Encouraging the use of mineral wastes in CLSM in the construction industry

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1. Introduction to CLSM
2. Properties of CLSM
3. Materials
4. Site trials
5. Concluding remarks

1.Introduction to CLSM

What is CLSM:

Controlled low-strength material (CLSM) is a self-compacting, flowable, low-strength, cementitious material

Used primarily as backfill, void fill, and utility bedding as an alternative to compacted fill.

Many terms are currently used to describe this material, including:

flowable fill, unshrinkable fill, controlled density fill, flowable mortar, plastic soil-cement, soil-cement slurry, and various other names.

The U.S. Bureau of Reclamation (*USBR*) documented the first known use of the CLSM. Plastic soil-cement, as the Bureau called it, was used as pipe bedding on over 320 miles of the Canadian River Aqueduct Project in north-western Texas in 1964. Since then, the CLSM has become a popular material in North America for projects such as structural fill, foundation support, pavement base, and conduit bedding.

Flowable cementitious fill was initially used as a replacement for poorly compacted soil in Europe back in 1970's and has been used in different applications since.

Not yet as widely used in Europe.

Specifications:

CLSMs are defined by ACI 116R as materials that result in a compressive strength of **8.3** MPa **or less**.

Most current CLSM applications require unconfined compressive strengths of **2.1** MPa **or less**. This lower-strength requirement is necessary to allow for future excavation of the material.

CLSM has a flow spread of **at least 500 mm.**

Typical CLSM mixture usually consists of 0.5 to 3 % cement (30-110 kg), 7-12 % of flyash, 70-85% of sand and 7-17% of water.

ACI 229R-99, 2003, states that non-standard materials can also be used to produce CLSM mixtures as long as the materials have been tested and found to satisfy the intended application and project requirements.

More importantly, incorporating mineral waste materials in CLSM would make it a –ve cost product !

Common Applications:

- Backfills
- Sewer trenches
- Utility trenches
- Building excavations
- Bridge abutments
- Structural Fills
- Pavement bases
- Sub footings
- Floor slab bases
- Abandoned pipe/tank fill or disused mine shafts
- Alternative to foamed concrete for many applications.

Benefits:

•Readily available
•Easy to deliver and place
•Ready placement at inaccessible locations
•Versatile
•Strong and durable
•Can allow fast return to traffic
•Reduces excavation costs
•Ease of re-excavation
•Reduces equipment needs
•Utility identification
•Lower in-place cost & Shortened project times
•Worker safety
•Allows all-weather construction
•No storage requirements
•Makes use of Mineral wastes

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2. Properties of CLSM

Since CLSM is a composite material, the characteristics of the component materials and their proportions in the mixture control the properties of the resultant CLSM.

2.1 **Plastic properties**

Flowability:

Flowability is the property that allows CLSM to completely fill a void area, self-level, and self-compact without any conventional placing or compacting equipment.

A mix is flowable when the spread is 510 – 620 mm in diameter (flow table test BSEN 12350-5, 2000).

Hardening time:

Factors affecting the hardening or setting time of a CLSM are:

- Type and quality of cementitious material
- Permeability and degree of saturation of surrounding soil that
  is in contact with the CLSM
- Water content of the CLSM
- Mixture proportions of the CLSM
- Ambient and mixture temperature
- Humidity
- Depth of fill

The time of final setting can be as short as 1 hour (ACI 229R-99, 2003), but generally takes 3 to 5 hours under normal conditions

Pumping:

Pumpability can be enhanced by careful proportioning to provide adequate void filling in the mixture.

Segregation:

For highly flowable CLSM without segregation, adequate fines are required to provide suitable cohesiveness.

Subsidence:

Most of the subsidence occurs during the placement and the degree of subsidence is dependent upon the quantity of free water released.

2.2 Hardened properties

Strength:

A CLSM compressive strength of 0.3 to 0.7 MPa equates to an allowable bearing capacity of a well-compacted soil (ACI 229R-99, 2003). It may be important to determine the long-term strength of a mixture that may be excavated at a later date.

Permeabilty:

Permeability of most excavatable CLSM is similar to compacted granular fills. Typical values are in the range of 10^{-6} to 10^{-7} m/sec. Finer constituent materials and mixtures of higher strength can achieve permeabilities as low as 10^{-9} m/sec (ACI 229R-99, 2003).

