October 28-29, 2025
Orlando, FL

TRANSPORTATION SYMPOSIUM

Evolution of Pavement Technology: Balancing Performance, Safety, & Longevity

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Transportation Symposium Website
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Presentation Objectives

- FDOT Usage of Open-Graded Friction Courses (OGFC)
  - History of OGFCs
  - Benefits and Challenges
  - Future of OGFC
- Early Detection of Raveling Conditions with 3D Imaging System and Future Open-Graded Only Resurfacing Program
  - Digitize raveling detection
  - Replace manual surveys with automated 3D imaging
  - Leverage AI for OGFC analysis
  - Propose a cost-saving resurfacing strategy using new technology

Safety Message

Be Rail Smart!

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FDOT Usage of Open-Graded Friction Courses

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Open-Graded Friction Courses (OGFC)

- Special type of asphalt surface mixture
  - Designed to improve safety by allowing water to pass through the pavement layer
- Composed primarily of coarse aggregate
  - Only a small portion of fine aggregate,
  - Air void content ~20% vs 4% for dense-graded asphalt mixtures
- Typically placed on high-speed multi-lane roadways to reduce the risk of hydroplaning and improve visibility in wet conditions (minimize splash and spray)
- In Florida, we currently call OGFC FC-5

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Dense-Graded Pavement Surface

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Open-Graded Pavement Surface

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OGFC in Florida (FC-5)

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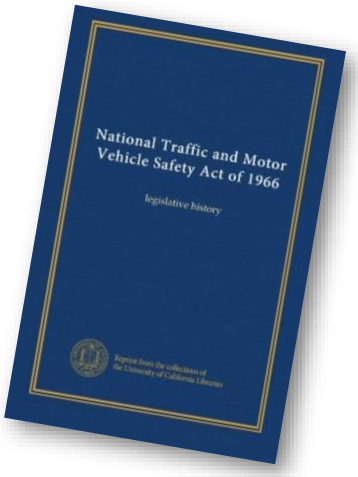
FDOT Usage of OGFC

- Highway Safety Act of 1966
  - States were required to develop "…standards for pavement design and construction with specific provisions for high skid-resistant qualities"
- Late 1960s: FDOT constructed 17 test sections to evaluate the frictional characteristics of 12 different aggregate types



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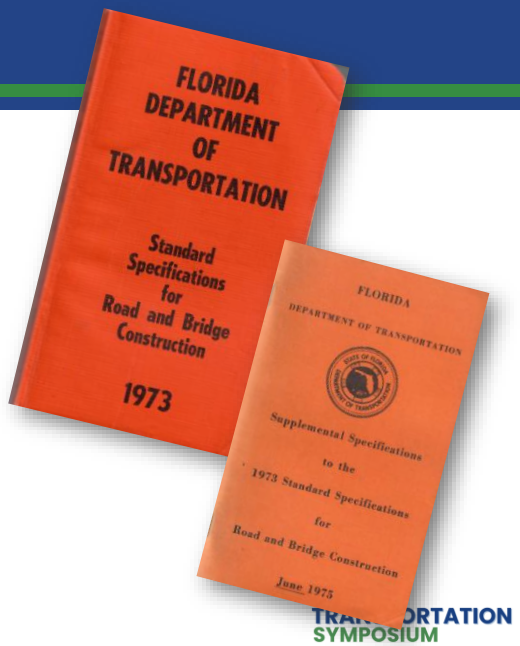
FDOT Usage of OGFC

- 1973 Specifications for Wearing Course (WC) Mixtures
  - June 1975 Supplemental Specifications
    - WC-1 Modified Type II Asphalt Concrete - Slag
    - WC-2 Modified Type II Asphalt Concrete - Granite
    - WC-3 Modified Type II Asphalt Concrete - Gravel
    - WC-4 Special Sand Asphalt Hot Mix
    - WC-5 Open-Graded Mix (Oolite)
    - WC-6 Open-Graded Mix (Slag)
    - WC-7 Open-Graded Mix (Granite)
    - WC-8 Open-Graded Mix (Gravel)
- Wearing Course mixtures were placed 1” thick



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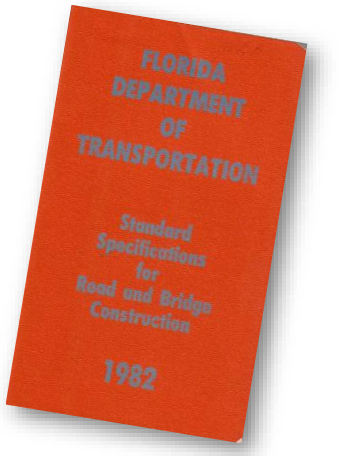
FDOT Usage of OGFC

- Due to poor performance, the wearing course specifications were modified in the late 1970s and early 1980s
- 1982 Specifications
  - Open-graded wearing courses (WC-5, WC-6, WC-7, and WC-8) consolidated and became FC-2
- FC-2:
  - Based on FHWA recommendations for plant-mixed seal coats
  - 3/8” top-sized aggregate
  - Placed 3/8 to 1/2-inch thick
  - Used unmodified asphalt cement (AC-20)



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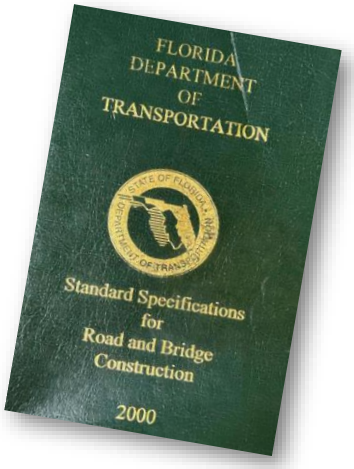
FDOT Usage of OGFC

- Late 1990's developed the FC-5 OGFC
  - Based on Georgia DOT's OGFC
  - 1/2" top-sized aggregate
  - Placed 3/4" thick
  - Uses modified binder (ARB-12 and then PG 76-22) along with stabilizing fibers, liquid anti-stripping additives, and hydrated lime (for granite mixtures)
- Significantly improved performance over FC-2 and Wearing Course mixtures



