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Development of a Field Test to Determine Chip Seal Aggregate Embedment

NCHRP Project No. 10-124

UNIVERSITY OF ARKANSAS

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Research Team

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- Co-PI: Andrew Braham, University of Arkansas
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- Scott Shuler, Shuler Consultants

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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

Treatment	Expected Performance	
	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)

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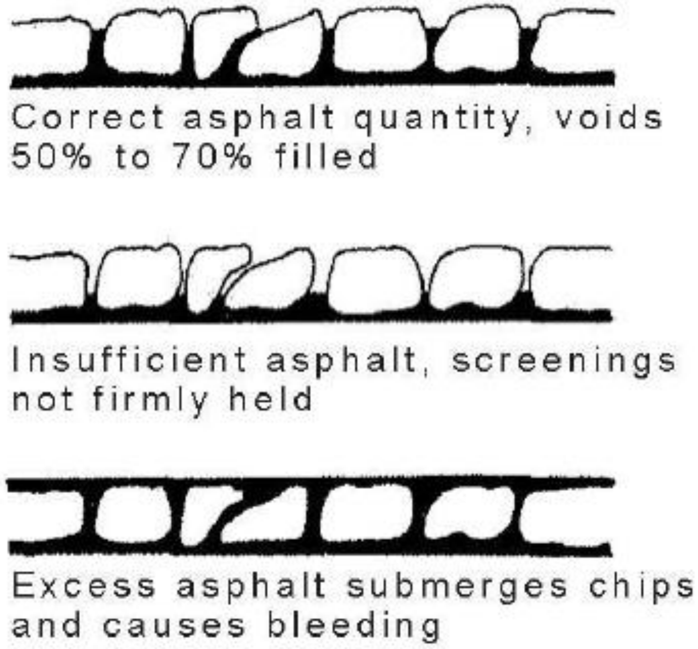
Background

- Chip Seal Design

Determine:	Given:
Grade, type, and application rate for a bituminous binder	Aggregate size and type, surface condition of existing pavement, traffic volume

