repeated up to a minimum of six inches (0.15m) above the crown of the pipe.

Flowable fill can be used as an alternative to compacted granular material, however special precautions are necessary for a successful installation. Flowable fill may cause the pipe to float or misalign. Therefore the pipe will need to be weighted with sandbags or held with some type of anchoring system. The flowable fill may also be poured in layers that are allowed to cure before the next layer is poured to help reduce the tendency for the pipe to float. As with any backfill material, proper installation of the flowable fill around the pipe is critical to the structural performance of the pipe. For additional information on the use of flowable fill, refer to Technical Note 5.02: *Use of CLSM as Backfill Material for HDPE Pipe*.

Final backfill, which extends from the initial backfill layer to the ground surface, does not directly support the pipe. For 4- to 48-inch (100mm-1200mm) diameters the final backfill shall be a minimum of six inches (0.15m) and shall be a minimum of eighteen inches (0.5m) for 54-inch and 60-inch (1350mm and 1500mm) diameters for a total of twelve and twenty-four inches of minimum cover, respectively, for single run applications (see Figure 5-2). For applications where flexible pavement is installed over the pipe zone, height of cover is measured from the crown of the pipe to the bottom of the flexible pavement. Where rigid pavement is installed over the pipe zone, height of cover is measured from the top of the pipe to the top of the rigid pavement. When no pavement will be installed, but vehicle traffic is expected (e.g. gravel driveway), a minimum cover of 18" for 4- to 48-inch diameters and 30" for 54- and 60-inch diameters is recommended to minimize rutting. Proper compaction in this area is not nearly so critical for the pipe as in the other layers. However, if roads or drives will be crossing the pipe, a relatively high degree of compaction is needed to prevent pavement settlement. Excavated materials may be of adequate quality for final backfill, depending on the intended use at the surface. Selection, placement and compaction of final backfill shall be as directed by the design engineer.

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Table 5-3
Recommendations for Installation and Use of Soils and Aggregates

Backfill Zone	Class 1A	Class 1B	Class 2	Class 3
General Restrictions	Do not use where conditions may cause migration of fines from adjacent soil and loss of pipe support.	Process material as required to obtain gradation which will minimize migration of adjacent materials.	Where hydraulics gradient exists check gradation to minimize migration.	Do not use where water condition in trench may cause instability.
Foundation	√	√	√	√ *- Do not use in thicknesses greater than 12-in. total.*
Bedding	√ *- 4" for 12"-24" pipe 6" for 30" to 60" pipe* *- Loosely place middle 1/3*OD with remainder compacted to min. 90% SPD*	√ *- 4" for 12"-24" pipe 6" for 30" to 60" pipe* *- Loosely place middle 1/3*OD with remainder compacted to min. 90% SPD*	√ *- 4" for 12"-24" pipe 6" for 30" to 60" pipe* *- Loosely place middle 1/3*OD with remainder compacted to min. 90% SPD*	√ *- 4" for 12"-24" pipe 6" for 30" to 60" pipe* *- Loosely place middle 1/3*OD with remainder compacted to min. 90% SPD*
Haunch	√ *- Work in around pipe by hand to provide uniform support* *- knife in to remove any voids*	√ *- Work in around pipe by hand to provide uniform support* *- Compact to min. 85% SPD*	√ *- Work in around pipe by hand to provide uniform support* *- Compact to min. 85% SPD*	√ *- Work in around pipe by hand to provide uniform support* *- Compact to min. 90% SPD*
Initial Backfill	√ *- Install to a minimum of 6" above pipe crown* *- knife in to remove any voids*	√ *- Install to a minimum of 6" above pipe crown* *- Compact to min. 85% SPD*	√ *- Install to a minimum of 6" above pipe crown* *- Compact to min. 85% SPD*	√ *- Install to a minimum of 6" above pipe crown* *- Compact to min. 90% SPD*
Final Backfill	√ *- Place and compact as required by the engineer*	√ *- Place and compact as required by the engineer*	√ *- Place and compact as required by the engineer*	√ *- Place and compact as required by the engineer*

1) √ = Material may be suitable. Ultimately, the design engineer must determine the acceptable backfill material based on specific project conditions and structural requirements for the product.

