PAAMA
Pennsylvania Association of Asphalt Material Applicators

2025 Annual Conference - Innovations in Pavement Preservation

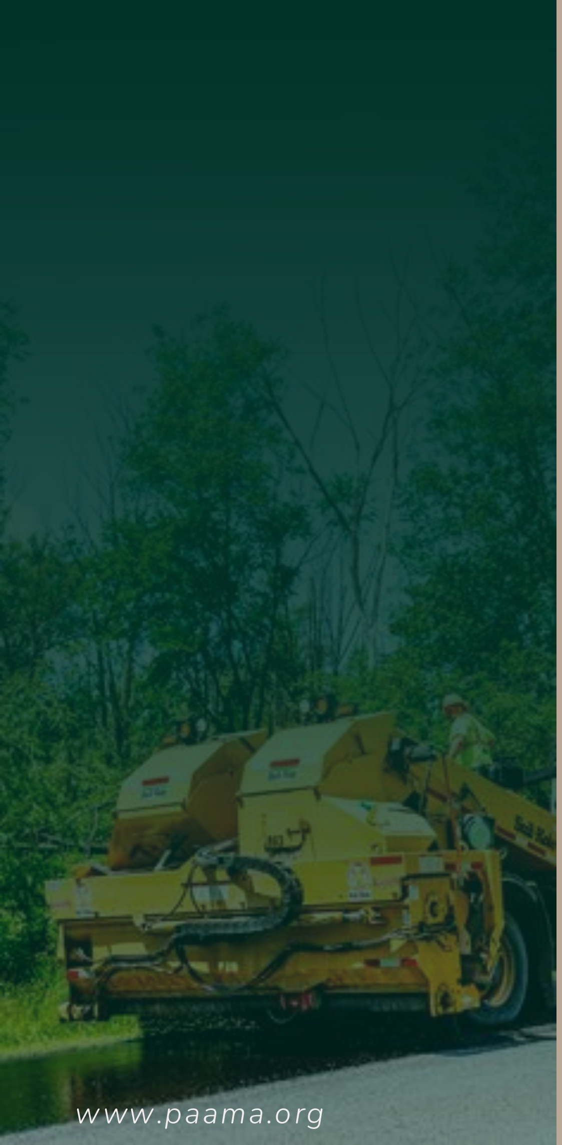
Development of a Field Test to Determine Chip Seal Aggregate Embedment

www.paama.org

PAAMA
Pennsylvania Association of Asphalt Material Applicators

Disclaimer

This investigation is sponsored by the Transportation Research Board (TRB) under the National Cooperative Highway Research Program (NCHRP) Program. Any opinions and conclusions expressed or implied in the resulting research products in this presentation are those of the individuals and organizations who performed the research and are not necessarily those of TRB; the National Academies of Sciences, Engineering, and Medicine; the Federal Highway Administration (FHWA); or NCHRP sponsors. Data reported are work in progress. Contents of this research presentation may have not been reviewed by the NCHRP project panel, nor do they constitute a standard, specification, or regulation. All data and copyrights are owned by the National Academy of Sciences.



PAAMA
Pennsylvania Association of Asphalt Material Applicators

NCHRP Project 10-124

Research Team

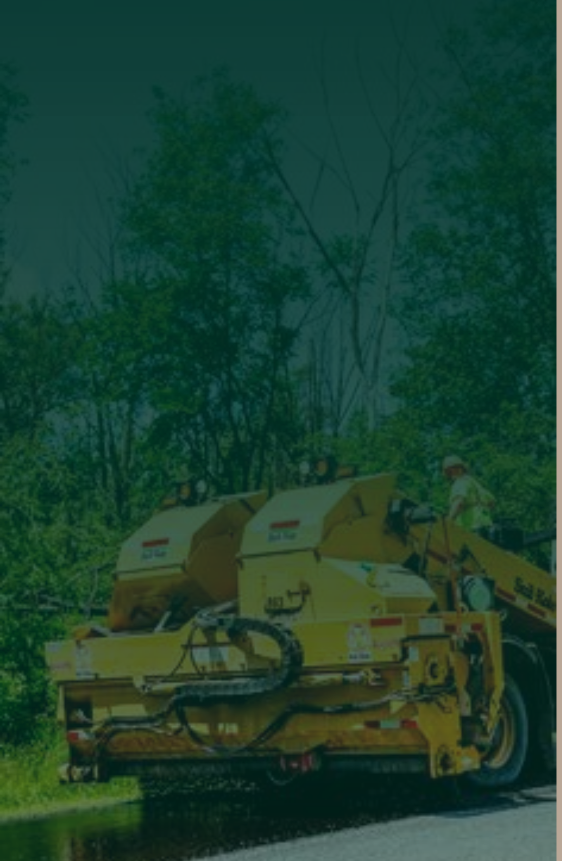
PI: Adriana Vargas, Auburn University - NCAT

Co-PI: Andrew Braham, University of Arkansas

Malcolm Williamson, University of Arkansas - CAST

Angelia Payne, University of Arkansas - CAST

Scott Shuler, Shuler Consultants



www.paama.org

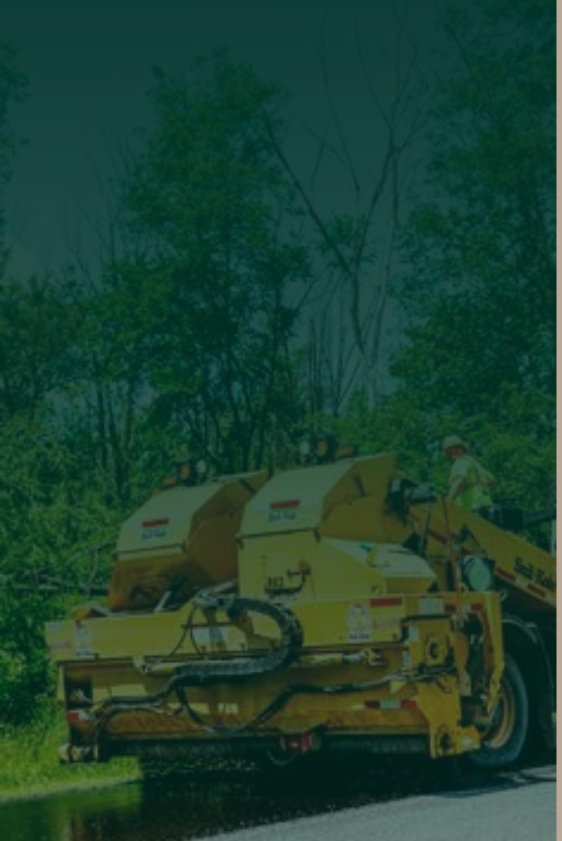
PAAMA
Pennsylvania Association of Asphalt Material Applicators

Background

- Chip seals are popular pavement preservation treatments
- Seal fine cracks in underlying pavement
- Prevent water intrusion
- Aggregate protects the asphalt layer and provides a skid-resistant surface

	Expected Performance	
Treatment	Treatment Life (yr)	Pavement Life Extension (yr)
Chip seal		
Single course	3–7	5–6
Double course	5–10	8–10

(Peshkin et al. 2011)



PAAMA
Pennsylvania Association of Asphalt Material Applicators

Background

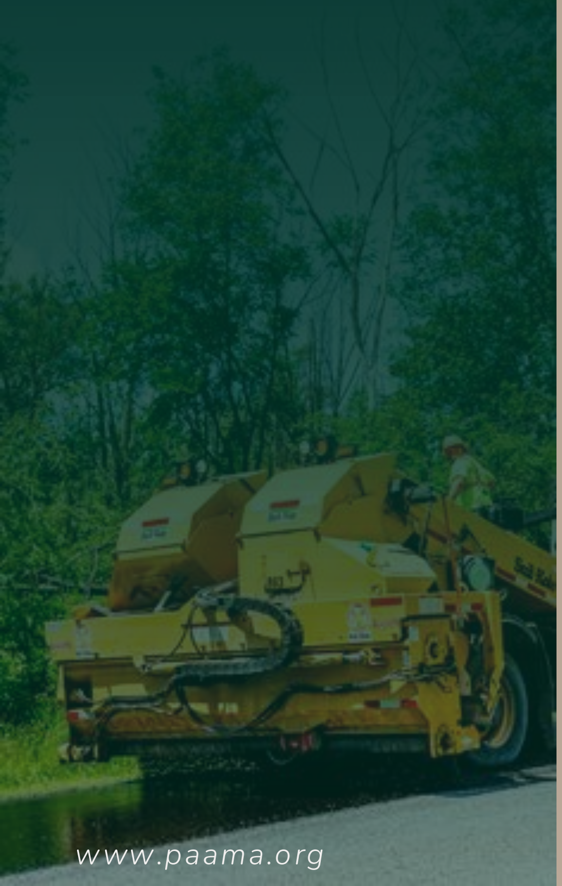
Chip seal design

Determine:

Grade, type, and application rate for a bituminous binder

Given:

Aggregate size and type, surface condition of existing pavement, traffic volume



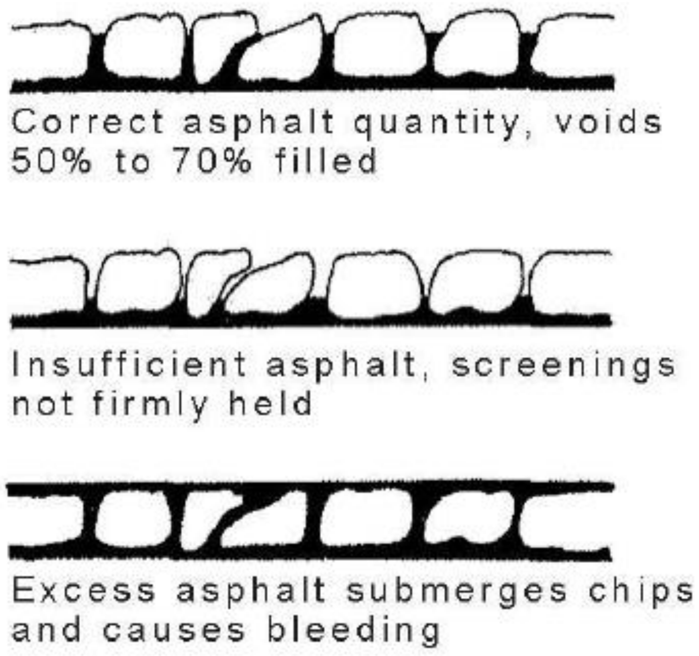
www.paama.org

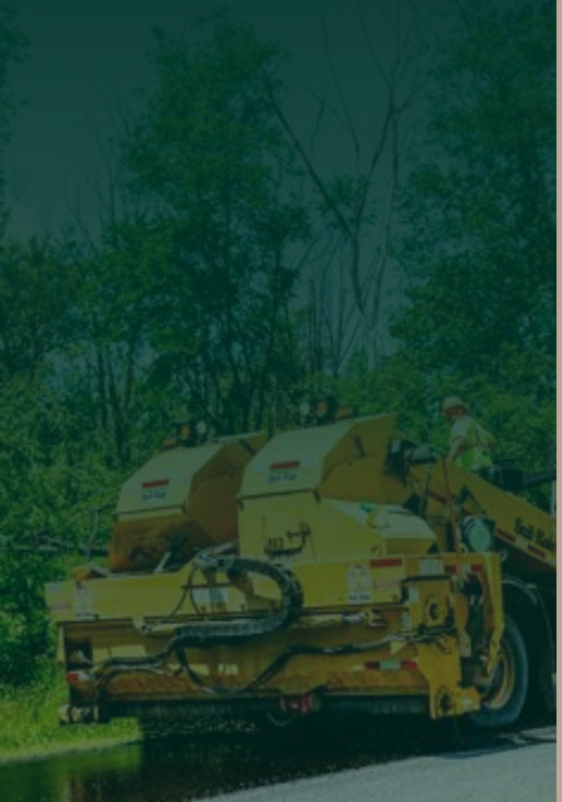
PAAMA
Pennsylvania Association of Asphalt Material Applicators

Background

Design methods target embedment rate

Typically 50-70%



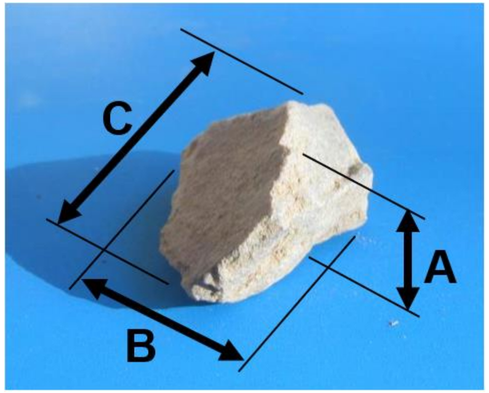


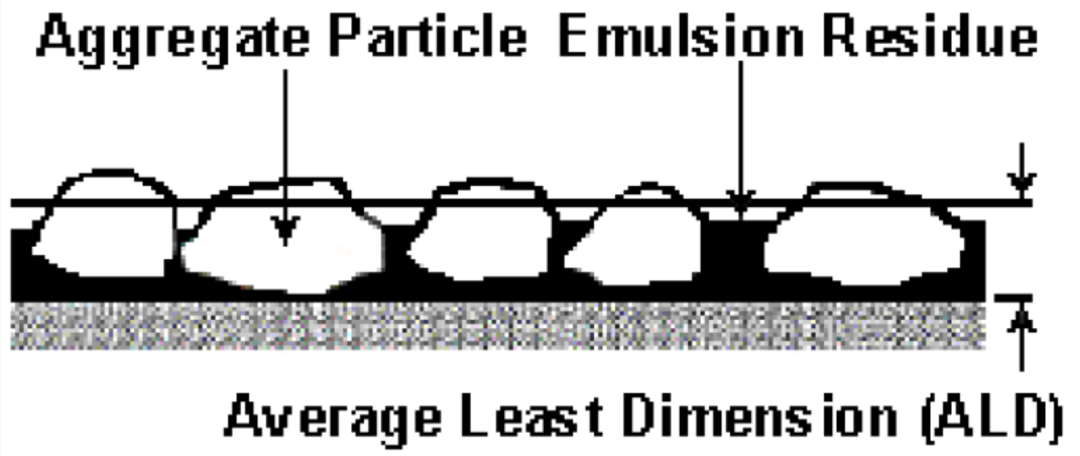
PAAMA
Pennsylvania Association of Asphalt Material Applicators

Background

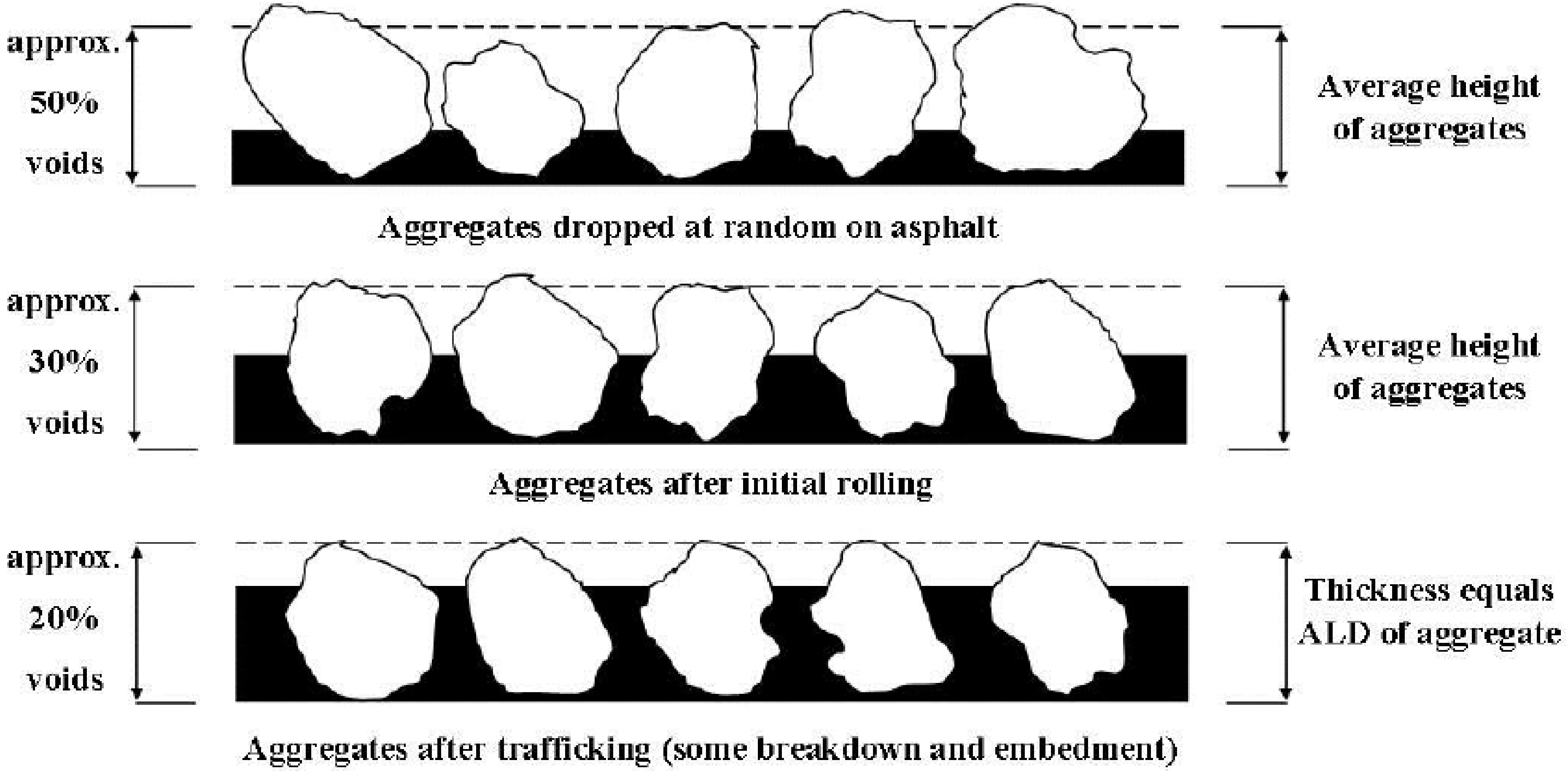
Percent embedment (PE) is the percentage of the average least dimension (ALD) of the aggregate enveloped by the binder

ALD can be measured directly or computed based on particle size distribution and Flakiness Index





