

08-13-11

## **THE FIVE TYPES OF PIPELINE TRENCHES**

### **SUMMARY**

There are five basic types of pipeline trenches based on the embedment construction. The five types reflect a significant difference in the contractors operations. The differences reflect significant variations in mobilization, equipment, labor, and embedment material. The five types apply to both rigid and flexible pipe.

For the pipeline designer, one of the five types of trench construction can be matched with the soil conditions at the site, availability of imported material, re-use of native materials, and urban or rural settings.

For the contractor, the five types reflect a significant difference in the construction operations. The differences reflect significant variations in mobilization, equipment, labor, and embedment material.

### **INTRODUCTION**

For pipeline installation in trenches, there are five basic types of pipeline trenches. The five types are based on the construction of the embedment. The five types apply to both rigid and flexible pipe. However, the types do not relate to a specific type of pipe. ASTM standards, AWWA standards and manuals, and ASCE manuals unnecessarily show specific installation requirements based on a particular type of pipe. The installation should be specified based on soil conditions and design issues not related to the type of pipe. Uniform installation requirements can be used covering many types of pipe and thus reduce confusion for the contractor and inspection personnel.

For the pipeline designer, one of the five types of trench construction can be matched with the soil conditions at the site, availability of imported material, re-use of native materials, and urban or rural settings.

For the contractor, the five types reflect a significant difference in the construction operations. The differences reflect significant variations in mobilization, equipment, labor, and embedment material.

## FIVE TYPES OF PIPELINE TRENCHES

As shown in Figure 1, there are five basic types of pipeline trenches based on the **embedment** construction. The five types reflect a significant difference in the contractors operations. The differences reflect significant variations in mobilization, equipment, labor, and embedment material. The five types apply to both rigid and flexible pipe. The left side of each diagram represents the trench as typically used for flexible pipe and the right side represents rigid pipe.

There can be deviations in each of the types that slightly affect these factors that reflect minor differences in local practices, manufacturer's recommendations, and standards.

**Type 1** is the standard trench will the embedment soil compacted in layers to a specified density. Haunch support is poor and this method requires the most labor and time.

**Type 2** is relatively unknown and uses cohesionless soils compacted in one thick layer using water and internal vibration. This method provides excellent haunch support and requires little labor and time. Normally this system requires initial test section.

**Type 3** involves dumping the embedment soil in beside the pipe. This method is the most common but provides the least support for the pipe. Dumping in the embedment takes little time and labor.

**Type 4** uses flowable fill as the embedment. Since this method is fast, and requires little labor, it is used in urban areas where time is important. However, the system is costly because cement is mixed into the soil. Considerable money can be saved using on-site mixing of local soils instead of using ready-mix material. See Tech Note "Flowable Fill Using Insitu Soils" under downloads at AmsterHoward.com. Using flowable fill also provides excellent haunch support.

Flowable Fill is used to describe a mixture of soil, cementitious material, and water that hardens into a product that is stiffer than the native soil. This material is also known as CLSM (controlled low strength material), CDF (controlled density fill), soil-cement slurry, flow fill, and others. However, the most common term used around the world is "flowable fill."

**Type 5** is a combination of Type 4 and any of the other types. The flowable fill is used only in the haunch area. Type 5 provides maximum haunch support with the economy of using less costly methods for the remainder of the support for the pipe.

