

57th Idaho Asphalt Conference

October 26, 2017
University Inn, Moscow, Idaho

the 2017 Presentations

- 1 [AASHTOWare Pavement ME Design Update](#), Dr. Linda Pierce, PE, NCE
- 2 [Every Day Counts](#), Jeffrey A. Zaharewicz, FHWA, Washington, DC
- 3 [Determining the Correct Mixing and Compaction Temperatures for Using High RAP Content in HMA](#), Alejandro Rosales, Idaho Asphalt Supply, Inc., Boise, Idaho
- 4 [The Chip Seal Process and Why we do it that way](#), Stephen Van de Bogert, Western States Asphalt, Inc., Spokane, WA
- 5 [Subgrade Chemical Stabilization](#), Rex Klentzman, PE, URETEK USA and URETEK ICR
- 6 [Use of Visual Distress Survey and Deflection Data for Rehabilitation Decisions in Idaho](#), Dr. Deb Mishra, Assistant Professor, Boise State University, Boise, ID
- 7 [Using Your Paver as it was Intended](#), Todd Mansell, CAT Paving
- 8 [Compaction Theory and Best Practices](#), Dave Johnson, PE The Asphalt Institute, Billings, MT

57th Idaho Asphalt Conference

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Speakers of the 57th Idaho Asphalt Conference, October 26, 2017

From Left: Deb Mishra, Emad Kassem, Fouad Bayomy, Mike Santi, Linda Pierce, Dave Johnson, Stephen Van de Bogert, Jeffrey A. Zaharewicz and Alejandro Rosales

Not Pictured: Rex Klentzman and Todd Mansell

57th Idaho Asphalt Conference – October 25-26, 2017

Participant List

Andy Abrams

Engineering Manager
GPI
6 O'Donnell Road
Pullman, WA 99163
5093392000
aabrams@geoprocorp.com

Mohammad Al Assi

Graduate Student
University of Idaho
alas9935@vandals.uidaho.edu

Hamza Mohammad Alkuime

Graduate Student
University of Idaho
alku4068@vandals.uidaho.edu

John Arambarri

Materials Engineer
Idaho Transportation
Department District 3
3311 W. State Street
Boise, ID 83703
208 332-7176
John.Arambarri@itd.idaho.gov

Don Armstrong

Trans Tech Sr
Idaho Transportation
Department
PO Box 837
Lewiston, ID 83501
2087995090
daniele.ireland@itd.idaho.gov

Brian Arnold

QC Technician
Idaho Materials and
Construction
924 N. Sugar St
Nampa, ID 83687
208-870-1846
barnold@idahomaterials.com

Curtis Arnzen

Engineer Manager
Idaho Transportation
Department
PO Box 837
Lewiston, ID 83501
2087995090
daniele.ireland@itd.idaho.gov

Drew Baden

Project Engineer
JUB Engineers
7825 Meadowlark Way
Coeur d'Alene, ID 83815
2087628787
abaden@jub.com

Mohamed Badran

Research Associate
Udaho
Udaho
Moscow, ID 83843
2085963789
badran@uidaho.edu

Andrew Balavage

Special Inspector
Budinger & Associates, Inc.
1101 N Fancher Rd
Spokane, WA 99212
5095358841
randrews@budingerinc.com

Terri Ballard

Laboratory Manager
Budinger & Associates, Inc.
1101 N Fancher Rd
Spokane, WA 99212
5095358841
randrews@budingerinc.com

Don Barr

Street Superintendent
City of Nampa
106 W. Railroad St
Nampa, ID 83651
208-468-5830
barrd@cityofnampa.us

David Barrett

Design/Construction Engineer
Idaho Transportation
Department District 3
3311 W. State Street
Boise, ID 83703
208 332-7176
David.Barrett@itd.idaho.gov

Fouad Bayomy

Professor
University of Idaho
875 Perimeter Dr MS 1022
Moscow, ID 83844-1022
208-885-6784
bayomy@uidaho.edu

Riley Bender

Staff Engineer
Idaho Transportation
Department
PO Box 837
Lewiston, ID 83501
2087995090
daniele.ireland@itd.idaho.gov

Ed Benson

QC Manager
Interstate Concrete & Asphalt
8849 W. Wyoming Ave
Rathdrum, ID 83835
208-666-6111
ed.benson@oldcastlematerials.com

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Participant List

Tim Bentley

Quality Control Manger
Idaho Materials and
Construction
924 N. Sugar St
Nampa, ID 83687
208-870-1846
timothy.bentley@idahomaterials.com

John Bilderback

Engineer Manager
Idaho Transportation
Department
3311 W. State St.
Boise, ID 83703
(208) 334-8426
john.bilderback@itd.idaho.gov

Andrew Blanchard

Graduate Student
University of Idaho
blan1531@vandals.uidaho.edu

Scott Bontrager

Assistant City Engineer
City of Moscow Engineering
221 E. Second St
Moscow, ID 83843
2088837030
scollins@ci.moscow.id.us

Walter Burnside

Engineer Manager 1
Idaho Transportation
Department
216 South Date Street
Shoshone, ID 83352
208-886-7849
Walter.Burnside@itd.idaho.gov

Bob Buvel

Staff Engineer
City of Moscow Engineering
221 E. Second St
Moscow, ID 83843
2088837034
bbuvel@ci.moscow.id.us

Anthony Caito

Domestic Sales Coordinator
Instrotek
acaito@instrotek.com

Brian Cardon

Street Division Superintendent
City of Idaho Falls
380 Constitution Way
Idaho Falls, ID 83402
2086128490
bcardon@idahofallsidaho.gov

Robinur Mohshin Chowdhury

Graduate Student
University of Idaho
chow4381@vandals.uidaho.edu

Chad Clawson

DME2
Idaho Transportation
Department
PO Box 837
Lewiston, ID 83501
2087995090
daniele.ireland@itd.idaho.gov

Angie Comstock

Project Engineer
JUB Engineers
7825 Meadowlark Way
Coeur d'Alene, ID 83815
2087628787
acomstock@jub.com

Brian Dagon

Construction Manager
Interstate Concrete & Asphalt
8849 W. Wyoming Ave.
Rathdrum, ID 83858
208-765-1144
bdagon@oldcastlematerials.com

Kris Dugger

*Development/Review
Supervisor*
City of Lewiston
PO Box 617
Lewiston, ID 83501
208-746-1316
shood@cityoflewiston.org

George Elliott

Staff Engineer
Idaho Transportation
Department
PO Box 837
Lewiston, ID 83501
2087995090
daniele.ireland@itd.idaho.gov

Chris Faus

Transportation Engineer 1
WSDOT
2714 N. Mayfair Street
Spokane, WA 99207
509-324-6217
FausCI@wsdot.wa.gov

Chris Fredericksen

Public Works Director
City of Idaho Falls
380 Constitution Way
Idaho Falls, ID 83402
2086128256
jkopplow@idahofallsidaho.gov

57th Idaho Asphalt Conference – October 25-26, 2017

Participant List

Josh Giudice

Sales Representative
Western States Asphalt
jgiudice@wsasphalt.com

Drew Harris

Project Manager
Knife River - Northwest
5450 S Gowen Rd
Boise, ID 83709
2083501224
drew.harris@kniferiver.com

Chris Hartman

Project Manager
Knife River - Northwest
5450 S Gowen Rd
Boise, ID 83709
2083501224
chris.hartman@kniferiver.com

Mumtahir Hasnat

Graduate Student
University of Idaho
hasn6815@vandals.uidaho.edu

Wahid Hassan

Graduate Student
University of Idaho
hass0897@vandals.uidaho.edu

Seth Helms

EIT
Idaho Transportation
Department
216 South Date Street
Shoshone, ID 83352
208-886-7816
Seth.Helms@itd.idaho.gov

Kent Henderson

CA Inspector
JUB Engineerins Inc
422 W Riverside #304
Spokane, WA 99201
509-590-5577
kentspokane@gmail.com

Wayne Herbel

Federal-aid Engineer
LHTAC
3330 Grace Street
Boise, ID 83703
2083440565
wherbel@lhtac.org

Joel Heston

TTE
Idaho Transportation
Department
600 W. Prairie
Boise, ID 83703-5879
2087721238
Andrea.Littlefield@itd.idaho.gov
v

Carrie Ann Hewitt

Staff Engineer
Idaho Transportation
Department
600 W. Prairie
Coeur d'alene, ID 83815
2087721238
andrea.littlefield@itd.idaho.gov

Ryan Hillam

Transportation Engineer 2
WSDOT
2714 N. Mayfair Street
Spokane, WA 99207
509-324-6240
HillaRH@wsdot.wa.gov

Clint Hoops

Technical Engineer
Idaho Transportation
Department
3311 W. State St.
Boise, ID 83703
(208) 334-8426
clint.hoops@itd.idaho.gov

Jared Hopkins

Engineer Technical 1
Idaho Transportation
Department
PO Box 837
Lewiston, ID 83501
2087995090
daniele.ireland@itd.idaho.gov

Tracy Hopkins

Managing Member
Specialty Construction Supply
348 NW 13th Place
Meridian, ID 83642
208-322-6800
thopkins@specialtysupply.com

Fred Howe

Transportation Engineer 3
WSDOT
1551 N. Wenatchee Ave
Wenatchee, WA 98801
509-667-3000
Turners@wsdot.wa.gov

Ahmed Ibrahim

Assistant Professor
University of Idaho
875 Perimeter Dr. MS1022
moscow, ID 83844
208 885 1328
aibrahim@uidaho.edu

Terry Jensen

Outside sales
Sage Supply
2810 S. Orchard
Boise, ID 83705
2083367748
tjensen@sagesupplyinc.com

57th Idaho Asphalt Conference – October 25-26, 2017

Participant List

Md Jibon

Graduate Research Assistant
Boise State University
Civil Engineering
Boise, ID 83725-2060
208/426-3710
mdjibon@u.boisestate.edu

D. Kody Johnson

Graduate Research Assistant
Boise State University
Civil Engineering
Boise, ID 83725-2060
208/426-3710
davidjohnson394@u.boisestate.edu

Dave Johnson

Regional Engineer
Asphalt Institute
2501 Montana Ave, Ste. 21
Billings, MT 59101
406-256-2211
djohnson@asphaltinstitute.org

Jason Johnston

Estimator/Project Manager
Interstate Concrete & Asphalt
8849 W Wyoming Rd
Rathdrum, ID 83858
208-666-6104
jason.johnston@oldcastlematerials.com

Justin Joy

Idaho Asphalt Supply
jjoy@idahoasphalt.com

Emad Kassem

Assistant Professor
University of Idaho
875 Perimeter Dr MS 1022
Moscow, ID 83844-1022
208-885-1025
ekassem@uidaho.edu

Mohammad Solaiman Khan

Graduate Student
University of Idaho
khan0241@vandals.uidaho.edu

Dan Kircher

Traffic Control Administrator
Specialty Construction Supply
348 NW 13th Place
Meridian, ID 83642
208-322-6800
dkircher@specialtysupply.com

Rex Klentzman

Director of Engineering
URETEK USA
Tomball, TX

Eric Kokernak

Staff Engineer
Idaho Transportation
Department
PO Box 837
Lewiston, ID 83501
2087995090
daniele.ireland@itd.idaho.gov

Megan Koski

EIT
Idaho Transportation
Department
600 W. Prairie
Boise, ID 83703-5879
2087721238
Andrea.Littlefield@itd.idaho.gov

Simpson Lamichhane

Graduate Student
University of Idaho
lami6023@vandals.uidaho.edu

Kevin Littleton

Materials Lab Engineer
Washington State Department
of Transportation
2714 N Mayfair Street
Spokane, WA 99207
509-324-6170
TeleckA@WSDOT.wa.gov

Yang Lu

Assistant Professor
Boise State University
Civil Engineering
Boise, ID 83725-2060
208/426-3783
yanglufrank@boisestate.edu

Robert Mager

Public Works Foreman
City of Grangeville
225 WEST NORTH ST
Grangeville, ID 83530
2089832851
durquhart@grangeville.us

Stuart Malley

Area Manager
ALLWEST Testing and
Engineering
690 W. Capstone Court
Hayden, ID 83835
2087624721
smalley@allwesttesting.com

Scott Malone

Engineer Manager 2
Idaho Transportation
Department
216 South Date Street
Shoshone, ID 83352
208-886-7804
Scott.Malone@itd.idaho.gov

57th Idaho Asphalt Conference – October 25-26, 2017

Participant List

Todd Mansell

Product Application Specialist
CAT Paving Products, Inc.
Maple Grove, MN

Dewayne Matlock

Assistant State Construction Engineer
Washington State Department of Transportation
310 Maple Park Ave SE
Olympia, WA 98504-2361
360-705-7830
MatlocD@wsdot.wa.gov

Myron McCarty

Streets Dept
City of Heyburn
941 18th St / PO Box 147
Heyburn, ID 83336
2086798158
apclerk@heyburn.id.gov

Jack McCoy

Western States CAT
jackmccoy@wseco.com

Chris McKissen

Testing Manager
ALLWEST Testing and Engineering
690 W. Capstone Court
Hayden, ID 83835
2087624721
cmckissen@allwesttesting.com

Jeff Miles

Administrator
LHTAC
3330 Grace St
Boise, ID 83709
2083440565
jmiles@lhtac.org

Marti Miller

Project Manager - Division of Public Works
Dept of Administration/Division of Public Works
502 N 4th Street
Boise, ID 83720-0072
2083321920
marti.miller@adm.idaho.gov

Debakanta Mishra

Assistant Professor
Boise State University
Civil Engineering
Boise, ID 83725-2060
208/426-3710
debmishra@boisestate.edu

Greg Moses

Transportation Technician 2
WSDOT
2714 N. Mayfair Street
Spokane, WA 99207
509-324-6245
MosesG@wsdot.wa.gov

Ahmed Muftah

Post-Doctoral Fellow
University of Idaho
Muftah@uidaho.edu

Ted Owens

Engineering Technician
City of Moscow Engineering
221 E. Second St
Moscow, ID 83843
2088837034
towens@ci.moscow.id.us

Anson Parke

Streets Department Manager
City of Heyburn
941 18th St / PO Box 147
Heyburn, ID 83336
2086798158
apclerk@heyburn.id.gov

Ned Parrish

Research Program Manager
Idaho Transportation Department
P.O. Box 7129
Boise, ID 83707-1129
208-334-8296
ned.parrish@itd.idaho.gov

John Perfect

Civil Engineer
3460 Greenwich Road
Coeur d Alene, ID 83815
2086644630
jperfect@gmail.com

Jason Perry

Estimator/ Project Manager
Interstate Concrete and Asphalt
8849 W. Wyoming Ave
Rathdrum, IA 83858
2082907018
jason.perry@oldcastlematerials.com

Linda Pierce

PE
Nichols Consulting Engineers
Spokane, WA
lpierce@ncenet.com

Brian Poole

ITD
Idaho Transportation Department
5151 South 5th Avenue
Pocatello, ID 83276
208-239-3303
brian.poole@itd.idaho.gov

57th Idaho Asphalt Conference – October 25-26, 2017

Participant List

Justin Price

Engineer Manager 1
Idaho Transportation
Department
216 South Date Street
Shoshone, ID 83352
208-886-7851
Justin.Price@itd.idaho.gov

Jody Qualley

Transportation Engineer 3
Washington State Department
of Transportation
2714 N Mayfair St
Spokane, WA 99207
509-324-6000
jamescl@wsdot.wa.gov

Md Rabbi

Graduate Research Assistant
Boise State University
Civil Engineering
Boise, ID 83725-2060
208/426-3710
mdfazerabbi@u.boisestate.edu

Kevin Ramirez

Graduate Student
University of Idaho
rami5165@vandals.uidaho.edu

Marvin Ramirez

Staff Engineer
Idaho Transportation
Department
PO Box 837
Lewiston, ID 83501
2087995090
daniele.ireland@itd.idaho.gov

Dave Richards

Technical Engineer
Idaho Transportation
Department
3311 W. State St.
Boise, ID 83703
(208) 334-8426
dave.richards@itd.idaho.gov

Greg Roberts

ITD
Idaho Transportation
Department
5151 South 5th Avenue
Pocatello, ID 83276
208-239-3303
greg.roberts@itd.idaho.gov

Alejandro Rosales

Research/Field Engineer
Idaho Asphalt Supply
Nampa, ID

Styles Salek

Design/Construction Engineer
Idaho Transportation
Department District 3
3311 W. State Street
Boise, ID 83703
208 332-7176
Styles.Salek@itd.idaho.gov

Mike Santi

Materials Engineer
Idaho Transportation
Department
PO Box 7129
Boise, ID 83707-1129
208-334-8450
mike.santi@itd.idaho.gov

Alan Scharbrough

Supervisor
Payette County Road & Bridge
3894 NW 1st Ave
New Plymouth, ID 83655
208-278-3402
alans@payettecounty.org

Kelly Schild

Representative
URETEK USA
PO box 478
Blackfoot, ID 83221
208-680-2632
kellyschild@gmail.com

Robert Schumacher

Engineer Manager
Idaho Transportation
Department
PO Box 837
Lewiston, ID 83501
2087995090
daniele.ireland@itd.idaho.gov

Ronald Shippy

QC Manager
Interstate Concrete & Asphalt
8849 W. Wyoming Ave
Rathdrum, ID 83835
208-666-6111
ron.shippy@oldcastlematerials.com

Brett Siweck

Construction Manager
Mead & Hunt, Inc.
330 E. Main, Ste B
Pullman, WA 99163
707-284-8673
brett.siweck@meadhunt.com

57th Idaho Asphalt Conference – October 25-26, 2017

Participant List

Josh Smith

Asphalt Operations Manager
Knife River - Northwest
5450 S Gowen Rd
Boise, ID 83709
2083501224
josh.smith@kniferiver.com

Joseph Sprague

Staff Engineer
Idaho Transportation
Department
600 W. Prairie
Boise, ID 83703-5879
2087721238
Andrea.Littlefield@itd.idaho.gov

Scot Stacey

Engineer Manager 1
Idaho Transportation
Department
216 South Date Street
Shoshone, ID 83352
208-544-7901
Scot.Stacey@itd.idaho.gov

Gene Staggs

ITD
Idaho Transportation
Department
5151 South 5th Avenue
Pocatello, ID 83276
208-239-3303
gene.staggs@itd.idaho.gov

Larry Stauffer

Dean, College of Engineering
University of Idaho
875 Perimeter Dr MS 1011
Moscow, ID 83844-1011
208-885-6470
stauffer@uidaho.edu

hannon Stein

Staff Engineer
Idaho Transportation
Department
600 W. Prairie
Boise, ID 83703-5879
2087721238
Andrea.Littlefield@itd.idaho.gov

Bryan Strasser

Project Manager
HDR Engineering
610 west hubbard
Coeur d'Alene, ID 83814
2086519418
bryan.strasser@hdrinc.com

Nate Suhr

Senior Engineering Technician
City of Moscow Engineering
221 E. Second St
Moscow, ID 83843
2088837034
nsuhr@ci.moscow.id.us

Robert Thatcher

Owner
Sage Supply, Inc
729 Commercial Ave
Twin Falls, ID 83301
208-734-0444
robert@sagesupplyinc.com

Fahmid Tousif

Graduate Student
University of Idaho
tous9485@vandals.uidaho.edu

Terry Troutman

TTE
Idaho Transportation
Department
600 W. Prairie
Boise, ID 83703-5879
2087721238
Andrea.Littlefield@itd.idaho.gov

Shawn Turpin

Senior Geotechnical Engineer
ALLWEST testing & Engineering,
Inc.
2705 E Main Street
Lewiston, ID 83501
(208) 743-5710
sturpin@allwesttesting.com

Stephen Van de Bogert

General Manager
Western States Asphalt
Spokane, WA
svandebogert@wsasphalt.com

Cody Vezina

Materials TTP
Idaho Transportation
Department
5151 South 5th Avenue
Pocatello, ID 83276
208-239-3317
cody.vezina@itd.idaho.gov

Troy Vitek

Assistant City Engineer
City of Twin Falls
P.O. Box 1907
Twin Falls, ID 83301
208-735-7248
lwilliamson@tfid.org

57th Idaho Asphalt Conference – October 25-26, 2017
Participant List

Jeffrey Zaharewicz

FHWA Center for Accelerating
Innovation
Washington, DC

Riannon Zender

Project Engineer
JUB Engineers
7825 Meadowlark Way
Coeur d'Alene, ID 83815
2087628787
rzender@jub.com

Muhammad Zubery

Federal Aid Engineer
LHTAC
3330 Grace Street
Boise, ID 83703
2083440565
mzubery@lhtac.org

AASHTOWare Pavement ME Design™ Update

Linda Pierce, NCE

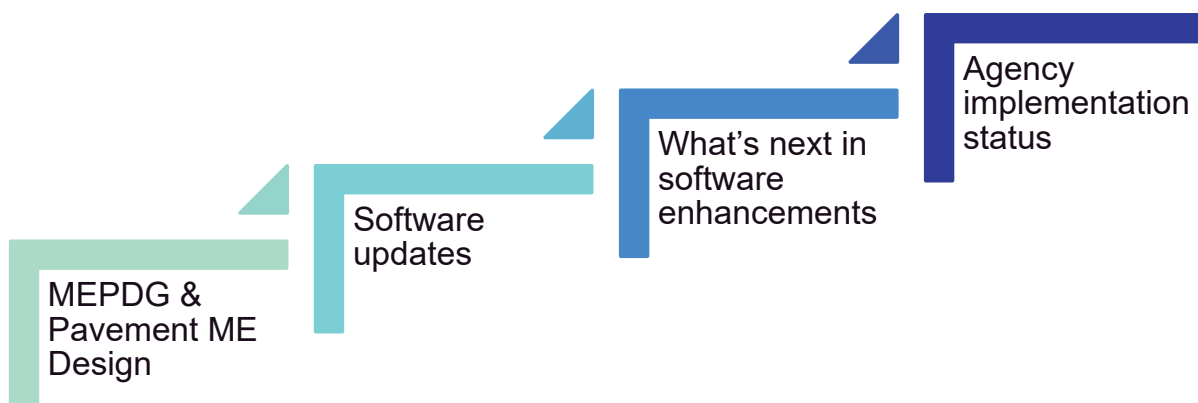
57th Annual Idaho Asphalt Conference

Moscow, ID

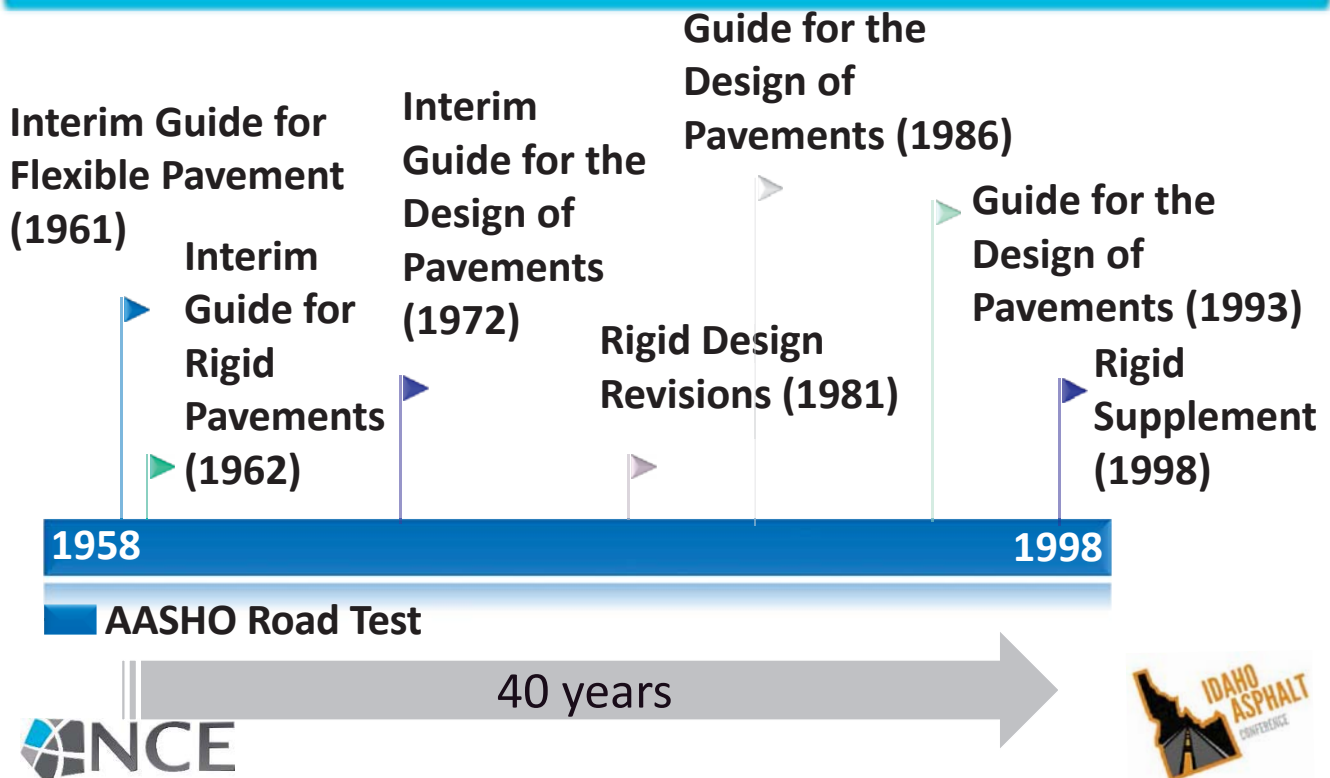
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Discussion Topics