Background



Pennsylvania Association of Asphalt Material Applicators

Background

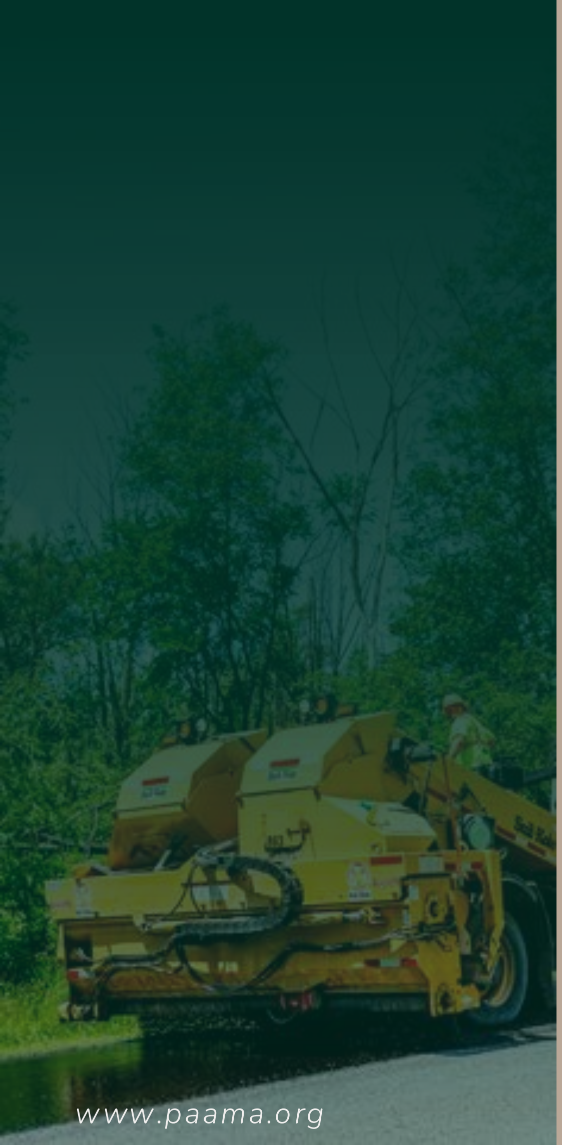
Proper embedment is a key component but field verification is not standardized

Inspectors often rely on visual inspection

PAAMA
Pennsylvania Association of Asphalt Material Applicators

Objective

Identify, adapt, or develop a rapid field test method(s) to determine the percentage embedment depth of a uniformly placed chip seal of known aggregate gradation.



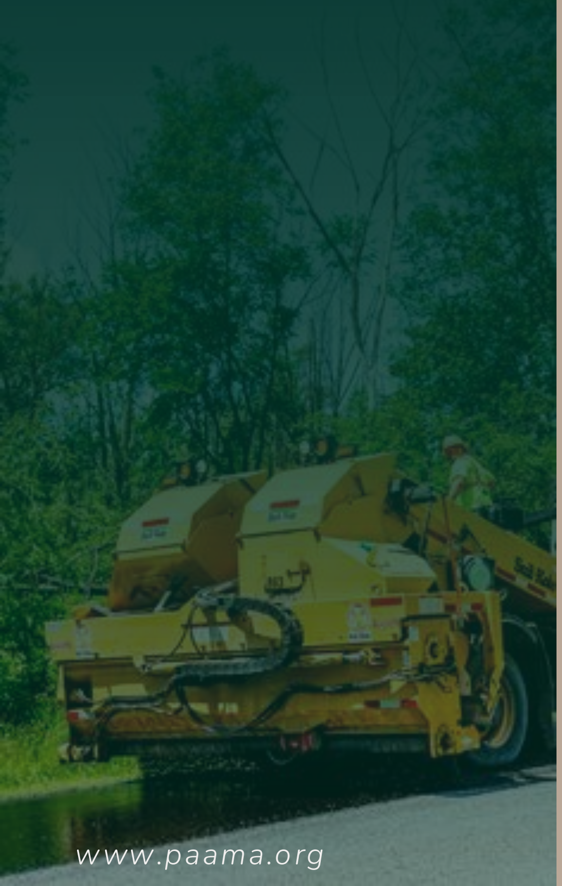
PAAMA
Pennsylvania Association of Asphalt Material Applicators

Research Approach

Phase I
- Task 1: Literature Review
- Task 2: Preliminary Evaluation
- Task 3: Interim Report 1

Phase II
- Task 4: Development of Work Plan
- Task 5: Interim Report 2

Phase III
- Task 6: Work Plan Execution
- Task 7: Interim Report 3
- Task 8: Technical Memorandum

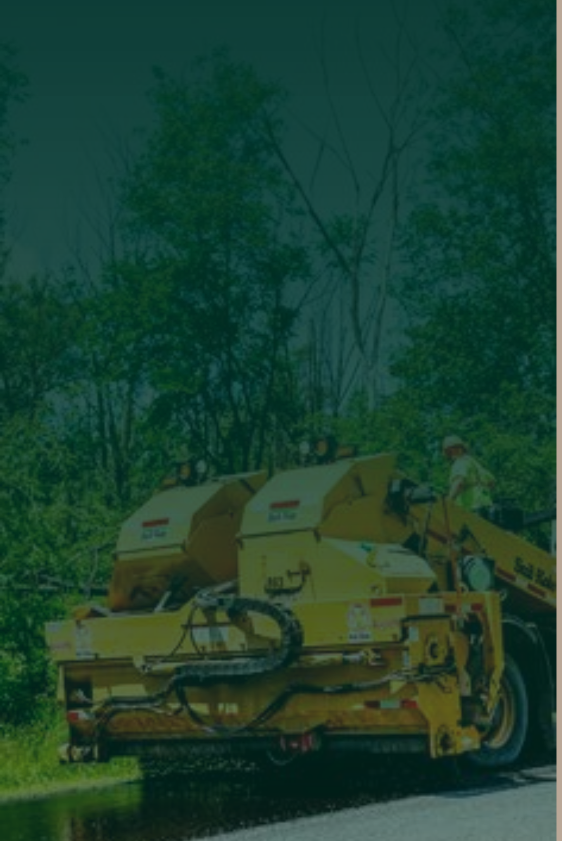


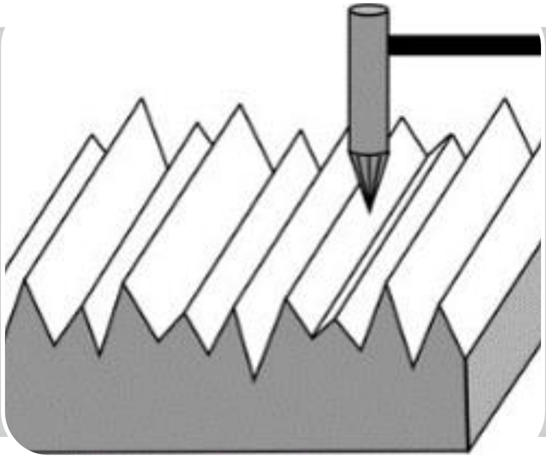
PAAMA
Pennsylvania Association of Asphalt Material Applicators

Literature Review

Identified several methods that could be used/adapted to measure embedment

- Volumetric
- Stylus profiling
- Laser-based
- Imagery-based





VOLUMETRIC

(sand patch, grease patch, putty impression, outflow meter)

PROS:

Very accurate, inexpensive

CONS:

Operator-dependent, time consuming

STYLUS PROFILING

PROS:

Very accurate, inexpensive

CONS:

Limited measuring range,

LASER-BASED DEVICES

(stationary, walking, high-speed, LiDAR)

PROS:

High resolution, large coverage area, fast, repeatable

CONS:

Higher cost, sensitivity to external variables

IMAGERY-BASED METHODS

(cross-section CRP, SLP)

PROS:

Accurate, potential for smartphone use

CONS:

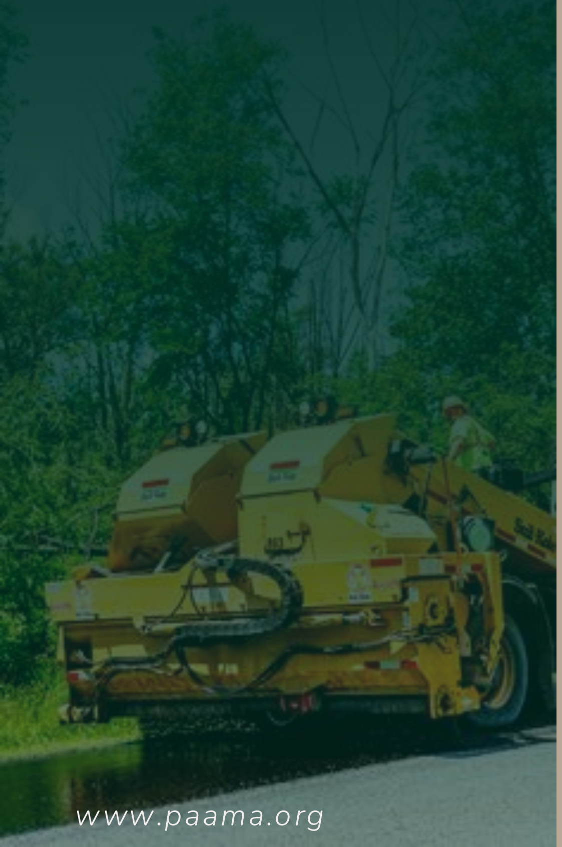
Data processing, sensitivity to external variables

