Controlled Low Strength Material (CLSM) in Transportation Projects

Presented By:
National Ready Mixed Concrete Association
Your Instructor Today...

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National Ready Mixed Concrete Association

- National Trade Association – Established in 1930
- HQ in Alexandria, VA
- 400+ Member Companies
- NRMCA Represents ~75% of North American Ready Mixed Production
- Mission - Serve Industry and Partners Through:
  - Compliance and Operations
  - Engineering
  - Government Affairs
  - Local Paving: Pave Ahead™ Initiative
  - Structures and Sustainability: Build With Strength™ Initiative

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The National Ready Mixed Concrete Association promotes the use of concrete products for pavement due to their safety, resilience, and long-term value.
About the Course

• Learning Objectives:
  – Recognize when CLSM may be used on transportation projects.
  – Learn about mixture design and the various component materials that may be used.
  – Understand the various properties that may be used to define CLSM.
  – Learn the test methods used to evaluate CLSM during the construction process.
Reference 1 - ACI 229R-13: Report on Controlled Low Strength Materials

Reference 2 – NCHRP Report 597

Reference 3 - www.flowablefill.org/

Reference 4 - NCPI

Reference 5 - ASTM STP1331: Specifications and Use of Controlled Low-Strength Material by State Transportation Agencies
Self-consolidating cementitious material used primarily as a backfill and as an alternative to compacted fill.
Controlled Low Strength Material

- Cement
- Sand
- Water
- Air-Entrainment
Controlled Low Strength Material Strength

- Compressive strength of 1,200 psi or less.
- Unconfined compressive strengths of 300 psi or less.
- Long-term strengths should be targeted to be less than 100 psi.
Controlled Low Strength Material Applications

- structural fill (~1,200 psi)*,
- backfill and bedding,
- anticorrosion fills,
- electrically conductive materials,
- low-permeability fills,
- thermal or insulating fills,
- durable pavement base, and
- erosion control.

*Note: Not to be considered as low strength concrete.
Controlled Low Strength Material Advantages

- Readily available
- Easy to deliver
- Versatile
- Strong and durable
- Quick opening to traffic
  - (4 hours or less)
- Does not settle
- Reduces excavation costs
- Improves worker safety
  - Allows all weather construction
  - Can be excavated
  - Requires less inspection
  - Reduces equipment needs
  - Requires no storage
  - Makes use of coal combustion by-product
Controlled Low Strength Material Cost Effectiveness

- CLSM generally costs more per cubic yard
- Lower in-place costs
- Only reasonable backfill method available
## Controlled Low Strength Material

<table>
<thead>
<tr>
<th>Labor</th>
<th>Granular Backfill</th>
<th>Flowable Fill</th>
</tr>
</thead>
<tbody>
<tr>
<td>Placement</td>
<td>$70.18</td>
<td>$35.09</td>
</tr>
<tr>
<td>(2 laborers @ 35.09*)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Compaction</td>
<td>$70.18</td>
<td>n/a</td>
</tr>
<tr>
<td>(2 laborers @ 35.09*)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heavy Equipment Operator</td>
<td>$45.82*</td>
<td>n/a</td>
</tr>
<tr>
<td>Hand Compactor</td>
<td>$15.00*</td>
<td>n/a</td>
</tr>
<tr>
<td>Backhoe</td>
<td>$25.00*</td>
<td>n/a</td>
</tr>
<tr>
<td><strong>Total labor/hour</strong></td>
<td><strong>$226.18</strong></td>
<td><strong>$35.09</strong></td>
</tr>
</tbody>
</table>

84% labor cost savings

* National industry average including overhead costs

Source: Chaney Enterprises
Controlled Low Strength Material Utility Identification
Controlled Low Strength Material Selection

• Availability
• Cost
• Specific application
• Necessary mixture characteristics
Controlled Low Strength Material Cement

- Type I or Type II ASTM C150
- Blended ASTM C595*
- Performance ASTM C1157*

*Note: if prior testing indicates acceptable results.
Controlled Low Strength Material with SCMs

- **Fly Ash:**
  - Class C or F ASTM C618 preferred
    - But not necessary (carbon contents up to 20-25% may be allowable)
  - High-fly-ash-content CLSM results in lower densities
Controlled Low Strength Material Air Entrainment

Air-entraining admixtures:

- improve workability,
- reduce shrinkage,
- little or no bleeding,
- minimal segregation,
- lower unit weights, and
- control of ultimate strength development.
Controlled Low Strength Material Water
Aggregates

- Meet ASTM C33
  - But not necessary
- The type, grading, and shape of aggregates affect the physical properties:
  - flowability and
  - compressive strength.
Uncontrolled excavation allowable in some cases.

Silty sands w/up to 20% passing #200 satisfactory.

Soils w/variable grading also effective.

Soils with clay fines have exhibited problems.
Controlled Low Strength Material Aggregates

• Other Non-Standard Acceptable Aggregates:*
  • coal combustion products,
  • crusher fines,
  • discarded foundry sands,
  • glass cullet,
  • reclaimed crushed concrete,
  • ground tire rubber.