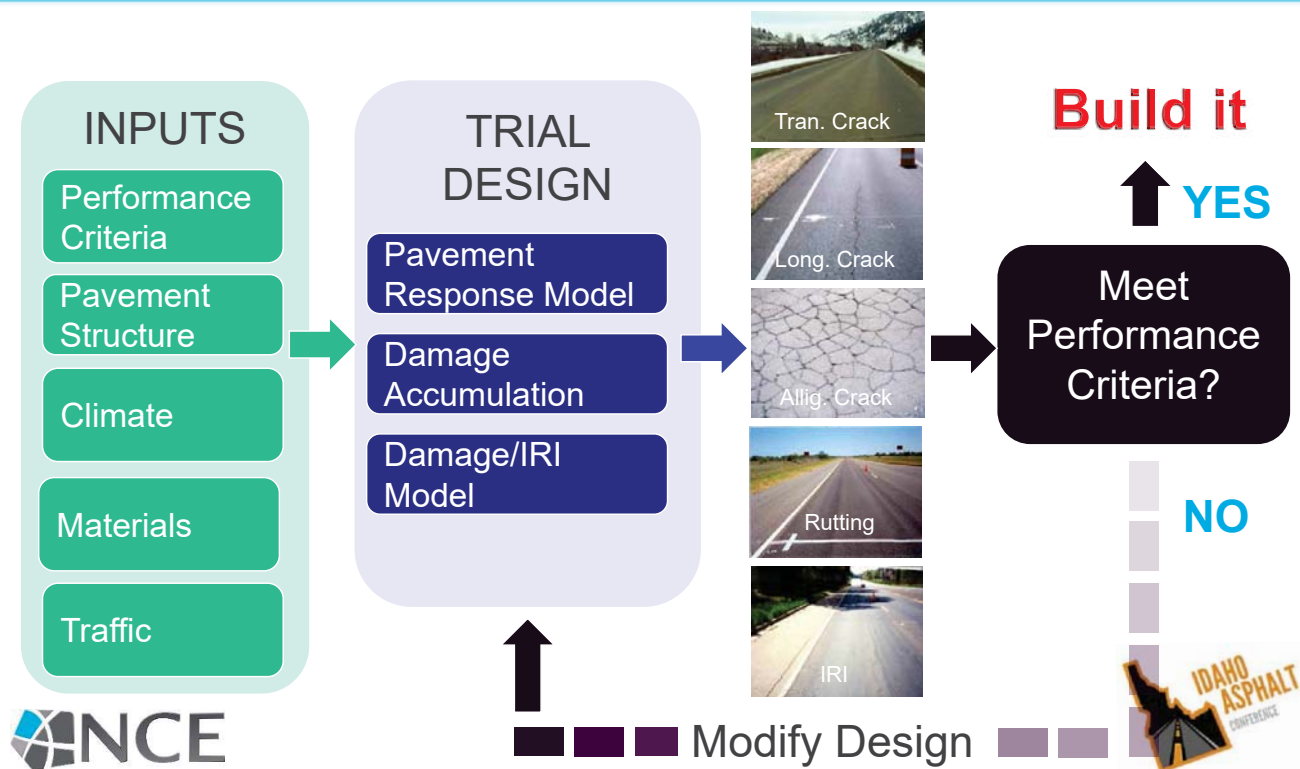
AASHO/AASHTO Pavement Design



NCHRP 1-37A

- 1998-2004
 - Develop guide & software
 - New & rehabilitated pavements
 - Mechanistic-empirical based models
 - Similar inputs
 - Traffic
 - Climate
 - Materials
- Estimate damage & predict performance

Design / Analysis Overview



Pavement Types

- Asphalt
 - New construction
 - Asphalt overlay
 - Concrete overlay
- Semi-Rigid
 - New asphalt over chemically stabilized base
 - Asphalt overlay
- Rigid
 - New jointed plain
 - New continuously reinforced
 - Asphalt overlay
 - Concrete overlay
 - o Bonded
 - o Unbonded
 - o Short jointed

Hierarchical Input Levels

- Level 1
 - Based on measured values
- Level 2
 - Limited test results & correlations
- Level 3
 - Regional averages or expert opinion

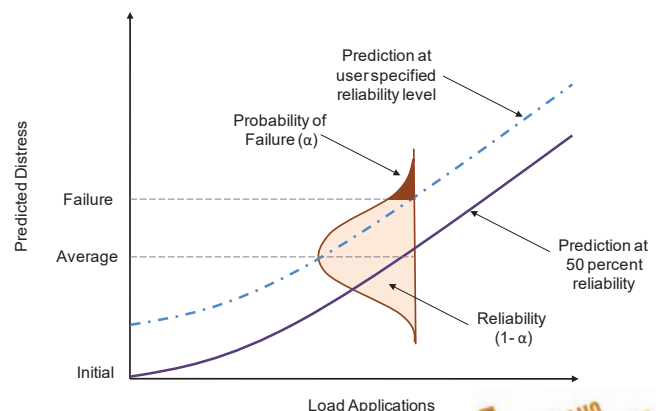
Analysis is the same
regardless of input level



Reliability

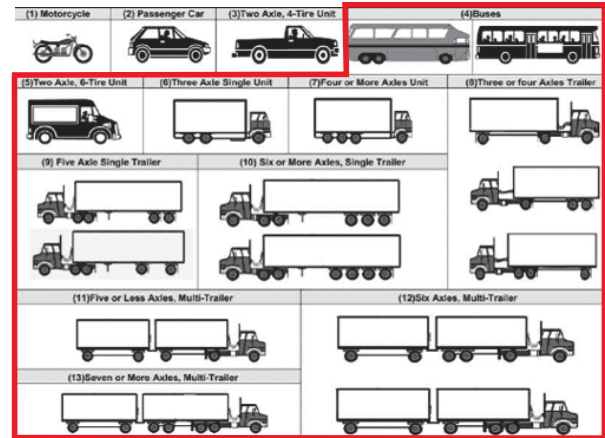
Probability that the predicted distress will be less than the critical distress over the design period

Functional Class	Urban	Rural
Interstate	95	95
Principal Arterial	90	85
Collector	80	75
Local	75	70



Traffic Characterization

- Axle load spectra
 - Class 4+ vehicles
 - Axle configuration
 - Axle weight
- Data collection
 - Weigh-in-Motion
 - Automated Vehicle Classification
 - Vehicle Count



Asphalt Materials

- Layer thickness
- Air voids
- Effective binder content
- Poisson's ratio
- Unit weight
- Binder type
 - PG, viscosity, or penetration grade
- Creep compliance
- Dynamic modulus
- Reference temperature
- Indirect tensile strength
 - Correlated (level 3)
- Heat capacity
- Thermal conductivity



Input Levels 1-3



Concrete Materials

- Thickness
- Poisson's ratio
- Unit weight
- Coefficient of thermal expansion
- Heat capacity
- Thermal conductivity
- Aggregate type
- Cementitious content
- Cement type
- Water/cement ratio
- Curing method
- Reversible shrinkage
- Zero-stress temp.
- Time 50% shrinkage
- Ultimate shrinkage
- **Strength**



Input Levels 1-3



Base Material Types

- Asphalt
- Concrete
- Chemically stabilized
 - Cement
 - Lime cement
 - Lime fly ash
 - Lime stabilized
 - Soil cement
- Sandwiched granular
- Non-stabilized
 - A-1-a to A-3
 - RAP (plant & in-place)
 - Crushed gravel
 - Crushed stone
 - Permeable aggregate
 - River-run gravel



Base Materials

- Thickness
- Poisson's ratio
- Coefficient of lateral earth pressure
- Resilient modulus
- Gradation
- Plasticity Index
- Liquid Limit



Foundation

Type

- Subgrade
 - A-1-a to A-7-6
- Bedrock
 - Highly fractured & weathered
 - Massive continuous

Inputs

- Thickness
- Poisson's ratio
- Coefficient of lateral earth pressure
- Resilient modulus
- Gradation, PI, PL



Climate

- Temperature
 - Asphalt
 - o Fatigue cracking, thermal cracking, & rutting
 - Concrete
 - o Slab cracking & faulting (JPCP) & punchouts (CRCP)
- Freeze/Thaw
 - JPCP performance
- Relative Humidity
 - Moisture gradients JPCP & CRCP
- Seasonal Variation
 - Resilient modulus
- Moisture Content
 - Rutting unbound layers



Performance Prediction

- Predict performance at any point in time
 - Asphalt
 - IRI
 - Rutting
 - Cracking
 - Semi-Rigid
 - IRI
 - Rutting
 - Cracking
 - Plain Jointed Concrete
 - IRI
 - Slab cracking
 - Faulting
 - Continuously Reinforced Concrete
 - IRI
 - Punchouts
- Top down
Fatigue
Thermal
Reflection

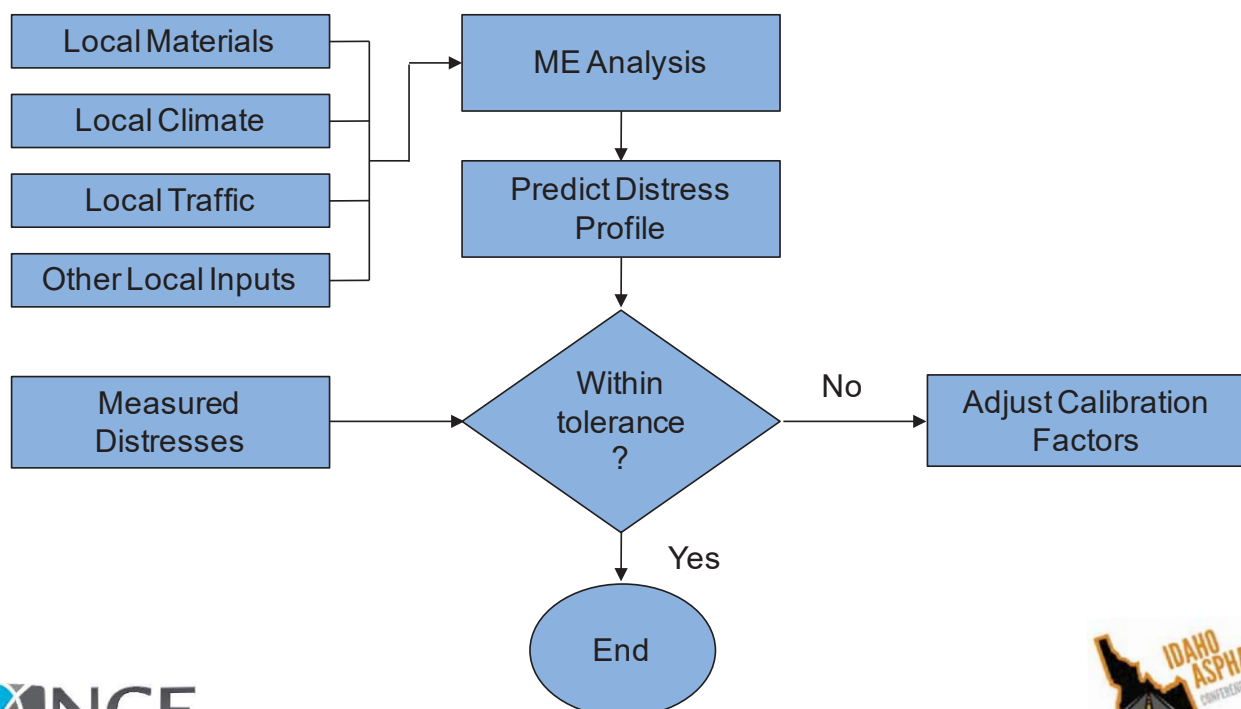


Characterizing Existing

- Pavement condition surveys
- Core samples
 - condition, thickness, material testing
- Soil borings
 - Subgrade modulus, depth to stiff layer
- Other
 - Ground penetrating radar, seismic analysis of surface waves, impact echo

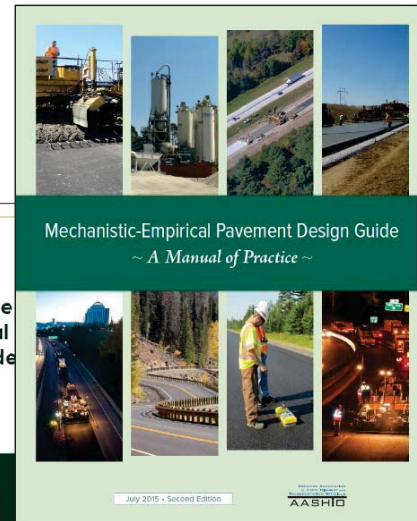


Local Calibration



AASHTO Products

- Manual of Practice
- Calibration Guide
- Software



Software Updates

- 2015 (v2.2)
 - Drainage Requirements in Pavements
 - MapME
 - Level 1, 2, & 3 inputs applicable for PCC & AC overlays of asphalt pavements
 - Reflection cracking model
 - Concrete pavement global re-calibration
 - Plastic deformation for each asphalt layer



Software Updates (continued)

- 2016 (v2.3)
 - Code modernization & review
 - Technical audit
 - Bonded concrete overlay design
 - North American Regional Re-analysis climate database
 - o 1083 locations
 - o 37 years continuous data



Software Updates (continued)

- 2017 (v2.4)
 - Correct unbound layer rutting model
 - Backcalculation tool
 - o Pre-processing
 - o Stiffness value determination
 - o Post processing results
 - Revisions based on technical audit



Software Updates (continued)

- January 2018 (v2.5)
 - *Manual of Practice* integration
 - Tran. crack access to inputs/outputs
 - Access to dynamic modulus calculations
 - **M**odern-**E**ra **R**etrospective **A**nalysis for **R**esearch & **A**pplications data
 - o Continuous hourly estimate of all climate-related data (NASA)
 - Re-calibrate flexible & semi-rigid models



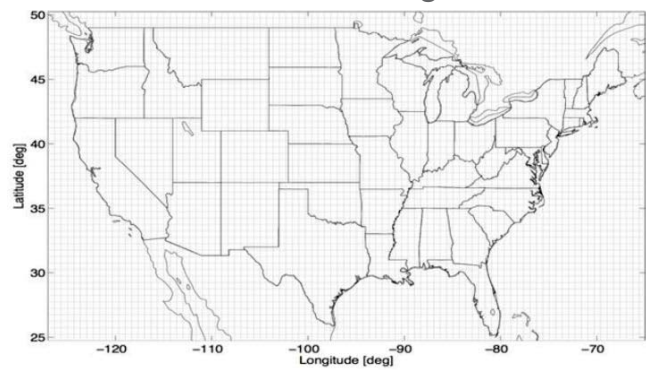
LTPP vs MERRA

PaveME weather database



MERRA grid points

31 mi x 37 mi grid



Software Updates (continued)

- July 2018 (v2.6)
 - Report customization
 - Input comparison filter tool
 - Maintenance strategy tool
 - Level 1 tensile strength
 - o Transverse crack prediction

Asphalt Pavements

Cold milling
Microsurfacing
Thin/ultra thin overlays
Hot in-place recycling

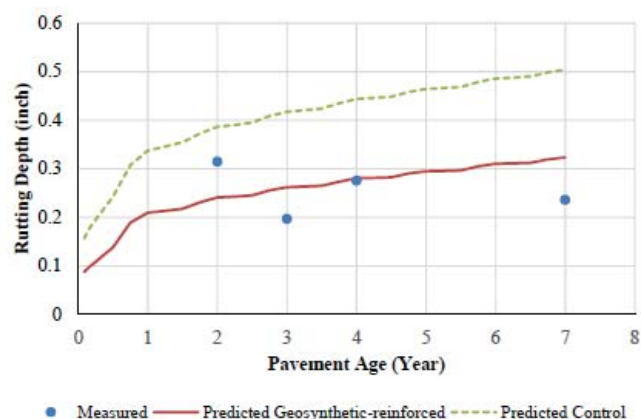
Concrete Pavements

Diamond grinding
Thin/ultra thin overlays



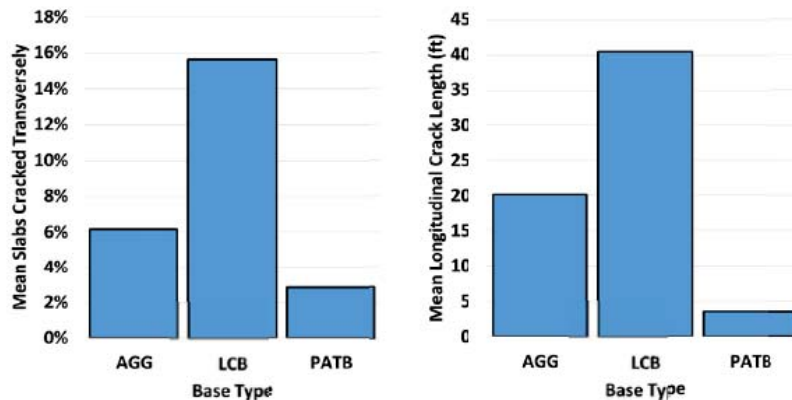
What's Next?

- Influence of Geosynthetics on Pavement Performance (NCHRP 1-50)
 - Unbound base layers
 - Planned for **FY 2019**



What's Next? *(continued)*

- Slab/Underlying Layer Interaction in Concrete Pavements (NCHRP 1-51)



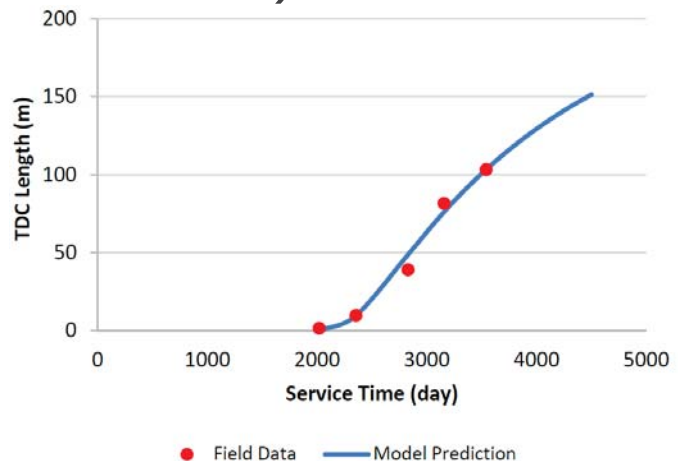
- Planned for **FY 2019**



What's Next? *(continued)*

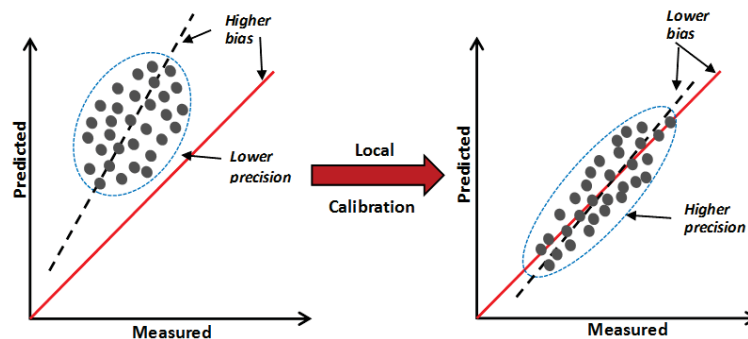
- Top-Down Cracking in Asphalt Pavements (NCHRP 1-52)

- Anticipated completion by end of 2017
- Planned for **FY 2019**



What's Next? *(continued)*

- Automated Local Calibration Tool
 - Significant agency challenge (time & \$)
 - o Section selection and data assembly
 - o Potentially thousands of software iterations
 - Planned for **FY 2019**



What's Next? *(continued)*

- Material Properties of CIP & Full-Depth Reclamation (NCHRP 9-51)
 - Software **Addendum** planned after release of final report

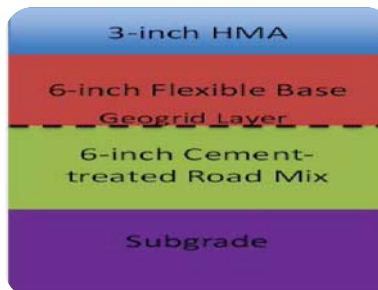


What's Next? *(continued)*

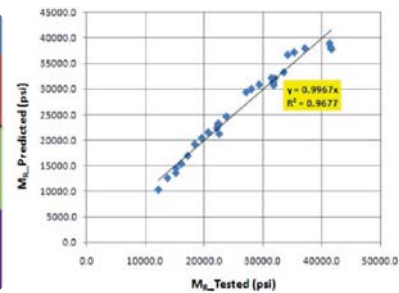
- Influence of Subgrade/Unbound Layers (NCHRP 1-53)
 - Anticipated completion June 2018
 - Planned for **FY 2020**