Literature and Practice Review

State DOT specifications

Most agencies maintain a standard specification for chip seals

22 agencies explicitly mention embedment
- “Proper” or “adequate” embedment
- Minimum number of roller passes



Arizona DOT	70% (80% above 4,000 ft elevation)
Illinois DOT	50 – 70%. Provides materials application rate table based on aggregate.
Nevada DOT	50 – 70%
Ohio DOT	2/3 of the stone chip height
Pennsylvania DOT	May require fog seal if less than 50%
Rhode Island DOT	50%
Utah DOT	50% before rolling; 70% after rolling
Wyoming DOT	65 – 75% by measuring macrotexture depth

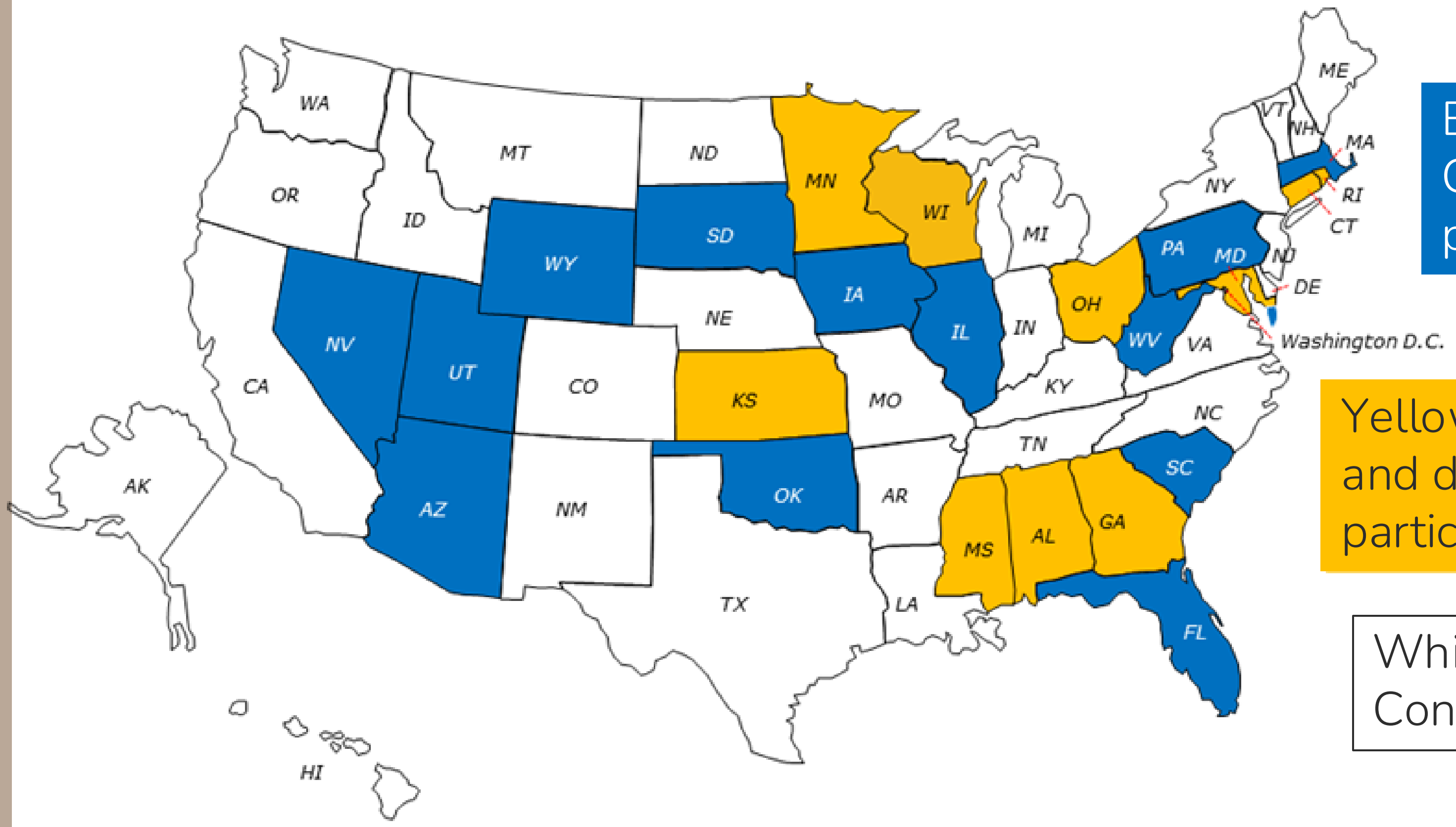
PAAMA
Pennsylvania Association of Asphalt Material Applicators

Literature and Practice Review

Targeted survey

31 Responses:

- State agencies
- Contractors
- Local agencies
- Material suppliers



Blue - Contacted and participated

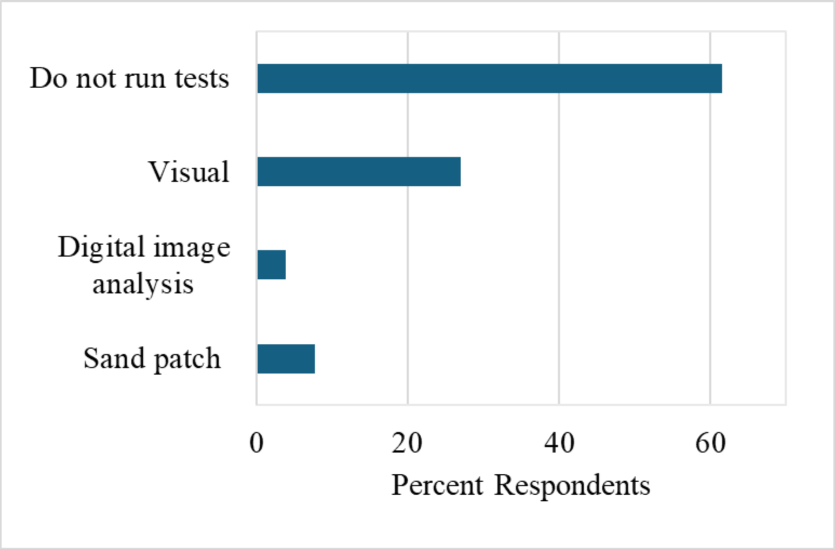
Yellow - Contacted and did not participate

White - Not Contacted

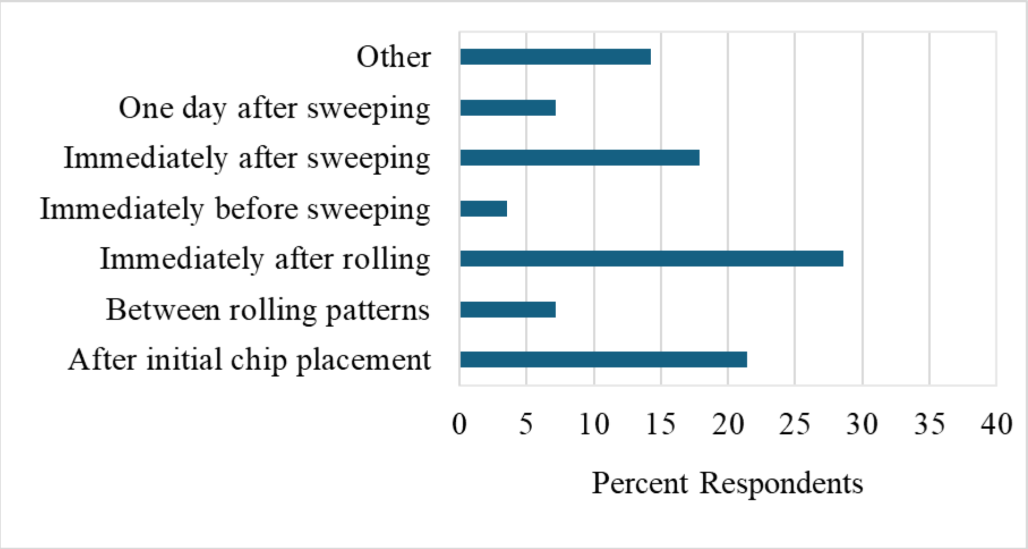
PAAMA
Pennsylvania Association of Asphalt Material Applicators

Literature and Practice Review

Tests used to determine aggregate embedment



Time when chip seal embedment is measured



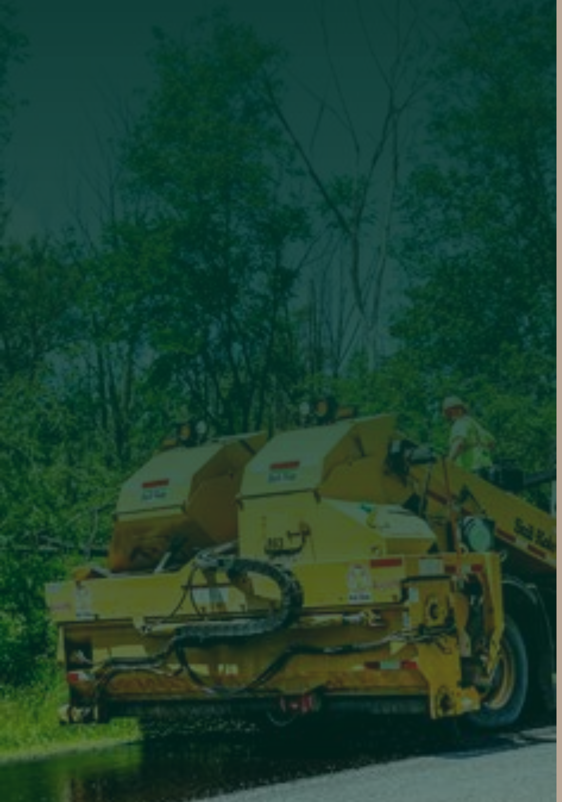
Takeaways from Task 1

Embedment is a key component but rarely measured
Various tests available that could serve this purpose

