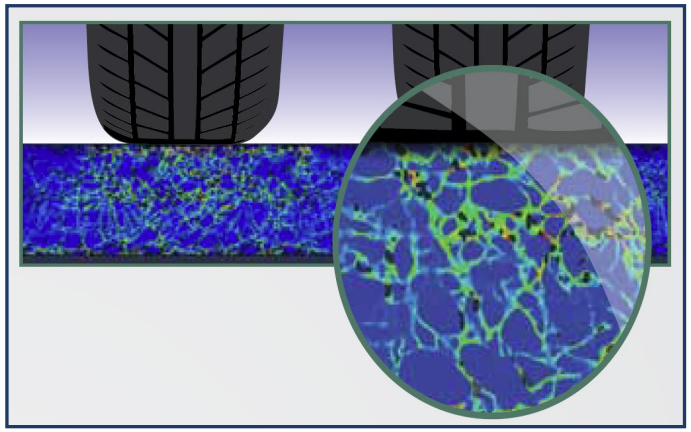
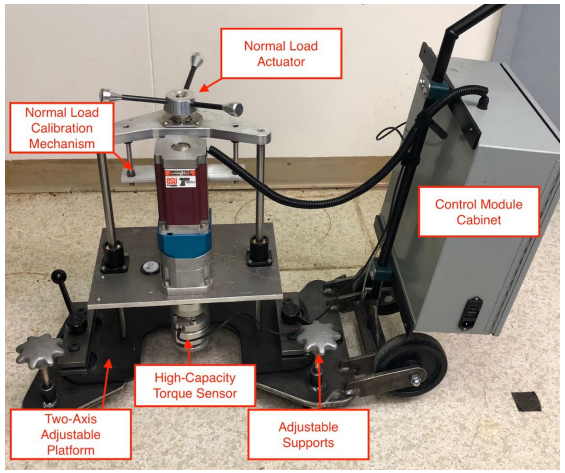
LCA, LCCA, and Sustainability



Advanced numerical modeling

Performance based specs



Technology development

OSU ASPHALT MATERIALS AND PAVEMENTS RESEARCH

Erdem Coleri, Ph.D.

Associate Professor

Director of OSU Asphalt Materials and Pavements Laboratory

School of Civil and Construction Engineering, Oregon State University

http://research.engr.oregonstate.edu/coleri/

Oregon State University

Oregon State University

OUTLINE

- OSU pavement research program overview and recent updates
- Vision for the OSU Asphalt Materials and Pavements (AMaP) Lab
- Info on "Balanced mix design", "High density joints", "Higher RAP", "FHWA-Climate Challenge" and "Chip seal" research studies
- Summary

OSU PAVEMENT RESEARCH PROGRAM OVERVIEW

FORMER GRADUATE STUDENTS

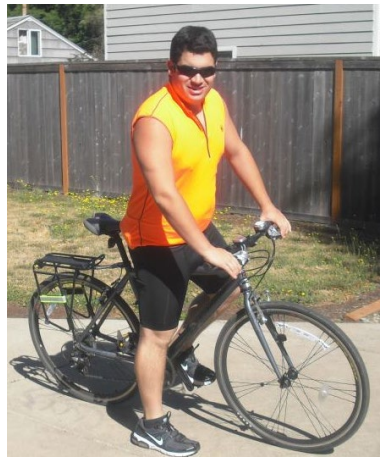
Aiman Mahmoud
ODOT

Rick Villarreal - **ODOT**

Josh Weaver- **ODOT**

Sogol Haddadi
Walmart Global Tech

Vikas Kumar
WSDOT



David Covey
Murraysmith

Blaine Wruck
Deschutes County

Matthew Haynes
GRI

Shashwath Sreedhar
GRI

Mostafa Estaji
County of Santa Barbara

Sunny Lewis
Skanska

Ihsan Obaid
University of AlQadisiyah

OSU PAVEMENT RESEARCH PROGRAM OVERVIEW

PAST AND CURRENT UNDERGRAD RESEARCH ASSISTANTS

1. David Covey
2. Caleb Lennon
3. Blaine Wruck
4. Dylan Kreiger
5. Jawad Qassem
6. Matthew Haynes
7. Nicholas Giles
8. Natasha Anisimova
9. Nicholas Kolstad
10. Timothy Flowerday
11. John Paul Morton
12. Lincoln Earl Chapman
13. Kirk Annekken Downer
14. Alec Nikunen Adams
15. Jacob Virell
16. Amanda Michelle Riley
17. Jonathon Robert Schwartz
18. Douglas Keys
19. Erick Daniel Moreno Rangel
20. Eduardo Ramirez
21. Andrew Johnson
22. Taylor Van Gordon
23. Josh Deaver
24. Connor Joseph Hull
25. Nicole Nickerson
25. Jon Weinberg
26. Alex Sutherland
27. Diane Fankhanel
28. Sunny Lewis
29. Joseph Neils
30. Rachael K. Oster
31. Meagan Nakamoto
32. Nathan Boechler
33. Luis Gonzalez
34. Skyler Lindner
35. Roland Perez
36. Mitch Sundstrom
37. Joshua Weaver
38. Will Muraviov
39. Zach Newton
40. Tongnoma Aime Jean De Dieu Nacoulma
41. Keely Creel
42. Zharita Zurita
43. Prescott Benner
44. Quentin Beers
45. Caleb Morris
46. Jonathan Stark
47. Miles Barnes
48. Tim Degener
49. Allyson Burket
50. Valentino Lim
51. Sarah Ambrozio Turini
52. Tyler McCleskey
53. Michael J. Schumacher
54. Li Ze Chai
55. Ashay Sameer Shah

OSU PAVEMENT RESEARCH PROGRAM OVERVIEW

ODOT RESEARCH PROJECTS

Completed Projects

1. HMAC Layer Adhesion Through Tack Coat
2. Adjusting Asphalt Mixes for Increased Durability and Implementation of a Tester
3. Binder-Grade Bumping and High Binder Content to Improve Performance of RAP/RAS mixes
4. Bridge Deck Asphalt Concrete Pavement Armoring
5. Implementation of ODOT Tack Coat Technologies and Procedures to Improve Long-Term Performance
6. Development of a Balanced Mix Design Method in Oregon
7. Constructing High-Performance Asphalt Pavements by Improving In-Place Density
8. Implementation of a Laboratory Conditioning and Testing Protocol to Evaluate Moisture Susceptibility of Asphalt Mixtures
9. Centerline Rumble Strip Effects on Pavement Performance

Current Projects

10. Constructing High-Density Longitudinal Joints To Improve Pavement Longevity
11. Implementation of Balanced Mix Design Methods in Oregon
12. Development of Procedures and Technologies for Chip Seal QC
13. Increasing Asphalt Recycling to Reduce Paving Costs and Reduce Environmental Impact
14. FHWA-ODOT Climate challenge research projects

OSU RESEARCH OVERVIEW - PROJECTS

Technology development for QC and design

- Tack coat tech development
- Tack coat tech implementation
- Chip seal QC techs
- Durability tester implementation
- Balanced mix design development
- Balanced mix design implementation
- Moisture susceptibility conditioning and testing
- High-density joints
- Increasing asphalt recycling

Environmental, LCA and LCCA

- Asphalt recycling
- Asphalt density improvement
- PACTRANS-Network-level decision making tool
- Pavement and fuel economy-UCPRC
- Increasing recycling
- FHWA smoothness research
- FHWA renewable fuels for asphalt plants

Numerical modeling and ME design

- Tack coat tech development
- Asphalt recycling
- Bridge deck asphalt concrete armoring
- Rumble strips performance
- Pavement and fuel economy-UCPRC
- Tallwood- CLT parking garage

Lab and field testing

All projects except:
- PACTRANS-Network-level decision making tool
- Pavement and fuel economy-UCPRC (field component completed by UCPRC)

Implementation of final products

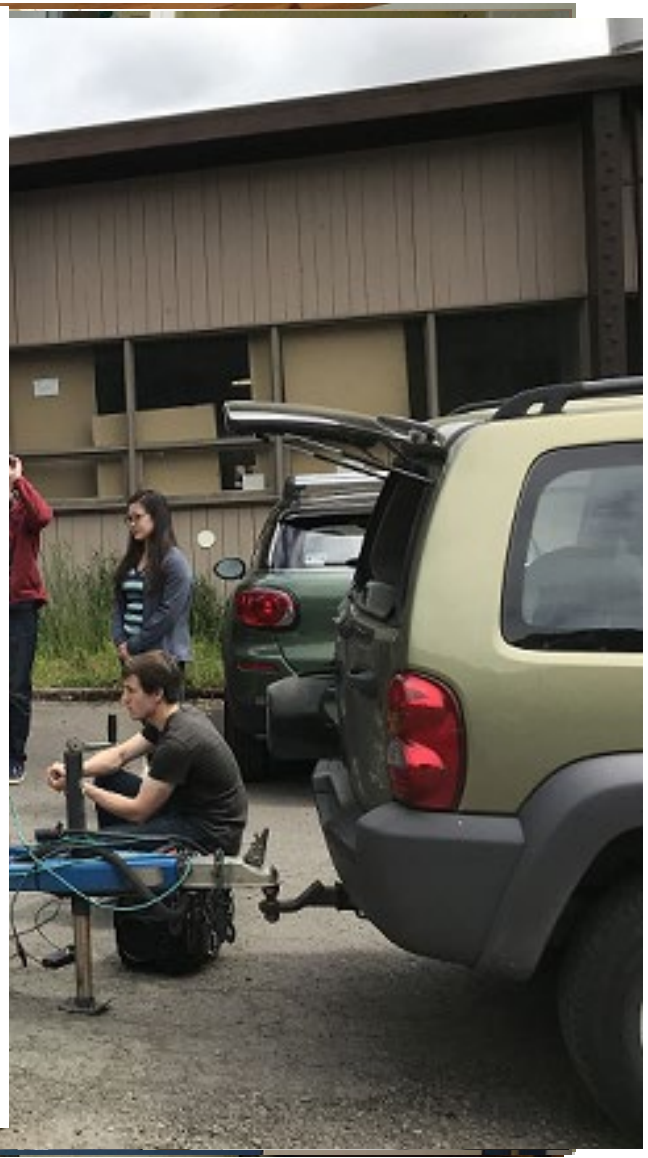
- Tack coat tech implementation
- NEW!!! Chip seal QC techs
- Durability tester implementation
- NEW!!! Balanced mix design implementation
- Moisture susceptibility conditioning and testing

OSU PAVEMENT RESEARCH PROGRAM OVERVIEW

OSU ASPHALT MATERIALS & PAVEMENTS LAB

OSU PAVEMENT RESEARCH PROGRAM OVERVIEW

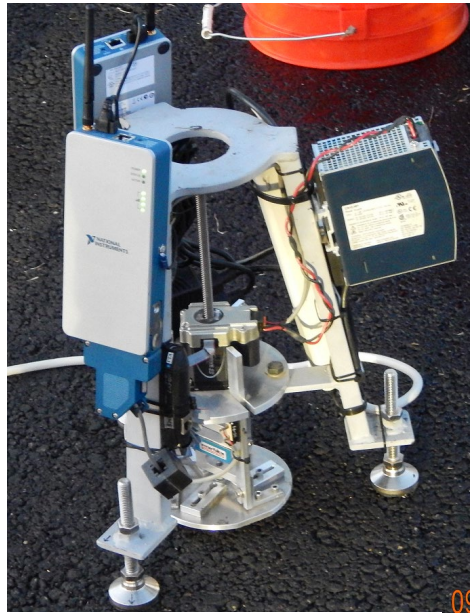
OSU ASPHALT MATERIALS&PAVEMENTS LAB



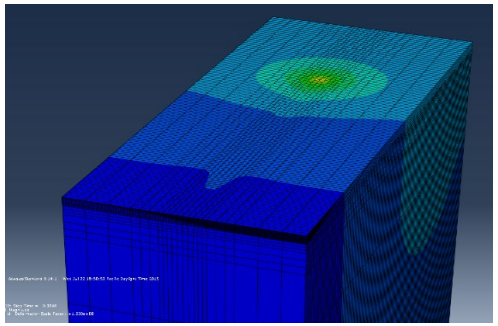
COMING SOON!!! - The Low-Cost Full-Scale Accelerated Pavement Test System