2) Refer to ASTM D2321 for more complete soil requirements.

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COMPACTION

The level of compaction will vary depending on the material and installation requirements, see Table 5-2 for minimum compaction requirements based on soil type. Crushed stone or similar materials are usually not compacted, but do require care during installation to eliminate large voids in the backfill envelope. Using a shovel to 'slice' the material under and around the pipe is many times sufficient.

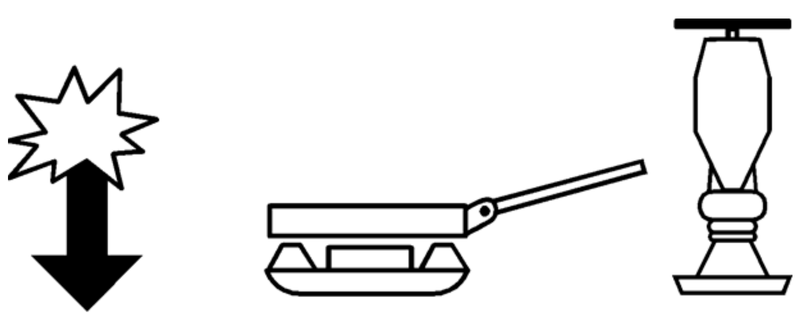
For other materials, compaction methods will depend primarily on the amount of compaction, or modulus of soil reaction, required and the moisture level of the material. At optimum moisture levels, some Class II and III soils can be compacted to minimum recommended levels simply by walking on each backfill lift. While this technique may not be acceptable for all installations, the point is that compaction need not always require a great deal of extra effort or mechanical equipment. If, however, mechanical compaction equipment is needed in the backfill envelope or elsewhere on the site, the subsequent paragraphs provide guidance on compaction equipment and the soils for which they are most appropriate.

MECHANICAL COMPACTION EQUIPMENT

Hand Tampers and Hand-Held Power Tampers: Compacting the haunching layer may require a small tamping mechanism to obtain the specified compaction in a confined area. A hand-held pole or two-by-four can be used to compact the haunching. Tampers for horizontal layers shall not weigh more than twenty pounds (89N) and the tamping face shall be limited to an area no larger than 6-inch by 6-inch (0.15 by 0.15m).

Rammers or rammer plates (Figure 5-3) use an impact action to force out air and water from between soil particles to consolidate the fill. This equipment works well on cohesive or high-clay content soils. Care should be taken not to use rammer-type compactors directly on the pipe. For heavy-duty compaction equipment, such as a Ho-pac® or equivalent type compactors, a minimum of 4-feet of backfill shall separate the pipe from the equipment at all times.

Figure 5-3
Rammer Compactors



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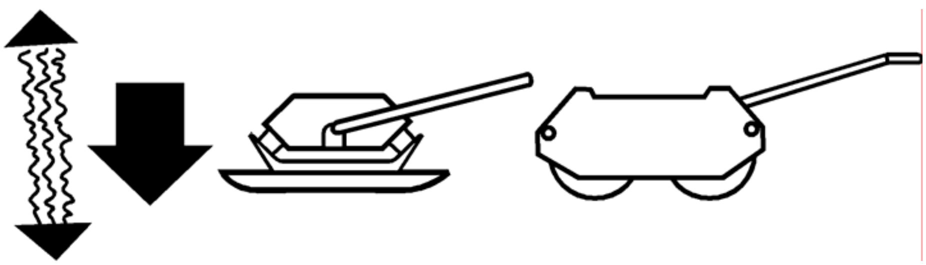
Static Compactors (Figure 5-4): Consolidation with static compactors occurs as a result of the rolling weight of the equipment itself. Sheeps-foot rollers employ projecting feet to concentrate the weight of the machine. Static compactors are most valuable when used on non-cohesive backfill away from the pipe. Other methods of compaction should be used near the pipe.