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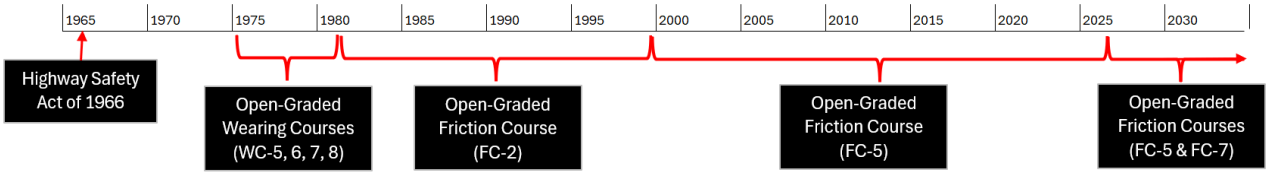
Timeline of OGFC



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FDOT Usage of OGFC

- Policy
  - OGFC used on high-speed Arterials and Limited Access. Multilane roadways 55 mph or greater
  - 48% of FDOT's roadways are OGFC (~22,000 lane miles)
- Why Florida uses it:
  - Safety: Reduces hydroplaning potential and splash & spray when the pavement is wet
- Shorter Pavement Life
  - On average 14-year service life
  - OGFC deteriorates by raveling

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Design of OGFC Mixtures

- Open texture → More oxidation and aging of the binder
  - Which leads to raveling and cracking
- Need enough asphalt binder in the mixture for good durability, however,
- Too much binder will create construction problems (draindown or bleeding), or it will fill up the texture in the pavement, or both!

Too Lean - Raveling

Too Rich - Bleeding

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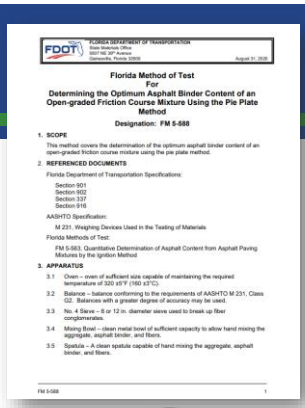
FDOT Design of OGFC

- Loosely based on a 1990 FHWA design procedure
  - Technical Advisory T5040.31: Open Graded Friction Courses
- Gradation is selected based on gradation band and available aggregates
- Binder grade and mix temperature is fixed
- Pie Plate method sets the optimum binder content
  - Visually
- Verified with Cantabro test (durability test)



Florida Method of Test
For
Determining the Optimum Asphalt Binder Content of an Open-graded Friction Course Mixture Using the Pie Plate Method

Designation: FM 5-588

1. SCOPE

This method covers the determination of the optimum asphalt binder content of an open-graded friction course mixture using the pie plate method.

2. REFERENCED DOCUMENTS

Florida Department of Transportation Specifications:

Section 901
Section 902
Section 337
Section 916

AASHTO Specification:

M 231, Weighing Devices Used in the Testing of Materials

Florida Methods of Test:

FM 5-563, Quantitative Determination of Asphalt Content from Asphalt Paving Mixtures by the Ignition Method

3. APPARATUS

3.1 Oven – oven of sufficient size capable of maintaining the required temperature of 320 ±5°F (160 ±3°C).

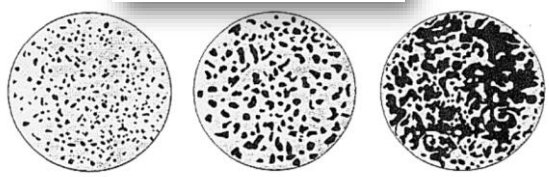
3.2 Balance – balance conforming to the requirements of AASHTO M 231, Class G2. Balances with a greater degree of accuracy may be used.

3.3 No. 4 Sieve – 8 or 12 in. diameter sieve used to break up fiber conglomerates.

3.4 Mixing Bowl – clean metal bowl of sufficient capacity to allow hand mixing the aggregate, asphalt binder, and fibers.

3.5 Spatula – A clean spatula capable of hand mixing the aggregate, asphalt binder, and fibers.

FM 5-588 1



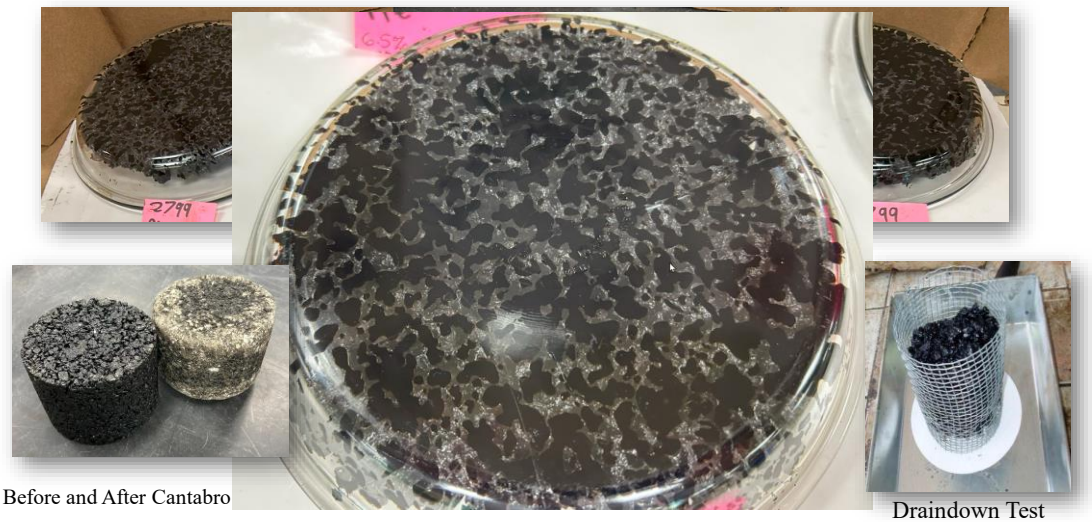
No Draindown
Increase Mixing Temp

Desired Draindown
Optimum Mixing Temp

Excessive Draindown
Decrease Mixing Temp

Figure 5. FHWA Test for Draindown Characteristics (FHWA, 1990)

