TECH Data

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Controlled Low Strength Material (CLSM)

Also commonly known as CDF

This bulletin discusses an engineered product designed to eliminate failures inherent in compacting soil and granular materials to provide stabilized fill. This product is called Controlled Low Strength Material (CLSM).

Controlled Low Strength Materials (CLSM) is a mixture of cementitious materials (Portland cement, slag cement, or Portland cement and fly ash or Portland cement and slag cement), aggregates, water, and admixtures proportioned to provide a **non-segregating, self-consolidating, free-flowing and excavatable** material which will result in a hardened, dense, non-settling fill. Many terms are currently used to describe CLSM including flowable fill, unshrinkable fill, controlled density fill, flowable mortar, plastic soil-cement, soil-cement slurry, K-Krete, and other various names.

History

In 1964, the U. S. Bureau of Reclamation documented the first known use of CLSM. Plastic soil-cement, as the Bureau called it, was used as pipe bedding on over 320 miles of The Canadian River Aqueduct Project, which stretches from Amarillo to Lubbock, Texas. It was estimated the CLSM reduced bedding costs 40%. Over 400,000 cubic yards of CLSM were used for pipe bedding and other back filling operations at the Denver International Airport in Colorado.

The Facts

The primary application of CLSM is as structural fill or backfill in place of compacted soils and granular fill. Per cubic yard of material, CLSM costs more than conventional granular backfill. The in-place cost of CLSM can be less than conventional compacted fill materials due to properties that cannot be found in standard fill material, such as the ability to flow and fill small void spaces, the ability to be placed with minimal labor, the elimination of compaction and associated equipment, and the ability to resist mild erosion. Many Engineers specify CLSM because it has load-bearing capacities and stability characteristics equal to or better than well-compacted standard fill.

Design

The fluidity/flowability, self-compacting and excavatable properties of CLSM mixes is what makes CLSM an economical alternative to standard compacted materials. CLSM should not be considered as a type of low-strength concrete, but rather a self-compacted backfill material used as an alternative to typical compacted fill. CLSM also differs from Portland cement concrete in that it can be designed to allow for future removal with machine or hand tools. These factors should be taken into consideration when designing CLSM mixtures.

Here are some factors that should be considered:

1. Removability (Excavatability)
2. Flowability
3. Available Materials
4. Load Transfer (Bearing capacity)

Future excavatability is usually determined by the maximum compressive strength. For this reason a maximum PSI should be used when designing or specifying CLSM mixes.

The type of excavation has a big impact in designing CLSM. When encasing electrical, gas and water pipes, consideration should be given to possible future removal with hand tools. Any hand removal should be taken into design consideration due to the difficulty and danger in using machines for excavating.

Design	**Ultimate Strength**
Hand Excavatable	100 PSI Maximum
Machine Excavatable	200 PSI Maximum
Non-Excavatable	200 – 1200 PSI

* Ultimate strength values are defined as long-term values not 28-day values.
** Compressive strength testing should be used for laboratory mix design prequalification purposes only. Field-testing of CLSM should be limited to load transfer acceptance criteria.

Materials

CLSM is typically composed of Portland cement, slag cement, fly ash, aggregate, water and admixtures.

Portland Cement:
Cement contents in CLSM generally range from 30-250 lbs/cy, depending on strength and hardening-time requirements. Increasing cement content while keeping all the other materials the same will increase strength and reduce hardening time.

Fly Ash:
When fly ash is available it can be used to improve the quality of CLSM. Fly ash adds fines to the low cement content to maintain a cohesive, non-segregating mixture. The spherical shape of fly ash also adds workability that is beneficial in high flow and pumped installations. Typical fly ash content ranges from 100 lbs/cy to 1000 lbs/cy depending on its use and desired properties. Some ready mix producers do not have the ability to produce CLSM with fly ash but can effectively produce quality CLSM using other available materials.

Slag Cement:
When slag cement is available it can be used as a stand alone product in CLSM. Slag cement is a hydraulic cement that does not require cement to hydrate. Typical slag cement contents in CLSM range from 100-400 lbs/cy, depending on strength requirements and the need for pumping. Slag cement can also be used in conjunction with Portland cement to speed hydration or to increase the ultimate strength of the CLSM.

Aggregate:
Typical aggregate content in CLSM ranges from 1500 lbs/cy to 2500 lbs/cy depending on the design. Aggregates complying with ASTM C33 are generally used but are not required to produce quality CLSM. Fine grain materials / sand provide for greater ease of future excavation, but coarser materials can be a part of the total aggregate if future excavation is not of concern. Soils with clayey fines have exhibited problems with incomplete mixing, stickiness of the mix, excess water demand, shrinkage, and variable strength. ACI report 229 references aggregates that have been successfully used in CLSM that include:

- ASTM C 33 specification aggregates within specified gradations
- Pea gravel with sand
- ¾ in minus aggregate with sand
- Native sandy soils, with more than 10% passing a No. 200 sieve
- Quarry waste products, generally 3/8 in. minus aggregates.
- Crushed Recycled Concrete

It should be noted that native materials should be non-plastic.

