New Techniques for Controlling Mixed In-Place Soil Cement Road Base

60th Annual Alabama Transportation Conference
February 10, 2017
Montgomery, AL

Presenter
Isaac L. Howard, PhD, PE
Materials and Construction Industries Chair
Civil and Environmental Engineering Dept.
Mississippi State University
662-325-7193, ihoward@cee.msstate.edu

Key References

Outline of Main Points
1. Traditional approaches to soil-cement activities and pitfalls
2. Plastic Mold Compaction Device (PM Device) development, operation, and attributes
3. Laboratory application of PM Device
4. Construction QC/QA application of the PM Device
5. MEPDG uses for the PM Device

PM Device 101
The Plastic Mold (PM) Device can be utilized for mix design and pavement layer thickness design and QC/QA

Acknowledgements
• This presentation is mostly an abbreviation of a TRB webinar: Improved Specimen Preparation for Soil-Cement Design and Construction Monitoring
• Several individuals have actively supported this work
  – Joe Ivy (MSU) Richard Sheffield (MDOT-Retired)
  – Brennan Anderson (MSU Alumni) Tim Cost (LafargeHolcim)
  – James Williams (MDOT) Bill Barstis (MDOT)
  – Mike Sullivan (MDOT) Caleb Hammons (MDOT)
  – Griffin Sullivan (MDOT & MSU Doctoral Student – Primary Collaborator)
• Mississippi Department of Transportation
  – Funded State Study 206 (complete)
  – Funding State Study 276 (active)

Traditional Soil-Cement Approach
• Practice review & 2012 survey of state DOTs (21 total)
  – All DOTs use compressive strength as criteria. Few DOTs use durability tests. (Most states use Proctor specimens)
  – Design criteria and curing protocols vary widely among all state DOTs
  – Most only check field spread rate and density. Five state DOTs make field specimens or cut cores for QC.
• Portland Cement Association and US Army Corps
  – Both have compressive strength and durability criteria
  – Both utilize Proctor specimens
• Overall, not a lot of consistency
Traditional Soil-Cement Approach

Pavement Design:
Performed using structural coefficient or using modulus testing performed with 2:1 h/d ratio specimens.

Laboratory Mixture Design:
with Proctor Specimens

Construction Quality Control / Quality Assurance
Check Spread
Check Pulverization
Check Density

Soil-Cement in MS
MDOT Uses Soil-Cement Routinely:
243 million yd² over past 6.5 yrs
Materials: Mainly M145 A-2-4 or USCS SM
Materials (Near 100% passing No 10 sieve)

Design and Operation of the PM Device
• The following slides discuss design and operation of the PM Device. A demonstration video is available for viewing at the following link
  – http://www.cee.msstate.edu/cmerc/technical-documents/
• Additionally, drawings of the PM Device are available in Appendix C of the following link

PM Device Concept and Design
• Compact soil-cement into a 3x6 inch plastic cylinder mold. Approximate dimensions: 11 x 10 x 9 inches

PM Device Concept and Design
• The split mold design closely surrounds the mold to prevent distortion while a modified Proctor hammer is utilized to compact the specimen.
• The PM Device is portable so that specimens can be fabricated in the lab and in the field (weighs approximately 25 pounds).

Plastic Cylinder Mold Modifications
• Cut hole in bottom and keep plastic cut-out
• Sand bottom smooth
• Place 1/16 inch thick aluminum plate in mold
• Tape plastic cut-out to bottom to fill gap
PM Device Operation
• Tape plastic cut-out to the bottom of the plastic mold to fill in the gap between mold bottom and aluminum plate.

PM Device Operation
• Place plastic mold in PM Device, clamp device closed with locking vise-grips, and place collar on top.

PM Device Operation
• Compact specimens in three equal lifts using 5 blows per lift with a modified Proctor hammer, and scarify the surface between each lift.

PM Device Operation
• After compaction, remove specimen from device and strike-off the top surface. Place plastic lid on the specimen.

PM Device Specimens
1.97:1 height to diameter aspect ratio as measured

PM Device Design and Operation Summary
• PM Device costs less than $1000 for a local machine shop to fabricate. Price could lessen with bulk orders.
• Plastic molds could be used multiple times and are not expensive
• It takes approximately 3 minutes to compact a specimen using the PM Device.
Specimen Properties: Diameter

- No two specimen diameters differed by more than 2% as per AASHTO M205

<table>
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<th>Average Specimen Diameter (mm)</th>
<th>Relative Frequency (%)</th>
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Average of at least 3 per test time

- n = 752
- Mean = 76.8
- Stdev = 0.16
- COV = 0.2%

Overall Average
- n = 752
- Mean = 76.6
- Stdev = 0.15
- COV = 0.2%

Not Everything Needs to Change

- Part of the PM Device integration is to keep what is working well intact
- Most UCS gain occurred within 56 days (>75 to 85% of 540 day strength)

Laboratory Mix Design (Very Brief Summary)

- Working toward test method that ends after specimen has been cured for 24 hr
- Compact with Modified Proctor hammer - vary number of blows as needed
- Lab bench cure for up to 24 hr in mold – extract from mold, cure in 100% humidity uncovered and not submerged

Construction QC/QA Applications

- Working toward test method that ends after specimen has been cured for 24 hr
- Modified Proctor hammer
- Compact a fixed number of blows per layer (5 to 7) – varying density that is corrected to some percentage of Proctor density
- Cure specimens in mold

Reduced Variability From Improved QC Tool

- Nobody wants this to be their boots
Field Issues Observed in Mississippi

- Structural Failure
- Soft Areas
- Shrinkage
- Cracking

Observed Soil-Cement Variability for MS Hwy

Mechanistic-Empirical Pavement Design Guide

- MEPDG requires a modulus input for soil-cement materials.
  - Level 1 – direct measurement of modulus (E)
  - Level 2 or 3 – $E=1200$ (UCS) or estimated 500,000 psi
- With traditional soil-cement approach, two different types of test specimens would be required
  - 2:1 h/d ratio specimen for modulus testing
  - Proctor specimen for mixture design based on strength

MEPDG

- ASTM C469 – Elastic Modulus Testing
  - Directly measure modulus on the same type specimen tested for strength

Compressometer

MEPDG - Elastic Modulus

- MEPDG Equation: $E = 1200 \times 10^{-6} \times \text{UCS}$
- Trendline Equation: $E = C_t \times 10^{-6} \times \text{UCS}$

4 by 8 Version of PM Mold

(current 3 by 6 is for A-2-4 and similar types of soil)
Summary
1. PM Device offers many advantages over more traditional approaches to soil-cement design, quality control, and pavement design.
2. Project team has initiated the process of working toward a national standard test method.
3. Project team encourages others to give the PM Device a try – tell us what you think!

Questions?