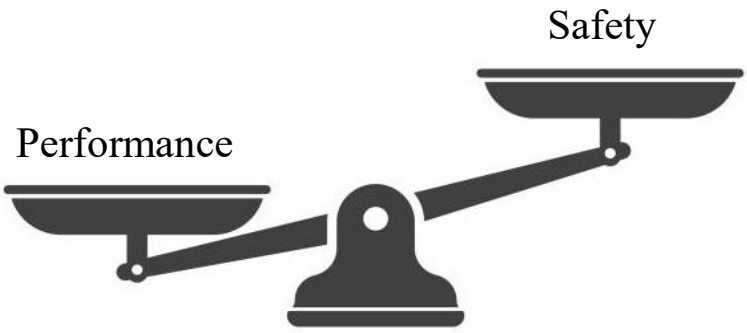
OGFC Design - Current



Before and After Cantabro

Draindown Test

The Balancing Act with OGFCs



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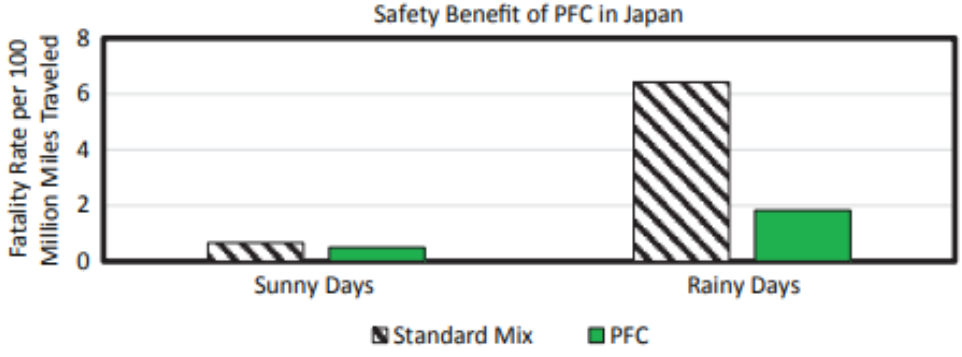
Safety

- OGFCs improve the safety of high-speed roadways



Fatality Reduction on Rainy Days (Shimero & Tanaka, 2010)

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Reduced Splash & Spray

(Watson et al. 2018)

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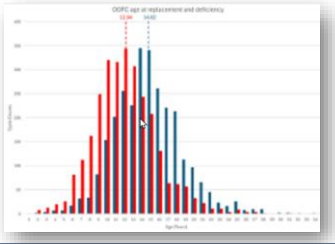
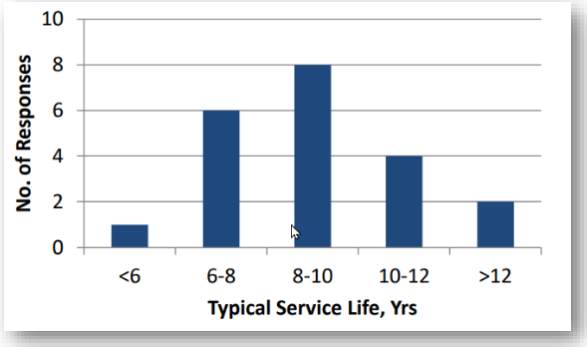
Performance

- Open-Graded Friction Courses are safer, but their long-term performance is not as good as dense-graded friction courses
  - This is true in Florida and in other states
- In Florida, its ~14 years vs. 17 years for dense-graded mixes.



Typical Service Life of State DOT OGFC Mixtures



NCAT Report 16-04 Phase V (2012-2014) NCAT Test Track Findings

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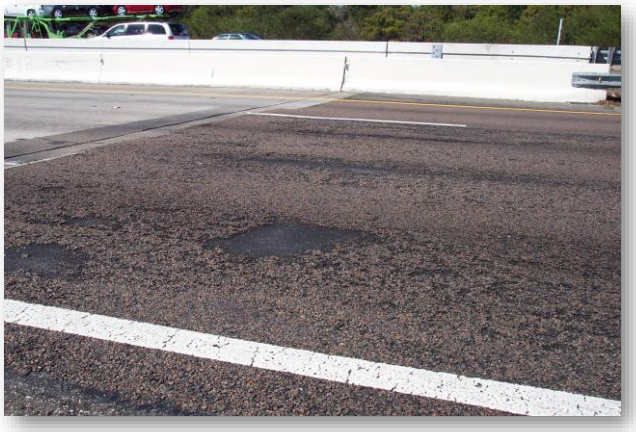
Raveling FC-5



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So how can we improve the longevity of FC-5 without compromising safety?

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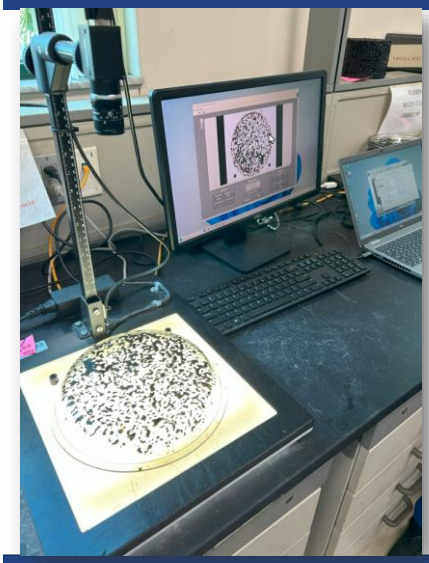
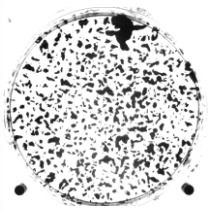
OGFC Design Optimization with AI





5.50%

6.00%

6.50%

```
**********************************************************************
Mix Design:     20286
Aggregate:      Granite
OBC Imaging System:     6.13613
**********************************************************************

**Inspector Data**
Empty Pie Visual Inspection Results:    6.4000
Empty Pie Back-calculated % Binder Area:        49.8479
Full Pie Visual Inspection Results:     6.1000
Full Pie Back-calculated % Binder Area: 42.6309

**Linear Interpolation**
OBC Imaging System:     6.13613
% Binder Area:  43.5000

**Master Slope Method**
Optimum Binder Content: 6.13312
Master Slope / % Binder Area:   0.0392 / 43.5000

**Individual Pies**
Image Name      Design Binder Content   % Binder Area   Individual OBC
20286 5.50.JPG  5.500   27.834  6.114
20286 6.00.JPG  6.000   40.225  6.128
20286 6.50.JPG  6.500   52.254  6.157
```

