Oregon Department of Transportation

Oregon State University

HMAC Layer Adhesion Through Tack Coat

Erdem Coleri

David Covey, Aiman Mahmoud,

James Batti, and Natasha Anisimova

Oregon State University

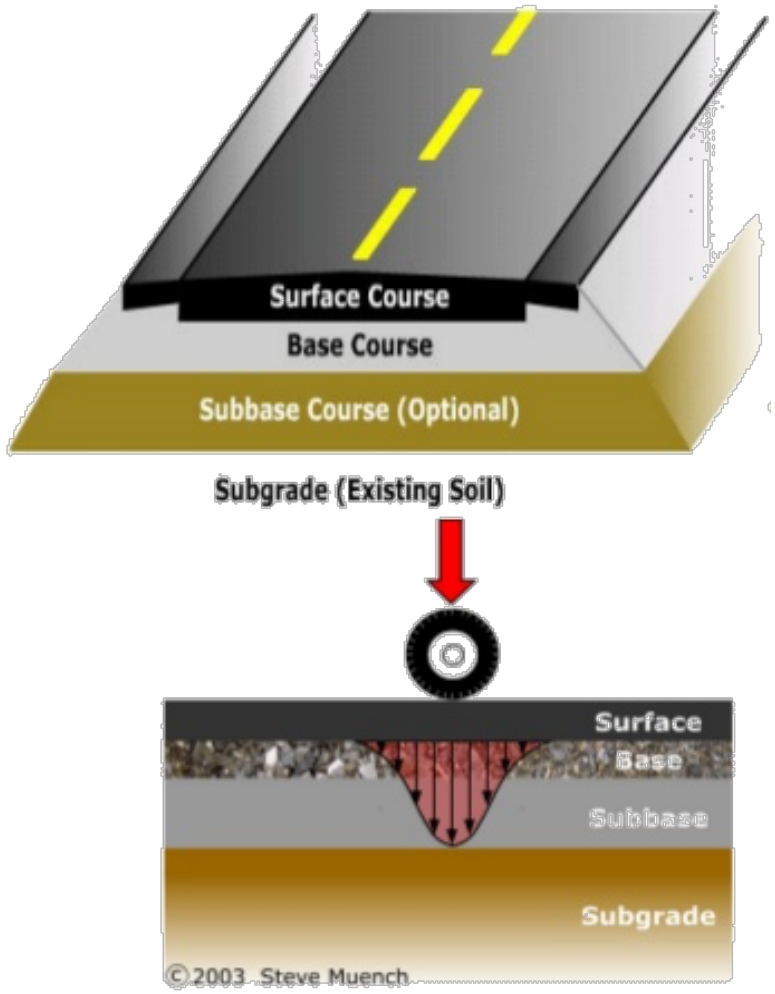
Other contributors

- TAC members:
  - Larry Ilg – ODOT
  - Justin Moderie - ODOT
  - Norris Shippen - ODOT
  - Chris Harris - ODOT
  - Keven Heitschmidt - Albina Asphalt
  - Troy Tindall - BlueLine
  - Anthony Boesen - FHWA
- Greyson Termini at OSU
- Wayne Brown at the ODOT lab
- ODOT coring crew
- Thanks to Ron Depue and David Davies for their help with field testing

Outline

- Introduction
- Literature review
- Interlayer shear strength
- Tack coat tracking
- Oregon field torque tester (OFTT)
- Oregon field tack coat tester (OFTCT)
- 3D viscoelastic finite element model
- Summary

PAVEMENT TYPES AND STRESSES



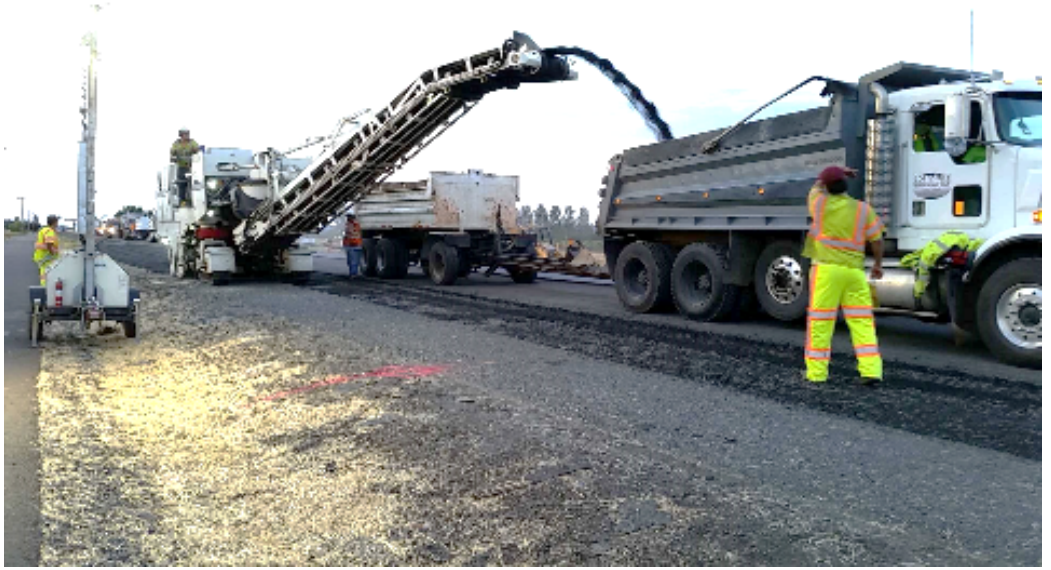
ASPHALT = FLEXIBLE

PAVEMENT DISTRESSES

TACK COAT TRACKING

CONSTRUCTION

1. Asphalt milling



2. Sweeping

CONSTRUCTION

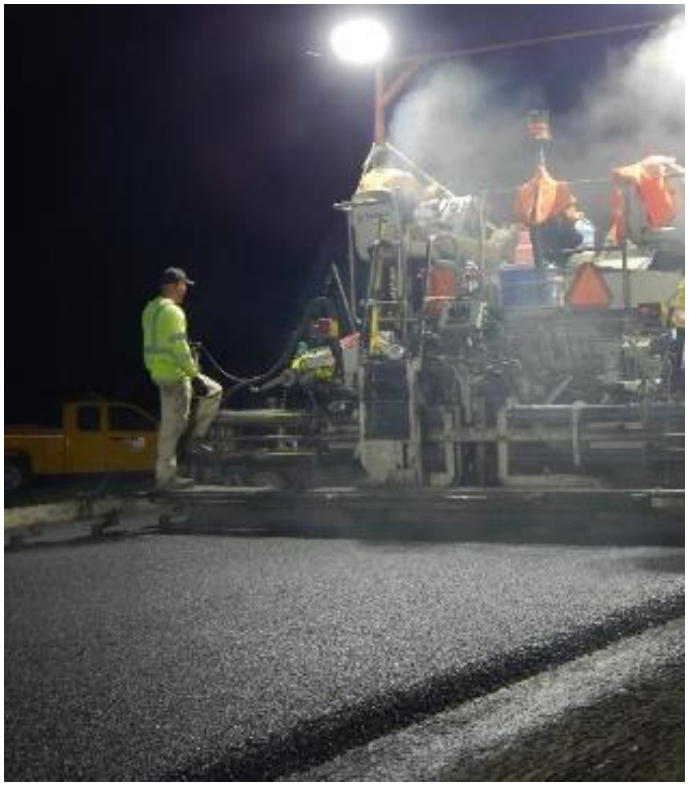
3. Tack coat application (distributor truck)



4. Paving train

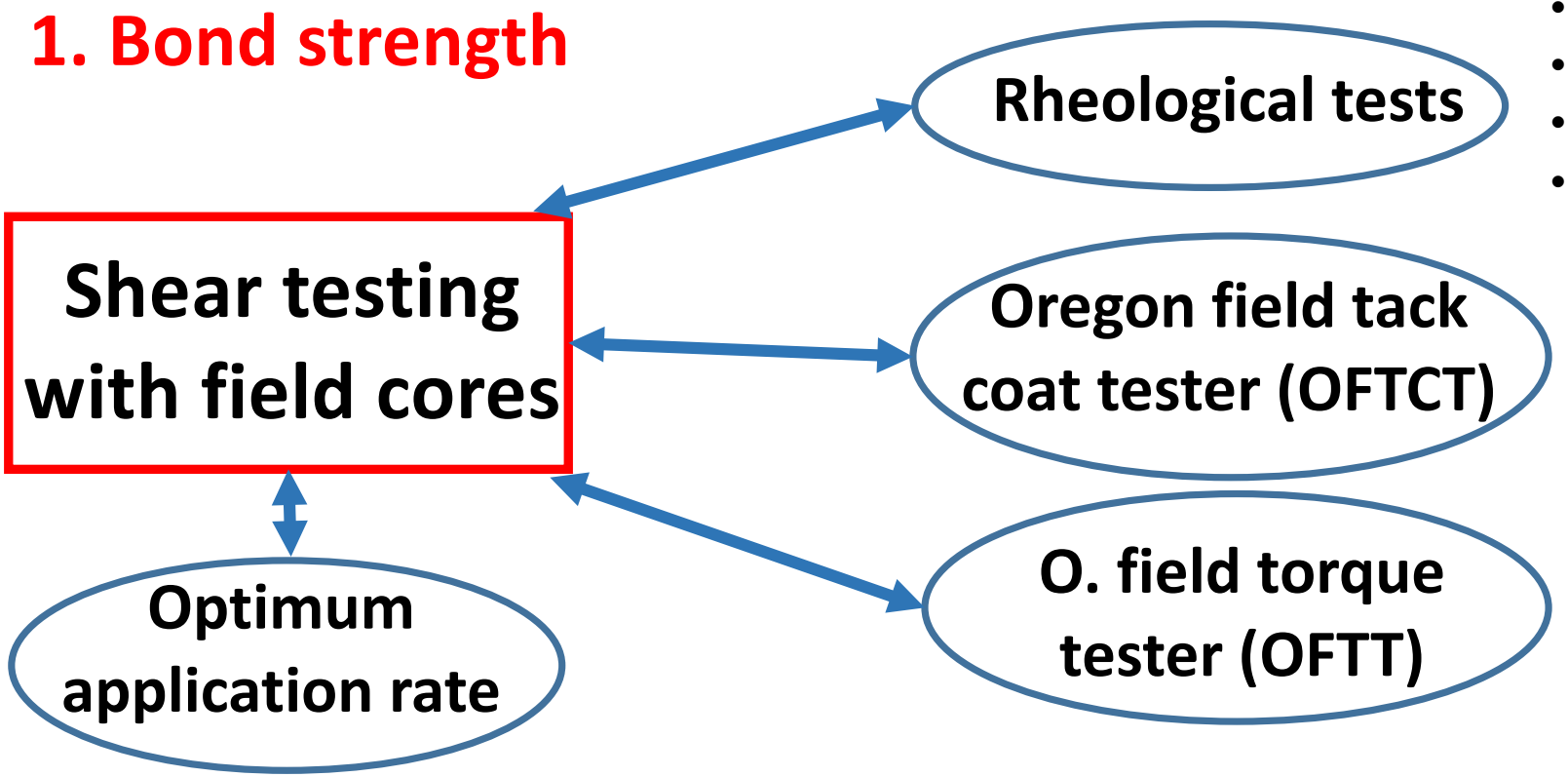

CONSTRUCTION

5. Apply overlay and compaction


Research Method

1. Bond strength



- Softening point
- Penetration
- Viscometer
- DSR

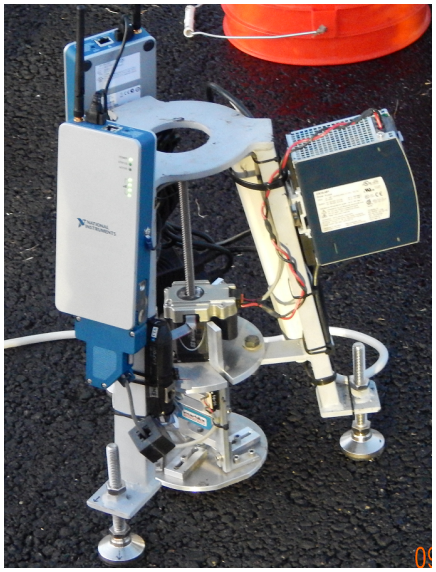
2. Importance of structural properties

- 3D finite element modeling
- Thickness, climate, material effects

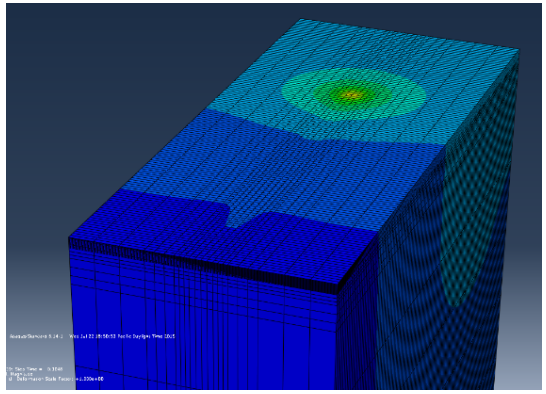
3. Tracking

- Weight measurements and app
- Wheel tracking device

DEVELOPED TECHNOLOGIES



Wireless OFTCT



Model to evaluate bond strength

IOS and Android apps for curing time notification

OFTT

Wheel tracking device

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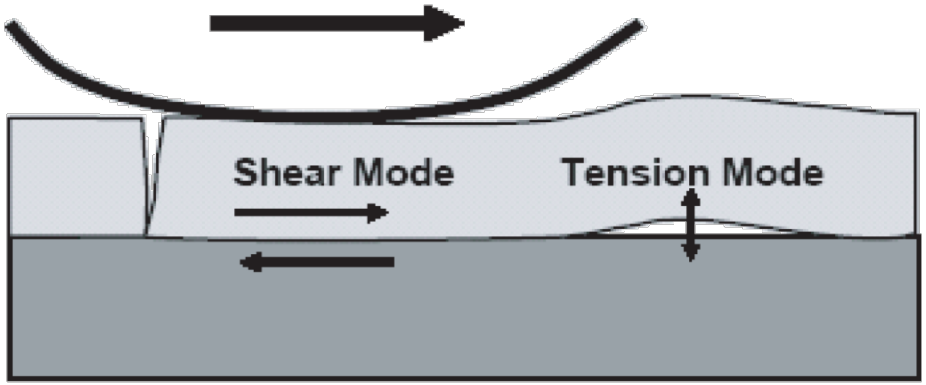
LITERATURE REVIEW
TACK COAT MATERIALS

- **Types**
  - Emulsions: SS-1, CSS-1H, RS-2
  - Binders: PG 58-28, 64-22, etc.
- **Application rates**
  - Surface type, condition
  - Application vs. residual
  - Varied ranges
- **Application methods**
  - Distributor truck
    - Spray bar height, pressure
    - Nozzle angle, selection
- **Curing time**
  - No consensus
  - Increased strength with time

LITERATURE REVIEW
IMPORTANCE OF BONDING

- **Roffe and Chaignon (2002)**
  - Lack of bond reduced service life from 20 to 7 years
- **King and May (2003)**
  - 50% loss in fatigue life when bond is reduced by 10%
- **Kruntcheva et al. (2005)**
  - Reduction of 80% in life for debonded interface between base and road base



Critical stress types at the interface (Raab and Partl 2004).

How to improve tack coat performance?

Research Objectives

- Applying the optimum rate
- Develop a QC/QA device – Oregon field tack coat tester
- Reduce tracking
  - Not allowing construction traffic before the set (How long do we need to wait?)
  - Using tack coats that track less
- Non-uniform and inaccurate spraying
- Using better tack coats (New emulsions, CO1 and CO2)
- Checking the bond strength for QC/QA
  - Coring and shear testing in the lab
  - Can we come up with a less destructive and an easier method?

HOW IMPORTANT IS THE BOND STRENGTH?

CAN WE EXTEND PAVEMENT STRUCTURAL LIFE BY USING BETTER TACK COATS?

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RESEARCH

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EVALUATION OF TACK COAT RHEOLOGICAL PROPERTIES AND THE EFFECTS ON INTERLAYER SHEAR STRENGTH

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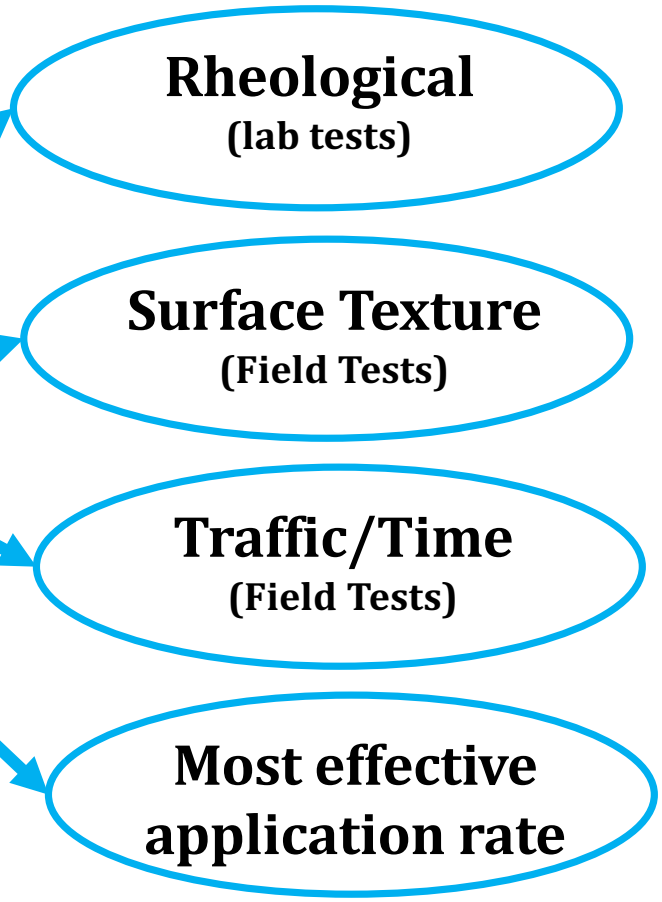
Oregon State University OSU

OBJECTIVES

Bond strength
(pavement longevity)

Interlayer Shear Strength
(field cores)



MATERIALS & METHODS

EXPERIMENTAL DESIGN

© GOOGLE IMAGES

MATERIALS & METHODS

EXPERIMENTAL DESIGN

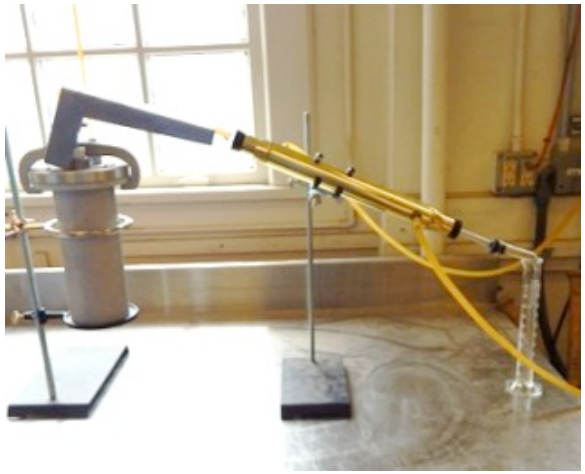
MATERIALS & METHODS

FIELD AND LAB EXPERIMENTS

(a)

MATERIALS & METHODS

FIELD AND LAB EXPERIMENTS



(a)

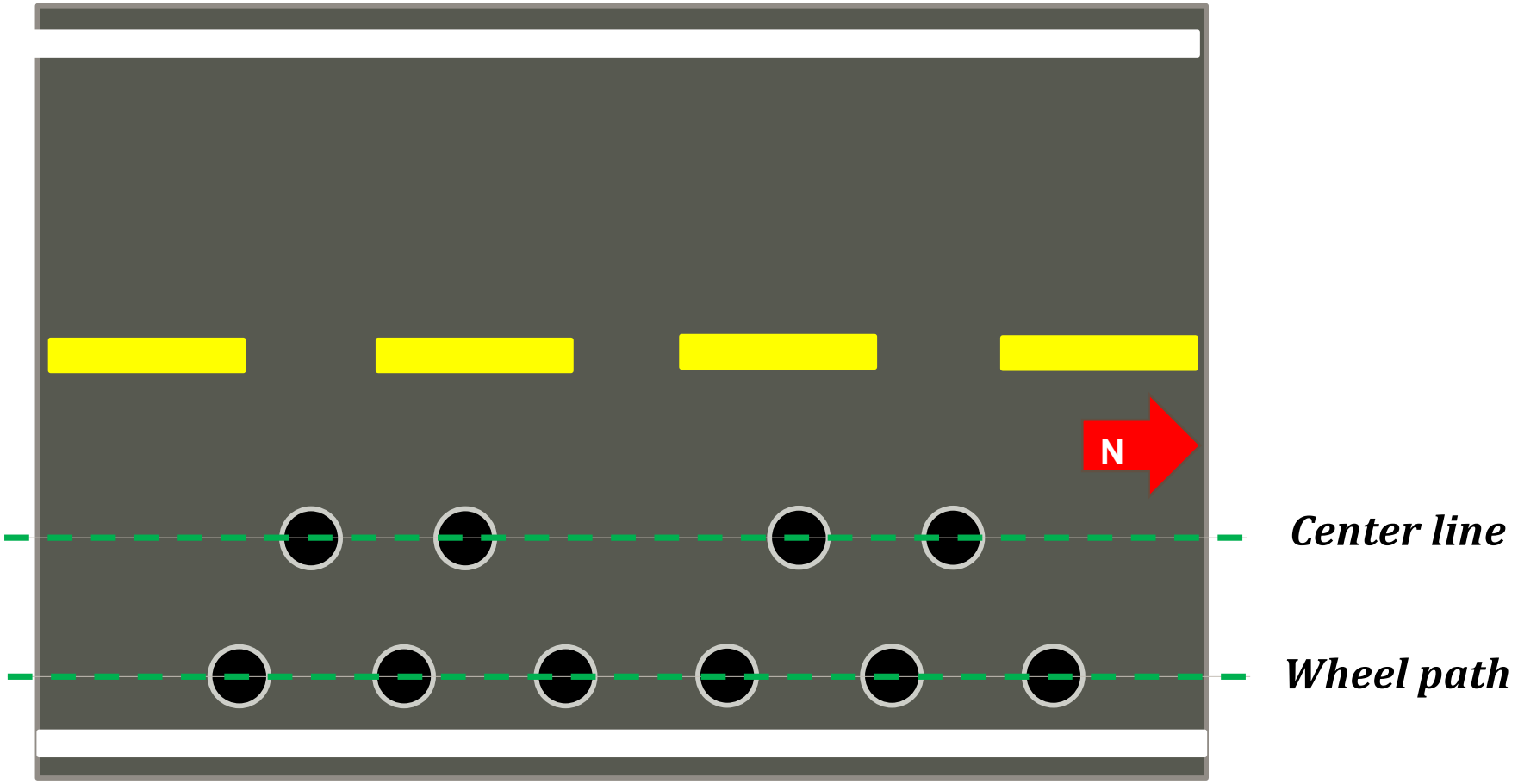
DSR: measures relaxation and stiffness together

Viscosity: measures workability, mixability

Penetration: characterize semi-solid asphalts, “soft” or “hard”

