
Rigid Pipes

A. Introduction

Rigid pipes are generally considered pipes that cannot deflect 2% of their diameter before failing. Common rigid pipes include concrete and clay as well as other specialized pipe materials. Because rigid pipes do not deflect significantly when loaded, the pipe itself must be capable of supporting the backfill placed over it and any additional loads that are applied to it.

A number of factors, including trench width, pipe strength, and bedding type, affect the magnitude of the load transmitted to the pipe and the ability of the pipe to carry the load. In an urban setting, most public utilities, including storm sewer, sanitary sewer, culverts, or water mains, are installed in an open trench; therefore, it is important to understand each of these characteristics and how they affect the structural capacity of a rigid pipe.

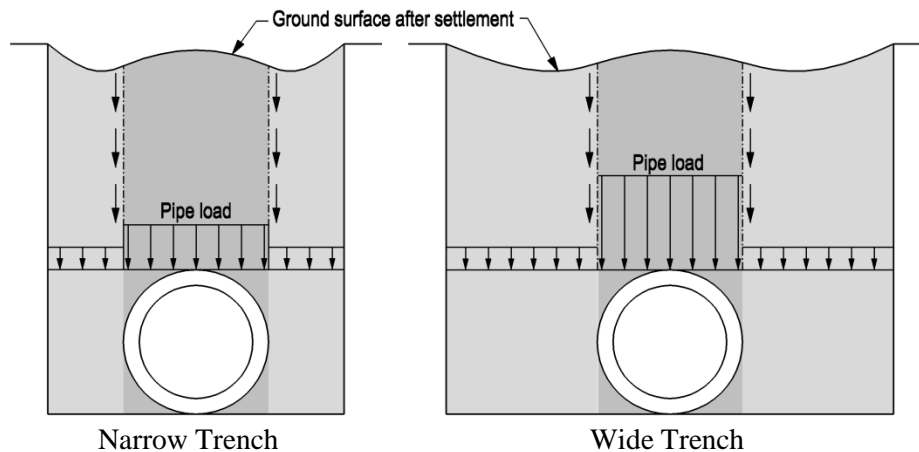
B. Trench Width

After trench excavation and pipe installation, bedding and backfill materials are placed in the trench. Even with proper compaction, the bedding and backfill materials in the trench will continue to undergo settlement. Because the height of the soil columns between the pipe and the trench walls are greater than the height of the soil column immediately above the pipe, and because a rigid pipe does not deflect, the areas adjacent to the pipe will undergo greater settlement than the soil column directly over the pipe.

As differential settlement occurs between the soil columns adjacent to the pipe and the columns directly above it, frictional forces are generated along the trench walls and along the central soil column over the pipe. As the adjacent soil columns settle, they drag the central soil column down, transferring a portion of their load to the pipe. Consequently, a rigid pipe tends to carry the entire load of the soil column directly above it and a portion of the load from the soil columns adjacent to it. The magnitude of the load from the adjacent soil columns that is transferred to the pipe varies, depending on trench width (see Figure 9B-2.01).

As the trench width increases, the load on the pipe will continue to increase until reaching a limiting value called the transition width. At this point, any additional increase in trench width does not affect the load on the pipe, and the pipe behaves as if it were buried in an embankment.

It should be noted that it is the width of the trench at the top of the pipe that affects the load on the pipe. The width or shape of the trench walls above this level can be sloped or stepped without increasing the load on the pipe.

Figure 9B-2.01: Effect of Trench Width on Rigid Pipe Load

In 1913, Anson Marston published a report on the interaction between the pipe and the surrounding soil after studying the problem at Iowa State College. The resulting “Marston Equation” has been used extensively to determine the earth load on pipes. For additional information on the Marston Equation, transition width, and the method of determining actual backfill loads, refer to the “Marston/Spangler Design Procedure” in the American Concrete Pipe Association’s (ACPA) *Concrete Pipe Design Manual*.

C. Pipe Strength

A three-edged bearing test is used to determine the strength of a rigid pipe. The pipe is supported at two locations along the bottom, and a vertical load is applied at the top until the pipe fails. For concrete pipe, two failure methods are defined. The first, $D_{0.01}$, is the load at which a 0.01 inch crack develops in the pipe. The second, D_{ult} , is the ultimate load that the pipe can carry. D-load strengths are measured in pounds per liner foot per foot of pipe diameter. For design purposes, the $D_{0.01}$ value is used to provide a factor of safety. The following table correlates the pipe class with the two D-load values.

Table 9B-2.01: RCP Load Equivalents

Pipe Class ¹ (ASTM C76)	$D_{0.01}$ (lb/ft/ft diameter)	D_{ult} ² (lb/ft/ft diameter)
Class II	1,000	1,500
Class III	1,350	2,000
Class IV	2,000	3,000
Class V	3,000	3,750

¹ SUDAS specifies concrete pipe according to pipe class (minimum Class III)

² Iowa DOT specifies pipe by the ultimate load (e.g. Class III RCP is specified as 2000D)

Clay pipes are also tested, using a three-edged bearing test. The specified strength of clay pipe does not follow the D-load concept and varies depending on pipe diameter. Clay pipe strengths are the ultimate strength of the pipe and vary from 2,000 to 8,000 pounds per foot.

