Controlled Low Strength Material (CLSM) in Transportation Projects

Presented By:

National **R**eady **M**ixed **C**oncrete **A**ssociation

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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.

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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.

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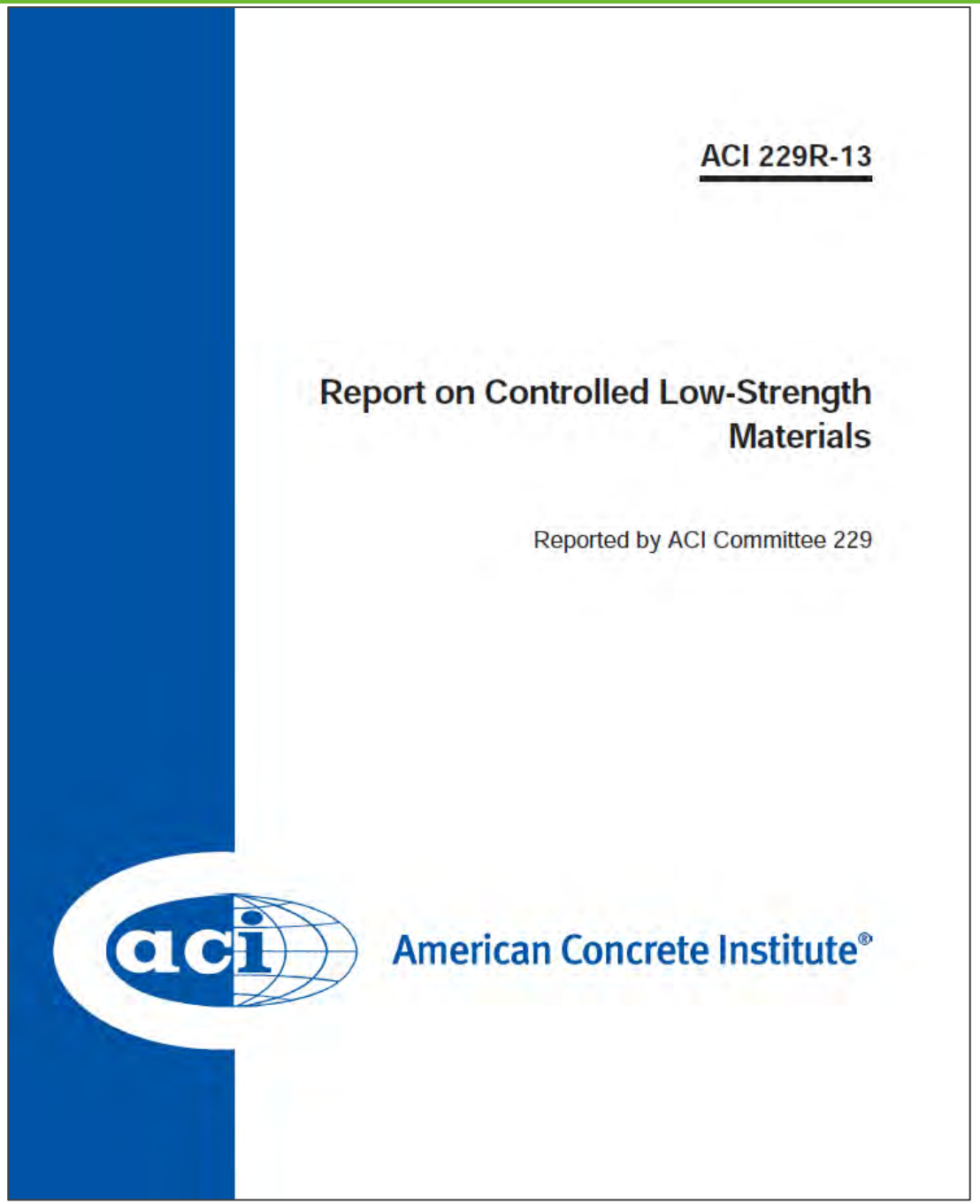

Reference 1 - ACI 229R-13: Report on Controlled Low Strength Materials

Reference 2 – NCHRP Report 597

Reference 3 - www.flowablefill.org/

Reference 4 - NCPI National Clay Pipe Institute

Reference 5 - ASTM STP1331: Specifications and Use of Controlled Low-Strength Material by State Transportation Agencies

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Controlled Low Strength Material

Self-consolidating cementitious material used primarily as a backfill and as an alternative to compacted fill.

