Proceedings of the 20th Plastic Pipes Conference, PPXX
September 6-8, 2021, Amsterdam, Netherlands

FLOWABLE FILL FOR PLASTIC PIPE

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SHORT SUMMARY (*One paragraph, ~6 sentences maximum*)

KEYWORDS (*Mandatory, please give ~3-5 keywords)*
flowable fill, pipe installation, sustainability, buried pipe, cement

ABSTRACT

Flowable fill is used for many applications, but mainly for pipe trench embedment and backfill. There are three ways that using flowable fill can be kind to the environment.

Because flowable fill is self-leveling and has a strength greater than the native soil, the trench cross section can be minimized. This means less excavation which means less energy used to excavate the trench, handle the spoil pile, and to backfill the trench. In urban areas, pipeline installation can proceed quicker which means reducing traffic delays, traffic detours, truck traffic, business interruptions, and the impact on the community.

Secondly, flowable fill can be made using many waste products or recycled materials. Flowable fill is basically a mixture of cementitious material, aggregate, and water. Admixtures can be used for special circumstances, but are not necessary. Typically, flowable fill is thought of as a mixture of Portland cement, concrete sand, and potable water. It is usually batched at a ready-mix plant and transported to the site in transit mixers. However, since low strength is a desirable property of flowable fill, materials not usually considered for concrete can be used. Class C flyash, cement kiln dust, and waste by-products of coal fired electricity plants have been used in place of Portland cement. Recycled concrete, Class F flyash, foundry sand, and aggregate plant by-products have been used as aggregate. Using these recycled products and waste materials in flowable fill keeps them out of the landfills.

The third way that flowable fill can be sustainable is to use the native soils excavated from the trench as the aggregate in the flowable fill mix. The flowable fill can be mixed using trench-side mixing equipment or portable batch plants that move along with the pipe installation. Using the soil excavated from the trench reduces spoil pile waste, spoil pile handling, importing aggregate materials, and transit mixer traffic from ready-mix plants

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Sustainability is achieved through less time for excavation, less handling of soil excavated from trench, less hauling of materials (both to and from construction sites), and reuse and recycling. This all means less energy consumption:

In many cases, these reuse and minimizing methods result in flowable fill that can be competitive with compacted earth fill.

INTRODUCTION

Innovative approaches to making flowable fill result in a sustainable product that can be competitive with compacted earth fill.

Flowable fill is a fluid mixture of cementitious material, aggregate, and water that hardens to a material that is stiffer than compacted soil. While the main use of flowable fill is pipe embedment and backfill, it has been used to fill abandoned pipe, mines, and other voids. In the urban environment, flowable fill is useful because filling trenches with the material is much faster than compacting soil into the opening. Some mixes can set up fast enough that pavement can be placed about an hour after backfilling.

Flowable fill is known by many names (CDF, CLSM, liquid soil in Europe), but the majority of state DOTs and most organizations around the world use “flowable fill.”

The main properties for flowable fill are strength, flowability, and set time. Flowable fill typically has low strength, 50 to 100 psi, so that it can be easily excavated in the future. Since strength is not critical, a variety of cementitious materials and aggregates can be used. The mixture must flow into all of the opening, so simply adding more water increases the flow characteristics. The water/cement ratio is not an important criterion for flowable fill. In some cases, the constituents and admixtures can be selected so that the material hardens in a relatively quick time.

For pipeline installation, using flowable fill can be more sustainable and environmental friendly through the proper selection of materials and methods. Specifically, flowable fill can be more “green” using the following methods:

REDUCE minimize trench cross section

RECYCLE use waste materials and by-products for the cementitious material and aggregate

REUSE use the native soil excavated for the trench

- Sustainability is achieved through all or some of the following factors:
  - Less energy consumption:
    - Less time for excavation
    - Less handling of soil excavated from trench
    - Less hauling of materials, both to and from construction site
    - Less inspection and construction control testing

In many cases, these reuse and minimizing methods mean flowable fill can be competitive with compacted earth fill.

The most comprehensive study of sustainable flowable fill to date is Trejo, Folliard, and Du (2004).

DISCUSSION

MINIMIZE TRENCH CROSS SECTION

Often flowable fill is used in place for compacted embedment so that the dimensions of the trench excavation remain the same. This is referred to as the "trench filler" method as shown in Figure 1. However, if the native soil can provide good support for the pipe, then flowable fill can be used to simply fill the gap between the pipe and the native soil. This is referred to as the "gap filler" method, as shown in Figure 2.

