



Best Practices for Controlling Segregation in Asphalt Concrete Pavement

Ohio Asphalt Paving Conference
Fawcett Center, The Ohio State University, Columbus
February 1, 2023

Shad Sargand, Russ Professor,
Ohio Research Institute for Transportation and the Environment
Russ College of Engineering and Technology
Ohio University, Athens, Ohio

Outline

- Background and Objectives
- Survey responses
- Review of literature
- Review of state specifications
- Summary and recommendations

Complete report published by ODOT under title “Division of Construction Research On-Call Services 2020-2023 Task 1: Detection of Segregation in Asphalt Concrete Pavement” at <https://www.dot.state.oh.us/Divisions/Planning/SPR/Research/reportsandplans/Reports/Final%20Reports/136126%20t1%20Final%20Report.pdf>



Background

- ODOT 2017 *Construction Administration Manual of Procedures* defines segregation as: “The separation of the coarse and fine particle sizes in an aggregate or asphalt mixture”
- Segregation causes patching, raveling, and stripping, leading to failure of pavement.
- ODOT inspectors monitor asphalt stockpile management and visually observe mix in haul trucks, paver, and in the mat.
- Segregation requires stopping paving, determining and fixing causes, and replacing segregated pavement.
 - Can lead to disputes with contractors
- Can ODOT find a more objective test method or criterion to reduce disputes and improve pavement performance?
 - Examine approaches used by other states



Objective

- 1. Find a more objective test or inspection method/criterion to identify segregation
- 2. Find out what better countermeasures and remedies are available
 - Identify useful new technologies
- Goals of project:
 - Improve performance of completed pavement
 - Reduce costly disputes with contractors
- Note focus of project is on segregation involving aggregate gradation, not thermal segregation



Basic approach

- Survey state DOTs via email and online survey
 - Qualtrics
- Literature search
- Review state construction and materials specifications or other documents



Survey



OHIO
UNIVERSITY

Survey method

- Sent out to RAC Listserv February 1 by ODOT research
- Second round sent to non-responding states February 22
- 32 complete Responses as of March 23 (24 by Feb 21)
- We have responses from:
 - 31 States: AL, IL, OK, LA, PA, TN, MD, VA, MT, AZ, AK, TX, WI, MO, AR, MI, NJ, CO, MN, UT, WA, SD, VT, KS, NV, SC, FL, CA, KY, NY, IN
 - 1 Canadian Province: SK (Saskatchewan)
 - Other incomplete /unidentified responses deleted
 - No contact info or written responses on these
 - ODOT added response for comparison



Survey: Overview

- In Qualtrics Question Q1 was the introduction – no responses collected or expected
- Q2-Q6: contact information for respondent
- Q7: definition of segregation
- Q8: Who is responsible
- Q9-13: How segregation is identified
 - Field observations and tests, lab tests
- Q14-18: How segregation is remedied and by whom
- Q19-20: How DOT has handled segregation
- Responses to key questions are summarized in following slides.
- For some questions, states cited a specification or gave links to documents online with details.