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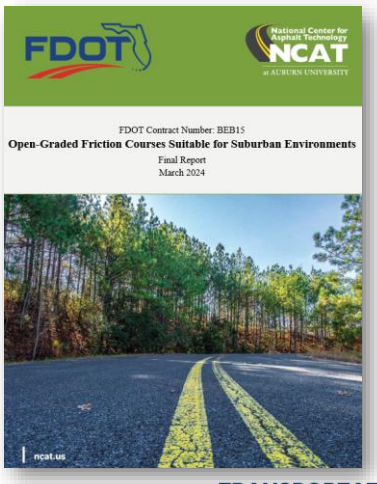
NCAT Research on OGFCs in Suburban Environments

- Looked at various mixture types:
  - FC-5 (control)
  - FC-5 with High Polymer binder
  - 9.5 mm OGFC (FC-7)
  - “Alternate” Friction Course
  - Stone Matrix Asphalt (SMA)
- Considered the following factors:
  - Durability
  - Permeability
  - Drainability
  - Cracking Resistance
  - Rutting Resistance
  - Friction
  - Macrotexture



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Summary of NCAT Research

Factor	Durability	Permeability	Drainability	Cracking Res.	Rutting Res.	Friction	Macrotexture
FC-5	O	O	O	O	O	O	O
HP	++	O	O	++	O	O	O
9.5 mm OGFC	+	O	O	O	O	O	O
AFC	++	-	-	+	+	+	-
SMA	++	--	--	+	++	+	--

Notes:
O = No change;
+ Positive effect;
- Negative effect

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FC-7

- FC-7 is a new OGFC with a 9.5 mm aggregate size
  - Similar to FC-5 but with a smaller aggregate size (9.5 mm vs. 12.5 mm)
  - Placed 3/4” thick
- Will contain fibers, liquid antistrip, and hydrated lime (granite)
- Research shows FC-7 has better durability than FC-5
  - Slightly lower permeability
- Usage: Multi-lane Arterials with design speed 55 mph or greater
  - District option to use FC-5 or FC-7 in those areas
- To-date it has been placed on:
  - US-19 Levy County (2010) – Quiet Pavement Study
  - US-301 Clay County (2024) – Asphalt Test Road
  - US-1 Monroe County (2025)

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FC-5 & FC-7

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FC-5 & FC-7 on the Asphalt Test Road

NMAS: 12.5 mm
Binder: PG 76-22 PMA
Binder Content: 6.28% (Production Mix)
Friction: 51.8 (FN40R)
Texture: 0.056
Permeability: 58,956 x 10^{-5} cm/s

NMAS: 9.5 mm
Binder: PG 76-22
Binder Content: 6.79% (Production Mix)
Friction: 48 (FN40R)
Texture: 0.045
Permeability: 34,082 x 10^{-5} cm/s

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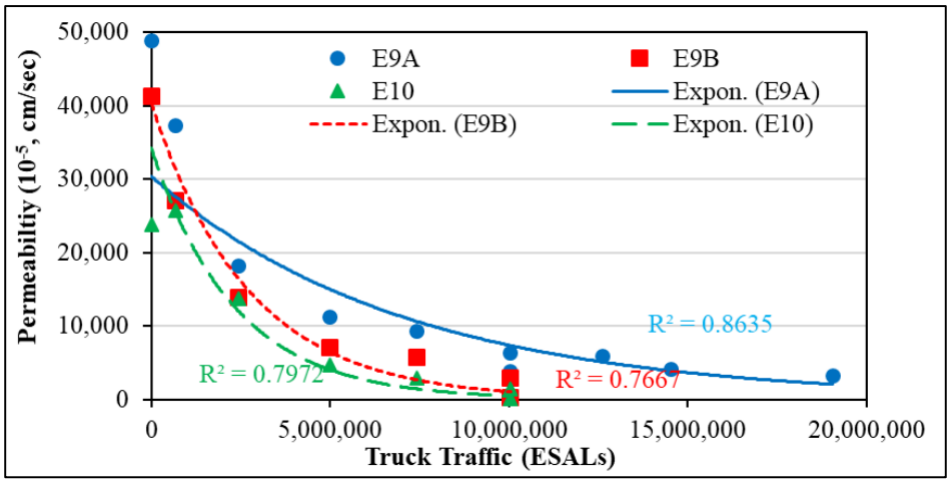
Permeability



Data from NCAT Test Track

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FC-7 Adoption

- Flexible Pavement Design Manual changes currently being reviewed
  - Publication date: November 1, 2025
  - Effective date: January 1, 2026
- Construction Specification (Section 337) currently being reviewed by FHWA
  - Will become effective July 2026 Letting

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Summary

- FDOT has been using OGFCs since the mid-1970s
- OGFCs historically have a shorter life expectancy than dense-graded mixtures
- The design of OGFC mixtures is based on a visual determination of the optimum binder content
  - Future designs will be based on Artificial Intelligence assessment of binder content.
- The FC-7 is a new alternative to FC-5.
  - Should have improved durability (raveling resistance) and is recommended to be placed on Arterials.
- Since they have slightly better permeability, FC-5 mixtures are still going to be placed on Limited Access facilities.
- Visually there will be minimal differences in the mixtures.
- Material costs for FC-7 should be roughly $2-$3/ton more than FC-5

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Early Detection of Raveling Conditions with 3D Imaging System and Future Open-Graded Only Resurfacing Program

Mateo Carvajal, P.E.
Florida Department of Transportation

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Presentation Objectives

- Highlight goals:
  - Replace visual surveys with automated 3D imaging
  - Digitize OGFC raveling detection
  - Leverage AI for Open Grade Friction Course (OGFC) analysis
  - Propose a cost-saving resurfacing strategy using new technology

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Assessment of Raveling

- Balance
  - Safety, Performance, & Longevity
- Raveling:
  - Primarily in OGFC
  - Monitor loss of aggregate
  - Determine decay rate of aggregate loss
  - Identify hazards
    - ✓ Can cause windshield damage from loose aggregates

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Old Method: Raveling Limitations of Visual Surveys

- Subjective distress ratings
- Slower Process (frequency/cost/time)
- Safety and labor constraints (MOT)
- Poor resolution of data (Chunk Data)
- Lack of data verification (images)

