

An educational document from the American Concrete Pipe Association for users and specifiers

Although flowable fills are not generally required for concrete pipe installations, this paper has been prepared to address those conditions where flowable fill may be necessary. Flowable fill, also known as soil-cement slurry, controlled low strength material (CLSM), soil-cement grout, unshrinkable fill, flowable mortar, controlled density fill (CDF), plastic soil-cement, and K-Krete, is a compound that can be used as embedment or backfill material in lieu of compacted soil. It is made up of soil, cementitious material and water, and is generally used in pipeline construction. **ASTM Standard D 4832-02**, “*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

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 can often provide the majority of the strength of the soil-pipe structure, and thus it is often more economical to use the existing insitu soil rather than flowable fill. With flexible pipe, embedment material is a major contributor to the soil/pipe structure. Thus, the use of flowable fill with flexible pipe will likely result in a higher quality finished structure in a more time efficient manner instead of compacted soil as embedment and backfill material. Although flowable fill is often thought of as the solution to poor in situ soil conditions, it is important to remember that the soil envelope is a combination of the flowable fill and the soil in the trench wall, thus wider trenches may be required for poor 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 D 4832**, “*The CLSM transfers the load from the pipe to the insitu material*,

so the native soil must be able to provide the necessary support for the pipe.”



Figure 2. Flowable Fill Dry

Flowable fill can be used in one of two ways: as an embedment material or as a backfill material. When employed as an embedment material, flowable fill works either as a gap filler or a trench filler. When it is a 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, which form in the haunch area, while the soil remains as the primary side support for the pipe. Conversely, when flowable fill is used as a trench filler it completely replaces the volume of the embedment and bedding soil, effectively doing away with the need to compact the soil in this hard to reach haunch area. Additionally, the flowable fill acts as the primary side support for the installed pipe.

If the native soil is weak, it would not be appropriate to use the gap-filler method (which simply acts as a load transfer material between the pipe and the soil). The flowable fill is the main form of support for flexible pipe (if compacted soil is not used) so, when the soil is weak, more must be excavated and replaced with flowable fill. When used as an embedment material the flowable fill should rise to the same height that the compacted soil would rise.

Using flowable fill instead of traditional soil compaction, allows for faster installation and ensures adequate support for the pipe. Due to the speed with which flowable fill can stabilize an installed pipe, this method is generally used when pipes run under streets and highways. It is also used in tight spaces where compacting soil is difficult to achieve.



Figure 4. Flowable Fill

When used as a backfill material, flowable fill can be advantageous because, provided high early-strength cement is used, excavation and paving can be completed in one day.

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 (often even



Figure 3. Flowable Fill Installation

this is not necessary) 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 Issues

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

1. 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.
2. 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 6in cover of moist earth should cover the slurry until the overfill is applied.
3. Flowable fill is not waterproof. In most applications, it will leak and wick water. Therefore, designers and owners should not count on flowable fill to seal leaking joints.
4. 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 5. 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 for installation, and the necessary 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 to the flowable fill; this also improves the flow characteristics of the mixture. Fly ash can be used to 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 of the flowable fill through the delivery hose. Common mix proportions are listed below.

| | <u>Cement</u> | <u>Fly Ash</u> | <u>Soil</u> | <u>Water</u> |
|-----------------------------------|---------------|----------------|-------------|--------------------|
| • 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 flowable fill 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 18in 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 another concern related with the use of flowable fill. When placing the fill, the height to which the flow reaches and the weight of the pipe all contribute in determining whether or not the pipe will float. The potential for pipe flotation can be calculated using the density of the flowable fill (approximately 130lbs/ft³). If the potential for floating is significant, various approaches can be taken to prevent its occurrence. The flowable fill could be placed in lifts that would control the amount of slurry placed in the trench. When the slurry reaches the height at which flotation was calculated to occur, the slurry would be stopped and allowed to reach an initial set. At this time the remaining flowable fill could be added without possibility of flotation due to the adhesion between the pipe and the first layer of flowable fill. Another method would be to place sand bags, or another type of weight,



Figure 6. Otay River 60in HDPE

on top of the installed pipe. Also 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.

Placing

The method of placing the material is important because the strength and longevity of the pipe depend on the uniformity of the filler. Non-uniformity means that pressure points could form, reducing the lifetime of the pipe. One method of placing the flowable fill is to raise the pipe on two sand bags so that there are gaps under the pipe. Then allow the fill to flow under the pipe until the fill is seen on both sides of the pipe. After filling in the gaps between the insitu soil and the pipe, the fill can be vibrated as necessary (if the fill bleeds excessively or when the mix is stiffer, 8-10in slump, rodding is necessary). Many times it is impractical to lay the pipe on two sand bags; in this case the pipe can 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 the flowable fill is filling in all the gaps.

Conclusion

The use of flowable fill can reduce construction concerns and costs associated with poor insitu 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 insitu soil material are taken into account when establishing the soil-pipe structure.

References:

1. 2003. 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.