Range in complexity, accuracy, cost
Relationship between texture and embedment

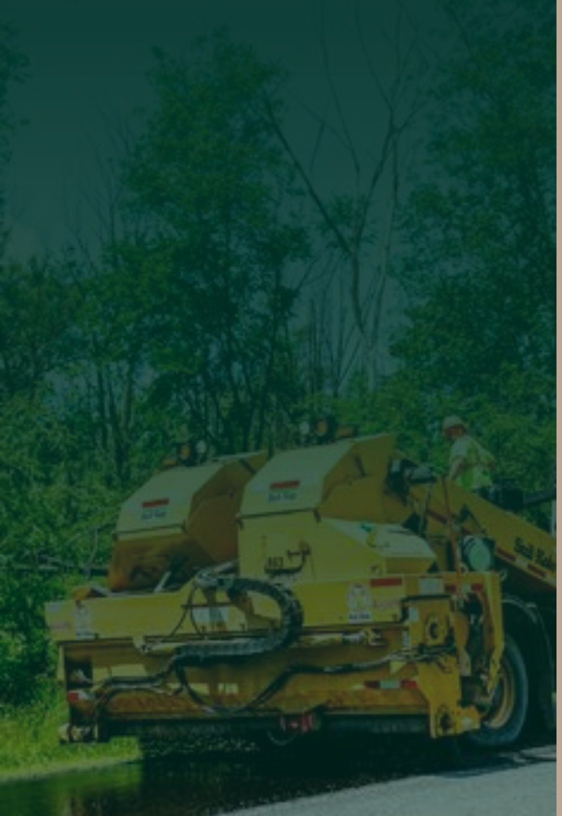
Proposed test has to be:

- Effective over range of embedment values
- Able to measure at different stages of construction
- PRACTICAL



PAAMA
Pennsylvania Association of Asphalt Material Applicators

Preliminary Evaluation



- Rating system
- Based on 5 categories
  - Accuracy
  - Simplicity
  - Cost
  - Time
  - Practicality
- 1 to 5 scale; 1 = worst, 5 = best

SELECTED TESTS:
- Sand patch
- Laser Texture Scanner (LTS)
- Circular Texture Meter (CTM)
- Photogrammetry

Preliminary Evaluation

Test methods have different parameters (MTD, MPD, etc.)

Can they capture the relationship between the parameter and the percent embedment?

PAAMA
Pennsylvania Association of Asphalt Material Applicators

Preliminary Evaluation

<u>Stage 1</u>

Reference sample

Uniform particles of known dimensions embedded to a known depth

Not a true representation of a chip seal

Objective is to compare measurements

PAAMA
Pennsylvania Association of Asphalt Material Applicators

Preliminary Evaluation

<u>Stage 2</u>

Aggregate samples

Use actual chip seal aggregates of different sizes

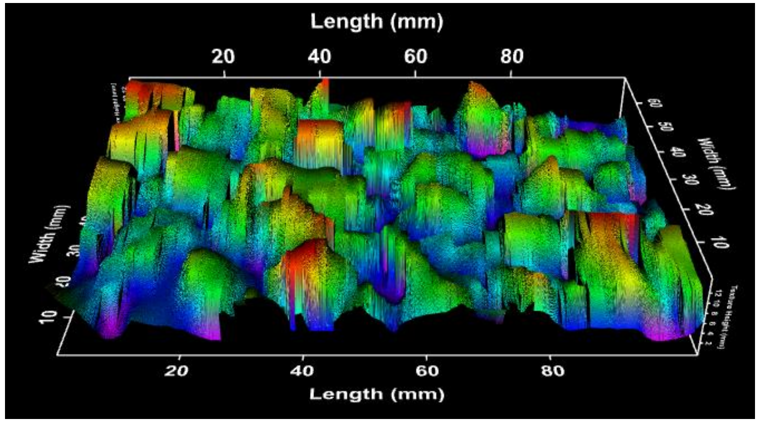
Fabricate to design embedment (AASHTO R 102)

Determine ALD based on gradation and flakiness index

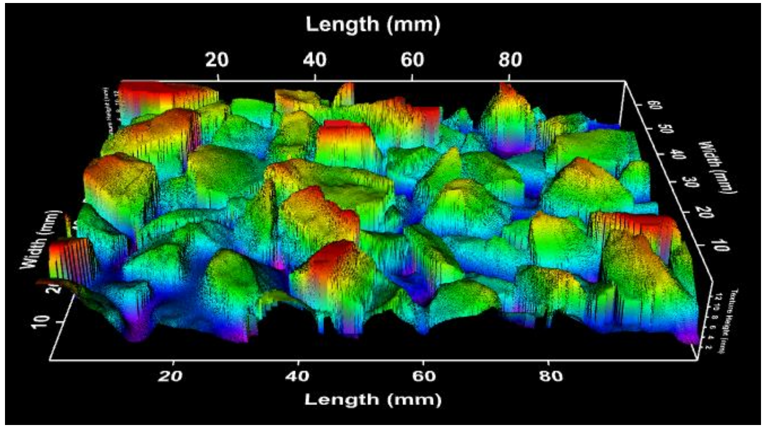
PAAMA
Pennsylvania Association of Asphalt Material Applicators

Preliminary Evaluation

Testing - LTS



20 scan lines
MPD = 4.72 mm
Test time: 1.5 minutes

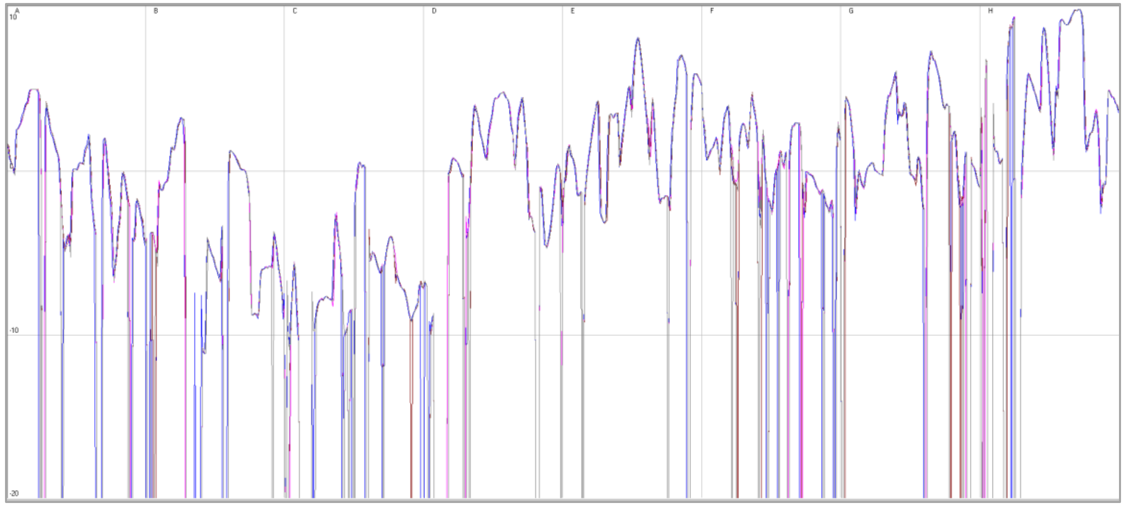


100 scan lines
MPD = 4.85 mm
Test time: 7.5 minutes

PAAMA
Pennsylvania Association of Asphalt Material Applicators

Preliminary Evaluation

Testing - CTM

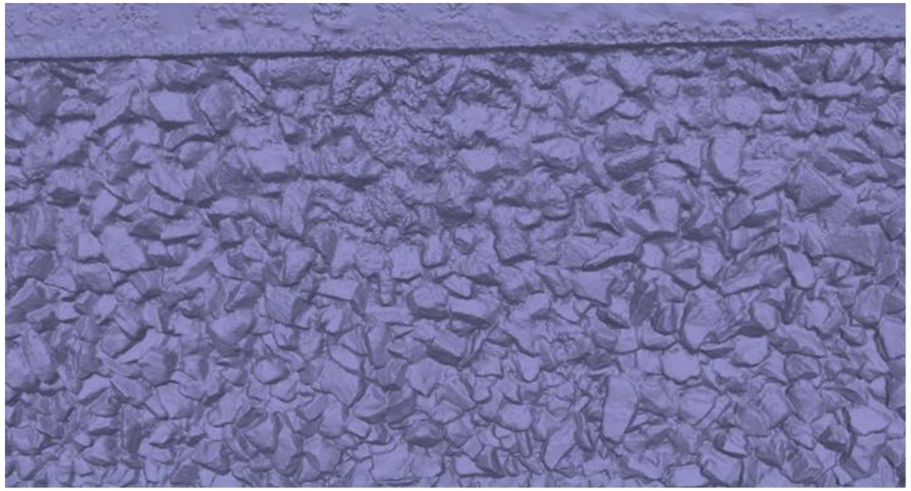


Circular profile is highly repeatable

PAAMA
Pennsylvania Association of Asphalt Material Applicators

Preliminary Evaluation

Testing - Photogrammetry



Digital Elevation Model (DEM) produced to measure maximum and minimum heights within a given neighborhood