Testing



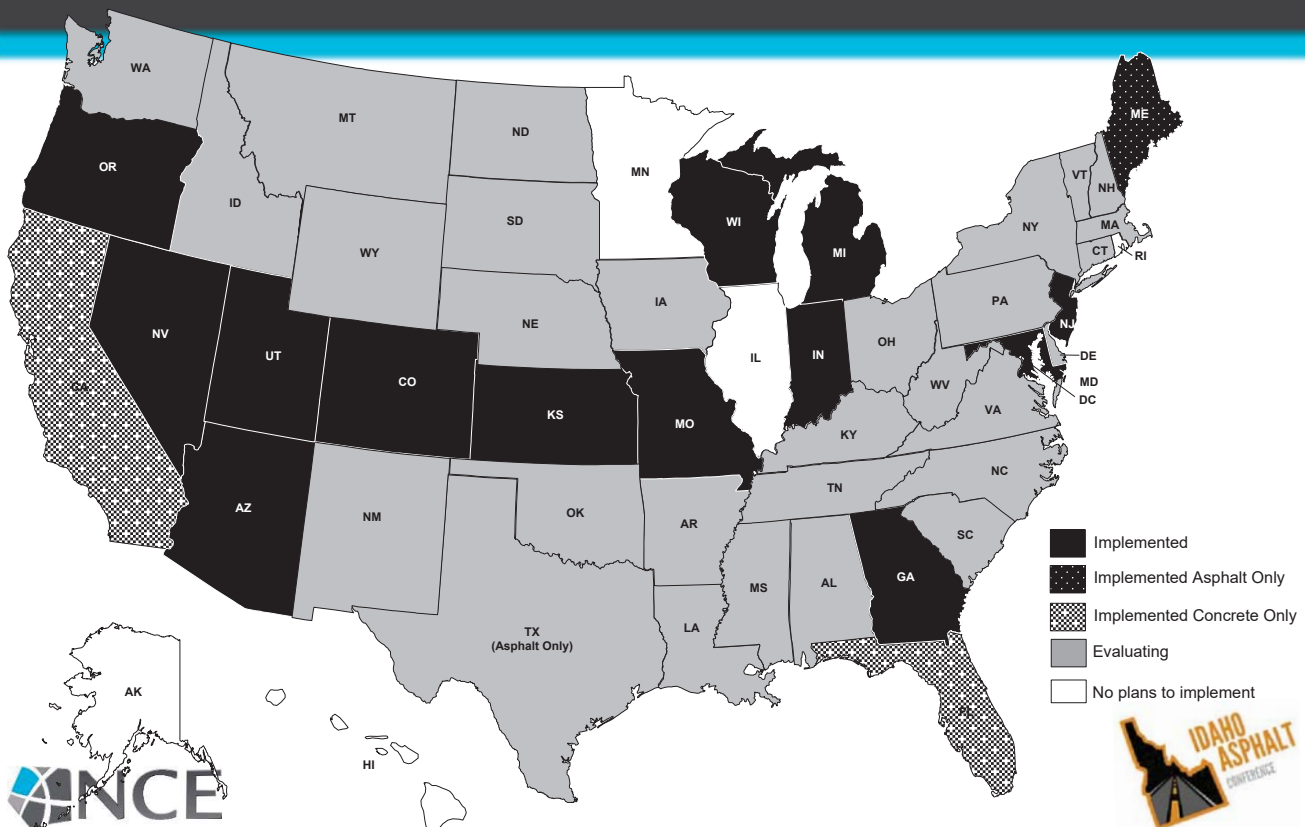
Existing Pavements



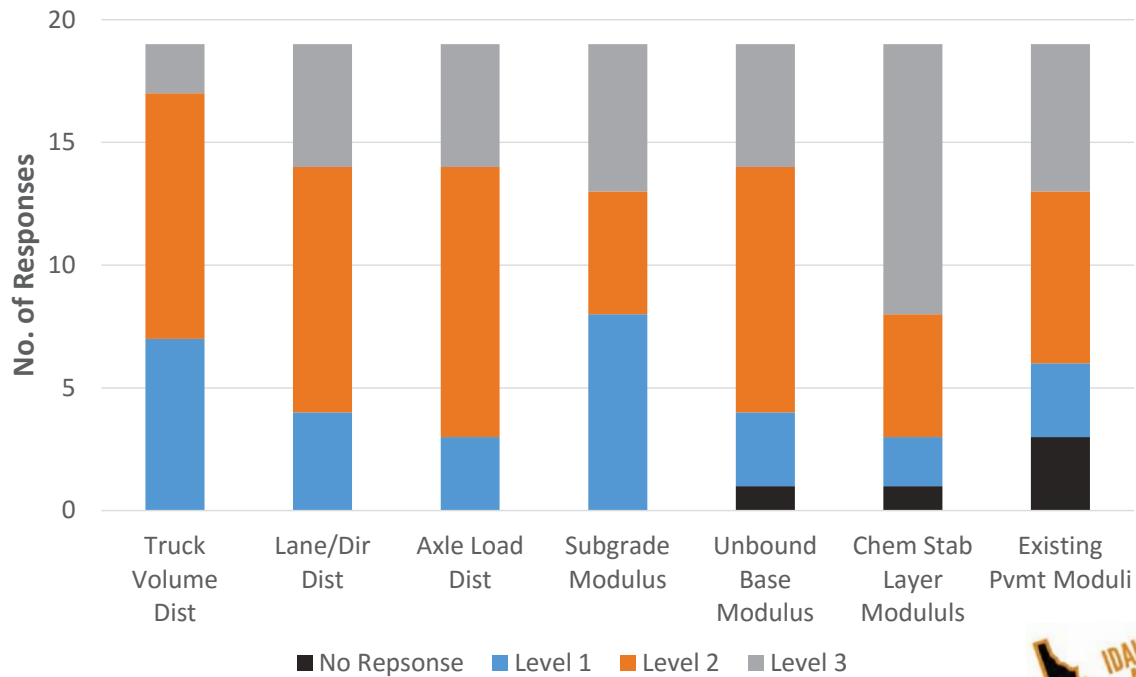
Property



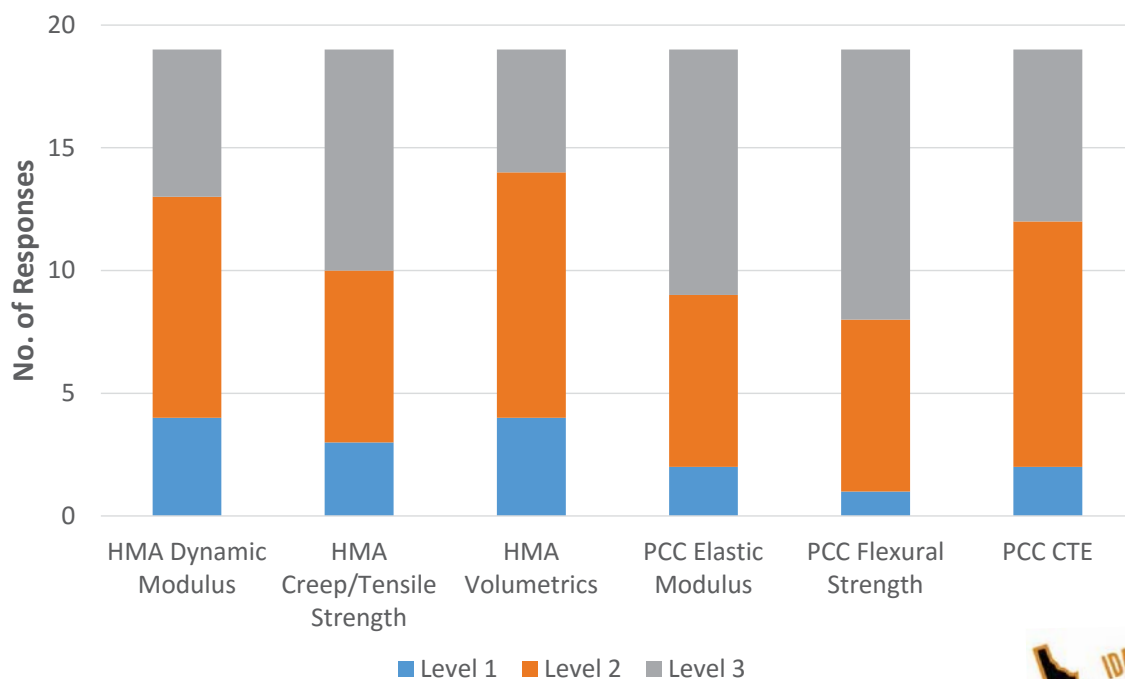
Implementation Status



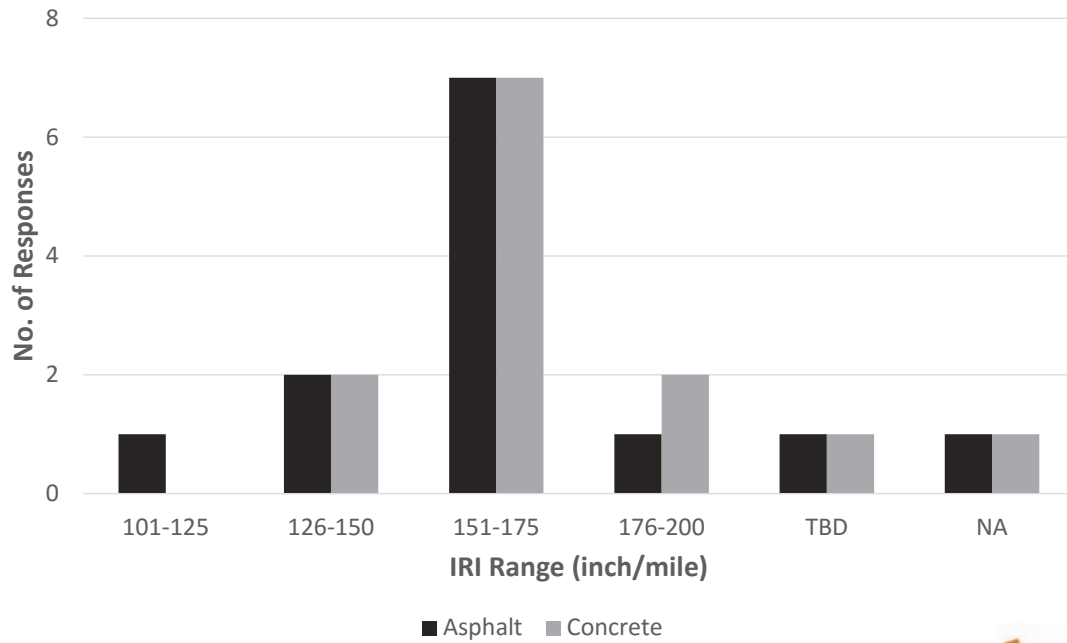
Input Levels



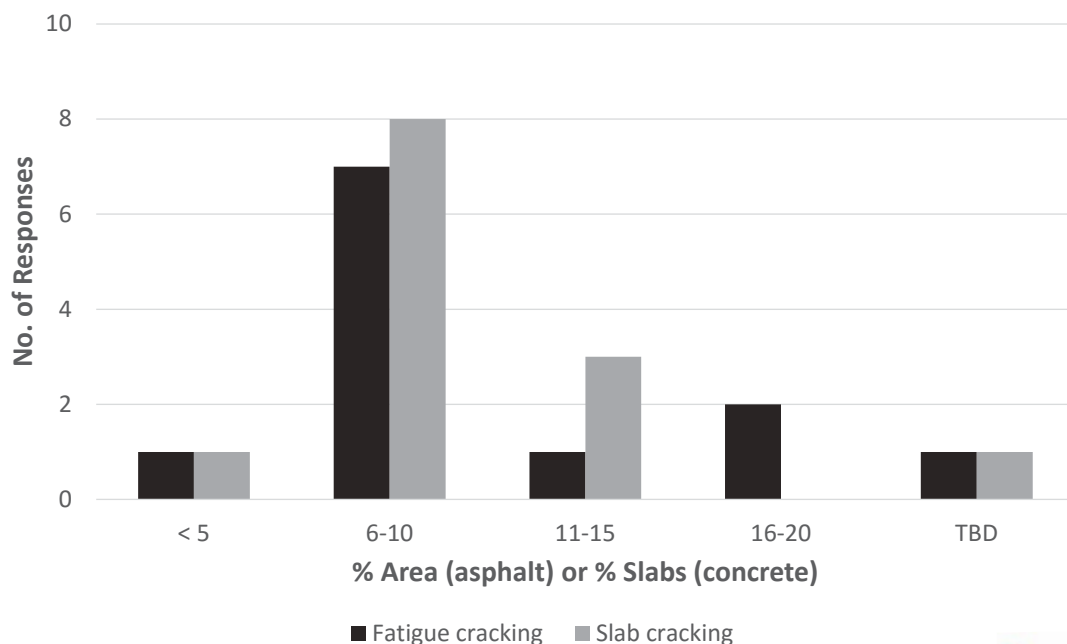
Input Levels (continued)



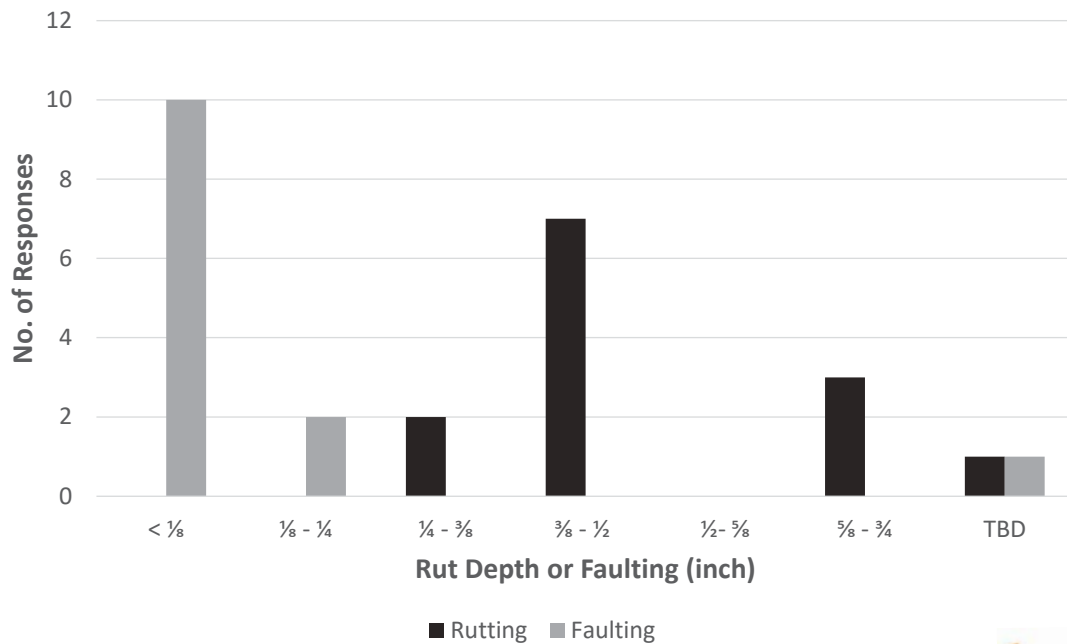
Performance Thresholds



Thresholds (continued)



Thresholds *(continued)*



Implementation Challenges

- Local calibration
- Designing pavements with features not included or have not been calibrated
- Material characterization (all layers)
- Traffic characterization
- Availability of performance data to verify/calibrate prediction models



User Group Meeting

- FHWA Transportation Pooled Fund
 - Conduct meetings
 - o Information sharing
 - o Identify implementation issues
 - o Identify research needs
 - o Organize regional/national implementation efforts



User Group Meeting (continued)

- Annual Meeting Dates
 1. December 14-15, 2016 - Indianapolis
 2. October 11-12, 2017 - Denver
 3. Sep/Oct/Nov 2018 - Nashville

<http://www.pooledfund.org/Details/Study/549>



Questions?



Linda Pierce
Principal
lpierce@ncenet.com
505.603.7993





Idaho Asphalt Conference
Moscow, Idaho
October 26, 2017



FHWA Office of Innovative Program Delivery Mission

Improve transportation performance by driving innovation into action through partnerships, technology development, and capacity building

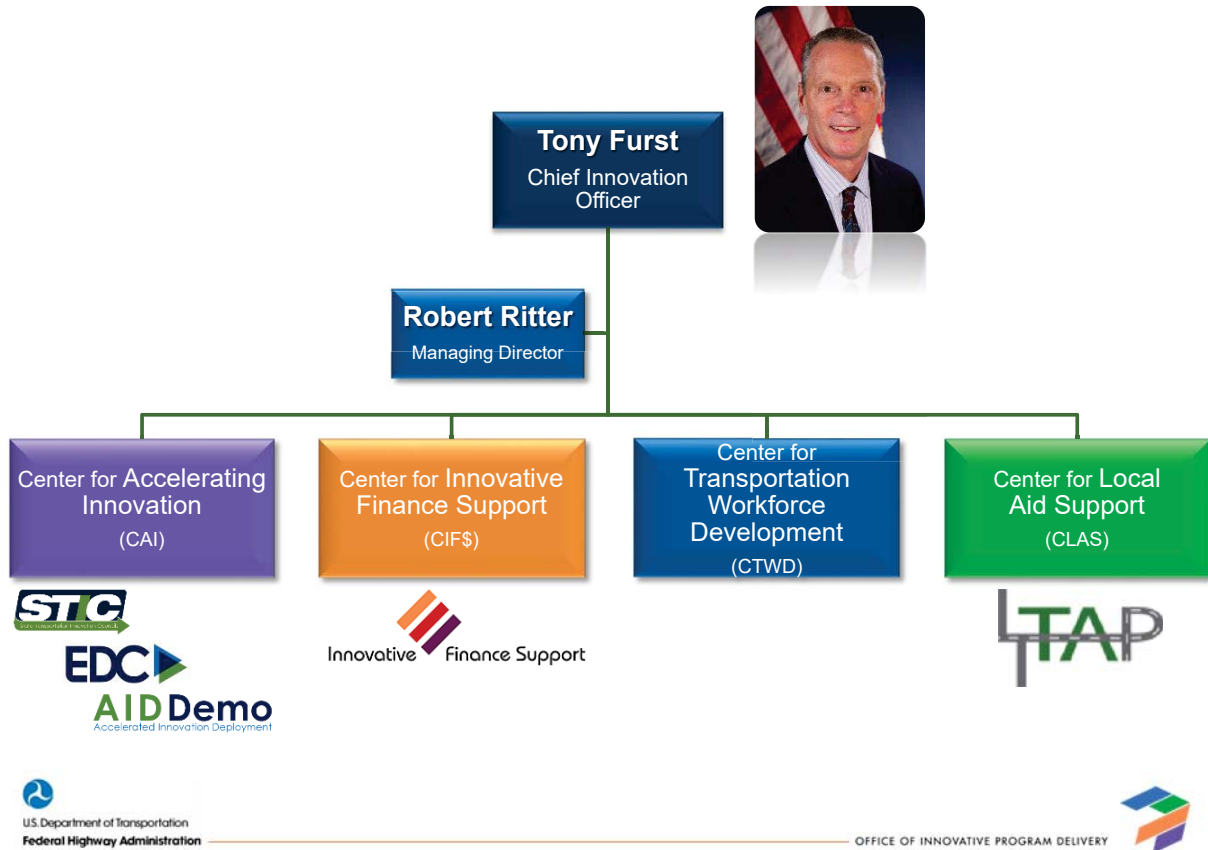
Foster a Culture of Innovation



<https://www.fhwa.dot.gov/innovativeprograms/>



OIPD Centers



CENTER FOR ACCELERATING INNOVATION

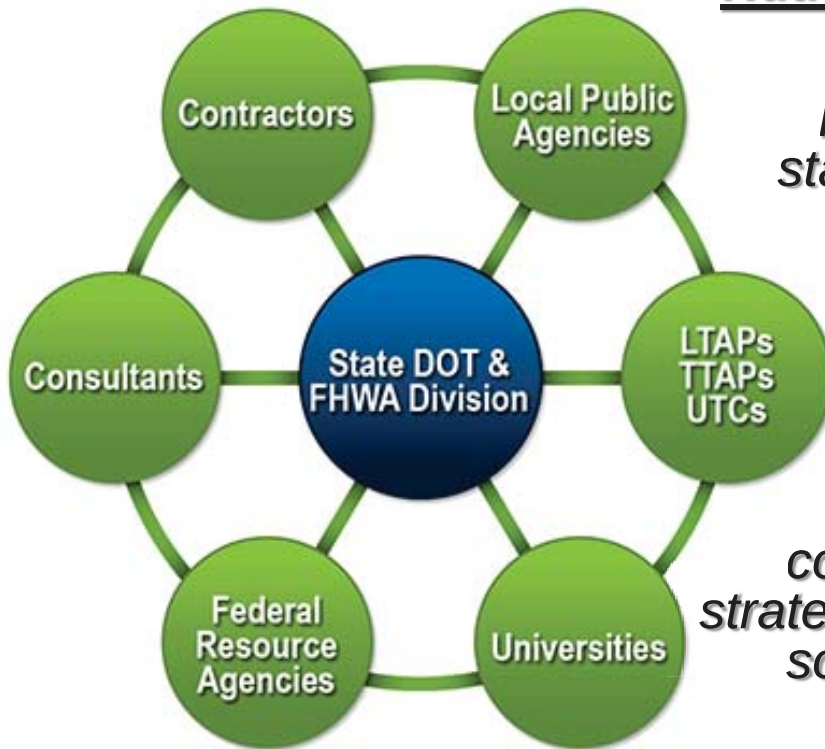
Tom Harman, Director

Accelerates implementation and delivery of new innovations and technologies at the national and local levels

- Facilitates rapid deployment of innovation in the transportation community through the Every Day Counts initiative;
- Fosters & supports the State Transportation Innovation Councils' national network; and
- Supports innovation through the Accelerated Innovation Deployment grant program.



National STIC Network



Represents multiple stakeholders from the transportation community

comprehensively and strategically considers all sources of innovation



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6

3

What is “Every Day Counts”?



Stakeholder-based model to identify and rapidly deploy proven innovations



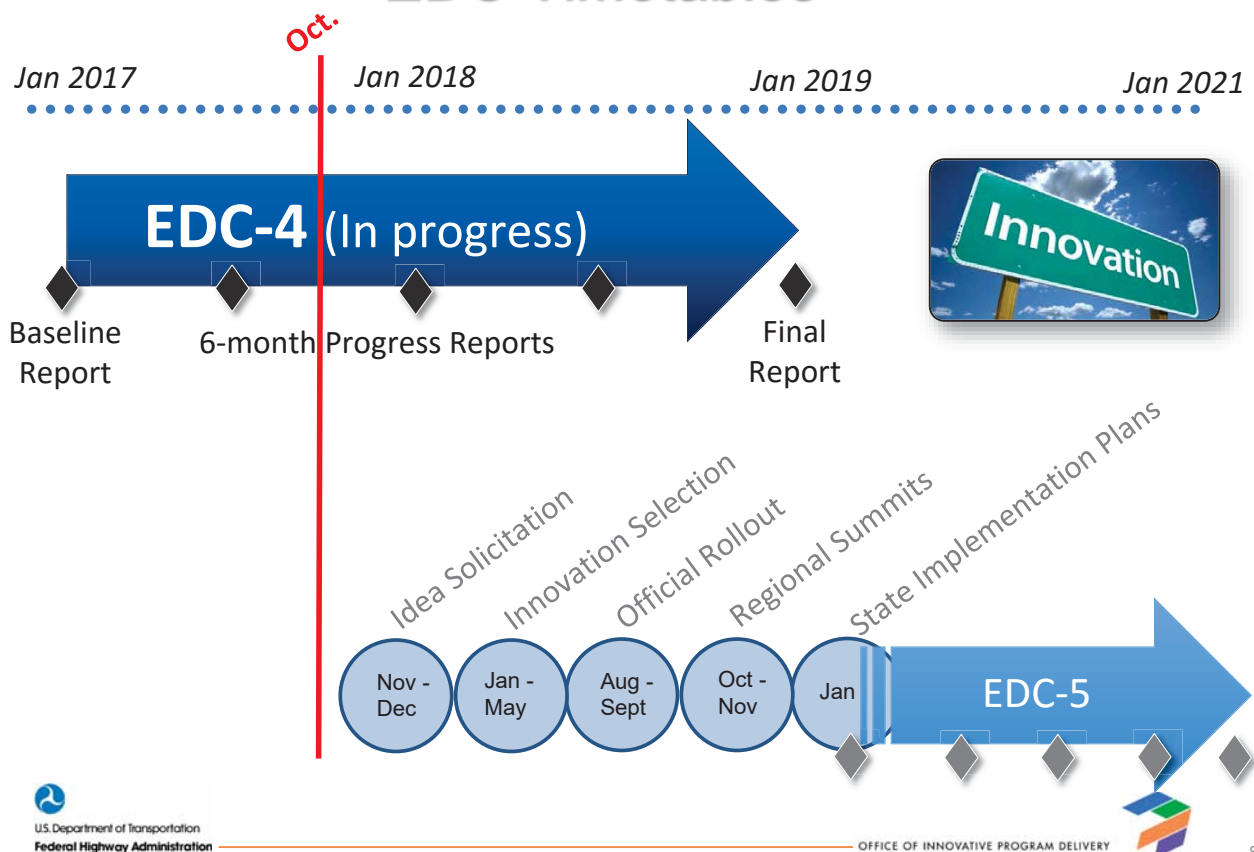
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7

EDC Timetables



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8

How EDC Works: Deployment

Multidisciplinary deployment teams:

- Assist states to finalize implementation plans
- Provide technical assistance and support:
 - Training
 - Webinars and workshops
 - Demonstrations
 - Peer exchanges
 - Case studies
 - Guidance and specifications



How EDC Works: Reporting

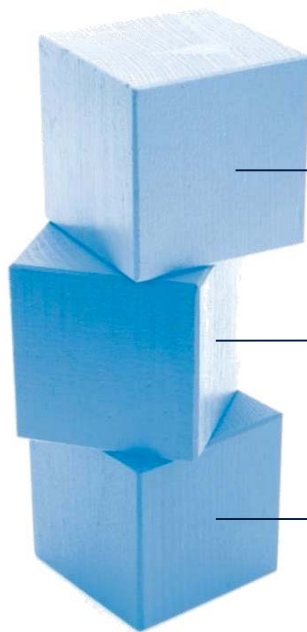
FHWA monitors and reports on state-of-the-practice and successes in accelerating innovations:

- Website
- EDC News (weekly e-newsletter)
- Innovator (bi-monthly e-newsletter)
- EDC Progress reports
- Articles
- Videos

- Institutionalized
- Assessment
- Demonstration
- Development
- Not Implementing



Building on our Achievements



EDC-4 (2017-2018)

- 11 innovations (2 from EDC-3)

EDC-3 (2015-2016)

- 11 innovations (1 from EDC-2)

EDC-2 (2013-2014)

- 13 innovations (3 from EDC-1)

EDC-1 (2011-2012)

- 14 innovations

Accelerating deployment of 43 innovations



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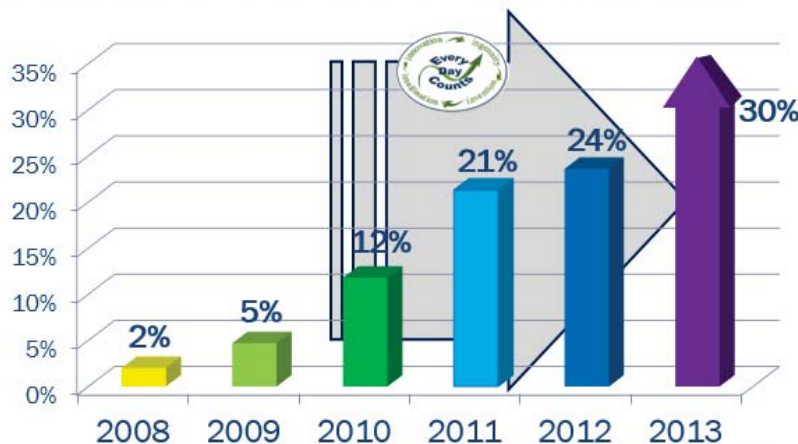


11

Achievements:

WMA Usage

Percentage of Total Asphalt Production in US



Source: National Asphalt Pavement Association



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6

“Mission Accomplished”

47 States and all 3 Federal Lands Highway Divisions have specifications and/or contractual language that allows **Warm Mix Asphalt** on projects



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Every Day Counts

Better, Faster, Smarter

EDC-4
(2017-2018)



EDC Overview Video



ATSPMs



Collaborative
Hydraulics (CHANGE)



Community
Connections



Data-Driven Safety
Analysis



e-Construction and
Partnering



Integrating NEPA and
Permitting



Pavement
Preservation (When,
Where, How)



Road Weather
Management –
Weather-Savvy Roads



Safe Transportation for
Every Pedestrian



Ultra-High
Performance Concrete
Connections



Using Data to Improve
Traffic Incident
Management

Every Day Counts

An Innovation Partnership with States

EDC Rounds

EDC-4 (2017 - 2018)

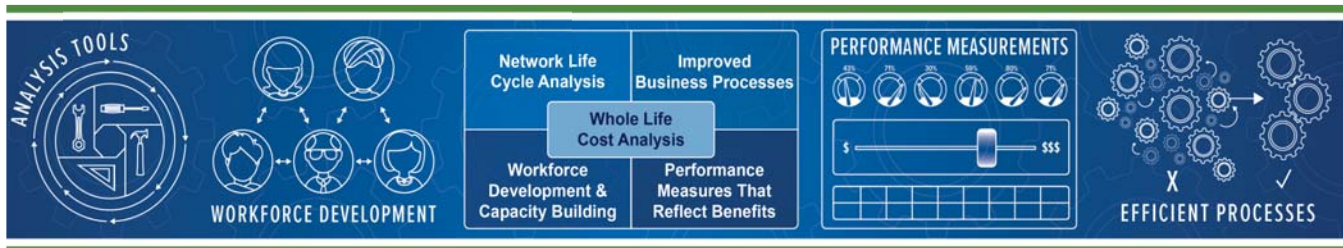
EDC-3 (2015 - 2016)

EDC-2 (2013 - 2014)

EDC-1 (2011 - 2012)

[Find an Innovation »](#)

Pavement Preservation: When and Where



Benefits to Using a Whole-Life Approach to Pavement Preservation Project and Treatment Selection



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Pavement Preservation: When and Where

Vision

- Focus the use of preservation to **promote** effective strategies that **reduce** the annual cost of managing the pavement network at acceptable performance levels.