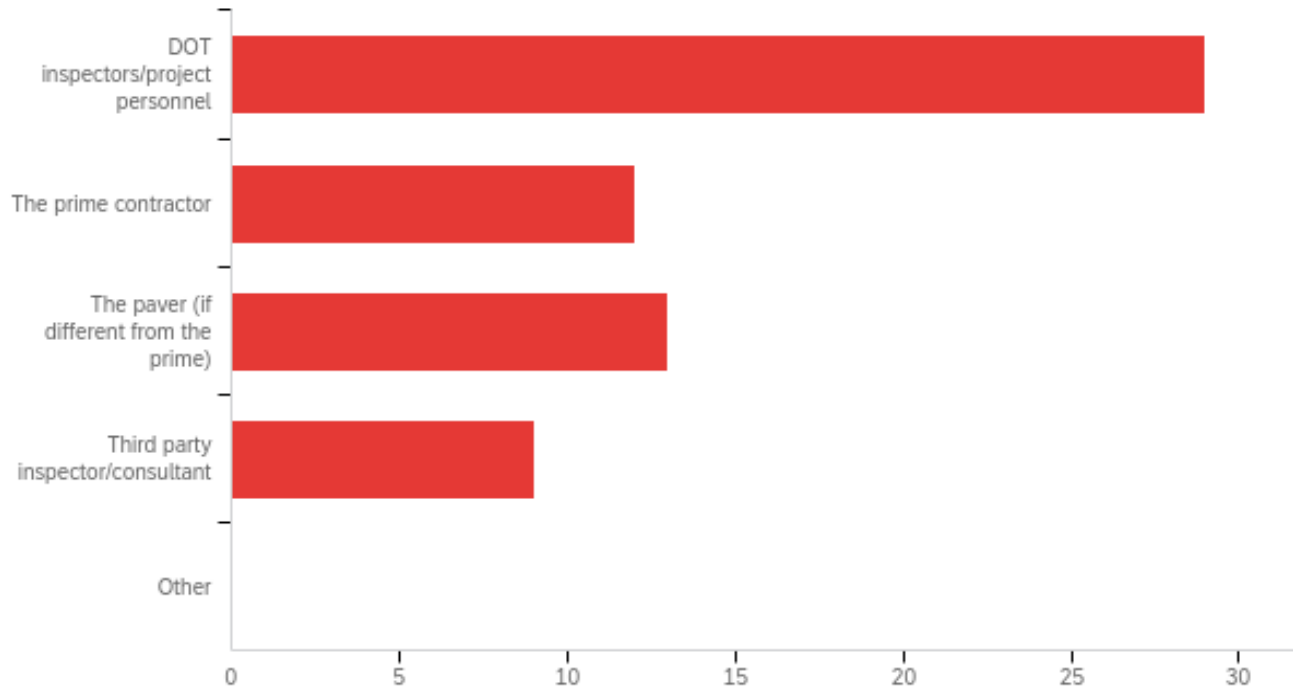


Q7 - How does your organization define segregation in AC pavement in its construction and materials specifications?

- 32 agencies responded, 16 responses (50%) had substantial definitions, and 7 (22%) cited specifications
- Type of definition (some use more than one):
 - Quantified binder content difference between cores (1, 3.13%)
 - Quantified gradation analysis between cores or differs from Job Mix Formula (JMF) (2, 6.25%)
 - Quantified Density variation (e.g. nuclear gauge) (3, 9.38%)
 - Ordinal scale of severity (e.g. Low, Medium High) (2, 6.25%)
 - Separation/non-uniform distribution of aggregate particles (not specified otherwise, or “bad enough we can see it”) (9, 28.13%)
 - Visual and thermal (1, 3.13%)
 - Paver Mounted Thermal Profilers (PMTP) have eliminated problem (1, 3.13%)