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Business Need: Automating Pavement Surveys for Raveling

- Objective surveys and data driven decisions
- Digitize Pavement Surveys
- Tools - Allows for early resurfacing (raveling) intervention/project selection
- Pavement lifecycle (provides cheaper resurfacing cost options)
- Early detection would provide maintenance strategies options and resurfacing solutions which are timely and cost effective

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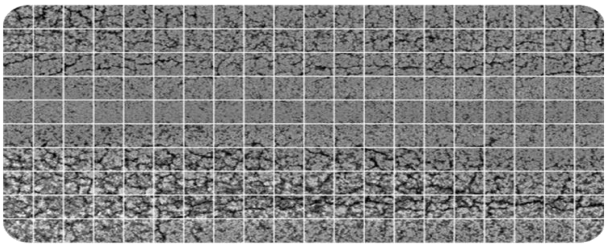
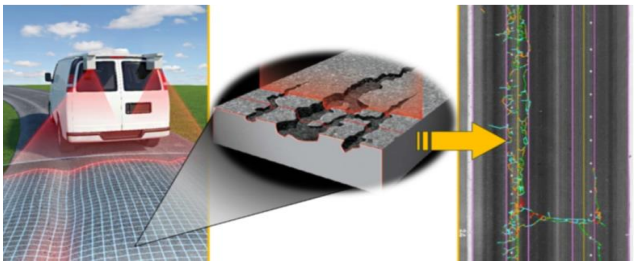
Solution: Introducing the New 3D Automated Distress Measurement System





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3D Automation Distress Measurement System

- 3D laser-based collection for cracking, raveling, rutting, & faulting
- Pavement Smoothness
- Cross-slope & grade
- Forward/Downward imaging (20 ft)
- GPS (sub-meter accuracy)

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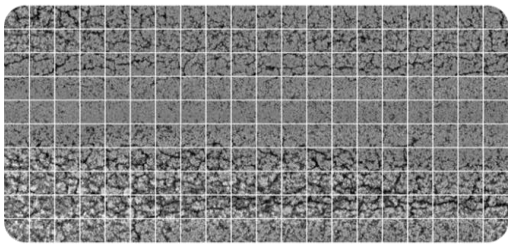
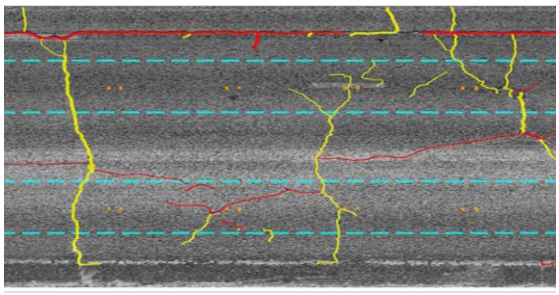
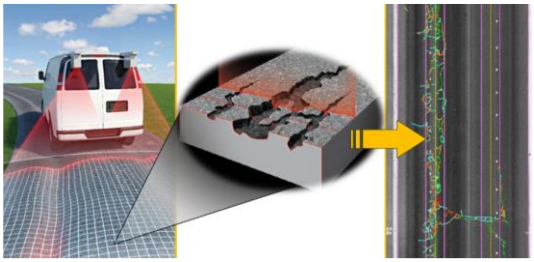
Pavement Data: Digital Transformation

- **Leveraging Computing and Analytics Tools**
  - High-resolution 3D digital data, automate data analysis, reduce field verifications, and increase data accuracy.







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Automated Pavement Condition Survey Program

- Collect 100% Annual Survey
  - Measuring Crack, Rut, Ride and Raveling
  - Forward Imaging
  - 25,000 lane miles tested per Year
- Department has five 3D systems
  - 4 Production Systems
  - 1 QC System
- Implemented full automated reporting in 2024

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How is Artificial Intelligence used to Detect Raveling?

- Role of AI in Pavement Analysis
  - Pattern recognition with Machine Learning
  - Feature extraction from 3D images
  - Continuous learning model

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Machine Learning Development for Raveling Detection

- FDOT Research Project
- Building AI model (Machine Learning)
  - Utilized 3,000+ downward images (ground truth) from FDOT network
  - Convert each 3D image into a raveling category:
    - ✓ None, Low, Medium, and Severe
- Accuracy – 84% Confidence

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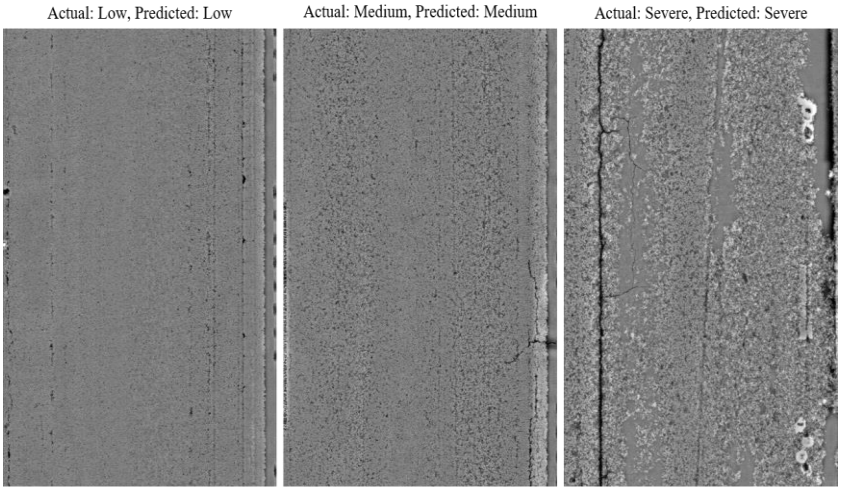
Machine Learning Development for Raveling Detection



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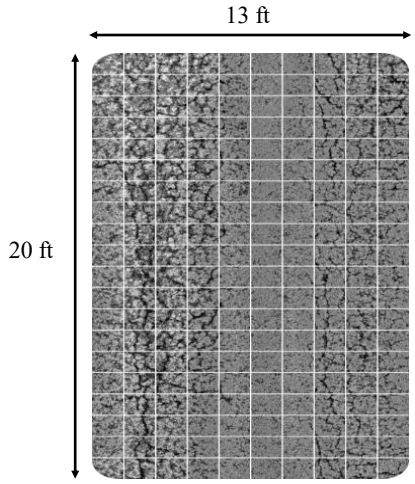
3D Image Processing (Raveling Detection Reporting)