Mission

- Provide **guidance** and **implementation tools** that
 - ✓ **Assist** agencies in selecting cost-effective pavement preservation projects that **sustain** pavement performance programs
 - ✓ **Demonstrate** the cost savings and other benefits that can be realized through effective pavement preservation programs
 - ✓ **Facilitate** accelerated national deployment of proven practices that support inclusion of pavement preservation as an asset management strategy.



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Why is this important?

- Performance-based investment decisions
- Development of a 10-year Transportation Asset Management Plan
 - Includes consideration of life cycle planning & risk
 - Sets minimum standards for the use of pavement management systems
 - Links investments to performance targets



Challenges

- Shifting from a worst-first strategy when funding is tight
 - Agencies tend to fight fires
- Availability of qualified contractors, strong construction practices, & good candidates for preservation treatments
- Quantifying the benefits to pavement preservation
 - Lack of adequate distress information
 - Inconsistency in terminology
 - Inconsistencies in treatment use



Challenges

- Aligning District/Region project selection with agency performance targets
 - Inconsistencies across the state
 - Project selection may or may not lead to statewide goals
- Allocating funding based on need (i.e., conditions)
 - Districts or Regions using preservation are penalized



State Practices Illustrate Benefits

A whole life approach reduces the annual cost of preservation, which allows agencies to redirect available funding to other agency priorities

Increased investments in



Pavement Preservation Treatments

- Crack sealing
- Chip seals
- Microsurfacing



Bridge Preservation Treatments

- Sealing of bridge decks
- Cleaning bridges



Culvert Preservation Treatments

- Debris removal
- Erosion protection

Graphic: Ohio DOT

Allowed the Ohio DOT to redirect

\$300M over

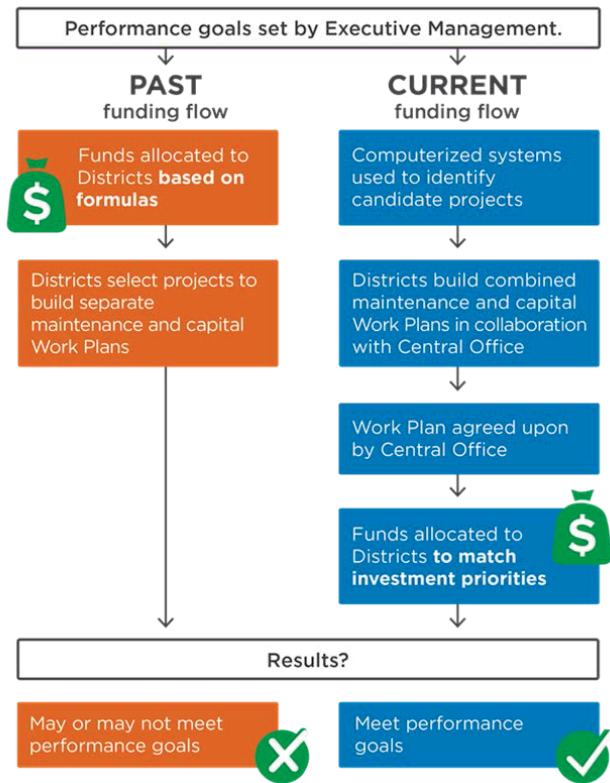


6 years to other pavement, bridge, & culvert priorities



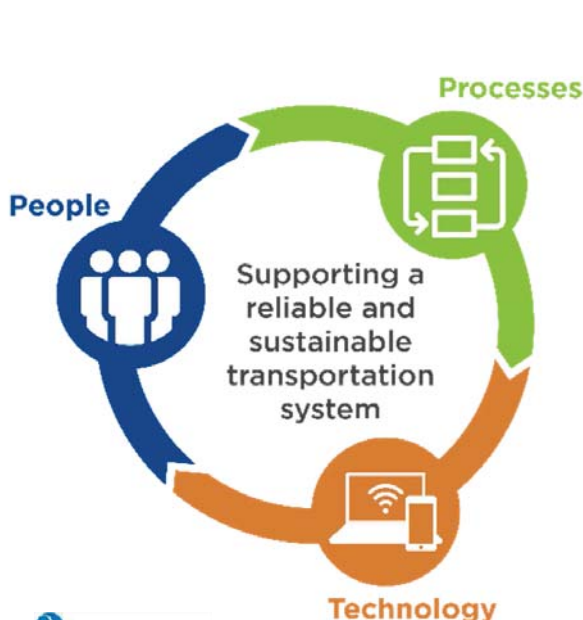
Additional Benefits

The development of a network-level preservation strategy helps ensure agencies will meet performance targets



Additional Benefits

- Building workforce competencies helps ensure the success of the new way of doing business



Source: Ohio DOT

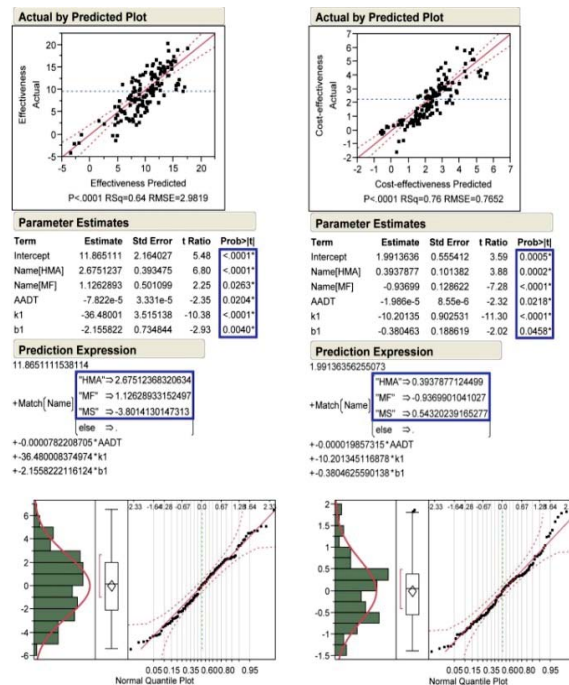


The Knowledge Management Plan is designed to ensure that:

- Employees are prepared to identify when actions are needed
- Share what they've learned with others.

When and Where Program: Resources

- Selection Guide
- Analysis Tool
- Peer-to-Peer Exchanges
- Communications Plan
- Asset Management Strategy Guidance
- Cost Effectiveness Metrics



Every Day Counts

An Innovation Partnership with States

EDC Rounds

- EDC-4 (2017 - 2018)
- EDC-3 (2015 - 2016)
- EDC-2 (2013 - 2014)
- EDC-1 (2011 - 2012)

[Find an Innovation »](#)

Pavement Preservation – How



Source: Applied Pavement Technologies, 2016



Source: VSS Macropaver, 2016



Source: FHWA, 2013



Source: American Concrete Pavement Association, 2016

Pavement Preservation: How Quality Construction and Materials

Flexible Pavements

- Micro surfacing
- Chip Seal
- Slurry Seal/Scrub Seal
- Ultrathin bonded wearing course



Rigid Pavements

- Diamond grinding
- Partial-depth repair
- Full-depth repair
- Dowel bar retrofit/cross stitching



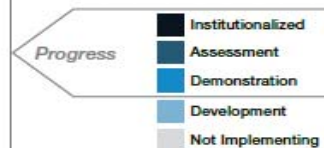
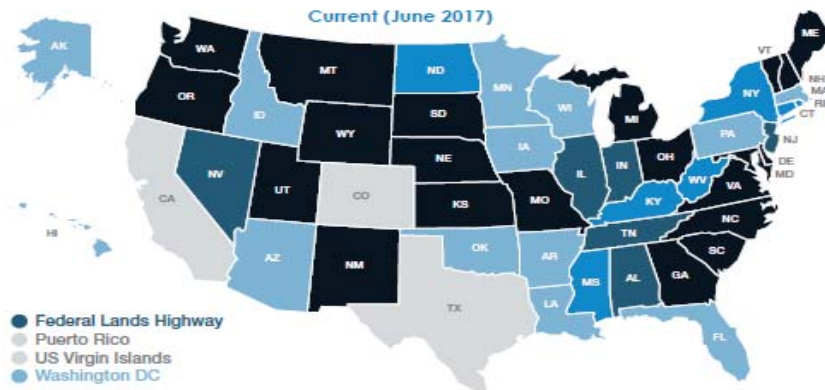
“How” Program Resources

- Peer-to-Peer Exchanges
 - ✓ Share experiences and collect specifications
- Update Pavement Preservation Checklists
- Develop and Deliver Web-based Training
 - ✓ Flexible and Rigid Pavements
- Develop Best Practice Technology Briefs
- Videos Highlighting Best Practices



Pavement Preservation: When and Where

Thirteen States and Washington, DC, are developing implementation plans and learning more about when and where to apply pavement preservation treatments. Fourteen States and FLH are demonstrating and assessing the when and where component of pavement preservation. Another 21 States have made it a standard practice to manage pavements proactively to preserve highway investments.



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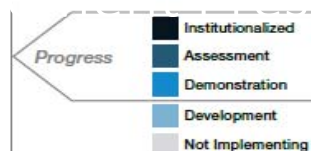
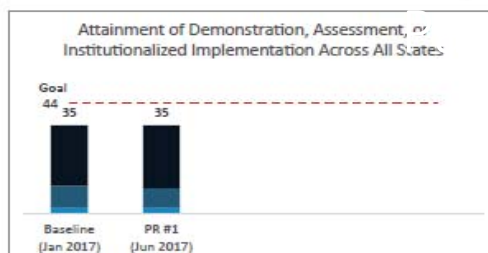
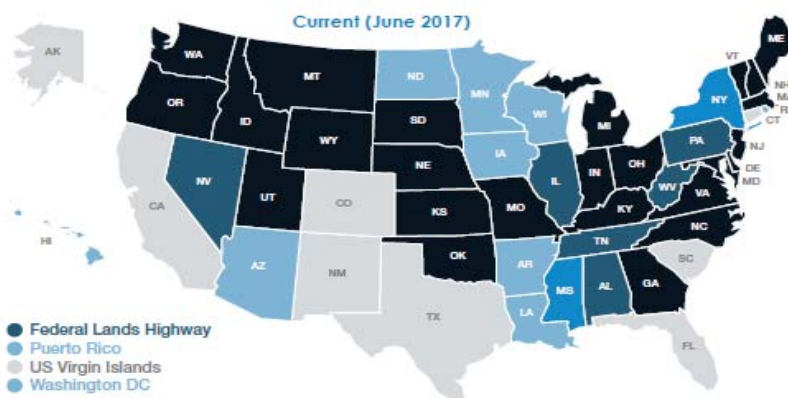
Innovation Spotlight



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Pavement Preservation: How

Nine States, Puerto Rico, and Washington, DC, are developing implementation plans and learning more about how to apply pavement preservation treatments. Nine States and FLH are demonstrating and assessing the how component of pavement preservation. Another 25 States have institutionalized the use of quality construction and materials practices to preserve pavements.



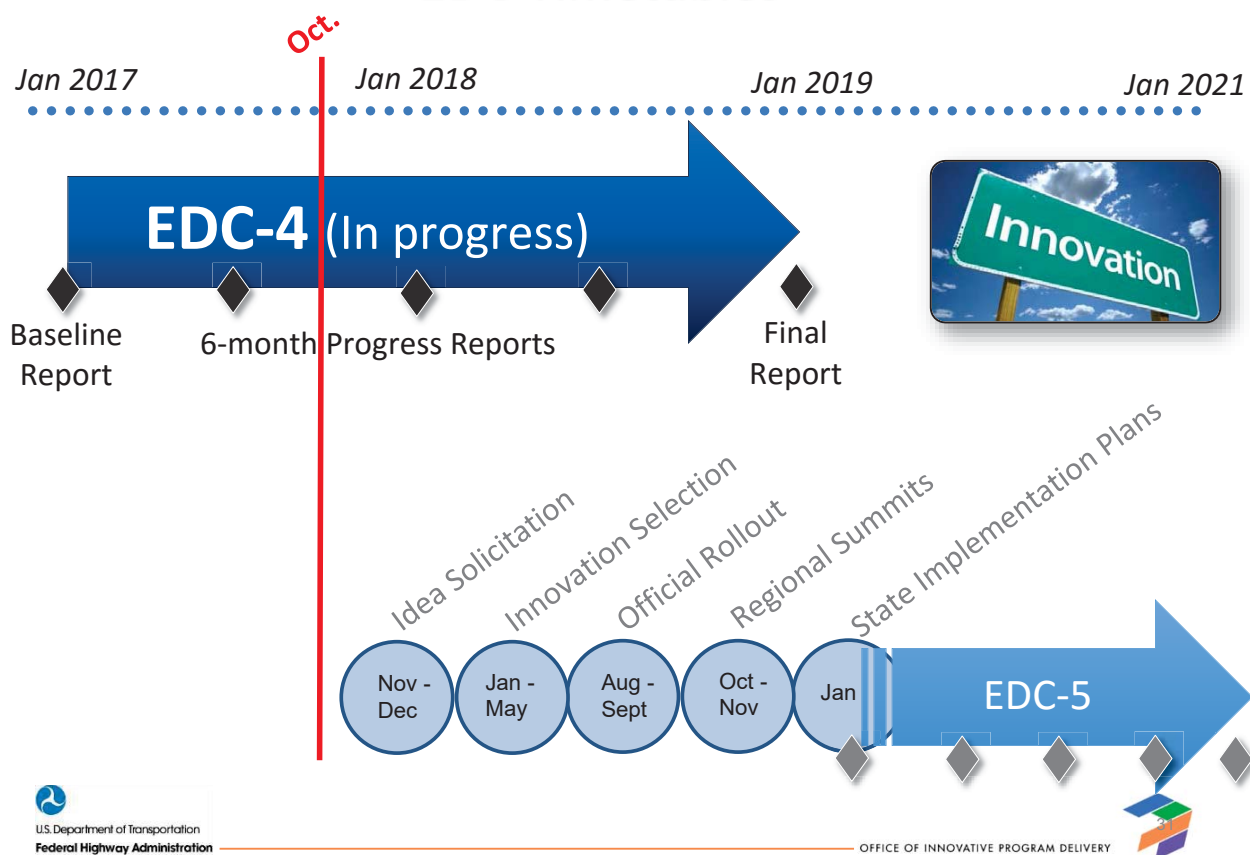
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Innovation Spotlight



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EDC Timetables



Technical Contacts:

Pavement Preservation When and Where	Thomas Van FHWA Office of Infrastructure	Thomas.Van@dot.gov
Pavement Preservation When and Where	Steve Gaj FHWA Office of Infrastructure	Stephen.Gaj@dot.gov
Pavement Preservation When and Where	Jason Dietz FHWA Resource Center	Jason.Dietz@dot.gov
Pavement Preservation How	James Gray FHWA Office of Infrastructure	James.Gray@dot.gov



Thank You!!!

Jeff Zaharewicz

Senior Advisor

FHWA Center for Accelerating Innovation

(202) 366-1325

Jeffrey.Zaharewicz@dot.gov



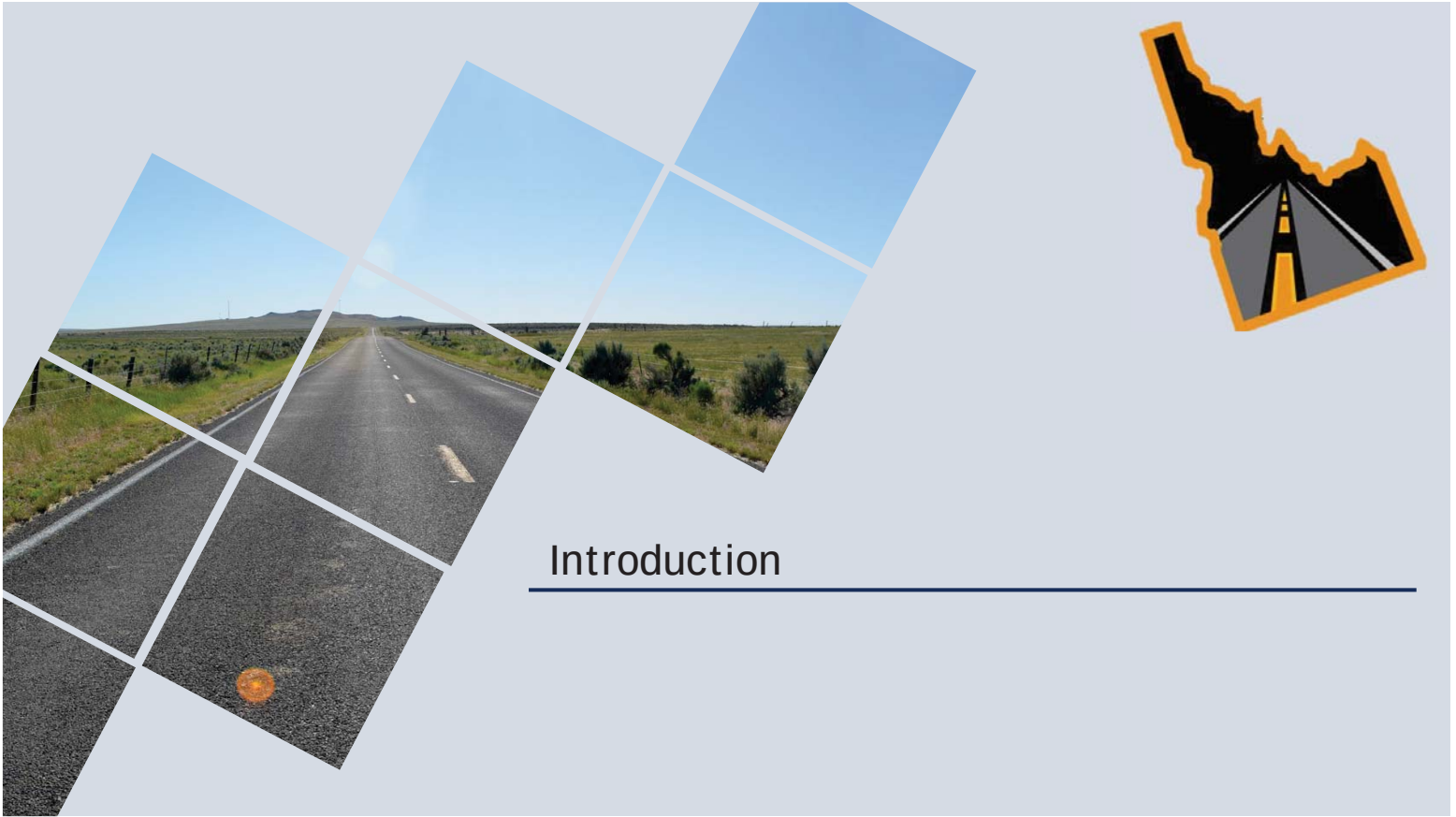


Determining the Correct Mixing and Compaction Temperatures for Using High RAP Content in HMA

Huachun Zhai, Ph.D, P.E.
Alejandro Rosales
Erin L. Russell

2017 Idaho Asphalt Conference

1. Introduction
2. Objectives
3. Material and Test Methods
4. Results and Discussion
5. Summary of Findings



2017 Idaho Asphalt Conference

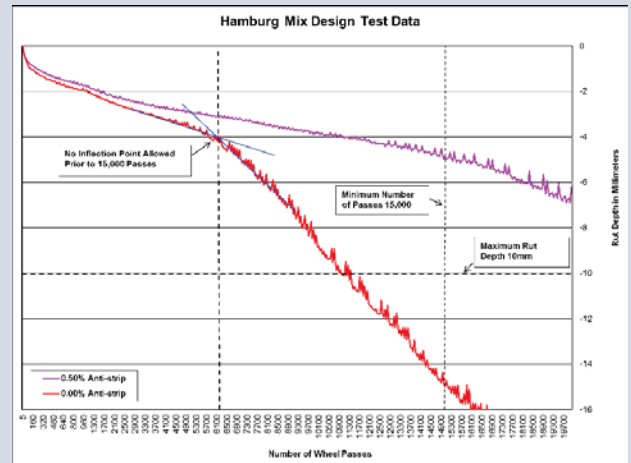
Introduction

- Significant increase in RAP% in HMA designs in Northwest region
 - Washington: Less than 20% in 2014 to amount allowed to meet the target PG grade (Based on Blending Chart)
 - Target PG 70-28, RAP grade PG 88.7-16.5
 - 20% RAP: PG 65.8-30.8; 40% RAP: PG 59.8-35.7
 - Idaho: Open the 20% limit in 2014 to basically 100% → Cap at 30% currently
 - Based on Blending Chart to the designed grade
 - ODOT: 20% RAP and RAS Combined. Pushing for up to 40%.

