Flowable Fill - Pipeline Construction

Although flowable fills are not generally required for concrete pipe installations, there may be situations where it is desirable. This method is commonly used in tight spaces where compacting soil is difficult to achieve. Using flowable fill instead of traditional compacted soil is basically a Type 1 Standard Installation and ensures adequate support for the pipe. Flowable fill is referenced by many names including:

- soil-cement slurry
- controlled low strength material (CLSM)
- soil-cement grout
- unshrinkable fill
- flowable mortar
- controlled density fill (CDF)
- plastic soil-cement
- K-Krete

ASTM Standard D4832, "Standard Test Method for Preparation and Testing of Controlled Low Strength Material (CLSM) Test Cylinders," defines flowable fill as:

> Controlled Low Strength Material (CLSM) – A mixture of soil, cementitious materials, water, and sometimes admixtures, that hardens into a material with a higher strength than the soil but less than 8400 kPa (1200 psi). Used as a replacement for compacted backfill, CLSM can be placed as a slurry, a mortar, or a compacted material and typically has strengths of 350 to 700 kPa (50 to 100 psi) for most applications. [1]

Figure 1. Flowable Fill Mix

Figure 2. Cured Flowable Fill

The Use of Flowable Fill

The decision to use flowable fill not only depends on the surrounding soil characteristics but also the pipe characteristics. Rigid pipe by design provides the majority of the strength of the soil-pipe structure, and thus it is often more economical to use the existing in-situ soil rather than flowable fill. With flexible pipe, by definition the embedment material is the major contributor to the soil/pipe structure. Thus, the use of flowable fill with flexible pipe may result in a higher quality finished structure and may require less labor when compared to traditional compacted granular backfill.

Although flowable fill is often thought of as the solution to poor in-situ soil conditions, wider trenches may be required if soils that cannot brace the flowable fill. When determining the appropriateness of flowable fill for a pipe installation, the strength characteristics of the native soil should first be determined. As stated in **ASTM D4832**, "*The CLSM transfers the load from the pipe to the in-situ material, so the native soil must be able to provide the necessary support for the pipe.*"

Flowable fill can be used in one of two ways:

1. Embedment: When employed as an embedment material, flowable fill works either as a gap filler or a trench filler.
   - Gap Filler- It is used as a thick load transfer material between the surrounding soil and the pipe. In this way the flowable fill is able to eliminate the voids, but does not contribute any side support to the pipe. If the native soil is weak, it would not be appropriate to use this method.
   - Trench Filler- Flowable fill completely replaces the volume of the embedment and bedding soil, filling in the haunch area and providing the primary side support for the installed pipe. As mentioned previously, when the soil is weak along the trench walls the trench width may need to be increased. This is especially true with flexible pipelines because the flowable fill is providing the pipeline structure.

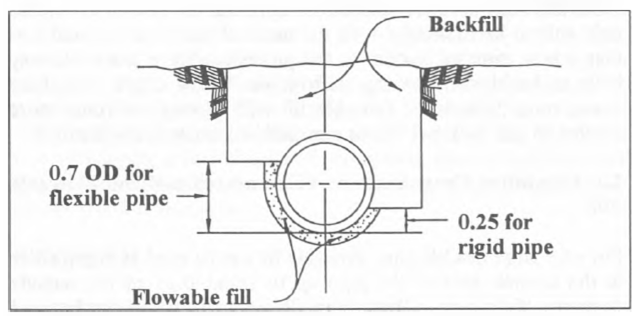

Figure 3. Flowable Fill as Gap Filler

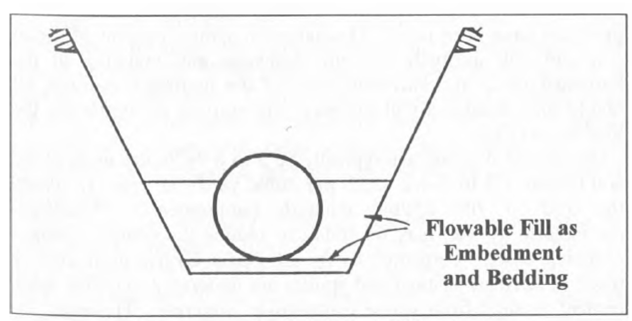

Figure 4. Flowable Fill as Trench Filler

2. Backfill: Flowable fill replaces the entire trench up to the subgrade. When used as a backfill material, flowable fill can be advantageous. For example, excavation and paving can be completed in one day, provided high early-strength cement is used.

Figure 5. Flowable Fill Installation

Primary Advantages

There are many advantages to using flowable fill rather than compacted soil.

1. Costs associated with the moving of excavated soil are reduced.
2. The time, manpower, and equipment needed to vibrate if the flowable fill are much less than that needed to assure sufficient compaction of soil.
3. Testing associated with determining the strength of the flowable fill is more efficient than the testing associated with determining the strength of the compacted soil.
4. Because the placement of flowable fill generally results in accurate installation on the first try, the problems and subsequent costs associated with re-compacting and re-testing the surrounding soil are eliminated when dealing with flexible pipe products.
5. It can be made with local soil, which can contain up to 20-25% non-plastic or slightly plastic fines. The presence of these fines suspends the sand in the mixture, enabling easier flow and prohibiting segregation of the fill.
6. For installations such as flexible pipe that require considerable soil support, embedment soils often have to be imported to the site, increasing the cost and making flowable fill a more economical method.

Design Considerations

As with all methods there are also disadvantages to using flowable fill as an embedment material.