- Using laser-based technology, pixel values are identified and cataloged
- High resolution Image (~1.5M pixels)
- Approximately 200 tiles
- Random Forest Raveling model combined with statistical information from the pixel values in each tile are used as the input for the category (none, low, medium, severe)



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Implementation of Categories on a Statewide Level for Raveling (2.3 Million Images for OGFC)

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Raveling Tools for Project Selection

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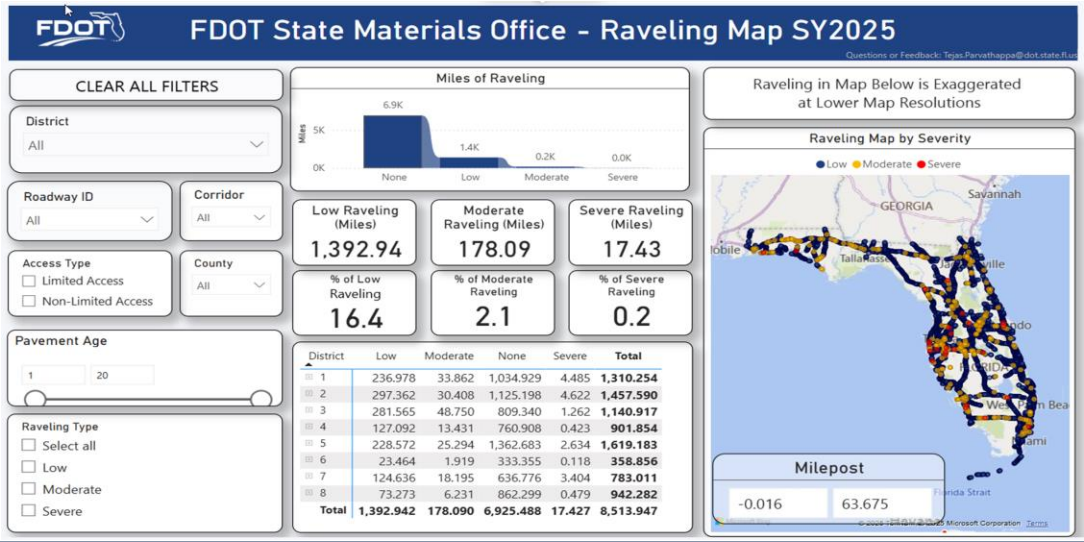
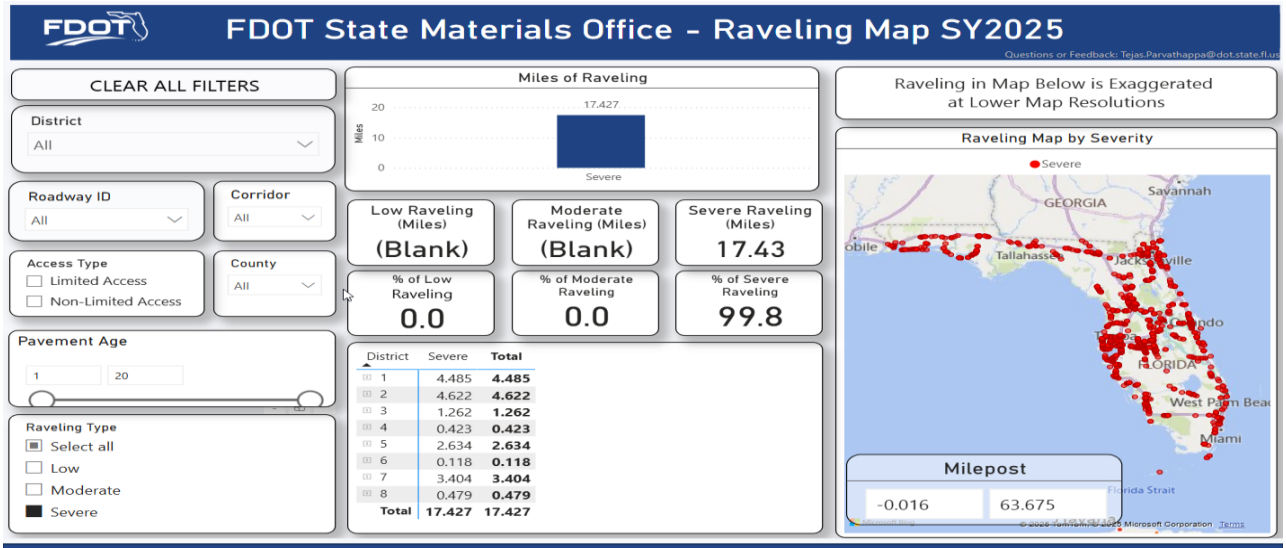
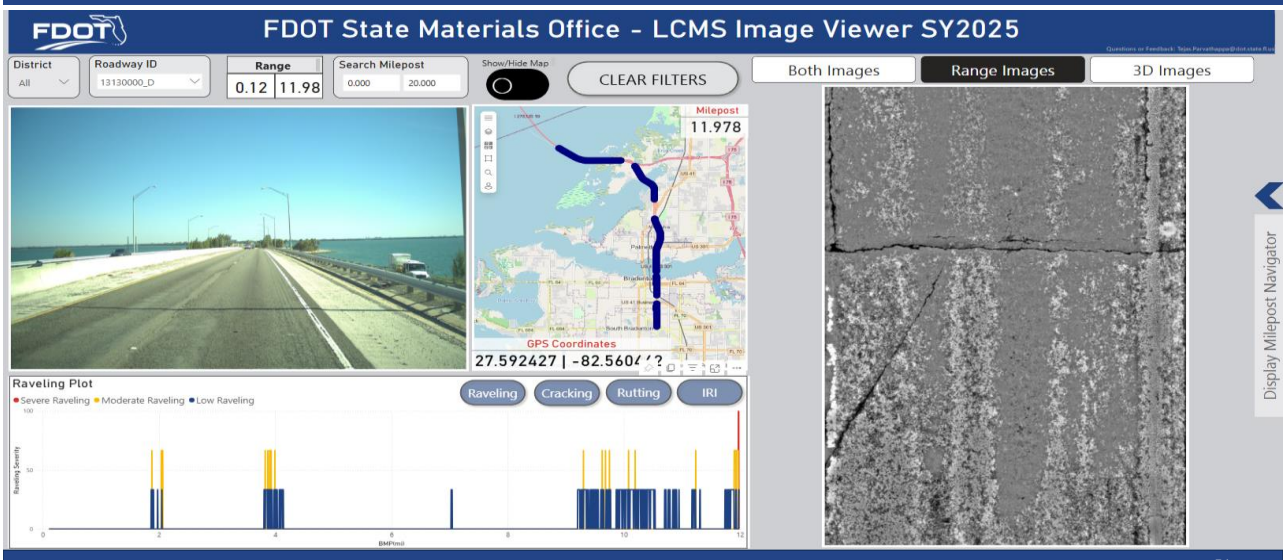
Statewide Raveling Map (All Raveling)