2017 Idaho Asphalt Conference

Introduction

- Problems
 - Too many different low temperature grades
 - PG 52-34, PG 52-40, PG 58-40, PG 64-40, PG 70-34, PG 76-34, etc
 - Mix Design Failures (Repeatability)
 - Hamburg (Washington)
 - **Stripping Inflection Point**
 - No stripping at 15,000 passes
 - **Rut Depth**
 - 10 mm at 15,000 passes
 - Immersion-Compression Test (Idaho)
 - **85% Retained Strength**



10/26/2017

Joe Devol, Presentation at 2014 Washington Asphalt Conference

5

2017 Idaho Asphalt Conference

Introduction

- Current Solutions (**It is always the oil**):
 - Adding antistrip (up to 1.5%)
 - Changing grade
 - Changing formulation
 - Changing Supplier
- Possible Causes: (**It is not always the oil**)
 - RAP quality (Source/Grade/Gradation)
 - Interaction between RAP and Virgin Oil (Coating)

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Introduction

- Coating of the Agg/RAP
 - Not enough binder → Need more virgin binder
 - Mixing and Compaction (Temperatures too low)
- The mixing and compaction temperatures
 - The virgin binder (Low) **NCHRP 452**
 - The blended virgin/RAP binder (Medium)
 - The RAP binder (High)

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Objectives

- Will higher mixing and compaction temperatures affect the OAC for HMA using RAP ?
 - NCHRP 9-36: SGC compaction process is insensitive to binder stiffness
 - FHWA/TX-11/0-6092-2: Increasing the mixing and compaction temperatures significantly lowers the OAC
- Will higher mixing and compaction temperatures affect the mechanical properties for HMA using RAP ?
 - NCHRP 9-36: Mechanical tests on HMA are affected by mixing and compaction temperatures
 - FHWA/TX-11/0-6092-2: Lower temperature → higher OAC → More Durable Mixes

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Materials and Test Methods

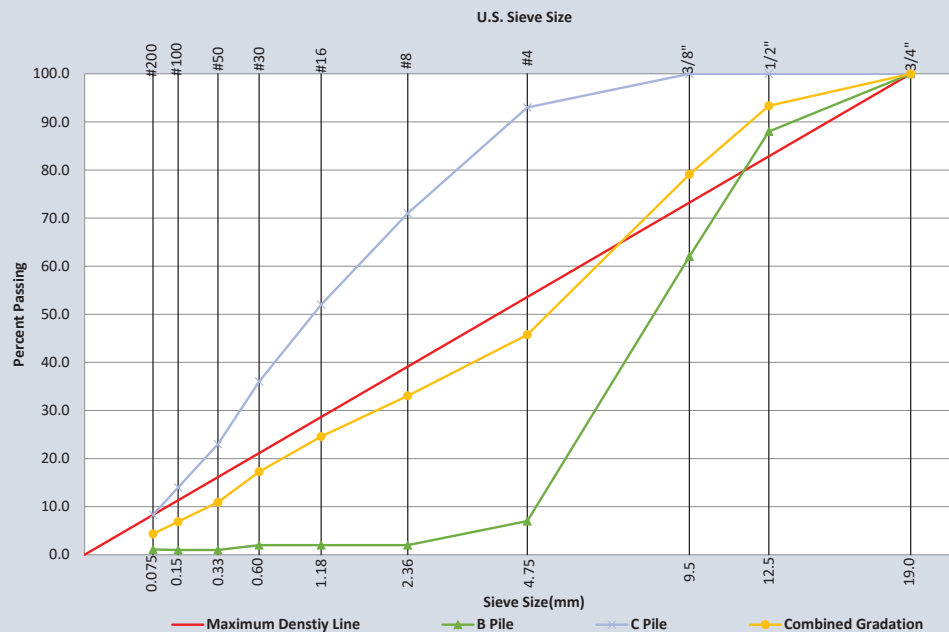
- Materials
 - Aggregate:

Sieve Size		B Pile (45%)	C Pile (55%)	Combined
Mesh	(mm)	45.0%	55.0%	100.0%
1-1/2"	37.5	100%	100%	100%
1"	25.0	100%	100%	100%
3/4"	19.0	100%	100%	100%
1/2"	12.5	88%	100%	95%
3/8"	9.5	62%	100%	83%
#4	4.75	7%	93%	54%
#8	2.36	2%	71%	40%
#16	1.18	2%	52%	30%
#30	0.6	2%	36%	21%
#50	0.33	1%	23%	13%
#100	0.15	1%	14%	8%
#200	0.075	1.1%	8.3%	5.1%

10/26/2017

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Materials and Test Methods



10/26/2017

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Materials and Test Methods

• RAP :

- RAP was made by blending 4.5% RAP Asphalt with the same aggregate
- RAP Asphalt: PG64-22 after 40 hrs PAV
- To eliminate the variances in RAP source and binders
- RAP Contents: 0%, 15% and 30%

Sieve Size		RAP
Mesh	(mm)	
1-1/2"	37.5	100%
1"	25.0	100%
3/4"	19.0	100%
1/2"	12.5	91%
3/8"	9.5	74%
#4	4.75	43%
#8	2.36	21%
#16	1.18	6%
#30	0.6	1%
#50	0.33	0%
#100	0.15	0%
#200	0.075	0.1%

• Virgin Binders:

- PG52-34 (Neat Asphalt)
- PG64-28ER (SBS modified asphalt)

Neat Asphalt	15% RAP	30% RAP
4.0%	4.7%	5.4%
4.5%	5.2%	5.9%
5.0%	5.7%	6.4%
5.5%	6.2%	6.9%

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Materials and Test Methods

	RAP	PG 52-34	PG 64-28ER
HT	90.7	54.0	68.8
LT	-22	-35.4	-30.7

	PG 52-34		PG 64-28ER	
	15% RAP	30% RAP	15% RAP	30% RAP
HT	59.5	65.01	72.0	75.4
LT	-33.3	-31.38	-29.3	-28.1
PG Grade	PG 58-28	PG 64-28	PG 70-28	PG 76-28*

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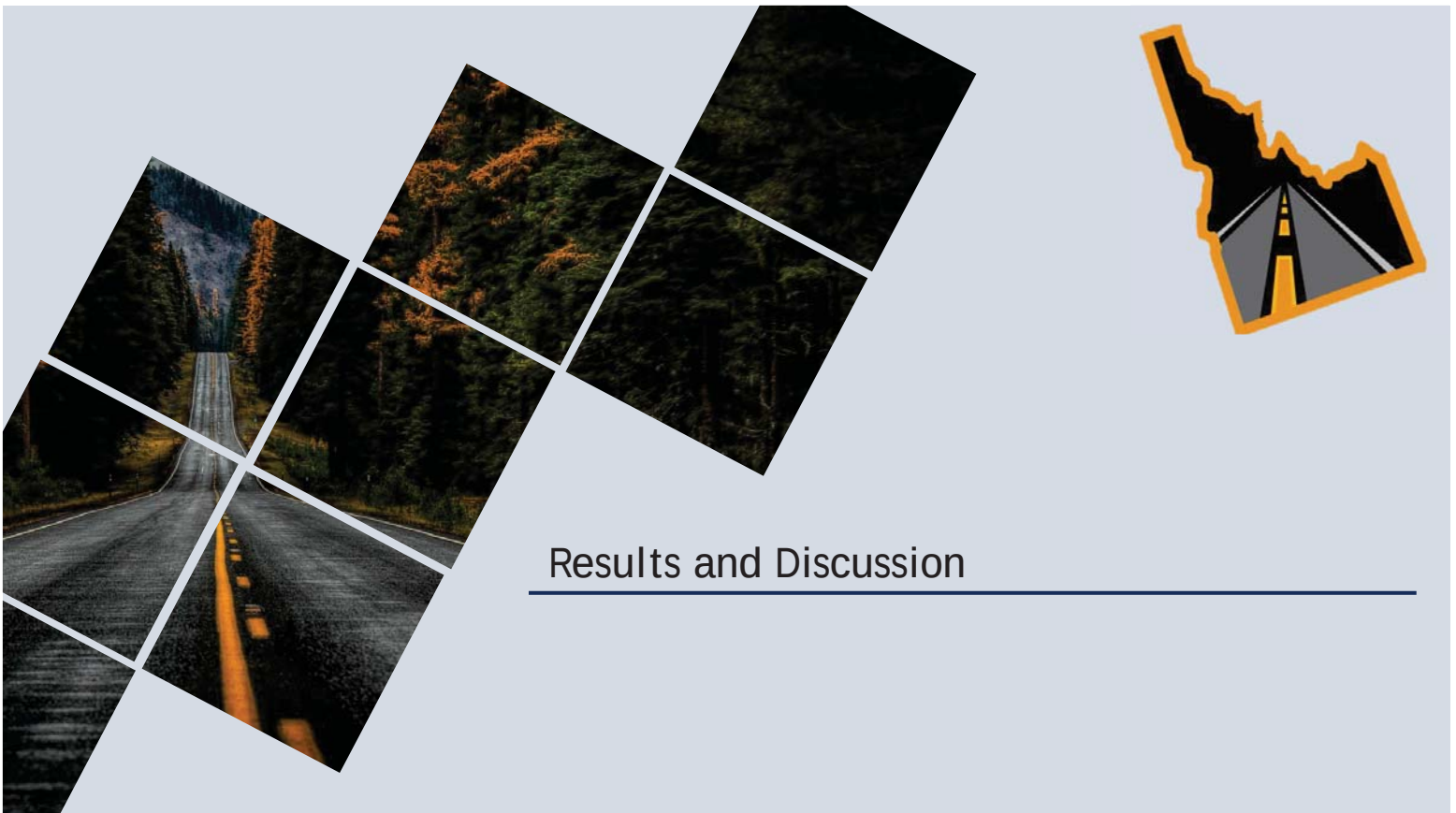
14

Materials and Test Methods

	Mixing Temp	Compaction Temp
PG 52-34	143°C (289°F)	132°C (270°F)
PG 64-28	160°C (320°F)	145°C (293°F)
PG 76-28	169°C (336°F)	153°C (307°F)
RAP	177°C (350°F)	169°C (337°F)

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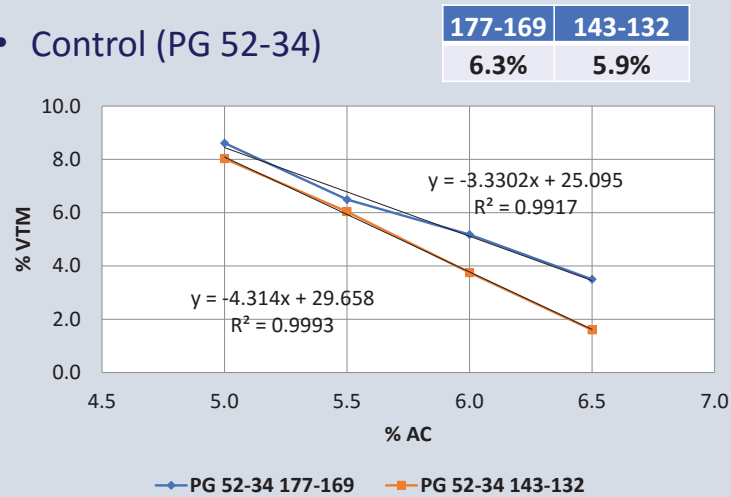


Results and Discussion

2017 Idaho Asphalt Conference

Results and Discussion

- Control (PG 52-34)



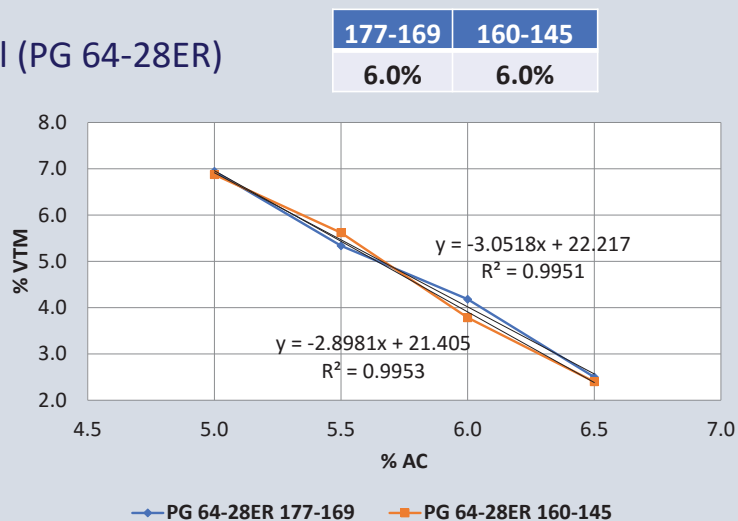
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Results and Discussion

- Control (PG 64-28ER)



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Results and Discussion

	PG52-34	PG64-28ER
135°C	235 mPas	624 mPas
150°C	127 mPas	326 mPas
165°C	69 mPas	186 mPas

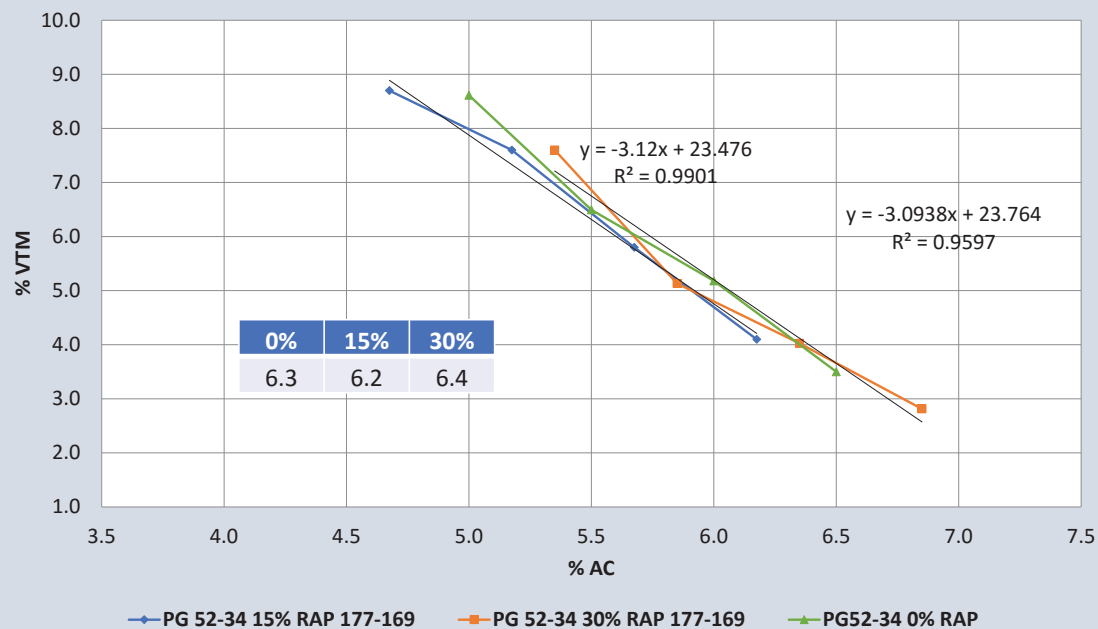
- Absorption:

- At 177C, PG52-34 viscosity around 40 mPas; PG64-28ER, 123 mPas
- Polymer network may limited the extend of absorption.

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Results and Discussion

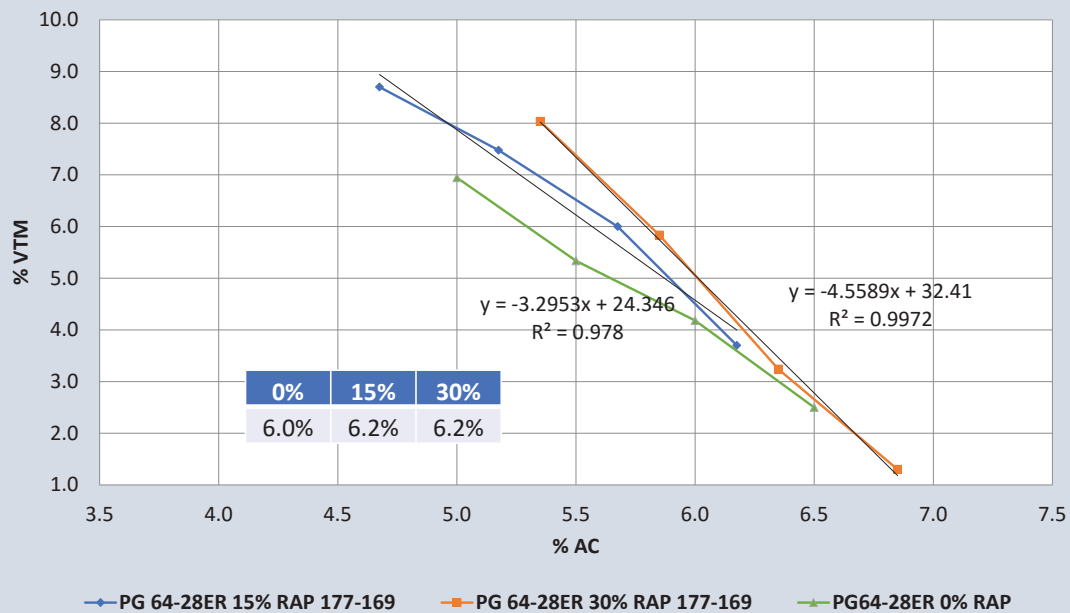


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Results and Discussion

RAP % has no effect on OAC (Total AC) at temperatures between Neat and target PG

	PG52-34				PG64-28ER		
Temp	0	15	30	Temp	0	15	30
177/169	6.3	6.2	6.4	177/169	6.0	6.2	6.2
160/145	N/A	5.8	5.9	169/153	N/A	6.1	6.3
143/132	5.9	5.9	6.0	160/145	6.0	6.1	6.1

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Results and Discussion

Number of Gyration to achieve 92% Gmm. Not much difference at different compaction temperatures, asphalt type or RAP%.

PG52-34				PG64-28ER			
Temp	0%	15%	30%	Temp	0%	15%	30%
177/169	28	24	24	177/169	22	18	23
160/145	N/A	25	28	169/153	N/A	23	22
143/132	25	24	26	160/145	21	18	25

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Results and Discussion

Summary:

- Will higher mixing and compaction temperatures affect the OAC for HMA using RAP ?
 - Depends on the grade of the virgin binder and how high the temperatures are.
 - For regular grade, we can consider that the OAC to be the same between Virgin Binder range to target PG grade range

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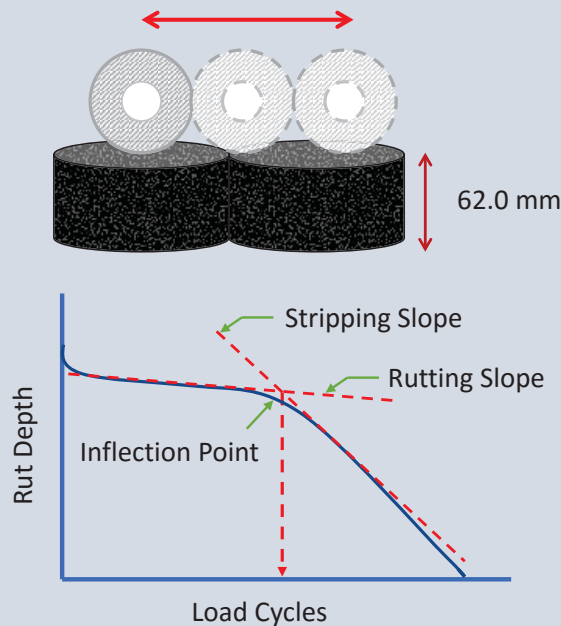


Results and Discussion

Performance Testing: Hamburg

Performance Testing: Hamburg

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AASHTO T324

- 62.0 mm height
- 150 mm diameter
- 7.0%±1.0% air voids

- Minimum Criteria WSDOT
 - 50°C
 - 10 mm Rut Depth at 15,000 passes
 - No stripping at 15,000 passes

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Performance Testing: Hamburg

PG 52-34

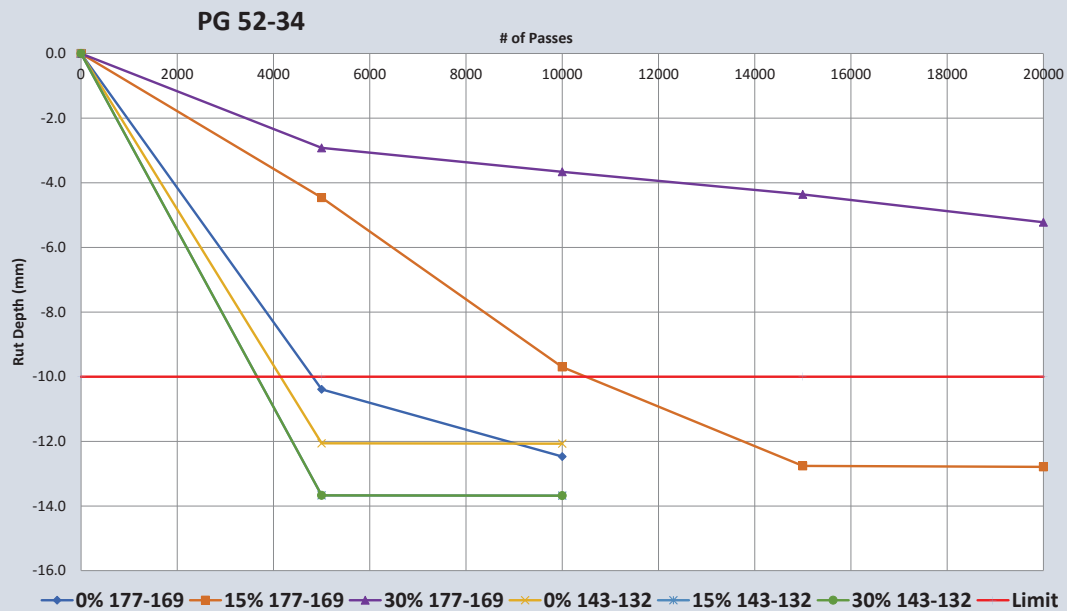
	177-169°C			143-132°C		
Passes	0% RAP	15% RAP	30% RAP	0% RAP	15% RAP	30% RAP
5000	-10.39	-4.46	-2.92	-12.06	-13.67	-13.67
10000	-12.47	-9.70	-3.66	-12.07	-13.68	-13.68
15000		-12.76	-4.36			
20000		-12.79	-5.22			

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Performance Testing: Hamburg

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PG 52-34 0%RAP 143-132°C



PG 52-34 0%RAP 177-169°C



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Performance Testing: Hamburg

PG 64-28ER

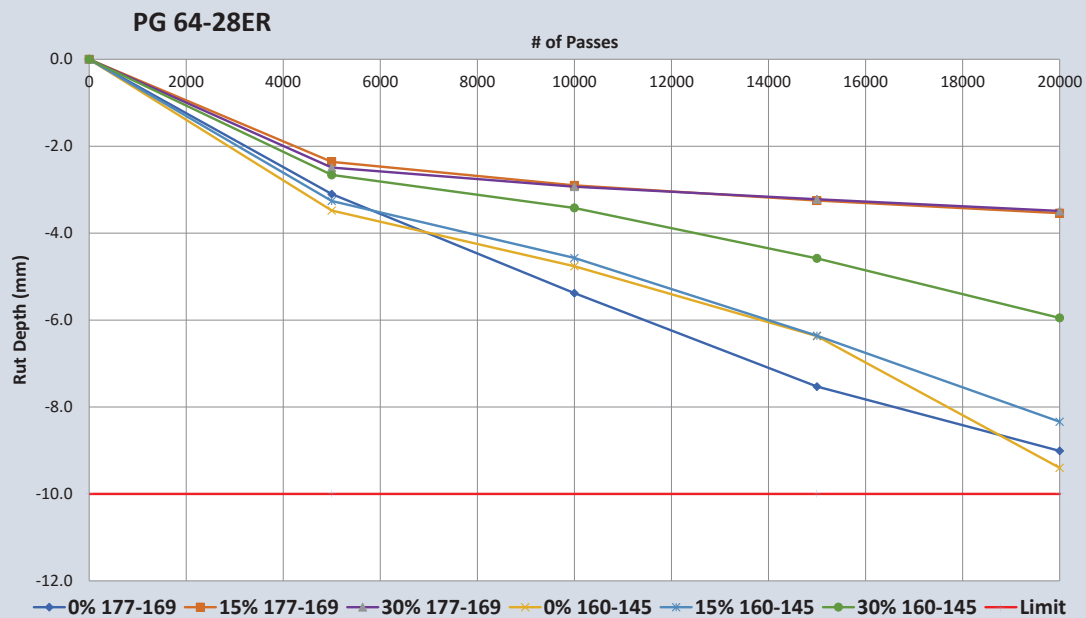
	177-169°C			160-145°C		
Passes	0% RAP	15% RAP	30% RAP	0% RAP	15% RAP	30% RAP
5000	-3.10	-2.36	-2.49	-3.48	-3.26	-2.66
10000	-5.38	-2.90	-2.93	-4.76	-4.57	-3.42
15000	-7.53	-3.25	-3.22	-6.37	-6.36	-4.58
20000	-9.01	-3.54	-3.49	-9.40	-8.34	-5.95

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PG 64-28ER 0%RAP 177-169°C



PG 64-28ER 15%RAP 177-169°C



PG 64-28ER 30%RAP 177-169°C



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Performance Testing: Hamburg

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PG 64-28ER 0%RAP 160-145°C



PG 64-28ER 15%RAP 160-145°C



PG 64-28ER 30%RAP 160-145°C



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Performance Testing: Hamburg

PG 64-28ER

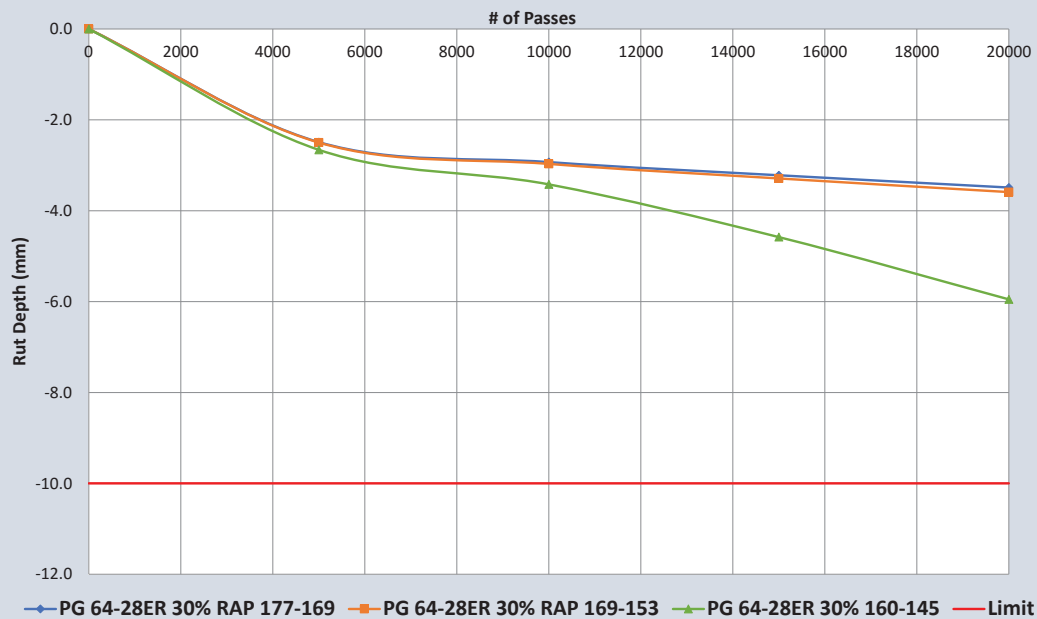
	30% RAP		
	177-169°C	169-153°C	160-145°C
5000	-2.49	-2.50	-2.66
10000	-2.93	-2.97	-3.42
15000	-3.22	-3.29	-4.58
20000	-3.49	-3.59	-5.95