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Controlled Low Strength Material

- Cement
- Sand
- Water
- Air-Entrainment

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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

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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.

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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

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Controlled Low Strength Material Cost Effectiveness

- CLSM generally costs more per cubic yard
- Lower in-place costs
- Only reasonable backfill method available

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Controlled Low Strength Material

Labor	Granular Backfill	Flowable Fill
Placement (2 laborers @ 35.09*)	$70.18	$35.09
Compaction (2 laborers @ 35.09*)	$70.18	n/a
Heavy Equipment Operator	$45.82*	n/a
Hand Compactor	$15.00*	n/a
Backhoe	$25.00*	n/a
Total labor/hour	**$226.18**	**$35.09**

Source: Chaney Enterprises

84% labor cost savings

* National industry average including overhead costs

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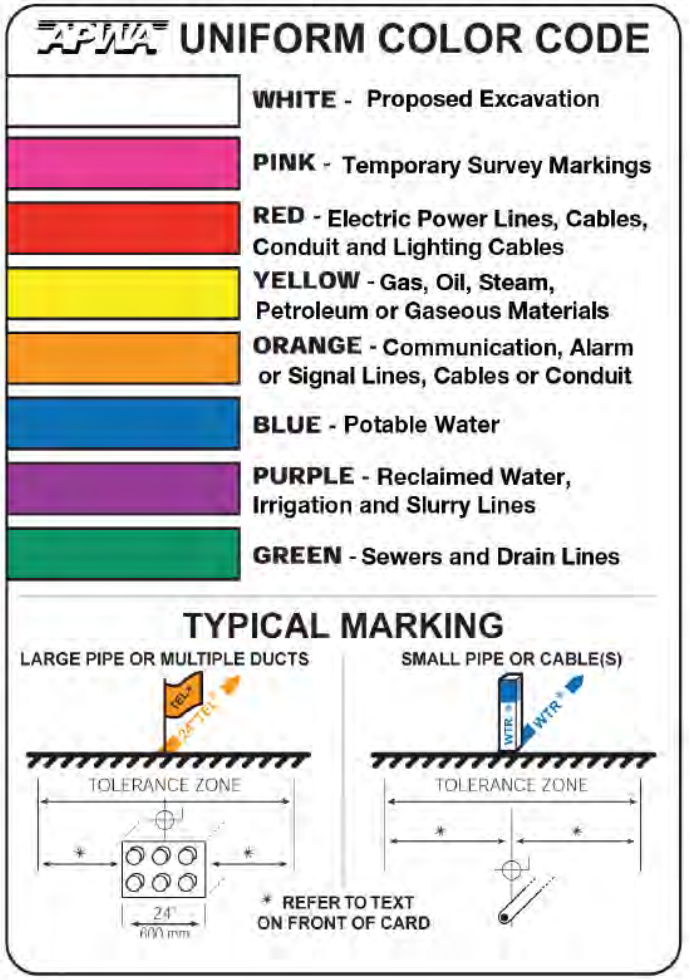
Controlled Low Strength Material Utility Identification