Figure 5-4
Static Compactors

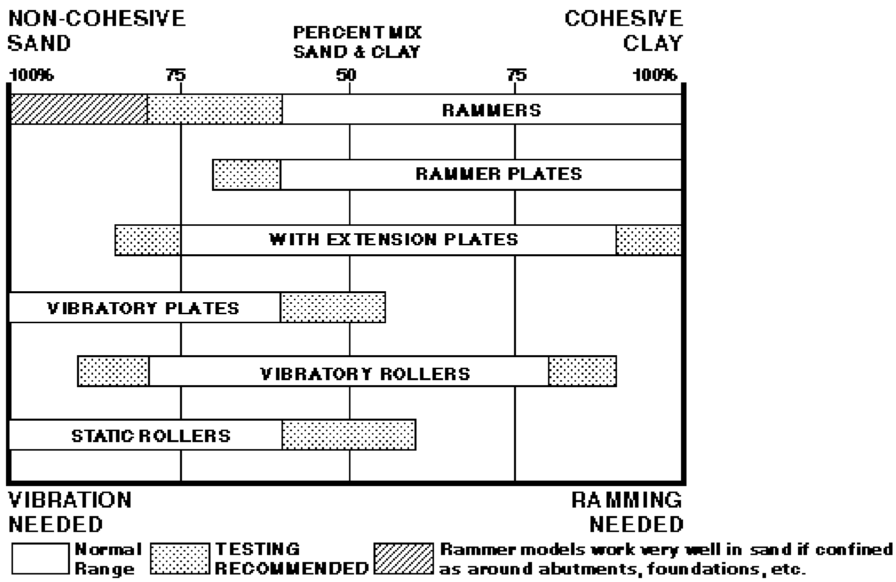
Vibrating Compactors (Figure 5-5): The motion of vibrating rollers or plates "shake" the soil particles into a more dense arrangement and work best with non-cohesive fills. Depending on the size and weight of the machine, vibrating compactors may be used close to the pipe. As always, care should be taken not to impact the pipe directly with a great deal of force.

Figure 5-5
Vibrating Compactors



Selecting the right equipment for the fill material is the key to achieving the most efficient compaction. For soil mixtures, the component having the highest percentage will dictate what type of compaction equipment is needed. Table 5-4 guides in the selection of compaction equipment.

Table 5-4
Compaction Equipment Selection Guide



5-5 JOINTS

Joints serve several purposes in a drainage system. Their primary purpose is to preserve the structural integrity by keeping the embedment material out of the system. Well-designed joints also preserve the hydraulic properties of the pipe by maintaining alignment between pipe ends. Joints can keep effluent inside the pipe, which is necessary when environmental issues are a concern. Site-specific requirements or local regulations will usually dictate the performance of joint required.

Three joint designs are available to meet the increasing demands on joint performance. The Hancor Hi-Q joint, with split band couplings, offers a soil tight joint. The Hancor Sure-Lok ST, integral bell and spigot joining systems meet or exceed soil-tight performance and Hancor BLUE SEAL offers a 10.8psi laboratory rated watertight joining system.

HI-Q PLAIN END (SOIL-TIGHT COUPLERS)

Hancor Hi-Q plain end pipe joint use external coupling bands, such as a split band coupler, that meet the soil-tight requirements of AASHTO M252, AASHTO M294 or ASTM F2306. Typically, soil-tight joints are used with perforated systems where soil migration is not a design concern.

SURE-LOK ST (GASKETED SOIL-TIGHT COUPLERS)

The Sure-Lok ST joining system is designed to perform in demanding soil conditions. The gasket meets all the testing requirements of ASTM F477. The gasket combined with an interference fit, provides outstanding joint performance meeting or exceeding the soil-tight joint performance requirements of AASHTO M252, AASHTO M294, or ASTM F2306.

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BLUE SEAL (GASKETED WATERTIGHT COUPLERS)

Watertight joints are designed to maintain a specified level of watertightness to keep effluent in the system and keep soils out. The Hancor 4- through 60-inch (100mm - 1500mm) BLUE SEAL joint meets the watertight joint performance requirements of AAHSTO M252, AASHTO M294, ASTM F2306. This joint showed no leakage when pressurized to 10.8 psi (74.5 kPa) under the laboratory conditions established in ASTM D3212.