- A full scale truck axle is currently being built.
- A laser texture scanner
- A profilometer system for surface profile monitoring
- A camera system with an image processing code for crack formation and progression monitoring

DEVELOPED TECHNOLOGIES – 100% MADE AT OSU

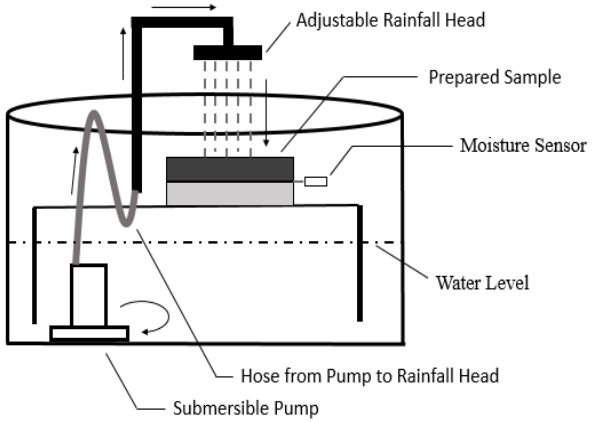


Wireless OFTCT



Model to evaluate pavement and bond strength

IOS and Android apps for curing time notification



Rainfall simulator and moisture sensor system

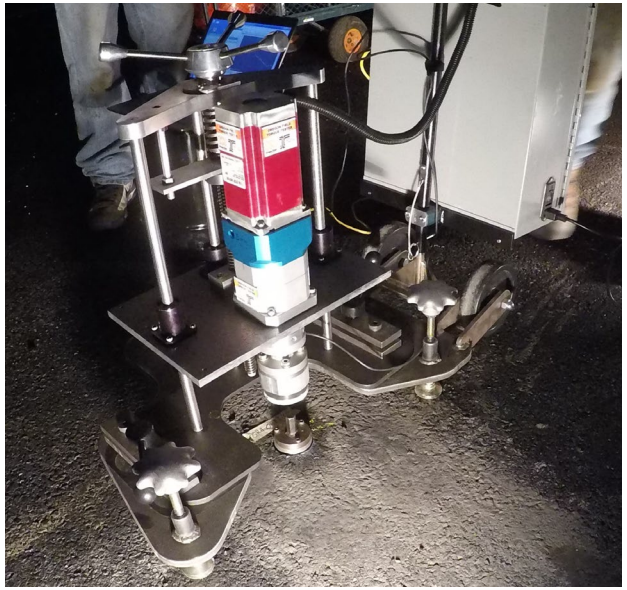
Wheel tracking device

Laser texture scanner for chip seals

OTHER TACK TECHNOLOGIES

OreTackRate

- curing time,
- application uniformity and accuracy, and
- distributor truck certification and validation



OreTackBond

- Bond quality control

OreTackClean

- Surface cleanliness

OSU ASPHALT MATERIALS RESEARCH PROGRAM OVERVIEW

OSU ASPHALT MATERIALS AND PAVEMENTS LAB

MISSION:

Develop and implement methods and technologies to construct transportation infrastructure that is more cost-effective, socially beneficial, and does less damage to the environment while teaching the fundamentals of pavement engineering to K-12 and college students and the public.

OUR VISION DOCUMENT IS POSTED AND AVAILABLE HERE ON OUR WEBSITE

UPDATE ON CURRENT ODOT PROJECTS

1. Implementation of Balanced Mix Design Methods in Oregon – VIKAS KUMAR AND VIPUL CHITNIS
2. Constructing High-Density Longitudinal Joints To Improve Pavement Longevity – VIPUL CHITNIS
3. Development of Procedures and Technologies for Chip Seal QC – SERVAN BARAN
4. Increasing Asphalt Recycling to Reduce Paving Costs, Improve Pavement Longevity, and Reduce Environmental Impact – MAYANK SUKHIJA
5. Climate challenge projects,
    i) Roadway smoothness and emissions – SEAN GIBSON
    ii) Renewable fuels for asphalt plants – JOHN HICKEY AND ZECHARIAH HECK

PROJECT#1 - BALANCED MIX DESIGN (BMD)

Asphalt-Surfaced Pavement Distresses

Source: https://www.pavementinteractive.org

Rutting

NOT A BIG PROBLEM IN OREGON

Low temperature cracking

NOT A BIG PROBLEM IN OREGON

Fatigue cracking

MAJOR DISTRESS MODE IN OREGON
Mostly delamination and moisture related

BMD AND PERFORMANCE BASED SPECS

Why do we need performance based specs?

Late 1920s, Francis N. Hveem, Hveem mix design

In 1939, Bruce G. Marshall developed Marshal Stability Method.

In 1993, Superpave (Superior Performing Asphalt Pavement) method was developed as part of SHRP program.

BUT NO PERFORMANCE TESTS WERE IMPLEMENTED FOR CRACKING AND RUTTING!!!

BMD AND PERFORMANCE BASED SPECS

Why do we need performance based specs?

Good old days

Can we achieve the best taste without tasting it?

Today's mixes

mix

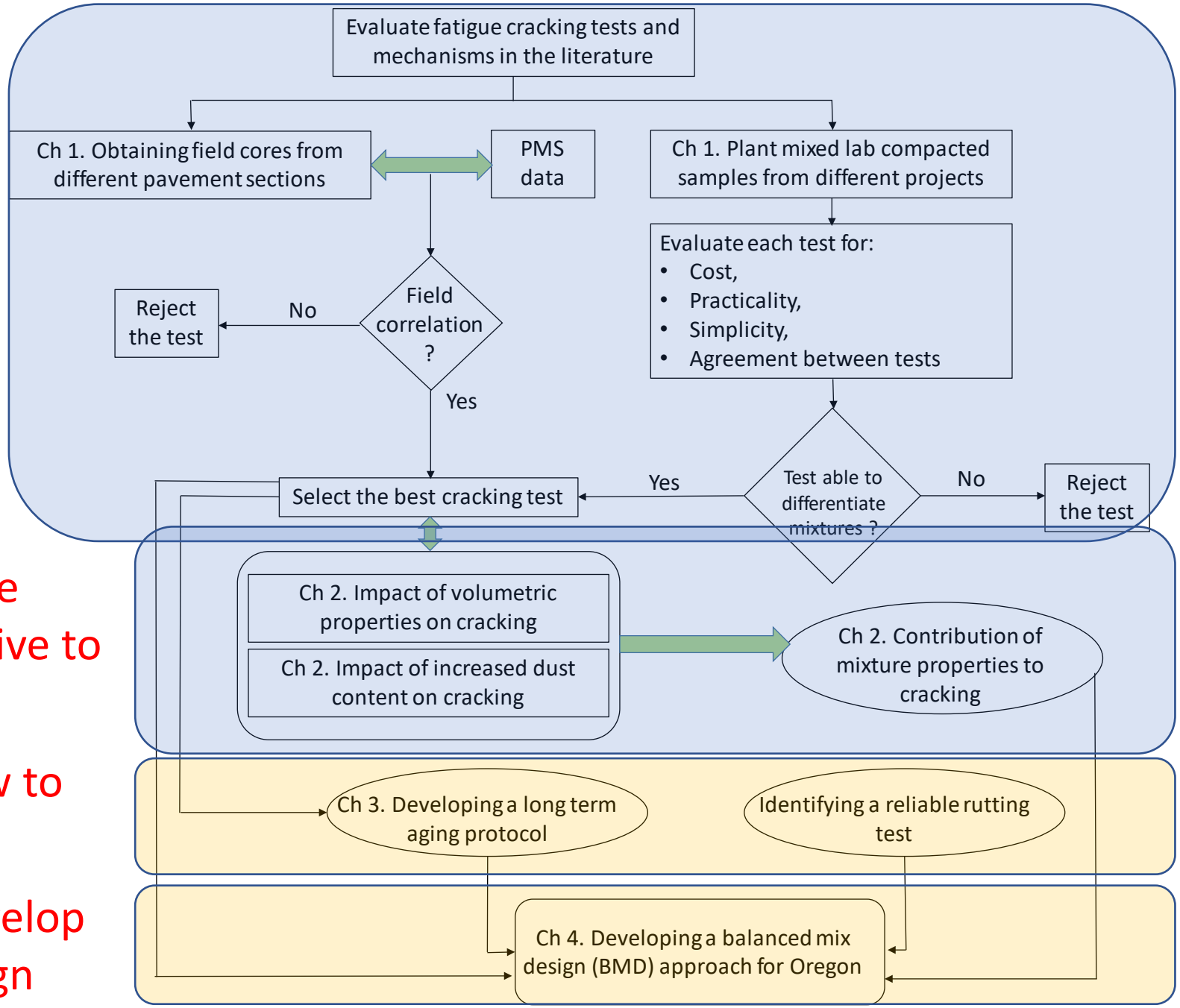
RESEARCH ROAD MAP FOR BMD

Part I-2015: Best cracking and rutting tests?

Part II-2016 – Are the selected tests sensitive to mix properties?

Part III-2018 – How to simulate aging?

