

Flexible 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 to 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 polyvinyl chloride (PVC), high density polyethylene (HDPE), and polypropylene. 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. Polypropylene pipe is used for both sanitary and storm sewer applications.

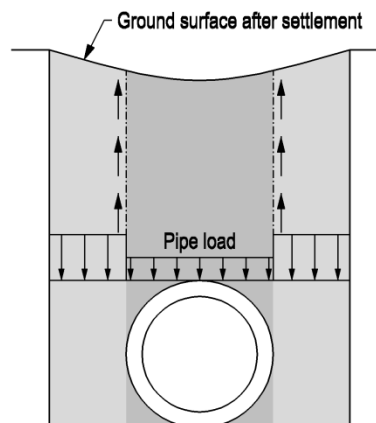
In order to take advantage of the benefits and avoid the limitations of flexible pipes, it is necessary to understand how they perform and how their properties are defined.

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 9B-3.01). 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 9B-3.01: 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

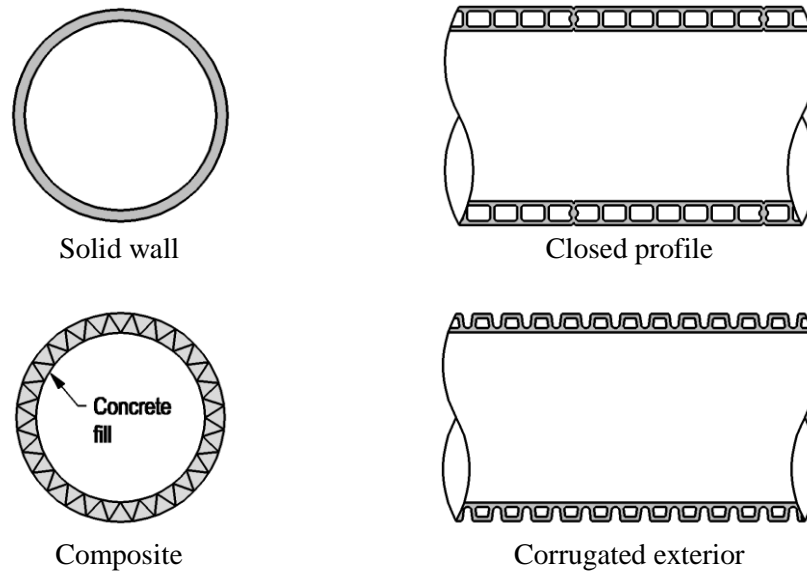
The design of most flexible pipes is based upon pipe stiffness. Pipe stiffness is a term used to describe the resistance of a flexible pipe to deflection when subjected to a load. Pipe stiffness is measured by placing a section of flexible pipe between two flat plates. A load is applied until the pipe is deflected 5% of its diameter. The load at which this occurs is the pipe stiffness. Pipe stiffness is specified in lb/in².

In general, pipe stiffness is related to the material properties and wall thickness of the pipe (see Figure 9B-3.02). 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/in². 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/in² 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 9B-3.02: 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. Use of PVC pipe for storm sewer applications requires specific approval by the Engineer due to the increased potential for impact to the pipe envelope and subsequent damage to the pipe from adjacent or crossing excavation activity.

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/in².

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. Use of HDPE pipe for storm sewer applications requires specific approval by the Engineer due to the increased potential for impact to the pipe envelope and subsequent damage to the pipe from adjacent or crossing excavation activity.

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.

3. **Polypropylene:** Polypropylene pipe can be used for both sanitary sewer and storm sewer applications. It is made from polypropylene resin to form a pipe that has improved impact resistance and less susceptibility to brittleness than HDPE pipe.

The minimum pipe stiffness allowed in the SUDAS Specifications is 46 psi. The smaller pipe diameters (12 inch to 30 inch) are double walled with a smooth interior and corrugated exterior.

In order to maintain the minimum pipe stiffness in the larger diameters (30 inch to 60 inch), the pipe is triple walled. Both the double wall and triple wall pipe have an integral bell and spigot joint.

Use of polypropylene pipe for storm sewer applications requires specific approval by the Engineer due to the increased potential for impact to the pipe envelope and subsequent damage to the pipe from adjacent or crossing excavation activity.

D. Flexible Pipe Bedding

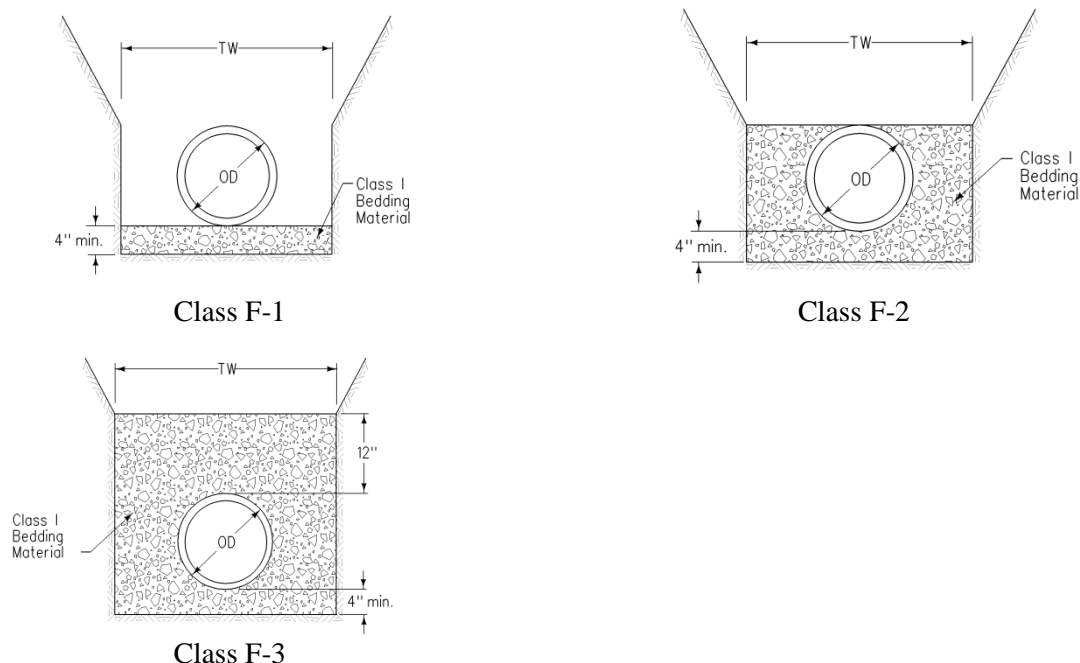
For most gravity installations with flexible pipe, granular bedding material is recommended. Suitable granular bedding material is self-compacting when placed in the trench. This ensures proper pipe support is provided in the area below the springline, where it is difficult to provide mechanical compaction. 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 9B-3.03: Flexible Pipe Bedding Types



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/in².

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.