Excavatability:

In general, an unconfined compressive strength of 0.3 MPa or less can be excavated manually. Mechanical equipment, are used with stronger materials, typically with compressive strengths of 0.7 to 1.4 MPa (ACI 229R-99).

Mixtures using fine materials as the aggregate filler have been reported to be excavated with a backhoe up to strengths of 2.1 MPa.

It is suggested that long-term strength test results be conducted to estimate the potential for late excavatability.

Density:

Wet density of normal CLSM in place is in the range of about 1850 to 2350 kg/m^3.

Settlement:

Compacted fills can settle even when compaction requirements have been met. In contrast, CLSM does not settle after hardening.

Shrinkage:

Shrinkage (cracking) of CLSM is very small and has been reported to be in the range of 0.02 to 0.05%. This small amount will not affect the performance of a CLSM. Where shrinkage cracks do occur, subsequent lifts of CLSM will fill these cracks.

Thermal insulation/conductivity:

Conventional CLSMs are not considered good insulating materials.

Lightweight aggregates, including bottom ash, can be used to reduce density.

Potential for corrosion:

Electrical resistivity tests can be performed on CLSM in the same manner that natural soils are compared for their corrosion potential on corrugated culvert pipes.

Compatibility with plastics

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Candidate materials (1)

- Sodium sulphate slag (Britannia Refined Metals Ltd.)
- Spent borax slag (Britannia Refined Metals Ltd.)
- Ferrosilicate slag (lumps from Britannia Refined Metals Ltd. sand size from Britannia Zinc Ltd.)
- Ferrosilicate copper slag (IMI Refiners Ltd.)
- Soda slag (Britannia Refined Metals Ltd.)
- Chrome Alumina slag (London& Scandinavian Metallurgical Co.)
- Cement Kiln Dust ,CKD (Rugby Cement)
- Run of station ash (Ash Resources Ltd.)
- Lagoon ash (UK quality Ash Association)
- PFA (Ash Resources Ltd.)
- Steel slag (Tarmac Quarry Products Ltd.)
- Granulated Blast Furnace Slag, GBS (Tarmac Quarry Products Ltd.)

Candidate materials (2)

- Burnt Oil Shale (Tarmac Quarry Products Ltd.)
- By-product Gypsum (Biffa Waste Services Ltd.)
- Glass cullet (Mercury Recycling Ltd.)
- GGBS (Ground granulated blastfurnace slag)
- Limex70 (British Sugar Plc.)
- Shell foundry sand (Bruhl UK Ltd., Hepworth Minerals & Chemicals Ltd.)
- Green foundry sand (Castings Plc. And Bruhl UK Ltd.)
- Fire kettle setting (Britannia Refined Metals Ltd.)
- Fine rotary fascia bricks (Britannia Refined Metals Ltd.)
- Sodium sulphate solution (Britannia Refined Metals Ltd.)

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Novel Composite Landfill Liners

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MIRO

Minerals Industry Research Organisation Project RC 133
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Background

• £0.8 M Project, 1998 – 2004, 24 MIRO Partners/ participants (EA &BRE)

• Current landfill practice largely relies on HDPE liners which require sand / bentonite overpack and a “graded” waste layer

• These are costly, susceptible to rupture and require drainage blankets

• Emplacement of graded waste layer requires waste to be manually sorted (at least in the UK) leaving waste vulnerable to wind dispersal