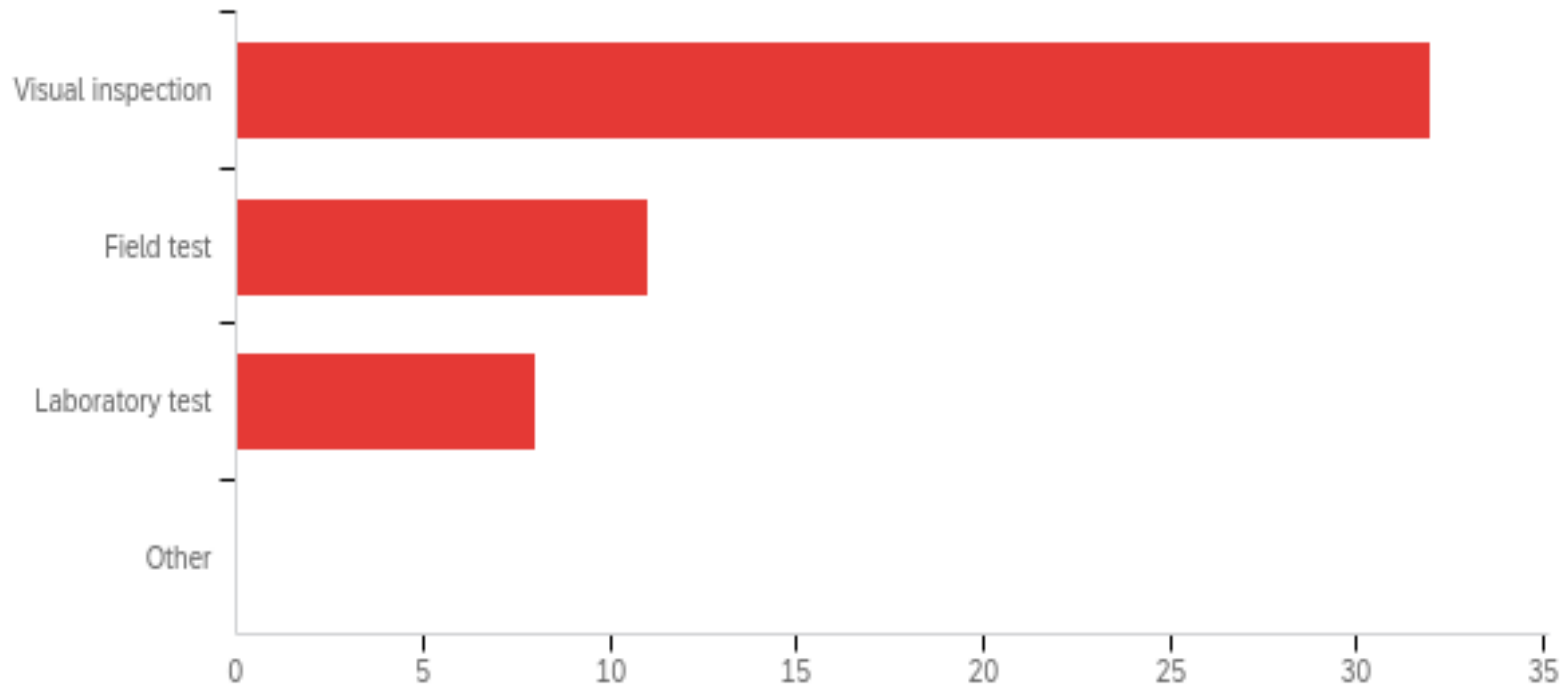


Q8 - Who has the contractual responsibility to determine if the asphalt is segregated? Choose all that apply.



Answer	% of 32	Count
DOT inspectors/project personnel	90.63%	29
The prime contractor	37.50%	12
The paver (if different from the prime)	40.63%	13
Third party inspector/consultant	28.13%	9

Q10 - How does your organization determine segregation in the field at the time of construction? Choose all that apply



Answer	% of 32	Count
Visual inspection	62.75%	32
Field test	21.57%	11
Laboratory test	15.69%	8

Q11 - What are the acceptance criteria for visual inspection?

Acceptance criteria provided (States may use more than 1)

- Gradation difference between cores (1, 3.13%)
- Restate answer to Question 7 (definition) (1, 3.13%)
- Mention tests/measures without giving criteria (2, 6.25%)
- “No visible segregation” or like (8, 25.00%)
- Uniform texture (3, 9.38%)
- Not in writing/not established (5, 15.63%)
- NA (3, 9.38%)
- “Undefined” (1, 3.13%)
- Ordinal scale (Moderate, Severe, etc.) (2, 6.25%)
- Based on area of segregation (2, 6.25%)
- Engineer judgement (2, 6.25%)



Q12 - What field tests are used to determine or measure segregation?

- 9 states (28.13%) replied with specs or document links
- Methods cited:
 - Density Profile (1, 3.13%)
 - Nuclear density gauge (6, 18.75%)
 - Non-nuclear density gauge (1, 3.13%)
 - Thermal camera (1, 3.13%)
 - Thermal imaging system (2, 6.25%)
 - Permeability test (1, 3.13%)
 - Surface macrotexture (1, 3.13%)
 - Core density and thickness (Measure cores in lab) (1, 3.13%)



Q13 - What Laboratory tests are used to determine or measure segregation?