Figure 1 Trench Filler Flowable Fill

Figure 2 Gap Filler Flowable Fill

The gap filler method reduces the amount of excavation, which reduces the size of the spoil pile and the energy used to handle the excavated material. The reduced excavation means less time to excavate, which translates to less traffic disruption, detours, interruption to businesses, and dust abatement in urban areas.

Since a wider trench is necessary at the joint for welding, checking the gasket, etc., the gap filler method is not convenient for short sections of pipe unless an internal method of checking for joint leaks is used. So the gap filler method is most useful for large diameter pipe where the trench width would allow for workers to guide the pipe for joining and for personnel to enter the pipe for joint pressure testing. The gap filler method would probably be the most economical for large diameter pipe.
To use the gap filler method, the in-situ soil must have a stiffness that will support a rigid pipe or prevent excessive deflection of flexible pipe.

A backhoe bucket with a round shape on the bottom half is essential for minimizing the amount of excavation. The round bottom bucket, shown in Figure 3, should be the outside pipe diameter plus 6 or 12 inches. If there are several different pipe diameters being installed, it may not be practical to have many different sizes. Round bottom buckets are not commonly available.

Figure 3 Round Bottom Excavator Bucket

The pipe are typically supported on soil pads or sand bags. Concrete supports should not be used because they have the potential of being a point load on the bottom of the pipe. Soil pads have a lower stiffness than the hardened flowable fill. The added advantage of a soil pad is that the height is easily adjusted to maintain grade.

RECYCLED WASTE MATERIAL AND BY-PRODUCTS

Traditionally flowable fill is batched in a ready-mix plant and transported to the job site in transit mix trucks. For small quantities, this still may be the best source. However, for larger projects, there are more economical ways to provide flowable fill.

Since flowable does not need to be a strong material, the ingredients can be products that have been discarded or left over from other projects or procedures. The cementitious material, the aggregate, and the water need not be top quality matter. The varieties of possible materials fall into two categories:

1 Materials that have been successfully used in construction.
2 Materials investigated by graduate students but not yet tried in construction.

The first group includes:

Cementitious materials: Class C flyash
Aggregate: Class F flyash
Spent foundry sand
Quarry waste products
Non-standard sands and fine gravels
Recycled glass
Recycled concrete
Native soil excavated from trench (discussed separately later)

The second group includes:

Cementitious materials: cement kiln dust
Aggregate: crumb recycled rubber
recycled gypsum
bottom ash
ground granulated blast furnace slag
Water: non-potable water

The bibliography of all the Master and Doctorate theses trying unusual materials is too voluminous to include here but may be found on the website **AmsterHoward.com** under links titled “Flowable Fill References.”

Almost all of these waste materials and by-products will require preliminary trial batches to find the proper proportions. The properties that should be evaluated are:

compressive strength ASTM D 4832
Obtain 28 day strengths for specification requirements and 7 day and 90 day to evaluate the strength gain over time.

flowability ASTM D 6103
A 3-inch by 6-inch cylinder is filled with flowable fill and quickly raised. The mix has the right flow characteristics when the diameter of the patty formed is between 8 and 12 inches.

set time ASTM D 6024

A "Kelly ball" is raised and dropped onto surface of flowable fill. When the diameter of the impression is 3-inches or less, backfill or pavement can be placed. The procedure is not convenient because of the size of the apparatus.

USE OF NATIVE SOILS

There are several contractors who have been successfully using the native soils excavated from the trench to make flowable fill. In-situ soils that are a mixture of sand and silt are ideal for flowable fill. The soil is easily processed into soil clods that can be mixed with cementitious material and water. Clayey soils typically require more processing but have been used in pipeline construction (Finney et al 2008)

Two different equipment set-ups have been used. "Trench Side Mixing" will be used to refer to machines that travel beside the trench. They mix the soil, cement, and water and discharge the flowable fill directly into the trench. "Portable Batch Plants" have also been used (Randolph and Howard 2010). Portable batch plants are mobile and can be set up near the trench and moved along the alignment as the construction progresses. Soil from the trench is stockpiled next to the batch plant, screened if necessary, and batched on a weight basis similar to ready-mix concrete.