Part IV-2019 – Develop balanced mix design

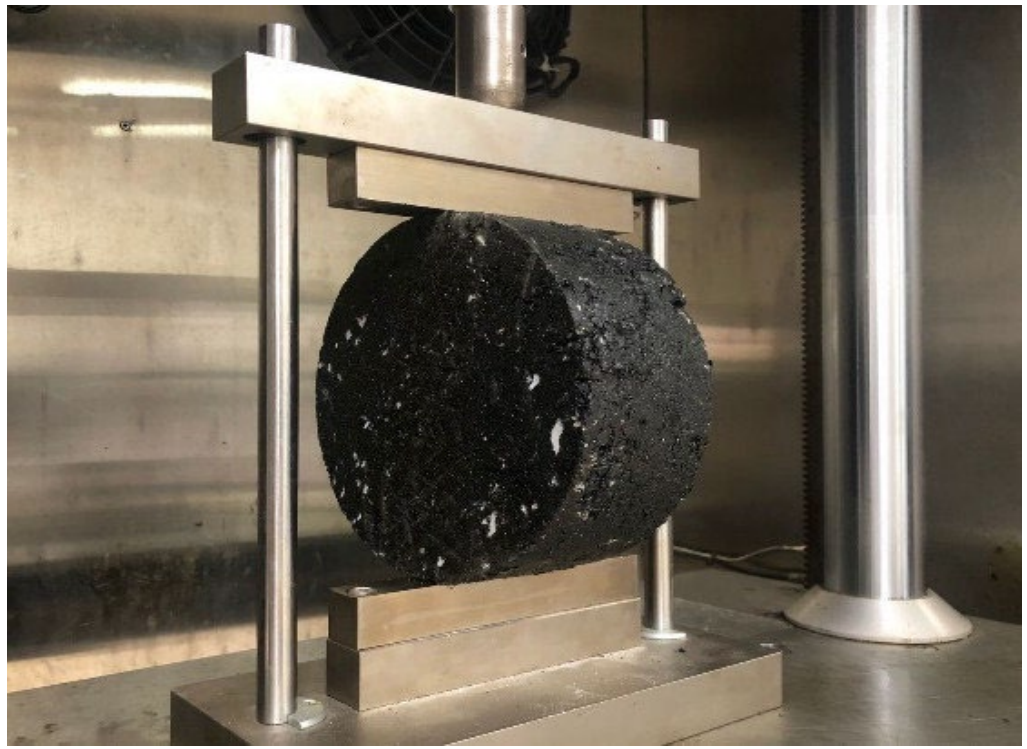


IMPLEMENTATION OF PERFORMANCE-BASED SPECS AND BMD

Part I-2015 and Part II-2016: Best cracking and rutting tests for Oregon

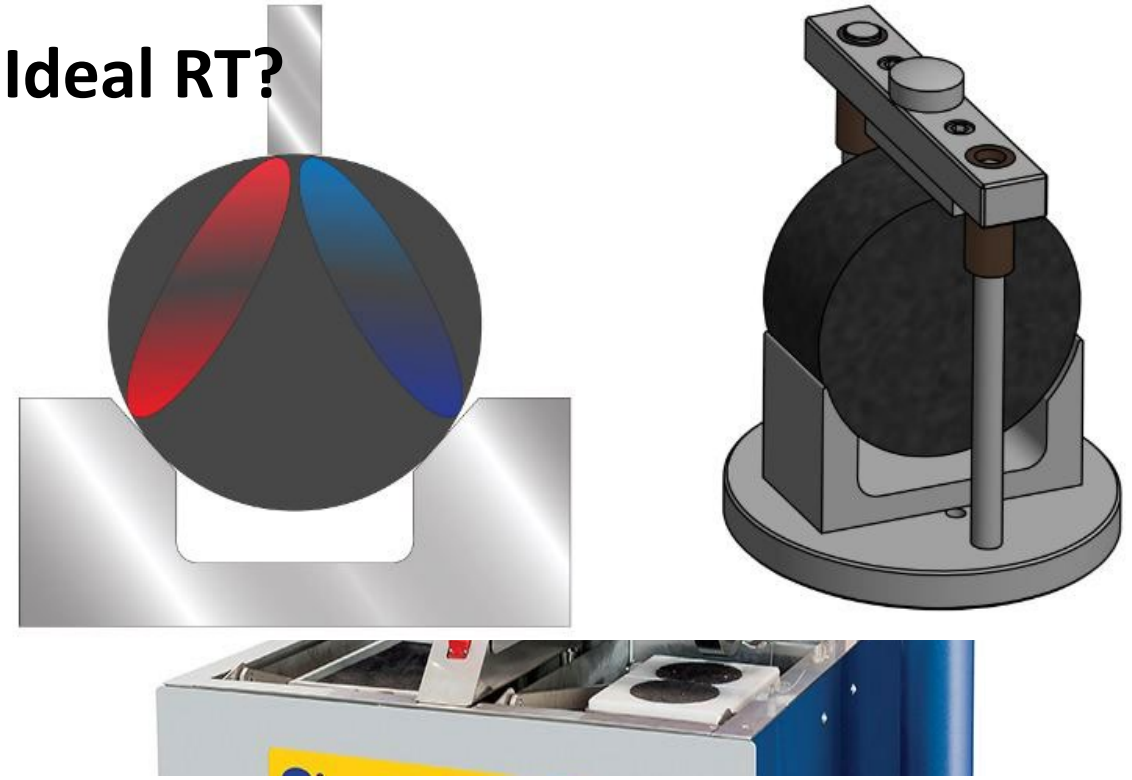
Selected and considered performance experiments

FOR CRACKING PERFORMANCE



Ideal CT – Indirect Tension Test

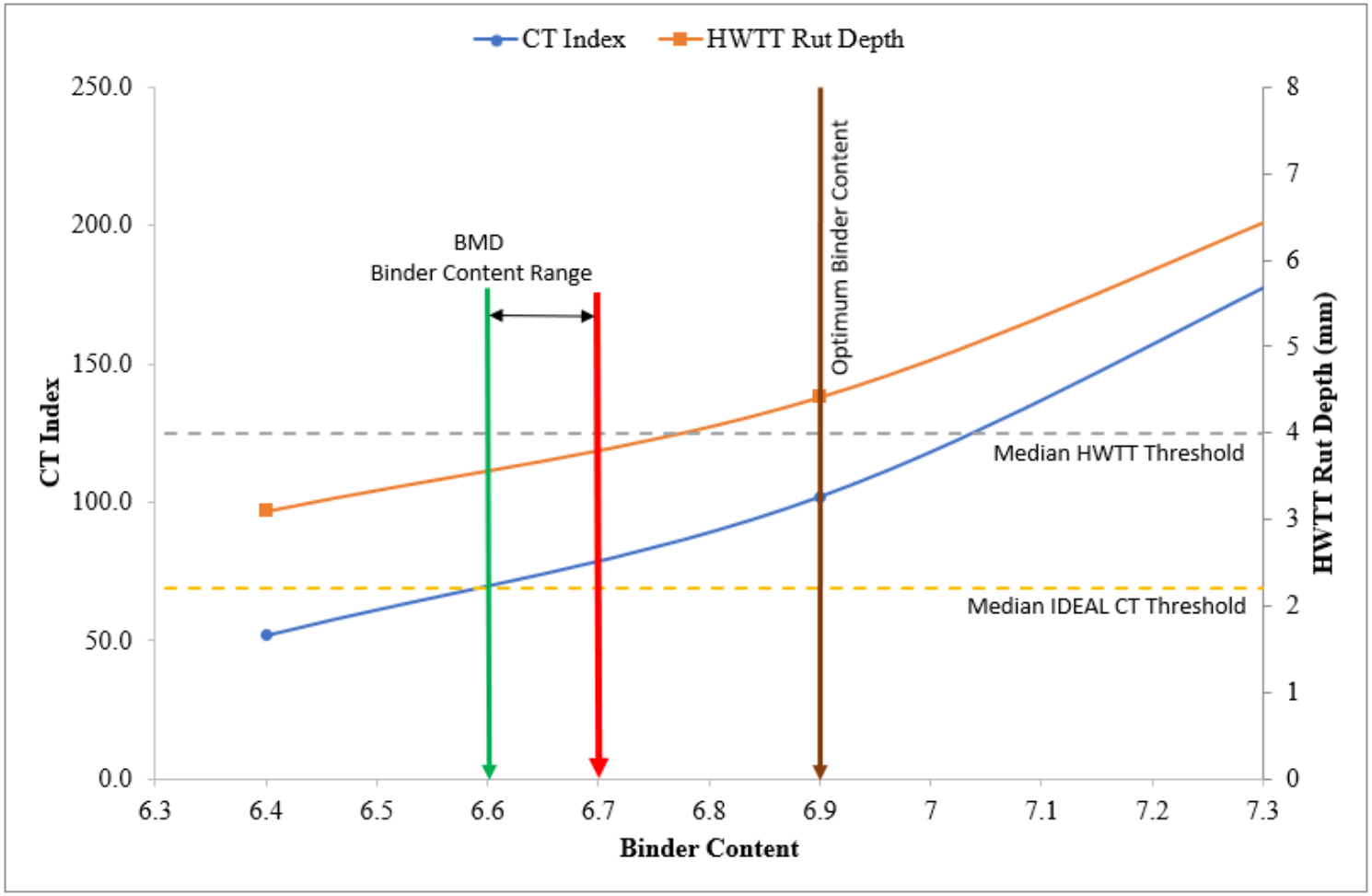
FOR RUTTING PERFORMANCE



Hamburg wheel tracking test

IMPLEMENTATION OF PERFORMANCE-BASED SPECS AND BMD

The BMD PROCESS



IMPLEMENTATION OF PERFORMANCE-BASED SPECS AND BMD

Part III-2018 – How to simulate aging?

- ***Short-term aging***

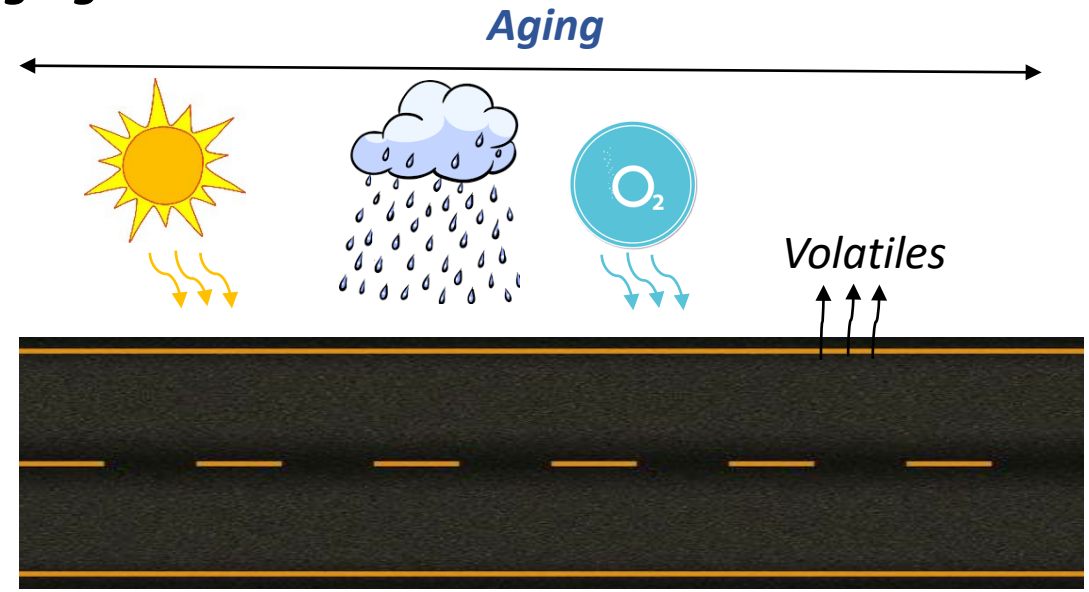
Wikipedia

www.hotmixtrucks.co.uk

sloan-construction.com

- ***Long-term aging***

Before



After

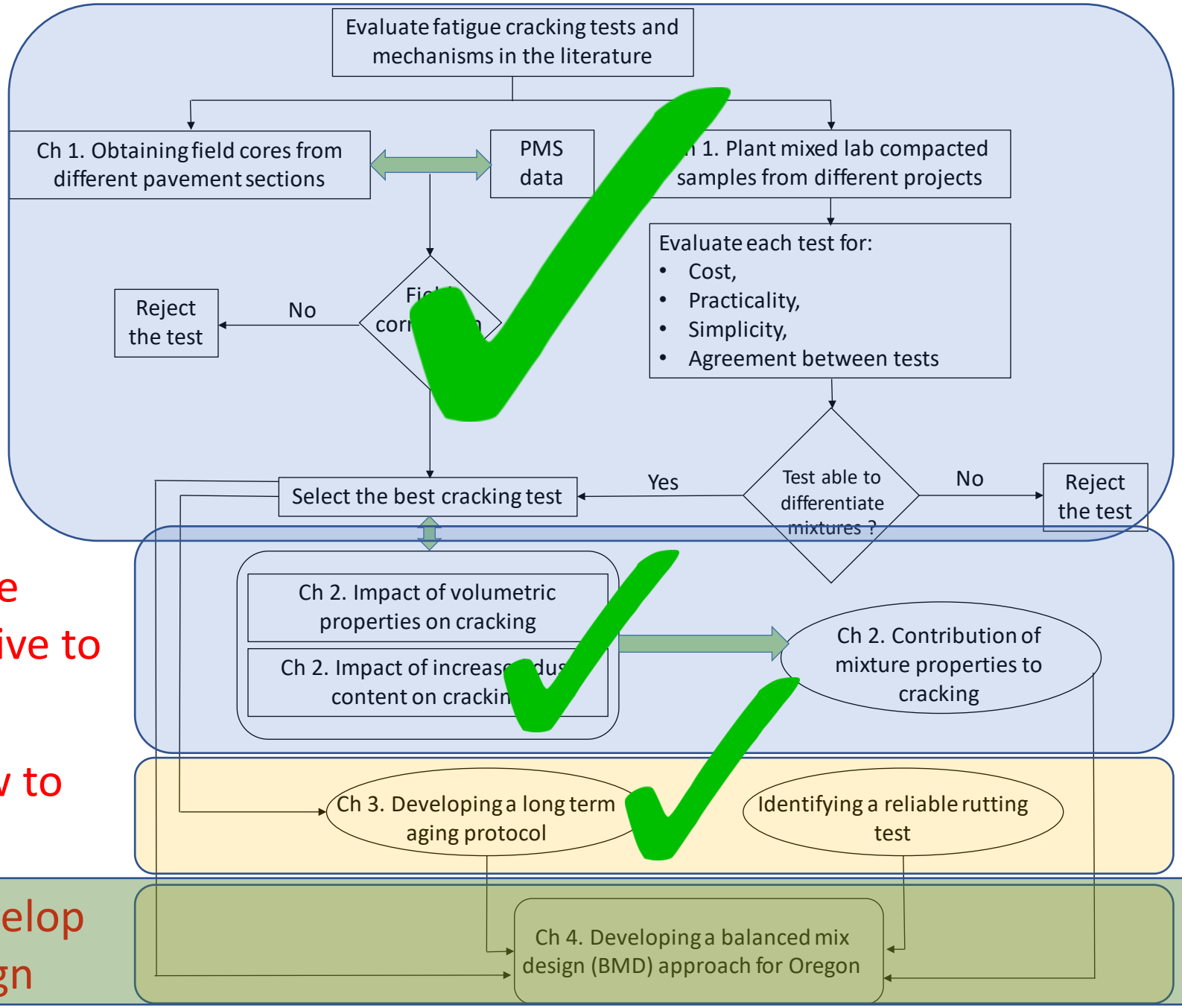
RESEARCH ROAD MAP FOR PERFORMANCE BASED SPECS

Part I-201 Best cracking nd rutting te

Part II-201 – Are the selec tests sensitive to mix propertie ?

