

FLOWABLE FILL

INTRODUCTION

The purpose of this Technical Note is to highlight various technical requirements which are considered fundamental to the satisfactory use of flowable fill cementitious material. Flowable fill^{1,2,3} is a self levelling, self compacting and low strength cementitious material that has been available locally over the past 15 years from the major concrete suppliers under various tradenames. Flowable fill is characterised in its plastic state by its flowable consistency and may be used to replace conventional compacted granular fill in many backfilling applications without the need for conventional placement and compaction equipment.

The material is typically a mixture of cement, fly ash, fine aggregate and water and has a consistency similar to that of a thick slurry or grout. Slag and silica fume may also be used in the mixture. Chemical admixtures and additives may also be used from time to time to further enhance the performance properties of the flowable fill mixture. Variations to the proportioning of the typical mixture may also be provided thus underlying the versatility in design of the flowable fill material.

In contrast to concrete, flowable fill does not require curing. However, some protection may be necessary during very cold weather applications or wet conditions.

ADVANTAGES OF FLOWABLE FILL

The major technical and practical advantages of flowable fill are as follows:

- a) Easy to place by discharging directly from a concrete agitator truck (Fig. 1). Where access is a major problem a concrete pump may be used.
- b) Reduction in overall organisational requirements with regard to labour, equipment, materials, handling and placing compared to conventional backfilling.
- c) Reduction in completion time as the labour intensive spreading and compaction component is eliminated.
- d) Reduction in equipment requirements, as loaders, rollers, compactors and vibrators are not required for this self - levelling and self compacting product (Figs. 1 & 2).
- e) Improves worker safety by removing labour from direct placement area.
- f) Can be applied in tight or restricted areas where placement and compaction of conventional fill would be difficult or even impossible to undertake (Fig. 1).
- g) Shoring of trenches is not required during placement.
- h) Re-excavation where necessary can be done using conventional methods such as hand tools or backhoe. This is particularly so for the low compressive strength flowable fill mix grade since this is generally comparable in rippability to in- situ earth material.
- i) Durable and more resistant to erosion since it is often less permeable than the in situ material.

LIMITATIONS OF FLOWABLE FILL

Some limitations that should be considered are as follows:

- a) Lightweight pipes or other lightweight embedments may need to be anchored to avoid flotation.
- b) Due to its liquid state lateral pressures need to be taken into consideration.
- c) Due to its flowability, it needs to be confined to the area being filled until setting has taken place.
- d) The higher strength grades cannot be readily re-excavated. However for permanent fill, this does not matter.
- e) Cold or wet weather conditions may prolong the product's setting time.
- f) Utility lines such as gas, water, power and telephone may require a protective cover prior to pouring.
- g) Deeper applications may require pouring in stages depending on the lateral pressures exerted and the type of formwork. In such cases up to 12 hours or longer may be required between the successive stages of placement.
- h) Cost compared with alternative suitable backfill materials.
- i) Some early shrinkage may take place. However, from practical experience this has not been found to be excessive and does not affect the performance of flowable fill. No detectable settlement has been observed in the hardened state. However, some settlement may take place during the plastic state particularly where mixes are overly wet as the material self consolidates.

CHARACTERISTICS OF FLOWABLE FILL

Strength Grades

Flowable fill is generally available in three different strength grades corresponding to relevant strengths as follows:

- a) Compressive strength in the range of 0.5 to 2.0 MPa at 28 days which is generally compatible with the surrounding ground and makes it easy to excavate at a later date. Compressive strengths of between 0.3 MPa and 0.7 MPa may provide an equivalent bearing capacity to well compacted back fill materials.
- b) A maximum compressive strength of 3.0 MPa at 28 days which makes it stronger than the surrounding ground and where easy re-excavation is not a major criteria. Generally used where higher strength is a backfill requirement.
- c) For special situations where strength requirements range from 3.0 MPa to 8.0 MPa at 28 days. Such situations may be structural fill or pavement subbase (Fig. 3).

The flowability for all mix grades can be adjusted from low to high. It should be noted that for some special applications flowable fill with strength grades of up to 60 MPa may be manufactured by some concrete suppliers.

Re-excavation

Where subsequent re-excavation may be required the compressive strength of the flowable fill should be limited as follows:

- For manual re-excavation using hand tools such as shovels - compressive strength < 0.3 MPa. High amounts of air entrainment admixtures may have to be used to keep the strength very low.
- For re-excavation using mechanical equipment such as a backhoe – compressive strength < 1.5 MPa. However, it should be noted that some further in-situ strength development may take place over the longer term particularly for fly ash mixes and as such this should be taken into account prior to placement.