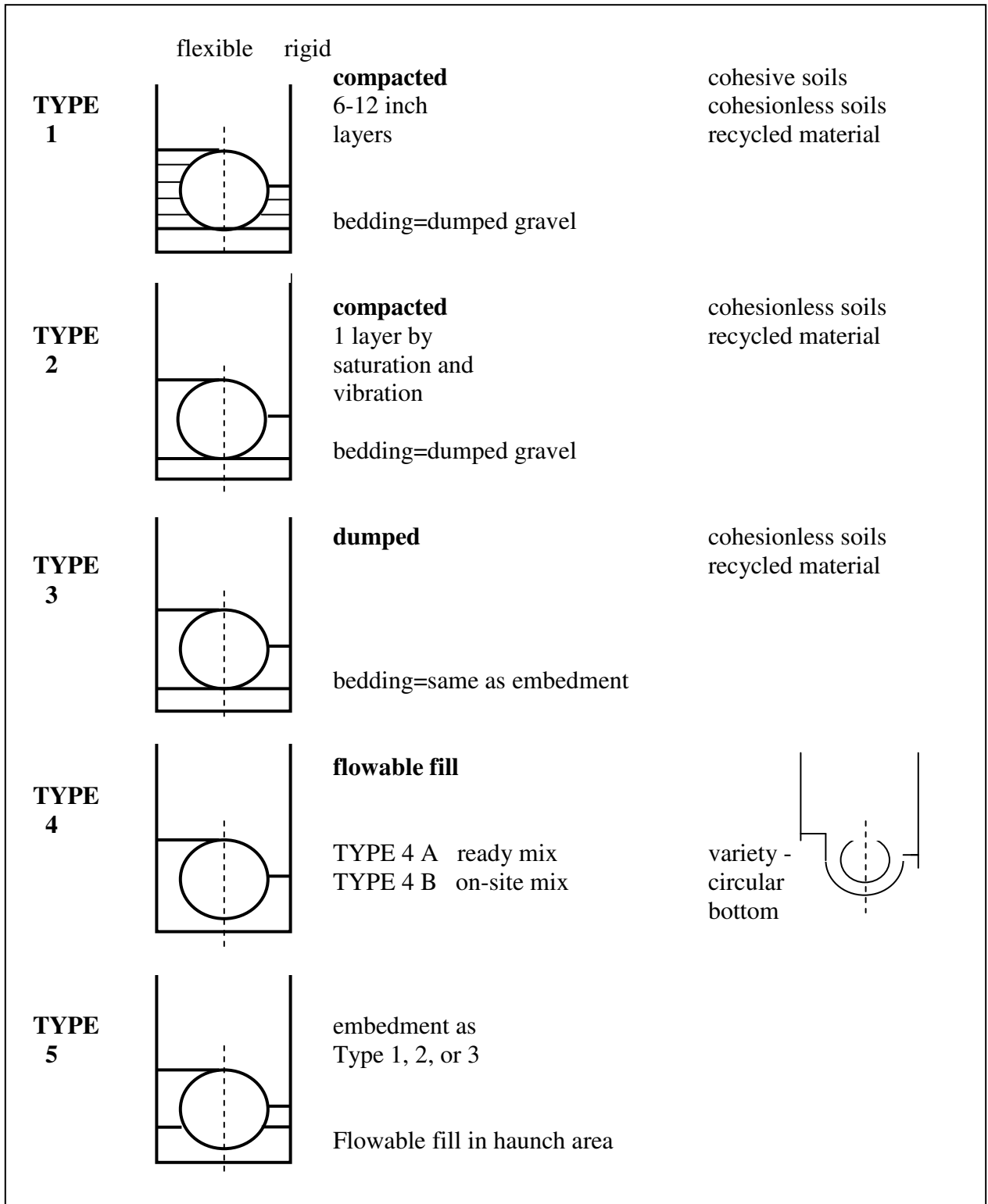


Figure 1 Five Types of Pipeline Trenches

## EMBEDMENT VARIATION

The height of the embedment relative to the pipe varies widely among standard groups and specifying agencies, as shown below in Figure 2.