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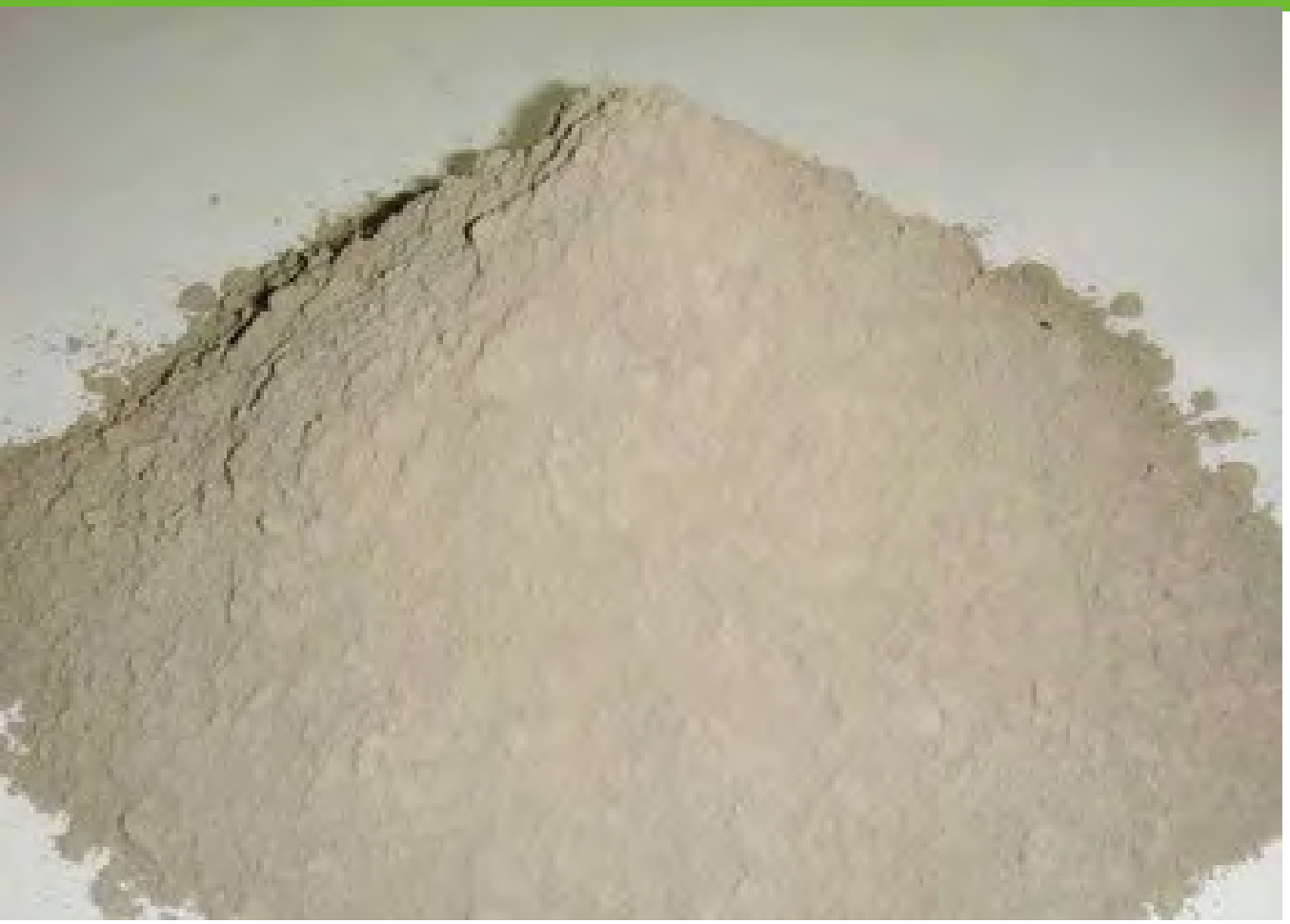
Controlled Low Strength Material Selection

- 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.

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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.

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Controlled Low Strength Material Water

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Controlled Low Strength Material Aggregates

Aggregates

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

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Controlled Low Strength Material Aggregates

- 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

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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

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Controlled Low Strength Material Wet Properties

- 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




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Controlled Low Strength Material Wet Properties

- Segregation
  - Separation of materials when flowability produced by adding water.
  - Adequate fines for highly flowable w/out segregation

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Controlled Low Strength Material Wet Properties

- Subsidence
  - Normal volume reduction as it releases water and entrapped air through mixture consolidation.
  - Excess water

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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).