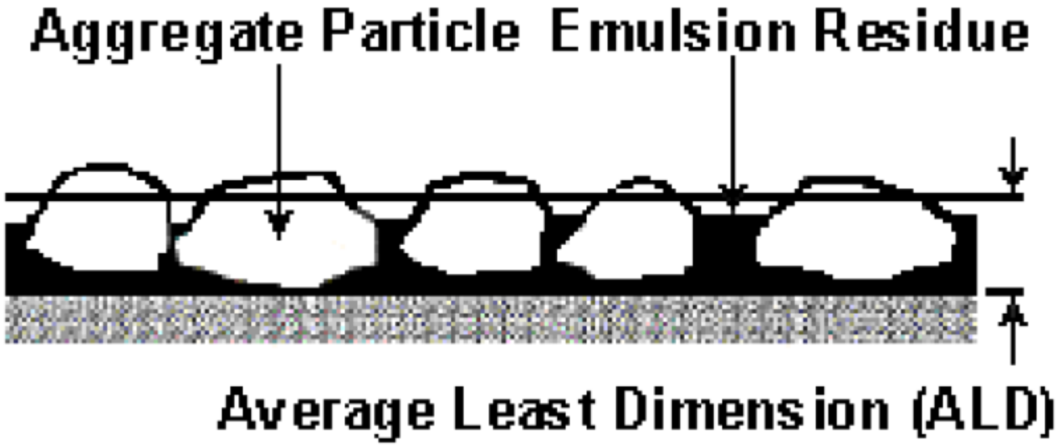
Background

- Design methods target embedment rate
  - Typically 50-70% after one year

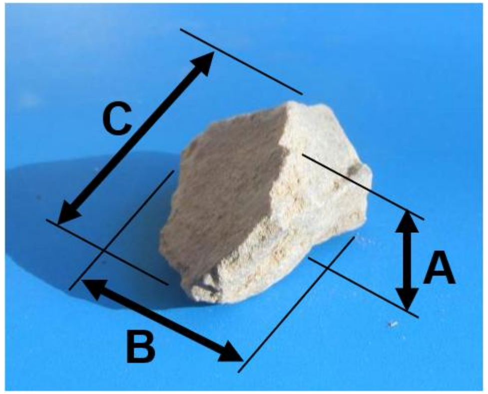


Background

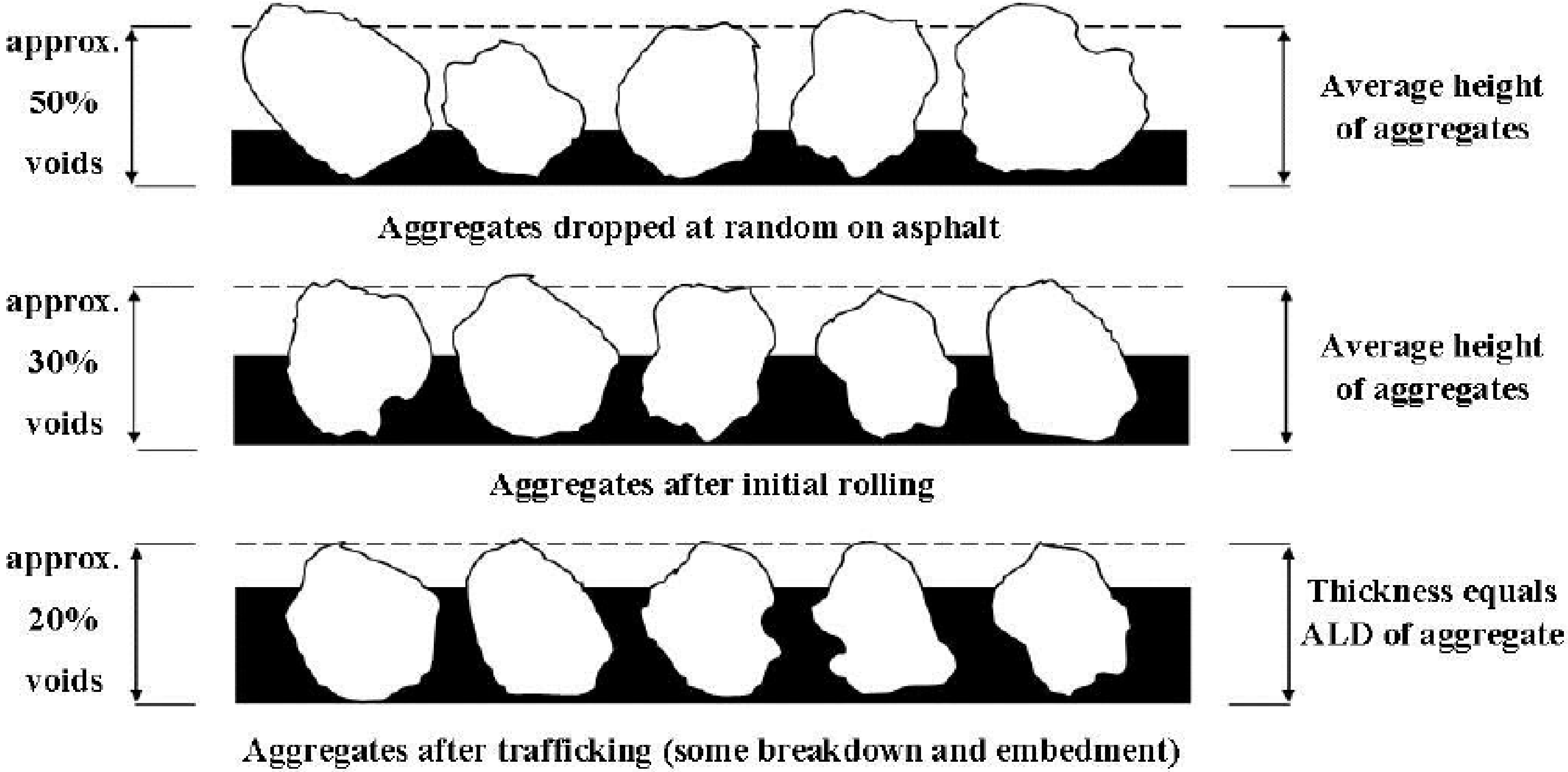
- Percent embedment (PE): percentage of average least dimension (ALD) of aggregate enveloped by the binder



- ALD can be
  - Measured directly
  - Computed from gradation, flakiness Index



Background – related to field



Right after chip placement

Right after rolling, before sweeping

Right before release to traffic

After ~1 year

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Background

- Proper embedment
  - Key component
  - Field verification not standardized
  - Inspectors often rely on visual inspection

Objective of NCHRP 10-124

- **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.

Research Approach

Phase I

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

Complete

Phase II

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

Complete

Phase III

In progress

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

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Phase III Work Plan

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Laboratory Experimental Plan

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

Factor	Levels	Response
Aggregate gradation	Types A, B, and C	Difference between known and measured embedment
Embedment level	Design, Design-20%, Design+20%	
Aggregate color	Light, medium, dark	