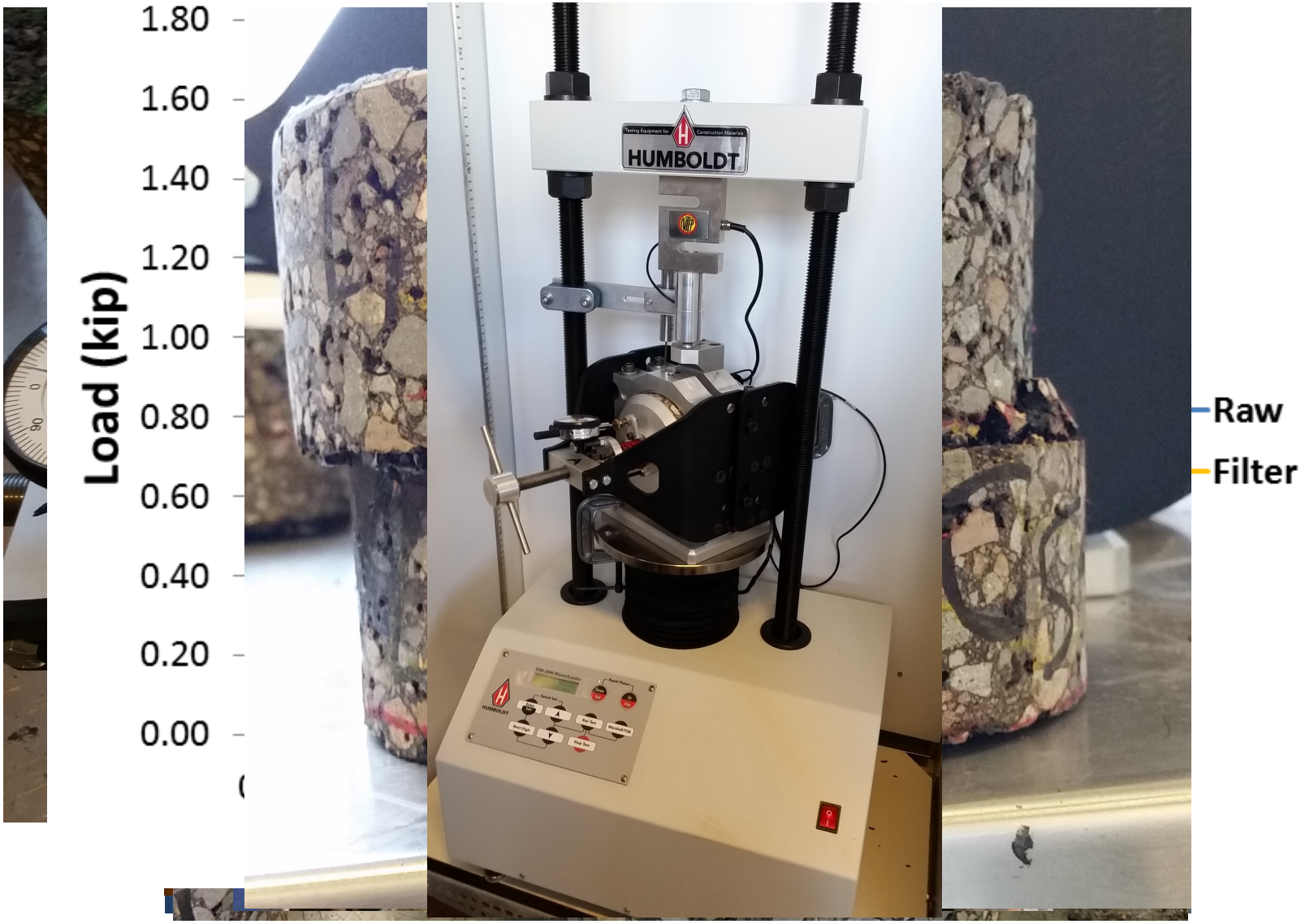
MATERIALS & METHODS

PROCEDURE FOR DETERMINING ISS



MATERIALS & METHODS

PROCEDURE FOR DETERMINING ISS



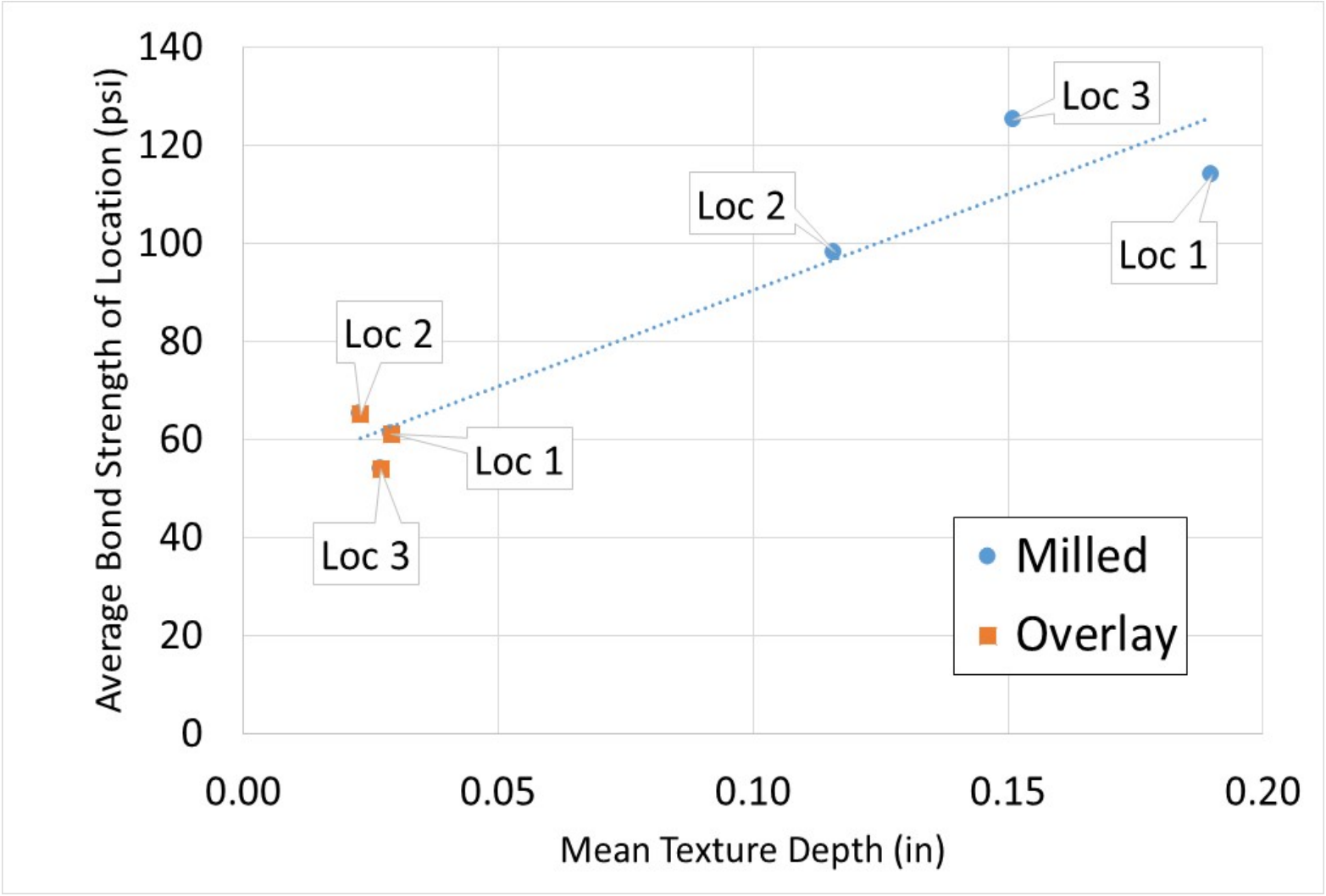
Results & Discussion

Effects of surface texture on ISS

MILLED SURFACE OVERLAY SURFACE

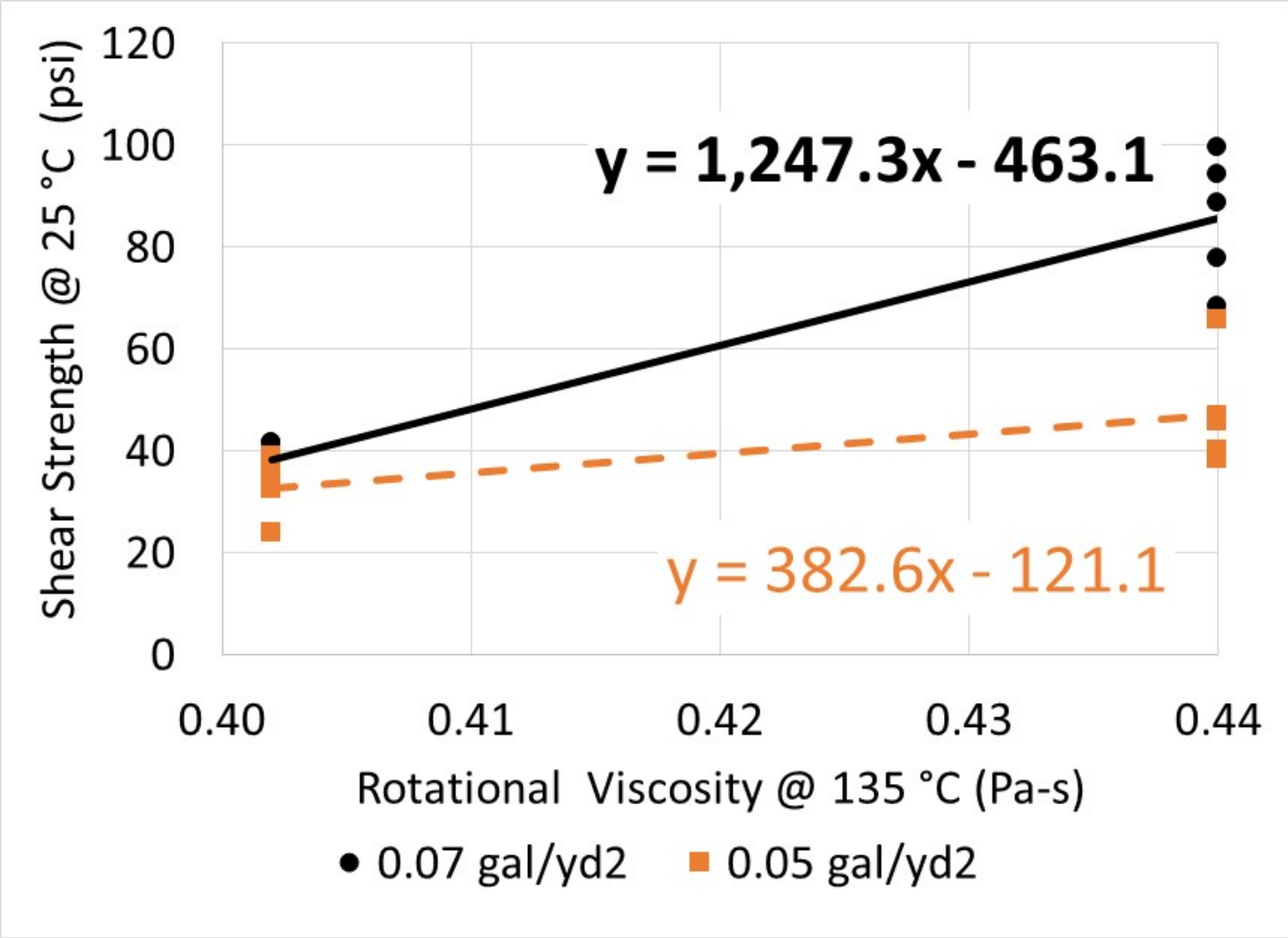
RESULTS & DISCUSSION

SURFACE TEXTURE RESULTS ON ISS



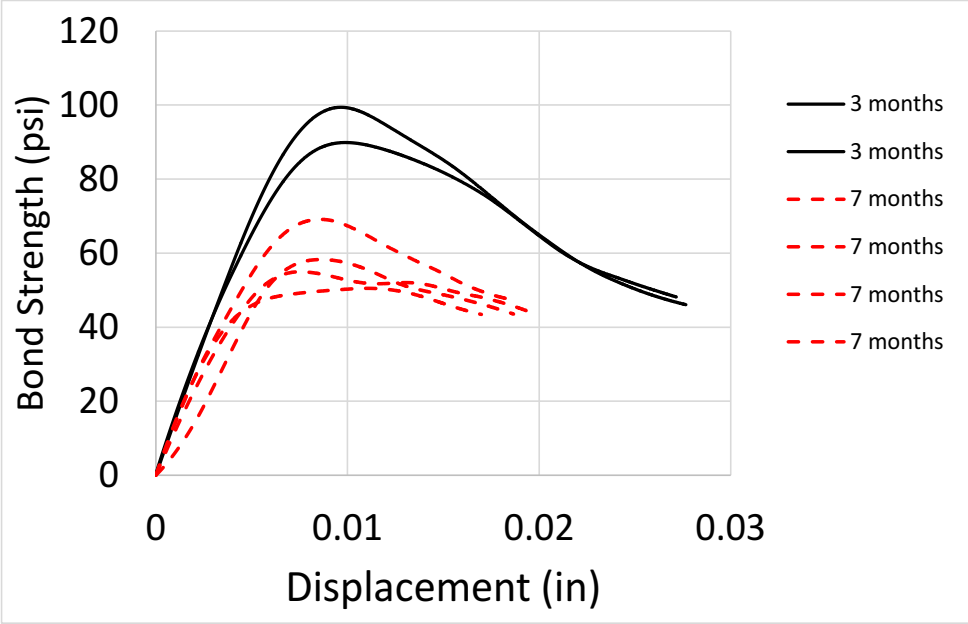
Results & Discussion

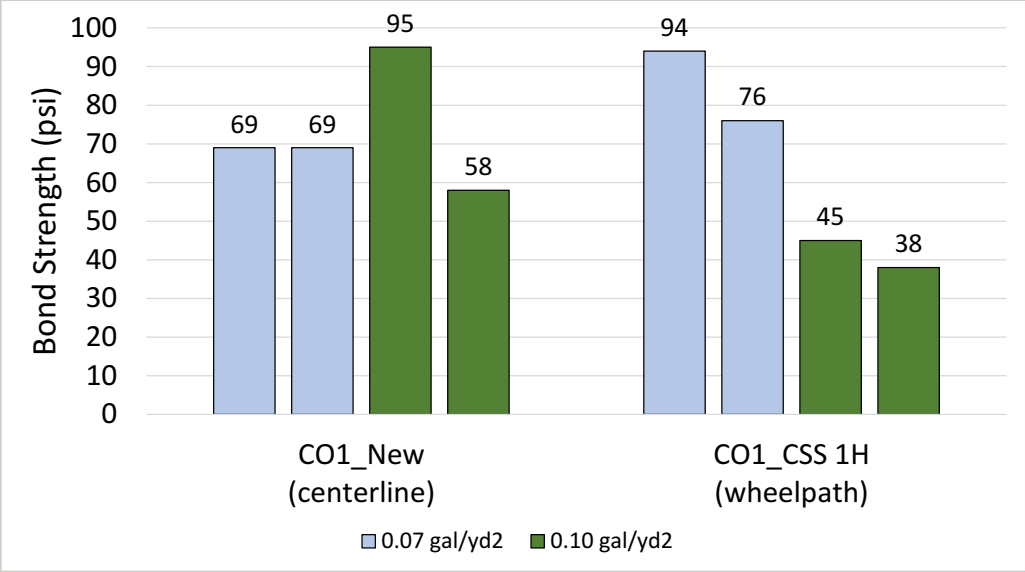
Effects of rheological properties on ISS



RESULTS & DISCUSSION

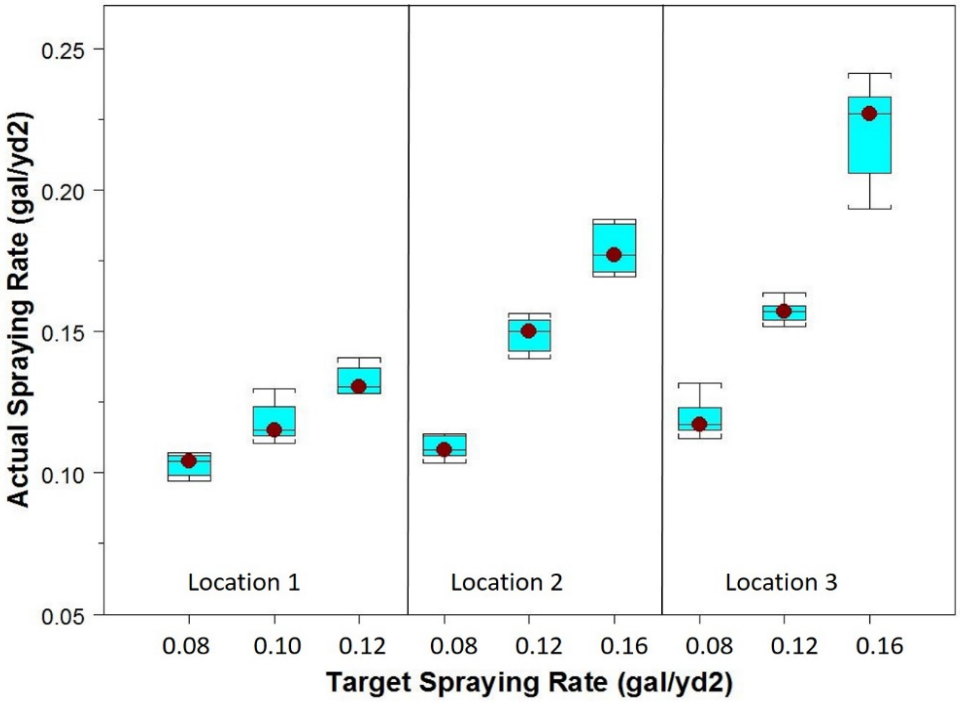
EFFECTS OF TRAFFIC ON ISS





RESULTS & DISCUSSION
ISSUES WITH APPLICATION RATES

Milled Surface



Contractor's truck used

RESULTS & DISCUSSION

ISSUES WITH APPLICATION RATES

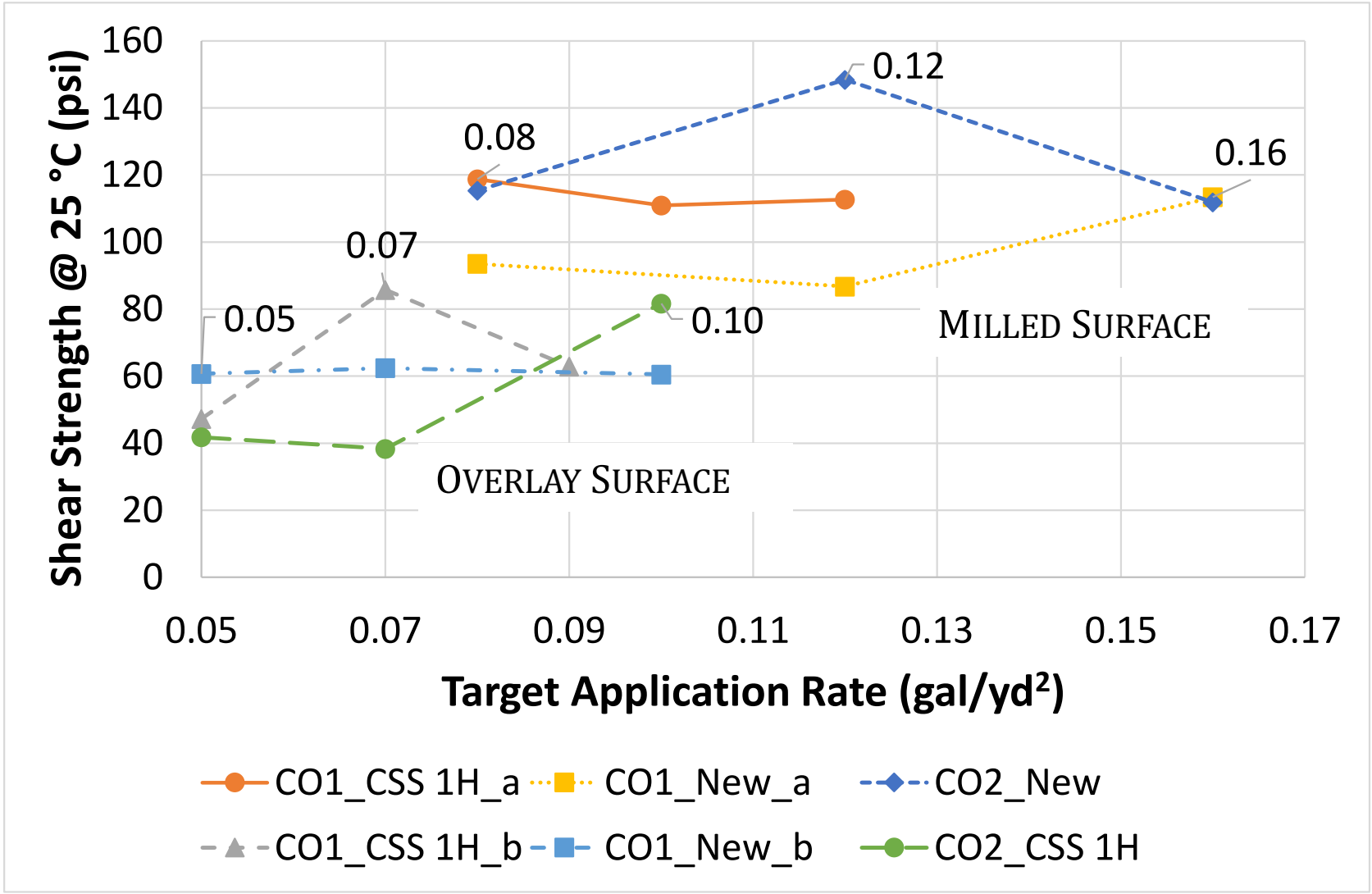
UNIFORMITY ISSUE WITH THE OLD TRUCK

Old truck – Loc 3-Sec 3

New truck

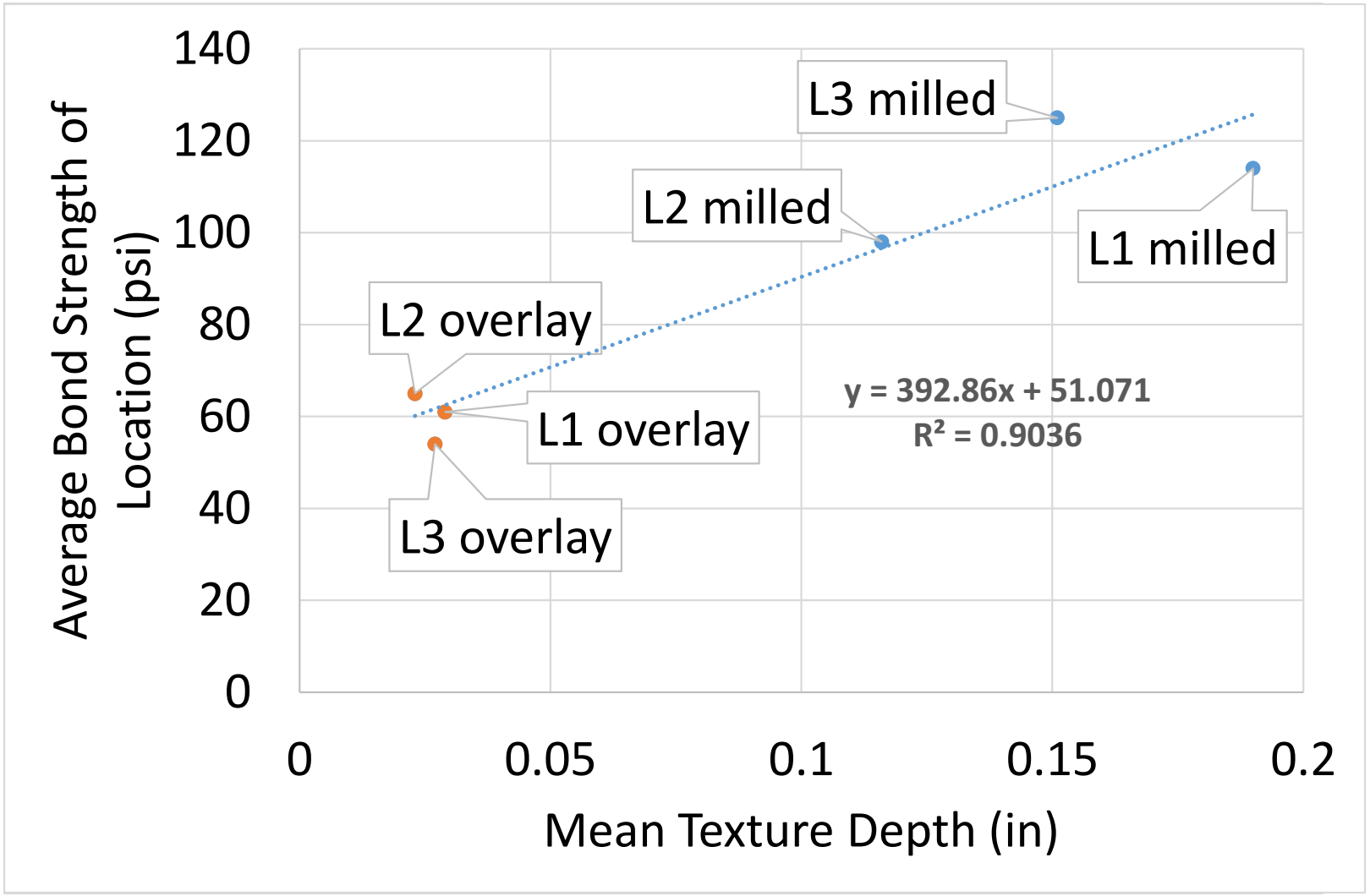
Results & Discussion

Most effective application rate to maximize ISS



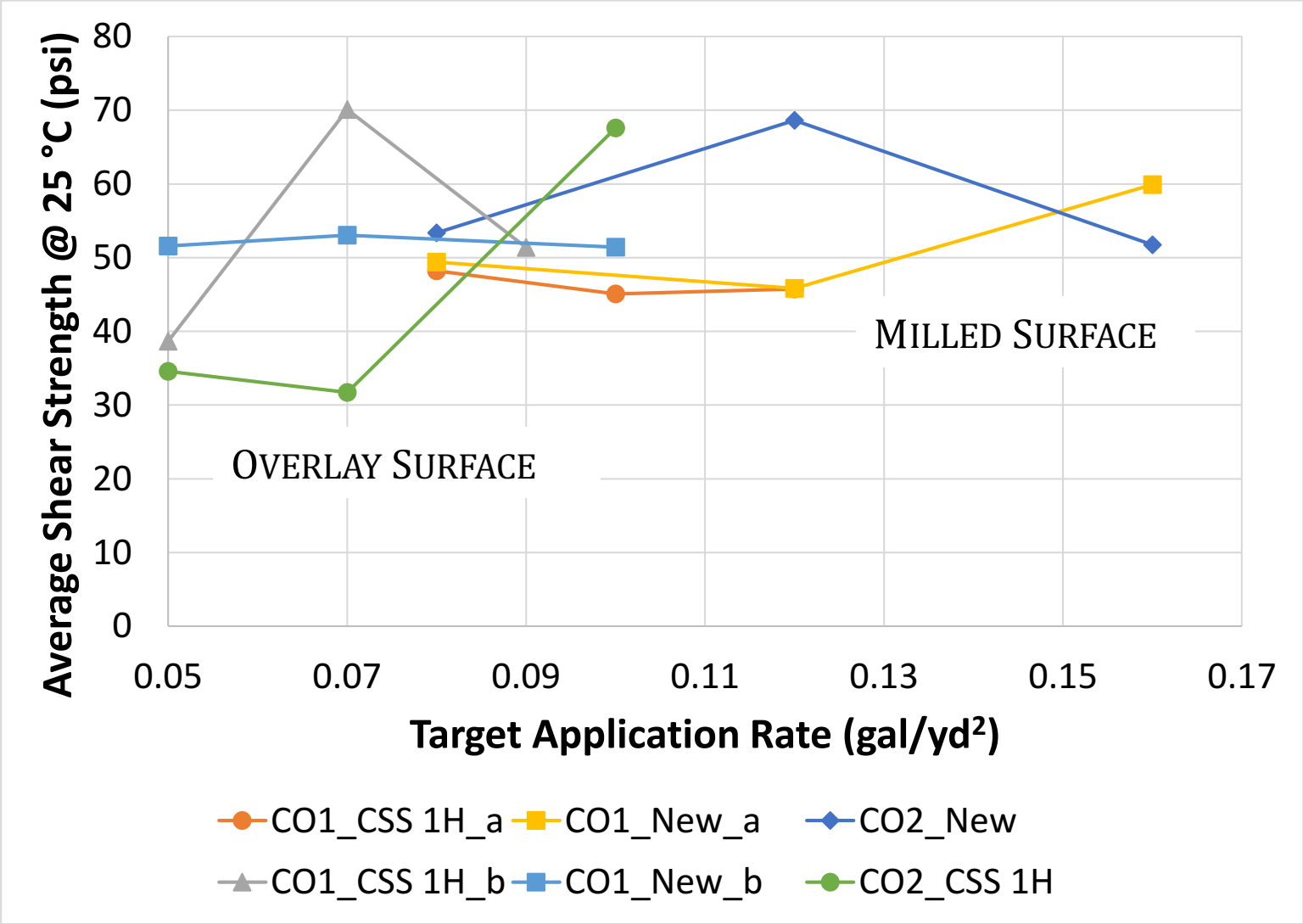
RESULTS & DISCUSSION :

SURFACE TEXTURE RESULTS ON ISS



Results & Discussion

Most effective application rate to maximize ISS



RESULTS & DISCUSSION

MOST EFFECTIVE APPLICATION RATE TO MAXIMIZE ISS

Tack Coat Material	Surface Type	[1]Effective Rate (gal/yd2)
CO1_CSS 1H_a	Milled	0.08
CO1_New_a	Milled	0.16
CO2_New	Milled	0.12
CO1_CSS 1H_b	Overlay	0.07
CO1_New_b	Overlay	0.05
CO2_CSS 1H	Overlay	0.10

Note: [1] All suggested, "effective rates" are application rates and not residual rates.