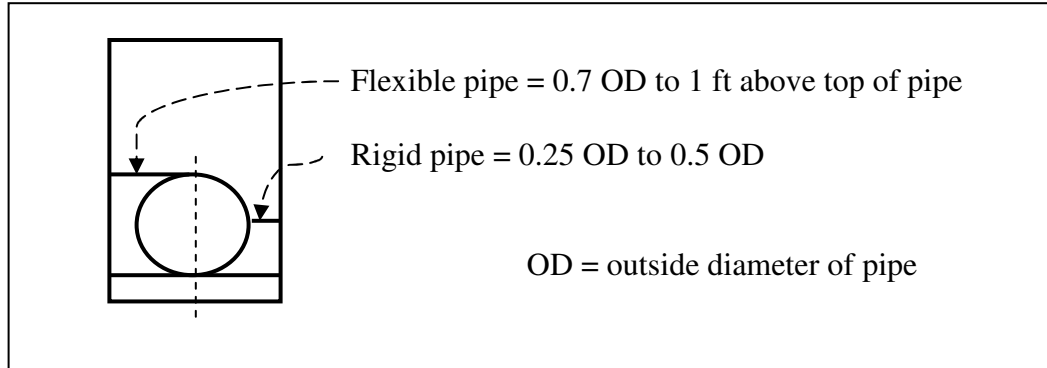


Figure 2 Typical Embedment Height

In this document, the generic version, as shown above, will be used to represent all the variations of the height of the embedment.

## BEDDING

Each of the trench types is shown with a bedding. In the past, many pipe were laid directly on the trench bottom. Differential settlement, expense of fine-grading the bottom, insufficient bell holes, and poor haunch support creating line-loads on the bottom lead to many organizations and agencies requiring a loose bedding of gravel, or other cohesionless material. Some organizations still require the bedding to be compacted, typically to the same percent compaction as the embedment. However, many standards and manuals now recommend uncompacted bedding in the middle third of the trench width. When the pipe is laid on uncompacted material, the weight of the pipe creates a bedding angle and thus distributes the load (Howard 1996). This loose area also contributes to the arching action of the backfill soil over the pipe. This layer of loose, cohesionless material is highly recommended. Typically, the thickness of the bedding layer ranges from 4 inches for pipe about 48 inches and smaller and 6 inches above 48 inches. For pipe larger than 48 inches in diameter, one criterion is the pipe diameter divided by 12. For example, a 84 inch diameter pipe would need a bedding thickness of 7 inches.

Typically, the bedding material has to be imported. However, for Trench Type 4 and 5, the flowable fill is often the bedding material and this is discussed later for those trench types.

If the bedding is a coarse, open graded gravel (100% 1 inch rock, for example), then a geofabric separator may be required between the bedding and the embedment material. Migration of finer graded embedment material into the voids of the bedding material may be a possibility.

### **APPLICATION**

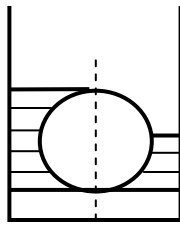
There are many types of pipe products now available on the market. For installation purposes, they can be put into two groups, rigid and flexible. Rigid pipe basically depend on the strength of the pipe to carry the load on the pipe, and flexible pipe basically depend on the strength of the embedment soil to carry the load on the pipe.

The five trench types do not relate to a specific type of pipe, such as PVC, concrete, etc. ASTM standards, AWWA standards and manuals, and ASCE manuals unnecessarily show specific installation requirements based on a particular type of pipe. The installation should be specified based on native soil conditions and design issues. The trench type need not related to the type of pipe. Uniform installation requirements can be used covering many types of pipe and thus reduces confusion for the contractor and inspection personnel. For a project with five different types of pipe, it should not be necessary for the contractor and the inspector to carry around five different installation manuals.

The following pages give the specifics about each type of trench, how construction, the advantages of each type, and the disadvantages.

## TRENCH TYPE 1

flexible rigid

**compacted**6-12 inch  
layers

bedding=dumped gravel

cohesive soils  
cohesionless soils  
recycled material

**Trench Type 1** is the typical pipeline installation for a trench. The pipe is laid on a bedding of dumped gravel or other cohesionless soil. The soil is compacted in 6 to 12 inch lifts, depending on the soil and the desired percent compaction.