- Tests mentioned:
 - Core density (2, 6.25%)
 - Aggregate gradation from core (5, 15.63%)
 - Binder content (2, 6.25%)
 - No specific test (1, 3.13%)

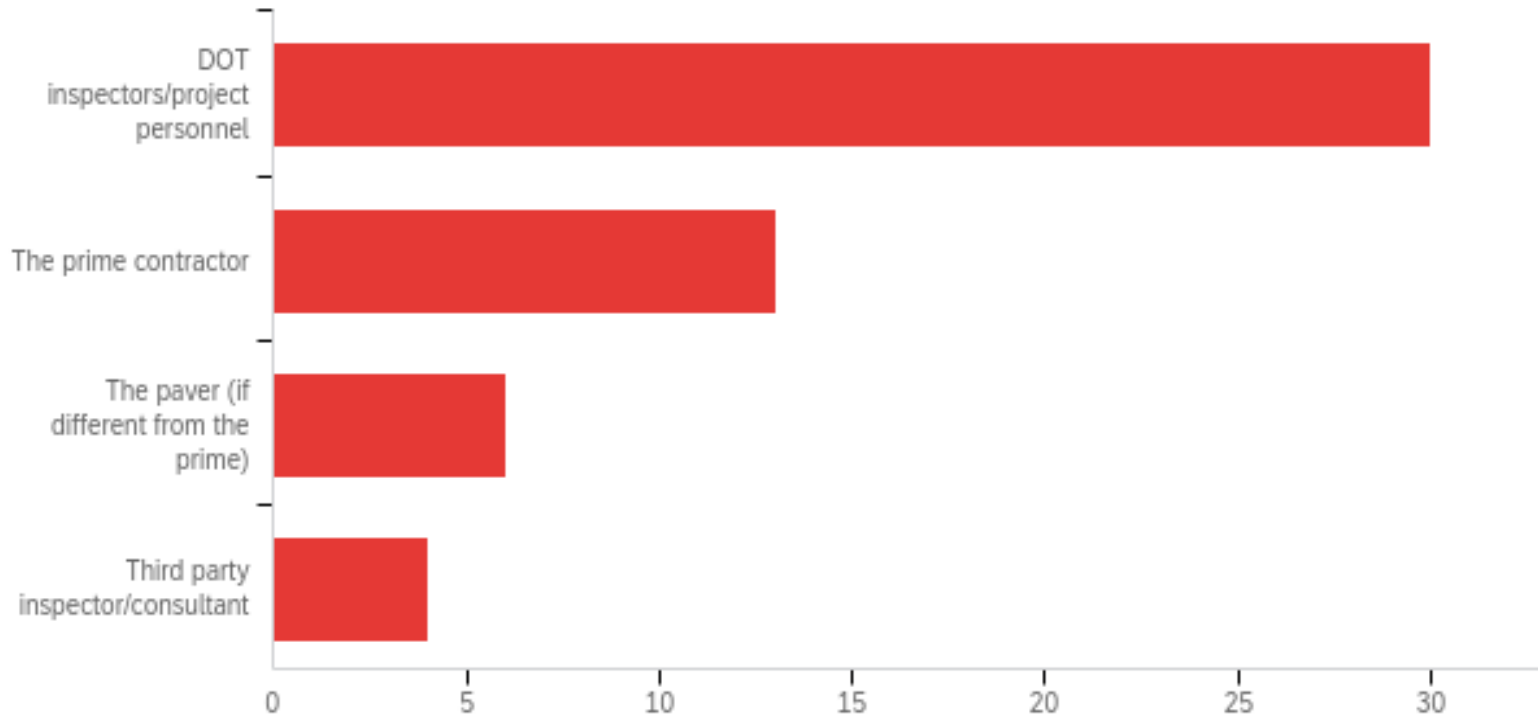


Q15 - How is segregation in asphalt concrete remedied when it is encountered?