This level of watertightness is recommended for systems that will be pressure tested, or that require a very tight joint for other site and/or environmental reasons.

Guidelines for deciding what joint performance is appropriate in a particular application are provided in Table 5-5.

Table 5-5
Guidelines for Joint Performance Selection

	Joint Performance Options		
	Soil Tight		Water Tight
Project Conditions	**Hi-Q Plain End (4"-30")**	**Sure-Lok ST Gasketed (4"-60")**	**BLUE SEAL (4"-60")**
SOIL FACTORS			
Potential for small or negligible soil migration (e.g., gravel, medium to coarse sands, cohesive soil).	√	√	√
Potential for moderate soil migration (e.g., fine sands, silts).	N/R	√	√
Potential for severe soil migration (e.g., very fine sands, non-cohesive fines).	N/R	N/R	√
EFFLUENT CONDITIONS			
Effluent is permitted to infiltrate into ground; poses little or no environmental concern.	√	√	√
Effluent has potential to cause groundwater or other contamination.	N/R	N/R	√
PRESSURE CONDITIONS			
Installation will operate under non-pressure conditions.	√	√	√
Installation will operate under non-pressure conditions; minimized leakage desired.	N/R	√	√
Installations with low temporary pressures and ASTM D3212 joint quality required. Installed system to be hydrostatic pressure tested.	N/R	N/R	√

√ The most restrictive of the project conditions will ultimately determine minimum joint quality. Ultimately, the design engineer must determine the acceptable joint quality for the project.

N/R Not recommended by manufacturer. Final approval contingent on design engineer.

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Where more than one product or joint design will be acceptable in a particular installation, the most cost effective alternative should be selected. Bell-and-spigot joints keep the job going because they require little time and effort to assemble. The result can be significant overall cost savings.

5-6 OTHER INSTALLATION CONSIDERATIONS

Not all drainage projects can be considered "typical" installations. Unusual soil conditions cannot always be found until the actual excavation is made. More complicated pipe configurations may be needed to arrive at the desired drainage pattern or to increase the capacity of an existing drainage network. Hancor cannot anticipate all situations encountered on specific installations; however, several common questions are answered in the following material. Contact Hancor's Application Engineering Department or visit our website at www.hancor.com for answers to other unique conditions.

CONSTRUCTION AND PAVING EQUIPMENT

Some construction vehicles, such as many types of paving equipment, are not as heavy as the design load. For situations with relatively light construction vehicles, the one-foot (0.3m) minimum cover criteria discussed in Section 2 can be decreased during the construction phase; however, rutting may still occur at the surface. Table 5-6 presents the surface applied loads and the corresponding minimum cover that can be permitted on a temporary basis. *These criteria should only be employed during construction; finished projects should always have minimum cover as set forth in Table 2-8 of the Structures section. Vehicles exceeding these criteria must not be permitted to drive over the installation.*

Table 5-6
Temporary Cover Requirements for Light Construction Traffic

Type of Vehicle	Vehicular Load at Surface, psi (kPa)	Temporary Minimum Cover, in (mm) for:	
		4"-48" (100mm-12mm) Pipe	54"-60" (1350mm-1500mm) Pipe
Semi-tractor[1]	75 (517)	9 (230)	12 (300)
Loaded pick-up truck[2]	50 (345)	6 (150)	9 (230)
Skid steer loader[3]	25 (172)	3 (80)	6 (150)

1. Based on typical 3-axel day-trip tractor without trailer.

2. Chevy® 3500 Series, fully loaded

3. Bobcat® T180 Model skid steer loader

Very heavy construction traffic poses additional concern for buried flexible pipe when buried at shallow depths. The extremely high loads created by construction vehicles can potentially reduce the safety factors below reasonable levels in minimum cover conditions. It is recommended that three feet (0.9m) of cover be used over the pipe in installations involving

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construction vehicles between 30T and 60T (267-534kN). For heavier vehicles a greater amount cover is required. The amount of cover is dependent on the load and loading footprint. This additional cover can simply be mounded and compacted over the pipe during the construction phase and then graded following construction. If, in a particular installation the pipe already has minimum amounts of cover, no additional precautions are needed.