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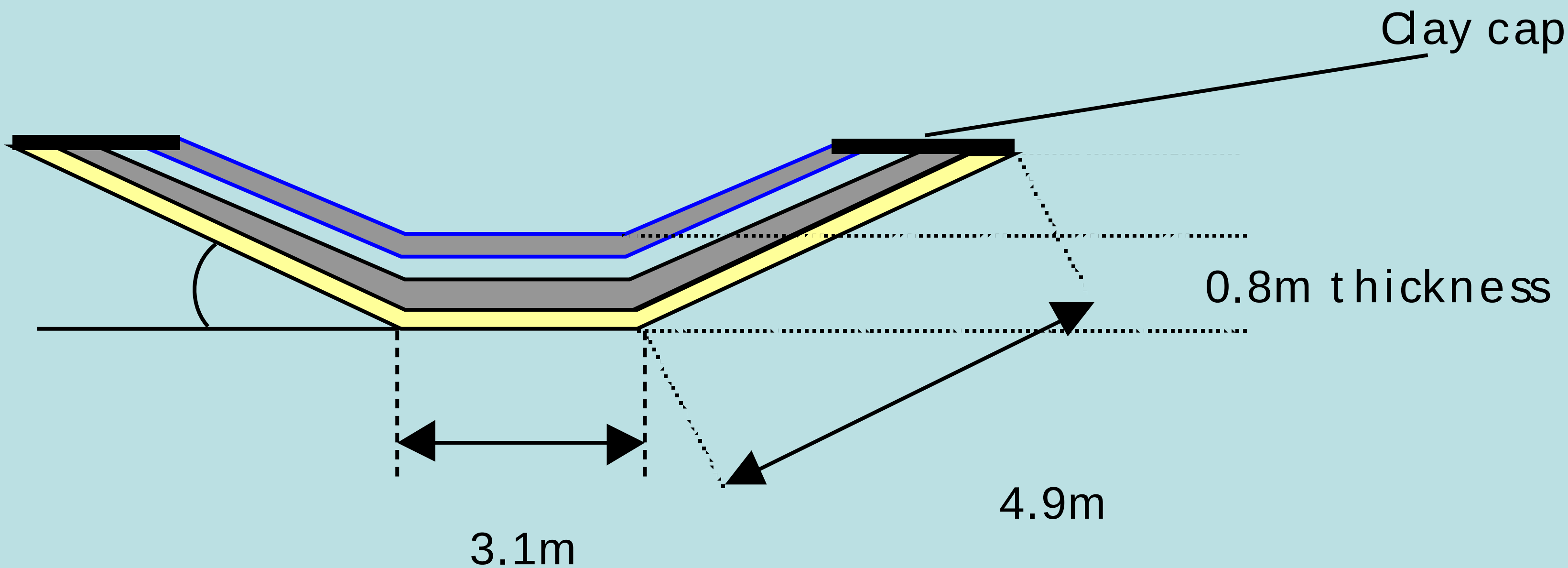
• To develop alternative technology using <u>Mineral *waste materials*</u> to construct landfill liners.

• Using waste to contain waste.

• Faster, cheaper and stronger than HDPE liners.

A concrete-clay-concrete barrier does not require a protective overpack-
This means it may be made thinner than conventional technology,
increasing the airspace available for waste -

More waste may be emplaced in a given area of landfill



Compare this thickness to the 1 to 2m of packing required in HDPE liner

Philosophy of Design I

- The nuclear sector of the waste management industry relies on the ability of cementitious backfill to chemically condition the pore solution close to the waste.
- Raising the pH in the local chemical environment, reduces the abundance and mobility of many elements

Philosophy of Design II

- The transition metals tend to form colloids from low concentration, which will be trapped by the clay membrane, rather than precipitate as mineral overgrowths in pores

- The use of a partially sacrificial barrier has not (intentionally) been applied to non-nuclear waste containment

Concept

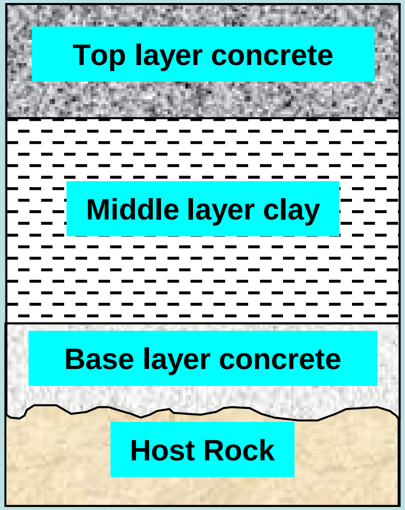
The design comprises a concrete-clay-concrete “sandwich”:

Composition

Alkali activated slag concrete Containing spent foundry sands and metallurgical slags aggregates

Non-swelling clay membrane

Portland cement concrete containing aggregate of spent foundry sands and crushed demolition waste