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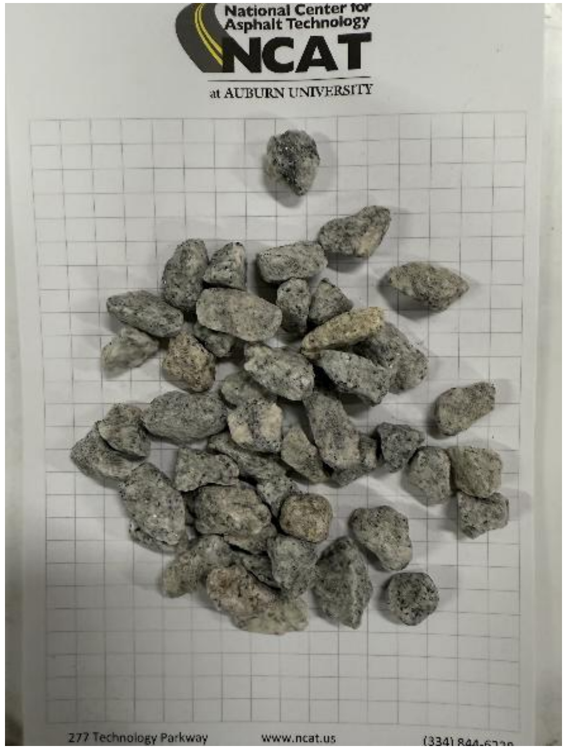
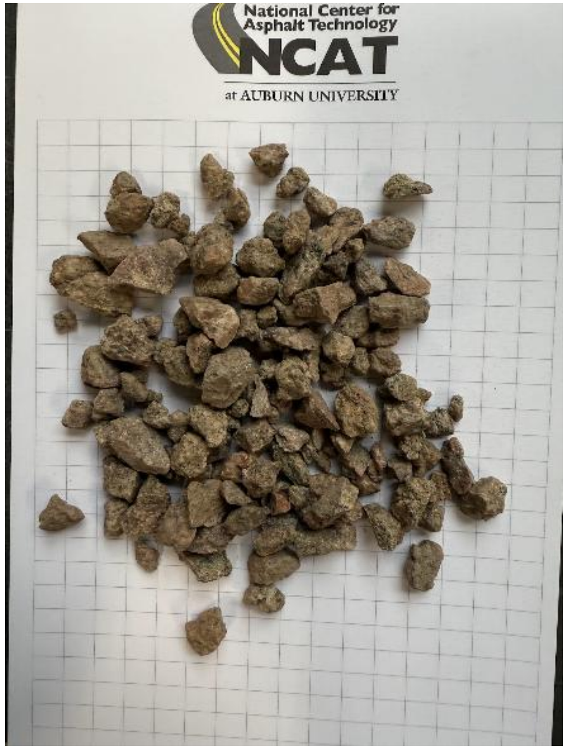
Laboratory Experimental Plan

- Three aggregate sources



Light
Georgia granite



Medium
New Mexico sandstone

Dark
Alabama RAP

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Laboratory Experimental Plan

- Gradations → all three sources fractionated to meet actual

Sieve size	Passing, %					
	Type A - Coarse		Type B - Medium		Type C - Fine	
	Requirement	Actual	Requirement	Actual	Requirement	Actual
¾ in.	100	100	–	100	–	100
½ in.	90 – 100	95	100	100	–	100
⅜ in.	5 – 30	20	90 – 100	95	100	100
No. 4	0 – 10	0	5 – 30	20	90 – 100	95
No. 8	–	0	0 – 10	0	5 – 30	20
No. 16	0 – 2	0	–	0	0 – 10	0
No. 30	–	0	0 – 2	0	–	0
No. 50	–	0	–	0	0 – 2	0

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Laboratory Experimental Plan

- Design (AASHTO R 102)

$$A = \frac{\left\{5.61e \times d \times \left[1 - \left(\frac{W}{62.4G}\right)\right] T\right\} + V}{R}$$

where:

A = emulsified asphalt quantity, gal/yd^2;
5.61 = constant for converting the units to gal/yd^2
e = percent embedment from Figure 1 expressed as a decimal;
d = average mat depth, 1.33 Q/W;
Q = quantity of chips from the board test, lb/yd^2;
W = dry loose unit weight of chips, pcf (see T 19M/T 19, Section 12 on shoveling);
62.4 = unit weight of water, pcf
G = dry bulk specific gravity of chips (see T 84 and T 85);
T = traffic correction factor from Table 1;
V = pavement surface correction factor; and
R = emulsified asphalt residue, expressed as a decimal, e. g., 0.65 = 65 percent.

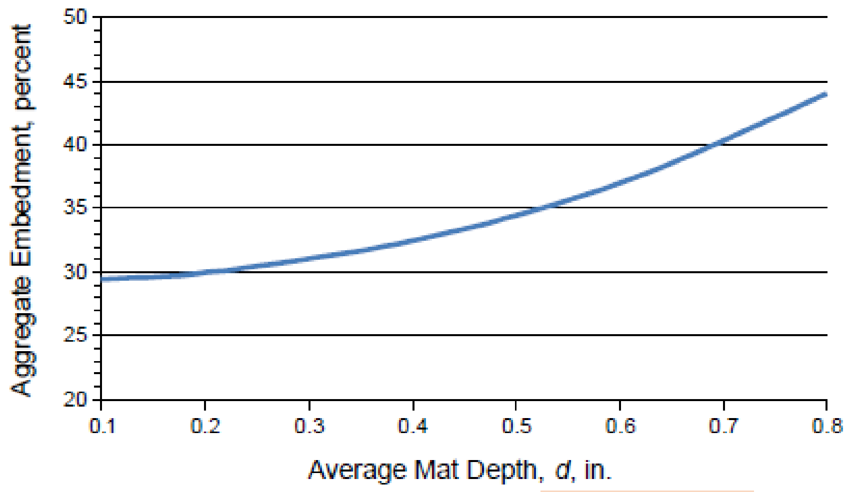

Figure 1—Aggregate Embedment, percent, e (before Rolling)