JOINING DIFFERENT PIPE TYPES OR SIZES

Drainage systems often involve connecting pipe of different materials or sizes. Options to make these transitions are often limited by the joint quality required. One very common method of connecting different types of pipe of the same size, and in some cases different sizes, is through the use of a concrete collar. This generally provides a minimum silt-tight joint quality but ultimately depends on workmanship. A concrete collar is formed by butting the two pipe ends together, wrapping the junction with a geotextile to keep out most soil and concrete, and then pouring a concrete collar that covers both pipe ends.

Another option may be using fittings or adapters specifically designed for this application. Hancor offers a selection of fittings designed to make the transition from one material directly to another. In other cases a Hancor fitting may need to be used in combination with another manufacturer's gasket, for example, to complete the transition. Transitions made in this manner may be more watertight than a concrete collar.

FIELD CONNECTIONS

Field connections may be necessary to complete pipe runs for short pipe lengths or for repairs to pipe damaged during construction. Field connections and repairs should be performed with couplers compatible to the overall system. See Technical Note 5.03: *HDPE Pipe Repair Options* for more details on field cuts and connections.

CURVILINEAR INSTALLATIONS

Hancor HDPE pipe can be laid on a curved alignment as a series of tangent (straight sections) deflected horizontally at each joint. However, the amount of joint articulation is dependent on the type of joint selected. Typically, Hancor Sure-Lok ST and BLUE SEAL bell and spigot pipe joints can only accommodate small deflection angles (< 1^{o}) and maintain the soil-tight or water tight joint performance for which they are designed. Split couplers and bell-bell couplers will also permit small deflection angles (approximately 1^{o} to 3^{o}). See Table 5-7 for minimum bend radii based on joint type.

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Table 5-7
Bend Radii for Dual Wall Pipe

Diameter, in (mm)	Joint Type	Maximum Deflection at Joint (deg)	Radius, ft (m), per pipe length		
			10 ft (m)	13 ft (m)	20 ft (m)
4 – 60 (100 – 1500)	Hi-Q (split band or bell-bell couplers)	3	191 (58)	248 (76)	382 (116)
4 – 60 (100 – 1500)	Sure-Lok ST or BLUE SEAL (bell & spigot)	1	n/a	745 (227)	1146 (349)

Bend radii calculated with joint articulations only. Calculations do not assume any bend in the pipe wall.

MANHOLE AND CATCH BASIN CONNECTIONS

Manholes and catch basins can be used at changes in pipe material, size, grade, direction and elevation. Manholes and catch basins can be more costly than other alternatives but also allow grade and directional changes in addition to changes in pipe material and size.

Consideration shall be given to the project performance specified when selecting manhole connections. For connection options, refer to Technical Note 5.04: *HDPE Pipe Connections to Manholes and Structures*.

VERTICAL INSTALLATIONS

HDPE pipe is sometimes installed vertically for use as catch basins or manholes, meter pits, and similar applications. Vertical installations do not behave the same as pipe that is installed horizontally because the pipe/soil interaction is different. The soil surrounding a vertical pipe locks into the corrugations, allowing the pipe to move along with the soil consolidation that occurs over time. This movement can cause a rippling of the interior liner that generally does not affect the performance of the finished installation.

Installation requirements are especially important for vertical installations. Backfill material and compaction levels will determine the performance of the finished installation. Backfill shall extend a minimum of one-foot (0.3m) completely around the vertical structure. Backfill material recommendations are identical to those for a horizontal installation; compaction levels and maximum lift requirements must be strictly adhered to (refer to Table 5-2).

Additional general applications limits include the following:

- Height of the vertical structure must not exceed eight feet (2.4m), unless the design is reviewed by the Hancor Application Engineering Department.
- If traffic will be driving over a vertical structure, a concrete collar or similar structure designed to transmit the load into the ground must be used. Traffic loads must *not* be transmitted directly into the pipe wall.