Water:
Well, city, and recycled water that is acceptable for concrete mixtures is acceptable for CLSM mixtures. Usually more water is used in CLSM mixtures than in normal concrete designs. Typical water content for CLSM mixtures is 250 lbs/cy to 600 lbs/cy depending on mix design criteria and air content.

Admixtures:
Admixtures are usually restricted to air-entraining agents because of cost but can include the use of water-reducers and accelerators. Air-entraining admixtures and foaming agents can be a valuable additive to increase the cohesiveness, reduce shrinkage, bleeding, and to control the ultimate strength of CLSM. Typical air contents are 10%-30% for CLSM.

Colors:
Color can be a valuable tool for the current and future contractors, sub-contractors, surveyors and owners to signify the location of the utility placement. Red pigment color in CLSM often signifies the encasement of electrical conduit.

Testing

Since CLSM is a replacement for structural fill and backfill and not concrete, the methods for onsite qualification testing are different. The ASTM volume 4.09 provides testing methods for flowable fill since it is considered a soil.

Design Testing

ASTM D4832 – Standard test method for preparation and testing CLSM test cylinders.

ASTM D5971 – Standard test method for sampling freshly mixed CLSM

ASTM D 6023 – Standard test method for Unit Weight,

Kelly Ball Test

Benefits

CLSM's advantages listed below facilitate the entire backfilling process, form order and delivery of material to clean up.

Readily available – Using locally available materials, ready mix suppliers can produce CLSM to meet most project specifications.

Easy to deliver – Ready mix trucks can deliver specified quantities of CLSM to the jobsite whenever the material is needed.

Easy to place – Depending on the type and location of the void to be filled, CLSM can be placed by chute, conveyor, pump, or bucket. Because CLSM is self-leveling, it needs little or no spreading or compacting. This speeds construction and reduces labor requirements.

Versatile - CLSM mix designs can be adjusted to meet specific fill requirements. Mixes can be adjusted to improve flow ability. Adding more cement or fly ash can increase strength. Admixtures can be added to adjust setting times and other performance characteristics.

Strong and durable – Load-carrying capacities of CLSM typically are higher than that of compacted soil or granular fill. CLSM also is less permeable, thus resistant to erosion. For use as a permanent structural fill, CLSM can be designed to achieve 28-day compressive strengths as high as 1200 psi.

Can be excavated – CLSM having compressive strengths up to 100 psi are easily excavated with conventional digging equipment yet is strong enough for most backfilling needs.

Requires less inspection – During placement, backfill must be tested after each lift for sufficient compaction. CLSM self-compacts consistently and does not need extensive field testing.

Allows fast return to traffic - Because CLSM can be placed quickly and can support traffic loads within several hours, it minimizes down time for pavement repairs.

Won't settle – CLSM does not form voids during placement and won't settle or rut under loading. This advantage is especially significant if the backfill is to be covered by a pavement patch. Soil or granular fill, if not consolidated properly, may settle after a pavement patch is placed and form cracks or dips in the road.

Reduces excavation errors – By being able to color code encased underground services you can eliminate downtime for improperly located lines.

Slump of self consolidating CLSM

Improves worker safety – Workers can place CLSM in a trench without entering the trench, reducing their exposure to possible cave-ins.

Allows all-weather construction - CLSM will displace any standing waste left in a trench from rain or melting snow, reducing the need for dewatering pumps.

Reduces equipment needs – Unlike soil or granular backfill, CLSM can be placed without loaders, rollers or tampers.

Requires no storage – Because ready mix trucks deliver CLSM to the jobsite in the quantities needed, storing fill materials onsite is unnecessary. There is also no leftover fill to haul away.

Makes use of a waste by-product – Fly ash is produced by power plants that burn coal to generate electricity. CLSM containing fly ash benefits the environment by making use of this industrial waste material. The uses of alternative aggregates or recycled concrete are cost effective without lowering the quality of the CLSM mixture.

Current

More than 20 states currently have specifications for CLSM. They include California, Colorado, Delaware, Florida Georgia, Illinois, Indiana, Kansas, Kentucky, Maryland, Massachusetts, Michigan, Minnesota, Nebraska, New Hampshire, New Mexico, North Carolina, Ohio, Oregon, Texas, Washington, West Virginia and Wisconsin.

Conclusion

The savings in time and money as well as the versatility and consistent quality of controlled low strength materials typically outweighs the use of conventional fill materials.

Tech Tips

1. Cold Weather

When placing CLSM in cold weather, it should be heated using the same methods for heating ready mixed concrete to prevent the material from freezing before it hardens.

2. Adding Water

Adding too much water to CLSM can cause placement problems. As the material self-consolidates, it displaces the extra water not needed for maximum density. This can lead to excessive bleeding and longer setting times.

3. Cement Content

Higher cement contents result in greater strengths. Adding too much cement can be a problem as low strengths are desired for future excavation.

4. CLSM Without Fly Ash

If fly ash is not readily available, the use of air entraining admixtures can help to limit strength development.

Slump of non self consolidating CLSM

5. Lifting Pipes

Pipe bedding may require placing CLSM in lifts to prevent floating of the pipe. Sometimes anchors or ballasts are used to stabilize the pipe until the material sets.

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