PAAMA
Pennsylvania Association of Asphalt Material Applicators

Preliminary Evaluation

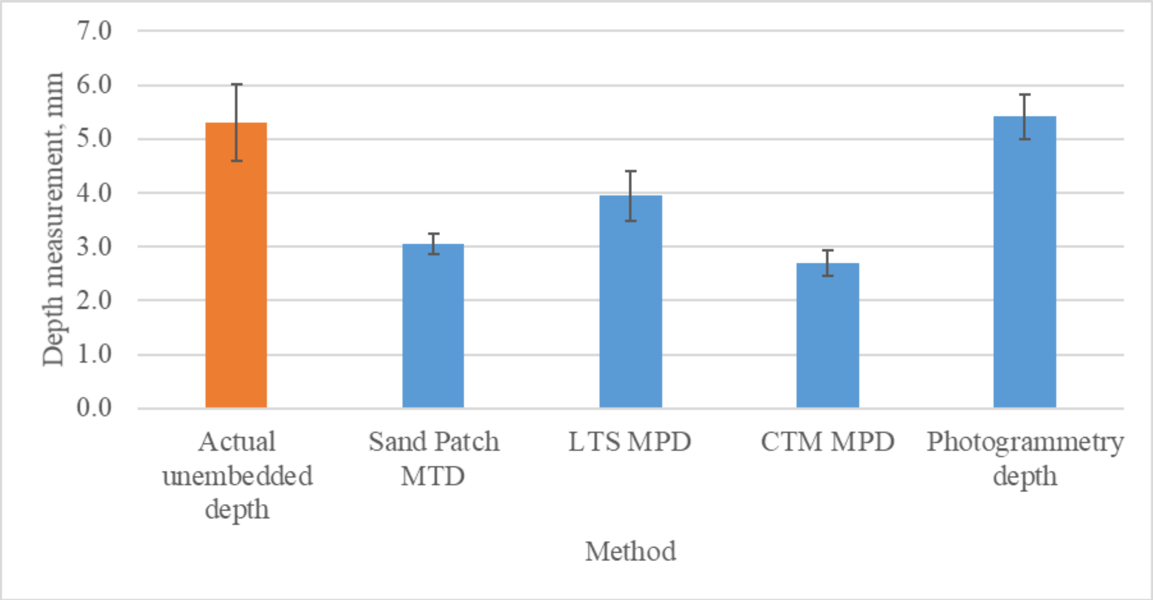
Testing – Sand Patch

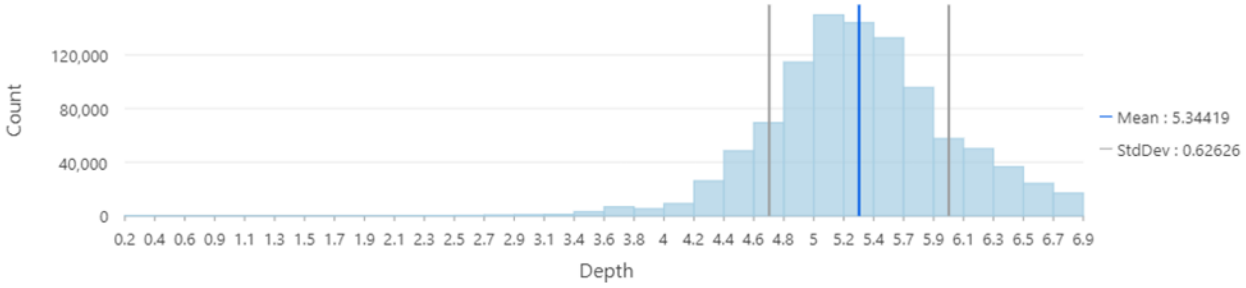
Tried to match same locations as LTS measurements

Varied volume of glass beads depending on aggregate size

Preliminary Evaluation

Results – Reference sample





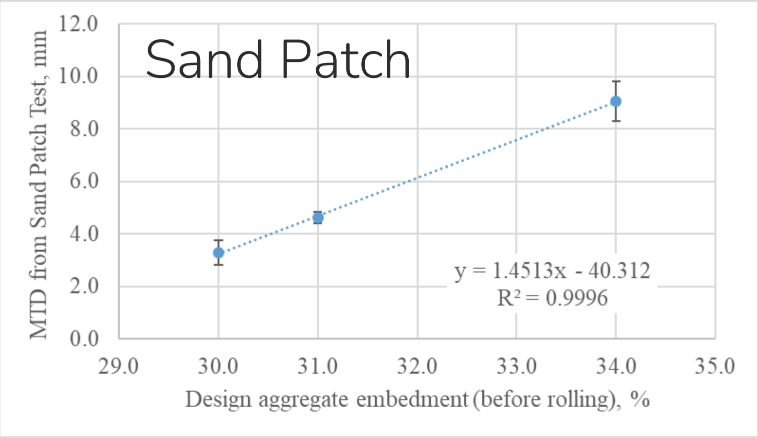
Photogrammetry is closest to actual unembedded depth

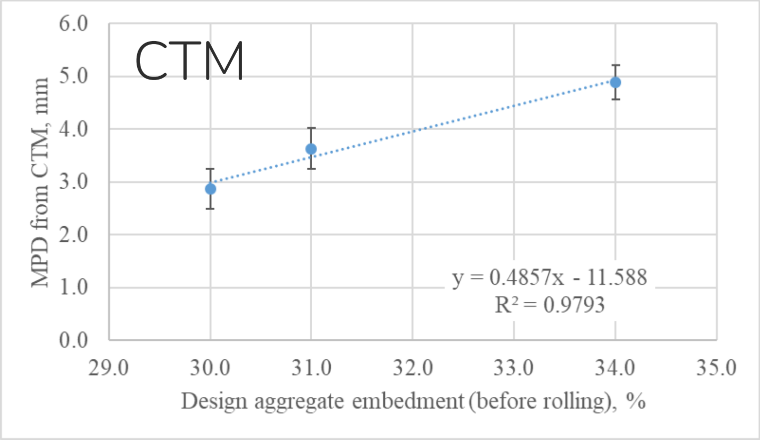
It also generates a depth distribution

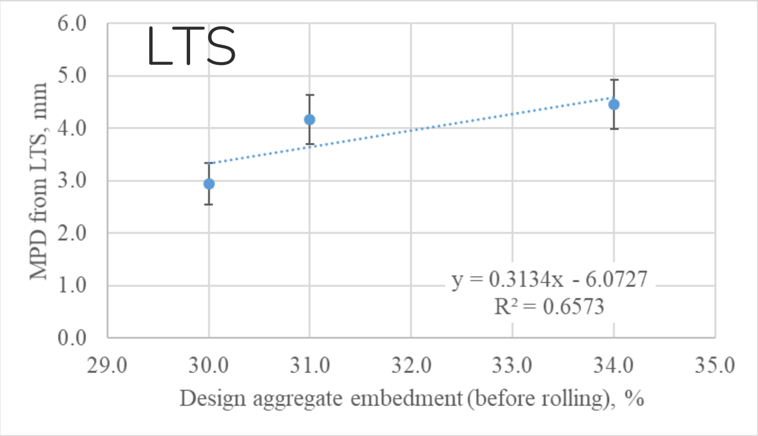
PAAMA
Pennsylvania Association of Asphalt Material Applicators