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PG 64-28ER 30%RAP 160-145°C



PG 64-28ER 30%RAP 169-153°C



PG 64-28ER 30%RAP 177-169°C



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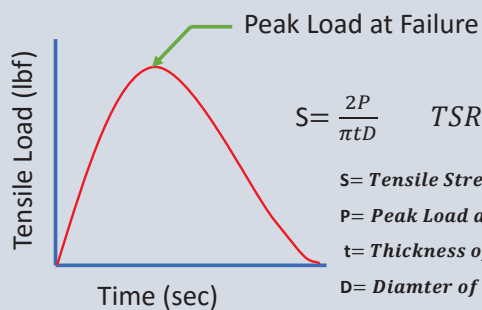
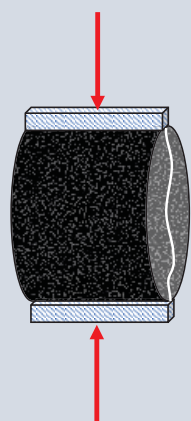
Results and Discussion

Performance Testing: Tensile Strength Ratio

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Results and Discussion

Performance Testing: Tensile Strength Ratio



Loading Rate: 2 in/min (50 mm/min)

$$S = \frac{2P}{\pi t D} \quad TSR(\%) = \frac{S_{t,wet}}{S_{t,dry}}$$

S = Tensile Stress at Failure (psi)

P = Peak Load at Failure (lbf)

t = Thickness of specimen (in)

D = Diameter of specimen (in)

AASHTO T283 (Modified Lottman Test)

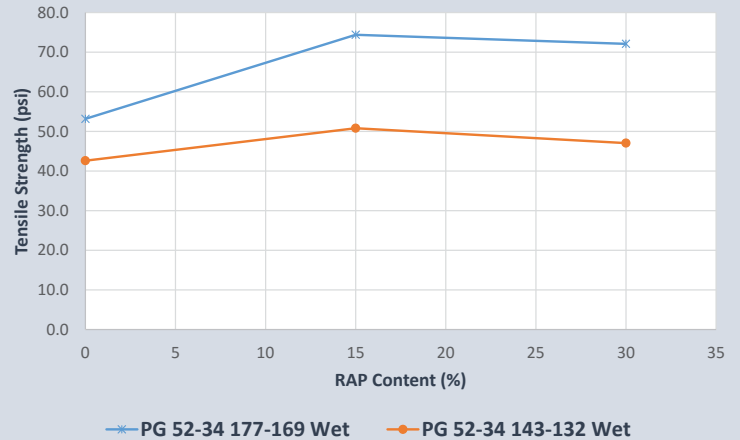
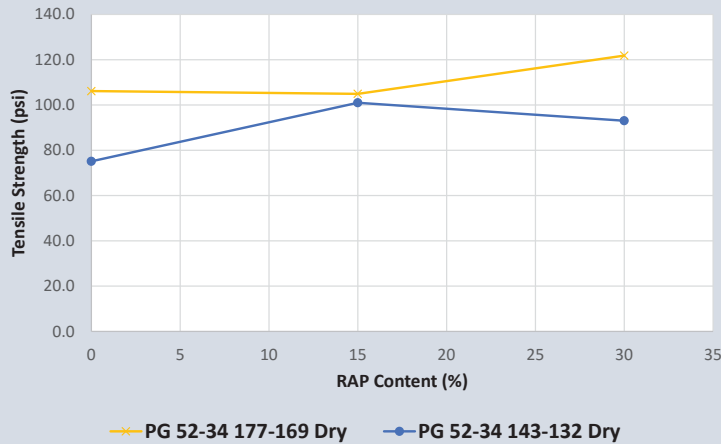
- Method 1: Freeze Thaw Cycle
- Method 2: No Freeze Thaw Cycle
- 3 Samples prepared for each condition
- Method 1: Freeze Thaw Cycle
 - 70%-80% Vacuum Saturation
 - 16 hr -18°C Freeze Cycle
 - 24 hr 60°C Thaw Cycle
 - 2 hr 25°C Equilibration Cycle
- **Method 2: No Freeze Thaw Cycle**
 - 70%-80% Vacuum Saturation
 - 24 hr 60°C Conditioning Cycle
 - 2 hr 25°C Equilibration Cycle

Minimum TSR value 80%

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Results and Discussion

Performance Testing: TSR



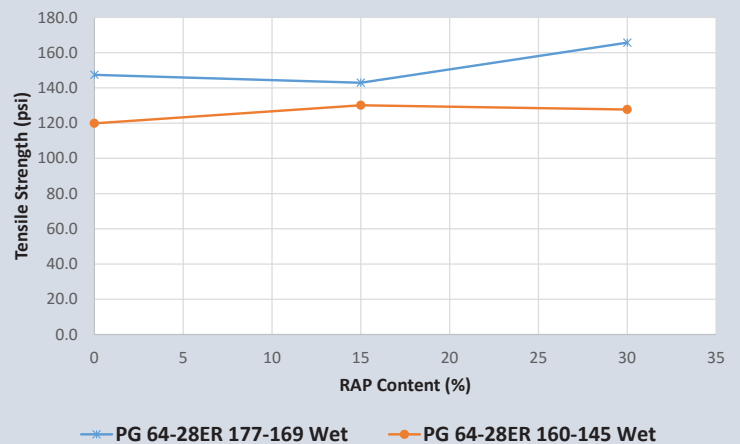
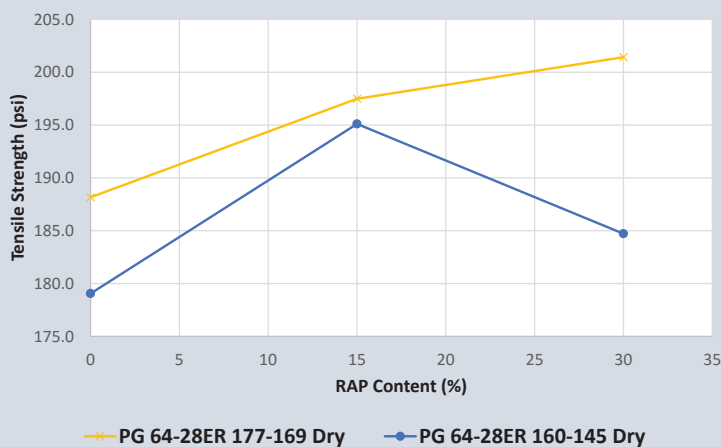
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Results and Discussion

Performance Testing: TSR



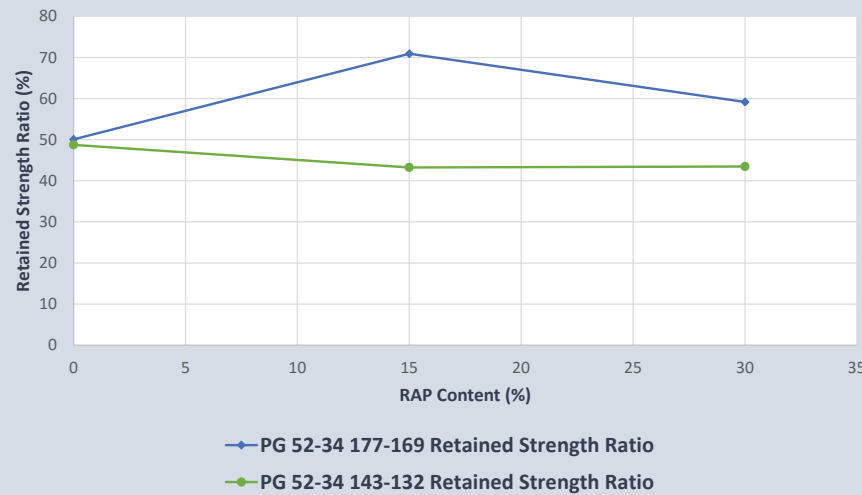
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Results and Discussion

Performance Testing: TSR



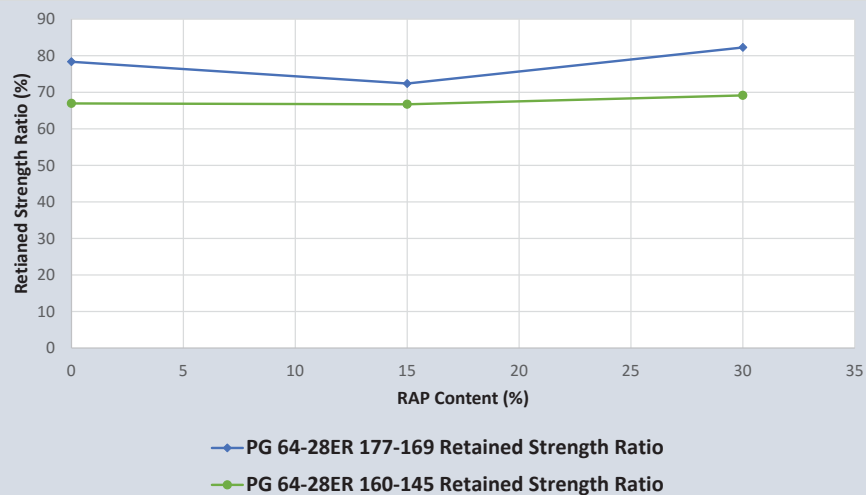
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Performance Testing: TSR



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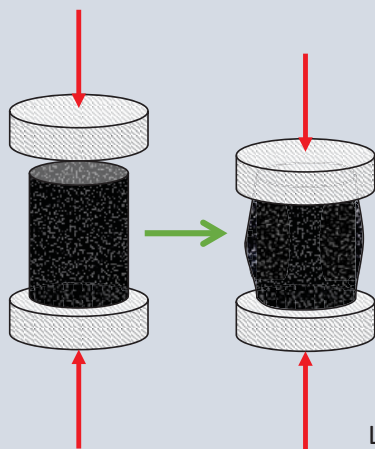
Results and Discussion

Performance Testing: Immersion Compression

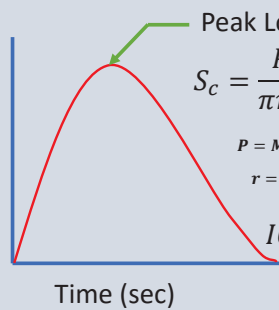
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Results and Discussion

Performance Testing: Immersion Compression



Compressive Load (lbf)



Peak Load at Failure

$$S_c = \frac{P}{\pi r^2}$$

P = Max Compressive Load at Failure (lbf)

r = Radius of specimen (in)

$$IC\ Ratio(\%) = \frac{S_{c,wet}}{S_{c,dry}}$$

Loading Rate: 0.2 in/min (5.08 mm/min)

AASHTO T165/T167
ASTM D1074/1075

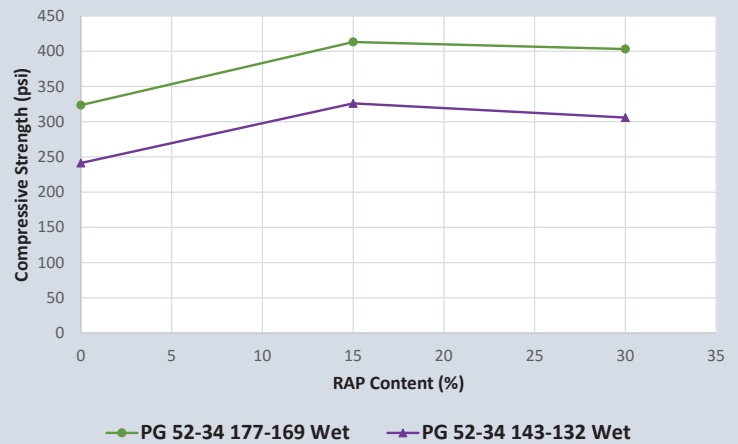
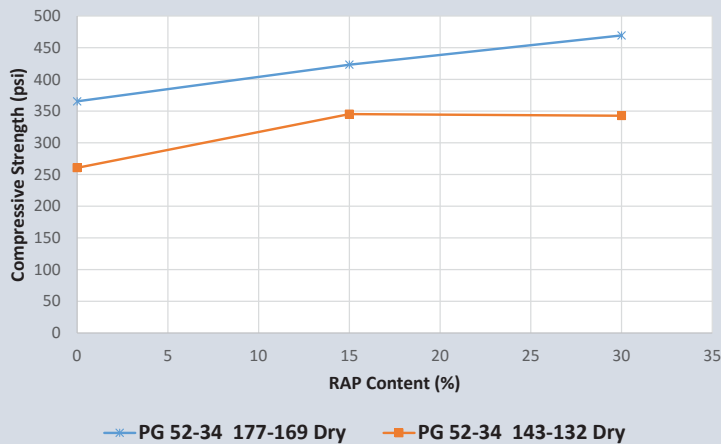
- Set of 3 samples for each condition are prepared
- Wet sample conditioned at 60°C (140°F) for 24 hrs
- Wet sample is transferred to 25°C (77°F) for 2 hrs
- Dry sample conditioned at 25°C (77°F) air bath for 4 hrs

Minimum IC Ratio value 85% (ITD)

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Results and Discussion

Performance Testing: Immersion Compression



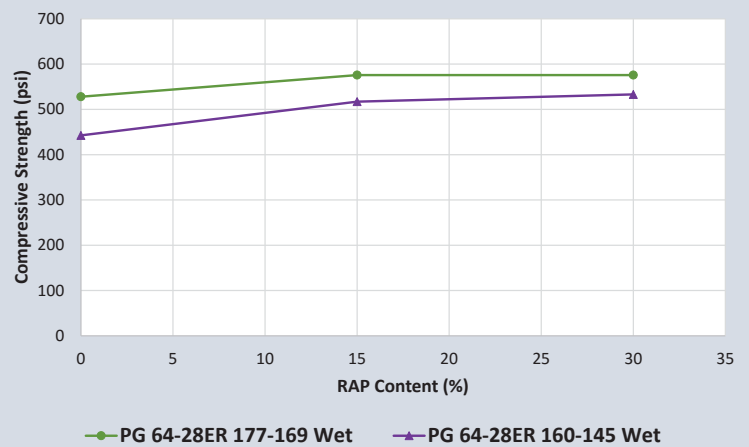
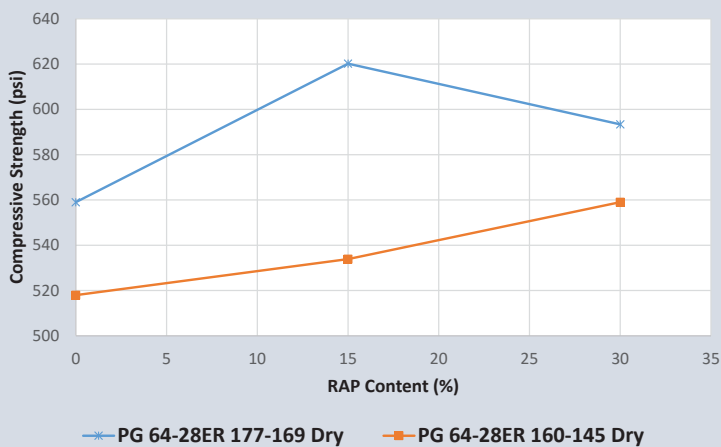
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Results and Discussion

Performance Testing: Immersion Compression



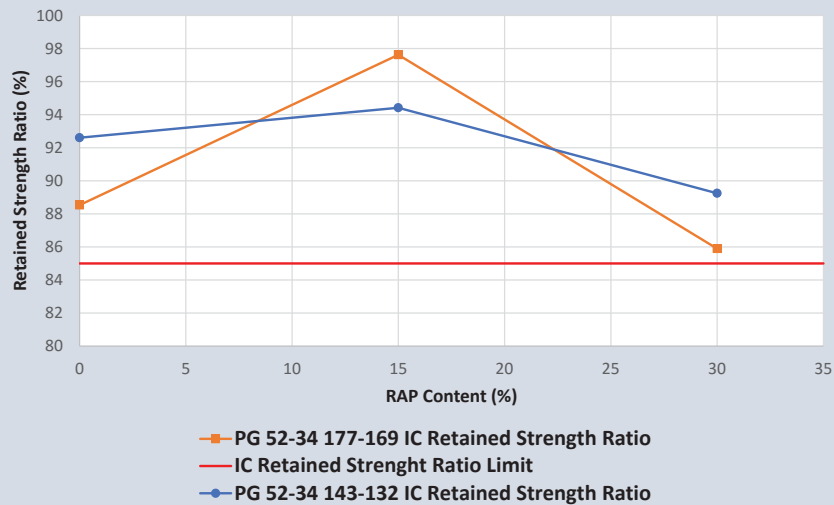
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Results and Discussion

Performance Testing: Immersion Compression



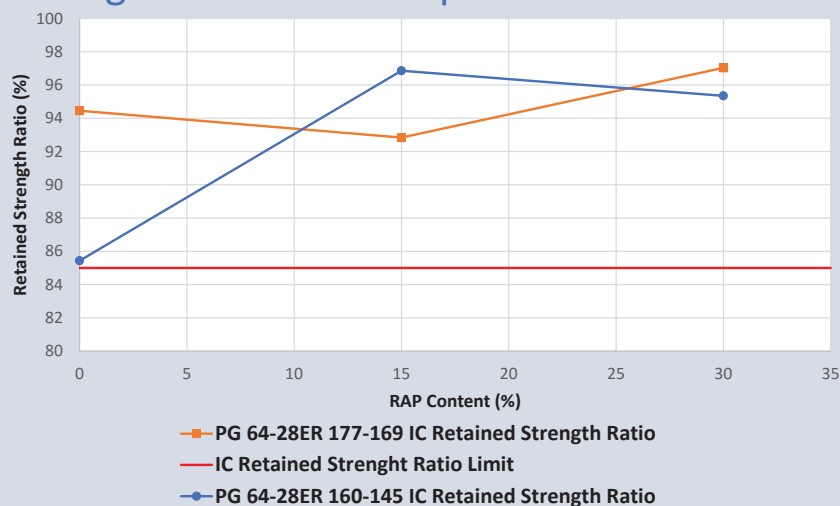
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Results and Discussion

Performance Testing: Immersion Compression



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Summary of Findings

Summary of Findings

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- Hamburg
 - Higher mixing and compaction temperatures lead to less rutting
 - Not necessary to target RAP temperature
 - Data suggests Target Blend yields same results
- Tensile Strength Ratio (TSR)
 - Higher mixing and compaction temperatures leads to higher tensile strength
 - Mixtures at higher mixing and compaction temperatures have higher tensile strength ratios
 - Target PG Blend yields better results
- Immersion Compression (IC)
 - Higher mixing and compaction temperatures yield higher compressive strength
 - Compressive strength ratios were higher when mix and compacted at hotter temperatures
 - Target PG Blend yielded same if not better results than hottest temperature

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Summary of Findings

- Will higher mixing and compaction temperatures affect the mechanical properties for HMA using RAP ?
 - Yes. Higher temperatures → less Distresses (Rut and Stripping)
 - **We should target the mixing and compact temperatures of final/blend PG grade.**

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Going Forward

- Finish performance tests at target blend temperature
- Include testing with other asphalt grades
 - Include other types of polymers
- Investigate the effect of Warm Mix Additives and temperature on mixture performance
- Include higher RAP content (50% RAP)
- Include field RAP
- Investigate Viscosity Temperature Curve
 - Recommended minimum viscosity to achieve better mixture performance

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Questions?

Contact:
Huachun Zhai, Ph.D., P.E.
hzhai@idahoasphalt.com

Alejandro Rosales
arosales@idahoasphalt.com

The Chip Seal Process and Why we do it that way



Standard Chip Seal:
Spray Emulsion Binder, Drop the Chips, Roll 3 times, let it
cure overnight, Sweep away the excess

Key Elements of the Process

- Design (McCleod)
 - Application rates
 - Rock Requirements
- Rolling
- Using Choke
- Fogging
- The Importance of time and when to seal
- Don't forget the road needs to be prepped and clean

Why do a chip seal design before starting

- Proper chip embedment is critical to seal success
 - Too little and we loose rock
 - Too much and we flush loosing skid resistance
- Chip embedment is affected by binder application rate as well as traffic load and road condition.
- A good chipseal design will give you the right emulsion and aggregate rates to give the seal proper chip embedment

Reference Sources

- **Chip Seal Design Program**
<http://www.dot.state.mn.us/materials/researchsealcoat.html>
- **Minnesota Seal Coat Handbook**
<http://www.lrrb.org/pdf/200634.pdf>

Chip Seal Design Method

- What should this design method do?
 - 1. Give amount of aggregate needed to cover 1 sq. yd² a single stone thick (Extra is wasted)
 - 2. Give starting binder application rate
 - Starting rate would yield approximately 70% embedment
 - Must adjust for current conditions of pavement
 - Recommendations for the crew to use to help adjust for different traffic levels and pavement conditions

Tests run on Aggregate for design

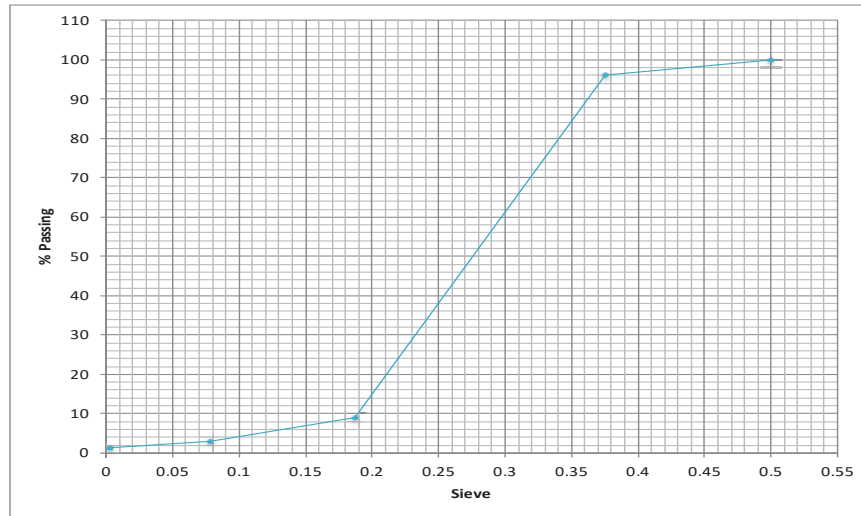
- Gradation – Binder ; for embedment
- Loose Unit Weight – To Calc. Voids / room for binder
- Specific Gravity – To Calc. Voids
- Absorption – Binder; for loss in absorb.
- Flakiness Index- Binder; for functional embedment.
How high will the chips sit up when finally embedded.

Precision is the Key to Success

- The higher the number of sieves used to grade the material the more accurate the design.
- The more cubical the rock the more precise the design.
- Accurate traffic count.
- Accurate Road evaluation.

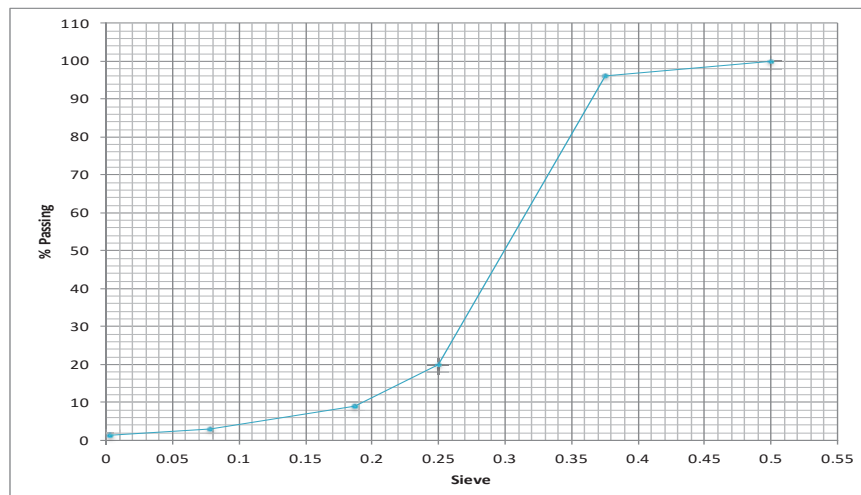
This grading shows 0.275 In median size

	Sieve	Passing
1/2	0.5	100
3/8	0.375	96
4	0.187	9
10	0.0787	3
200	0.0029	1.3



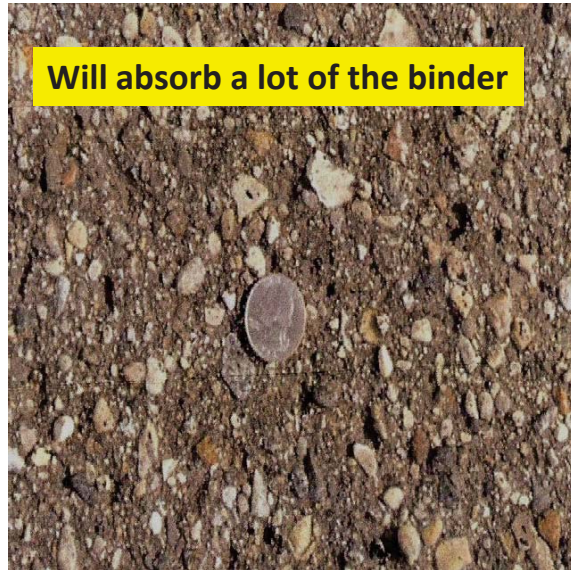
Adding one more sieve increases accuracy
Median is more accurately shown to be 0.3 in.