Statewide Raveling Map (Severe Raveling)



Raveling Segmentation



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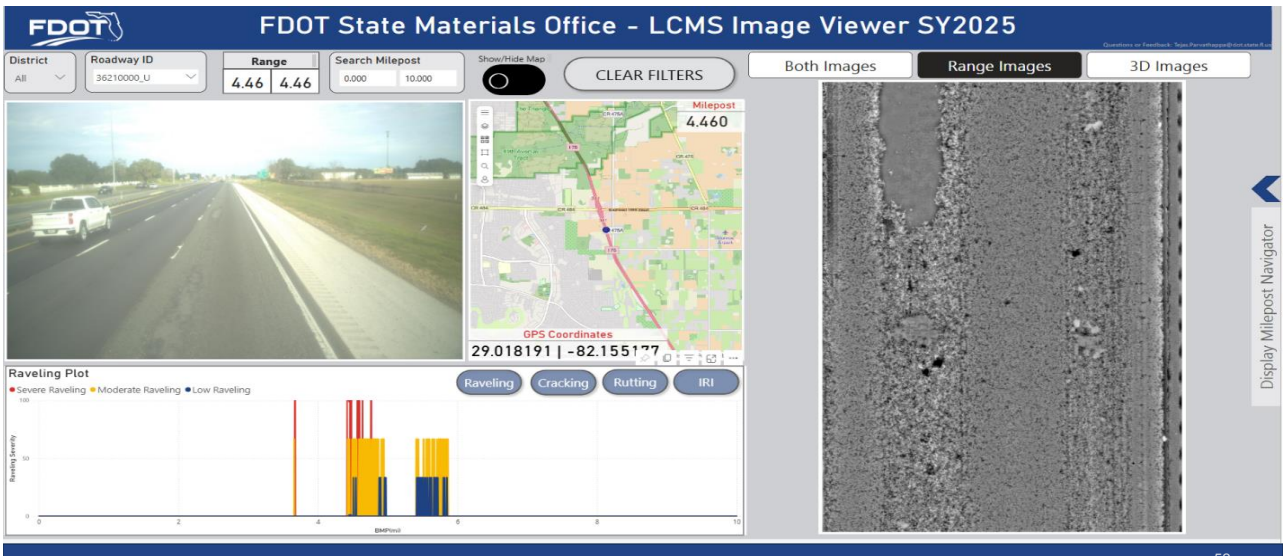
Raveling Segmentation



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Resurface Efficiency Goal: Using Technology for Data Driven OGFC Only Policy

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Open Grade Friction Course Only Policy

- The 2025 Resurfacing Program modernizes FDOT's approach with adding AI, OGFC-only resurfacing, and digital rating tools
- Statutory goals, cost efficiency, and predictive planning form the foundation for the program
- The program remains in a refinement phase—calibration and validation are ongoing
- Support and collaboration are key to building a smarter, resilient resurfacing system

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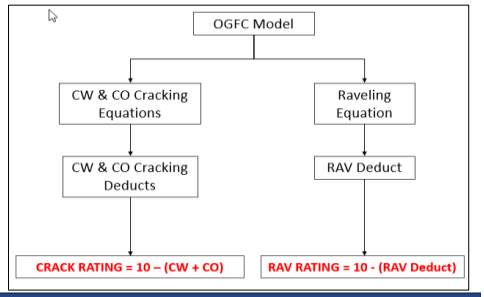
PCS Raveling Rating – 4th Dimension

- **Today – Identify Distress**
  - Rating of three Characteristics: Crack, Rut, and Ride
  - Ravel is embedded in crack rating
- **Tomorrow – Identify Distress**
  - Standalone ravel metric for a "3+1" dimension system

Crack
Rut
Ride
Ravel



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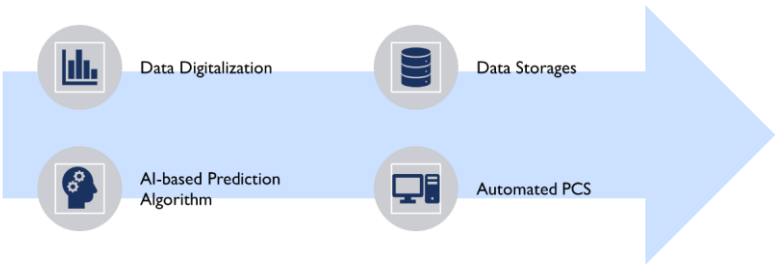
Evolution of Building an OGFC Only Program

Before 2025
- **No OGFC Only Resurfacing Program**
- Develop Raveling Model with Automated Data Equipment

2025-2027
- **Implement Raveling Detection**
- Cure Severe Raveling Area Concerns, Isolated Spots
- 528'-1/4 Mile Minimum Segment Length

2028 and Beyond
- Develop OGFC Friction Course Only Project Level Process
- Counts as Resurfacing Lane Miles
- Cost Saving Resurfacing Initiative



OGFC Only Resurfacing

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OGFC Only - A Targeted and Agile Program

Future: Project Response with Strategic Impact

- Surface-Level Opportunity:
  - Only friction course layer replaced (mill and fill 1”)
  - Structural layer must be in good condition
- Smarter Project Selection
  - AI + 3D Imaging: Machine learning pinpoints surface-only raveling.
  - Focus: Filters out structural issues—targets only what needs OGFC treatments.
  - Efficient Segments: Uses flowcharts and segmentation logic to define smart, workable sections.
- Delivery Flexibility: Construction, Maintenance, or Asset Management