*Note: expansive materials discouraged.
(e.g. wood, wood ash, other organics)
Controlled Low Strength Material In Service Properties

- Exhibits characteristic properties of soils.
- Affected by mixture constituents and proportions of the ingredients in the mixture.
Controlled Low Strength Material Wet Properties

- Flowability
- Segregation
- Subsidence
- Hardening time
- Pumping
• Flowability
  • Varies from stiff to fluid.
  • Methods of expressing flowability:
    • ASTM C939 grout flow cone.
    • ASTM C143 standard concrete slump cone
Controlled Low Strength Material Wet Properties

- ASTM D6103:
  - 3 x 6 in. open-ended cylinder modified flow test
Controlled Low Strength Material Wet Properties

• Segregation
  • Separation of materials when flowability produced by adding water.
  • Adequate fines for highly flowable w/out segregation
Controlled Low Strength Material Wet Properties

- Subsidence
  - Normal volume reduction as it releases water and entrapped air through mixture consolidation.
  - Excess water
Controlled Low Strength Material Wet Properties

• Hardening time
  • Approximate time for CLSM to go from the plastic state to a hardened state.
  • Time is greatly influenced by the amount and rate of bleed water released.
  • Chemical admixtures may be used to accelerate set (excludes CaCl).
Controlled Low Strength Material Wet Properties

• Hardening time
  • Time can be as short as 1 hour, but generally takes 3 to 5 hours under normal conditions.
  • Suitable tests for determining CLSM hardening time:

Penetrometer or Kelly Ball
Controlled Low Strength Material Wet Properties

Pumping

- Voids in the mixture should be adequately filled with solid particles.
- The mixture should be statically stable.
- CLSM with high entrained-air contents can be pumped.
Controlled Low Strength Material In-Place Properties

- In-Place Properties
  - Strength
  - Density
  - Settlement
  - Thermal insulation
  - Permeability
  - Shrinkage
  - Excavatability
  - Shear Modulus
Controlled Low Strength Material In-Place Properties

- **Density:**
  - Normally **115 to 145 lb/ft³**,
  - with only fly ash, cement, and water should have a density between **90 to 100 lb/ft³**,
  - **Lower** unit weights can be achieved:
Controlled Low Strength Material In-Place Properties

- Permeability
  - Like compacted granular fills.
  - Typical values:
    - $10^{-4}$ to $10^{-5}$ in./s (or cm/s).
    - Mixtures with higher strength and higher fines content can achieve much lower permeabilities.
Controlled Low Strength Material In-Place Properties

- Shrinkage
  - Does not affect the performance.
  - CLSM with high volumes of fly ash exhibit higher amounts of linear shrinkage.
Controlled Low Strength Material In-Place Properties

- **Excavatability**
  - CLSM with a compressive strength of 100 psi or less can be excavated manually.
  - A removability modulus (RE) helps to determine excavatability

\[
RE = \frac{W^{1.5} \times 104 \times C^{0.5}}{10^6} \quad \text{U.S. Units} \\
RE = \frac{W^{1.5} \times 0.619 \times C^{0.5}}{10^6} \quad \text{Metric Units}
\]

RE < 1.0, is removable.  
RE > 1.0, is not easily removed.

[W is the dry mass density (lb/ft³ or kg/m³), and C is the 28-day unconfined compressive strength (lb/in² or kPa)]:

Credit: [Hamilton County, Ohio CLSM-CDF Specification](#) and as reported in NCHRP Report 597 (2008) and ACI Report 229
Controlled Low Strength Material In-Place Properties

- Excavatability
  - Mixtures with high coarse aggregate quantities can be difficult to remove by hand.
  - Mixtures using fine sand or only mineral admixtures have been excavated with a backhoe up to strengths of 100 to 300 psi.
Controlled Low Strength Material In-Place Properties

- **Excavatability**
  - Long-term performance from combined cement contents from 40 to 100 lb/yd³ and Class F fly ash contents up to 350 lb/yd³.
  - Lime (CaO) contents of fly ash that exceed 10 percent by weight can be a concern.
Controlled Low Strength Material In-Place Properties

• **Excavatability**
  
  • For CLSM with high cementitious content (or w/fly ash or slag), long-term (56, 90, or 180 days) strength tests should be conducted to estimate the potential for excavatability.
  
