General Information for Trench Design

A. Trench Theory

When designing a pipe, the first step is to determine the flow capacity required, which will then determine the pipe type, diameter, and grade. The capacity of the pipe must be sufficient to carry external loads once it is buried.

A buried pipe must resist the dead load of the soil above it and any live loads applied at the surface, or the pipe will fail. Because buried pipes interact with the surrounding soil based, in part, on the stiffness of the pipe, different design methodologies have been developed for determining loads on rigid and flexible pipes.

A rigid pipe has significant strength but will crack if it is deformed. Because of this, a rigid pipe relies on its strength to carry external loads when buried. However, because of its stiffness, a rigid pipe must carry the entire load of the soil above it, and even some of the load from the soil adjacent to it. Rigid pipe design methodology is described in more detail in Section 9B-2 - Rigid Pipes.

A flexible pipe does not have the strength of a rigid pipe, but it will not crack when deformed. Because of this, a flexible pipe relies on its ability to deform to reduce the load on the pipe by transferring most of the load to the surrounding soil. Flexible pipe design methodology is described in more detail in Section 9B-3 - Flexible Plastic Pipes.

When analyzing a proposed pipe installation, both the magnitude of the load imposed on the pipe and the capacity of the pipe to carry the load must be determined. Both of these values are influenced by a number of factors, including the pipe's flexibility or rigidity, the pipe bedding, soil properties, and installation practices. Because these factors all interact with each other, it is important to understand how each one affects the ultimate performance of the pipe. These properties are described in more detail below and in the following sections.

B. Bedding and Foundation Materials

1. **Granular Bedding Material:** Bedding is the material installed in the bottom of the trench on which the pipe is laid. Proper pipe bedding is critical to the load carrying capacity of both rigid and flexible pipes. Clean, crushed Class I granular bedding material should be used for all gravity sewer installations. Granular bedding material is commonly used as backfill in the haunch zone (below the springline) as well as for primary and secondary backfill zones, depending on the pipe material.

   Although the interaction between the soil and pipe is different for rigid and flexible pipes, both types require proper placement and compaction of the bedding material under the pipe and in the haunch zone for proper support. By supporting rigid pipes along the bottom of the pipe, the pipe load is distributed over a larger area, thereby reducing the concentrated stresses at the invert of the pipe. Flexible pipes require proper bedding and haunch backfill to provide sidewall support for the pipe. As a flexible pipe deflects vertically, the sides of the pipe move outward. Without proper sidewall support and resistance to these lateral deflections, the vertical pipe deflections can exceed allowable levels.

Because bedding and haunch support is critical to the performance of both rigid and flexible pipes, proper installation of materials in these areas is critical. Most pipe installation guides recommend hand placement and slicing of granular bedding material with a shovel to ensure there are no voids in the haunch zone. Soil backfill should be compacted with hand compaction equipment in the haunch zone after placement of the pipe. Due to a variety of factors, including time constraints, lack of inspection, and concerns over trench safety, hand working and compacting backfill around a pipe are almost non-existent in today's construction industry.

In order to address these issues, the use of clean, self-compacting granular bedding and backfill material is recommended. Properly graded, clean, crushed stone that is dumped into a trench and shaped requires little or no additional compaction effort to provide a moderate degree of compaction. In addition, this material will bridge over some soft or yielding soils, reducing the need for over-excavation and foundation material. SUDAS Class I Material is a 1 inch, clean, crushed stone that should be used for most pipe bedding applications.

Where Class I or similar material is not available, gravel or crushed concrete may be used. However, these materials do not possess the self-compacting quality that Class I material has. Additional time and effort will be required to place and compact these materials. Increased construction observation may be required to ensure that the materials are properly placed and compacted.

2. **Stabilization (Foundation) Material:** The bottom of the trench should be firm, stable, and uniform to support the pipe and prevent movement during backfill and compaction. When Class I bedding material is inadequate for bridging trench bottoms with soft or yielding soils, overexcavation of the trench bottom and installation of stabilization material should be considered.

   Stabilization material consists of 2 1/2 inch clean crushed stone. It is installed in the bottom of the trench after overexcavation to remove any soft or yielding soils. The required depth of overexcavation and stabilization material varies as required to provide a firm base. Class I granular bedding and normal backfill are placed on top of the stabilization material as in a normal installation.

   Stabilization material can also be substituted for Class I bedding material when installing heavy pipe, such as concrete pipe 48 inches and greater. For heavy pipe, Class I bedding may be susceptible to movement under the weight of the pipe. Since stabilization material is significantly larger, it is better able to resist movement under heavy loads.

C. Backfill Materials

1. **Haunch Support:** The haunch support zone extends from the top of the bedding material to the springline, or mid-point, of the pipe. Like pipe bedding, this zone is critical to the support and performance of the pipe. For flexible pipes, this zone should be backfilled with Class I granular bedding material in order to provide adequate sidewall support to the pipe. Rigid pipes may be backfilled with Class I bedding material or suitable native soil, depending on the depth of the installation. Because a portion of the haunch zone is located underneath the pipe, this area is difficult to compact. If Class I granular bedding material is not used to backfill the haunch support zone, careful attention must be paid to ensure that proper compaction is achieved in this area and that the pipe is not damaged by compaction equipment.

2. **Primary and Secondary Backfill:** The primary backfill zone extends from the springline of the pipe to the top of the pipe. The secondary backfill zone extends from the top of the pipe to 1 foot over the top of the pipe. For most plastic pipes, the Class I granular bedding material should be extended from the haunch through the primary and secondary backfill zones. While these areas can be more easily compacted than the haunch area, plastic pipes are susceptible to damage by compaction equipment. Therefore, this zone is typically backfilled with Class I bedding material in order to protect the pipe from damage during compaction.

   Though care must still be taken during compaction, rigid and ductile iron pipes may be backfilled with suitable native materials.

3. **Final Backfill:** The final backfill zone extends from the top of the secondary backfill (1-foot above the top of the pipe) to the top of the trench. The materials placed in the final backfill zone have little impact on the load carrying capacity of the pipe. However, it is important that this area be backfilled with suitable soils and properly compacted to avoid future settlement. This is particularly important when the trench is located under future paving.

D. Dewatering

All pipes should be installed in a trench with a dry bottom. Ideally, the water table should be at least 2 feet below the bottom of the excavation. For installations below the water table in soils with a high coefficient of permeability, dewatering may be required. Due to the slow flow of water, installations in clay soils do not generally require dewatering, and water in the trench can be controlled with sump pumps. A number of methods are available when dewatering is required.

Well points (often called sand points) are one of the most common methods of dewatering. The well point system consists of a number of small diameter wells installed at regular intervals (typically 3 to 8 feet) adjacent to the proposed trench. Each well contains a pipe that extends down to the bottom of the well. At the surface, the end of each pipe is connected to a header pipe, which is connected to a vacuum pump. The use of well points results in a localized drawdown of the water table. Because groundwater is extracted by vacuum, the maximum depth of dewatering by well points is limited to 15 to 20 feet.

For installations where the trench bottom exceeds the limits of the well point system, or where the well points interfere with the construction, a deep well system may be required. A deep well system consists of a single well or a much smaller number of wells than a well point system. Wells may be spaced at 50 foot intervals or larger. In a deep well system, each well has a pump located at the bottom of the casing. This eliminates the depth limitations of the well point system. Deep wells can be installed to depths of up to 100 feet with a single-stage pump. Deep wells can draw down the water table over a significantly larger area than a well point. For this reason, they should be used with caution in areas where existing structures are present, as the reduction in water table level can cause settlement.