- Remedies cited (some states use more than one):
 - Certify/inspect equipment (1, 3.13%)
 - Suspend work to address cause (7, 21.88%)
 - Remove and Replace (19, 59.38%)
 - Corrective action (repair) (5, 15.63%)
 - Use MTD (3, 9.38%)
 - Fog Seal (1, 3.13%)
 - Chip Seal (2, 6.25%)
 - Microsurfacing has been used (1, 3.13%)
 - “Reject” (2, 6.25%)
 - Cost deduction (3, 9.38%)
 - No specific remedy (2, 6.25%)

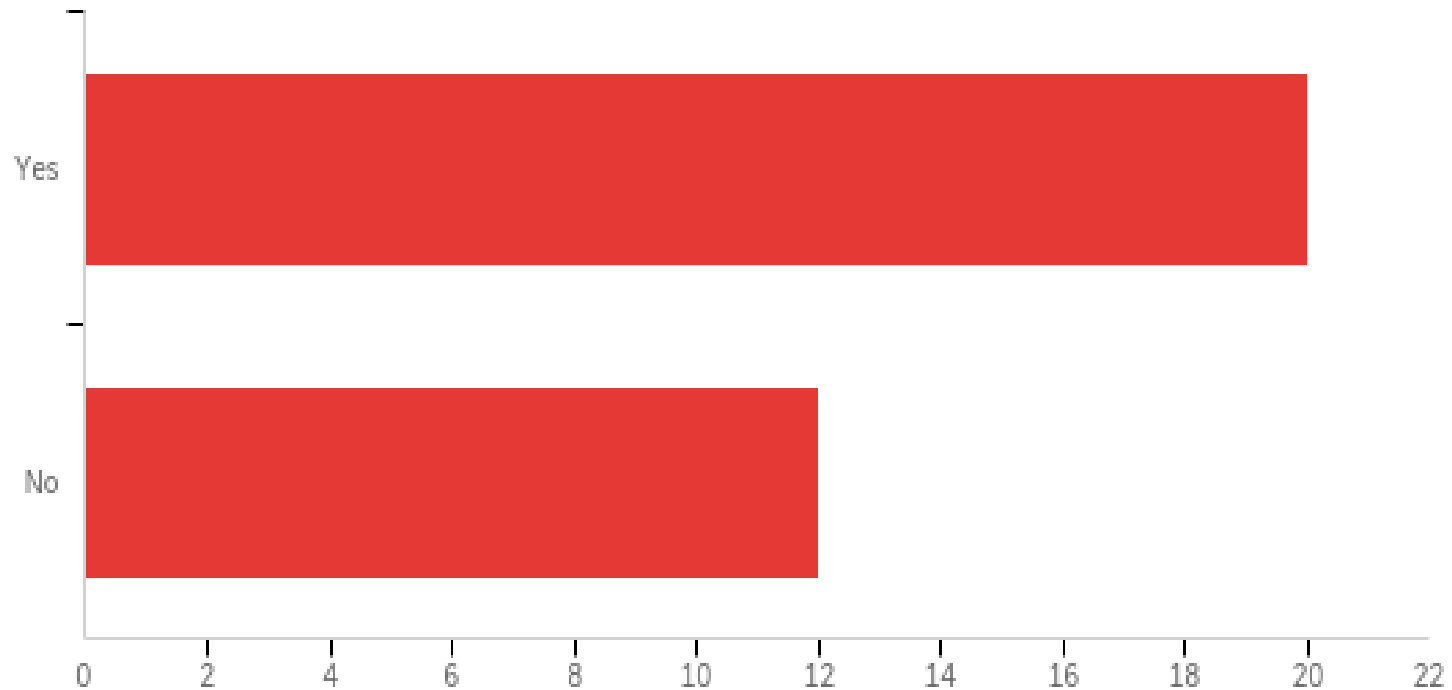


Q16 - Who has the contractual responsibility to determine the applicable remedy and determine if it has been implemented?