Part III-2 18 – How to simu e aging?

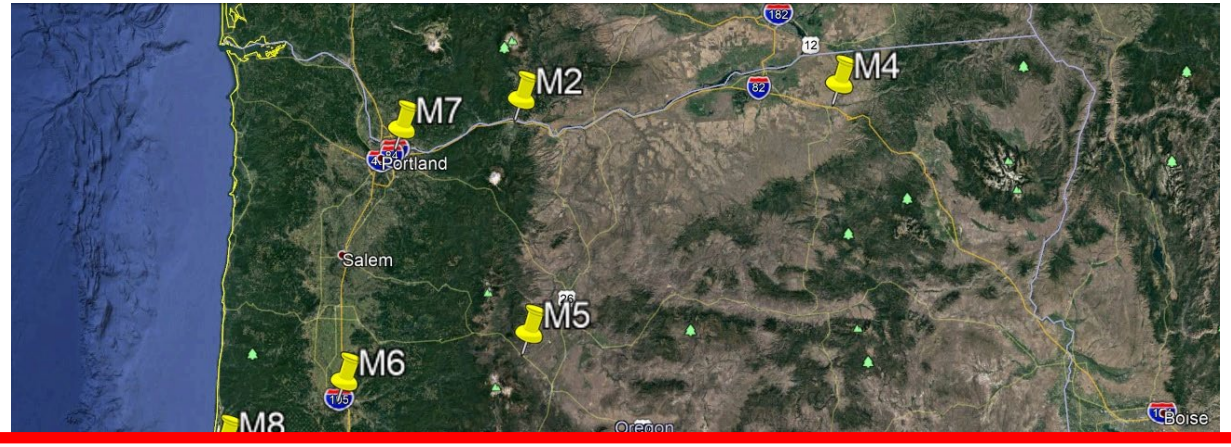
Part IV-2019 – Develop balanced mix design



IMPLEMENTATION OF THE BMD PROCESS

Part IV-2019 – Balanced mix design and performance based specs

8 construction projects in Oregon – Over 600 experiments conducted in this phase



4. Implementation of Balanced Mix Design Methods in Oregon – Pilot Projects

IMPLEMENTATION OF THE BMD PROCESS

Implementation of Balanced Mix Design Methods in Oregon – Pilot Projects

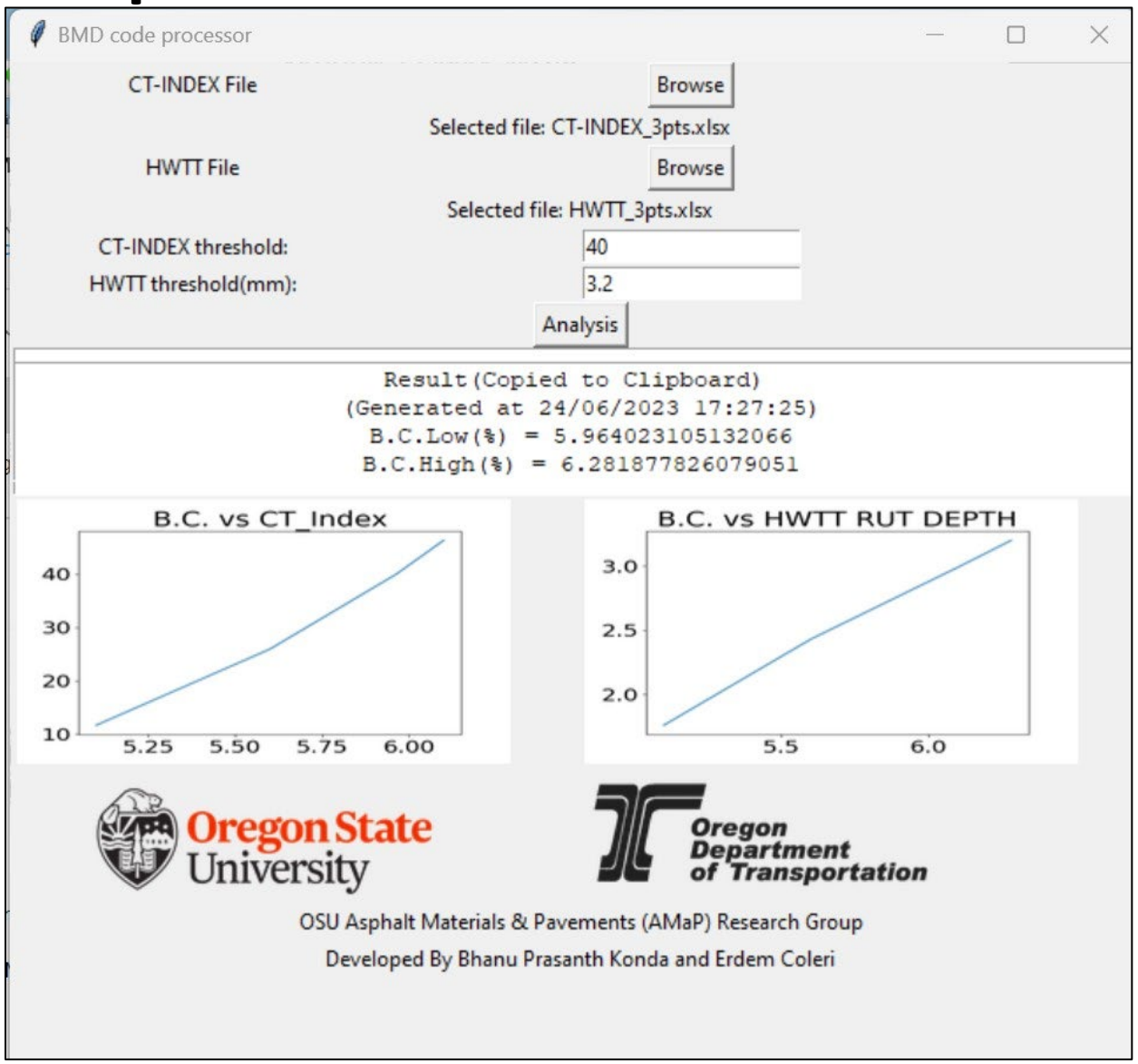
- A comprehensive literature review
- Developed codes for: i) processing laboratory test results
  ii) performing the BMD
  iii) conducting the final checks for volumetrics

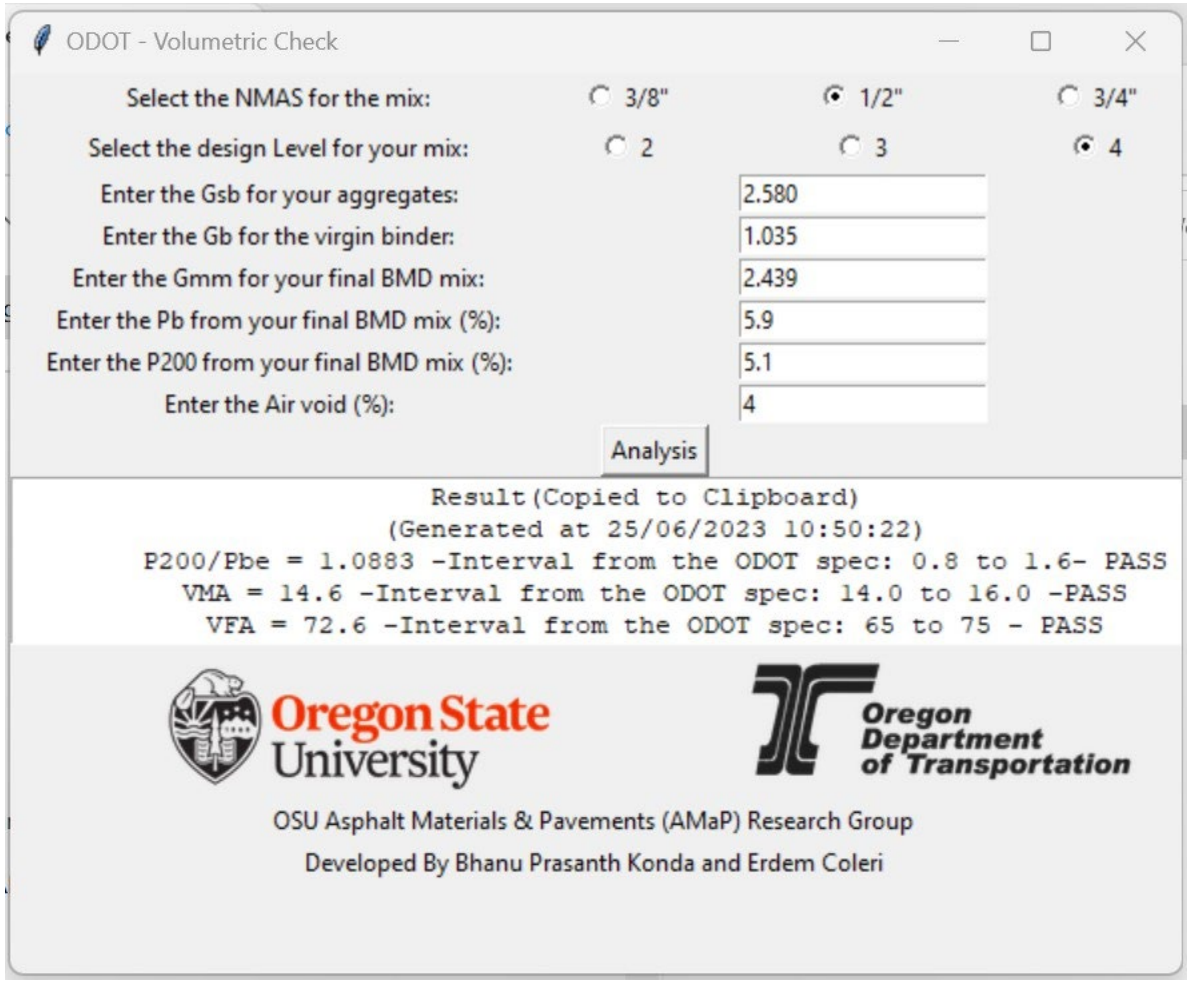
- Finalized the development of laboratory test protocols to improve the practicality and accuracy of the process

- Sampled five mixes with aggregates, binder, and production mix and completed the BMD process

