Test Standards For Flowable Fill

Although agencies and owners are increasingly using flowable fill, they are often not aware of the existence of applicable construction control test standards. Flowable fill is a mixture of soil, cementitious matter and water that hardens into a material stiffer than compacted soil. Typically placed as a self-leveling slurry, flowable fill may be an economical alternative to compacted soil.

Flowable fill (also known as CLSM or CDF) may be used as bedding, embedment and backfill for pipeline installation. As long as strength and flowability requirements are met, the ingredients and mixing of flowable fill may vary widely. Pipeline projects have been using concrete test standards not realizing that ASTM has standards specifically for flowable fill. Because flowable fill has properties unique to its use, there are separate ASTM standards for strength, flowability, set time, yield and unit weight, and sampling.

Flowable fill for pipe installation is gaining popularity because of the reduced amount of inspection and testing, and the elimination of reworking and restressing compacted soil. A consistent mix and placement are much easier to maintain with flowable fill than with compacted soil. Soil requires re-compactation when the field density tests performed on the soil result in unacceptably low densities.

Typical construction can result in 10 to 25 percent of the soil having to be re-compactated, especially at the beginning of construction when some experimentation with the compaction procedures is necessary to obtain the required density. Instead of density tests, construction control of flowable fill placement typically involves testing for compressive strength, flowability and set time.

The ASTM standards applicable for flowable fill are:
- ASTM D 4932, Standard Test Method for Preparation and Testing of Controlled Low Strength Material (CLSM) Test Cylinders
- ASTM D 5791, Standard Practice for Sampling Freshly Mixed Controlled Low Strength Material (CLSM)
- ASTM D 6023, Standard Test Method for Unit Weight, Yield, Cement Content, and Air Content (Gravimetric) of Controlled Low Strength Material (CLSM)
- ASTM D 6024, Standard Test Method for Ball Drop on Controlled Low Strength Material (CLSM) to Determine the Suitability of Load Application
- ASTM D 6103, Standard Test Method for Flow Consistency of Controlled Low Strength Material (CLSM)

Sampling

The ASTM standard specifically for sampling of flowable fill material is ASTM D 5791. The standard is similar to ASTM C 172 for concrete.

Currently, ASTM D 5791 states that it applies only to central mixed flowable fill transported to the job site. For volumetric mixers and trench side mixers, the project specification should state requirements for sampling, or use wording such as “obtain samples using procedures similar to principles in ASTM D 5791.”

Compressive strength

Compressive strength testing involves determining the seven-day and/or 28-day compressive strength of the hardened mixture. The compressive strength tests are performed to check the adequacy and uniformity of the mixes. A minimum of two 6- by 12-inch compressive strength cylinders should be prepared to represent each sampled batch. In the initial stages of a job, three test cylinders are recommended in order to obtain representative data. Multiple 6 by 12 cylinders are recommended because the strength can easily vary ± 50 percent due to the low strength, inherent variability of the material, handling and testing machine sensitively.

The preparation and testing of the flowable fill cylinders should be in accordance with ASTM D 4832. The test procedure is similar to ASTM C 39 for concrete, except that flowable fill cylinders are more fragile, and require more care in handling and testing.

A minimum compressive strength value of 40 pounds/inch² is suggested (Howard 2015) so that the flowable fill would be stronger than the existing soil, and have enough strength to be tested. The compressive strength need not be higher than 80 psi because more strength is not necessary. The flowable fill should be able to be removed using an excavator, not jackhammers. Sometimes there is a need to remove the hardened flowable fill in case of repairs, crossing lines, etc.

Flow test

Using a standard slump cone for flowable fill is not practical because the material can spread up to three feet due to its fluidity. The consistency (flowability) of the flowable fill mixture can be measured using ASTM D 6103. This procedure was developed specifically to quantify the flow characteristics of flowable fill. Those who work with concrete are trained to keep the water content as low as possible. As a result, it is sometimes difficult to get construction workers, transit mix operators, or construction inspectors to add enough water to flowable fill so that the mix is fluid enough to fill all void spaces between the pipe and the trench walls. The test involves filling a 3-inch-by-6-inch open cylinder with the slurry, lifting the cylinder, and measuring the diameter of the patty that results. Two diameter measurements, at 90 degrees apart, are averaged, and the average should be between 8 and 12 inches for the mix to have the proper consistency.

For flowable fill mixtures placed on a slope, or when a stiffer mix is required, the slump cone test (ASTM C 143) becomes a more useful indicator of consistency. A trial may be necessary at the beginning of the placement to establish the appropriate slump. A balance should be found between stiffness and filling all the space around the pipe.

Set time

Backfilling over flowable fill is usually the day after the flowable fill is placed. However, backfill and/or pavement over the flowable fill sometimes needs to be placed as quickly as possible.
ble. The ASTM test procedure uses a Kelly Ball to measure when the flowable fill has set up enough to place backfill over it. As described in ASTM D 6024, the test involves dropping a steel ball five times on the surface of the hardened material and measuring the diameter of the impression. If the diameter is 3 inches or less, the material is able to have backfill or pavement placed over it.

The test apparatus is the same equipment as that used in ASTM C 360 for concrete, but the procedure is slightly different. In C 360, the ball is suspended at the surface of fresh concrete, released, and the depth of penetration measured. The average depth penetration of three determinations is correlated with the standard slump test.

Some agencies have required the use of a Proctor penetrometer, ASTM D 1558, to judge set time. The 1-inch tip for the Proctor penetrometer should be used, particularly for native flowable fill containing soil clods. The penetrometer is much more convenient to use than a Kelly ball. The suggested procedure is to perform companion tests of the Kelly ball and the Proctor penetrometer early in the project and establish a correlation so that only the penetrometer need be used. This correlation should be repeated if there are significant changes in the mixture. Alternatively, the pocket penetrometer used for soils has also been used.

**Unit weight, yield, air content**

ASTM D 6023 has been developed to measure the unit weight of the fresh material. The procedure also gives formulas for calculating the yield, cement content, and the air content of the soil-cement slurry. The procedure is similar to ASTM C 138 for concrete. A container of known volume (capacity depends on the maximum particle size present in the mixture) is filled with the slurry, the top struck off level, and the container weighed.

For stiffer mixes of flowable fill, ASTM C 138 may be more appropriate to use, since it prescribes rodding or vibrating the mixture to remove air pockets that do not exist when the material is in slurry form.

**REFERENCES**

Howard, Amster (2015) Pipeline Installation 2.0, Relativity Publishing
ASTM C 39, Test Method for Compressive Strength of Cylindrical Concrete Specimens
ASTM C 138, Standard Test Method for Unit Weight, Yield, and Air Content (Gravimetric) of Concrete
ASTM C 143, Standard Test Method for Slump of Hydraulic-Cement Concrete
ASTM C 172, Standard Method of Sampling Freshly Mixed Concrete
ASTM C 960, Standard Test Method for Ball Penetration in Fresh Portland Cement Concrete
ASTM D 1558, Standard Test Method for Moisture Content Penetration Resistance Relationships of Fine-Grained Soils

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