SUMMARY & CONCLUSIONS

1. Bond strength
(pavement longevity)

Interlayer Shear Strength
(field cores)

- Geological (lab tests)
- Surface Texture (field Tests)
- Traffic/Time (field Tests)
- Variability and texture

Overlay surfaces

High influence

0-39%

Most effective application rate

Prediction Equation

$$y = mx + b$$

- ISS
- QC/QA

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RESEARCH

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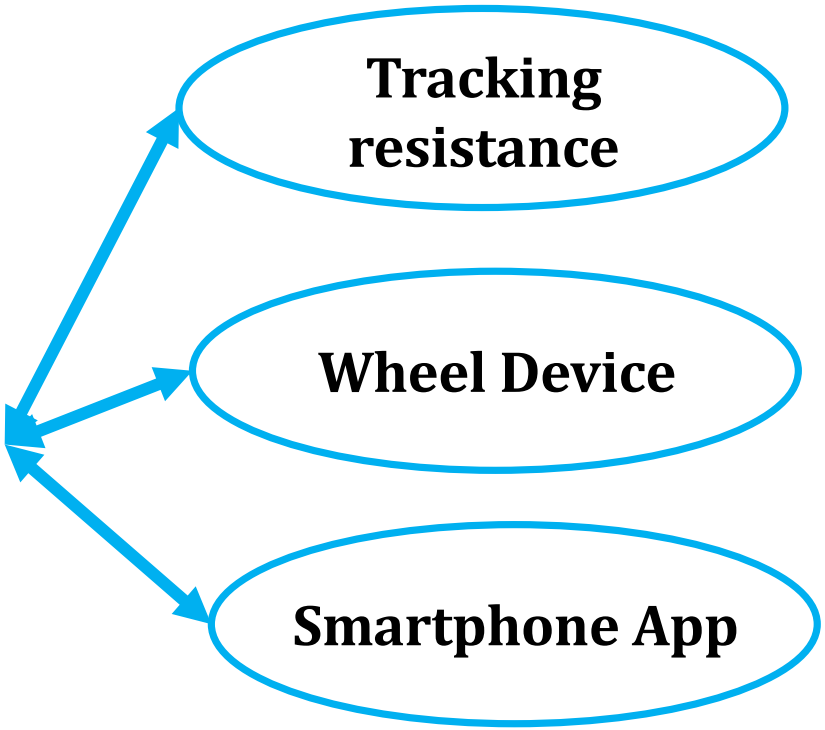
DEVELOPMENT OF A SMARTPHONE APP AND DEVICE TO REDUCE TACK COAT TRACKING

OBJECTIVES

Tack coat tracking
(improved methodology)



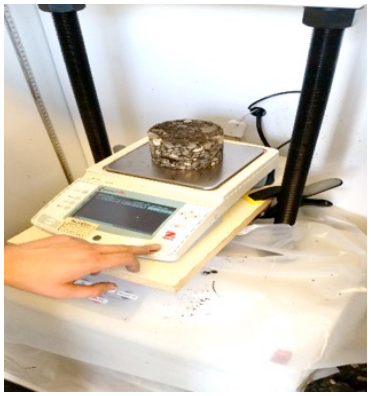
MATERIALS & METHODS

TACK COAT MATERIALS AND CURING TIME TEST PLAN

Parameter	Experimental Setting
Emulsion	• CO1_CSS 1H • CO1_New • CO2_CSS1 • CO2_New
Temperature (°F)	Low: 59 °F, High: 95 °F
Application Rate (gal/yd^2)	0.045 (L), 0.105 (M), 0.164 (H)
Texture	Open grade (OG), dense grade (DG), steel plate (SP)

MATERIALS & METHODS

PROCEDURE FOR DETERMINING TACK COAT CURING TIME



(a)

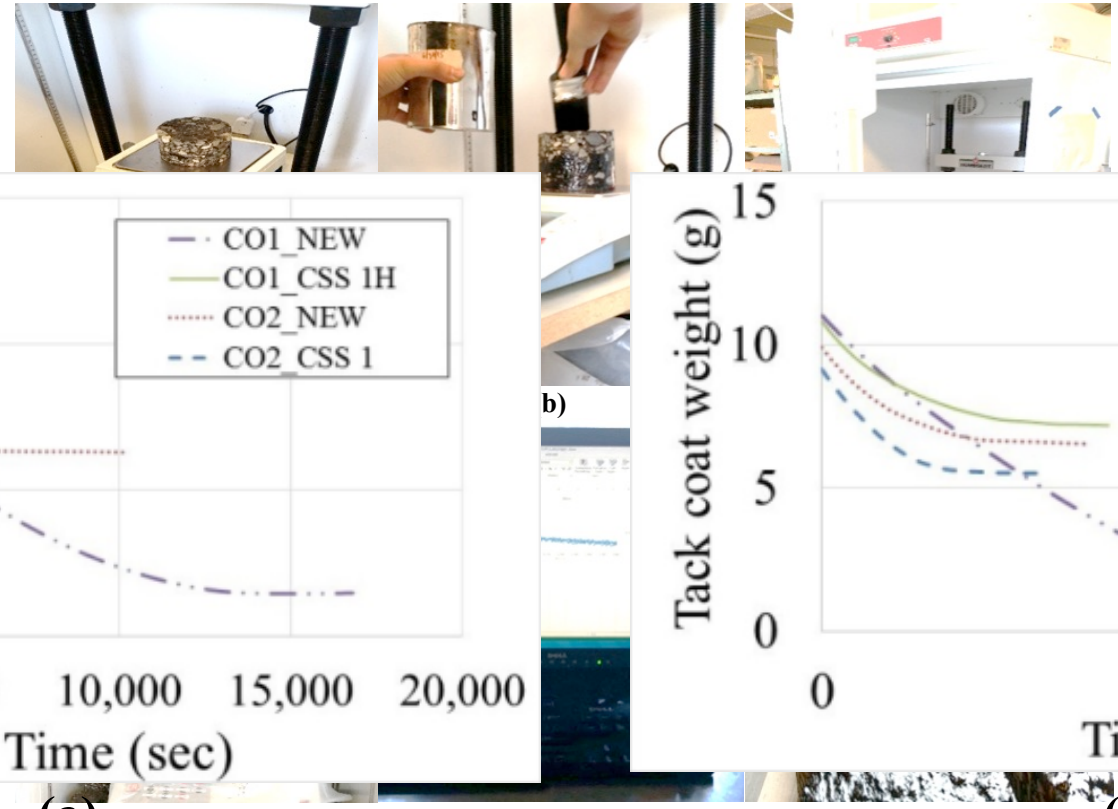
MATERIALS & METHODS

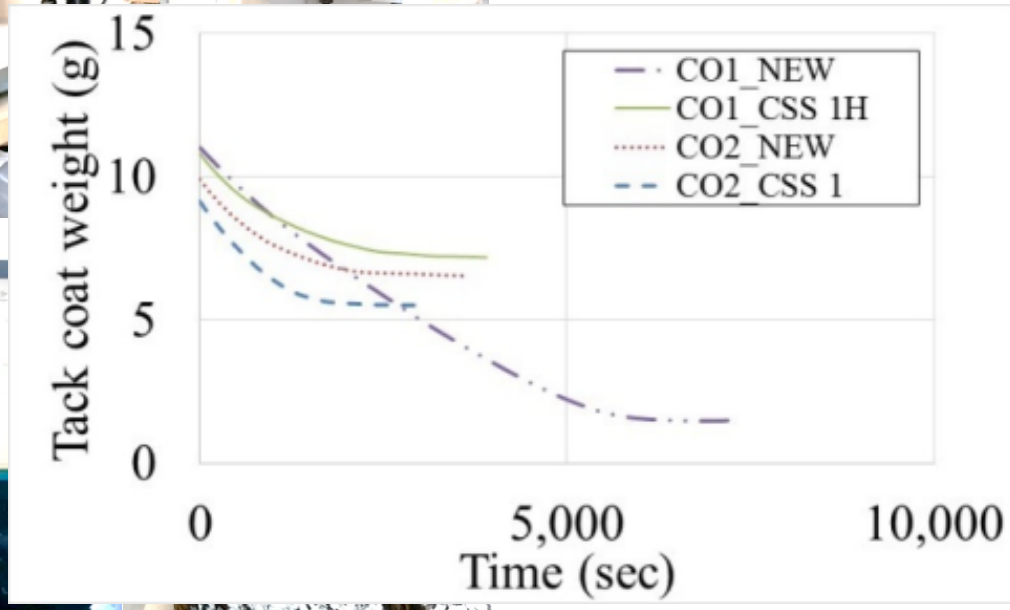
DEVELOPMENT OF SMARTPHONE APP

$$Set\ Time \sim Temperature + Emulsion + Rate + Wind\ speed$$

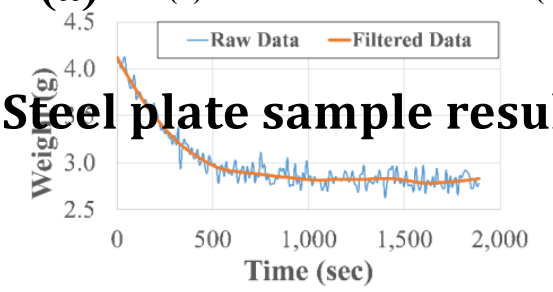
RESULTS & DISCUSSION

LABORATORY CURING TIME DETERMINATION

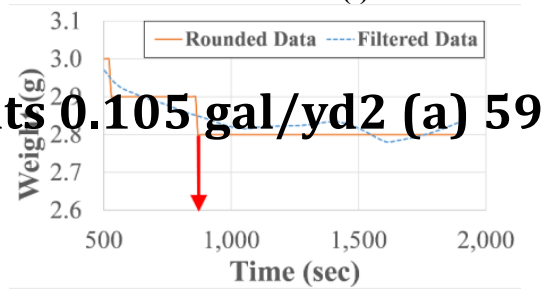




(a) (b)



(g)

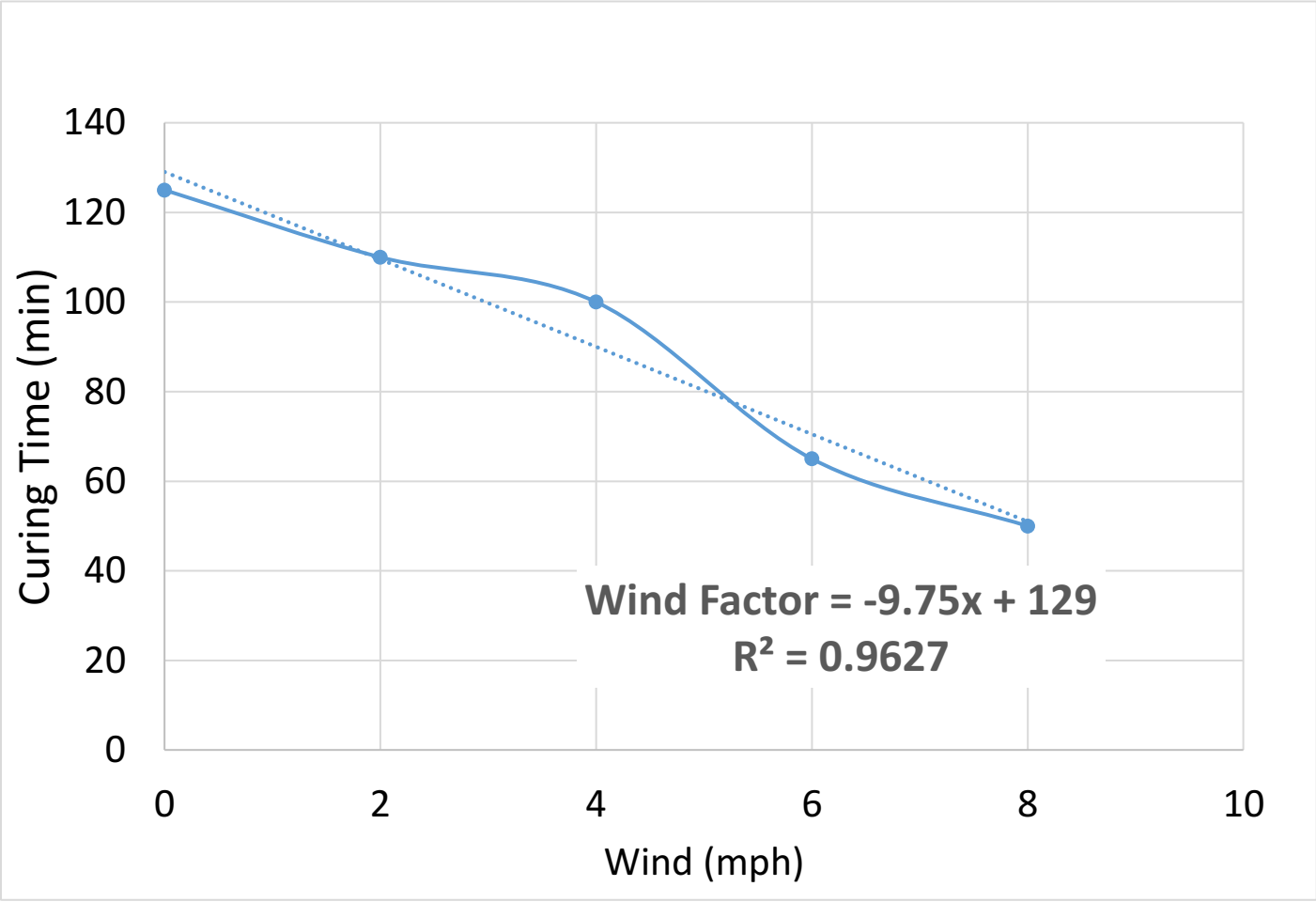


(h)

Steel plate sample results 0.105 gal/yd2 (a) 59 F (b) 95 F

Results & Discussion

Adjustments to regression model

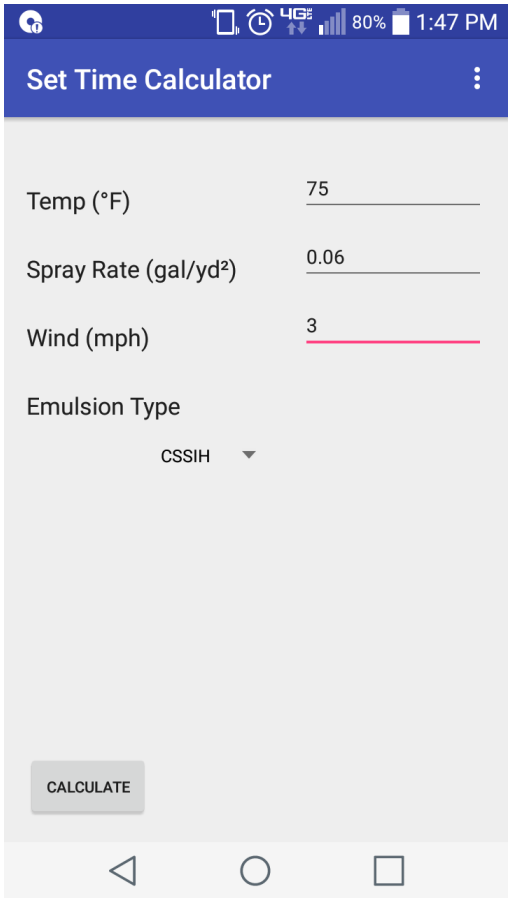


$$Cure\ Time = SET * Wind\ Factor$$

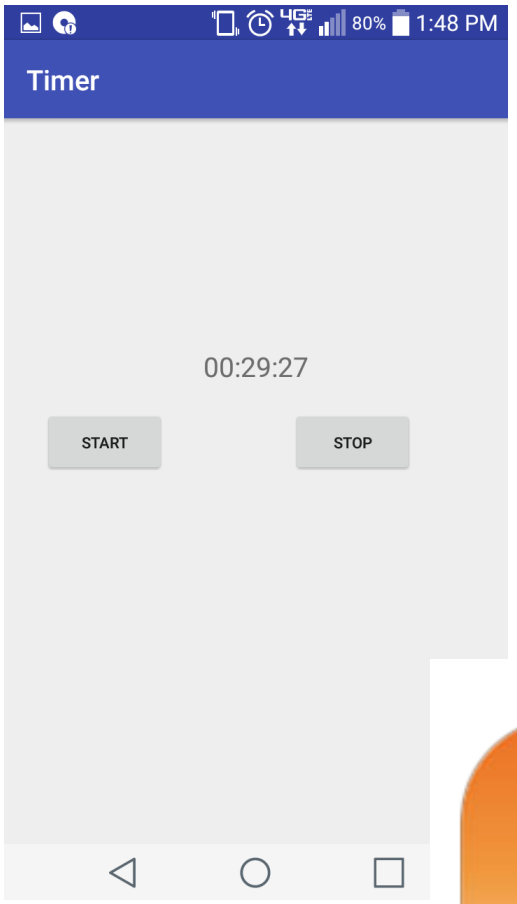
RESULTS & DISCUSSION

SMARTPHONE APP

APPLE



(a)



(b)

AVAILABLE ON IOS AND ANDROID
Search "Set time anisimova"

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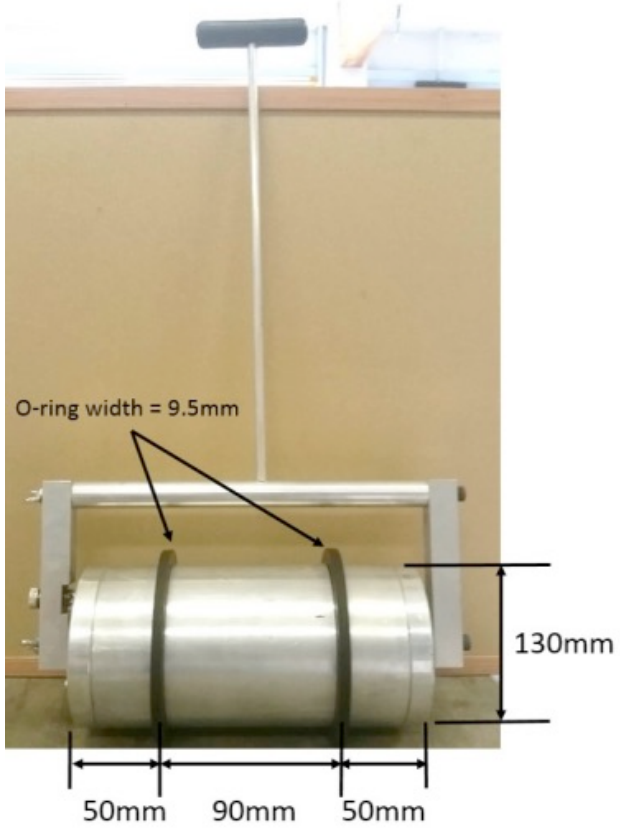
MATERIALS & METHODS

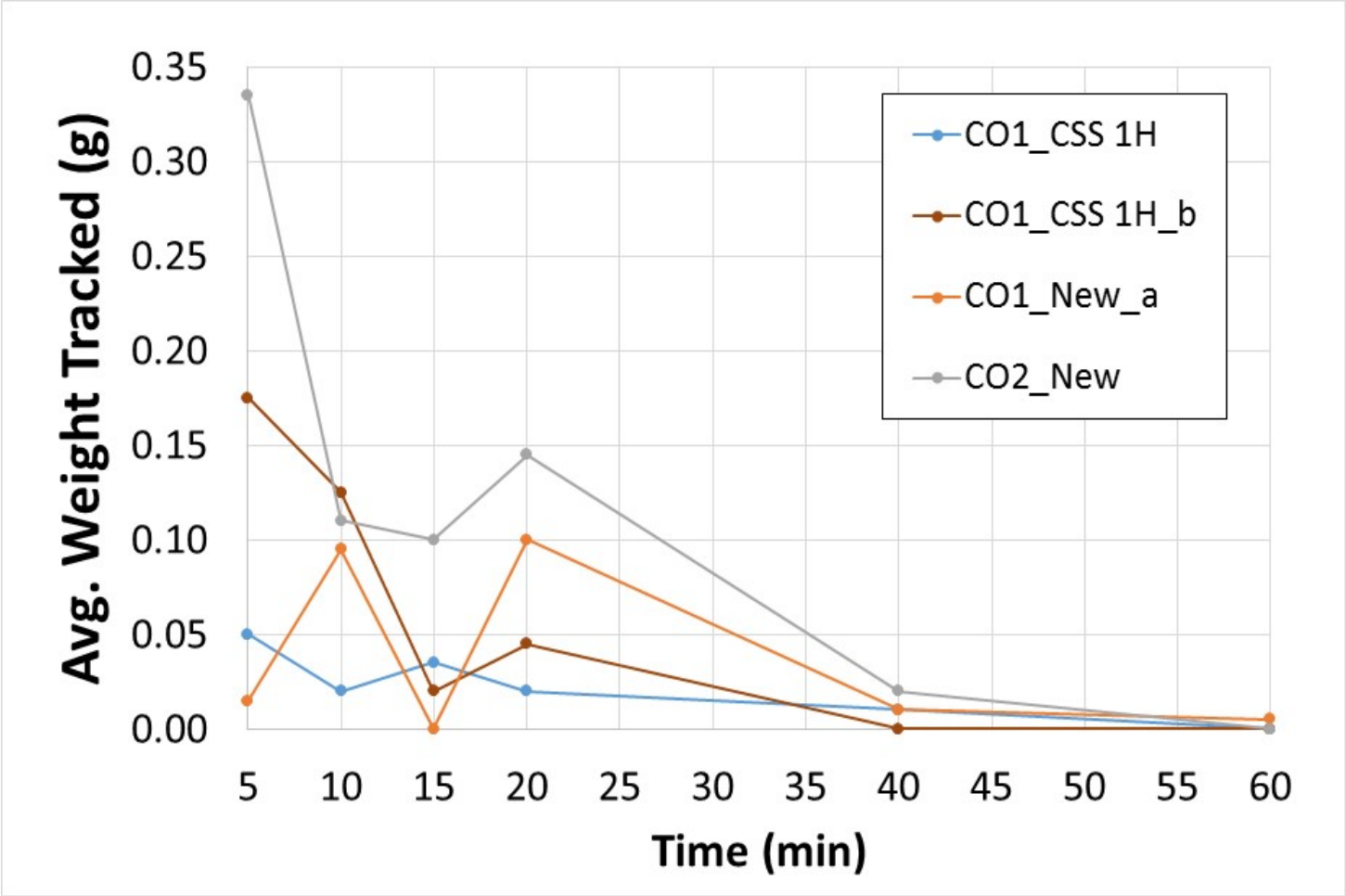
DEVELOPMENT OF A DEVICE TO MEASURE TACK COAT TRACKING



(a)

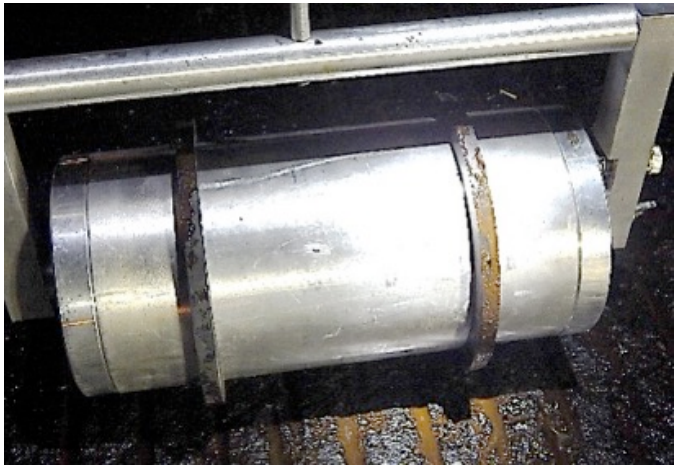
Results & Discussion

Parking lot tack coat tracking



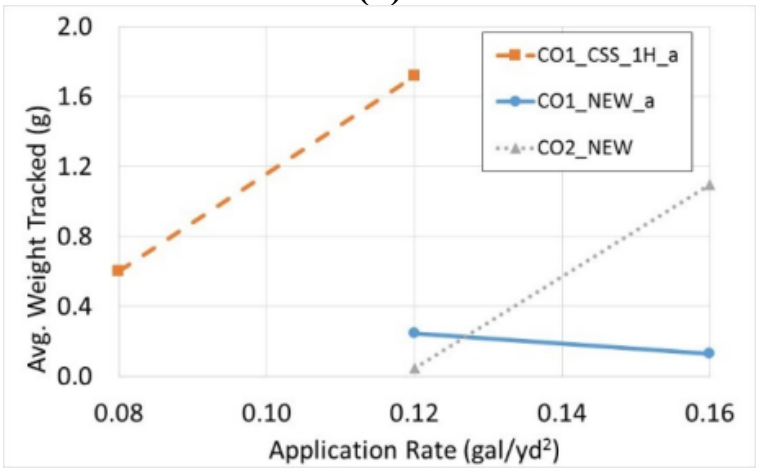
RESULTS & DISCUSSION

FIELD TACK COAT TRACKING



(a)

(b)



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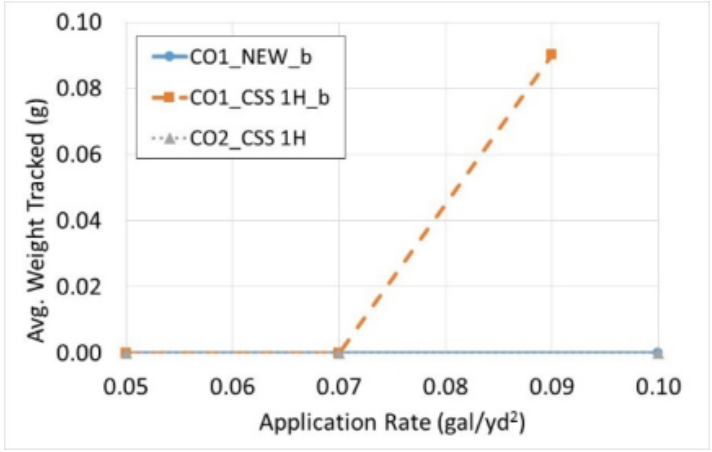
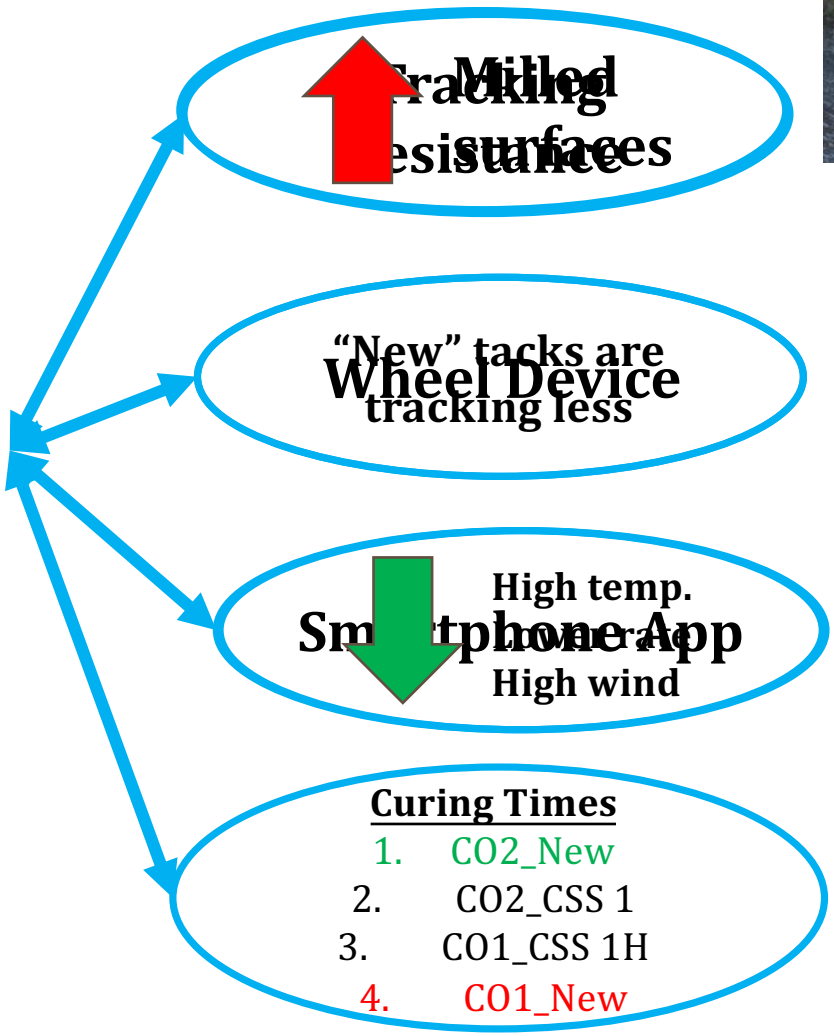
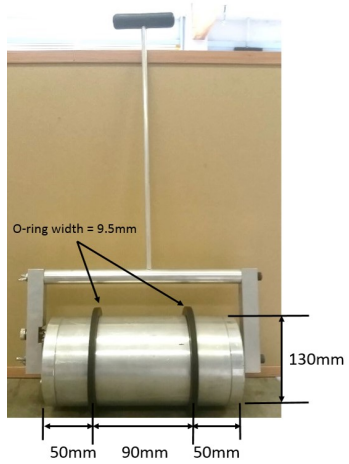


(d)

SUMMARY & CONCLUSIONS

2. Tack coat tracking
(improved methodology)





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RESEARCH

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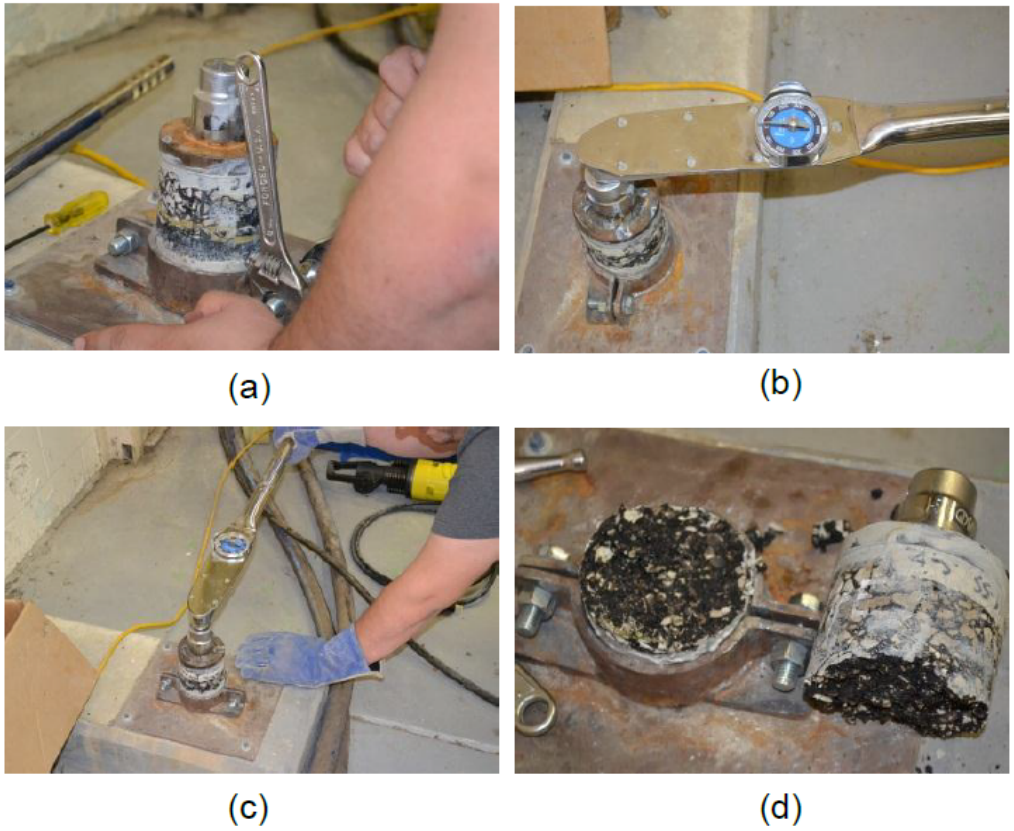
DEVELOPMENT OF A FIELD TORQUE TEST TO EVALUATE IN-SITU TACK COAT PERFORMANCE