Used "A" as middle value, then ± 20%

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Laboratory Experimental Plan

Aggregate Embedment

The seal coat design method, the construction operations and considerations for climatic conditions should be aimed at providing adhesion between the asphalt binder and the aggregate and proper embedment of the aggregate into the asphalt film. Improper adhesion and/or inadequate embedment depth will result in loss of coverstone aggregate. Suggested percent embedment depths during the life of seal coats are listed below:

immediately after construction	30 ± 10%
start of cool weather (first year)	35 ± 10%
start of cold weather (first year)	45 ± 10%
after two years of service	70 ± 10%

For low traffic facilities aggregate embedment immediately after construction should be in the range of 30 to 40 percent while 20 to 30 percent embedment is the preferred range for high traffic volume facilities.

Epps et al., 1981

Per Modified Kearby: we're assuming 30% before releasing to traffic

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Sample Preparation

Transitioned to silicon mold

Sample Preparation – Conga Line

Left to right:
Fernando
Brooke
Tanner

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Sample Preparation

50 lb surcharge added for:
- One step beyond sweep test
- “soft” silicon substrate

Rasool providing the muscle

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27 Samples for Photogrammetry

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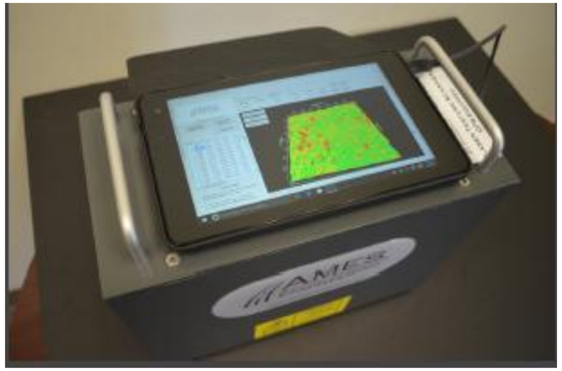
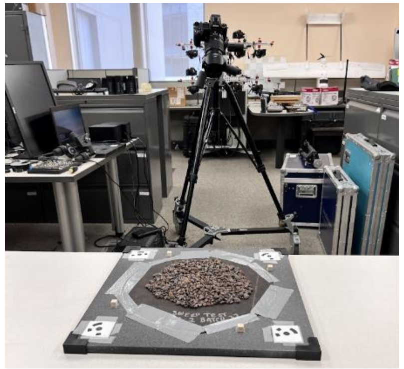
Laboratory Experimental Plan

- Four test methods – in order

Test	Category	Equipment Details
Laser scanning	Laser-based	Laser texture scanner (LTS)
Photogrammetry	Imagery-based	DSLR and smartphone cameras
Structured light projection	Imagery-based	Blue light technology 3D scanner, “Space Spider”
Sand patch	Volumetric	Glass beads, spreader tool, measuring tape.