IMPLEMENTATION OF THE BMD PROCESS

Implementation of BMD – Software packages

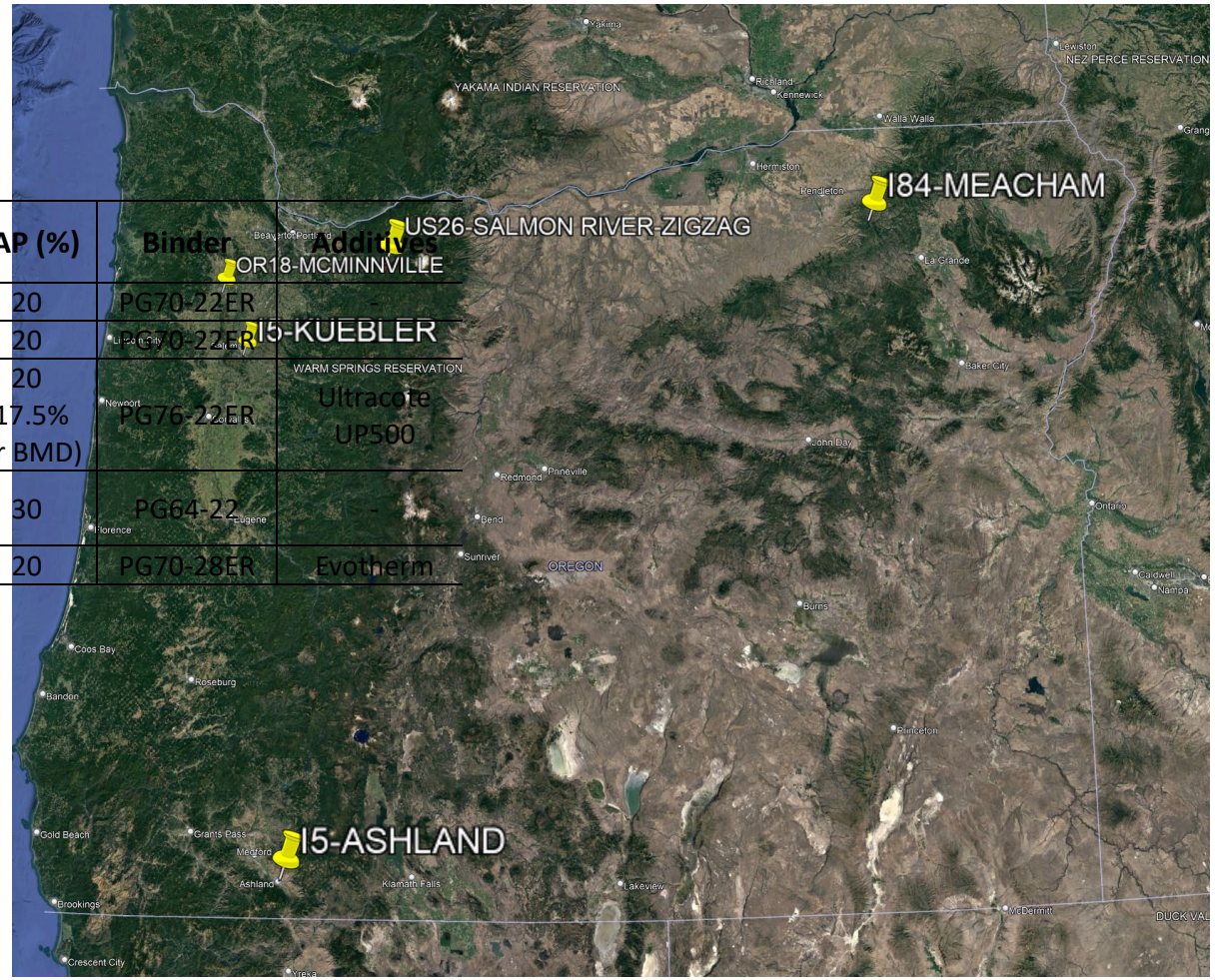




IMPLEMENTATION OF THE BMD PROCESS

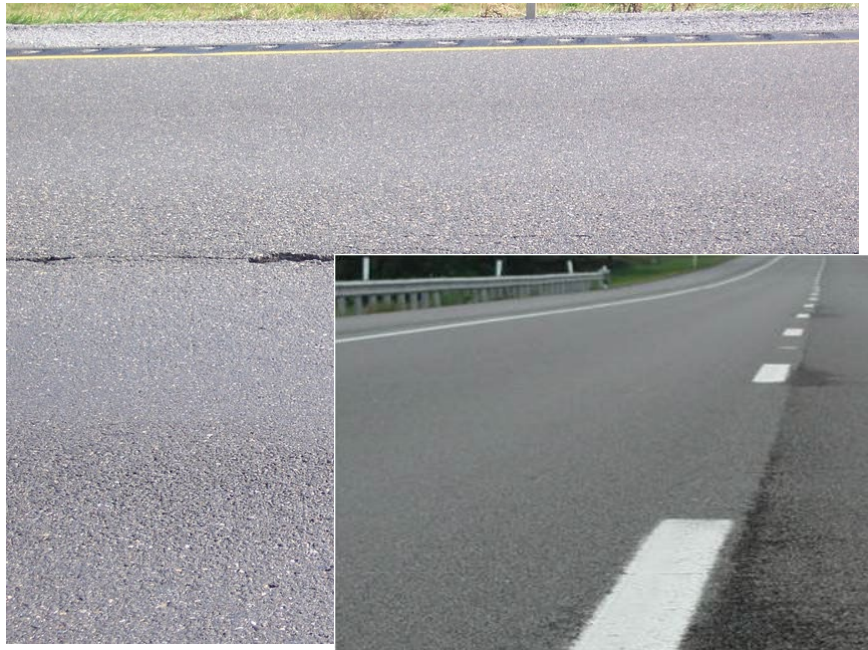
Implementation of Balanced Mix Design Methods in Oregon – Five Pilot Projects

Location	Optimum BC (%)	BMD BC (%)	RAP (%)	Binder	Additives
OR18-McMinnville	6.0	5.9	20	PG70-22ER	-
I5-Kuebler	5.6	5.9	20	PG70-22ER	-
I5-Ashland	6.2	6.3	20 (17.5% for BMD)	PG76-22ER	Ultracote UP500
US26-Salmon River/Zigzag	5.3	5.7	30	PG64-22	-
I84-Meacham	6.2	5.9	20	PG70-28ER	Evotherm

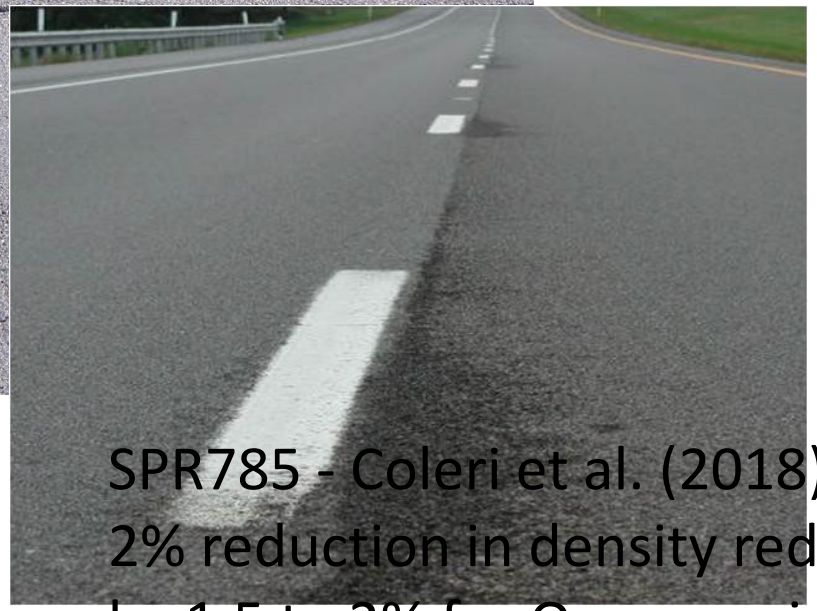


PROJECT#2 - CONSTRUCTING HIGH-DENSITY LONGITUDINAL JOINTS TO IMPROVE PAVEMENT LONGEVITY

- Lower densities and higher permeability along the longitudinal joints leading to premature cracking



FHWA and AI study (2012), no joint construction specs } 2-5% lower density at the joint than the mat



Tran et al. (2016)

1% reduction in density can create 33.8% to 66.3% reduction in the long-term fatigue cracking and rutting performance, respectively.

SPR785 - Coleri et al. (2018)
2% reduction in density reduces cracking resistance by 1.5 to 2% for Oregon mixes

Oregon State University

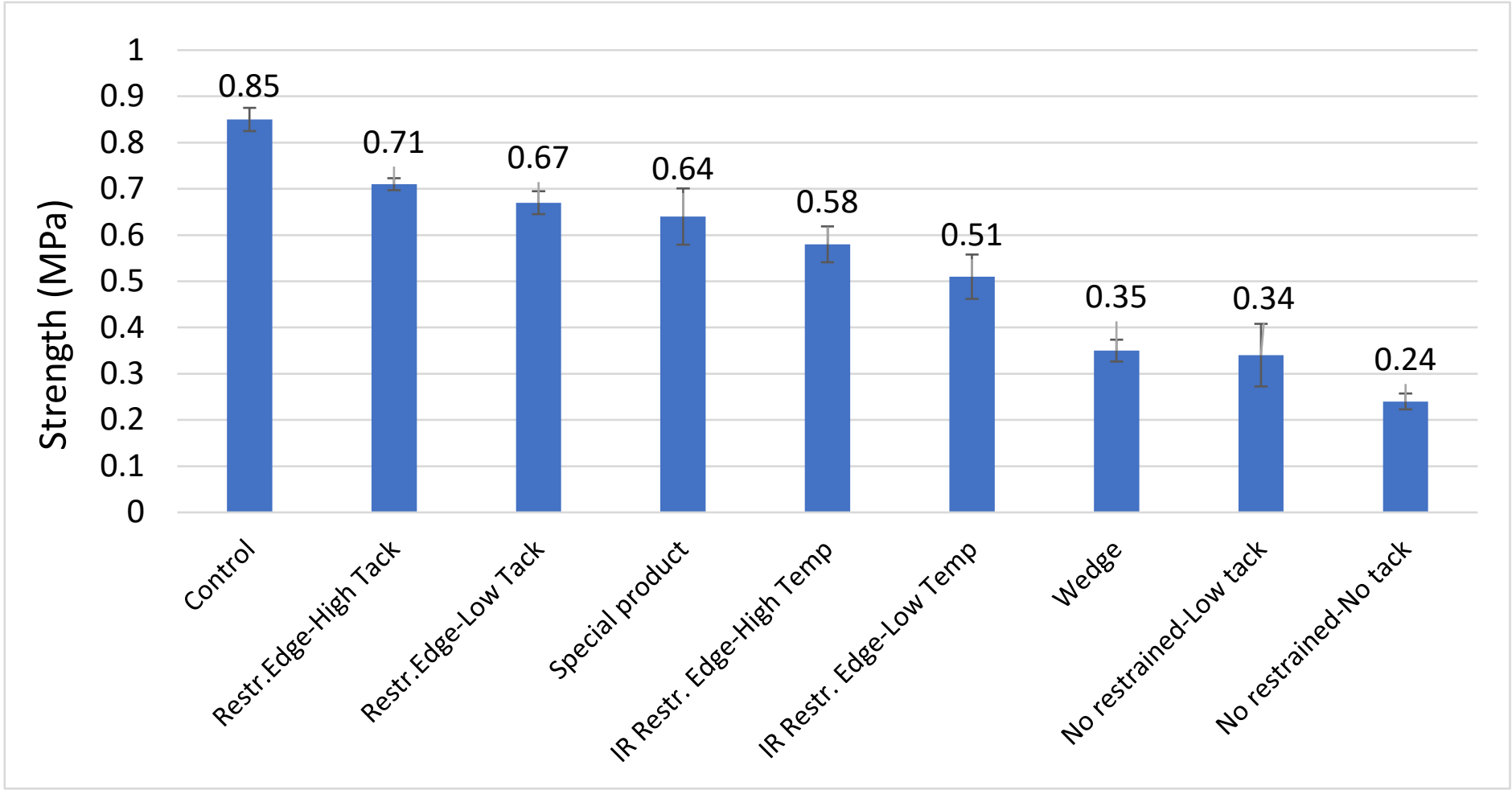
PROJECT#2 - CONSTRUCTING HIGH-DENSITY LONGITUDINAL JOINTS TO IMPROVE PAVEMENT LONGEVITY