BACKGROUND:

CURRENT TECHNOLOGIES



Torque bonding test: (a) Clamping the specimen, (b) setting the torque device, (c) applying torque to the specimen, and (d) tested specimen

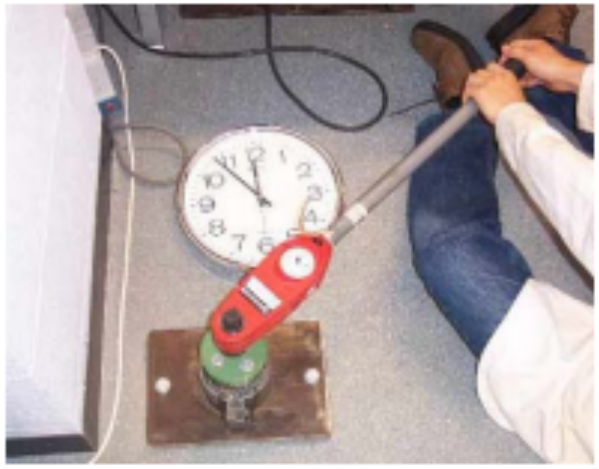
(CORTINA, 2012)

BACKGROUND:

CURRENT TECHNOLOGIES

(a) Torque grip

(b) Specimen set-up

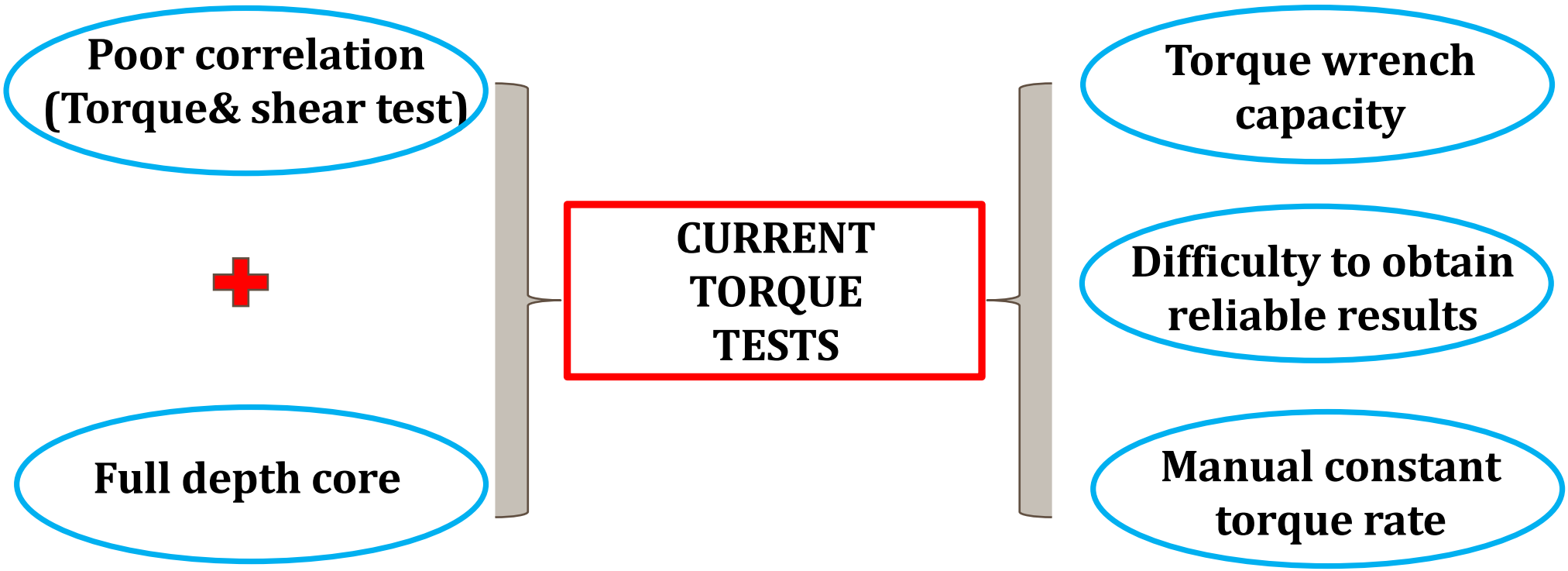


(c) laboratory test

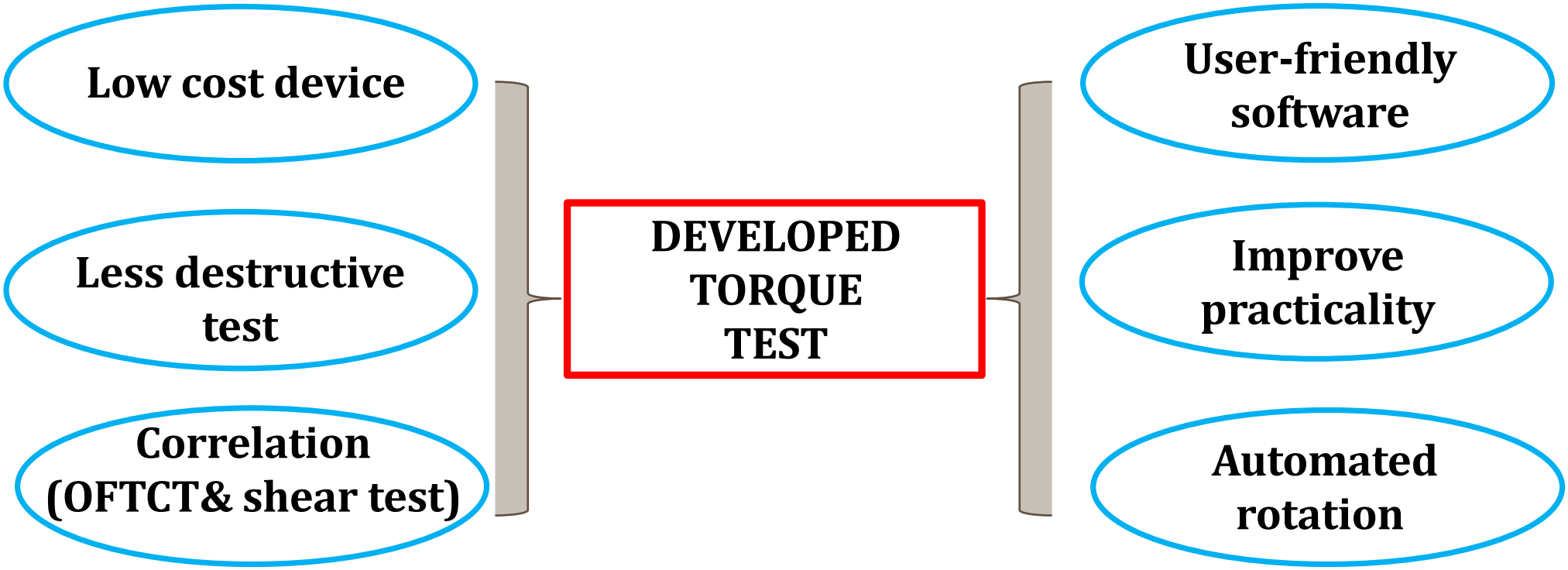
(TASHMAN, 2006)

BACKGROUND:

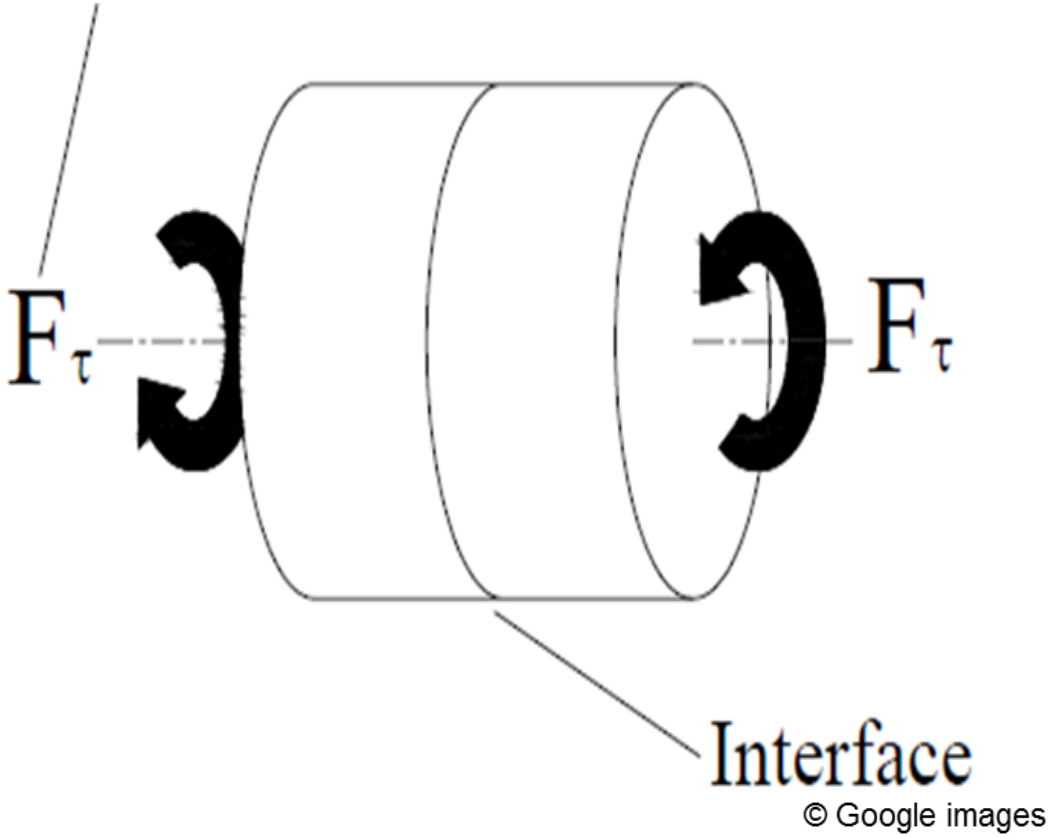
LIMITATIONS OF AVAILABLE TESTS



OBJECTIVES:


Low cost device
Less destructive test
Correlation (OFTCT& shear test)
DEVELOPED TORQUE TEST
User-friendly software
Improve practicality
Automated rotation

RESEARCH METHOD:
TORQUE TEST



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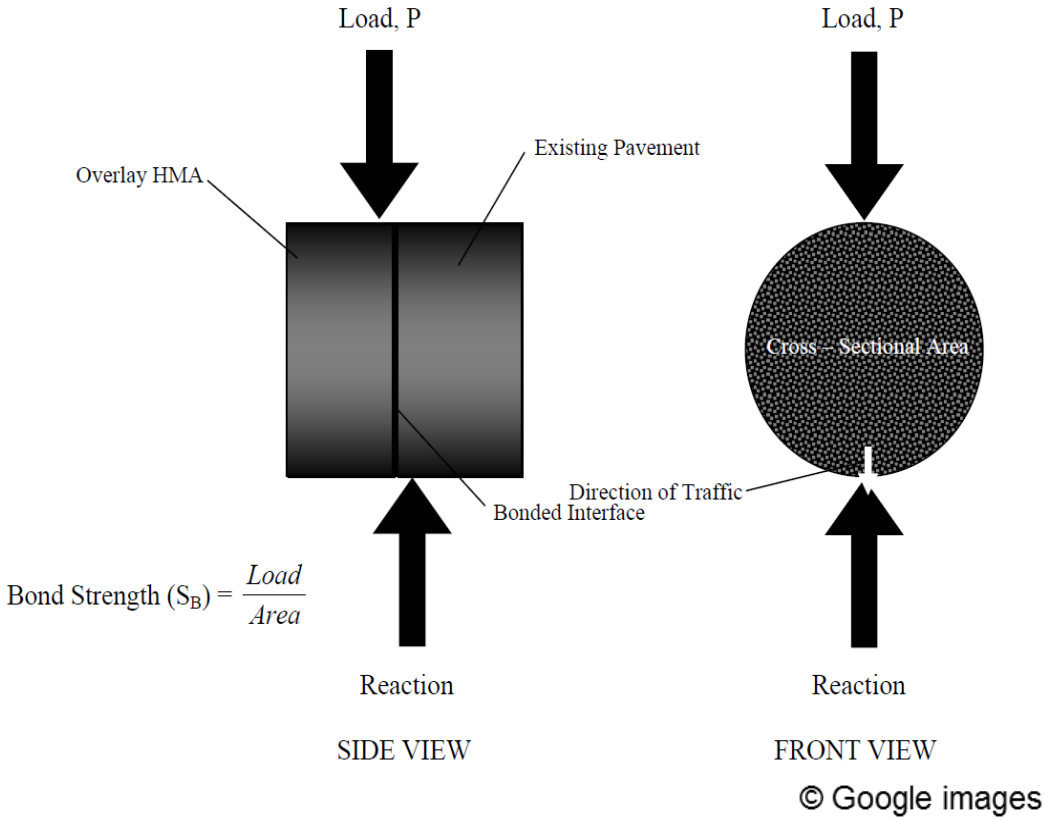
RESEARCH METHOD:
DIRECT LAB SHEAR TEST



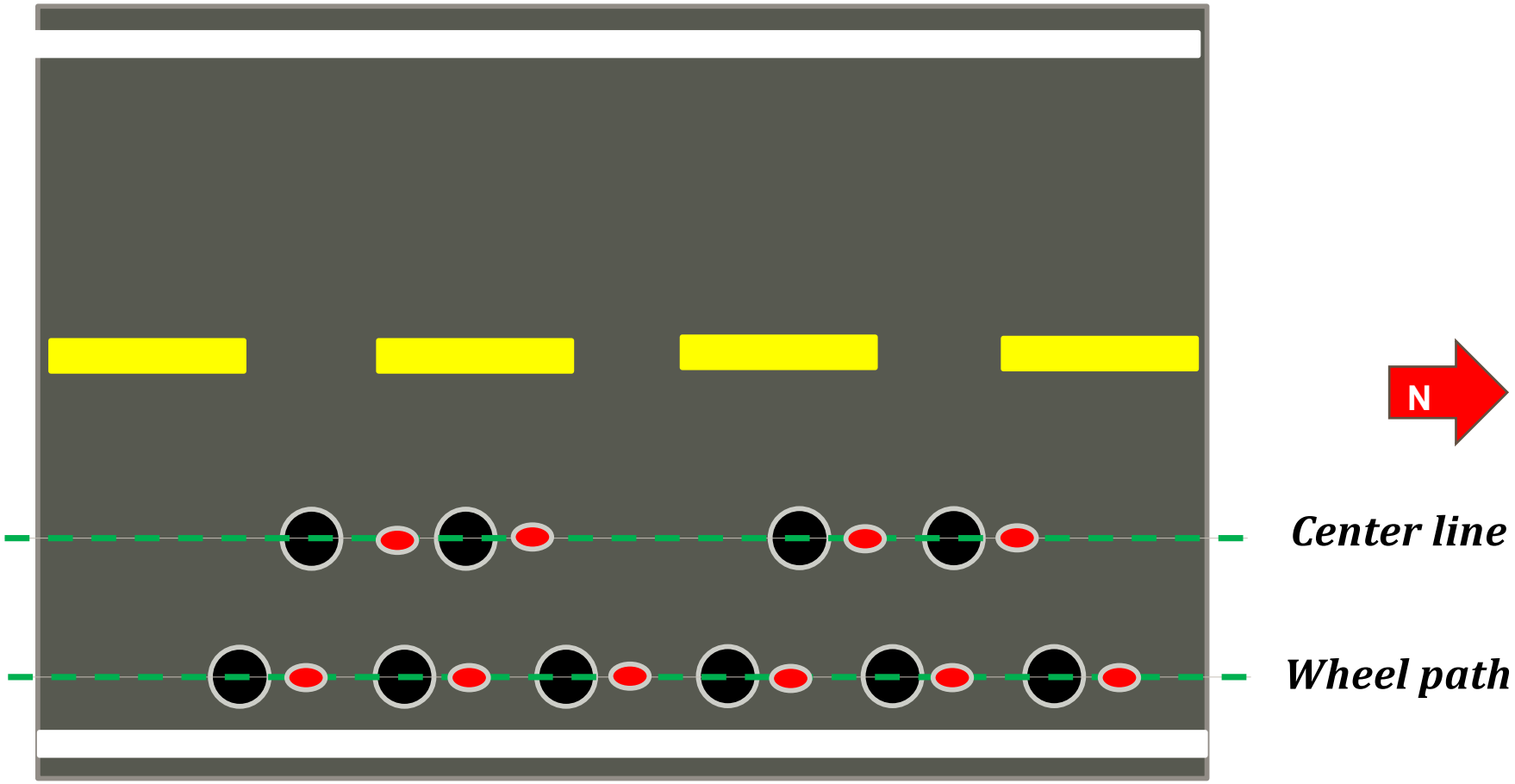
$$\text{Bond Strength } (S_B) = \frac{Load}{Area}$$

MATERIALS & METHODS:

SITE OVERVIEW

1	Day 4	CO1_CSS 1H_b	0.05, 0.07, 0.10
2	Day 5	CO1_New_b	0.05, 0.07, 0.09

MATERIALS & METHODS:
PROCEDURE FOR THE OFTT TEST

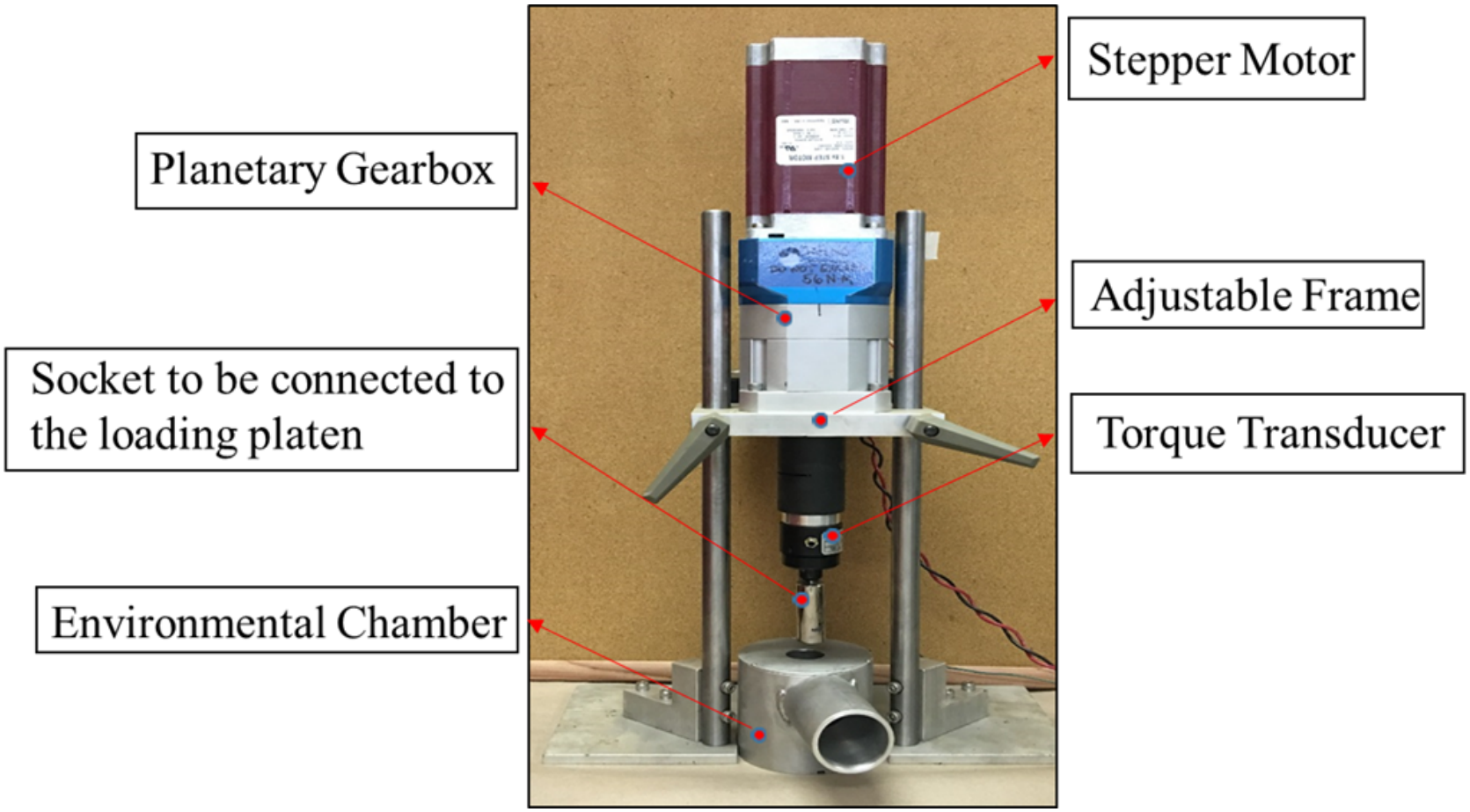


MATERIALS & METHODS:

OFTT TEST PROCEDURE

OREGON FIELD TORQUE TESTER (OFTT):

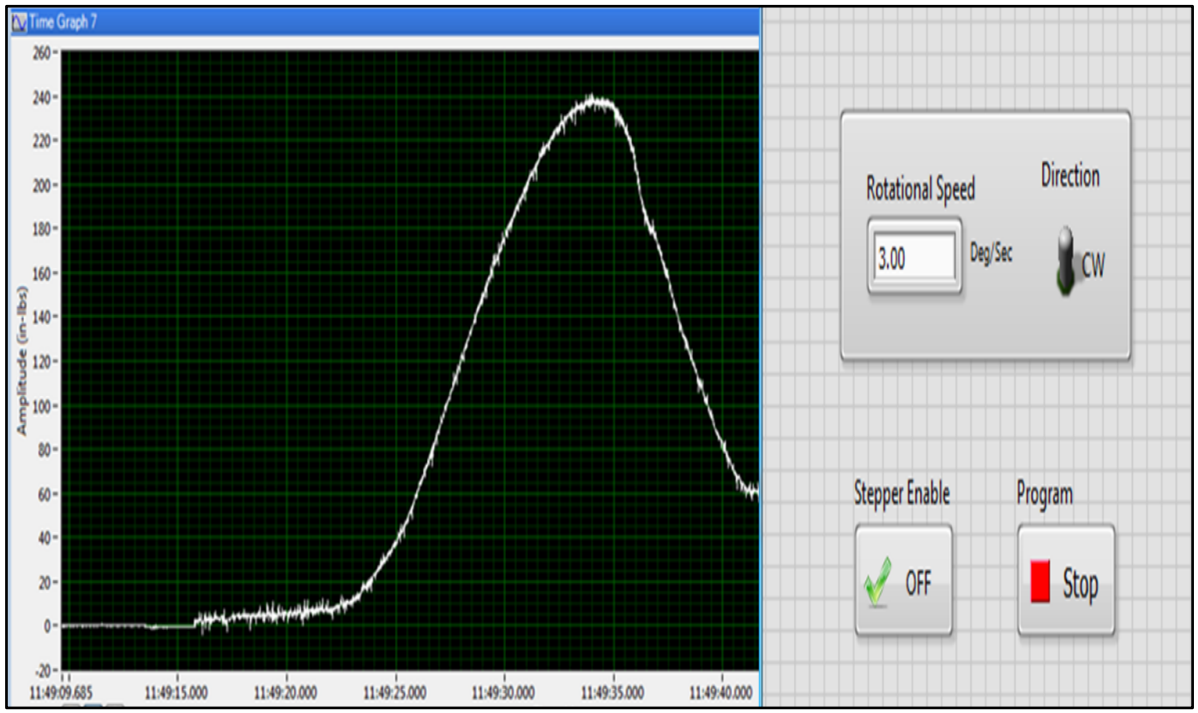
HARDWARE



OFTT DEVICE

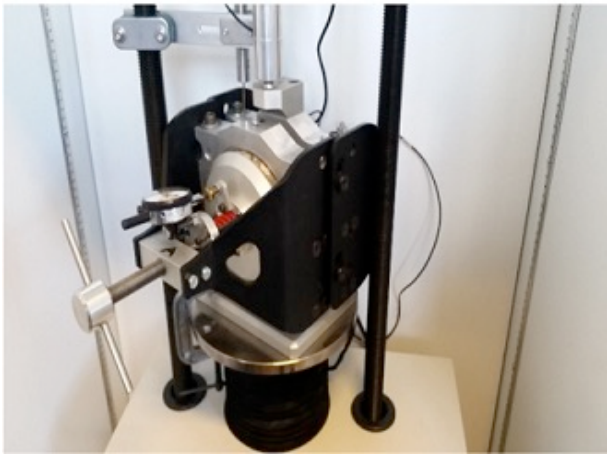
OREGON FIELD TORQUE TESTER (OFTT): SOFTWARE

- Real time viewing and analysis of the data.
- Control the stepper
- Control the direction of rotation
- Control the rotational rate



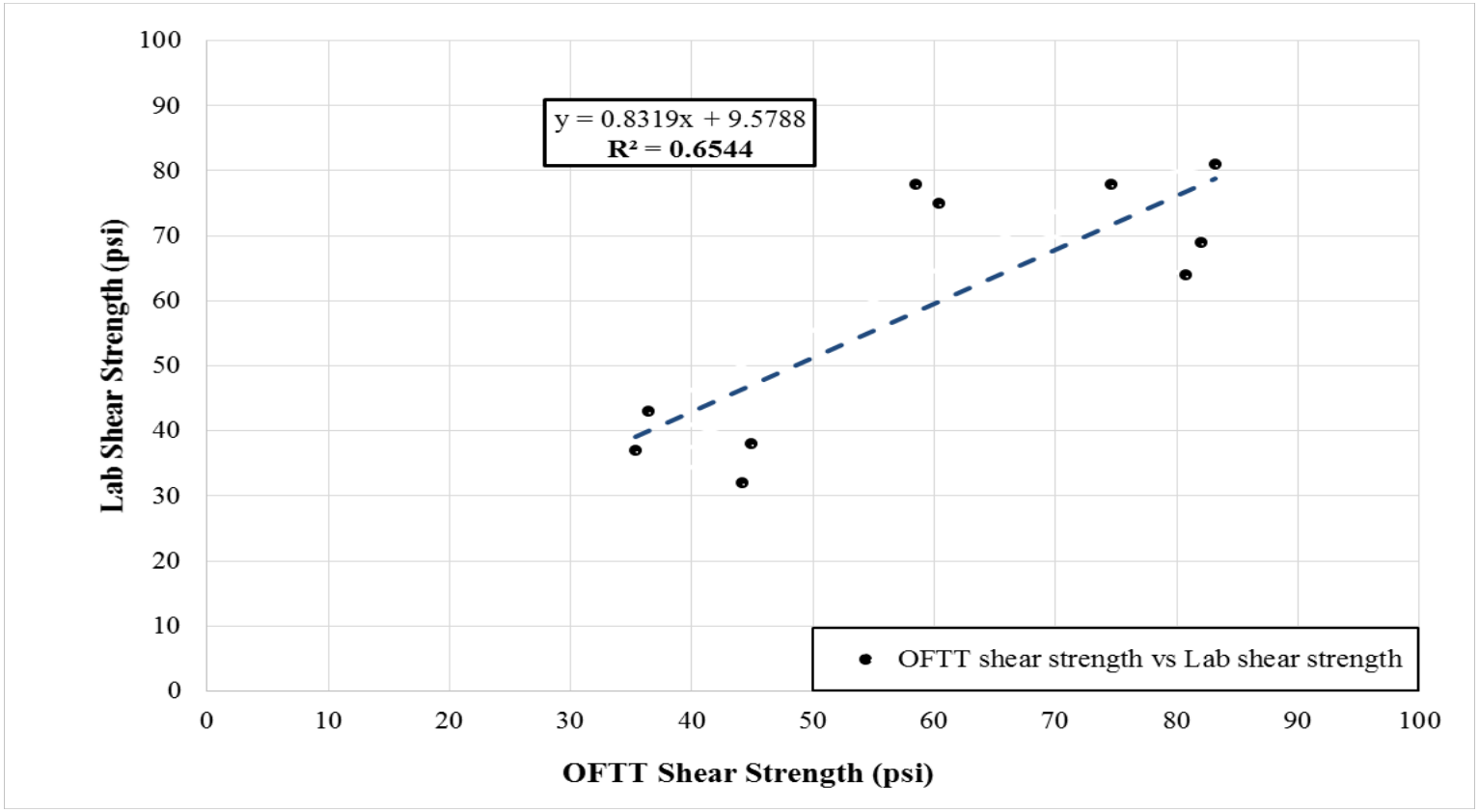
MATERIALS & METHODS:

PROCEDURE FOR DETERMINING ISS (AASHTO TP114, 2015)



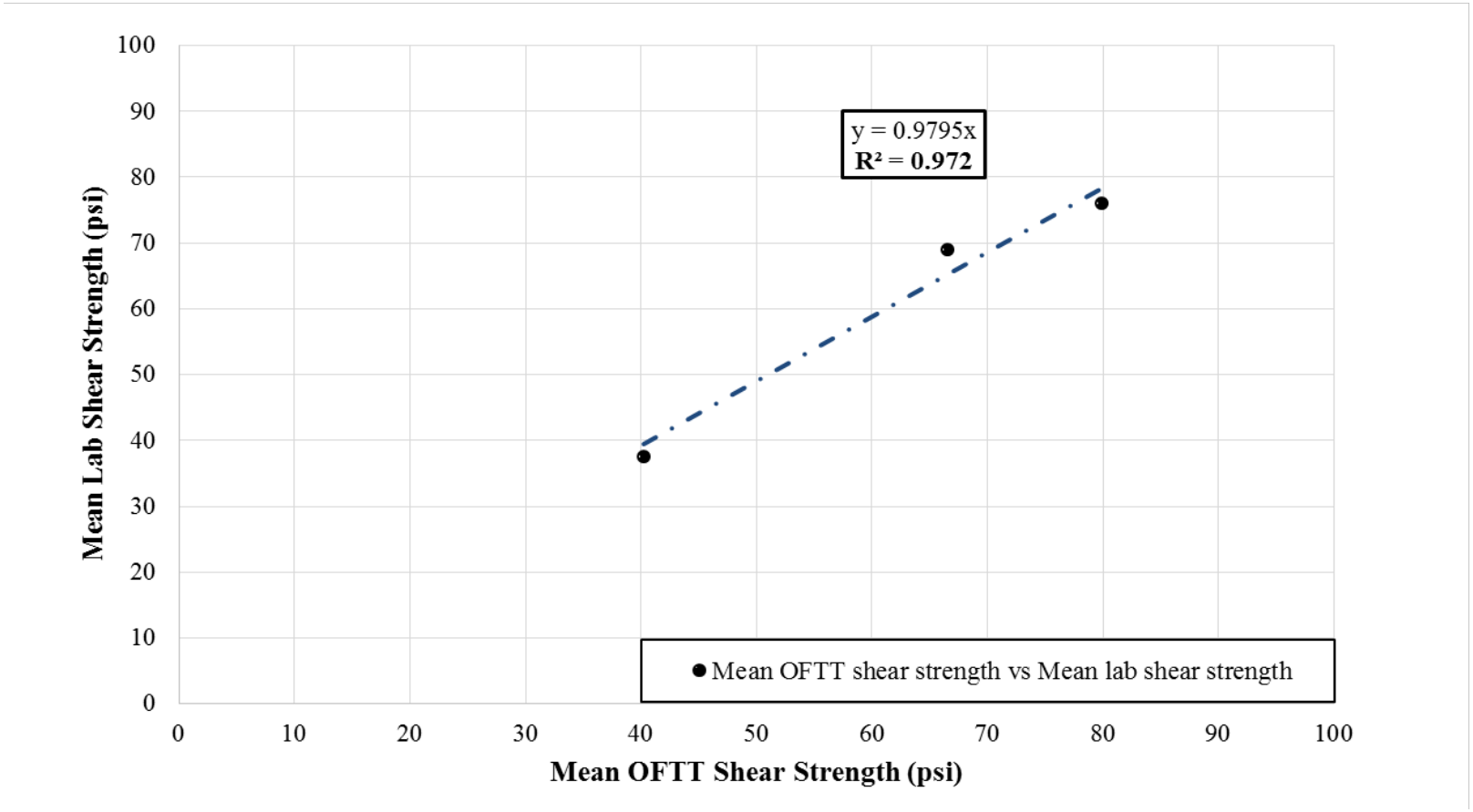
RESULTS & DISCUSSION:

CORRELATION BETWEEN THE RESULTS FROM THE OFTT OVERLAY FIELD TESTS AND LAB SHEAR TESTS



RESULTS & DISCUSSION:

CORRELATION BETWEEN THE RESULTS FROM THE MEAN OFTT OVERLAY FIELD TESTS AND MEAN LAB SHEAR TESTS



Outline

- Introduction
- Literature review
- Interlayer shear strength
- Tack coat tracking
- Oregon field torque tester (OFTT)
- Oregon field tack coat tester (OFTCT)
- 3D viscoelastic finite element model
- Summary

Development of a Wireless Field Tack Coat Tester to Evaluate In-Situ Tack Coat Performance

BACKGROUND:

CURRENT TECHNOLOGIES

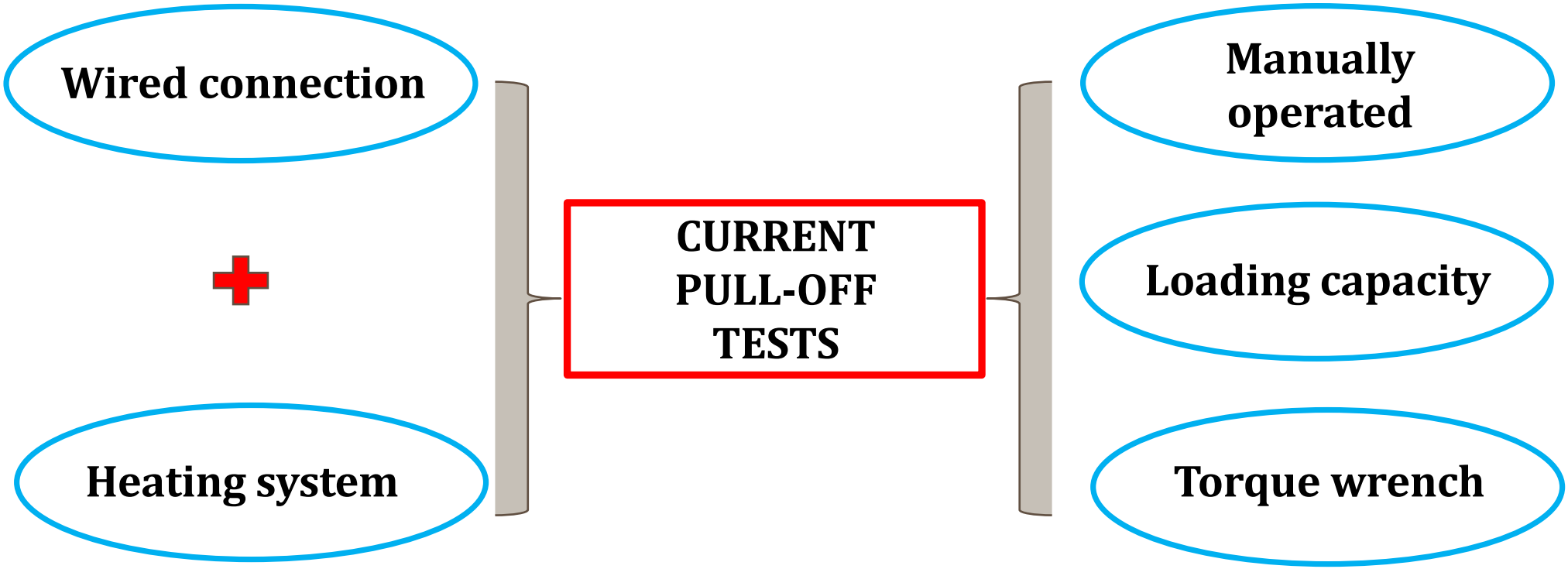
Louisiana Tack Coat Quality Tester (LTCQT) Device

LTCQT Heating System

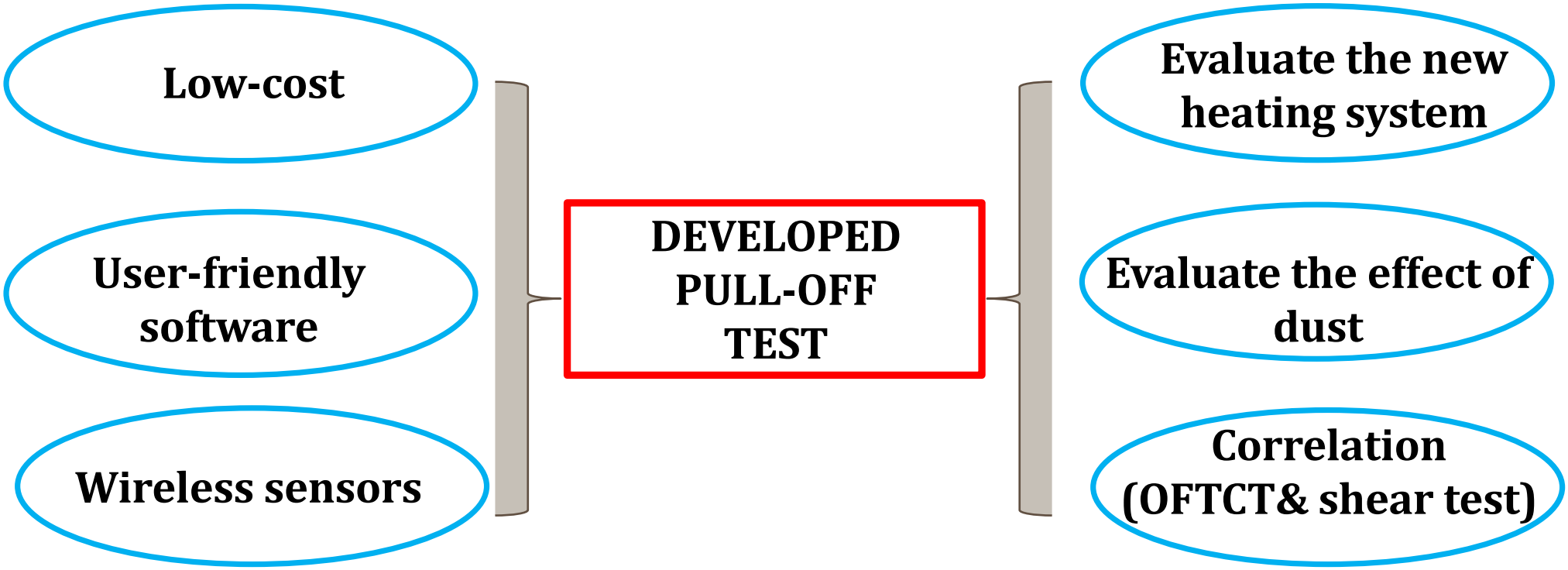
(MOHAMMED ET .AL, 2012)

BACKGROUND:

LIMITATIONS OF AVAILABLE TESTS

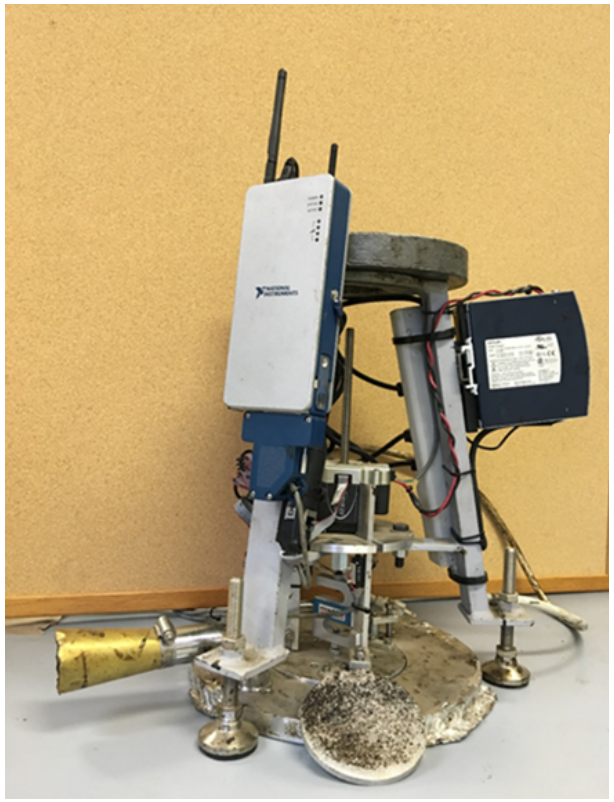


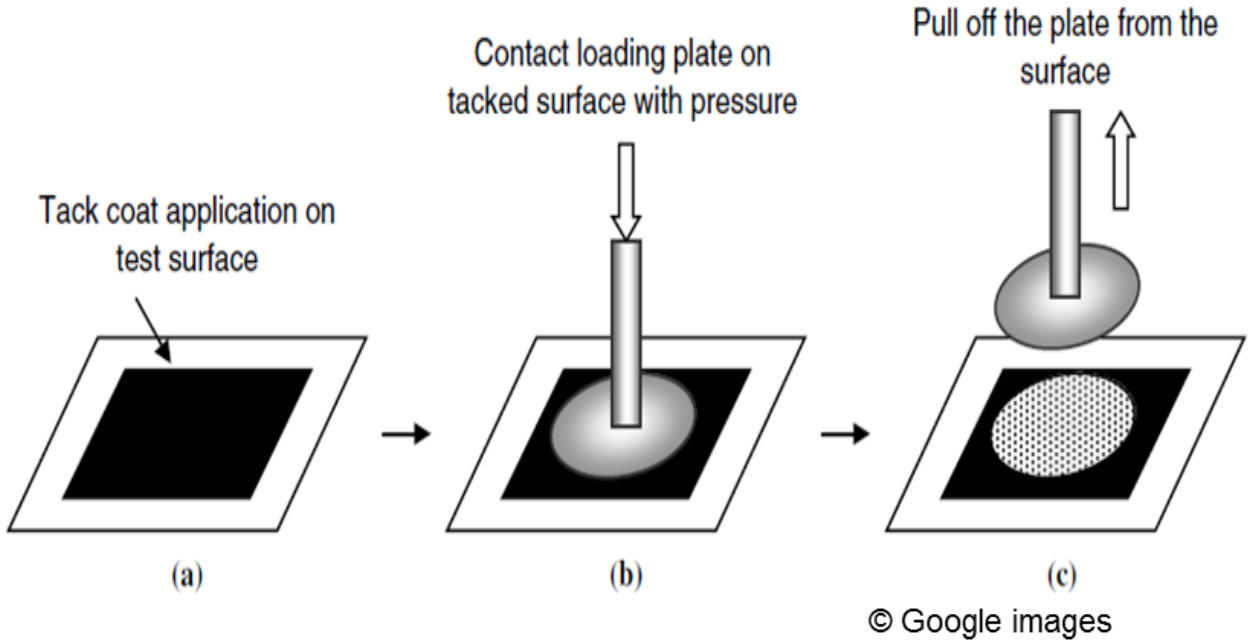
OBJECTIVES:


Low-cost
User-friendly software
Wireless sensors
DEVELOPED PULL-OFF TEST
Evaluate the new heating system
Evaluate the effect of dust
Correlation (OFTCT& shear test)

RESEARCH METHOD:

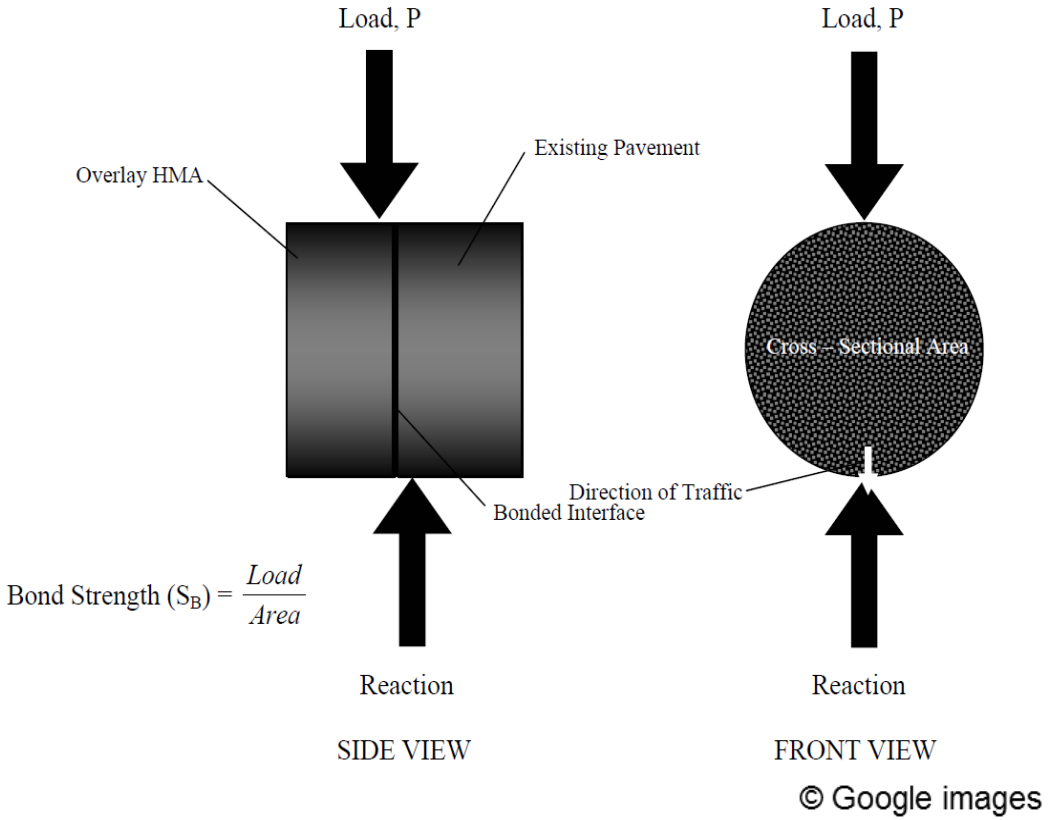
TACK COAT TENSILE STRENGTH TEST





© Google images

RESEARCH METHOD:
DIRECT LAB SHEAR TEST



$$\text{Bond Strength } (S_B) = \frac{Load}{Area}$$

MATERIALS & METHODS:

SITE OVERVIEW

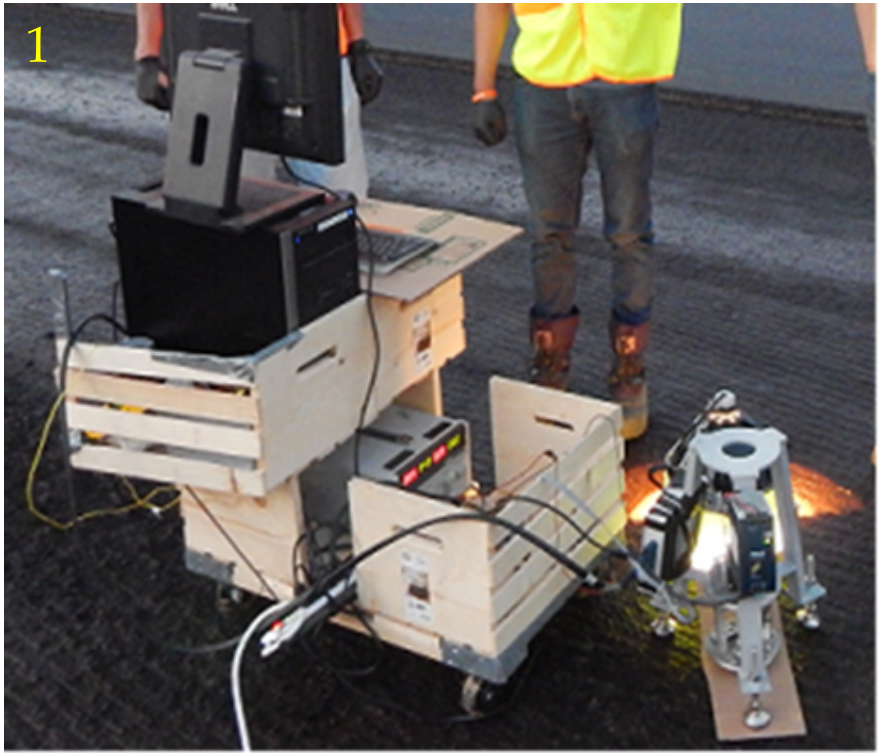
MATERIALS & METHODS:
EXPERIMENTAL DESIGN

Surfa	tion /yd²)
	, 0.12
Mill	, 0.16
	, 0.16
	, 0.10
Over	, 0.09
	, 0.10

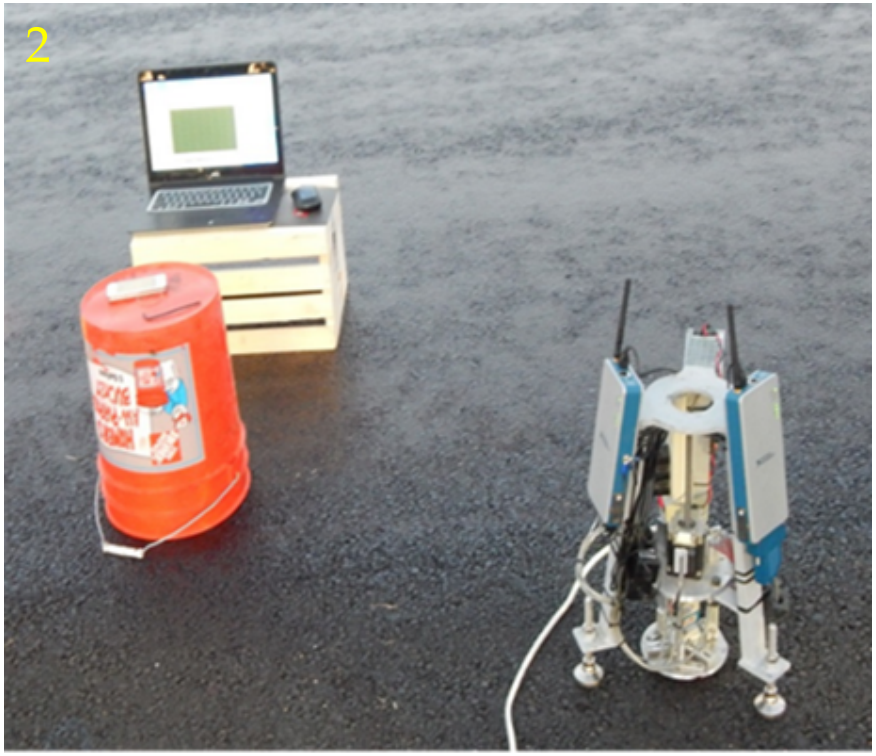
MATERIALS & METHODS:

DEVICE IMPROVEMENTS

OREGON FIELD TACK COAT TESTER



OFTCT PROTOTYPE VERSION



OFTCT WIRELESS VERSION

MATERIALS & METHODS:

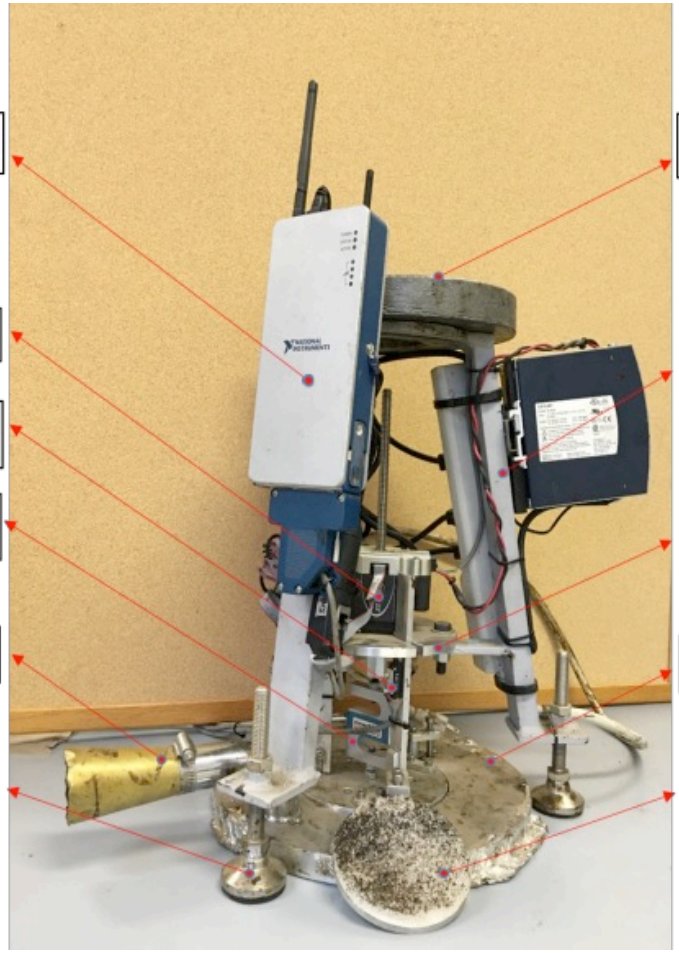
OFTCT FIELD TEST PROCEDURE

MATERIALS & METHODS:

CAN WE USE OFTCT AS A CLEANLINESS EXPERIMENT?