We’re here





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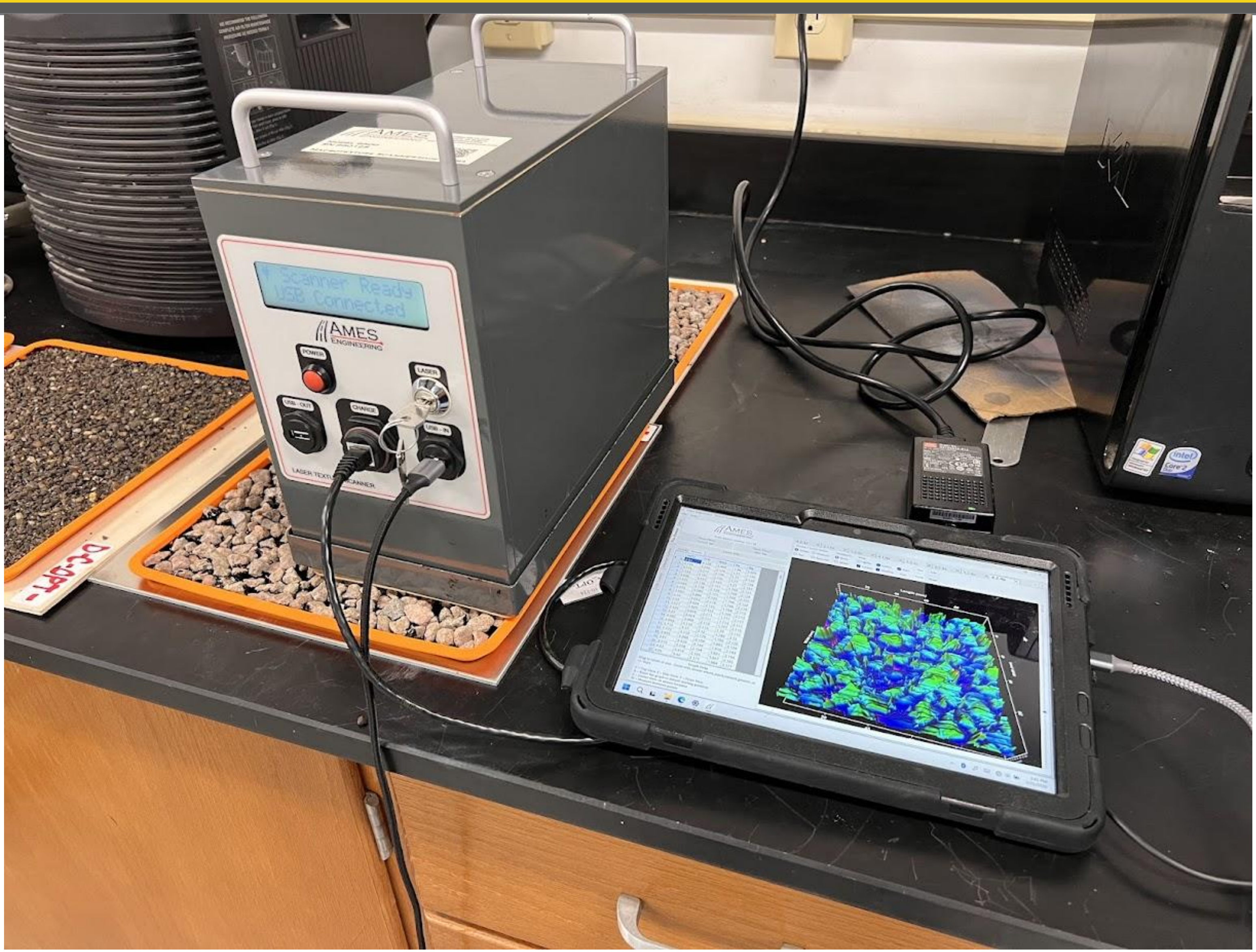
Laser-Based Testing



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Laser-Based Testing – Reflection Issue

- Exposed asphalt emulsion residue "reflection" causes mean profile depth bump in post curing
  - Data filtering – in progress
  - Baby powder / spray paint
- Parallel experimental study
  - Optimal application rate, "light aggregate" for three gradations
- Ran LTS on sample
  - Immediately after fabrication
  - Immediately after seating (no sweeping)
  - After curing and sweeping
  - After spray painting