Answer	% of 32	Count
DOT inspectors/project personnel	93.75%	30
The prime contractor	40.63%	13
The paver (if different from the prime)	18.75%	6
Third party inspector/consultant	12.50%	4

Q17 - Is there a process through which the contractor can object to or appeal the Agency-required remedy?



Answer	% of 32	Count
Yes	62.50%	20
No	37.50%	12

Q19 - What internal steps has your organization taken to address segregation?

Some states used more than one approach

Answer	% of 32	Count
Training sessions	65.63%	21
Procedures in construction inspection manual or other documents	59.38%	19
Proposed specification(s)	34.38%	11
Research on the topic	12.50%	4
Other	12.50%	4
None	15.63%	5

“Other” includes: Require MTD/MTV on all paving projects, Include in training and certification process, Preparing a surface inspection guide



Literature and specifications review



OHIO
UNIVERSITY

Literature

- Reports
 - NCHRP Synthesis 477 by Mary Stroup-Gardiner [2015]
 - NCHRP Report 441 by M. Stroup-Gardiner and E.R. Brown [2000]
 - Authors were at NCAT at Auburn U.
 - Washington State DOT, Willoughby et al., 2001: *Construction-Related Asphalt Concrete Pavement Temperature Differentials and the Corresponding Density Differentials*
 - FHWA/TX-03/4126–1 by Sebesta and Scullion at TTI in 2002: *Using Infrared Imaging And Ground-penetrating Radar To Detect Segregation In Hot-mix Overlays*
- Articles
 - TRR, ASTM Journal of Testing and Evaluation
- International articles and reports



NCHRP Synthesis 477 [2015]

- Three types of segregation result in texture variations
 - End of truck load
 - Longitudinal
 - Random
- Segregation likelihood increases with maximum aggregate size
 - Survey respondents from industry agreed with this point
 - Rarely seen for aggregate size < 9.5 mm (3/8 in)
 - Dense mix with maximum size > 37 mm (1.5 in) is likely to segregate
- Amount of asphalt in mix controls thickness
 - It is necessary to keep aggregate particles stuck together
 - Too little asphalt binder increases likelihood of segregation
- Detecting segregation
 - Visual inspection
 - Surface texture measurement
 - Temperature differences
 - Density



NCHRP Synthesis 477 [2015]

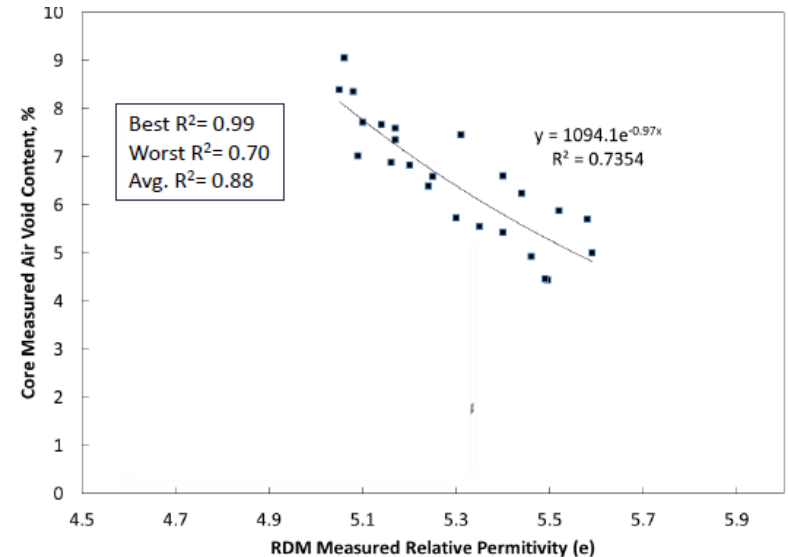
- Detection methods and equipment
 - Visual inspection is most common method
 - Measure ride quality immediately after construction
 - Monitor density
 - GPR
 - Pilot project to evaluate GPR
 - Nuclear or non-nuclear density gauge
 - Intelligent compaction roller can monitor density and detect segregation
- In place performance-based testing is not frequently used to evaluate rutting, fatigue, tensile strength, or permeability of segregated mix.
- Training and certification program is important