	Sieve	Passing
1/2	0.5	100
3/8	0.375	96
1/4	0.25	20
4	0.187	9
10	0.0787	3
200	0.0029	1.3



Know Your Pavement Condition

“Flushed Pavement” vs. “Badly Pocked Porous and Oxidized” and everything in between

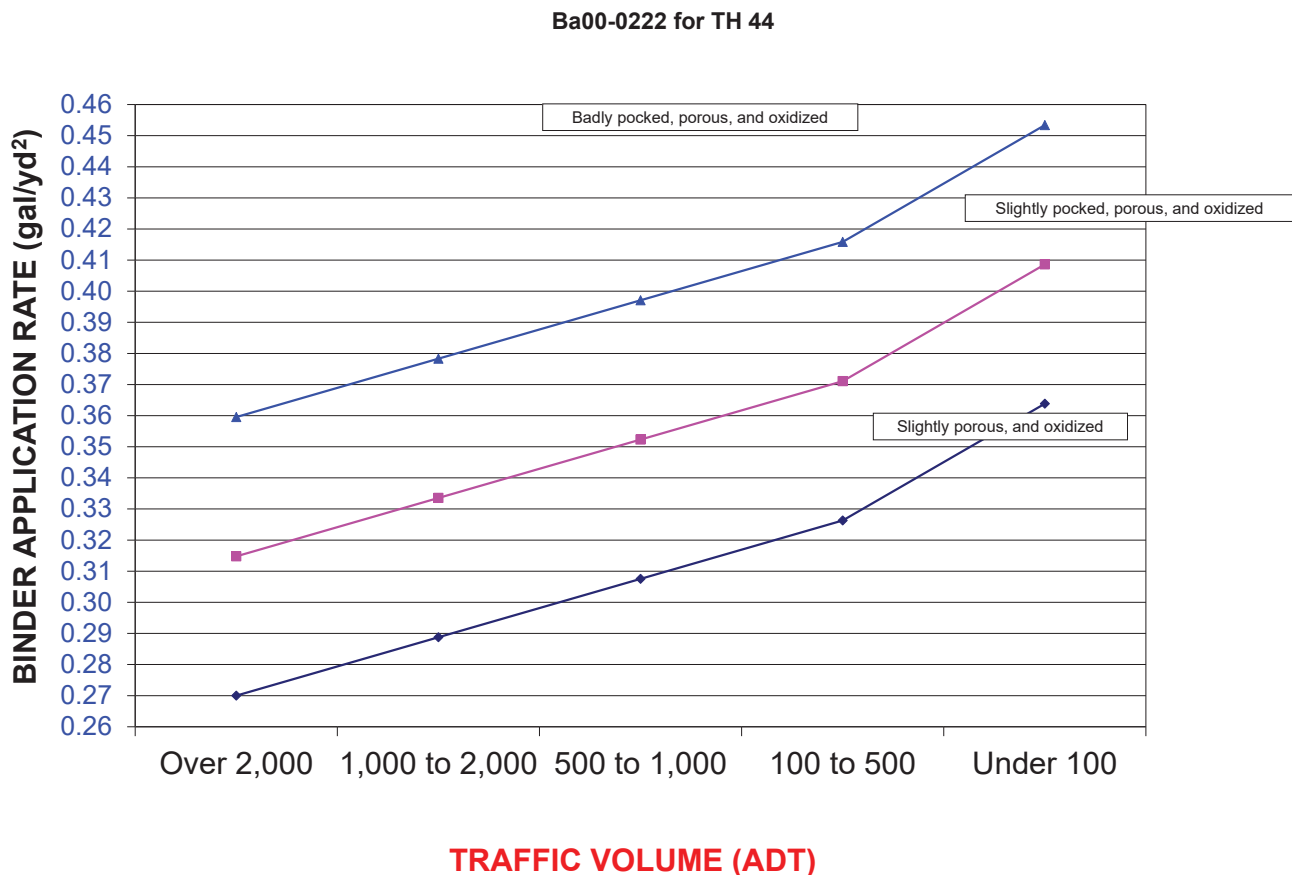


We need that Traffic Count

- We need the traffic count on the roads to be sealed
- Higher traffic compacts rock more
- Lower traffic compacts rock less
- Just like we need that info for hotmix paving

McLeod Emulsion Calculation

- $B(G/SqYd) = ((2.244 \times \text{Ave Least Dimension} \times \text{Traffic Factor} \times \text{Voids in loose Agg}) + \text{Surface Condition factor} + \text{Agg Absorb Factor}) / \text{Residual Asphalt Content of Binder}$. For Wheel Paths
- Then same calc on Median Rock Size instead of Average Least Dimension. For Non Wheel Paths
- Average the two.
- Only need calc on Median Rock Size if rock is very cubical.
- May not need to average if we can improve non - wheel path embedment. - Later in talk!



h Idaho Asphalt Conference, October 26, 2017				Flakiness ratio		0.9		0.294			
T	Traffic Factor			-100 ADT	0.85	100-500	0.75	500-1000	0.7	1000-2000	0.65
V	Voids in loose Agg			Single Chip	0.5						
S	Surface Condition			Smooth, non porous	0	Slightly porous & oxidized	0.03	Slightly pocked porous & oxidized	0.06	Badly pocked porous & oxidized	0.09
A	Agg Absorption			None	0						
R	Residual AC Cont			0.665							
100 ADT on Badly Pocked & oxidized											
Binder Appl Rate = 0.557 Gal/yd2 2.244 0.294 0.85 0.5 0.09 0											
0.665											
100 ADT on Slightly pocked, Porous & oxidized											
Binder Appl Rate = 0.512 Gal/yd2 2.244 0.294 0.85 0.5 0.06 0											
0.665											
100 ADT on Slightly Porous & oxidized											
Binder Appl Rate = 0.467 Gal/yd2 2.244 0.294 0.85 0.5 0.03 0											
0.665											
100 ADT on Smooth non-porous											
Binder Appl Rate = 0.422 Gal/yd2 2.244 0.294 0.85 0.5 0 0											
0.665											
100-500 ADT on Badly Pocked & oxidized											
Binder Appl Rate = 0.507 Gal/yd2 2.244 0.294 0.75 0.5 0.09 0											
0.665											



Standard Chip Seal Aggregate Requirements

- Must be clean - For reliability
 - Less than 1% passing #200 sieve; better adhesion
- Durable - wear life
 - LAR, lower = harder, polish / wear resistant
- Flakiness Index - reliability
 - Lower = More cubicle, uniform shape easier to design around. More accurate design = More reliable seal.



- Single sized Chips
 - More uniformed height
 - Has more room for binder – Space not filled by smaller aggregate particles.
 - The more single sized the easier it is to develop a good chipseal design.

9-03.4 Aggregate for Bituminous Surface Treatment**9-03.4(1) General Requirements**

Aggregate for bituminous surface treatment shall be manufactured from ledge rock, talus, or gravel, in accordance with Section 3-01, which meets the following test requirements:

Los Angeles Wear, 500 Rev.	35% max.
Degradation Factor	30 min.

9-03.4(2) Grading and Quality

Aggregate for bituminous surface treatment shall conform to the requirements in the table below for grading and quality. The particular type or grading to be used shall be as shown in the Plans. All percentages are by weight.

The material shall meet the requirements for grading and quality when placed in hauling vehicles for delivery to the roadway, or during manufacture and placement into a temporary stockpile. The exact point of acceptance will be determined by the Engineer.

Crushed Screening Percent Passing					
	3/4" - 1/2"	5/8"-No. 4	1/2"-No. 4	3/4"-No. 4	No. 4-0
1"	99-100				
3/4"	95-100	99-100			
5/8"		95-100	99-100		
1/2"	0-20		90-100	99-100	
3/8"	0-5		60-85	70-90	99-100
No. 4		0-10	0-3	0-5	76-100
No. 10		0-3			30-60
No. 200	0-1.5	0-1.5	0-1.5	0-1.5	0-10.0
% fracture, by weight, min.	90	90	90	90	90

All percentages are by weight.

The fracture requirement shall be at least one fractured face and will apply to the combined aggregate retained on the No. 4 sieve in accordance with FOP for AASHTO T 335.

The finished product shall be clean, uniform in quality, and free from wood, bark, roots, and other deleterious materials.

Crushed screenings shall be substantially free from adherent coatings. The presence of a thin, firmly adhering film of weathered rock shall not be considered as coating unless it exists on more than 50 percent of the surface area of any size between successive laboratory sieves.

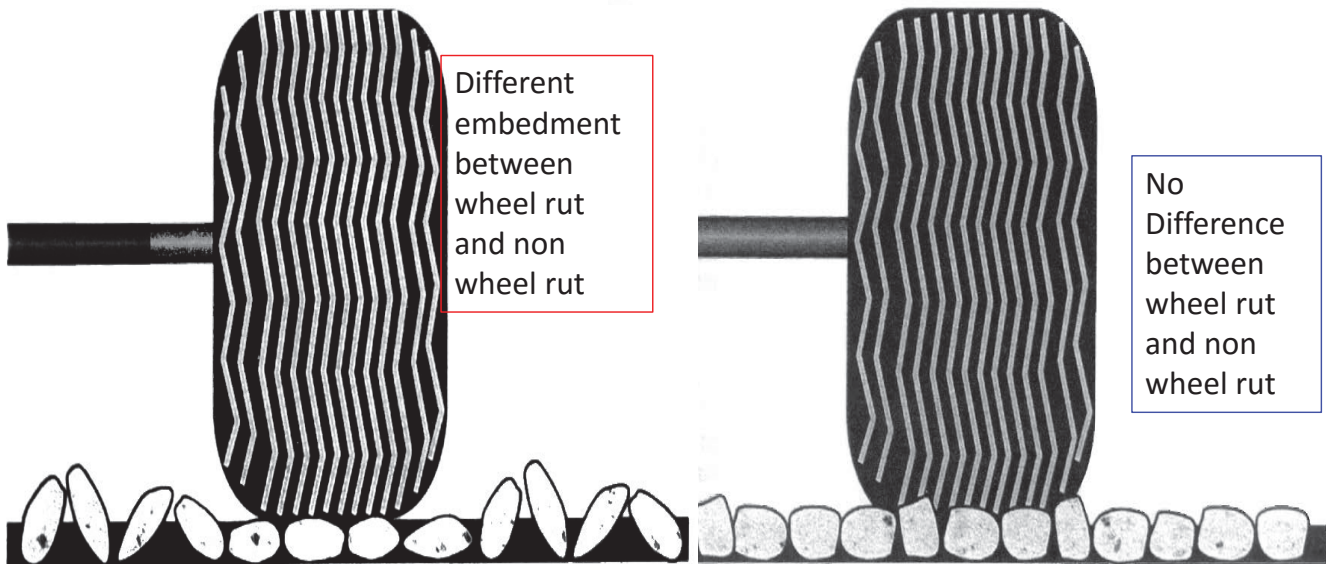
The portion of aggregate for bituminous surface treatment retained on a No. 4 sieve shall not contain more than 0.1 percent deleterious materials by weight.

Fine aggregate used for choke stone applications meeting the grading requirements of Section 9-03.1(2)B may be substituted for the No. 4-0 gradation.

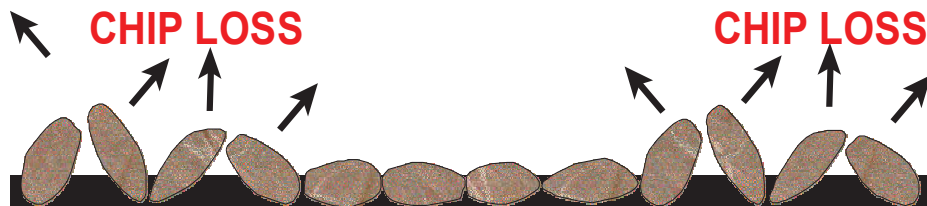
Aggregate Application Rate Calc

- Need - Ave least Dimension
- Need - Specific Gravity of the Aggregate
- Calculate the Voids in Loose Agg
 - $V = (\text{Loose unit weight (lbs/cubic ft)}) / (62.4 * \text{Spec Gravity})$
- Wastage factor Example 10% for high traffic, 5% for very low slow traffic $1 + .10 = 1.10$ high Traffic
- $C (\text{Appl Rate}) = 46.8 * (1 - (0.4) * \text{Voids in loose Agg} * \text{Ave Least Dimension} * \text{Specific Gravity} * \text{Wastage Factor for Traffic whip off})$

The Problem with Flat Chips

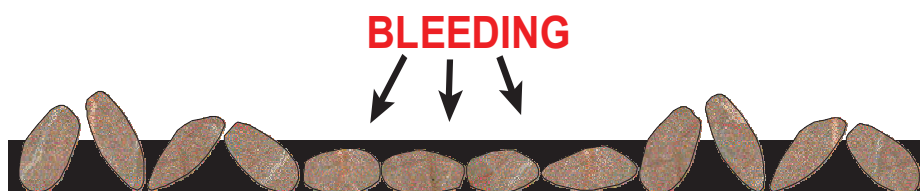


If the seal coat is designed for chips in the wheelpaths:



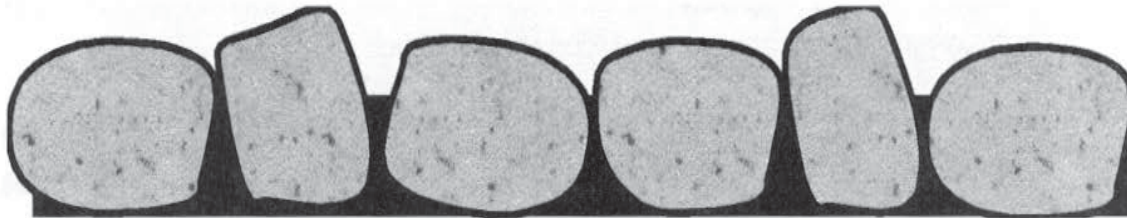
There is not enough binder in the non-traffic areas to prevent traffic and snow plows from dislodging the chips.

If the seal coat is designed for chips in the non- traffic areas:



There is too much binder in the wheelpaths after the flat chips lay on their flattest side.

Single Size vs. Graded Aggregate



Single Sized Aggregate Perfect for the
standard chip seal with CRS-2P, CMS-2P
Plenty of room for binder. (Adhesive)



Graded Aggregate / Not good for
CRS-2P or CMS-2P
Great for Otta Seal / Maintenance Seal with HF -150
Less room for binder, Relies on rock interlock

Binders



CRS-2P, CMS-2P

- Polymer Emulsions
- Stiffer binder - reduces bleeding
- Develops strength faster than other emulsions, can sweep sooner.
- Requires clean chips
- Must place chips immediately
- Most Expensive conventional chipseal emulsion

9-02

Bituminous Materials

9-02.1(6)A Polymerized Cationic Emulsified Asphalt CRS-2P

CRS-2P shall be a polymerized cationic emulsified asphalt. The polymer shall be milled into the asphalt or emulsion during the manufacturing of the emulsified asphalt. CRS-2P shall meet the following requirements:

	AASHTO Test Method	Specifications	
		Minimum	Maximum
Viscosity @122°F, SFS	T 59	100	400
Storage Stability 1 day %	T 59		1
Demulsibility 35 ml. 0.8% Dioctyl Sodium Sulfosuccinate	T 59	40	
Particle Charge	T 59	positive	
Sieve Test %	T 59		0.30
Distillation			
Oil distillate by vol. of emulsion %	T 59 ¹	0	3
Residue	T 59 ¹	65	
Tests on the Residue From Distillation			
Penetration @77°F	T 49	100	250
Elastic Recovery %	T 301 ²	50	

¹Distillation modified to use 300 grams of emulsified asphalt heated to 350°F ± 9°F and maintained for 20 minutes.

²The residue material for T 301 shall come from the modified distillation per note 1.



Why is rolling critical?

- When the rock is dropped into the binder the voids will approach 50%
 - At this level of voids the chip is not stable enough to withstand traffic and will ravel
- Rolling will drop that to around 30%
 - At this level of voids the chip is stable enough to withstand light traffic but not plowing and high traffic
- The final product to be achieved in the design will not occur until the voids are down around 20%
 - This usually does not occur without a lot of post construction traffic but each successive pass of the rollers over a seal under construction helps to move the seal to the final

Need more rolling

- While the wheel paths get the compaction needed for a successful seal
- Parking lanes, Fog line, Turn lanes, Qtr Crown, Center Line area, etc. do not.
- Traffic will take much longer to give these areas the compaction needed per the design.
- Give it extra attention while building (Give them extra Rolling)
- Add a STEEL roller

Steel Rollers

- Being used successfully by WSDOT, ODOT and many counties.
- Add it to the fleet, don't just replace a pneumatic. More rollers are always better.
- If it bridges the low points don't worry.
- The high points aren't getting enough traffic for embedment. Steel will help.
 - Steel immediately improves embedment, Cuts plow damage.
- Run the Steel Roller in static mode, vibe is not needed to orient and compact chips.

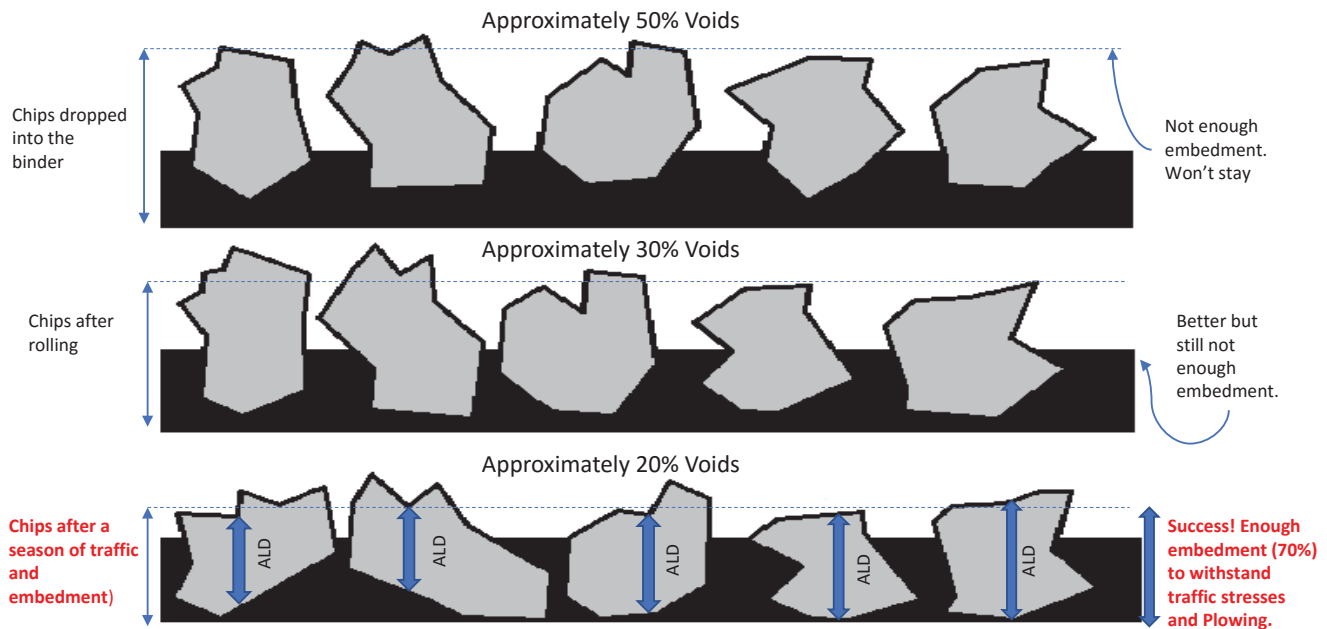
38,000 lb. Vibratory Roller Bonner County, Idaho



Note the Effect on the Aggregate Texture



Why we roll / Why we go early



Why you should chip seal early in the season

- A chip seal needs Time to fully cure:
 - **160 hours pavement temp exceeding 110 F**
- The warmth is needed to soften the binder residue so that the final few percent of water that is trapped in the seal can work its way out
- This means even with a good design if the seal is done late in the season the final product will not be achieved until the next season.
- The earlier the better!! Let the warm weather help traffic finish the seal
 - Late seals often don't reach final voids and most stable chip embedment and may not have released all their water making them susceptible to raveling and Plow damage.

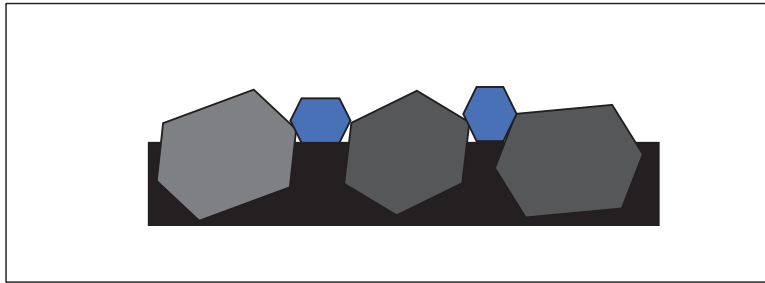
Sealed in Sept. on Shady Road. Emulsion did not cure, just stiffened. Peeled off under traffic. Section in full sun looks great.



Holes left by late season water vapor escaping the seal in the following season



Why we use Choke aggregate



- Choke acts as a blotter forming a barrier between vehicle tires and any exposed emulsion from the seal.
 - Don't use too much or too dirty that may not allow water vapor to escape the seal and delay curing
- Choke helps to keep the chips from rolling around
 - The choke aggregate wedges in between the chips
 - Those chips can't turn over which would expose fresh emulsion and cause the seal to track
- Choke helps the emulsion break
 - Emulsion wants to break when it makes contact with rock

Fog Sealing: Benefits over chipseal

- Extra Security against chip loss – Add'l emulsion residue
- Help in post construction traffic embedding action
 - Black color increases pavement temp to soften residue for improved embedment from traffic. Extends window to cooler days
- Aesthetics – black like new pavement

Fog Sealing

- .12 to .14 gal/yd² on chip seals
- .08 to .10 gal/ yd² on pavements
- Loss of skid resistance is a concern over dense pavements
 - Use of Sand is good temporary fix
- Recommended emulsions are CSS-1 or 1H Dil, Rapid Setting fogs, etc.

Fog Sealing has benefits beyond Chip Seal use

- TRB Paper 08-0632, Fog seals are cost effective
- Seal pavement against water/oxidation
- Reduce hardening - Flexibility of Pavement
- Reduce / delay deterioration - Maintain Texture
- Need to be applied early in pavement life
 - Start within 1 to 2 years of paving
- No or little visible cracking
- Fog wears off surface but stays in matrix.
 - Review of 4 yr. old fog seals show the seal effects still present. Retarding water infiltration

I -90 After First Winter
Was much tighter when new



Fresh fog
Filling voids – sealing against water and air
infiltration



Points to remember

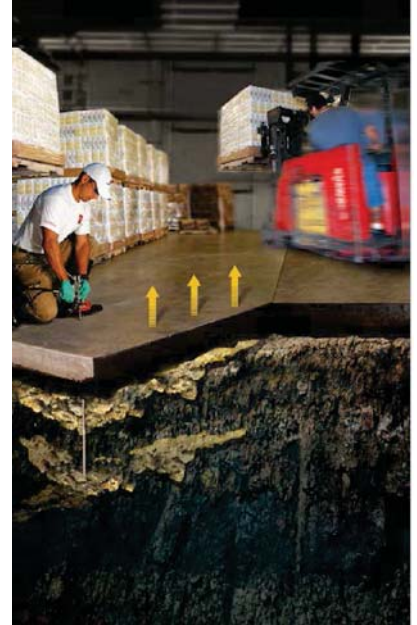
- Do your sealing early in the season (You need cure time)
- Do a design / Understand the size and cleanliness of your rock, the condition of the road and traffic count.
- Roll, Roll, Roll
- Add that steel roller
- Remember to compensate for new mats, open pavements, shady areas. They need more emulsion / Extra Rolling



REX KLENTZMAN, P.E.
DIRECTOR OF ENGINEERING,
URETEK USA
URETEK ICR

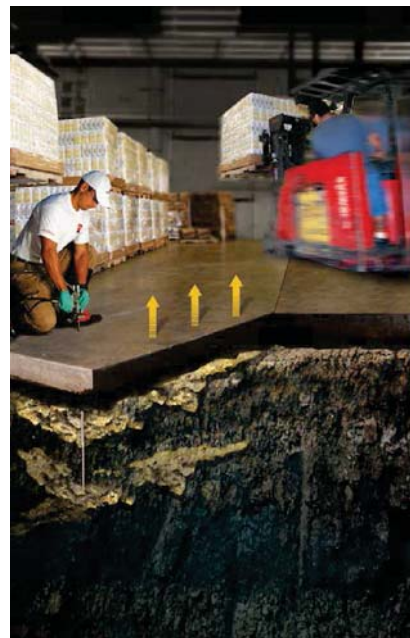
Welcome

*POLYURETHANE
GROUTING
Ground Modification*



today's agenda

- ✓ History of Polyurethane grouting
- ✓ Polyurethane grouting applications
- ✓ Poly-jacking
- ✓ URETEK deep injection™ Summary
- ✓ Testing
- ✓ Case Studies



1979



URETEK patents the polyurethane grouting process

URETEK advances equipment technology of total proportion and injection control of polyurethane and patents **The URETEK Method™** (U.S. Patent No. 4,567,708).

1988

Exclusive rights in U.S.

URETEK USA, Inc., is granted the exclusive license rights for sales and installment of product and services in the U.S. and Mexico.