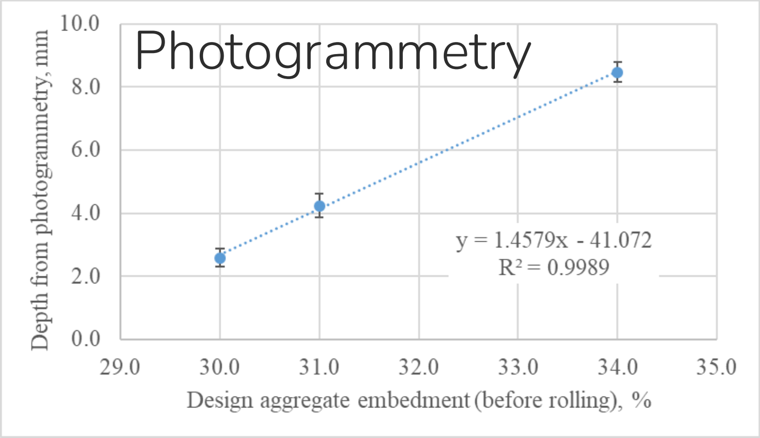
Preliminary Evaluation

Results – Aggregate Samples

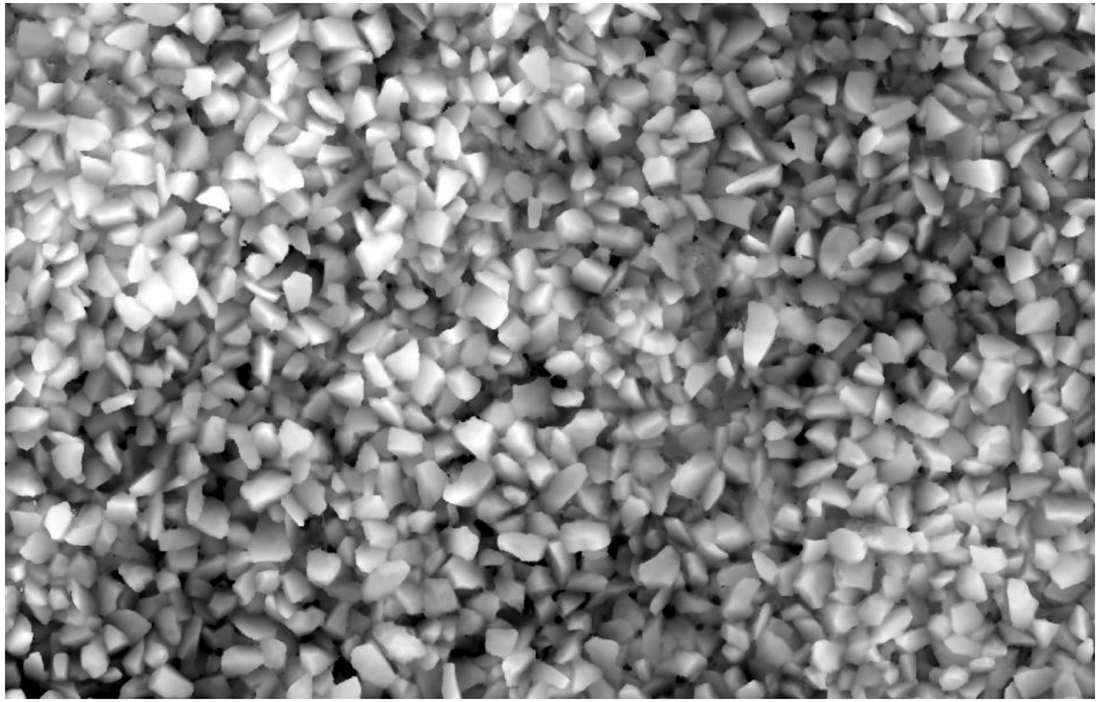








Preliminary Evaluation

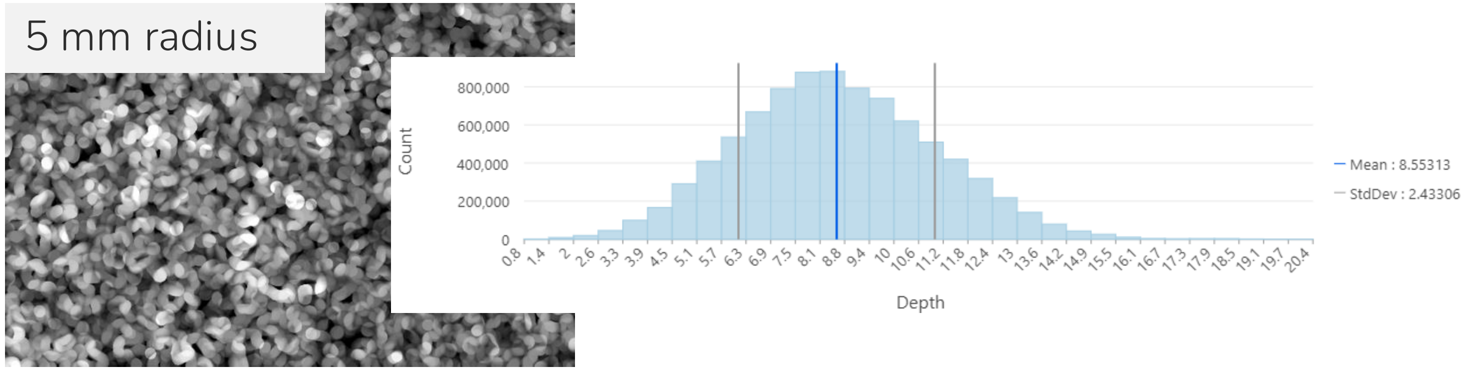


DEM from smartphone images
ALD = 9.4 mm

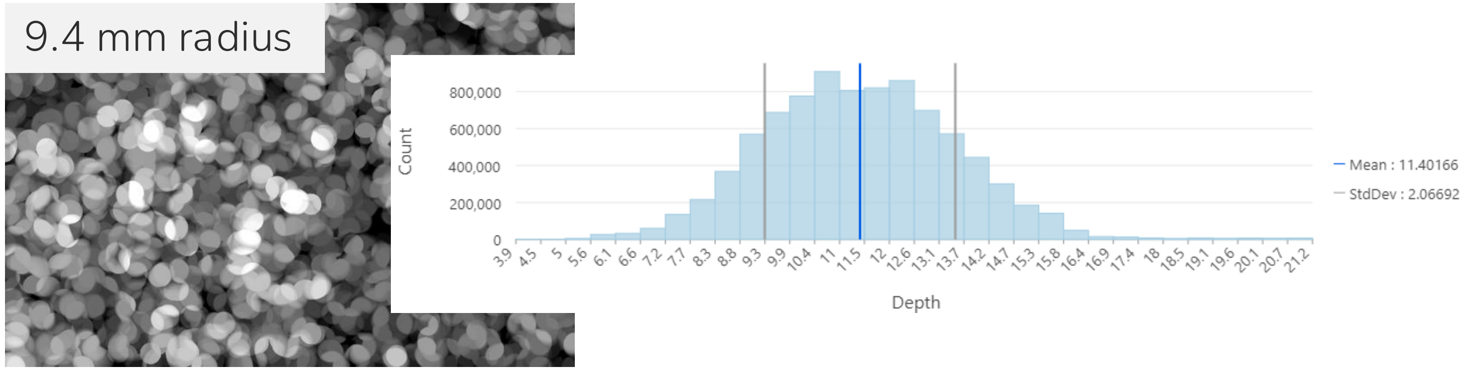
Pennsylvania Association of Asphalt Material Applicators