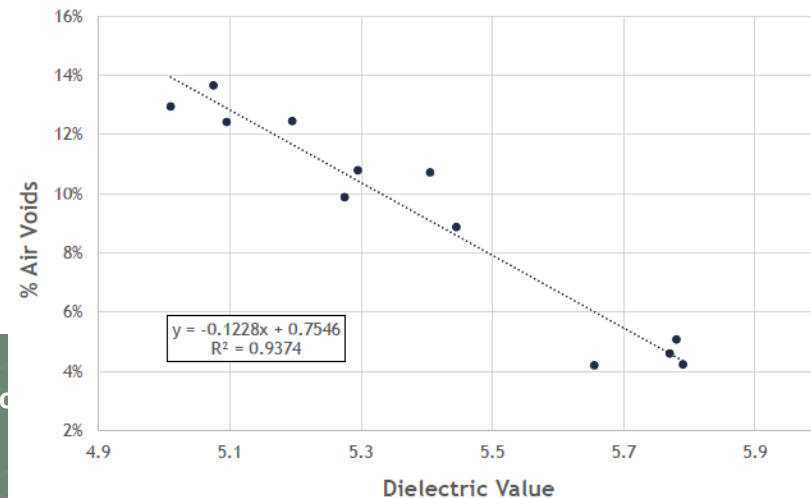
NRRA Pavement Workshop [2020]

Asphalt Density Measurement with Dielectric Profile Method

- Rolling density meter (RDM) and paver mounted thermal profiler (PMTP)
- From ODOT internal research



RDM vs gyratory compactor
RIC -71 Bulk Dielectric Correlation



State specifications review



OHIO
UNIVERSITY

State Specifications

- Most US state and territorial construction and materials specifications are linked from this FHWA web page:
<https://highways.dot.gov/federal-lands/specs/state-specifications>
 - Includes latest year of publication and title (“Specification Name”).
 - Exceptions: IA, MI, NY, PR, WI
- Look through each and search for “segregation”
 - Ignore references to segregation in PCC, segregation of aggregate, and other irrelevant contexts.
- Where possible look up referenced test methods, supplemental specifications, and other relevant documents



Test and measurement methods used in specifications – examples

- Visual inspection
 - Used by most if not all states
 - Several states have developed forms: CO, IA, TX
 - Alberta (Canada) has a detailed Segregation Rating Manual with photos. Saskatchewan working on something similar
- Sand patch test
 - PA Test Method 751 (like ASTM E965)
- Permeability Test
 - Illinois
- Density measurements
 - Cores: AL (ALDOT spec 389-98)
 - Nuclear Density gauge: KS, MI, MO, TX



Remedies from specifications – examples

- Segregation checklist or check points –
checklist of places to inspect equipment, etc.
to find causes of observed AC segregation
- Mandate PMTP (Paver Mounted Thermal Profiler) – uses infrared radar
- Material Transfer Device (MTD) or Materials Transfer Vehicle (MTV)
 - NJ, TN mandate MTD/MTV use
- Use finer aggregate
 - Wisconsin
- Details are in project report



Summary and recommendations



OHIO
UNIVERSITY

Summary

- Three approaches to addressing segregation:
 - Proactive: Review mix design and inspect equipment before paving begins to prevent segregation
 - Immediate monitoring in real time: Address problems as soon as they are seen at the paver
 - Reactive mode: Address visible problems after occurrence – for example when having laboratory tests
- Segregation due to gradation issues can overlap with thermal segregation.
 - Thermal segregation was outside of project scope



Findings and Conclusions

- There is no consistent and clear definition or standard criteria for what constitutes segregation in AC pavement.
- Half a dozen states do have different test criteria, which are based on gradation deviations from Job Mix Formula (JMF), binder content, density variations, surface texture measurements, or temperature differences.
- A significant amount of research has been done on equipment to monitor segregation. The most common parameters measured are temperature, density, texture depth, and stiffness.
- Density can be measured with non-nuclear gauges, ground penetrating radar, or rolling density meter.