D. Bedding Factors

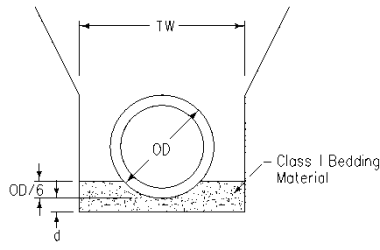
The forces imparted on a pipe in an installed condition are considerably different than the concentrated forces generated in the lab during a three-edged bearing test. In the installed condition, the pipe is supported and the load is distributed over the entire width of the pipe. Depending on the type of bedding provided, this can significantly increase the load carrying capacity of the pipe.

In order to relate the strength of the pipe from the three-edged bearing test to the actual capacity of the pipe in an installed condition, bedding factors have been developed to address a number of standard bedding types. The SUDAS Specifications closely follow the standard bedding types and the bedding factor values described in the *ACPA Concrete Pipe Design Manual*. For a given pipe strength, the $D_{0.01}$ strength is multiplied by the bedding factor to represent the strength of the pipe in the installed condition (see Figure 9B-2.02).

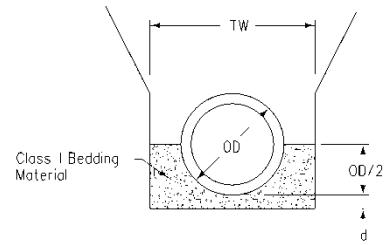
E. Live Load

In addition to the backfill load, a buried pipe must also support any live loads applied at the surface. For pipes installed under asphalt or concrete pavements, the live load from vehicular traffic is distributed sufficiently by the pavement that the live load transmitted to the pipe is negligible. Likewise, for pipes that are buried deeper than 6 feet, live load can usually be neglected. However, for shallow pipes in unpaved areas, or for pipes that cross under railroads, live loads on the pipe should be considered.

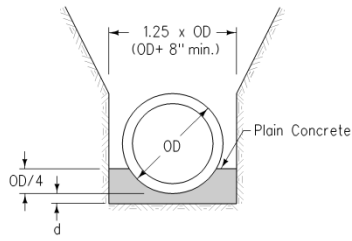
Figure 9B-2.02: Rigid Pipe Bedding Types and Bedding Factors



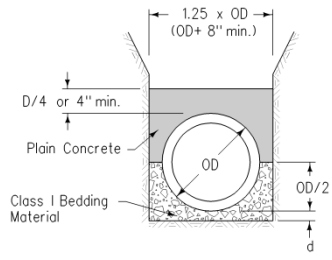
Class R-1
Bedding Factor = 1.5



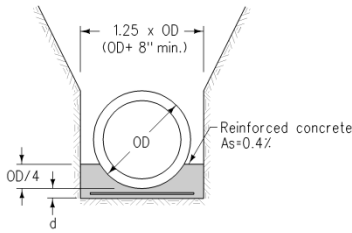
Class R-2
Bedding Factor = 1.9



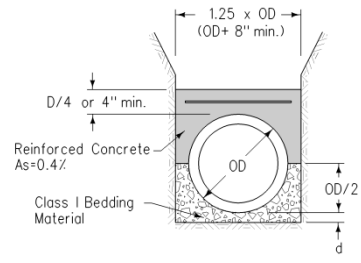
Class R-3 (Unreinforced)
Bedding Factor = 2.8



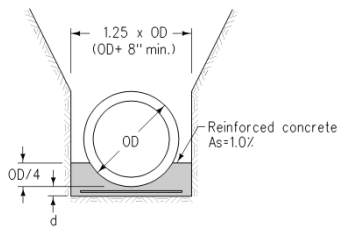
Class R-4 (Unreinforced)
Bedding Factor = 2.8



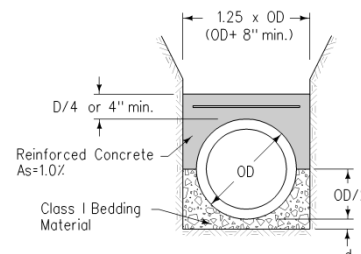
Class R-3 (0.4% Reinforcing)
Bedding Factor = 3.4



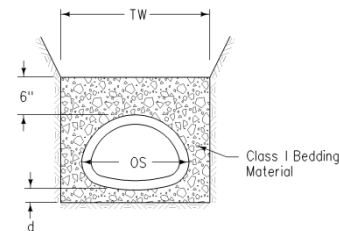
Class R-4 (0.4% Reinforcing)
Bedding Factor = 3.4



Class R-3 (1.0% Reinforcing)
Bedding Factor = 4.5



Class R-4 (1.0% Reinforcing)
Bedding Factor = 4.5



SUDAS Class R-5
Bedding Factor = 1.9

Figure Legend

- d = Bedding depth below pipe; OD/8 or 4" min.
- D = Pipe diameter
- OD = Outside pipe diameter
- TW = Trench width