Density

The typical density of flowable fill mixes can range between 1600 kg/m³ and 2240 kg/m³. However, where lower densities are required special chemical admixtures may be used in the mix where loading conditions are very minimal. In such applications, trials should be carried out to verify the required characteristics.

Hardening Time

Under normal conditions hardening of flowable fill to be able to support the weight of a person is generally between 3 to 5 hours. However, where early loading is required (i.e. to carry traffic or construction equipment) or where

no future re-excavation is required flowable fill mixes may be designed such that hardening takes place within 1 hour. Standard penetration resistance tests may be undertaken to establish the in-situ hardening and strength development where required.

Permeability

The permeability of flowable fill varies depending on the cementitious content and flowability range of the mix grade for particular applications. In general however, the permeability of the lower strength re-excavateable mixes is similar to most compacted granular fills, with typical permeability values in the range of 10⁻⁴ to 10⁻⁵ m/sec. Higher strength flowable fill with higher cementitious content may exhibit lower permeability, typically of the order of 10⁻⁷ m/sec.

Durability

Flowable fill does not have the capability to resist any chemical attack or any other aggressive contamination. However, if it deteriorates in-situ, it will still continue to function as a granular fill.

POSSIBLE APPLICATIONS

The following list provides some applications particularly for the lower strength grades of flowable fill:

- a) Backfilling to excavations for utility pipes, sewers, bridge abutments, retaining walls, pile, buried tanks and building excavations particularly where access is difficult.
- b) Backfilling road excavations and pavement repairs, abandoned underground tanks, pipes etc.
- c) Providing a level base as a working platform.
- d) Structural fill to foundations subbase, floor slabs, culverts, pipe bedding, sub footings etc.
- e) Other uses may be in the form of pressure grouting, slope stabilisation, soil erosion control etc.
- f) It is recommended however, that each application should be considered on its merits, and be discussed with technical staff from the relevant suppliers in order to ensure the most satisfactory and cost effective result.

TESTING PROCEDURES

Although testing is not always necessary, testing procedures are generally similar to those undertaken for concrete.

Fluidity/Flow Spread Test

Based on overseas research a flowability rather than a slump test is the criteria for consistency. A fluidity test can be undertaken to measure the flow spread rather than slump. This involves a 75 mm diameter, 150 mm long open ended cylinder which is placed on a firm, flat surface and filled with flowable fill. As the cylinder is raised, the fill will

spread. Satisfactory flow spreads usually range between 200 and 250 mm in diameter.

However, for indicative purposes flowability ranges related to slump can be as follows:

- Low flowability – slump < 150 mm
- Normal flowability – slump in range 150 mm – 180 mm
- High flowability – slump > 180 mm (self levelling and self compacting)

Standard Test Cylinders

Other testing involves the making, curing and crushing of standard test cylinders similar to concrete. It should be noted however that in the case of early strength requirements, due to the lower strengths, test cylinders should be stripped and handled with care to prevent damage. In the case of 28 days strength requirements this is not a problem.

Where special project requirements apply, trial testing can establish the proportions of the mix required to attain the desired strength and flowability with given materials.

RELATIVE COSTS

The magnitude of cost savings associated with the use of flowable fill depends on the size of the particular project. Although local relative cost comparisons are limited, initial indications (based on the lower strength mix grades of flowable fill) are that cost savings in the order of \$5 to \$15/ m³ can be achieved for the total backfilling job, compared to conventional backfilling operations.

Reductions in manpower, less equipment and lower equipment rentals and overall time savings will make flowable fill more cost effective than granular fill in specific applications.

It should also be noted that based on the American experience larger cost savings than mentioned above have been reported, particularly with larger quantities involved.

REFERENCES

1. *Controlled Low Strength Materials, ACI 229R, American Concrete Institute, Farmington Hills, MI, USA.*
2. *Flowable Fill Materials, Concrete in Practice, CIP No. 17, NRMCA, USA.*
3. *Private Communication.*

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Fig. 1 Highly flowable fill discharged directly from chute, passing through restricted opening



Fig. 2 Highly flowable fill travels over long distance to self level and self compact (L), Low strength flowable fill can be re-excavated using hand tools (R)



Fig. 3 Low strength flowable fill can be re-excavated using hand tools (L), Higher strength flowable fill loaded by small bus wheels

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