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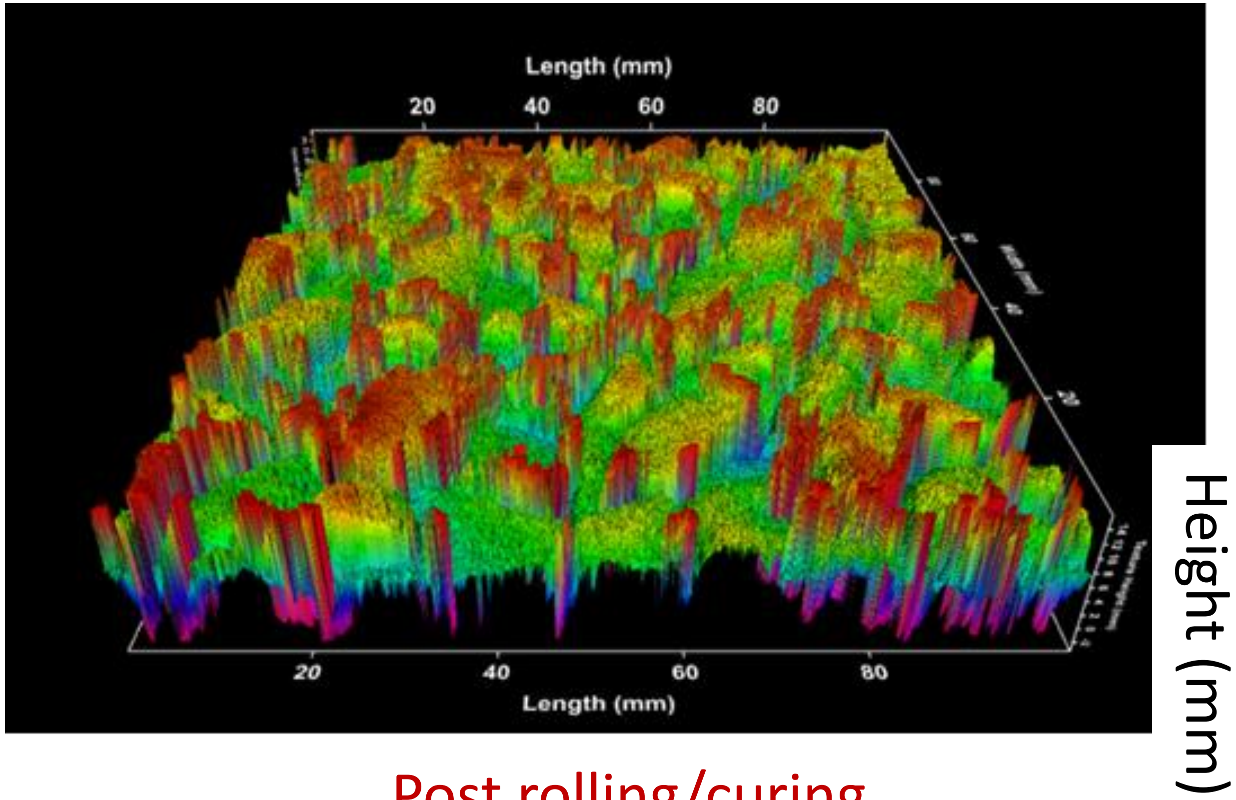
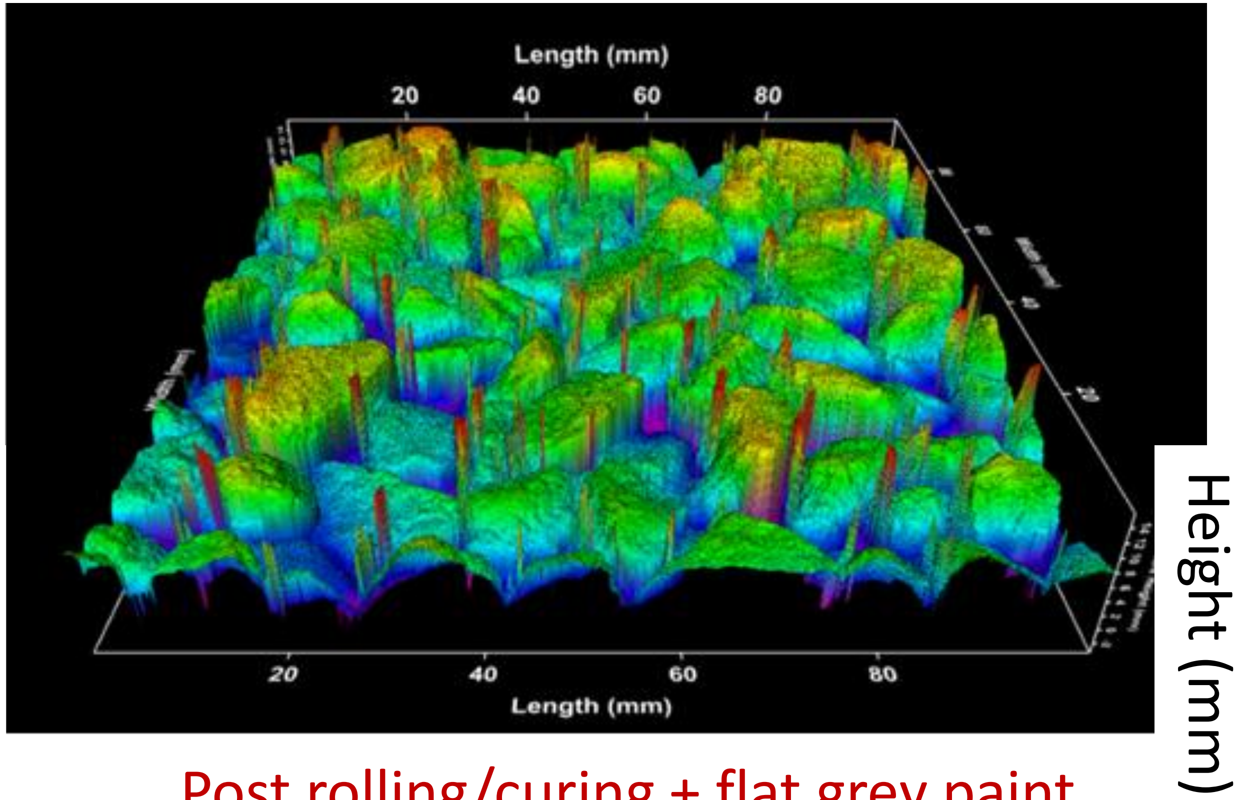
Laser-Based Testing – Reflection Spikes



