

Concrete in Practice

What, why & how?



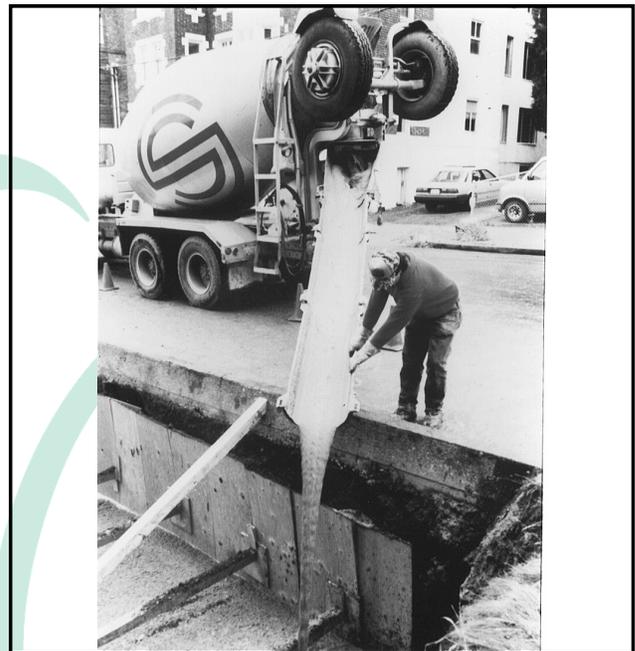
CIP 17 - Flowable Fill

WHAT is Flowable Fill

Flowable fill is a self-consolidating and self-leveling low strength cementitious material with a flowable consistency that is used as an economical fill as an alternative to compacted granular fill. Flowable fill is not concrete nor is it used to replace concrete. For design purposes its characteristics should be evaluated like soil or other fill materials. Terminology used by ACI Committee 229 is *Controlled Low Strength Material (CLSM)*. Other terms used are unshrinkable fill, controlled density fill, soil-cement slurry, flowable mortar, or lean-mix backfill.

The flowability is such that it can be placed with minimal effort, flow to fill the space, and not require consolidation after it is placed. It hardens to provide required bearing capacity or filling of voids with minimal subsidence or loss of volume.

Flowable fill is defined as a material with compressive strength less than 1200 psi (8.3 MPa). Most applications, however, use mixtures with strength less than 300 psi (2.1 MPa). The ability to excavate flowable fill will depend on the equipment used for the strength and type of mixture placed.



Mixtures can be developed for anti-corrosion, thermal resistance, electrical conductivity, and low permeability.

WHY is Flowable Fill Used

Flowable fill is an economical alternative to compacted granular fill affording savings in labor, equipment, and time. Because manual compaction is not needed, trench width or the size of excavation is significantly reduced and personnel do not need to enter an excavation. It provides a solution for filling inaccessible areas, such as underground tanks, where compacted fill cannot be placed.

Uses of Flowable Fill include:

1. **BACKFILL**—sewer trenches, utility trenches, bridge abutments, conduit encasement, pile excavations, retaining walls, and road cuts.
2. **STRUCTURAL FILL**—foundation sub-base, sub-footing, floor slab base, durable pavement bases, and conduit bedding.
3. **OTHER USES**—abandoned mines, underground storage tanks, wells, abandoned tunnel shafts and sewers, basements and underground structures, voids under pavement, erosion control, and thermal insulation with high air content flowable fill.

HOW is Flowable Fill Ordered

State the intended use and the expectation of future excavation of flowable fill when specifying or ordering the material. Flowable fill can use materials that do not comply with standards for use in concrete. Economical and recycled materials can be used. Site-excavated materials can be incorporated in flowable fill mixtures. Low-density flowable fill incorporates high air content with admixtures and pre-formed foam.

Strength—Strength will depend on bearing capacity required by design. In this regard, flowable fill is superior to compacted fill. The ultimate strength of the flowable fill should not exceed 200 psi (1.4 MPa) to be excavated with equipment like backhoes. Mixtures with coarse aggregate are more difficult to excavate. Low-density flowable fill limits strength gain and can be easily excavated. Flowable fill with a compressive strength of 50 to 100 psi (0.3 to 0.7 MPa) provides bearing capacity similar to well-compacted soil.

Hardening Time and Early Strength is important to support equipment, traffic, or construction loads and

to schedule subsequent construction. ASTM C403 or ASTM D6024 may be used to estimate hardening time. A requirement for higher early-age strength may make later excavation difficult due to continued gain in strength.