Findings and Conclusions

- Rolling density meters operate by measuring the dielectric constant. The presence of moisture will affect dielectric properties and thus may create inaccurate density measurements.
- Stiffness measurements, such as those made during smart compaction, are affected by temperature.
- Laboratory tests on core specimens will provide a direct measurement of gradation issues, but introduce delays in obtaining results.
- The use of visual inspections is nearly universal in identifying segregation, and most testing mentioned above is conducted on areas identified visually. However, these visual inspections involve engineering judgement and require trained and experienced inspectors.



Implementation Recommendations

- Information on segregation can be added to ODOT and Flexible Pavements courses for Mix Design Level II and III, either with a new course or by augmenting existing courses. Either way, this material should also be available to ODOT employees and people from private sector through the training program.
- Since the mix design courses are aimed at laboratory personnel, a new training program or course could be added for field inspectors with a focus on inspecting pavement and detecting segregation and offered in a similar manner.
- The ODOT Construction Manual of Procedures can be updated to reflect best practices for detecting segregation and assessing severity.
- Because the potential for segregation increases with larger aggregate or reduced binder content, ODOT can review specifications for HMA mix designs to identify possible opportunities to mitigate segregation. ODOT can also consider a testing approach similar to Alabama DOT Method with criteria based on binder content and gradation.



Implementation Recommendations

- Proactively monitor temperature and/or density at the paver to identify segregation during construction. ODOT's Office of Pavement Engineering has made some significant progress in this area regarding PMTP and RMD, which can serve as a basis for follow up work.
- The proactive approach to controlling segregation can use real-time monitoring of temperature or density to trigger an alarm to pause paving operations so that the cause of potential segregation can be located and immediately addressed to minimize the disruption and delay of paving progress. The alarm criteria will need to be determined and evaluated.
- The use of density measurements in the field with a nuclear density gauge, as is done in Washington, Missouri, and Kansas, can also be evaluated for use in Ohio.
- Texture measurements or international roughness index (IRI) are more useful for determining penalties after the fact rather than for corrective action during paving. Also, this approach only measures problems with the surface course; segregation in intermediate and/or base layers requires making measurements before the next layer is applied, which may not be a realistic option.



Implementation Recommendations

- Gather performance-based data to document the relationship between performance and segregation, including each layer of Ohio mix designs.
- A laboratory study of segregation could be conducted to better understand mechanisms and effects of segregation. One can start with specimens created with an ideal mix, then vary parameters to add some segregation effect in subsequent specimens, then compare the performance of the cores to measure the effect of the variation in parameter. Promising and significant results could then be validated in the field.
- An asphalt base evaluation project report found a relationship between high Cantabro mass loss and segregation in asphalt base cores. Further studies can deepen understanding of this relationship and identify a threshold value for Cantabro mass loss.



Where to get report

- On ODOT Research Section website
 - ODOT title: “Division of Construction Research On-Call Services 2020-2023 Task 1: Detection of Segregation in Asphalt Concrete Pavement”
 - State Job No 136126, Project ID No. 111441
- Go to “Final Reports” at:
<https://www.dot.state.oh.us/Divisions/Planning/SPR/Research/reportsandplans/Lists/Final%20Reports%20All/FinalReportsSC.aspx>
 - Search for “segregation”
- Direct URL for pdf file:
<https://www.dot.state.oh.us/Divisions/Planning/SPR/Research/reportsandplans/Reports/Final%20Reports/136126%20t1%20Final%20Report.pdf>



Create
for Good.



OHIO
UNIVERSITY