Function

Mechanical support of vehicles during operational phase and containment of leachate

Hydraulic barrier and ion exchange medium

Chemical conditioning of leachate by alkaline matrix. Suppression of transition metal solubility and promotion of autogenous crack-healing

Materials

This project screened a range of metal/mineral processing wastes and a number of foundry wastes to examine their suitability as components in concrete

- Potential Activators
  - Sodium sulphate slag
  - Sodium sulphate solutions
  - Soda slag (carbonate)
  - Borax slag

- Potential aggregates
  - Spent foundry sands
    - Shell sand
      - Castings Plc
      - Bruhl UK
    - Greensand
      - Castings Plc
      - Bruhl UK
  - Metal refining slags
    - Ferrosilicates
      - BZL
      - BRM
      - IMI
    - Chrome-alumina
      - LSM

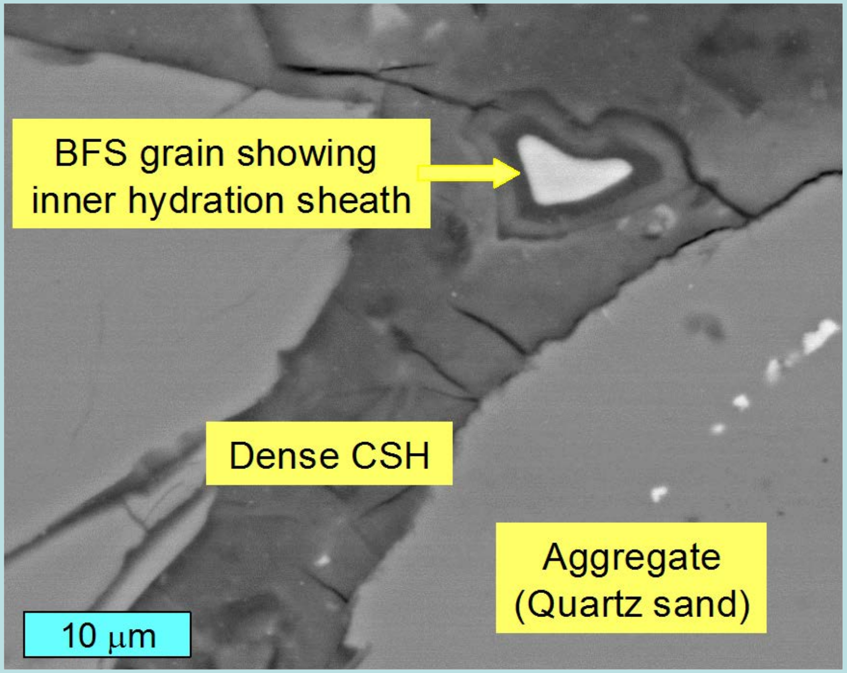
Alkali activated slag cements

Alkali activated slag, by comparison, uses soluble alkalis for this purpose. Typical examples are Group I metal carbonates, sulphates, silicates and hydroxyl solutions.

As BSF is less reactive than OPC, it is ground much finer, to ensure similar rates of hydration

As a consequence, AAS pastes exhibit a very low permeability and high paste-aggregate bond strengths

For this reason, they were chosen for use in this application



Conventional AAS Mortar

Site trial Materials for Novel Composite Landfill Liners project

Cell No. 1:

Top layer concrete:
- Spent Borax slag
- Ferrosilicate sand
- Limestone
- Water

Bottom layer concrete:
- GGBS
- OPC
- Chr. Al. slag
- Green sand
- Na2 SO4

Cell No. 2:

Top layer mortar:

- Ferrosilicate slag sand <5 mm
- C.K.D.
- L.A.
- Water

Bottom layer Concrete:

- Chrome Alumina Slag <40 mm
- Chrome Alumina Slag <5 mm
- Green sand
- C.K.D.
- P.F.A.
- Na2 SO4

Cell No. 3:

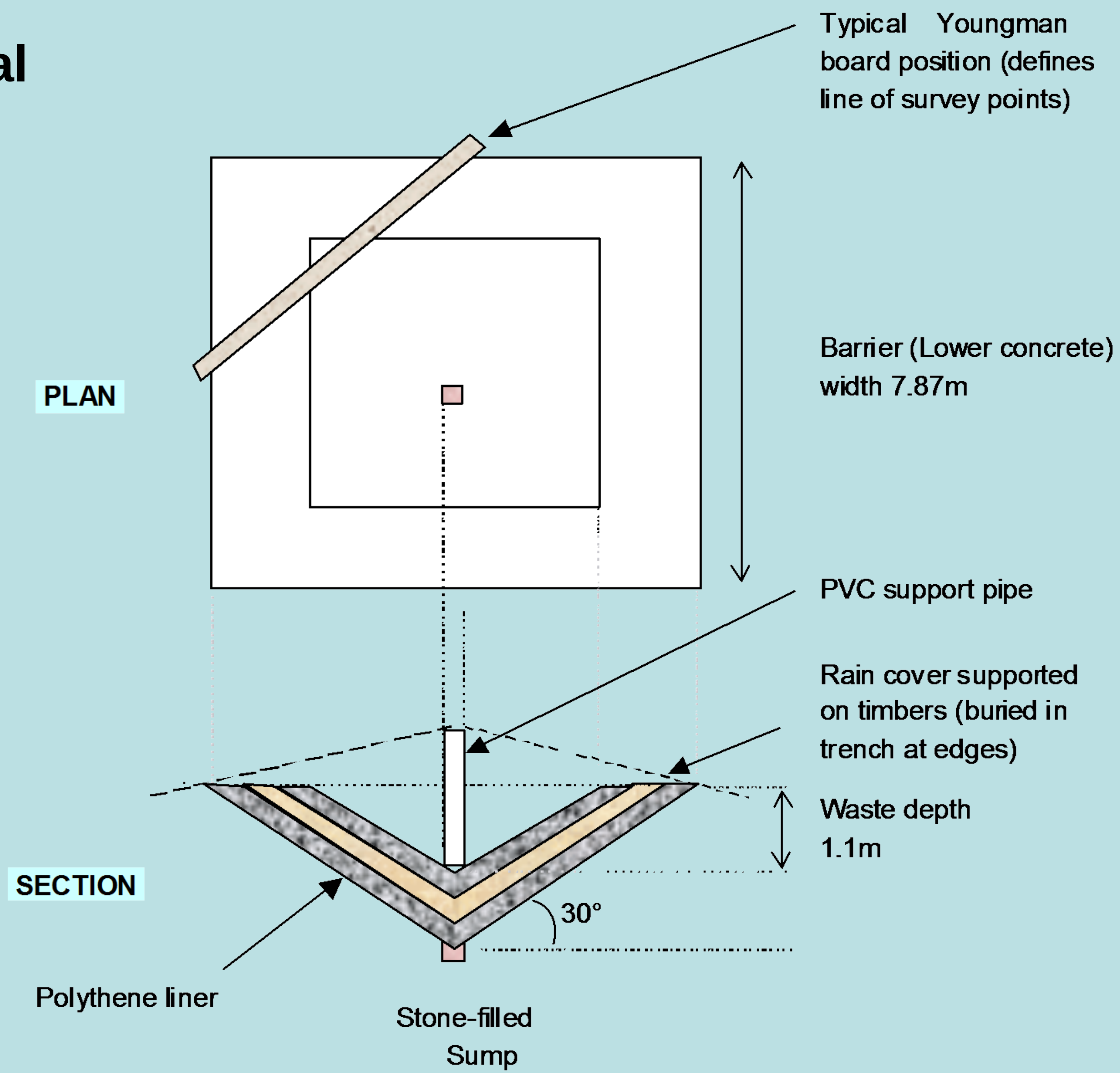
Top layer concrete:

- Limestone <20 mm
- Ferrosilicate slag sand <5 mm
- C.K.D.
- L.A.
- Water

Bottom layer Concrete:

- Chrome Alumina Slag <40 mm
- Chrome Alumina Slag <5 mm
- Green sand
- Portland cement
- C.K.D.
- L.A.
- Water

Field Trial


Typical Youngman board position (defines line of survey points)
PLAN
Barrier (Lower concrete) width 7.87m
PVC support pipe
Rain cover supported on timbers (buried in trench at edges)
Waste depth 1.1m
SECTION
30°
Polythene liner
Stone-filled Sump