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- Cast iron frames holding grates or lids must be seated on a concrete collar or similar structure so that the weight of the frame and grate or lid is transferred into the ground, *not* to the vertical pipe.

Vertical installations of any Hancor fitting should first be reviewed for suitability with Hancor Application Engineering. This includes, but is not limited to, tees, elbows, and reducers of any combination. Improper application or inadequate installation may affect the function of the part or the drainage system. There may also be other product performance limits depending on the application. Contact Hancor for further information.

GROUNDWATER

Excessive groundwater hinders proper placement and compaction of bedding and backfill. Hancor HDPE pipe will float in standing water, therefore, it is imperative that a dry trench be provided. In order to insure a stable trench bottom, the water level in the trench shall remain below the bedding during the installation procedure. It may be necessary to provide sump pumps, well points, deep wells, geofabrics, underdrains or a diversion ditch to insure a dry trench. The project engineer shall be consulted to determine appropriate dewatering methods given specific project conditions.

FLOTATION

Pipe of any material and size can float under the right conditions. The soil type and density, amount of cover, height of the water table, pipe weight, and the amount of effluent in the pipe will all have an effect on the flotation potential.

The pipe property affecting flotation is its weight: heavier products are not as likely to float. One of the primary installation benefits of Hancor polyethylene pipe is its light weight. The same quality that provides easy handling and installation also provides it with a greater opportunity to float. Table 5-8 gives approximate weights by inside diameter for Hancor HDPE pipes.

Table 5-8
Approximate Weight of Hancor HDPE Dual Wall Pipes

Inside Diameter		Approx. Weight		Inside Diameter		Approx. Weight	
in.	mm	lb/ft	kg/m	in.	mm	lb/ft	kg/m
4	100	0.44	0.65	24	600	11.0	16.4
6	150	0.85	1.3	30	750	15.4	22.9
8	200	1.5	2.2	36	900	19.8	29.4
10	250	2.3	3.4	42	1050	26.4	39.3
12	300	3.3	4.91	48	1200	31.3	46.6
15	375	4.6	6.8	54	1350	34.6	51.5
18	450	6.4	9.5	60	1500	45.2	67.3

In order to evaluate for possible flotation problems many factors were considered and several assumptions had to be made based on typical

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installation conditions. A detailed list of the design assumptions and other design considerations are available in Technical Note 5.05: *HDPE Pipe Flotation*. A summary of the fill required to prevent flotation is shown in Table 5-9. Note that in many cases, less than one foot (0.3m) is needed. However, for structural purposes, a minimum of one foot (0.3m) of cover is required.

Table 5-9
Minimum Cover Required to Prevent Flotation

	Diameter in. (mm)	Cover in. (mm)
Hi-Q, Sure-Lok ST, and BLUE SEAL	4 (100)	3 (77)
	6 (150)	4 (102)
	8 (200)	5 (127)
	10 (250)	7 (178)
	12 (300)	9 (368)
	15 (375)	11 (457)
	18 (450)	13 (559)
	24 (600)	17 (711)
	30 (750)	22 (914)
	36 (900)	25 (1067)
	42 (1050)	29 (1219)
	48 (1200)	33 (1372)
	60 (1500)	40 (1702)
Single Wall	3 (75)	2 (50)
	4 (100)	3 (77)
	6 (150)	4 (102)
	8 (200)	6 (152)
	10 (250)	7 (178)
	12 (300)	9 (368)
	15 (375)	11 (457)
	18 (450)	13 (559)
	24 (600)	17 (711)

Due to many factors affecting flotation, several assumptions had to be made. For a detail list of the assumptions made, please refer to Technical Note 5.05: *HDPE Pipe Flotation*.

In spite of their light weight, Hancor products will not float when of the adequate cover is placed on the pipe. Additionally, if effluent were in the pipe, as would be likely in the case of a fully saturated soil, its weight would further hinder flotation.