  • In addition to limiting the cementitious content, entrained air can be used to maintain low compressive strength.
Controlled Low Strength Material Proportioning

- Proportioning
  - Well-graded fine aggregate = more stable CLSM
  - Avoid too much clay!
  - Cementitious starting point:
    - 25 to 100 lb/yd$^3$ of cement and
    - up to 300 lb/yd$^3$ of fly ash
Controlled Low Strength Material Proportioning

- **Proportioning**
  - ACI 211.1 proportioning may be used to establish initial mixture design.
  - **Basic CLSM mixtures:**
    - fine aggregate: 2500 to 3500 lb/yd³,
    - water: 400 to 500 lb/yd³,
    - portland cement: 25 to 200 lb/yd³,
    - fly ash: 0 to 700 lb/yd³,
    - results in ~2-5% entrapped air.
## Table 6.4—Sample calculations for 1 yd³ (1 m³) of material

<table>
<thead>
<tr>
<th></th>
<th>1 yd³</th>
<th>1 m³</th>
</tr>
</thead>
<tbody>
<tr>
<td>94 lb cement/(3.15 × 62.4 lb/ft³) = 0.48 ft³</td>
<td>56 kg cement/(3.15 × 1000 kg/m³) = 0.018 m³</td>
<td></td>
</tr>
<tr>
<td>450 lb water/(1.00 × 62.4 lb/ft³) = 7.21 ft³</td>
<td>267 kg water/(1.00 × 1000 kg/m³) = 0.267 m³</td>
<td></td>
</tr>
<tr>
<td>Assumed air vol (3% × 27 ft³) = 0.81 ft³</td>
<td>Assumed air volume (3% × 1 m³) = 0.03 m³</td>
<td></td>
</tr>
<tr>
<td>Volume, sand = 27 ft³ − 0.48 ft³ − 7.21 ft³ − 0.81 ft³ = 18.5 ft³</td>
<td>Volume, sand = 1 m³ − 0.018 m³ − 0.267 m³ − 0.03 m³ = 0.685 m³</td>
<td></td>
</tr>
<tr>
<td>Weight, sand = 18.5 ft³ × (2.65 × 62.4 lb/ft³) = 3060 lb</td>
<td>Mass, sand = 0.685 m³ × (2.65 × 1000 kg/m³) = 1815 kg</td>
<td></td>
</tr>
</tbody>
</table>
# Controlled Low Strength Material

Table 6.6—Adjustments to proportioning (from ACI 229R-13)

<table>
<thead>
<tr>
<th>Property</th>
<th>Problem</th>
<th>Adjustment</th>
</tr>
</thead>
</table>
| Slump    | Too high  | a) Reduce water content  
               b) Increase fines          |
|          | Too low   | a) Increase water content  
               b) Add water-reducing admixture |
| Stability| Mixture is segregating |  
               a) Decrease water  
               b) Increase fines  
               c) Increase cementitious materials  
               d) Add air entrainment  
               e) Add viscosity-modifying admixture (VMA) |
| Yield    | Too low   | a) Confirm specific gravity used for constituents is correct  
               b) Increase constituents |
|          | Too high  | a) Confirm specific gravity used for constituents is correct  
               b) Decrease constituents |
| Strength | Too low   | a) Increase cementitious materials  
               b) Decrease air entrainment  
               c) Decrease water in conjunction with use of water-reducing admixture |
|          | Too high  | a) Decrease cementitious materials  
               b) Increase air entrainment |
Controlled Low Strength Material

• Mixing:
  • central-mixed concrete plants,
  • ready mixed concrete trucks,
  • pugmills, and
  • volumetric mobile concrete mixers.
Controlled Low Strength Material

• Mixing performed in trucks:
  • Load truck mixer at standard charging speed in the following sequence:
    • Add 70 to 80 percent of water required
    • Add 50 percent of the aggregate filler
    • Add all cement and fly ash required
    • Add balance of aggregate filler
    • Add balance of water
Controlled Low Strength Material

• Transporting
  • Ready mix trucks
  • Dump trucks/non-agitating mixers (discouraged)
  • Pumps (conveyed transporting)
  • Volumetric-measuring and continuous-mixing concrete equipment (VMCM) for jobsite mixing
Controlled Low Strength Material

- **Placing**
  - chutes,
  - conveyors,
  - buckets, or
  - pumps.
  - Internal vibration, compaction, or consolidation NOT required, consolidates under own weight.
Controlled Low Strength Material

- Placing
  - Protect from freezing
  - No need to cure
  - Place continually or in lifts
Controlled Low Strength Material

• Testing
  • Visual
  • Consistency
  • Strength
Controlled Low Strength Material

• Testing in place:

<table>
<thead>
<tr>
<th>ASTM D6024</th>
<th>This specification covers determination of ability of CLSM to withstand loading by repeatedly dropping metal weight onto in-place material.</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASTM C403/C403M</td>
<td>This test measures degree of hardness of CLSM. California DOT requires penetration number of 650 before allowing pavement surface to be placed.</td>
</tr>
<tr>
<td>ASTM D4832</td>
<td>This test is used for molding cylinders and determining compressive strength of hardened CLSM.</td>
</tr>
<tr>
<td>ASTM D1196/D1196M</td>
<td>This test is used to determine modulus of subgrade reaction (K values).</td>
</tr>
<tr>
<td>ASTM D4429</td>
<td>This test is used to determine relative strength of CLSM in place.</td>
</tr>
</tbody>
</table>
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