PROCEDURE TO EVALUATE THE EFFECT OF DUST

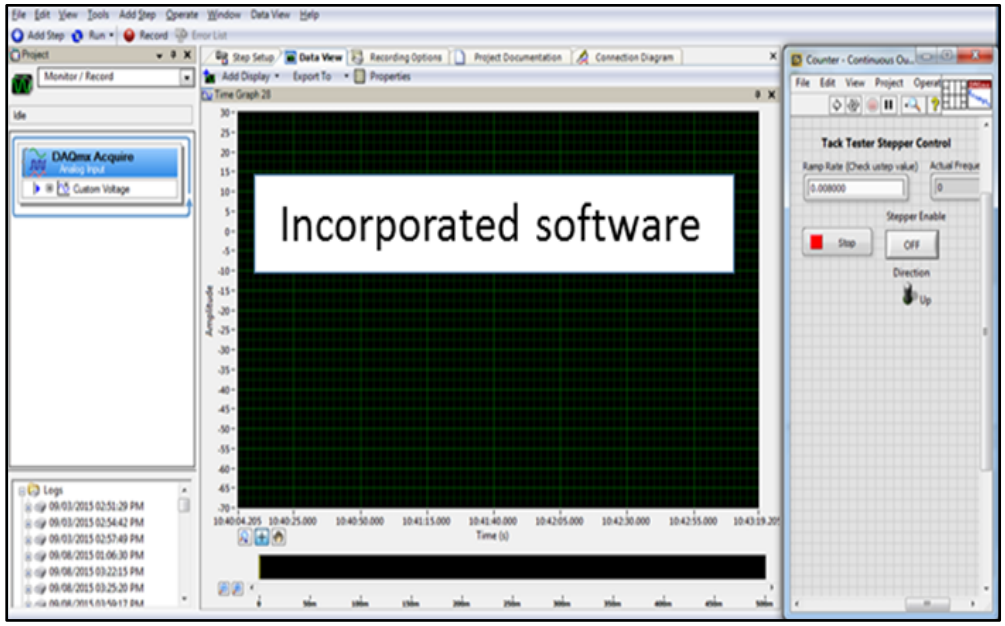
OREGON FIELD TACK COAT TESTER:
HARDWARE

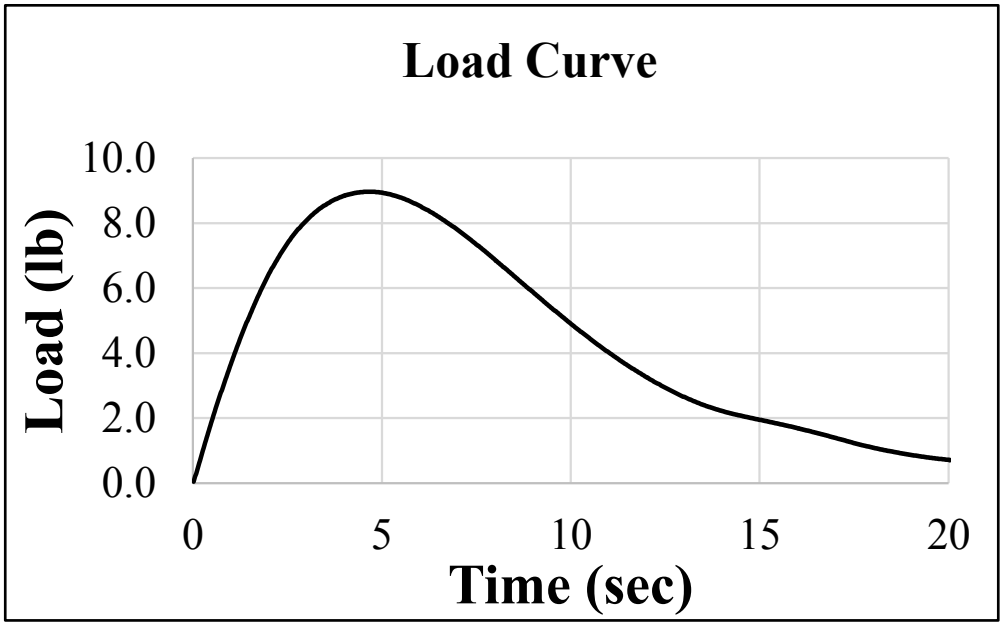


OFTCT DEVICE

OREGON FIELD TACK COAT TESTER:
SOFTWARE

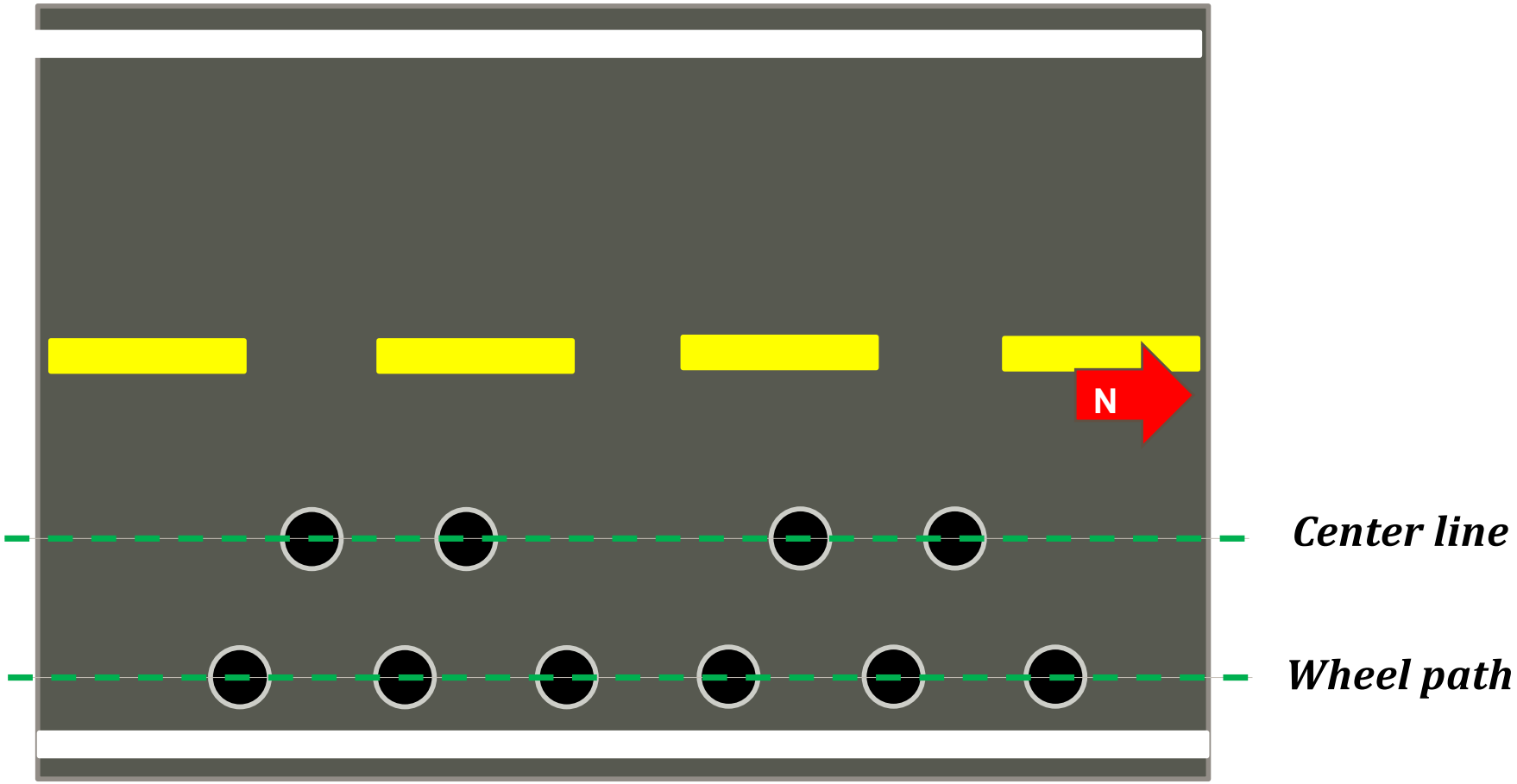
- ❑ Displacement rate.
- ❑ Deliver graphical results.
- ❑ Data acquisition system.





MATERIALS & METHODS:

PROCEDURE FOR DETERMINING ISS



MATERIALS & METHODS:

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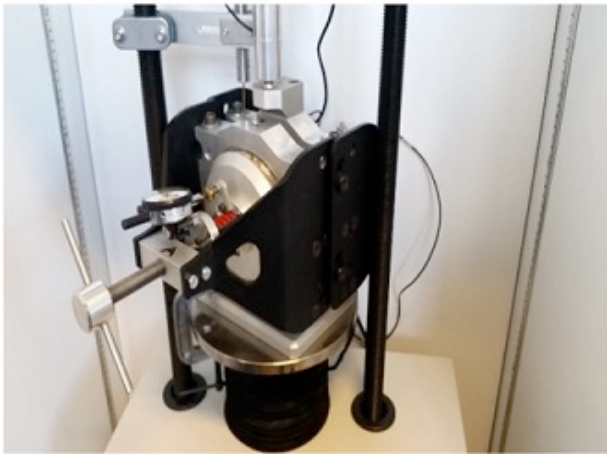
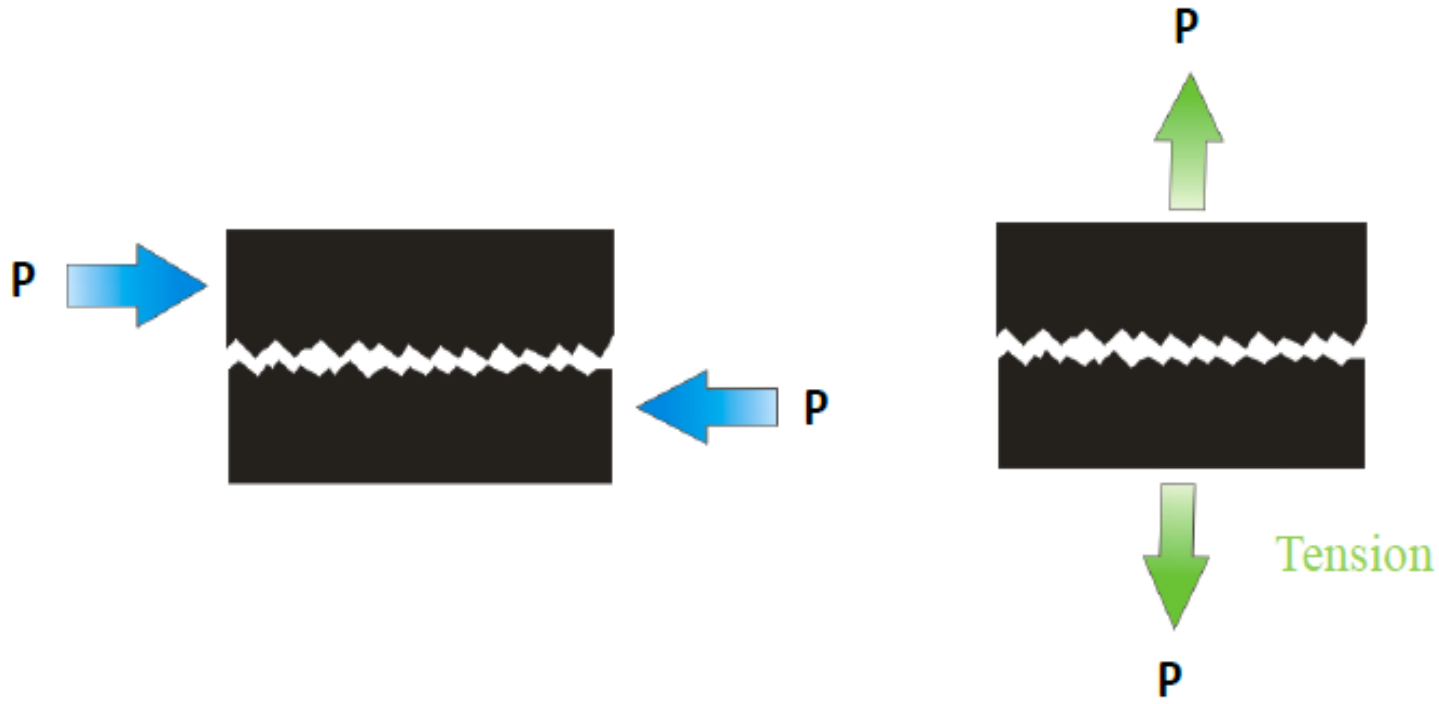


RESULTS & DISCUSSION :

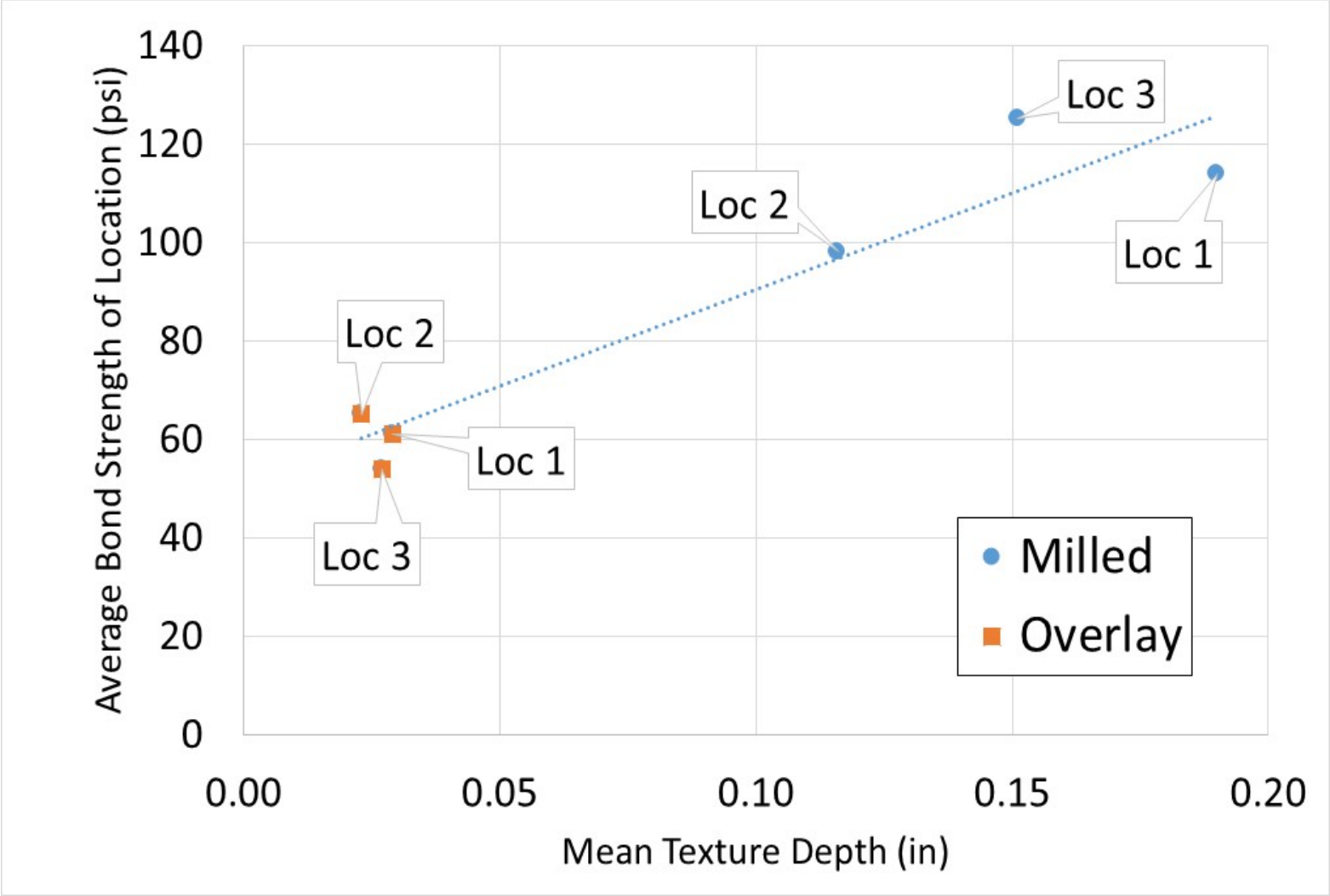
MOST EFFECTIVE APPLICATION RATE TO MAXIMIZE ISS

Milled surfaces can create high strength in shear test while processing poor bond strength in tension



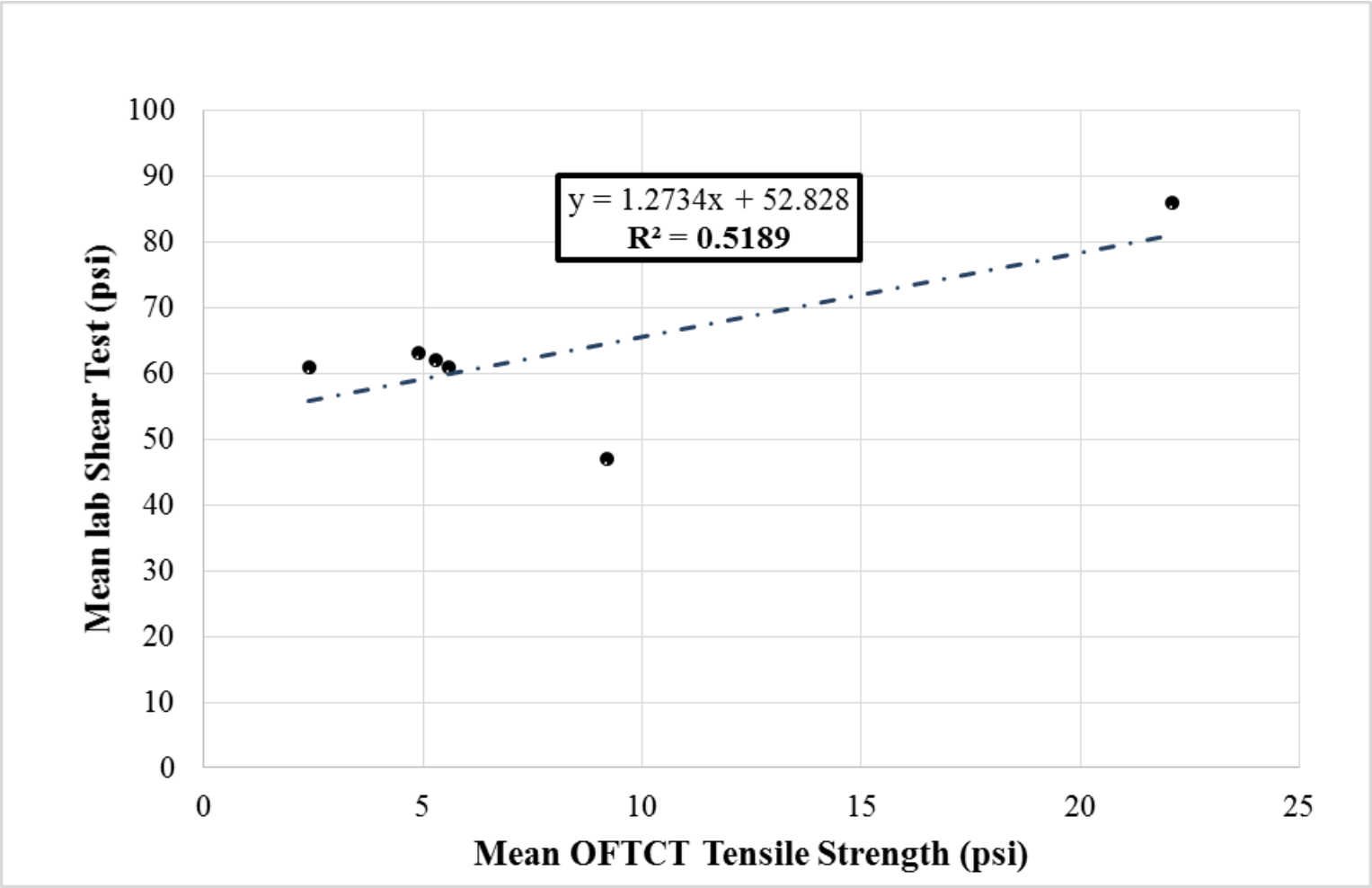
RESULTS & DISCUSSION :

SURFACE TEXTURE RESULTS ON ISS



RESULTS & DISCUSSION:

CORRELATION BETWEEN THE RESULTS OF THE **OFTCT** OVERLAY FIELD TESTS AND **LAB SHEAR** TEST (WP,CL, & TWO LOCATIONS)



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RESEARCH

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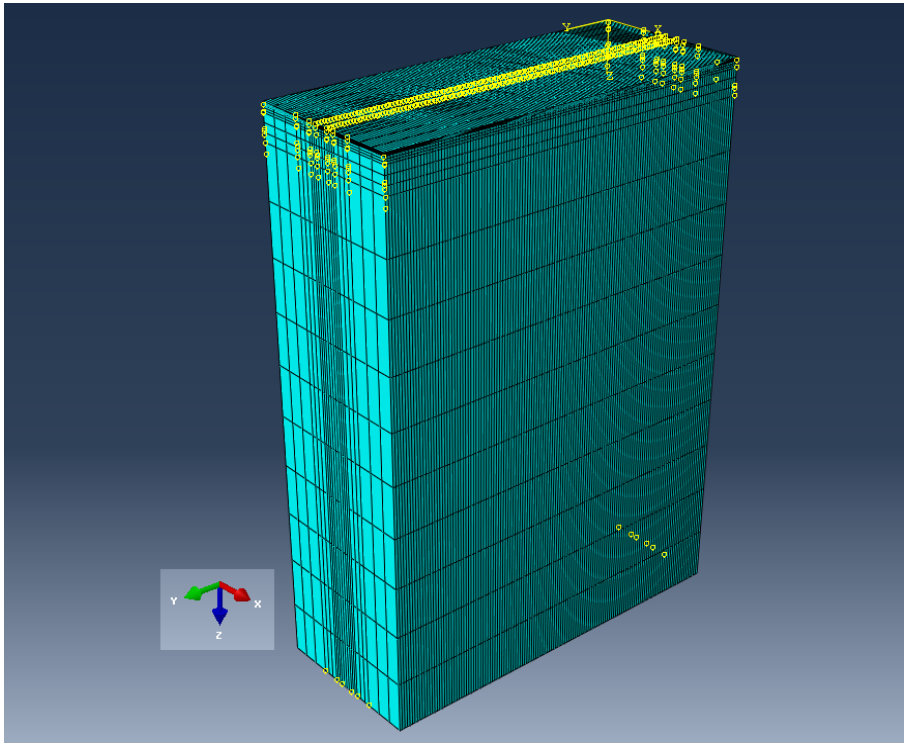
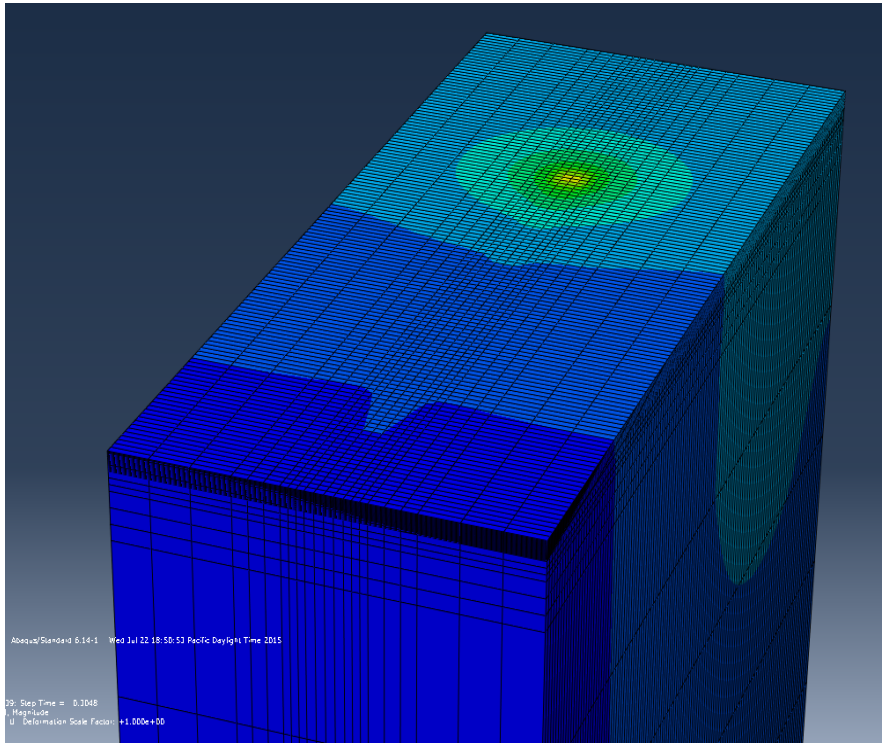
OSU Oregon State University

THREE DIMENSIONAL FINITE ELEMENT MODEL TO EVALUATE THE EFFECTS OF STRUCTURAL CHARACTERISTICS ON TACK COAT PERFORMANCE

3D viscoelastic finite element model to evaluate the effects of structural characteristics on tack coat performance





Dynamic truck wheel

3D viscoelastic finite element model to evaluate the effects of structural characteristics on tack coat performance

86 and 113°F – Temperatures

Overlay	2 and 4 inches thick
Existing AC	4 and 12 inches thick
Aggregate base	10 and 16 inches thick
Subgrade	5,800 and 14,500 psi

A TOTAL OF 32 MODELS

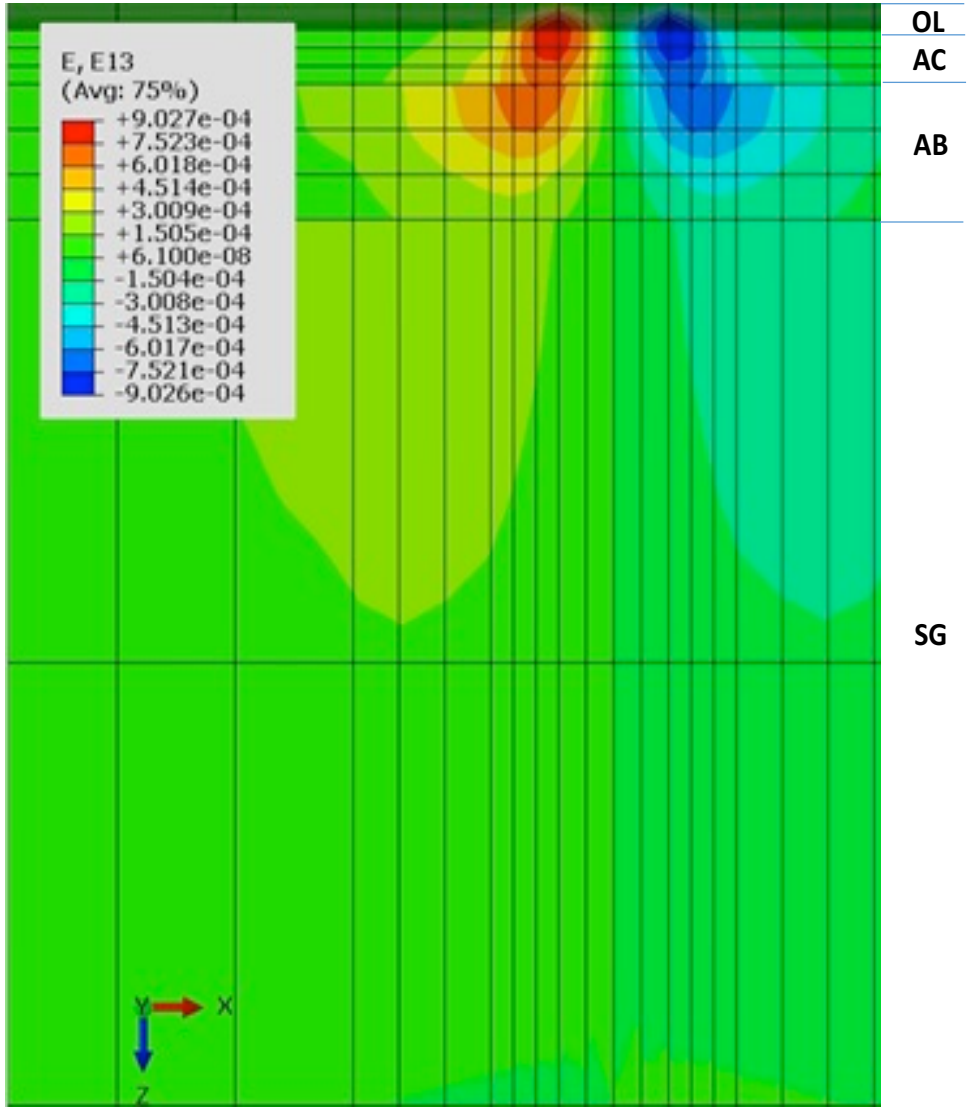
RESULTS

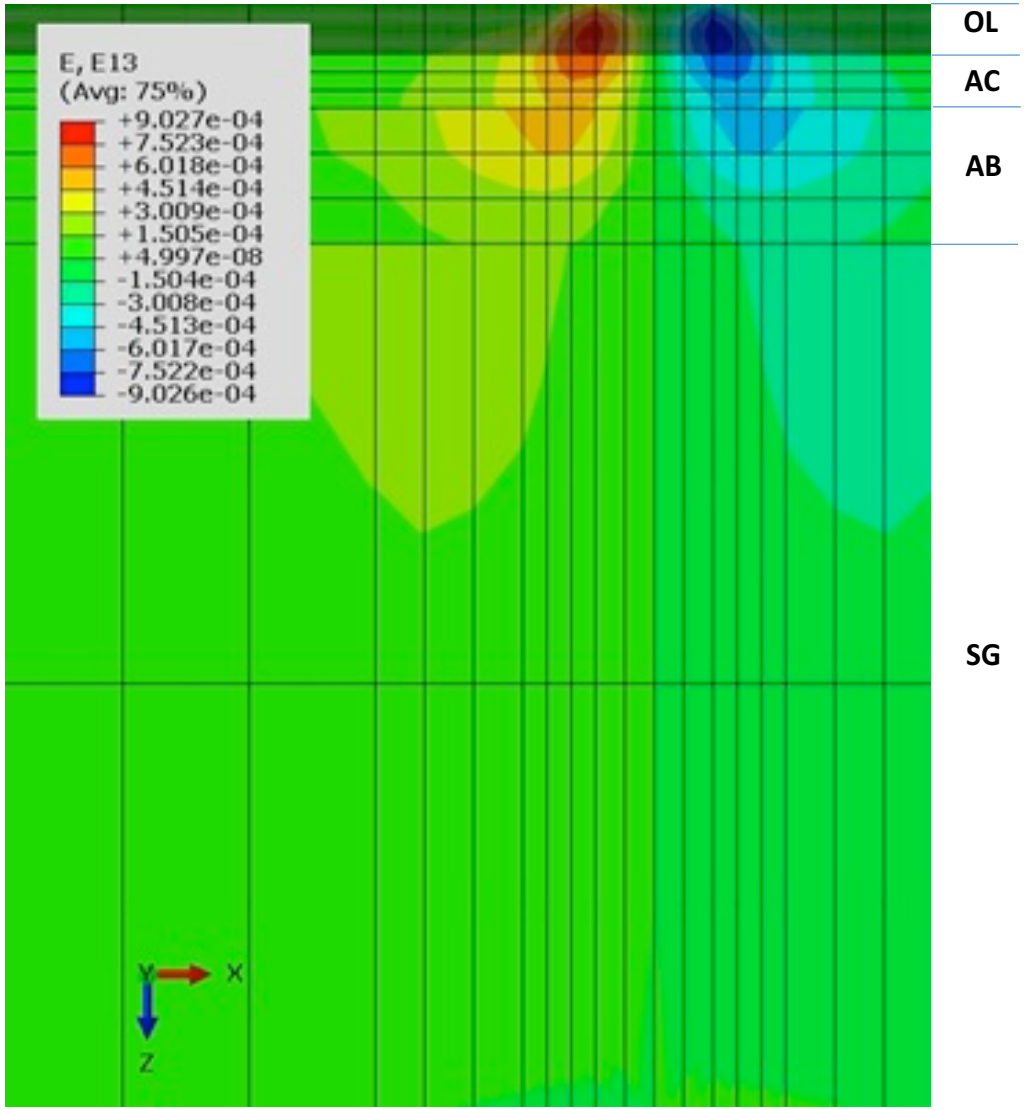
ANOVA table for critical tack coat shear strain values