### advantages:

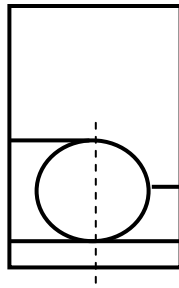
- can use soil from trench, if suitable
- expansive soils from excavation can be lime-treated and re-used
- can use imported materials:
  - select material*
  - crushed rock*
  - slag, shells*
  - recycled concrete*
  - quarry waste*

### disadvantages:

- results in poor haunch support
- labor intensive
- time consuming
- each layer should be tested for percent compaction
- excavated soil may have to be processed or scalped for oversize particles
- materials shown in italics under advantages may have to be tested to establish stiffness
- If soil is cohesive (silt/clay), lift thickness should be 4 or 6 inches, depending on required percent compaction.
- If bedding is clean, cohesionless sand/gravel, lift thickness should be 4 to 6 thickness if impact compacted, 12 inches if surface vibrated.
- if bedding is clean, cohesionless gravel, then geofabric separator may be necessary between finer-graded embedment material and the coarser bedding to prevent migration
- If embedment material is clean, cohesionless gravel, the embedment material may need to be wrapped in geofabric to prevent migration of finer-graded trench wall and backfill soil into the embedment material

The advantages/disadvantages of the following trench types (2, 3, 4, 5) are based on comparison to Trench Type 1.

## TRENCH TYPE 2



### **compacted**

1 layer by  
saturation and  
vibration

bedding=dumped gravel

cohesionless soils  
recycled material

Trench type 2 is relatively unknown but is specified by some agencies in the western US, such as the Bureau of Reclamation. It is commonly used in California and the use dates back to the 1940s. Water is added to the soil and internal vibrators inserted and slowly withdrawn. The internal vibrators are usually concrete vibrators, also known as wiggletails or stingers. The method has successfully been used to densify 8 ft lifts. The method also results in dense soil in the haunch area of the pipe. It is only a valid method when the soil has less than 15% fines (minus No 200 sieve material).

The method is material and equipment dependent. Typically, a test section is prepared ahead of construction to experiment. The resulting density depends on the type and number of vibrators, spacing of insertion, speed of withdrawal, and amount of water to aid compaction. Enough water must be added to lubricate the particles but not float the pipe (Howard 1996).

The degree of compaction can be based on percent Relative Density (ASTM D 4254 and D 4253) or percent compaction using the maximum density from D 4253 or D 7382. ASTM D 7382 is a new procedure that uses a hammer drill type of vibrating plate to densify the soil. The advantage of the procedure is less equipment cost and it does not need the extensive calibration that D 4253 requires.

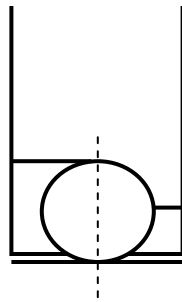
### **advantages:**

- only one layer
- faster
- less testing
- haunch soil gets compacted
- can use native soils if cohesionless

### **disadvantages:**

- limited to cohesionless soils with less than 15% fines
- initial test section necessary to determine amount of water, vibrator spacing, rate of withdrawal, etc.
- change in material may require new test section
- relatively unknown procedure, hence skeptical contractors
- gravels or crushed rock require special testing to get maximum density
- too much water can float the pipe

### TRENCH TYPE 3



**dumped**

cohesionless gravel-size soils (no sand)

recycled material  
(concrete, slag)

bedding=same as embedment

This method is only recommended for cohesionless and free-flowing soils. Excavated cohesive soils may be in large clumps and when placed in the trench will have significant voids that can lead to large settlements.

Dumped embedment using gravel, crushed rock, recycled concrete, etc. can provide adequate stiffness to support rigid and flexible pipe for installations with less than 10 feet of backfill over the top of the pipe.

If there is some question about the required support, the stiffness or modulus of the material may need to be determined from laboratory tests or control strips. Control Strips are constructed using the specific soil and compaction equipment that will be used for the installation. The soil is compacted to a specific degree and density, stiffness, or modulus, etc. can be measured to be used in quality control testing.