A second very important variable is the burial depth. During installation when the pipe has not yet been covered over with soil, flotation potential increases. If conditions on a specific project differ greatly from these and flotation is believed to be a valid consideration, Hancor Application Engineers are available to help determine the extent of the problem.

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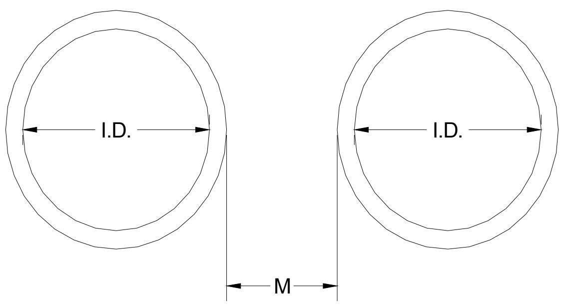
PARALLEL PIPE INSTALLATIONS

Storm sewers can be installed parallel when the capacity supplied by one of the pipes is not sufficient, such as in a relief situation.

A minimum amount of backfill is needed to provide adequate side support and a minimum spacing is also needed to compact the fill properly to develop this support. Generally, accepted minimum spacings are shown in Figure 5-6.

Figure 5-6
Minimum Pipe Spacing



UP TO 24" (600mm) I.D.: M=12" (0.3mm)
MORE THAN 24" (600mm) I.D.: M=½ I.D.

STEEP SLOPE INSTALLATIONS

In applications where a steep slope is necessary, generally slope equal to or greater than 12%, precaution must be taken to ensure the application conditions will not adversely affect the pipe structure or flow characteristics. One design consideration should be proper venting. The pipe must be properly vented to ensure negative pressure does not form inside the pipe. Venting can be provided along the pipe slope, at the head of the slope, or by designing the flow in the slope to not flow more than 75% full in peak design flow conditions. Next, thrust blocks must be used at all fittings and grade changes. Change in flow direction can cause excessive force against the pipe wall. Thrust blocks must be used to dissipate this energy. Thrust blocks should be constructed as designed and specified by the project engineer for the specific project conditions. Finally, consideration must be given to pipe slippage along the slope. Pipe slippage can result in slope failure of the surrounding soil, structural damage the pipe wall, or compromising of joint quality for the overall system. Pipe should be restrained through the use of concrete blocks or pipe anchors.

Note: Twelve percent grade is listed for reference purposes only, additional design consideration may be necessary for slopes less than 12% where slope stabilization, negative pressure, or water hammer, may be of concern.

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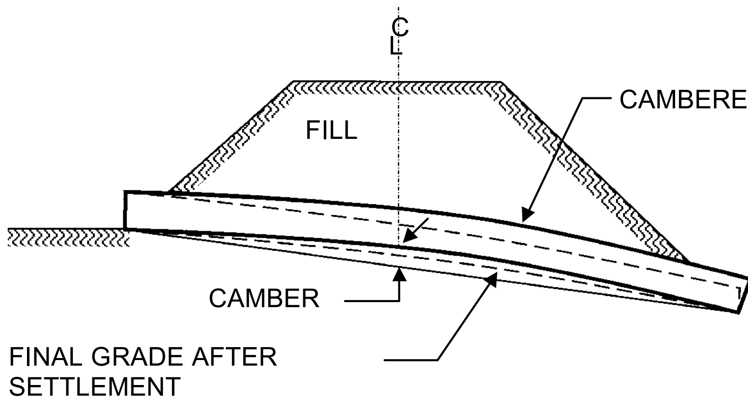
CAMBERED INSTALLATIONS

Some pipe installations may need to design for uneven settlement regardless of the backfill envelope quality and construction. High embankments are especially prone to uneven settlement because the load on the pipe near the center of the embankment will be greater than at the top of the slope. In order to eliminate low pockets under the embankment, the pipe should be cambered.

Cambering is the process of installing the pipe so that the expected settlement will create the design slope. It can be achieved by installing the upstream half of the pipe on a flat grade and downstream half on a grade that is larger than design, as shown in Figure 5-7. Corrugated pipe, because of its flexibility, can be cambered quite easily. A qualified soils engineer should be consulted for this specialized situation.