Post rolling/curing



Post rolling/curing + flat grey paint

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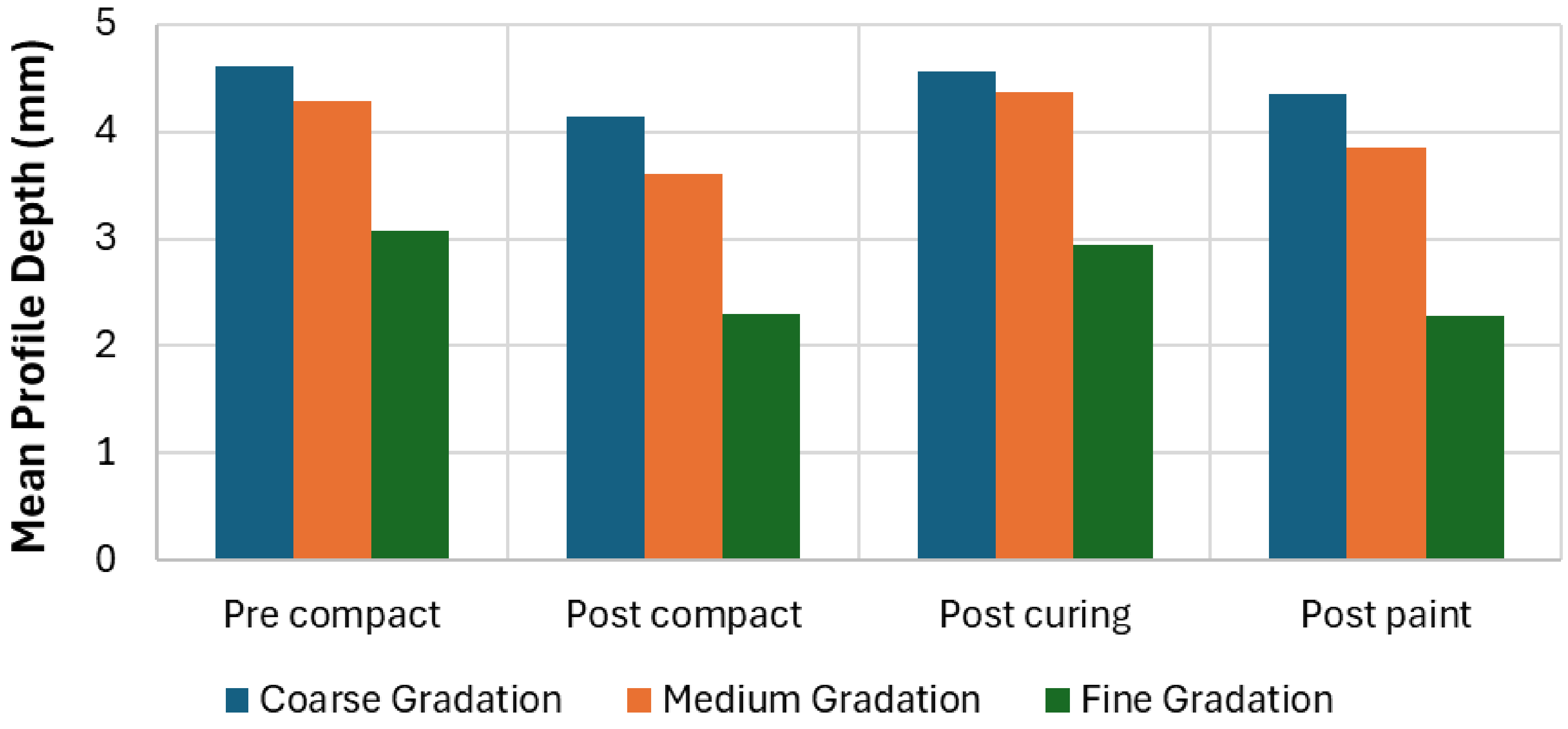
Laser-Based Testing – Mean Profile Depth



Exposed asphalt emulsion residue
“reflection” causes bump in post curing

Photogrammetry Testing

- Four samples manufactured
  - UA produced emulsion
  - Arkansas limestone
- Matches TREAT section
  - LTS, DFT, CTM data collected
- Building test process for photogrammetry with these four samples
- Next: run 27 samples from Alabama

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Moving forward

- Spring 2026
  - Complete lab testing
  - Understand impact of asphalt emulsion application rate, aggregate gradation, aggregate color
  - Recommend top 2-3 tests to run in the field
- Summer 2026
  - Field visits to four regions
  - Collect materials for lab testing and 2-3 tests in field
  - Repeat lab tests and correlate to actual field performance

Questions?

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Questions?