Specimen production and testing at the OSU Asphalt Materials and Pavements Lab

Hydraulic roller compactor simulating field construction

PROJECT#2 - CONSTRUCTING HIGH-DENSITY LONGITUDINAL JOINTS TO IMPROVE PAVEMENT LONGEVITY

- Laboratory component completed



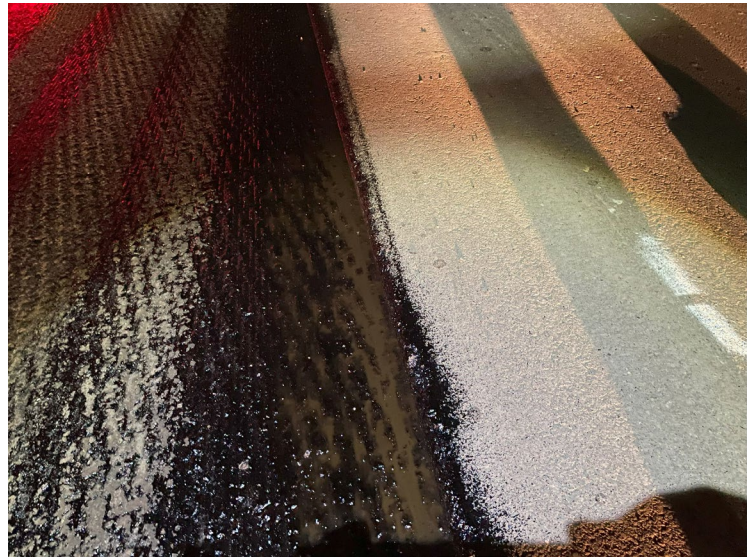
Field trials completed in the Summer of 2023

PROJECT#2 - CONSTRUCTING HIGH-DENSITY LONGITUDINAL JOINTS TO IMPROVE PAVEMENT LONGEVITY

- Field component

Infrared heating of the joint

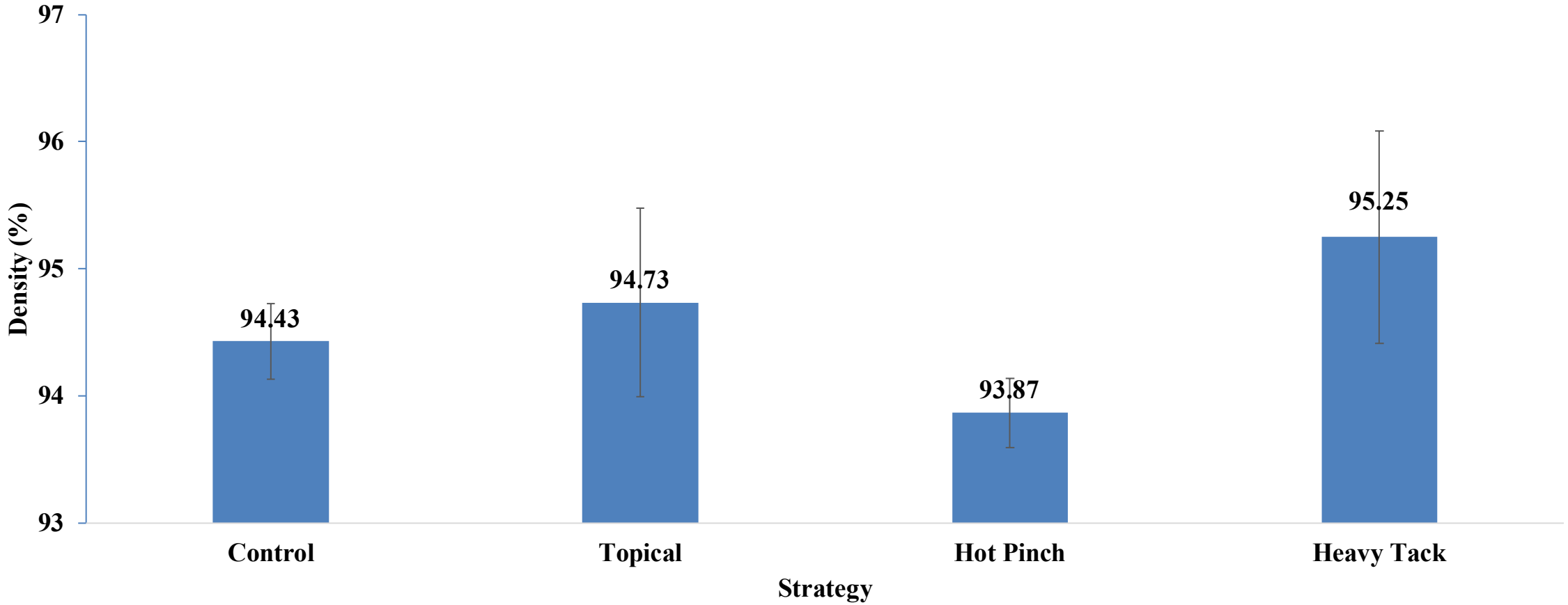
Topical product



Heavy tack application

PROJECT#2 - CONSTRUCTING HIGH-DENSITY LONGITUDINAL JOINTS TO IMPROVE PAVEMENT LONGEVITY

- Field component is in progress but here are some preliminary results from I5-Kuebler specimens close to Salem – Cores will be tested for strength soon



PROJECT#2 - CONSTRUCTING HIGH-DENSITY LONGITUDINAL JOINTS TO IMPROVE PAVEMENT LONGEVITY

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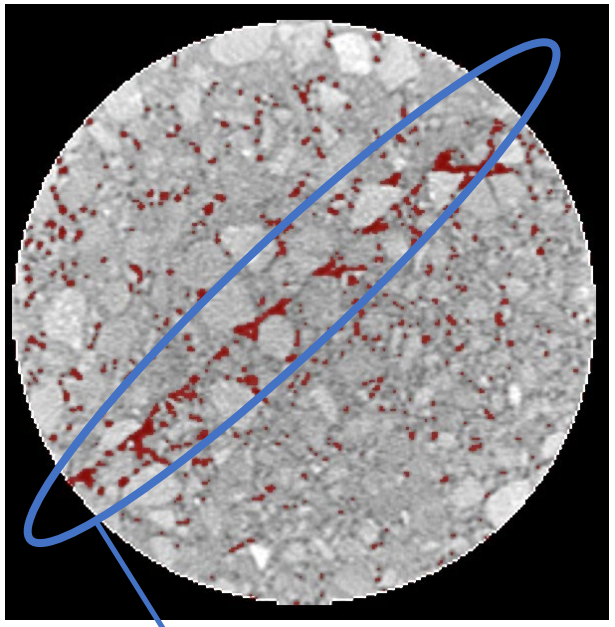
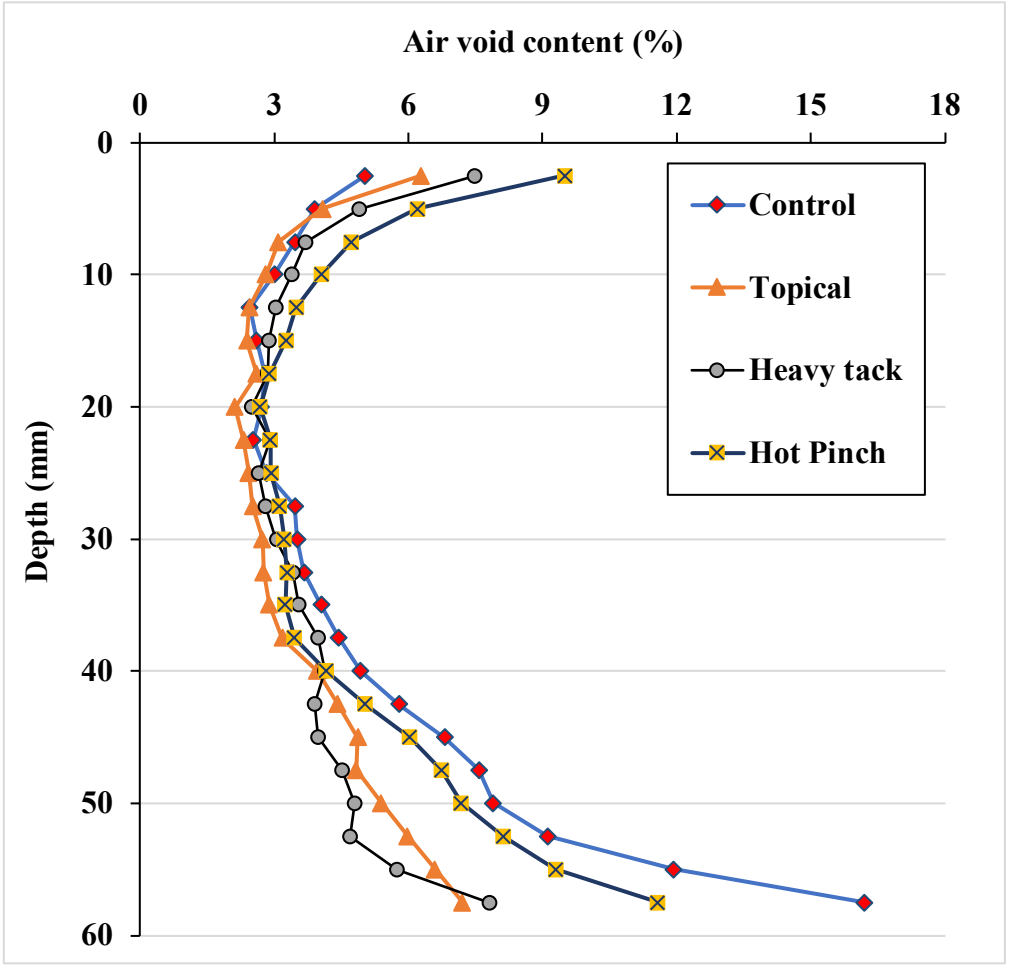




Combine topical with heavy tack

PROJECT#3 - DEVELOPMENT OF PROCEDURES AND TECHNOLOGIES FOR CHIP SEAL CONSTRUCTION QUALITY CONTROL IN OREGON

- Aggregate embedment measurement

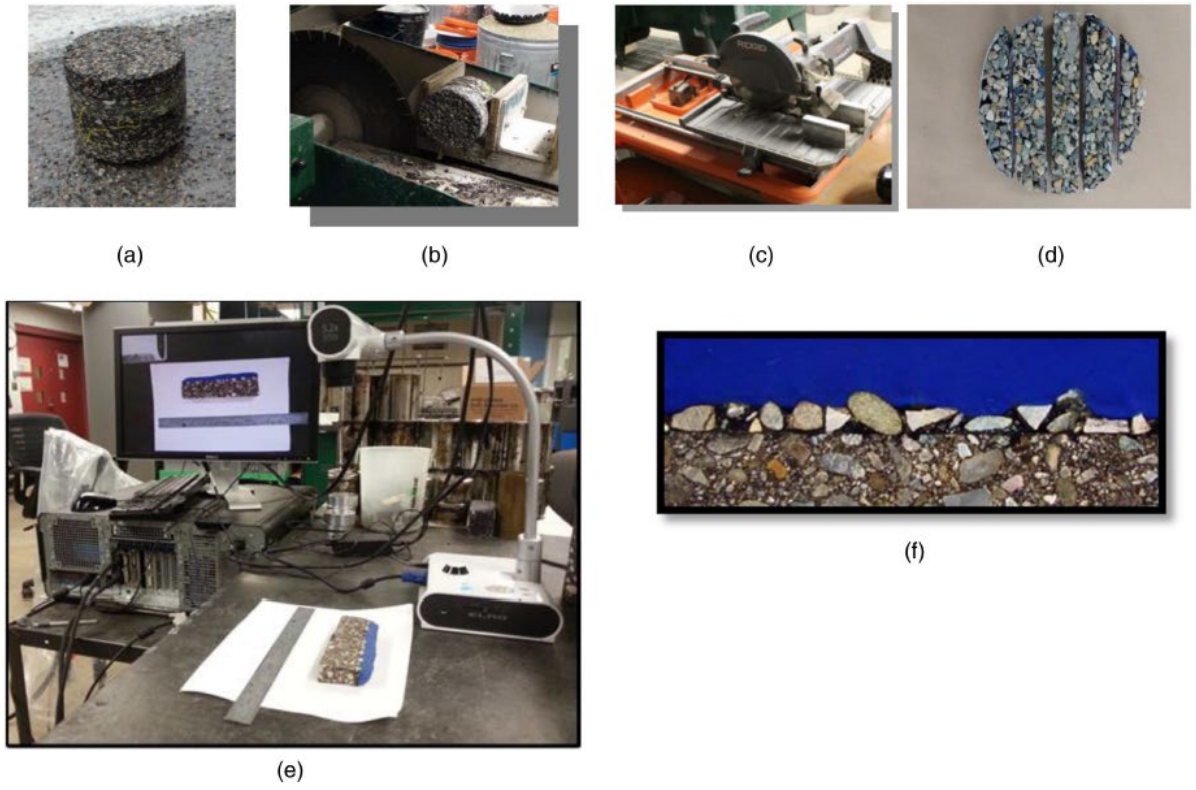


Fig. 2. Sample preparation and image acquisition: (a) field coring; (b) horizontal cutting; (c) vertical slicing; (d) core slices; (e) image acquisition of the core slice; and (f) desired image of the cross section.