Figure 6. Flowable Fill

1. Unless additional steps are taken, the potential for pipe flotation is high during the installation process according to TN 5.02[3]
2. One disadvantage is that testing the strength of the flowable fill is usually done seven days after the mix is used. Since installation is likely to already have been completed, any problems revealed during testing could be difficult to correct since the pipe has normally already been overfilled by this time. This can impact flexible pipe products as they depend on the strength of the pipe zone material to primarily carry the external loads.
3. Although flowable fill is easier to place, it usually takes about two to four hours before an initial set is achieved. Hence overfilling cannot be completed until the initial set is accomplished. If the overfill is not placed on the flowable fill for eight hours or more, a 6 in. cover of moist earth should cover the slurry until the overfill is applied.

4. Flowable fill is not waterproof. In most applications, it will wick water. Therefore, designers and owners should not count on flowable fill to seal leaking joints.
5. During construction, flowable fill should be installed with equal volumes of material on both sides of the pipe similar to a compacted soil backfill procedure to prevent movement or extra stresses to the pipe.

Figure 7. Large Steel Tie-Downs for HDPE Pipe

Mix Proportions

Just like concrete, a flowable fill mix design depends on the characteristics of the mix materials, the required strength, and the flowability. The common desired strength for flowable fill is between 350-700kN/m2 (50-100psi) at 7 days. Once the mix specifications are established, any method of batching and mixing can be used so long as the consistency is acceptable before the mix is placed. The best soil to use for flowable fill is silty sand with a maximum of 30% fines. Cement content will be around 3-6% by dry mass of the soil (usually between 1-1 ½ bags of cement per cubic yard). When a reduction in cement content is desired, admixtures can be added; this also improves the flow characteristics of the mixture. Fly ash can reduce the amount of cement used in the mix as well, however due to its strength variability, tests must be more thorough and frequent. If the mix is to be pumped to its location, bentonite can be added to improve the flow characteristics through the delivery hose. Common mix proportions are listed below.

	Cement	Fly Ash	Soil	Water
• Clean concrete sand, no fly ash	100	0	3000	600 (1 sack mix)
• Clean Concrete sand, fly ash	50	300	2700	600 (1/2 sack mix)
• Silty sand, no fly ash	50	0	3000	600 (1/2 sack mix)

Temperature Conditions

In cold climates it is especially important, when designing the soil-pipe system, to consider temperature effects. The ambient air temperature should remain above 40°F (4°C) when placing flowable fill However, if the temperature is 35°F (2°C) and rising, the flowable fill can still be placed safely. The temperature of the mix itself must be a minimum of 50°F (10°C) at the time of placing. Flowable fills must be kept from freezing in order for them to acceptably fill in all the gaps and support the pipe.

Covering the flowable fill with an insulation blanket before the initial set and with a layer of moist soil after the initial set can prevent such freezing. When temperatures are below 50°F (10°C) the moist soil layer should be 18 in. thick. Additionally, the flowable fill should not be placed in trenches where the trench bottom or walls are frozen or contain frozen material.

Pipe Flotation

Flotation of the pipe is a serious concern during installation. Pipes with light weight properties such as Polypropylene require more care than ever before. When placing the fill, the pipe weight and fill depth both contribute in determining whether or not the pipe will float. The potential for pipe flotation shall be calculated using the density of the flowable fill (approximately 130lbs/ft^3). If the potential for flotation is significant, various approaches can be taken. The flowable fill could be placed in lifts stopping short of the height at which flotation risk was calculated. Slurry placement would be suspended and the first lift allowed to cure. Once an initial set is reached the remaining flowable fill can be added without possibility of flotation. This is due to the adhesion between the pipe and the first layer of flowable fill. Another method would be to place weight such as sand bags, on top of the installed pipe. The pipe could be filled with water, which would add adequate weight to the pipe, prohibiting flotation. Finally, exterior inhibitors could be used; such as placing re-bars in an "X" shape over the pipe and tying them together where they cross, or placing horizontal bars on top of the pipe and wedging the bars against the side of the trench wall. It is recommended that a test section at the beginning of the job, be used to establish the mode by which flotation could be prevented.


Figure 8. Floating Pipe


Figure 9. Otay River 60in HDPE

Placing

One method of placing the flowable fill is to elevate the pipe on two sand bags creating gaps under the pipe. This allows fill to flow under the pipe until the fill is seen on both sides of the pipe. After filling in the gaps between the in-situ soil and the pipe, the fill can be vibrated as necessary (if the fill bleeds excessively or when the mix is stiffer, 8-10 in. slump, rodding is necessary). If impractical to lay the pipe on sand bags; the pipe may be laid directly on the trench bottom. Because, in this case, there is not enough space under the pipe for the flowable fill to flow, visual inspection must suffice in determining if all the gaps are filled.

Conclusion

The use of flowable fill can reduce construction concerns and costs associated with poor in-situ soils that would otherwise require expensive imported embedment materials, limited space, or lower strength pipe materials. The benefits in ease of construction do not come without due diligence in the design of the installation. When flowable fill is used it is not only important that the material is manufactured and placed appropriately, but that appropriate design issues related to the quality of the pipe and in-situ soil material are taken into account when establishing the soil-pipe structure.

References:

1. 2016. Standard Test Method for Preparation and Testing of Controlled Low Strength Material (CLSM) Test Cylinders. Annual Book of ASTM Standards 2003. Editors Dreyfuss, Robert H. et. al. Vol 04.08, pgs 939-943.
2. Howard, Amster. 2002. Soil-Cement Slurry (Flowable Fill). Pipeline Installation. Ed Howard, Jill S., Relativity Publishing. Lakewood CO. pgs 13-1 thru 13-15.
3. ADS Technical Note Flowable Fill Backfill for Thermoplastic Pipe TN 5.02