University of Arkansas

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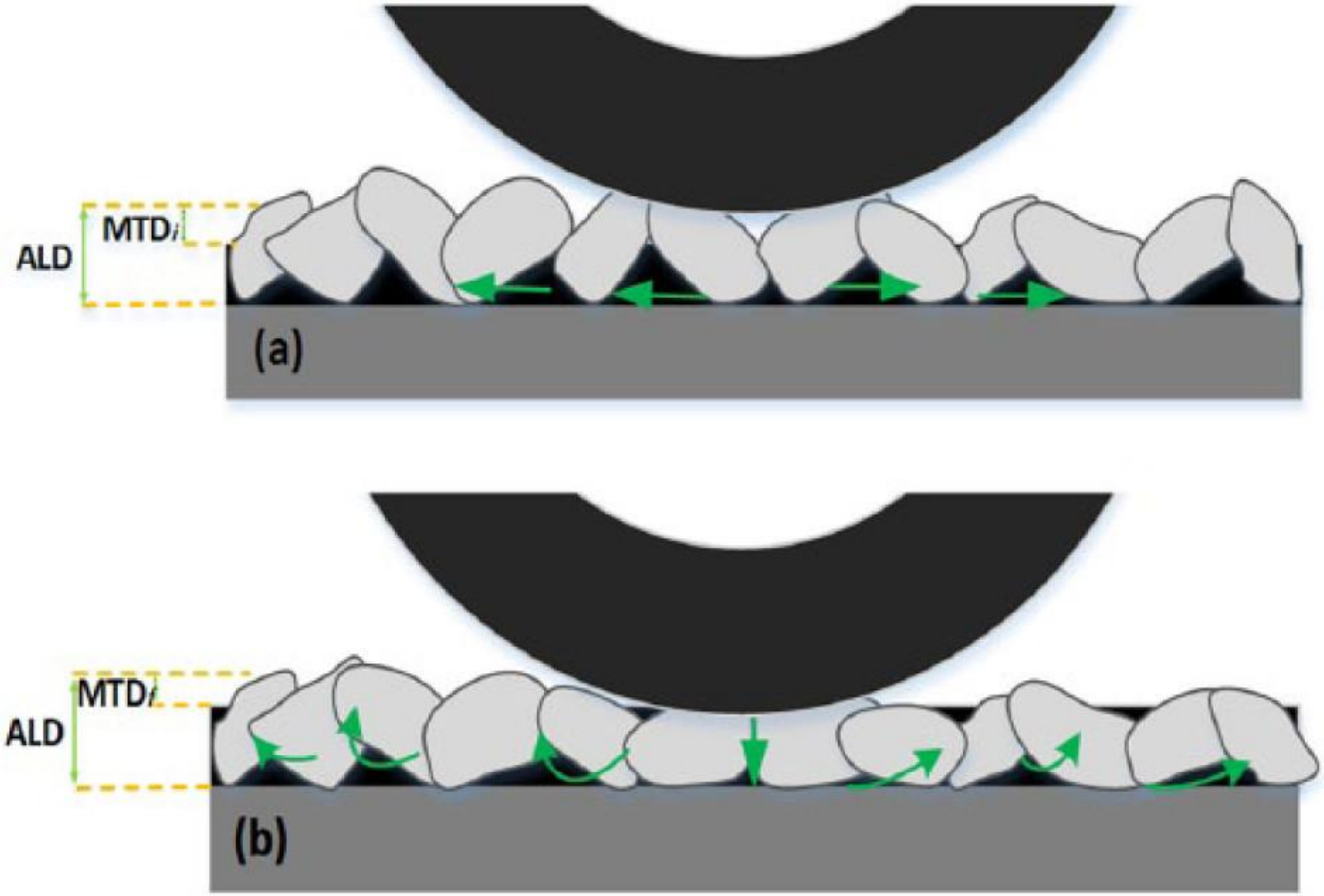
Laboratory Experimental Plan



Seitllari & Kutay, 2018

Laboratory Experimental Plan

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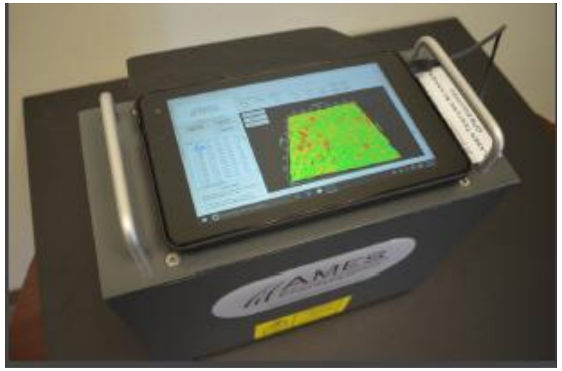

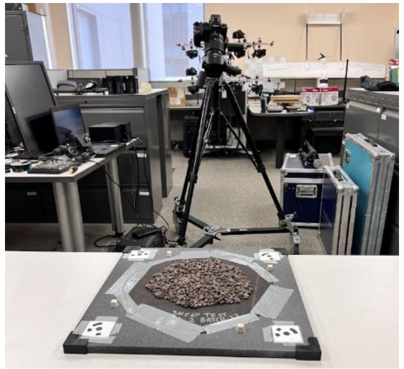

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