Concrete delivery to bucket

Placing the top layer concrete

Trench reinstatement trial at Coventry

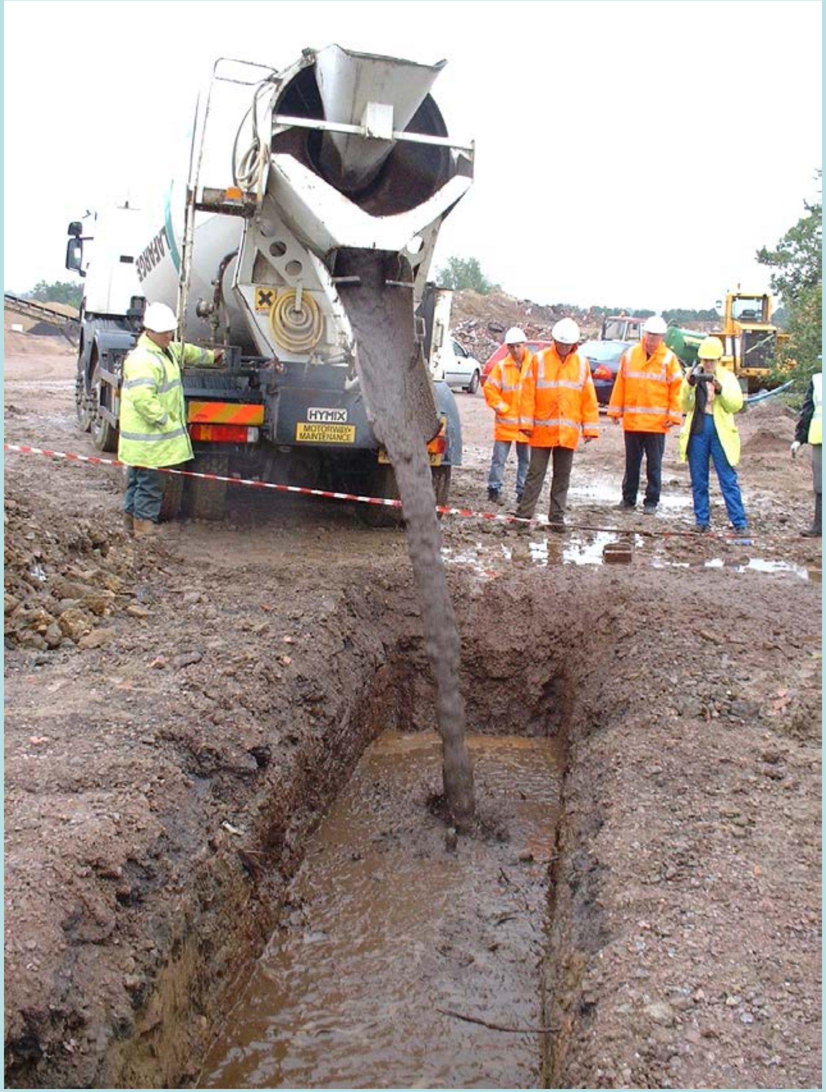
5 meter long, 1 meter wide and 2 meter deep.

Red Gypsum	**5.3 Tonnes**
BOS weathered slag	**8 Tonnes**
Water	**2400 Litres**
Calculated yield	**7.4 m^3**

CLSM pored July 2004.

Gypsum/Slag mix trial pour (mixing)

Gypsum/Slag mix trial pour



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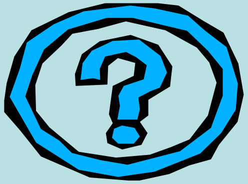
- Versatility of CLSM-CLSM mixtures can be adjusted to meet specific fill requirements. This makes it idea for making use of Mineral wastes.

- ACI 229R-99, 2003, states that non-standard materials can also be used to produce CLSM mixtures as long as the materials have been tested and found to satisfy the intended application and project requirements. Therefore, incorporating mineral waste materials in CLSM would make it a cheaper product.

- For highly flowable CLSM without segregation, adequate fine mineral wastes can provide suitable cohesiveness that the mixture require.

Thank You



Question Time