In-Place density of flowable fill is in the range of 115 to 145 lb/ft³ (1800 to 2300 kg/m³), typically higher than that of compacted fills. Low-density fill can be used for applications that need reduced dead load, thermal insulation, or to limit higher strength.

Flowability should be such that the mixture will flow into place without additional consolidation. Flowability can be varied to suit placement requirements of the application. Hydrostatic pressure and floatation of pipes should be addressed by placing in lifts and appropriate anchorage, respectively.

Subsidence of flowable fill mixtures with high water content is on the order of 1/4 in. per ft. (20 mm per m) of depth as the solid materials settle. Low-density flowable fill with less water has minimal subsidence.

Settlement—Flowable fill will generally not settle under load after hardening.

Permeability of flowable fill can be varied to suit the application. The permeability of flowable fill is similar to or lower than compacted fill.

Durability—Flowable fill materials should not be expected to resist cycles of freezing and thawing, abrasive or erosive actions, or aggressive chemicals; If flowable fill deteriorates in place it will continue to function like a granular fill. The pH of flowable fill can protect embedded metal from corroding, depending on the cementitious materials used.

HOW is Flowable Fill Delivered and Placed

Flowable fill is delivered by ready mixed concrete trucks and placed via the chute directly into the space or cavity to be filled. The mixer drum is kept in agitating mode to maintain a homogenous mixture prior to discharge. Flowable fill can be conveyed by pump, chutes, or buckets to its final location. Mixtures with granular material can be pumped more effectively. Due to its fluid consistency it can flow long distances from the point of placement.

Flowable fill does not need to be cured like concrete but should be protected from freezing until it has hardened.

References

1. ASTM Standards, ASTM Book of Standards, Volume 04.02 and 04.09, ASTM International, West Conshohocken, PA. www.astm.org
2. *Controlled Low-Strength Materials*, ACI 229R, American Concrete Institute, Farmington Hills, MI.
3. *Controlled Low Strength Materials*, ACI SP-150, ed. W.S. Adaska, American Concrete Institute, Farmington Hills, MI, www.concrete.org.
4. *The Design and Application of Controlled Low-Strength Materials (Flowable Fill)*, ASTM STP 1331, ed. A.K. Howard and J.L. Hitch, ASTM International, West Conshohocken, PA.
5. *Controlled Low-Strength Materials*, W.S. Adaska, Concrete International, April 1997, pp. 41-43, American Concrete Institute,

TESTING FLOWABLE FILL

Quality assurance testing is typically not necessary for flowable fill mixtures. Visual checks of mixture consistency and performance have proven adequate. Test methods and acceptance criteria for concrete are not applicable. When testing is needed, the following applies:

- Obtain samples of flowable fill in accordance with ASTM D5971.
- Flow consistency is measured in accordance with ASTM D6103. A spread diameter of at least 8 in. without visible segregation indicates good flowability. Mixtures without coarse aggregate can be tested using the flow cone method, ASTM C939. An efflux time of 10 to 26 sec is generally recommended.
- Density (unit weight), yield, and air content of flowable fill are measured by ASTM D6023.
- Preparing and testing cylinders for compressive strength tests is described in ASTM D4832. Use 3 x 6 in. (75 x 150 mm) plastic cylinder molds, fill to overflowing and then tap sides lightly. Other sizes and types of molds may be used provided the length-to-diameter ratio is at least 2. Cure cylinders in the molds (covered) until time of testing (or at least 14 days). Strip carefully using a knife to cut plastic mold off. Capping with sulfur mortar can damage these low strength specimens. Neoprene caps have been used but high strength gypsum plaster seem to work best.
- Penetration resistance tests such as ASTM C403 may be useful in judging the hardening time and strength development. Penetration resistance numbers of 500 to 1500 indicate adequate hardening. A penetration value of 4000, roughly equivalent to 100 psi (0.7 MPa) compressive strength measured on cylindrical specimens, is greater than the bearing capacity of most compacted soil. In-place hardening can be evaluated using the ball drop test, ASTM D6024. A diameter of indentation of less than 3 in. (75 mm) is considered adequate for most load applications. A mixture-specific relationship between compressive strength and penetration resistance can be developed for easier assessment of hardening.

CAUTIONS

1. Flowable fill while fluid will exert fluid pressure against forms, embankment, or walls used to contain the fill.
2. Placement of flowable fill around and under tanks, pipes, or large containers can cause these items to float or shift.
3. In-place fluid flowable fill should be covered or cordoned off for safety reasons.

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