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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

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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

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Controlled Low Strength Material In-Place Properties

- Density:
  - Normally **115 to 145 lb/ft^3**,
  - with only fly ash, cement, and water should have a density between **90 to 100 lb/ft^3**,
  - **Lower** unit weights can be achieved:

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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.

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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

U.S. Units

$$RE = \frac{W^{1.5} \times 104 \times C^{0.5}}{10^6}$$

Metric Units

$$RE = \frac{W^{1.5} \times 0.619 \times C^{0.5}}{10^6}$$

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

[W is the dry mass density (lb/ft^3 or kg/m^3), and C is the 28-day unconfined compressive strength (lb/in^2 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.

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Controlled Low Strength Material In-Place Properties

- Excavatability
  - Long-term performance from combined cement contents from 40 to 100 lb/yd^3 and Class F fly ash contents up to 350 lb/yd^3.
  - Lime (CaO) contents of fly ash that exceed 10 percent by weight can be a concern.

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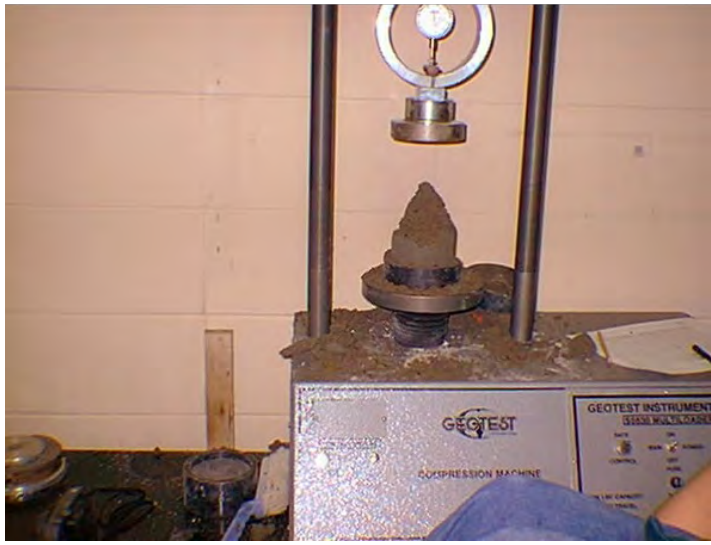
Controlled Low Strength Material In-Place Properties

- 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 MaterialProportioning

- Proportioning
  - ACI 211.1 proportioning may be used to establish initial mixture design.
  - Basic CLSM mixtures:
    - fine aggregate: 2500 to 3500 lb/yd^3,
    - water: 400 to 500 lb/yd^3,
    - portland cement: 25 to 200 lb/yd^3,
    - fly ash: 0 to 700 lb/yd^3,
    - results in ~2-5% entrapped air.

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Controlled Low Strength Material Proportioning

Table 6.4—Sample calculations for 1 yd^3 (1 m^3) of material

1 yd^3	1 m^3
94 lb cement/(3.15 × 62.4 lb/ft^3) = 0.48 ft^3	56 kg cement/(3.15 × 1000 kg/m^3) = 0.018 m^3
450 lb water/(1.00 × 62.4 lb/ft^3) = 7.21 ft^3	267 kg water/(1.00 × 1000 kg/m^3) = 0.267 m^3
Assumed air vol (3% × 27 ft^3) = 0.81 ft^3	Assumed air volume (3% × 1m^3) = 0.03 m^3
Volume, sand = 27 ft^3 – 0.48 ft^3 – 7.21 ft^3 – 0.81 ft^3 = 18.5 ft^3	Volume, sand = 1 m^3 – 0.018 m^3 – 0.267 m^3 – 0.03 m^3 = 0.685 m^3
Weight, sand = 18.5 ft^3 × (2.65 × 62.4 lb/ft^3) =3060 lb	Mass, sand = 0.685 m^3× (2.65 × 1000 kg/m^3) =1815 kg

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Controlled Low Strength Material

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

Property	Problem	Adjustment
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.

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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

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- 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.