Ozdemir et al. 2018 -

≈

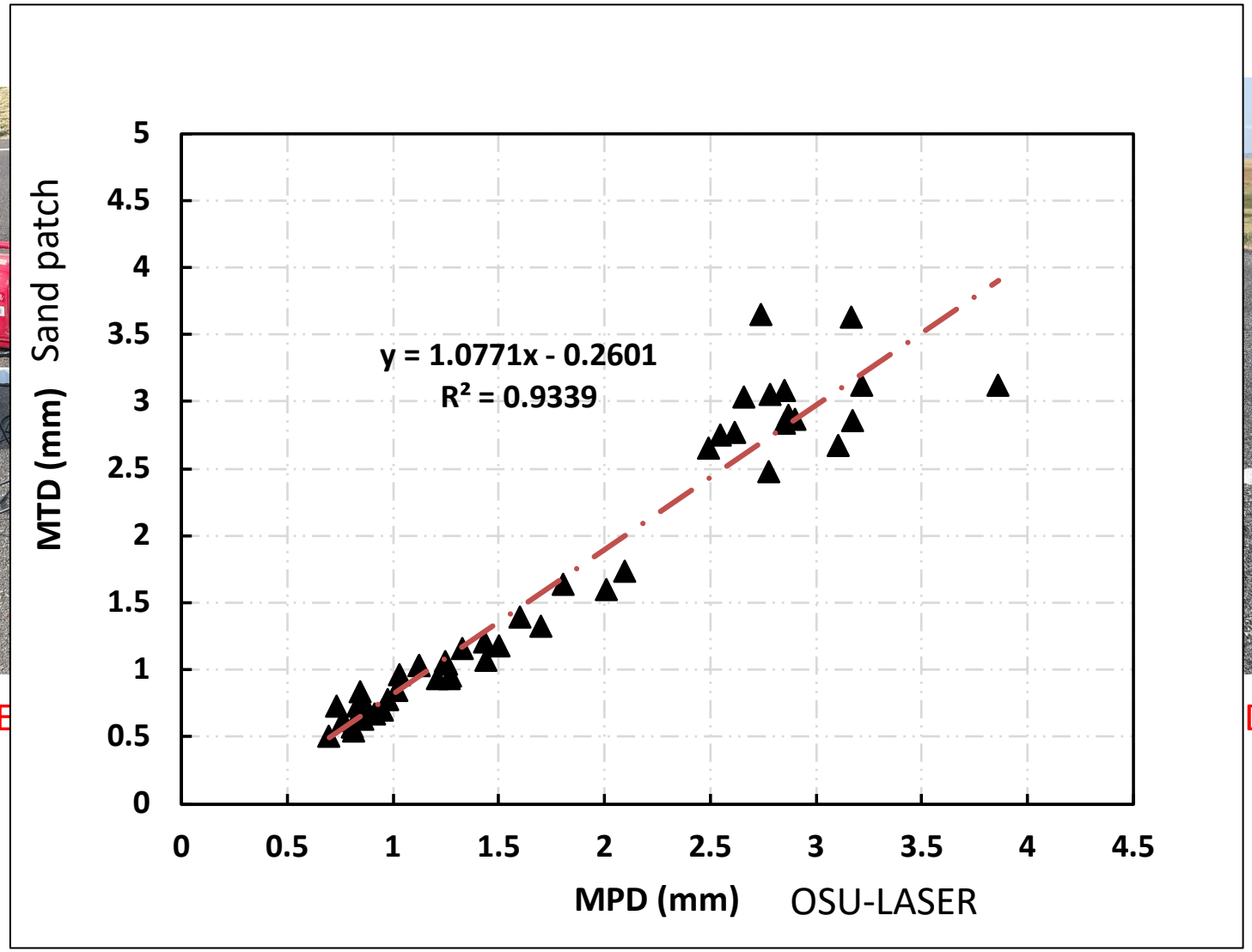
- Sand patch results
- Low cost laser texture scanner development

Can we measure embedment during construction in a practical way and accurately predict long-term embedment from it?