Preliminary Evaluation

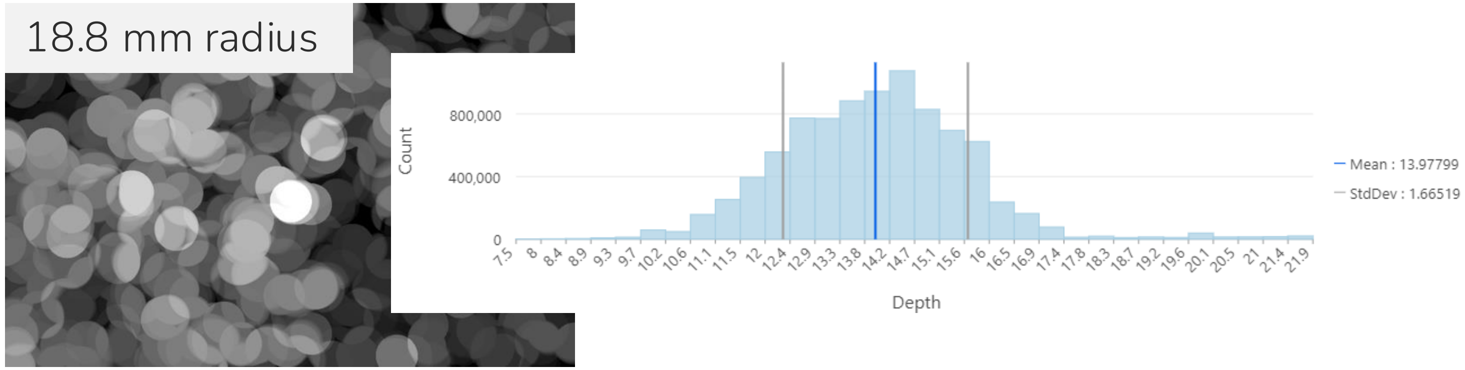
5 mm radius



9.4 mm radius



18.8 mm radius



PAAMA
Pennsylvania Association of Asphalt Material Applicators

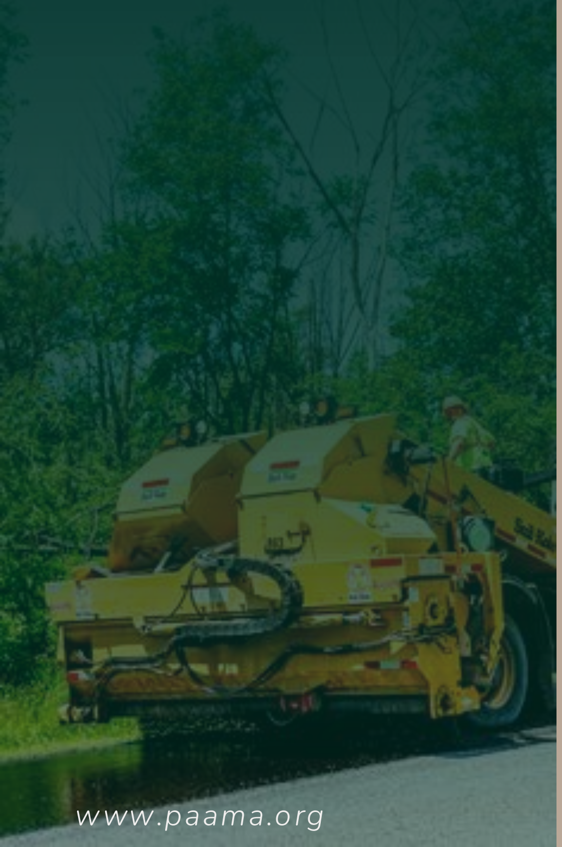
Takeaways from Task 2

All methods capture the relationship between testing parameter and embedment

Sand patch and photogrammetry show better correlation

LTS shows more variability

With some refinement, they may be used for field testing



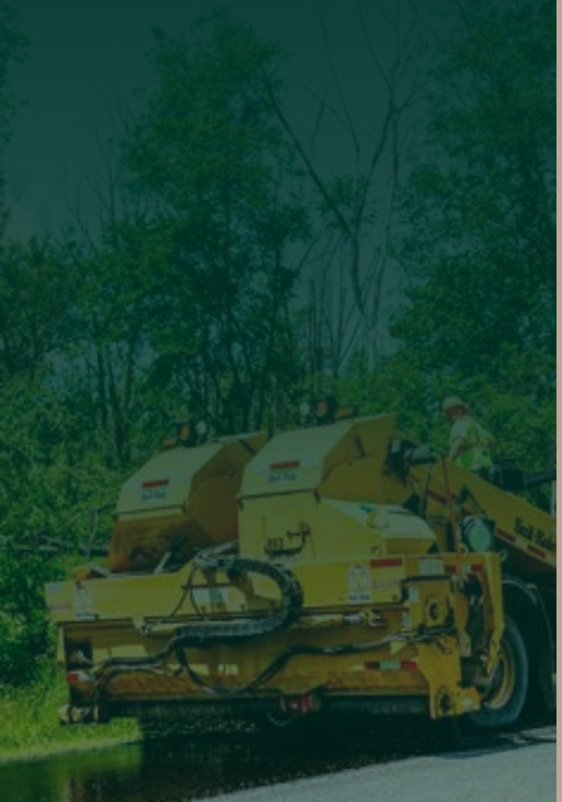
PAAMA
Pennsylvania Association of Asphalt Material Applicators

Phase III Work Plan

Laboratory Experimental Plan

3^3 full randomized factorial design
Analyze individual and combined effects of each factor on the response

Factor	Levels	Response
Aggregate gradation	Types A, B, and C	Difference between known and measured embedment
Embedment level	40%, 70%, 90%	
Aggregate color	Light, medium, dark	



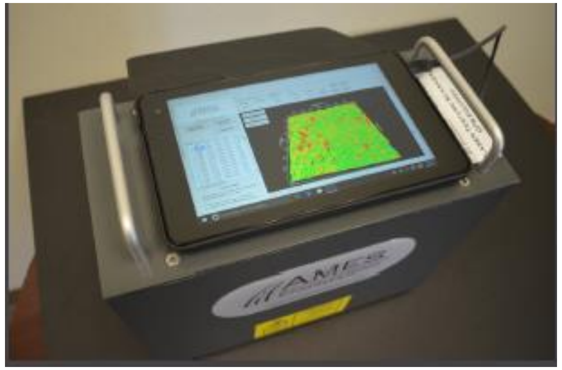
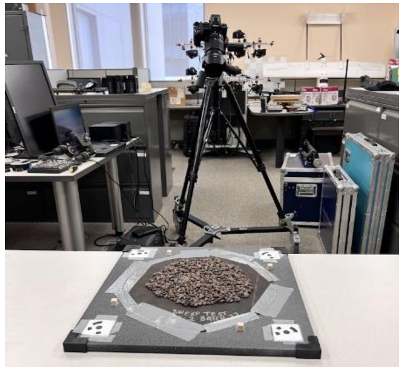
www.paama.org

Phase III Work Plan

Laboratory Experimental Plan

Consider four test methods

Test	Category	Equipment Details
Sand patch	Volumetric	Known volume of glass beads, spreader tool, measuring tape.
Laser scanning	Laser-based	Laser texture scanner
Photogrammetry	Imagery-based	DSLR and smartphone cameras
Structured light projection	Imagery-based	Blue light technology 3D scanner

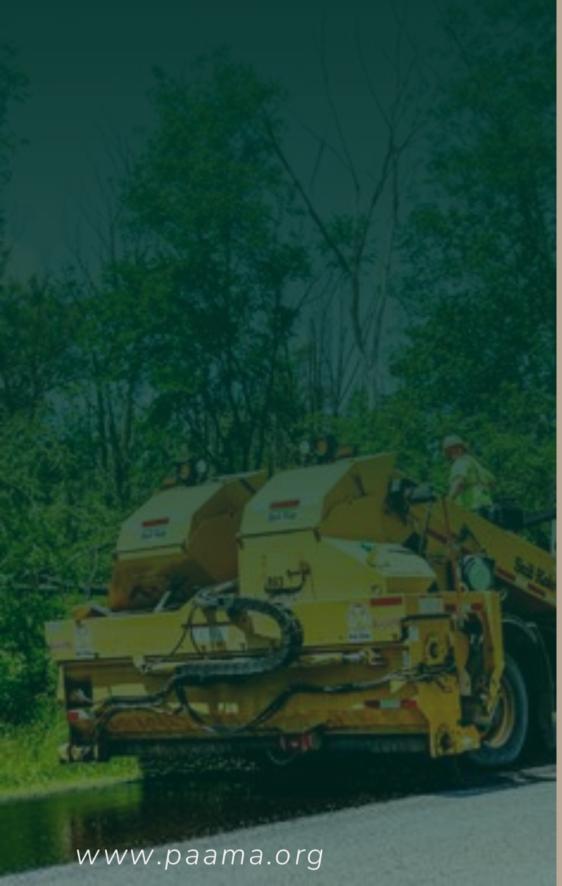

PAAMA
Pennsylvania Association of Asphalt Material Applicators

Phase III Work Plan

Field Evaluation

Identify modifications that may be needed to transition from controlled setting to an outdoor environment

Region	Possible State	Notable characteristics
Southeast	Texas	Wet-no freeze climate, extensive use of hot-applied binder
	Alabama or South Carolina	Wet-no freeze climate, use of lightweight aggregate
Midwest	North Dakota or South Dakota	Dry-freeze climate, typically low traffic applications
Rocky Mountain West	New Mexico	Dry-no freeze climate, use of RAP aggregate
	Arizona	Dry-no freeze climate, high traffic applications
Northeast	Massachusetts or New Hampshire	Wet-freeze climate, use of rubber chip seals



PAAMA
Pennsylvania Association of Asphalt Material Applicators

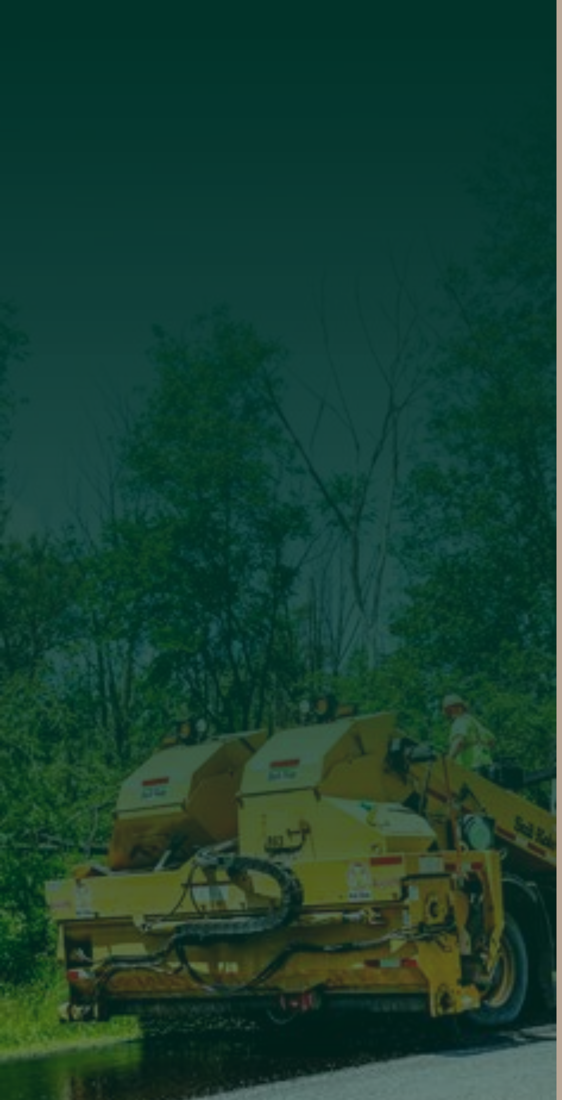
Phase III Work Plan

Performance Evaluation

Develop and incorporate approach to assess chip seal performance based on percent embedment

Materials	Binder application rate	Performance Evaluation	
		Aggregate loss	Bleeding
Two distinct combinations of aggregate gradation and aggregate color. One source of emulsified asphalt.	Design (as determined by AASHTO R 102) • Low • High	Percent loss by weight of aggregate and visual assessment.	Macrotexture and visual assessment.

PAAMA
Pennsylvania Association of Asphalt Material Applicators



Disclaimer

This investigation is sponsored by the Transportation Research Board (TRB) under the National Cooperative Highway Research Program (NCHRP) Program. Any opinions and conclusions expressed or implied in the resulting research products in this presentation are those of the individuals and organizations who performed the research and are not necessarily those of TRB; the National Academies of Sciences, Engineering, and Medicine; the Federal Highway Administration (FHWA); or NCHRP sponsors. Data reported are work in progress. Contents of this research presentation may have not been reviewed by the NCHRP project panel, nor do they constitute a standard, specification, or regulation. All data and copyrights are owned by the National Academy of Sciences.

PAAMA
Pennsylvania Association of Asphalt Material Applicators

2024 Annual Conference

Questions?

www.paama.org