Dumping sand is not recommended because the typical moisture of a stockpile is about the bulking moisture of sand, about 4 to 8 percent. At these moisture contents, each particle of sand gets a coating of water due to surface tension which keeps the particles apart (bulking). The resulting density is much lower than the minimum density determined on dry soil in laboratory tests. Depending on the sand gradation and placement moisture, dumped sand can decrease in volume 20 to 40 percent when saturated.

**advantages:**

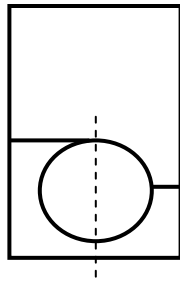
- no compaction
- faster
- less workers
- no testing

**disadvantages:**

- poor haunch support
- low stiffness embedment
- for slag, shells, recycled materials, etc. may need modulus tests
- sands dumped in at bulking moisture may settle considerably
- careless dumping can shove pipe out of alignment and open joints

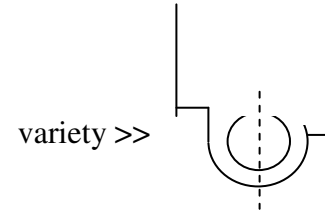


## TRENCH TYPE 4



### flowable fill

TYPE 4 A ready mix  
TYPE 4 B on-site mix



Flowable fill is a mixture of soil, cementitious material, and water that hardens into a product that is stiffer than the native soil. The typical strength is 40 to 80 psi. Low strengths are recommended so future additions, replacement, repairs, etc. can be easily excavated

There is considerable flexibility in the ingredients of the flowable fill. Various waste products can be used for the cementitious material, such as non-standard Portland cement, flue dust, cement kiln dust, Class C flyash, etc. The aggregate can be by-products or recycled materials, such as quarry waste, screening plant waste, foundry sand, recycled concrete, recycled glass, etc.

The pipe is typically placed on sand bags or soil pads so the fluid mixture flows beneath the pipe. The bags or pads also provide very easy ways to adjust grade.

ASTM standards are available for sampling, compressive strength, flowability, and set time.

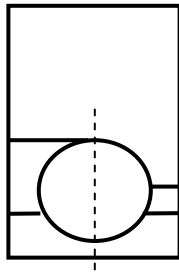
Typically, flowable is obtained from ready-mix concrete plants. However, contractors have used other methods to considerably reduce the cost. On-site batch plants have been used as well as special equipment that travels down the side of the trench and uses the spoil pile as the aggregate. Special shredders and mixers have successfully been used to make flowable fill from clayey soils.

### advantages:

- good haunch support
- no compaction
- faster
- less testing
- less inspection required
- can use waste products for cementitious materials and aggregate
- can use native soils from trench, if suitable
- no special bedding material needed
- easy to maintain line and grade
- increased worker safety, less time in trench

### disadvantages:

- ready mix flowable fill may be expensive
- Agencies and owners may be resistance to non-traditional mixes
- pipe floatation

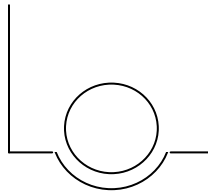
**TRENCH TYPE 5**

embedment same as  
Type 1, 2, or 3

Flowable fill in haunch area

This trench type has the advantage of using flowable fill for the haunch area of the pipe to provide good haunch support and the less expensive method of placing soil above the haunch area. This is useful when the embedment is to be compacted and a large diameter pipe (> 10 ft) prevents compacting soil in layers in the haunch area.

A common variety of this trench type is to excavate only a cradle beneath the pipe for the flowable fill, as shown below. This reduces the amount of excavated material and the amount of flowable fill to place in the space beneath the pipe.

**advantages:**

- same as type 4
- less expensive than type 4
- provide good haunch support for large diameter pipe

**disadvantages:**

- same as type 4

## SUMMARY

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## REFERENCES

Howard, Amster (2011), "The Five Types of Pipeline Trenches," Proceedings of the 2011 International Conference on Pipelines and Trenchless Technology, Beijing China

Howard, Amster (1996) **Pipeline Installation**, Relativity Publishing , Lakewood CO USA