PROJECT#3 - DEVELOPMENT OF PROCEDURES AND TECHNOLOGIES FOR CHIP SEAL CONSTRUCTION QUALITY CONTROL IN OREGON

- Aggregate embedment measurement

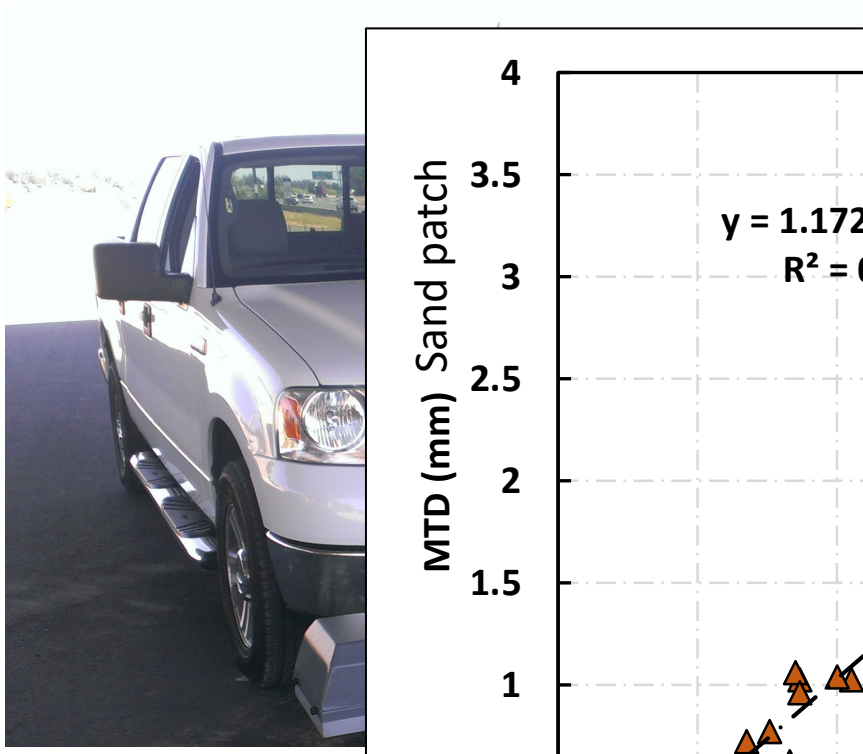
LASER TEXTURE SCANNE



D PATCH TEST

PROJECT#3 - DEVELOPMENT OF PROCEDURES AND TECHNOLOGIES FOR CHIP SEAL CONSTRUCTION QUALITY CONTROL IN OREGON

- Aggregate embedment measurement

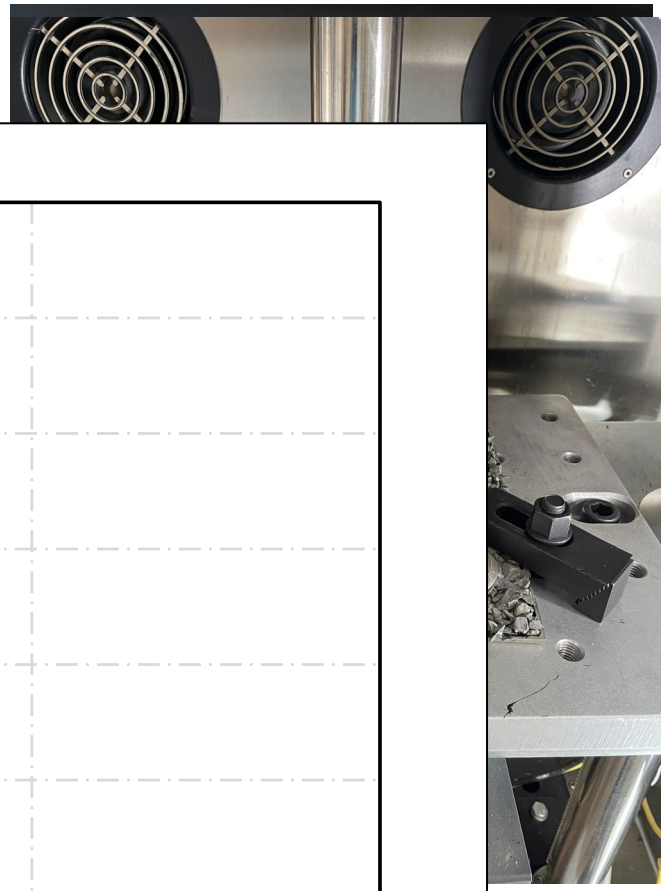


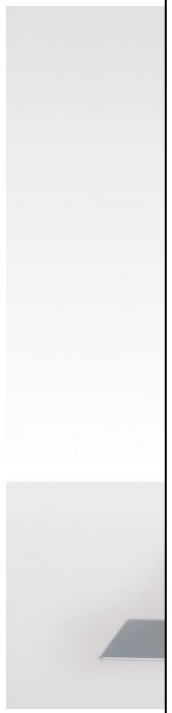
INERTIAL PROF

T SAND PATCH TEST

PROJECT#3 - DEVELOPMENT OF PROCEDURES AND TECHNOLOGIES FOR CHIP SEAL CONSTRUCTION QUALITY CONTROL IN OREGON

- Aggregate-binder adhesion measurement



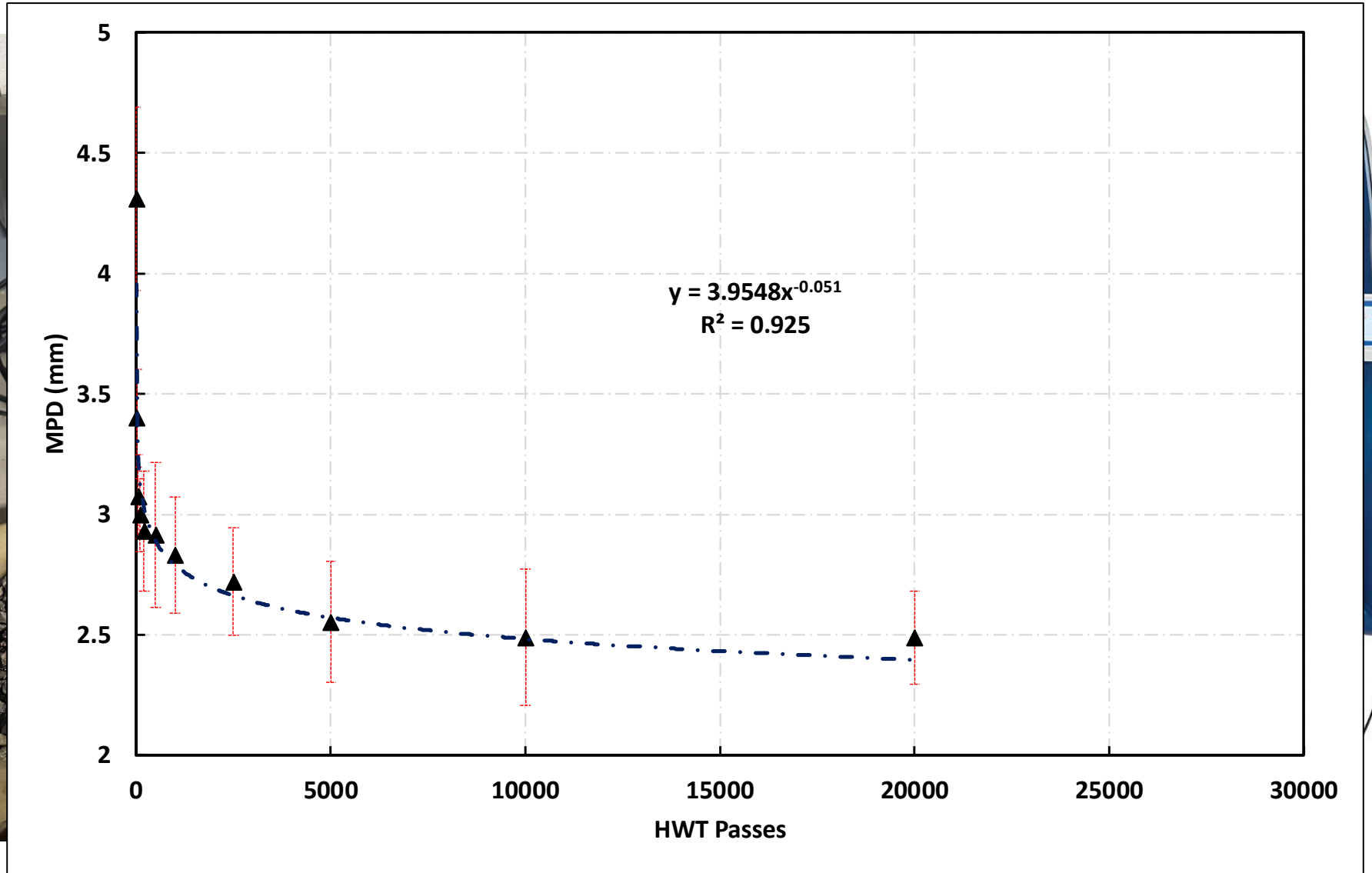


Vialit a

bed at OSU

PROJECT#3 - DEVELOPMENT OF PROCEDURES AND TECHNOLOGIES FOR CHIP SEAL CONSTRUCTION QUALITY CONTROL IN OREGON

- Bleeding potential measurement – Laser scanner and Hamburg Wheel Tracking Test



PROJECT
FOR CHI

- Aggr

A
a

Wirel

PROJECT#4 - INCREASING ASPHALT RECYCLING TO REDUCE PAVING COSTS, IMPROVE PAVEMENT LONGEVITY, AND REDUCE ENVIRONMENTAL IMPACT

Tasks and Research Plan

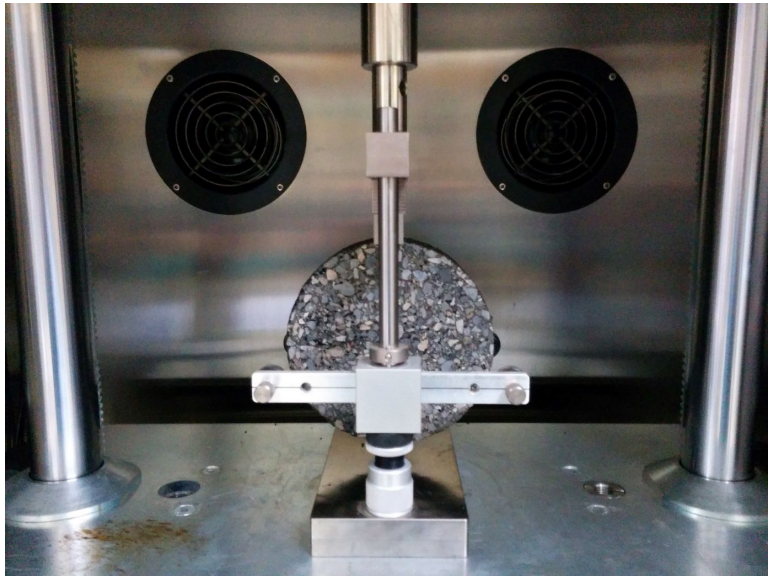
- **Task 2:** Literature review
- **Task 3:** Laboratory investigation - Rejuvenators and WMA
- **Task 4:** Laboratory investigation - RAP stockpile management
- **Task 6:** Life-cycle cost analysis (LCCA) and life-cycle assessment (LCA)
- **Task 7:** Incorporating rejuvenators and WMA into mix design
- **Task 8:** Field investigation

IS 40%-50% RAP POSSIBLE WITH MINIMAL IMPACT ON THE COST AND LONG-TERM PERFORMANCE?

PROJECT#4 - INCREASING ASPHALT RECYCLING TO REDUCE PAVING COSTS, IMPROVE PAVEMENT LONGEVITY, AND REDUCE ENVIRONMENTAL IMPACT

(Google Images)

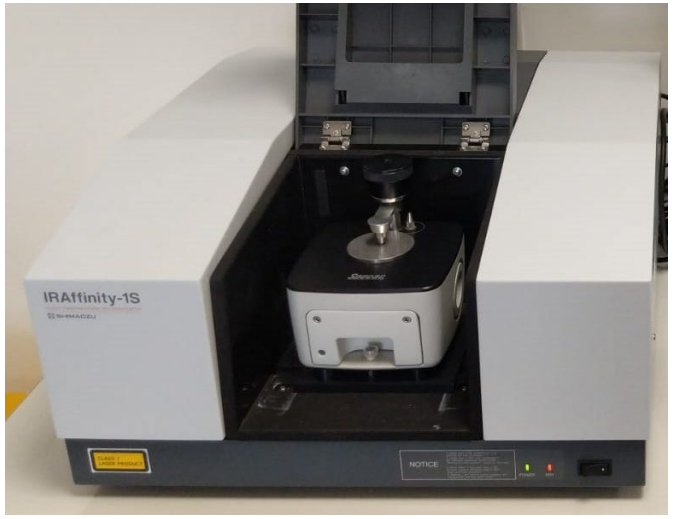
Resilient Modulus (RM) - Stiffness



Indirect Tensile Strength (IDT) - Strength and Flexibility

HWTT-Rutting

FTIR & AFM



DSR

PROJECT#5 – CLIMATE CHALLENGE#1 - SMOOTHNESS

- Higher road surface roughness ~ More fuel consumption; faster tire wear, and higher vehicle maintenance costs
- NCHRP 720 (2013) quantified the impact of roadway roughness on all those factors for several different vehicle types

- Developed a comprehensive code in Python that quantifies the impact of roughness on roads managed by ODOT (for the entire roadway network)
  - According to the preliminary results, the CO2 emissions that can be saved by reducing ODOT's roadway network roughness from 90in/mile to 40in/mile is **equivalent to about 50% of ODOT's current annual CO2 emissions.**
  - This reduction in roughness can also save road users about **$25-30 million annually** on roads managed by ODOT by reducing their fuel consumption, tire wear, and vehicle maintenance costs.
  - THESE RESULTS DO NOT INCLUDE THE LONG-TERM PERFORMANCE BENEFITS OF SMOOTH ROAD CONSTRUCTION. **SMOOTH ROADS STAY SMOOTH LONGER**

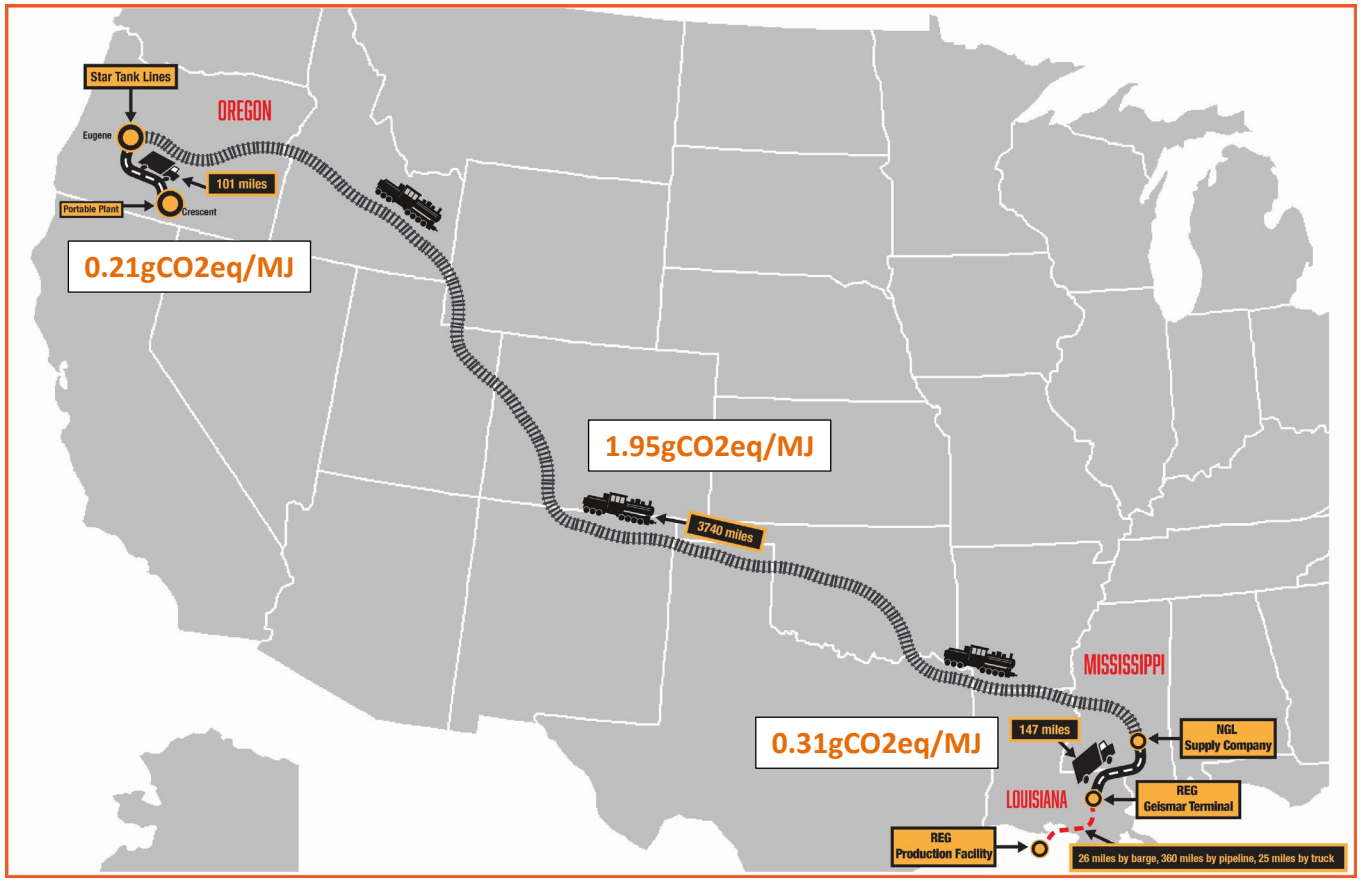
FINAL RESEARCH REPORT IS COMING SOON!!!

PROJECT#5 – CLIMATE CHALLENGE#2 – Renewable fuel use at asphalt plants

Cradle to gate pavement life cycle assessment (LCA)

In September 2022, ODOT partnered with the Asphalt Pavement Association of Oregon (APAO) and an Oregon-based asphalt contractor to test the viability of using renewable propane at a mobile asphalt plant.

RESULTS FOR THE RENEWABLE PROPANE TRANSPORTATION



PROJECT#5 – CLIMATE CHALLENGE#2 – Renewable fuel use at asphalt plants

PRELIMINARY RESULTS OF LCA

- **Using renewable fuels for the drum and binder tanks can reduce plant emissions by about 25% and can reduce ODOT's annual emissions by almost 10%**

- **New renewable fuel production technologies will further reduce emissions soon. Camelina crop and other new sources for fuel production**

- **Increasing RAP content from 20% to 40% can reduce emissions by about 15-20%**

FINAL RESEARCH REPORT IS COMING SOON!!!

SUMMARY

- Our pavement research and teaching programs are getting larger every year
- Recruiting students to create workforce for the agencies, industry, and academia
- Research findings are getting implemented via implementation research grants
- Life cycle cost analysis and life cycle assessment are an integral part of our research projects

Feel free to contact me for your research and recruitment needs and general questions

Email: colerie@oregonstate.edu

Oregon State University

Oregon Department of Transportation

Thank You

GO BEAVS!

Reach out:

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