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Controlled Low Strength Material

- Placing
  - Protect from freezing
  - No need to cure
  - Place continually or in lifts

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Controlled Low Strength Material

- Testing
  - Visual
  - Consistency
  - Strength

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- Testing in place:

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

NRMCA Resources

How Can We Assist You for Free?

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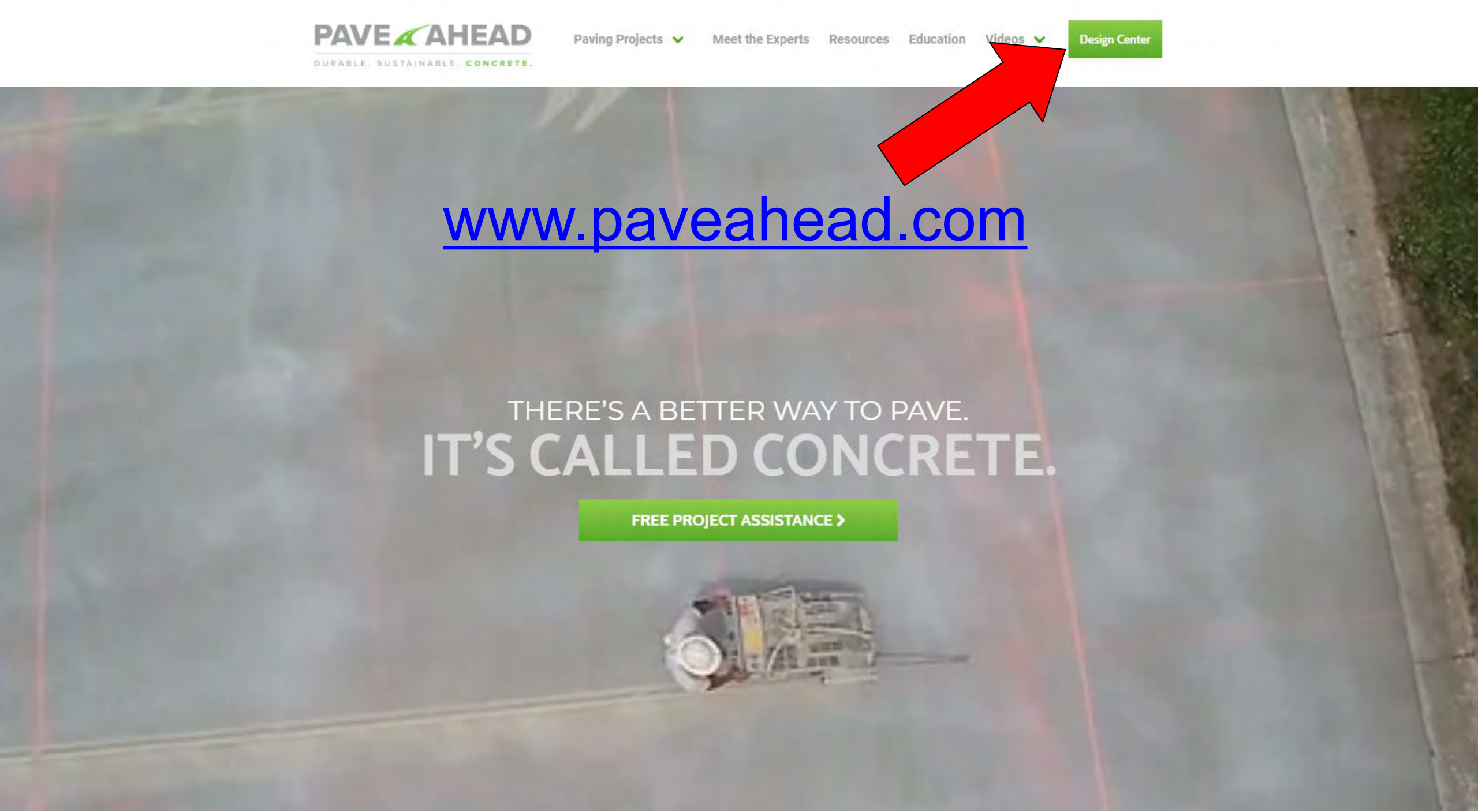
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