Figure 5-7
Cambered Pipe Installations



SLIPLINING

Due to abrasive or corrosive environments, premature deterioration of some types of pipe may occur. In lieu of a total replacement, sliplining the existing pipe with HDPE pipe is often an economical and efficient way to significantly extend a culverts' service life. Typically, HDPE pipe can only be used for open-ended applications where the pipe does not need to be bent for installation. Other considerations during design and pre-construction should include the inside and outside diameter of the carrier pipe and HDPE pipe, length of installation and grout installation. For more information, refer to Technical Note 5.06 *Sliplining Considerations* for more details.

POST-CONTRUCTION INSPECTION

Generally, no post construction is necessary for Hancor pipe installations, however it is good practice to perform a visual inspection to insure proper line and grade have been achieved. It is important to understand that

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under normal conditions, any deflection will be realized within the first thirty (30) days after installation. This affords the inspector the opportunity to inspect the pipe shortly after installation with the ability to note deficiencies before the project is complete. The inspection should be performed after the pipe has been laid and backfilled, but may be before final paving has been placed.

The following outlines various inspection methods commonly specified for flexible pipes (plastic or metal):

Visual Inspection

A visual inspection will usually reveal improper line and grade as well as excessive deflection. For most projects, which specify a soil tight or silt tight joint performance, a visual inspection is sufficient to insure a successful installation. Caution is advised when inspecting pipe or entering manhole or inlet structures to insure compliance with all OSHA regulations.

Infiltration/Exfiltration Testing

For systems designed for watertight applications without specifying any ASTM specification for testing, an infiltration/exfiltration test is a simple and easy method of insuring proper joint performance. For an infiltration/exfiltration test, a run of piping is tested by filling the system with water from structure to structure (manhole or inlets), allowing the system to stabilize for 24 hours measuring the water level and then measuring the water level again after a period of time. The drop in water level can then be converted to gallons leakage/ inch pipe diameter/ mile length of pipe /day and compared to the permissible level established for the project. In the absence of a specified level, 200-gal/ in. dia./ mi./ day is commonly considered watertight for storm sewer applications. An acceptable ASTM specification for testing infiltration/exfiltration is ASTM F2487.

Air Testing

After the pipe has been laid and backfilled, each section of pipeline between manholes may be tested by a low pressure air test. Individual joints may also be tested with appropriate equipment. This test is usually for systems where performance standards require watertight joints. ASTM F1417 may be used for air testing these systems and shall be completed from structure to structure or for individual joints. Fabricated structures and fittings shall not be tested to avoid damaging these components.

ASTM F1417 specifies a 3.5 psi air pressure be held for a specified length of time based on the pipe diameter with a maximum 0.5 psi pressure drop. Although the diameters listed in ASTM F1417 only include up to 36", linear interpolation for

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larger diameters is generally acceptable. Hancor does not recommend air testing of any pipe diameters 24-inch or larger. Air testing can pose significant safety risks due to the stored energy created and nature of the test method.

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5-7 OTHER TECHNICAL RESOURCES

Hancor Technical Notes

Technical Note 5.01: *Recommended Use of Trench Boxes*

Technical Note 5.02: *Use of CLSM as Backfill Material for HDPE Pipe*

Technical Note 5.03: *HDPE Pipe Repair Options*

Technical Note 5.04: *HDPE Pipe Connections to Manholes and Structures*

Technical Note 5.05: *HDPE Pipe Flotation*

Technical Note 5.06: *Sliplining Considerations*

Hancor Installation Guides

Dual Wall HDPE Pipe Installation Guide

Hancor Standard Details

Standard Detail 1.01: *Typical HDPE Pipe Trench*

Standard Detail 1.02: *Parallel Pipe Installation*

Standard Detail 1.03: *HDPE Pipe Anchoring*

Standard Detail 2.01: *Structure Connection Installation*

Standard Detail 2.02 (A-B): *Soil-tight Structure Connection*

Standard Detail 2.03: *WaterStop® Structure Connection*

Standard Detail 2.04 (A-E): *Watertight Structure Connections*

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