Processing

Use of native soil requires processing to make the soil the proper size and consistency. The mixing of the flowable fill is more effective if the clod size is about ½-inch or less and if the soil moisture is about the Plastic Limit (PL) or less.

For cohesionless sands and fine gravels, a preliminary screening to remove oversize particles is all that is required. Moisture content is not a concern. Many times this step is incorporated into the mixing operation.

Low plasticity soils (Plasticity Index [PI] below 20) can also be screened as part of the mixing operation if they are not too wet. Such soils can be spread out and let to dry for a day or more to obtain a workable moisture.

For medium to highly plastic cohesive soils, usually shredding is necessary to make the appropriate clod size. While some soil shredders can manipulate wet, sticky clays, the resulting material is usually too wet to mix. For soils that are too wet, the excavated material can be spread out and left to dry for a day or two. Since the excavators are usually a day or so ahead of the mixing and placing equipment, this does not significantly affect the overall installation time.

Shredding

The critical part of re-using in-situ clays is the shredding of the soil into 1/2 to 1 inch clods. There are commercially available shredders that can handle most materials. Fat clays in the plastic state (above the Plastic Limit) have been used in California to make flowable fill. The typical operation is to excavate the soil with a round bottom bucket and put into a spoil pile. About a day later, a backhoe with a commercial shredder picks up the material, shreds and dumps into the flowable fill processor. The processor mixes the soil clods with cement and water in a pug mill and then places it immediately into the trench. When the material is too wet to shred, more drying may be required. This process is now specified by some California utilities.

A typical flowable fill operation using in-situ clay soil can be seen in Figure 4. The soil from the hopper is fed into a pugmill from a conveyor belt. Cement is added to the soil on the belt with a vane feeder. Water is introduced at the beginning of the pug mill. This rig can successfully mix Fat Clay (CH) soils because of the pug mill mixing operation (Finney et al 2008).

A photo of a chunk of flowable fill made with this equipment, using insitu clay soil and Portland cement, is shown in Figure 5.

Figure 4 Insitu Soil Mixing Equipment

Figure 5 Chunk of flowable fill made using insitu clay soil

Other contractors have also developed mixing and placing equipment as shown in Figure 6.

Figure 6 Flowable Fill Placement Operation

Other descriptions, links, and references of contractors and equipment can be found in the technical note "Flowable Fill Using In-Situ Soils" under the DOWNLOADS page at AmsterHoward.com. More discussion can be found in Howard (2015)

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CONCLUSIONS
Flowable fill is used for many applications but mainly for pipe trench embedment and backfill. There are three ways that using flowable fill can be kind to the environment:

REDUCE: Because flowable fill is self-leveling and has a strength stronger than the native soil, the trench cross section can be minimized. This means less excavation which means less energy to excavate the trench, handle the spoil pile, and to backfill the trench. In urban areas, pipeline installation can proceed quicker which means reducing traffic delays, traffic detours, truck traffic, business interruptions, and the impact on the community.

RECYCLE: Flowable fill can be made using many waste products or recycled materials. Flowable fill is basically a mixture of cementitious material, aggregate, and water. Admixtures can be used for special circumstances but are not necessary. Typically, flowable fill is thought of as a mixture of Portland cement, concrete sand, and potable water. It is usually batched at a ready-mix plant and transported to the site in transit mixers. However, since low strength is a desirable property of flowable fill, materials not usually considered for concrete can be used. Class C flyash, cement kiln dust, and waste by-products of coal fired electricity plants have been used in place of Portland cement. Recycled concrete, Class F flyash, foundry sand, and aggregate plant by-products have been used as aggregate. Using these recycled products and waste materials in flowable fill keeps them out of the landfills.

REUSE: Flowable fill can use the native soils excavated from the trench as the aggregate in the flowable fill mix. The flowable fill can be mixed using trench-side mixing equipment or portable batch plants that move along with the pipe installation. Using the soil excavated from the trench reduces spoil pile waste, spoil pile handling, importing aggregate materials, and transit mixer traffic from ready-mix plants.

Sustainability is achieved through less time and energy consumption for excavation, handling of soil excavated from trench, hauling of materials (both to and from construction sites), compaction, reworking compaction due to density test failures, hauling water for compaction, transportation to landfills, personnel for inspection of the construction, for testing, detours and traffic delays. Sustainability also results from recycling waste materials and by-products. This also means less materials in landfills.

In many cases, sustainable methods result in flowable fill that can be competitive with compacted earth fill.

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