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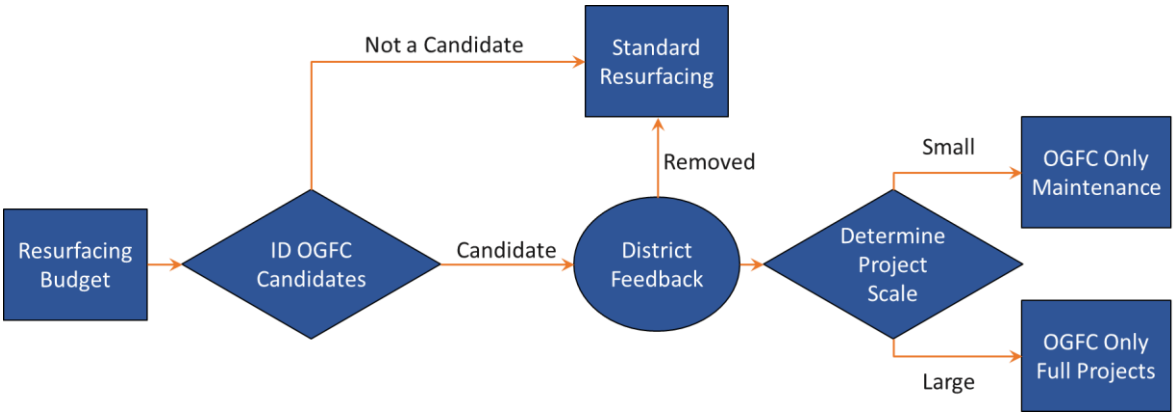
OGFC Only - Mainstream into Resurfacing

- **FY28**: Transition from reactive, emergency repairs (band-aid) to planned and full-size resurfacing projects; district collaboration
- **Credited**: OGFC Only projects will count for LM targets



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Proposed OGFC Only Resurfacing (Core)

- Project Level
- Full Lane Width
- Full Project Length
- All Lanes
- Cost Effective
- Minimum Plans
- Acceptance
- Warranty
- Smoothness

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Proposed OGFC Only Resurfacing (Option)

- Projects with minimum or discrete structural issues
- OGFC only but allows isolated deeper milling repairs for these areas

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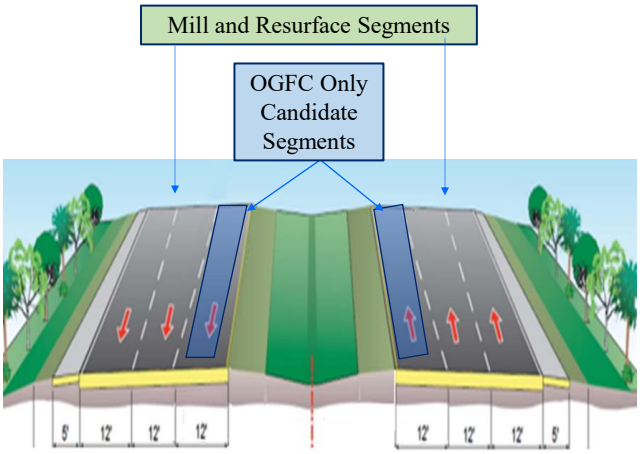
Proposed OGFC Only Resurfacing (Hybrid Option)

- Conventional resurfacing projects. Add OGFC only to projects where it makes sense
- Example:
  - Based on 3D Imaging
  - Inside lanes of a six-lane interstate resurfacing project.
  - Outer lanes will be standard mill and resurface



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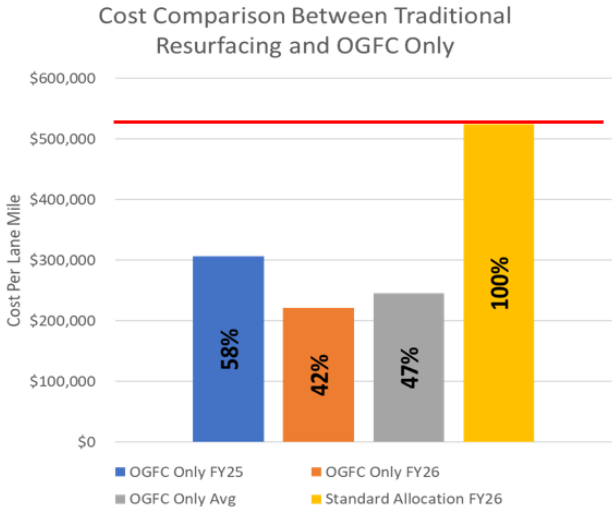
Cost Savings In OGFC Only Resurfacing

- FY 25-26 Cost Estimate
  - Isolated/Discrete raveling projects
  - 53% Reduction in paving costs/mile
- FY 27
  - Pending programming projects
- FY 28
  - Anticipate longer full project level
  - Anticipate further reduction in paving costs/mile



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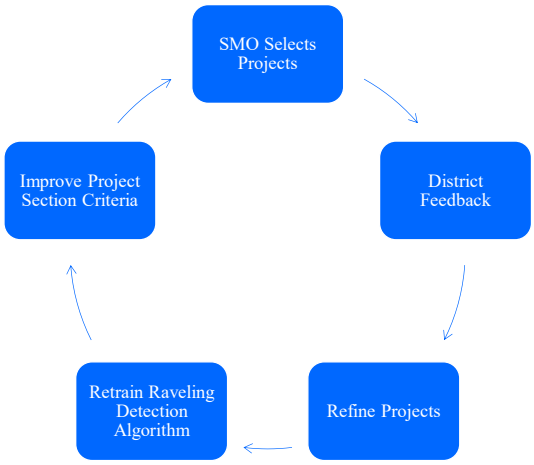
Continuous Improvement

- All aspects of the OGFC Only program will be continuously revised and improved based on feedback:
  - Leverage District relationships and coordination
  - Retrain the Machine Learning model for detecting raveling
  - Revise the project selection flowchart to better identify projects



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Thank you! Any Questions?

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October 28-29, 2025
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TRANSPORTATION SYMPOSIUM

DEADLINE

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Transportation Symposium Website

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