Variables	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
H_{OL} (in.)	1	351558	351558	40.61	0.0000
H_{AC} (in.)	1	2530	2530	0.29	0.5934
H_{AB} (in.)	1	34132	34132	3.94	0.0577
E_{SG} (psi)	1	565	565	0.07	0.8003
Temp. (^{o}F)	1	487548	487548	56.32	0.0000
Residuals	26	225086	8657		

BOND STRENGTH IS VERY IMPORTANT FOR THIN OVERLAYS

RESULTS





Increasing overlay thickness shifts critical strain location from the tack coat area to mid-overlay area

Outline

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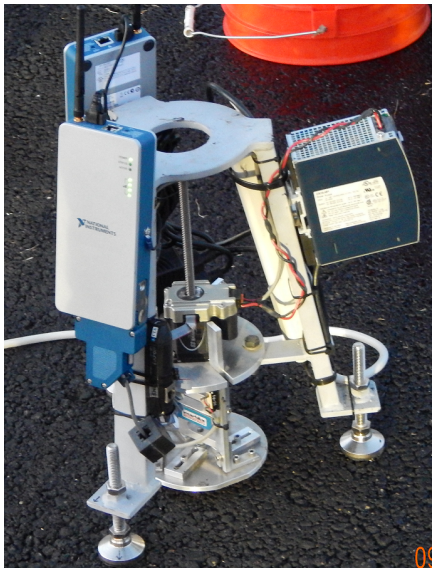
RESEARCH

Oregon Department of Transportation

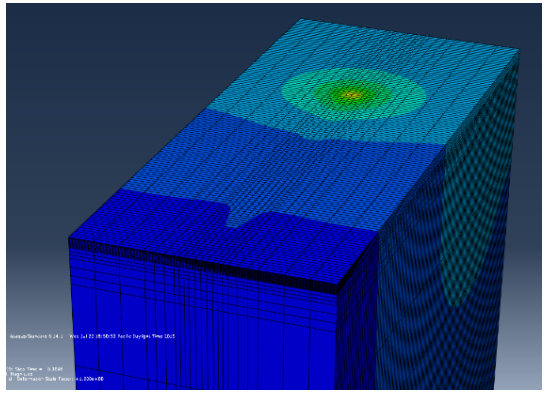
OSU Oregon State University

SUMMARY AND CONCLUSIONS

DEVELOPED TECHNOLOGIES



Wireless OFTCT



Model to evaluate bond strength

IOS and Android apps for curing time notification

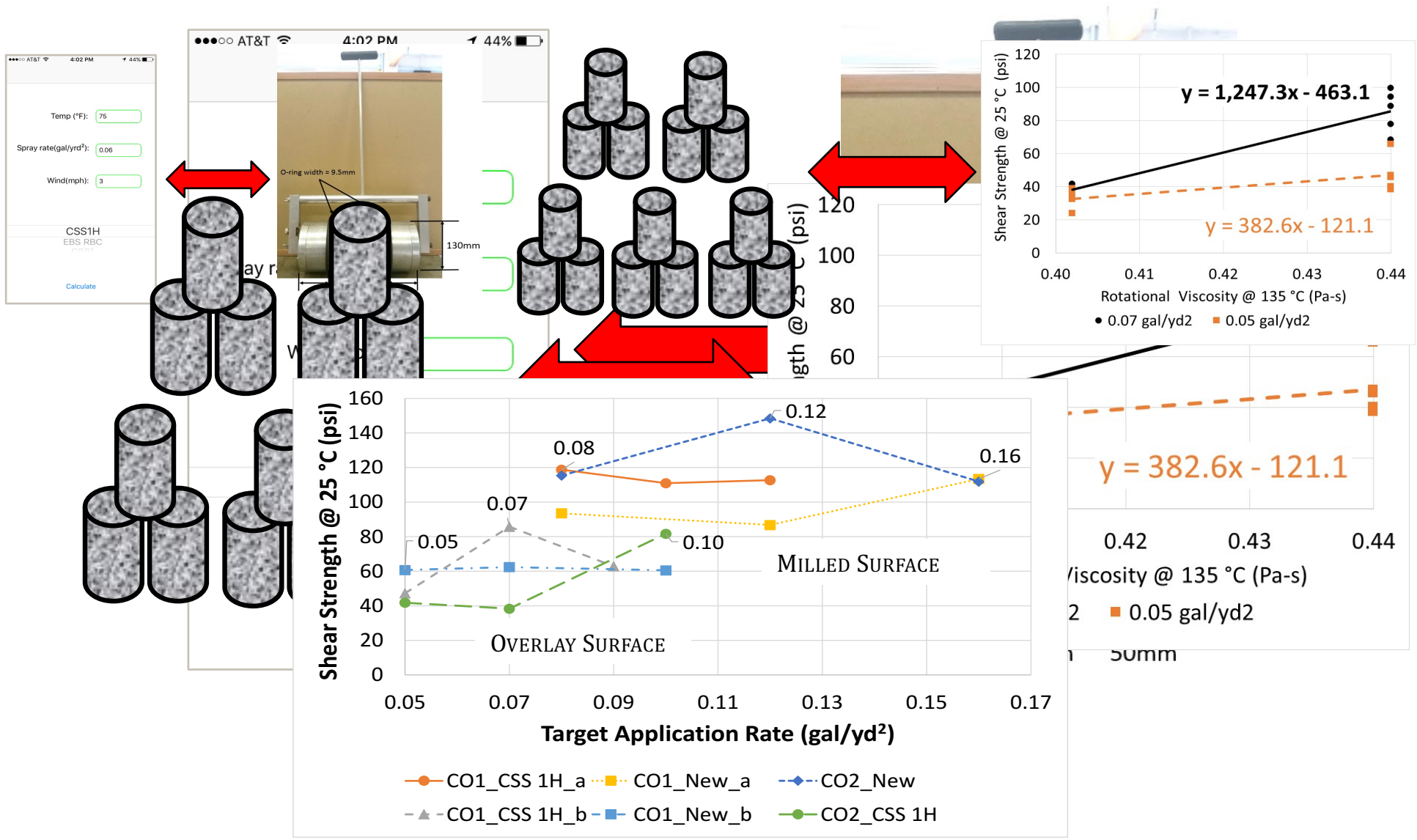
OFTT

Wheel tracking device

Other contributions to the knowledge and practice

- Correlation functions to predict long-term bond strength from simple binder experiments
- Recommendations to reduce tracking
- Most effective spraying rates to maximize bond strength
- Recommendations to improve current QC/QA procedures - Spraying rate QC/QA, different truck usage
- Effectiveness of new tack coat products
- Effects of surface texture and traffic/environment
- Curing times for Oregon tack coats
- Need high bond strengths for thin overlays

Future Work


Temp (°F): 75
Spray rate(gal/yrd²): 0.06
Wind(mph): 3
CSS1H
EBS RBC
Calculate
O-ring width = 9.5mm
130mm
y = 1,247.3x - 463.1
y = 382.6x - 121.1
Shear Strength @ 25 °C (psi)
Rotational Viscosity @ 135 °C (Pa-s)
0.07 gal/yd2
0.05 gal/yd2
Shear Strength @ 25 °C (psi)
Target Application Rate (gal/yd²)
Milled Surface
Overlay Surface
CO1_CSS 1H_a
CO1_New_a
CO2_New
CO1_CSS 1H_b
CO1_New_b
CO2_CSS 1H

FUTURE WORK

- Conduct additional experiments and identify practicality issues to improve the OFTT and OFTCT;
- Conduct more OFTT and OFTCT experiments on thin asphalt layers to investigate the effectiveness of these devices on thin overlay sections; and
- Develop procedures to quantify distributor truck tack coat application accuracy and develop procedures for truck cleaning.

GO BEAVS!

Q & A

Thank you!

Oregon Department of Transportation

RESEARCH
Oregon Department of Transportation

OSU
Oregon State
UNIVERSITY

This study is sponsored by Oregon Department of Transportation (ODOT). This funding is gratefully acknowledged.

OSU
Oregon State
UNIVERSITY

Oregon State University Asphalt Materials Laboratory

OPEN HOUSE

THURSDAY,NOVEMBER 17th, 2016

1:30pm - 4:00pm

Oak Creek Building, Room 177

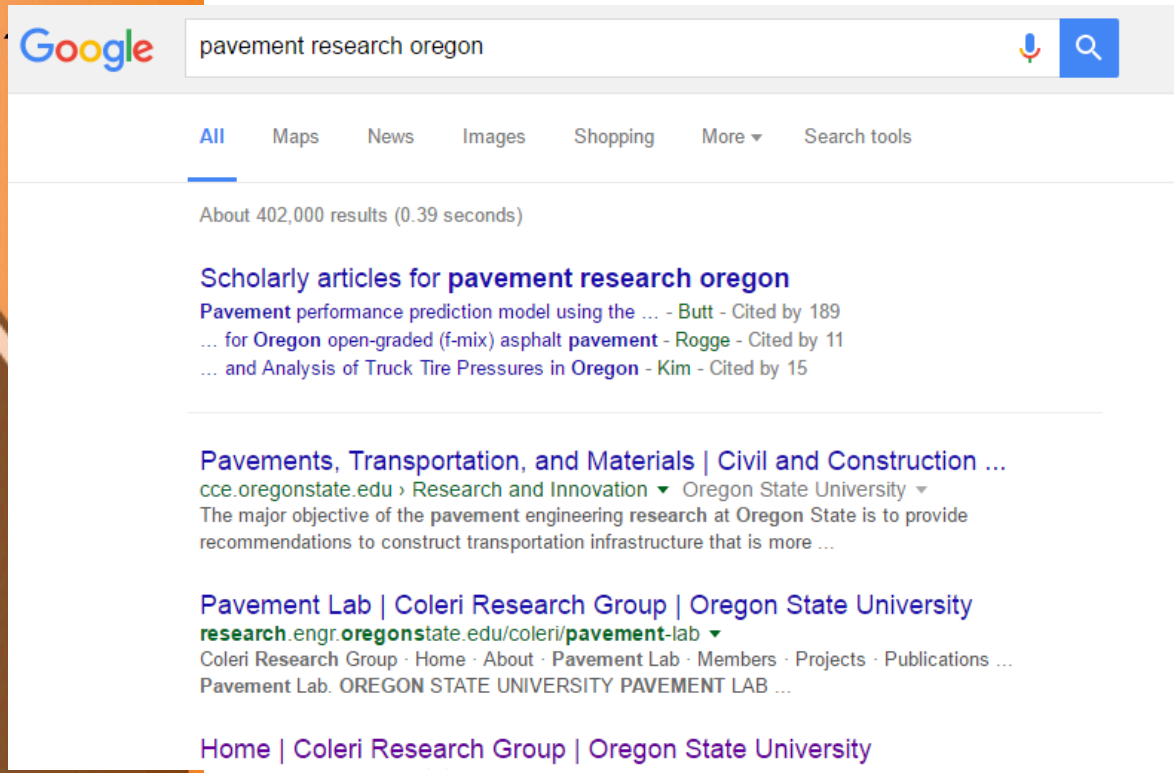
3015 SW Western Blvd, Corvallis,OR, 9733

Research Group Introductions
Current Research Projects
Laboratory Tour
Experiment Demonstrations
Refreshments

Questions and RSVP
510-305-6246
colerie@oregonstate.edu
RSVP by November 03

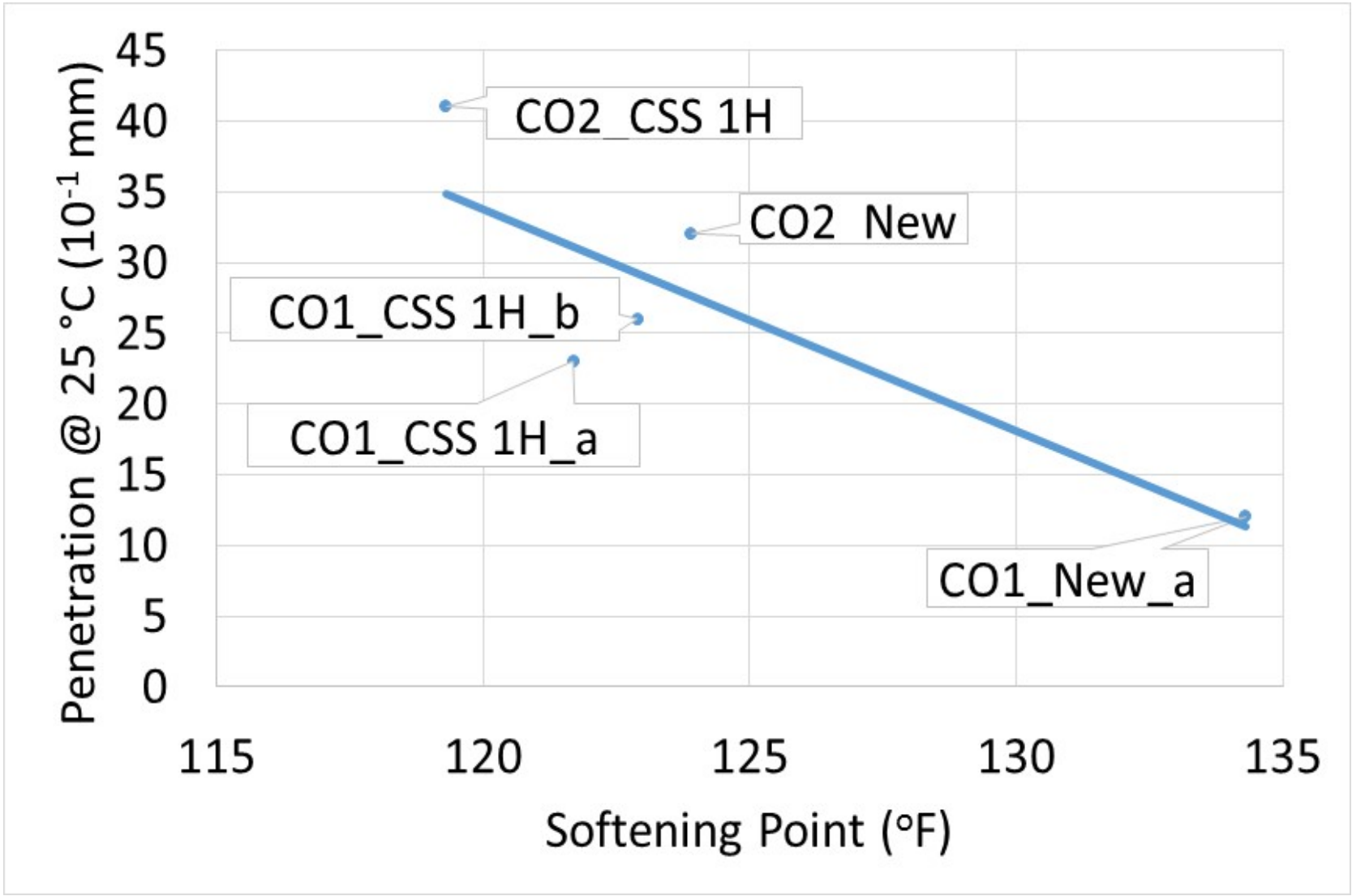
EMAIL TO RSVP:

colerie@oregonstate.edu



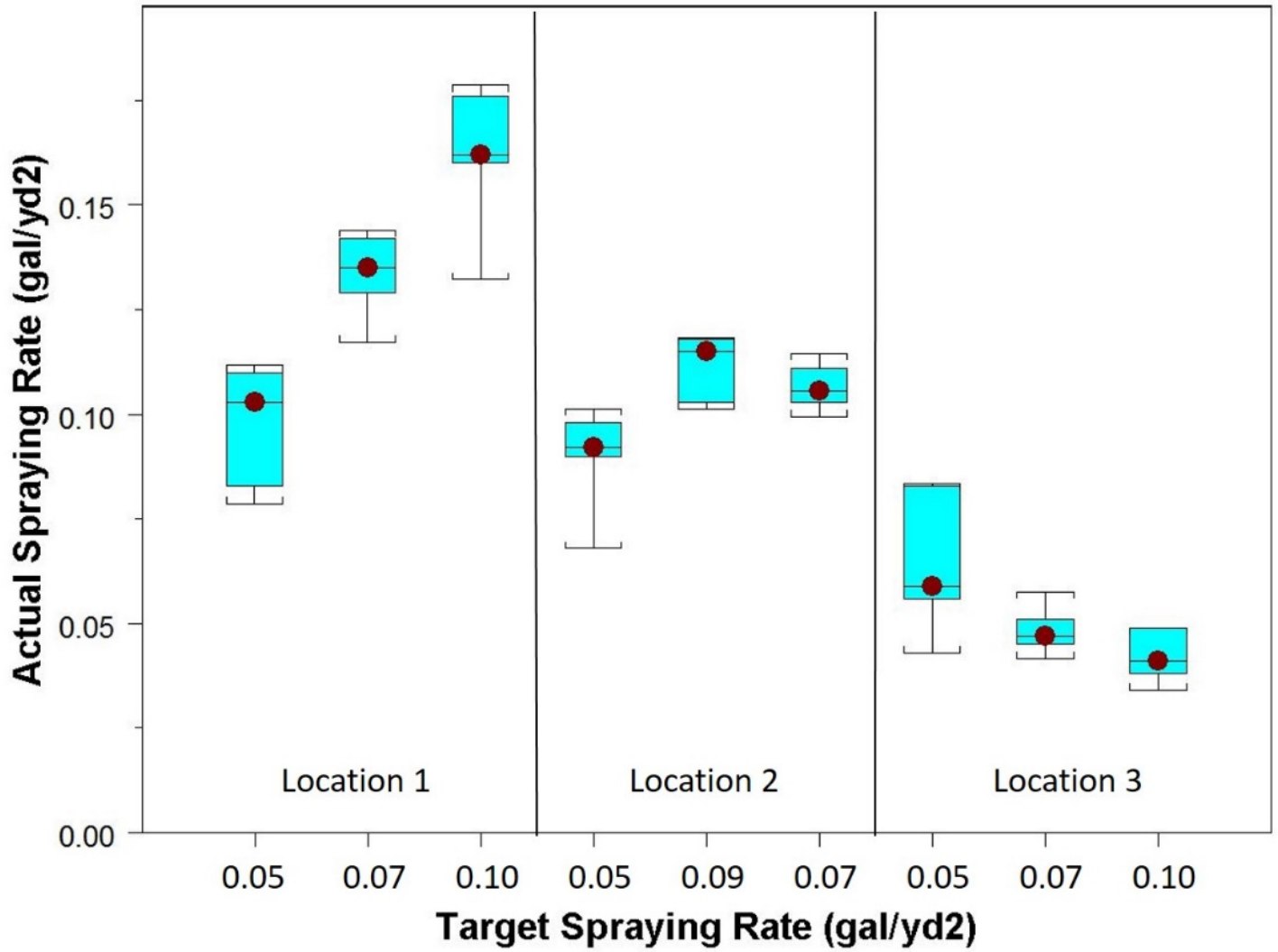
Results & Discussion

Rheological test results and correlations



RESULTS & DISCUSSION:

OVERLAY MEASURED APPLICATION RATE



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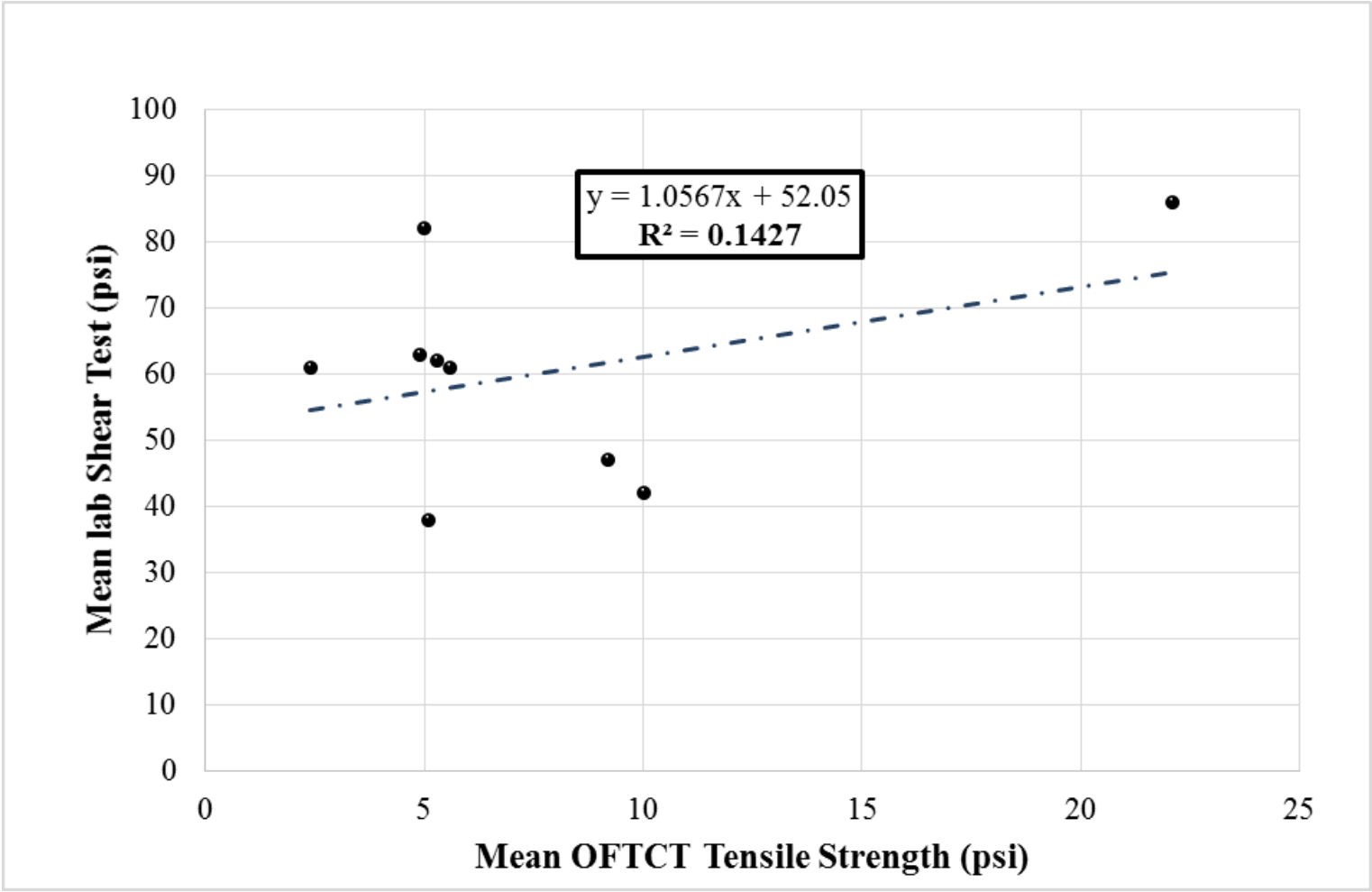
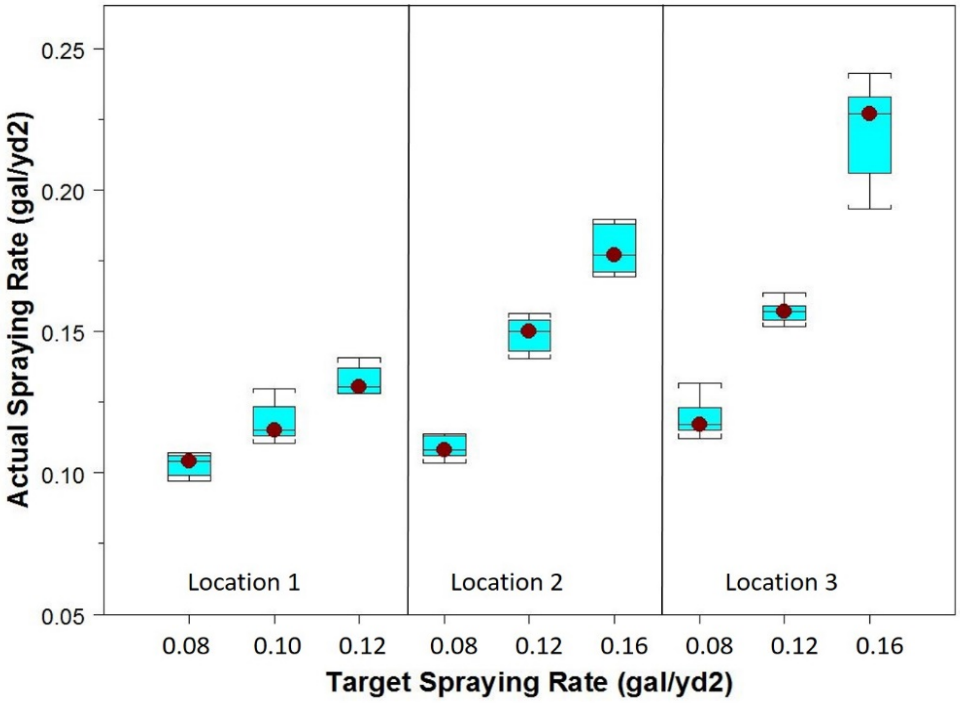


RESULTS & DISCUSSION:

MOST EFFECTIVE APPLICATION RATE TO MAXIMIZE ISS

Milled Surface



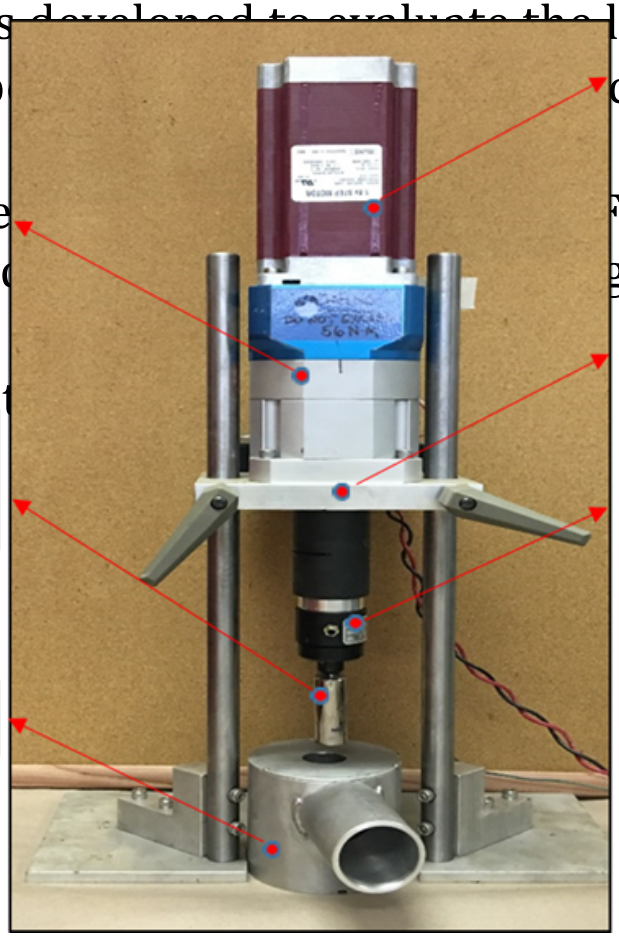
Contractor's truck used

RESULTS & DISCUSSION:

UNIFORMITY ISSUES WITH THE OLD TRUCK

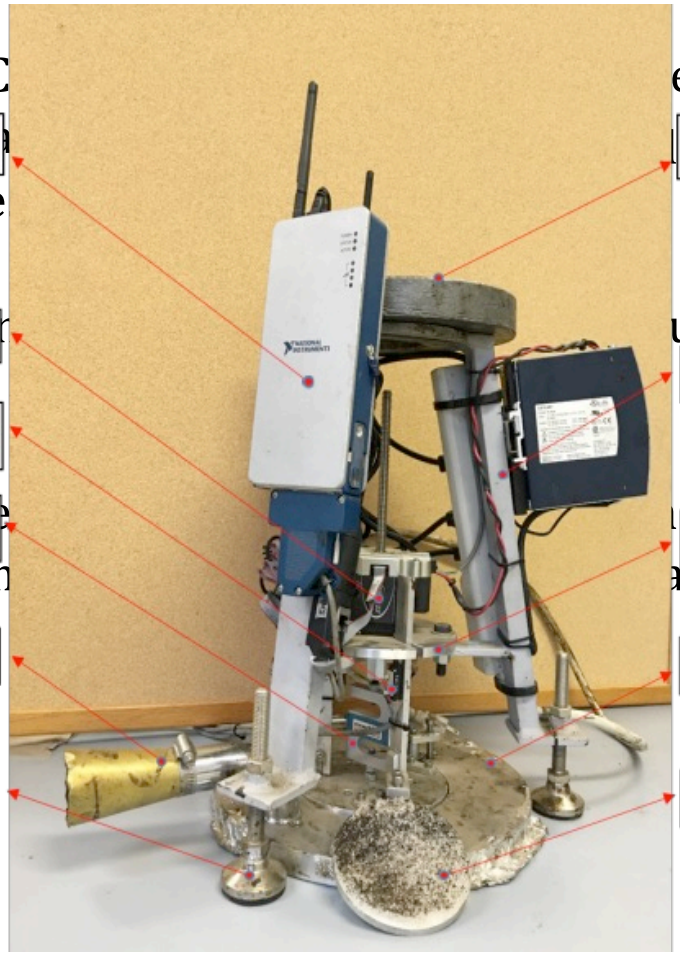
SUMMARY & CONCLUSIONS :

- A low cost, practical, and less destructive field test device, the Oregon Field Torque Tester (OFTT), is developed to evaluate the long-term post-construction tack coat p
- Resu e FTT is an effective test to characterize in-situ bond g-term bond performance.
- OFTT can be used to test



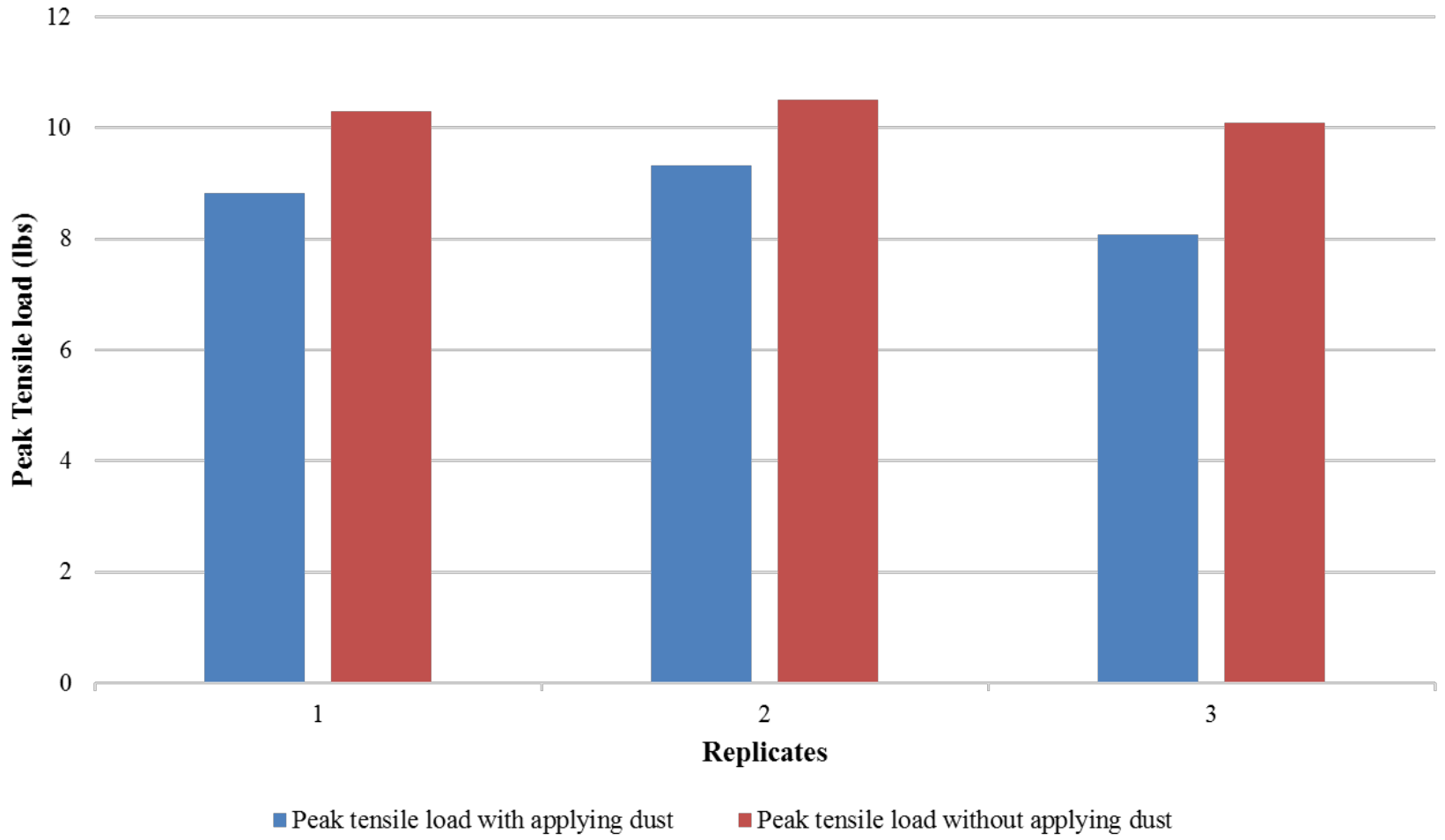
SUMMARY & CONCLUSIONS :

- The Oregon Field Tack C ed to predict the long-te ify the cleanliness of the pavement surface
- The correlat ults is determined to be statistically significant.
- The OFTCT test to quantify the cleanliness of the pavem application.



RESULTS & DISCUSSION:

EFFECT OF DUST ON THE TACKED SURFACE



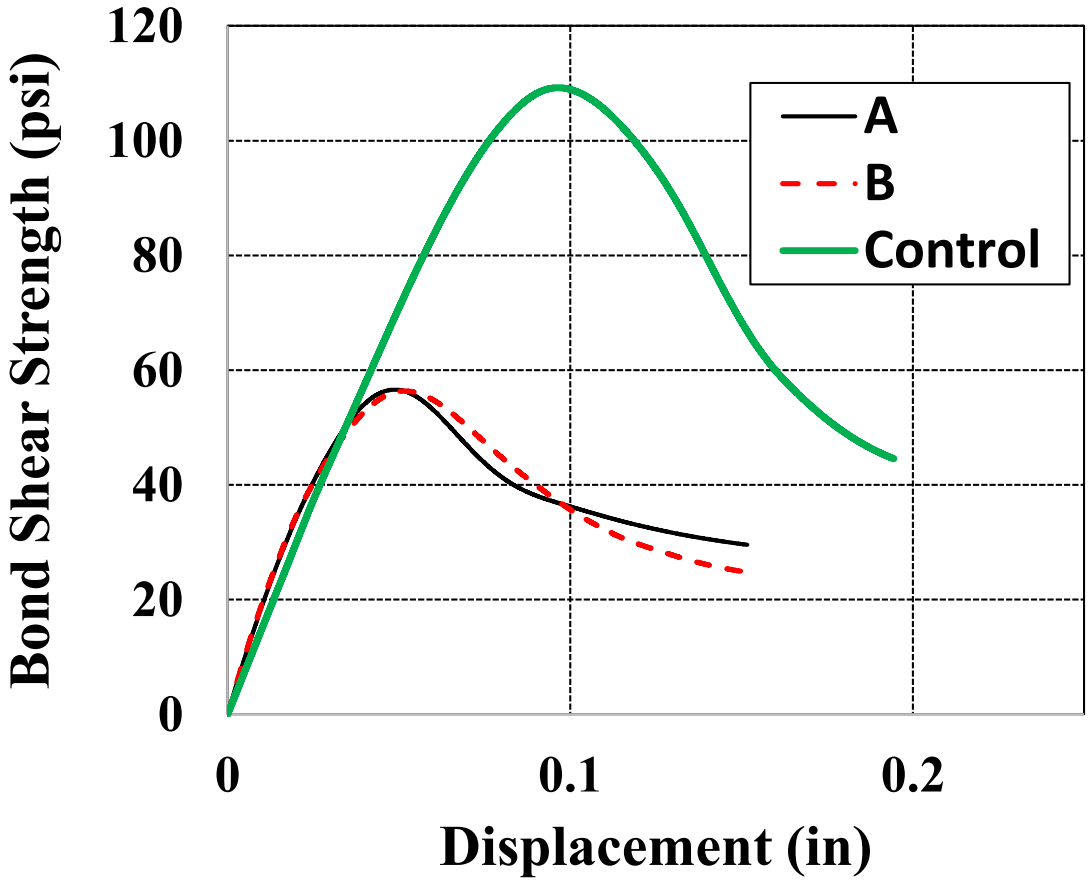
Spray pavers and current method

Spray pavers

Taken from worldhighways.com

Current method

Shear testing – Impact of rain on bond strength



OUTLINE

- INTRODUCTION
- LITERATURE REVIEW
- PAPER 1: INTERLAYER SHEAR STRENGTH
- PAPER 2: TACK COAT TRACKING
- **SUMMARY**

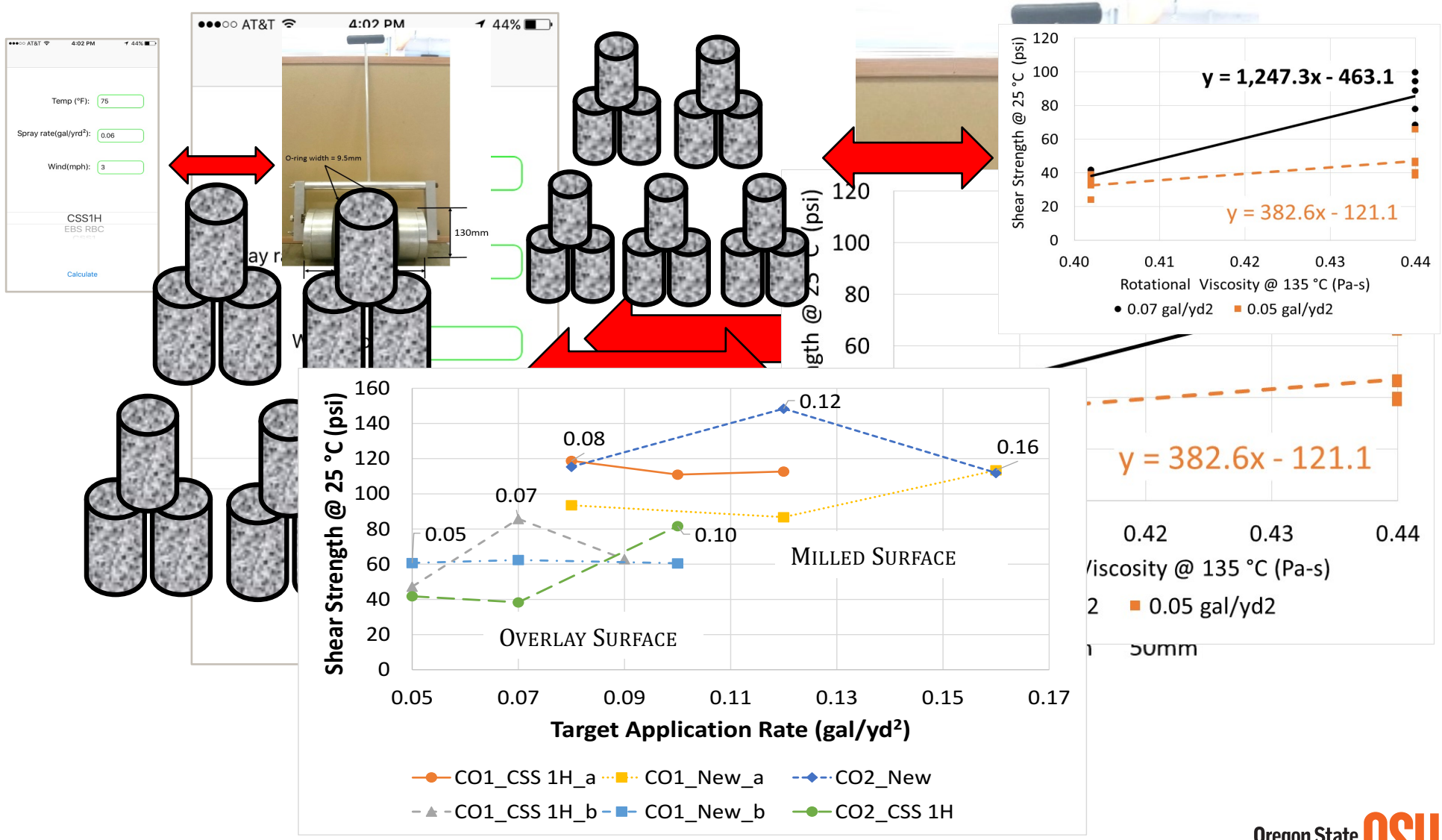
SUMMARY (1/2):

...for the state of Oregon are expected to impr
construction practices, reduce tracking, and impr
bond strength between pavement layers.

CONTRIBUTIONS

- Prediction equations for ISS
- Recommended spraying rates
- Effects of surface texture and time
- Curing times for Oregon tack coats
- Spraying rate QC/QA, different truck usage


SUMMARY (2/2):
FUTURE WORK



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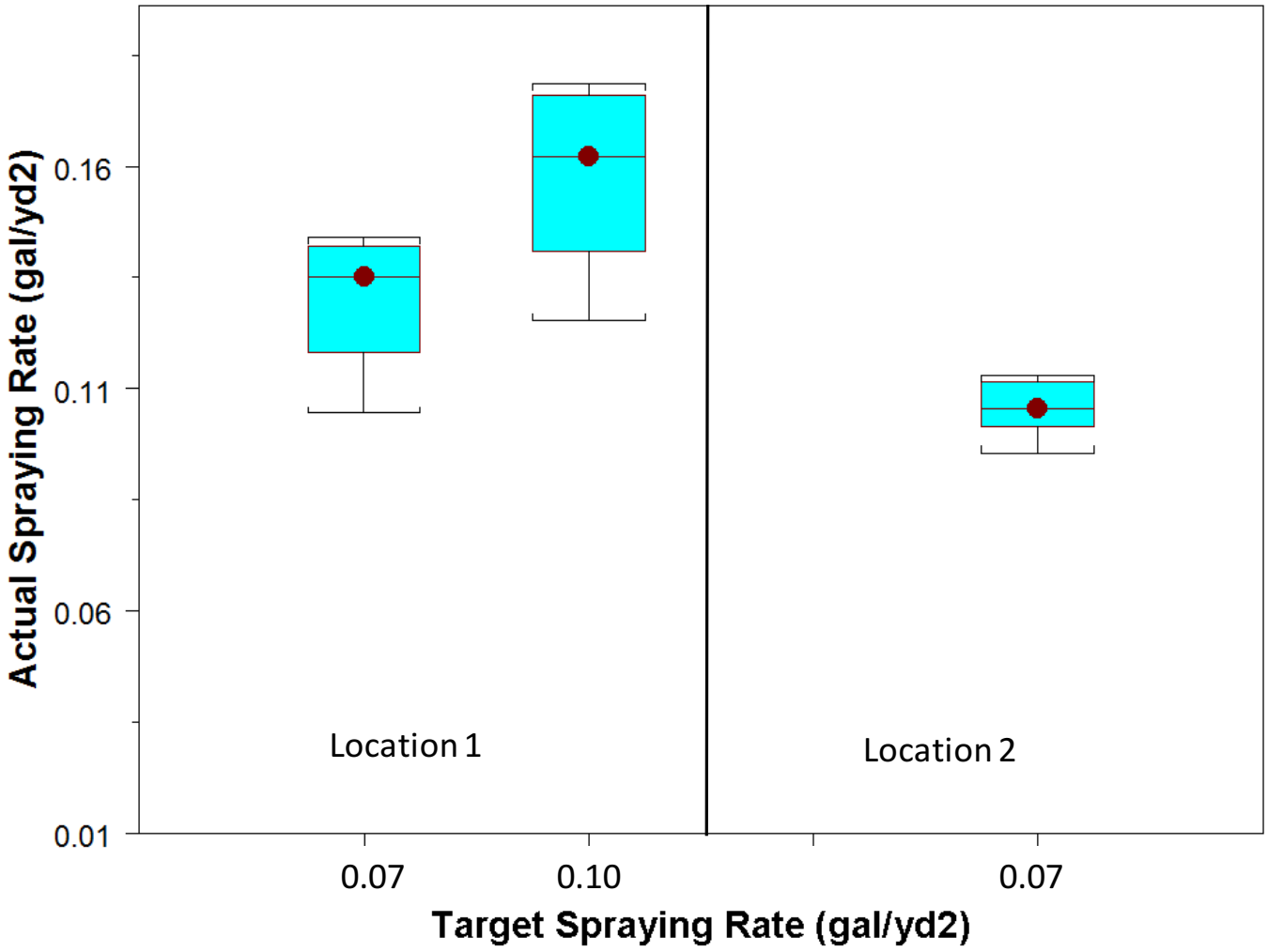
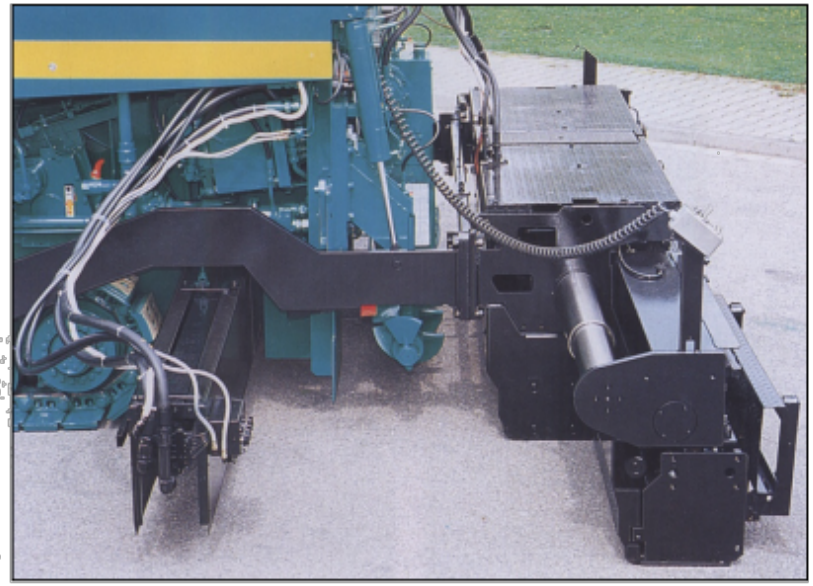
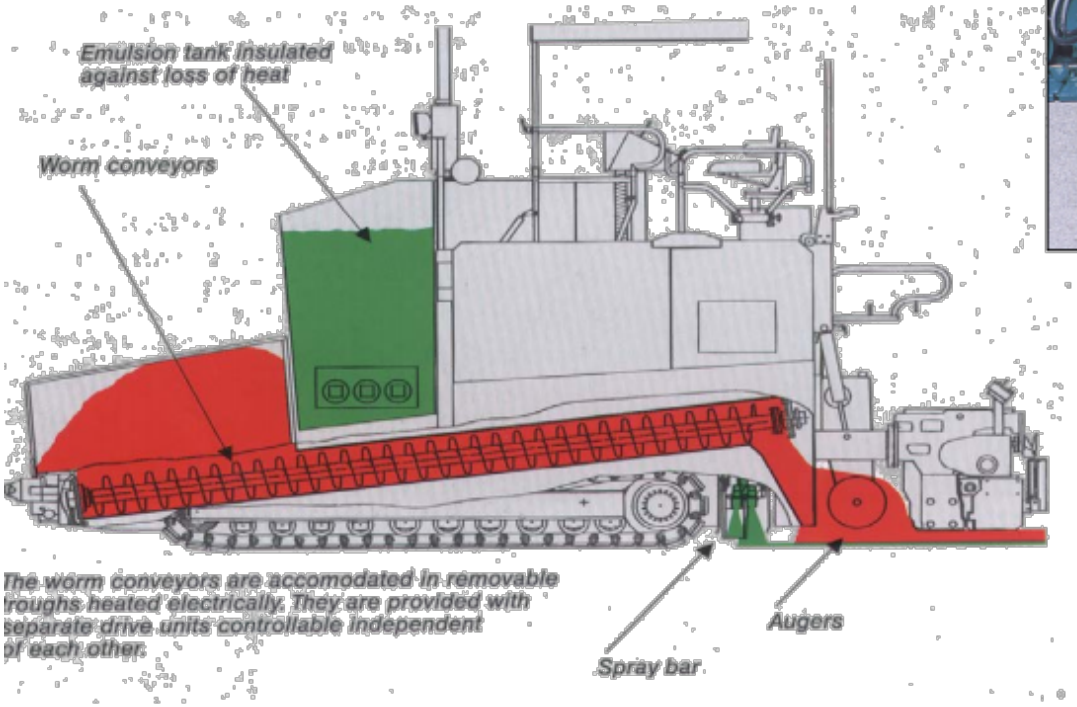


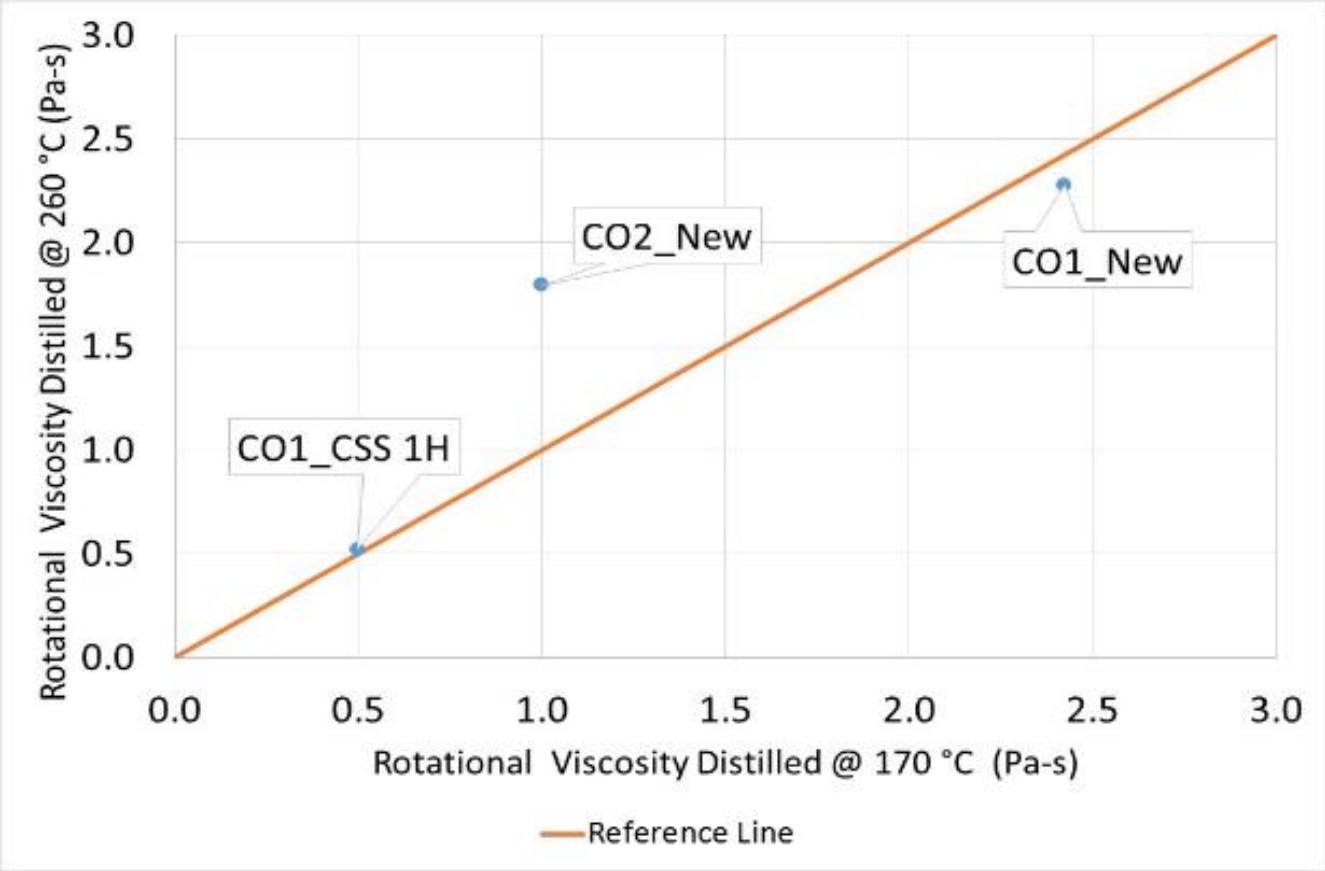
GRADUATE LEARNING OUTCOMES

1. **CONDUCT ORIGINAL RESEARCH** OR PRODUCE SOME OTHER FORM OF CREATIVE WORK
2. **DEMONSTRATE MASTERY** OF SUBJECT MATERIAL
3. CONDUCT SCHOLARLY OR PROFESSIONAL **ACTIVITIES IN AN ETHICAL MANNER**
4. DEMONSTRATE **EFFECTIVE COMMUNICATION SKILLS**
5. PARTICIPATE IN **PROFESSIONAL DEVELOPMENT**




Emulsion tank insulated against loss of heat
Worm conveyors
The worm conveyors are accomodated in removable troughs heated electrically. They are provided with separate drive units controllable independent of each other.
Spray bar
Augers

MATERIALS & METHODS (4/5):
FIELD AND LAB EXPERIMENTS



Tack Coat Type	Percent Water (%)
CO1_CSS 1H_a	51
CO1_New_a	73
CO2_New	62
CO1_CSS 1H_b	47
CO1_New_b	76
CO2_CSS 1H	55

RESULTS & DISCUSSION (X/X):

LINEAR REGRESSION MODEL