2003

Deep Injection Patented

URETEK's **Deep Injection Process** patent is issued, a process to increase the load bearing capacity of weak soils at individual depths through polymer injection.



2017

Chapter in progress...

URETEK's story continues as our **business growth and value are at an all time high.** New materials and solution offerings to clients to be unveiled later this year.



applications overview



- ✓ Lift sunken paving and structures
- ✓ Provide Strength to weak subgrade
- ✓ Extend pavement life by strengthening subgrade
- ✓ Restore/increase soil bearing capacity for existing structural footings including bridge footings
- ✓ Halt settlement caused by weak load bearing soils
- ✓ Infrastructure Stabilization, Soil Erosion Remediation

method

SLABleveling | POLYjacking



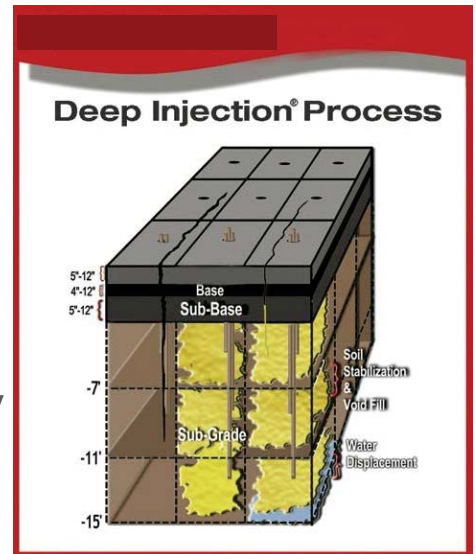
- 1993
- Two culverts run under road
- As much as 12" settlement



- 2008 photo
- Still smooth today after nearly 25 years

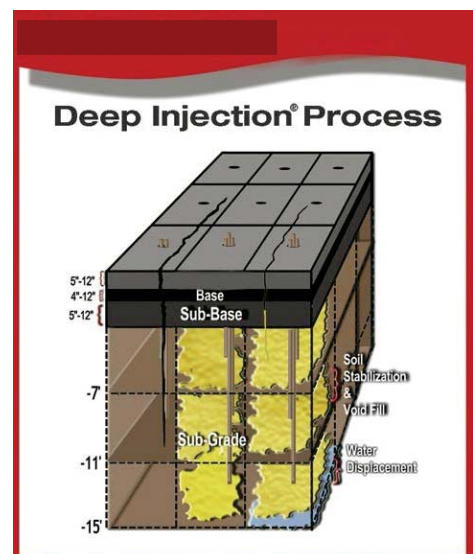
DeepInjection

increasing bearing capacity
and halting settlement



DeepInjection

- ✓ Multiple injection locations
- ✓ Expanding chemical substance is injected
- ✓ Injections result in compaction of soils
- ✓ Surface is monitored for motion
- ✓ 5 x Expansion of chemical after injection



DeepInjection

- ✓ drill 5/8" hole through foundation or footing as required
- ✓ set half inch steel rod at injection depth
- ✓ inject structural polymer
- ✓ continuously monitor surface elevations for movement



soil box injection demonstration



Injection inside steel reinforced, plexi-glass box so material flow could be observed

soil box injection demonstration



Stabilized soil mass was
free-standing after box
removed

Deep Injection

soil box
injection
demo

soil box injection demonstration



Vertical load
applied
using a
backhoe

soil box injection demonstration



Vertical load applied using an excavator





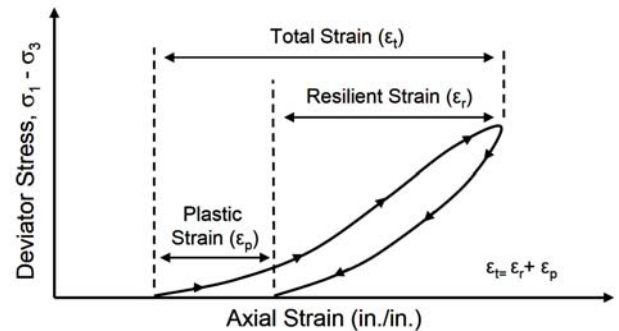
TEC Services
Testing • Engineering • Consulting

Boudreau Engineering, Inc.
PAVEMENT DESIGN, EVALUATION
& MATERIALS CONSULTANTS

Laboratory Research

Deep Injection Process

Effect on Unbound Pavement Base Lay



Laboratory Research
Deep Injection Process



TEC Services
Testing • Engineering • Consulting

Boudreau Engineering, Inc.
PAVEMENT DESIGN, EVALUATION
& MATERIALS CONSULTANTS

PURPOSE

Test Geo-materials with and without polyurethane injection treatment to determine effect on Strength

- Axial Strain
- Repeated Load Permanent Deformation (NCHRP 598)
- Youngs Modulus



Laboratory Research Deep Injection Process



Three geo-materials studied:

- graded aggregate base
- 57 stone,
- natural sand.



Laboratory Research URETEK Deep Injection Process



3-Phase Composition

- Geo-material is comprised of solids, liquid (water), and gas (air).
- Common physical properties, such as moisture content, density, void ratio, porosity, specific gravity, and saturation are all derivatives of this phase composition.
- The polyurethane product infiltrates the void structure (displacing air and most of the free water) to create a bound matrix.

Mass		Volume
$M_A = 0$	Air	V_A
M_W	Water	V_W
M_T		V_T
M_S	Solids	V_S

Laboratory Research URETEK Deep Injection Process



Strength Increase

Graded Aggregate Base

- 700%

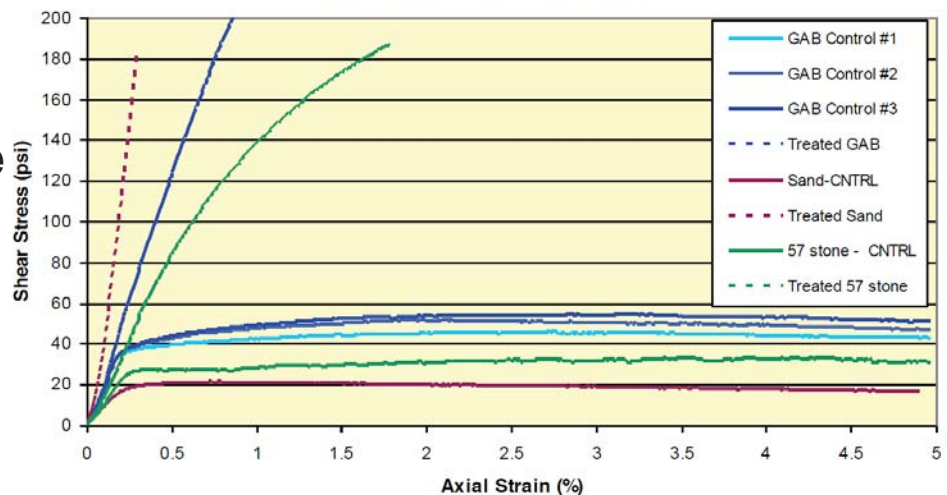
57 stone

- 1,000%

Natural sand

- 7,000%

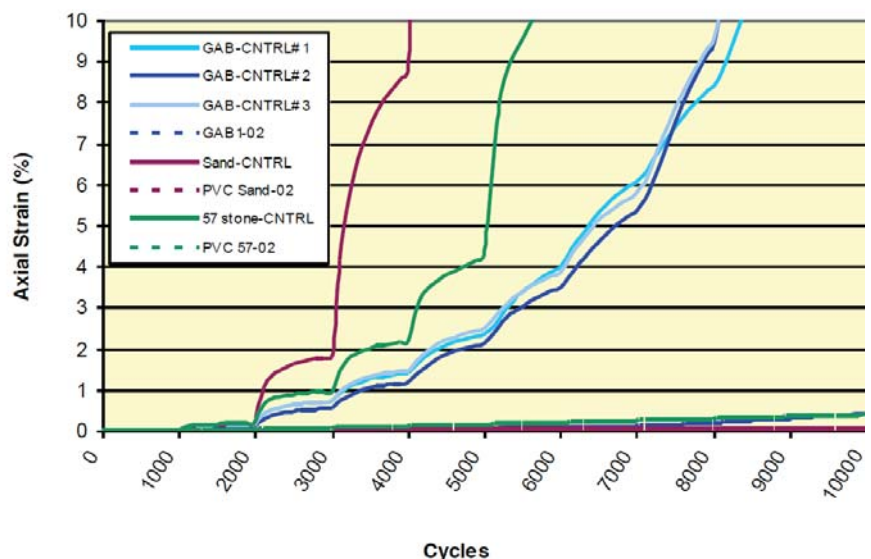
Quick Shear Test Results



Repeated Load Permanent Deformation Test (NCHRP Report No. 598)

- Polyurethane injection promotes a very high resistance to strains.

* These strains often produce pavement distresses such as rutting (flexible pavements) and faulting (rigid pavements).



TRANSPORTATION



**Asphalt pavement
systems - stabilization
and lifting**

TRANSPORTATION

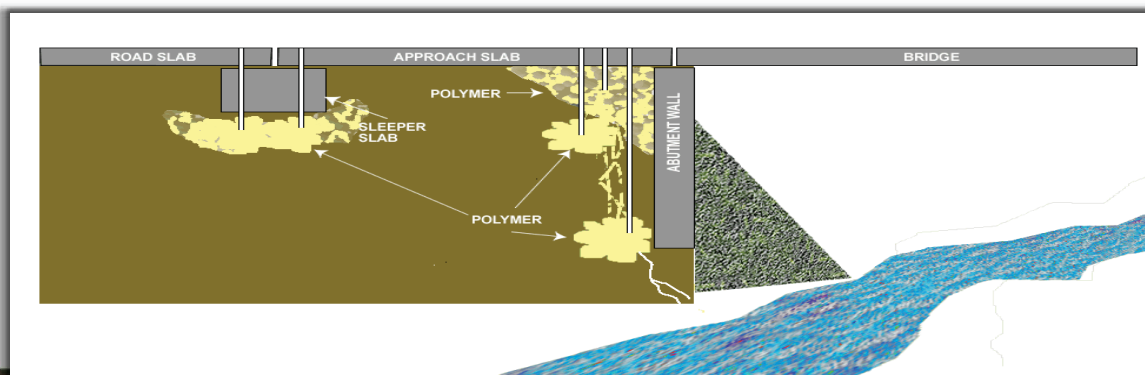
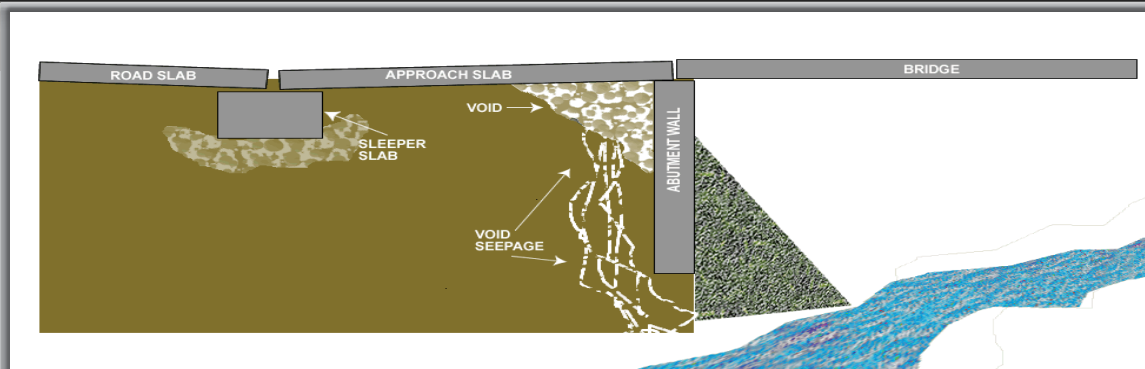


**Composite pavement
systems - stabilization
and lifting (including
pavement systems that
demonstrate reflective
cracking)**

TRANSPORTATION



BRIDGE APPROACH & DEPARTURE



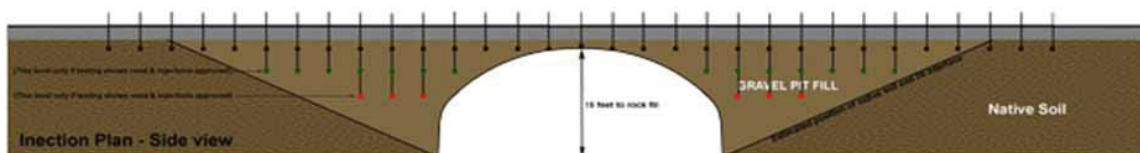
Road Settlement over Culvert Shelley, ID



Road Settlement over Culvert



● Approximate Location of Injections, on 4' grid pattern



- injection points for 1st level - approximately -3.5 feet depth
- injection points for 2nd level - approximately -6.5 feet depth, if DCP testing shows significant weakness at this level
- injection points for 3rd level - approximately -10 feet depth if DCP testing shows significant weakness at this level

MD Route 410, ROAD DIP



September 2003

- 6" Dip in road, 25'x15' section

MD Route 410, ROAD DIP



- August 2013, ten years later

Asphalt Pavement Repair

US 65 @ Route
WW

CARROLL
COUNTY
MISSOURI



US 65 is a two-lane asphalt highway with gravel shoulders; terrain = rolling hills

Hill in the project area was cut down 5' to provide better visibility

Base: 10" – 12" of reclaimed asphalt with crushed stone placed over the cut

Paving operations were stopped when the base exhibited 2" ruts and finger-width cracks

Emergency stabilization of subbase needed to open the road in time for Memorial Day 2011



Water Truck
used for
coring –
caused ruts
in base
material



Data Collection / Analysis

- MODOT = Falling Weight Deflectometer (FWD)
- URETEK USA = Dynamic Cone Penetrometer (DCP)

Injection Summary

- Injection depths and pattern based on FWD and DCP
- 12, 984 square feet of pavement stabilized

US 65 - Carroll County, Missouri			DCP	DCP #1	DCP #2	DCP #3	DCP #4	DCP #5
In	ft	cm						
depth	depth	depth	Blows	Blows	Blows	Blows	Blows	Blows
3.94	0.33	10	asphalt	base	base	base	base	base
7.87	0.66	20	asphalt	base	base	base	base	base
11.81	0.98	30	asphalt	base	base	base	base	base
15.75	1.31	40	60	10	58	9	3	
19.69	1.64	50	90	16	40	26	27	
23.62	1.97	60	50	12	7	10	3	
27.56	2.30	70	28	7	2	2	5	
31.50	2.62	80	13	1	3	4	10	
35.43	2.95	90	2	3	6	4	7	
39.37	3.28	100	0	6	6	6	6	
43.31	3.61	110	0	6	6	6	6	
47.24	3.94	120	0	6	6	6	6	
51.18	4.26	130	1	6	6	4	7	
55.12	4.59	140	2	6	7	5	8	
59.06	4.92	150	4	6	6	5	10	
62.99	5.25	160	5	5	7	3	10	
66.93	5.58	170	4	6	10	11	9	
70.87	5.90	180	5	7	15	14	11	
74.80	6.23	190	4	8	12	14	12	
78.74	6.56	200	6	18	11	16	16	
82.68	6.89	210	6	13	11	13	14	
86.61	7.22	220	10	16	9	10	12	
90.55	7.54	230	10	16	8	11	11	
94.49	7.87	240	9	21	7	12	11	
98.43	8.20	250	10	20	6	11	10	
102.36	8.53	260	12	18	7	11	9	
106.30	8.86	270	10	19	8	7	7	
110.24	9.18	280	10	20	10	6	6	
114.17	9.51	290	12		8	6	6	
118.11	9.84	300	12		14	11	12	
122.05	10.17	310	16		15	14	14	



MoDOT's falling weight deflectometer trailer



Injection Area



Displaced Water During Injection

Results

- Average increase in subgrade modulus after polyurethane injection = 60%
- Average decrease in maximum deflection after polyurethane injection = 35%
- By injecting continuously for 24 hours, the crew met the deadline and the road was open for the Memorial Day weekend



FINAL REPORT

FHWA-WY-14/01F

State of Wyoming
Department of Transportation

U.S. Department of Transportation
Federal Highway Administration

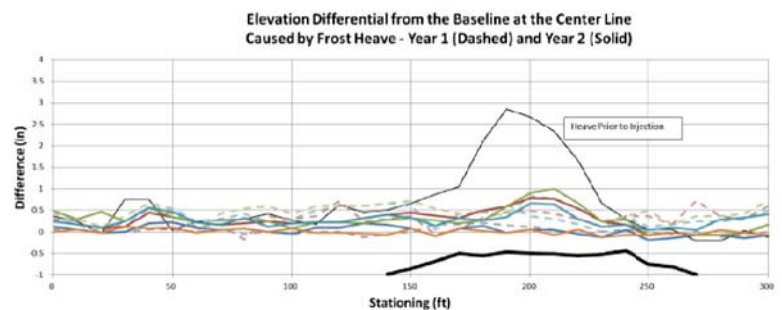
Frost Heave Mitigation

WY - 70

Encampment, WY

October, 2011

Instrumentation and Analysis of Frost Heave Mitigation on WY-70, Encampment, WY





FINAL REPORT

FHWA-WY-14/01F

Frost Heave Mitigation

WY - 70

Encampment, WY

October, 2011

Technical Report Documentation Page

Report No. FHWA-WY-14/01F	Government Accession No.	Recipients Catalog No.
Title and Subtitle Instrumentation and Analysis of Frost Heave Mitigation on WY-70, Encampment, WY		Report Date May 2014 Performing Organization Code
Author(s) Thomas V. Edgar, P.E., Ph.D.		Performing Organization Report No.
Performing Organization Name and Address Department of Civil and Architectural Engineering University of Wyoming 1000 E. University Avenue Laramie, Wyoming 82071		Work Unit No. Job No: RS05(211) Contact or Grant No. 1001139-4211-11681
Sponsoring Agency Name and Address Wyoming Department of Transportation 5300 Bishop Blvd. Cheyenne, WY 82009-3340 WYDOT Research Center (307) 777-4182		Type of Report and Period Covered Final Report June 2011 – May 2013 Sponsoring Agency Code
Supplementary Notes Research Director: Timothy McDowell, 307-777-4412		
Abstract This project investigated a novel procedure to reduce or prevent subgrade freezing non-destructively by injecting a two-part polymer foam at the top of the subgrade. Controlled injection of Uretek Star, expanding structural polymer foam, created a continuous three-inch thick layer of insulation that significantly reduced the heat loss from the deeper soil and almost totally eliminated frost heave at a site on highway WY-70, four and one-half miles west of Encampment, WY. The foam layer also prevented the upward movement of water from the warmer regime under the foam to the upper frozen regime above the foam. This prevented any segregational freezing in the upper zone. The two-year research project consisted of measuring pavement elevation changes along five 300-foot long lines over the heave area and monitoring subsurface temperatures at six locations inside and outside of the injection zone. The construction time for the 100-foot section was one week for injection and milling the surface. Construction was contained in one lane, leaving a lane open for the entire duration without a detour, increasing safety and minimizing impact for the driving public. Additionally, a procedure is developed for estimating the thickness of the foam layer required for other sites with different average temperatures.		
Key Words Frost Heave, Remediation, Urethane Foam, Injection, Insulation, Soils, Wyoming		Distribution Statement Unlimited
Security Classif. (of this report) Unclassified	Security Classif. (of this page) Unclassified	No. of Pages 125 Price

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FINAL REPORT

FHWA-WY-14/01F

Site Layout





FINAL REPORT

FHWA-WY-14/01F

Summary

- Reduce/Prevent Subgrade Freezing
- Non destructive injection of URETEK Polymer
- Create layer of insulation to reduce heat loss from lower soils
- Prevent upward movement of water from warmer lower soils
- 2 year monitoring of pavement elevations and subgrade temperatures
- **"Almost Totally Eliminated Frost Heave"**



FINAL REPORT

FHWA-WY-14/01F

Site Considerations

- Frost Heave creating dangerous driving conditions
- Sharp hump in road
- During Construction road raised by placing 3' of subgrade soil over non rippable rock outcrop
 - Silty Sand, Highly susceptible to frost heave
- Prior remediation attempts unsuccessful
 - Drainage pipes installed
 - Lateral drains installed





FINAL REPORT

FHWA-WY-14/01F

Proposed Remediation

- Injection of polymer at 18" below grade
- Level road surface and provide insulated polymer layer
- The road surface was milled
- Instrumentation was placed and wired to the data logger.
- The collection of data began on November 18, 2011
- The site was monitored over the next two winters



FINAL REPORT

FHWA-WY-14/01F

Frost Heave Reduction

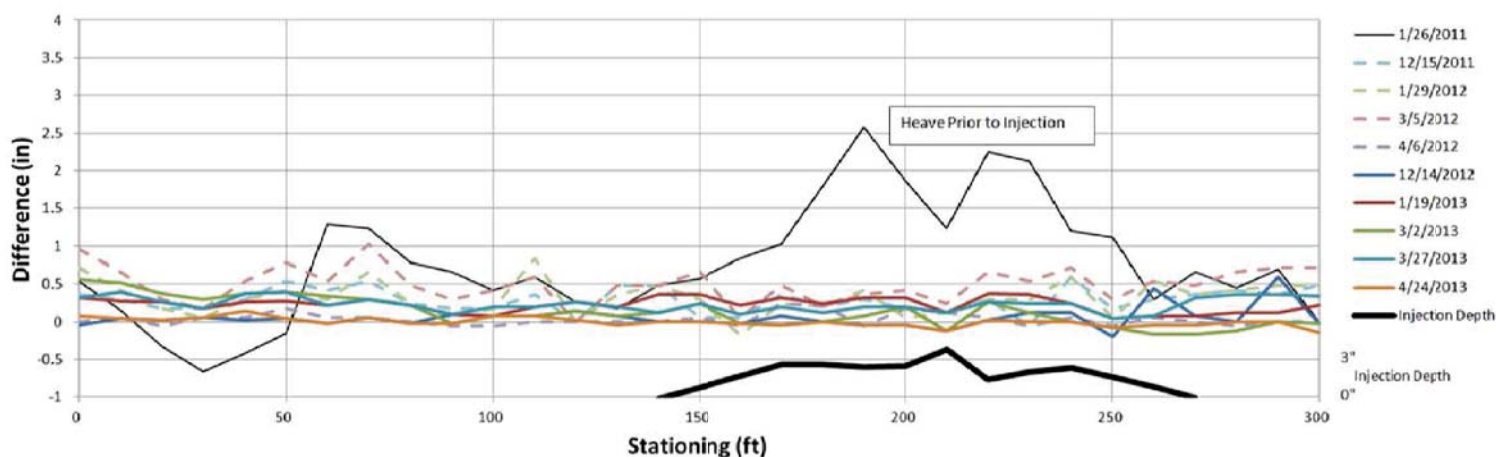


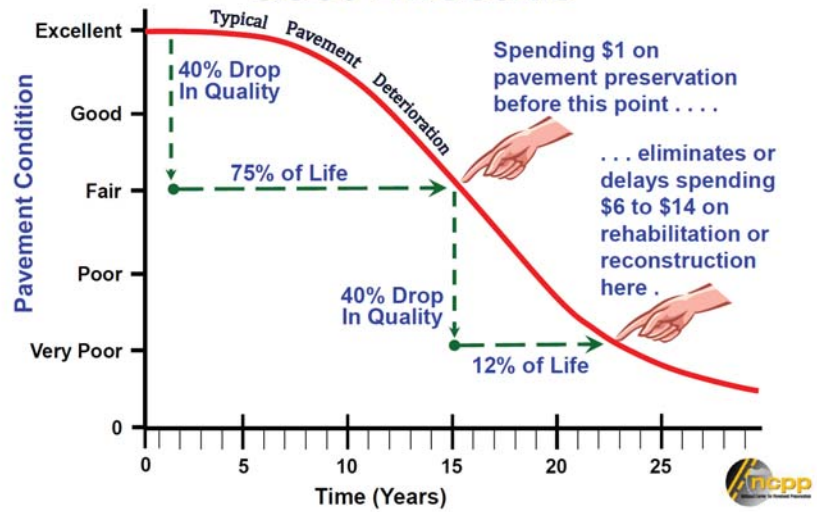
Figure 42. Graph. Frost heave along centerline of east bound lane (CLEB) – Year 1 (Dashed) and Year 2 (Solid)

Prior to Treatment = 4"

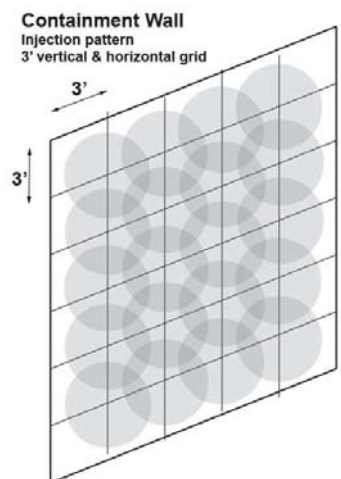
Post Treatment = 0.5"

BENEFITS OF INVESTING IN THE RESTORATION OF PAVING INFRASTRUCTURE

Pavement Preservation is Cost Effective



Injected containment barrier



**DOT Application: Re-direct flow away from road
base**

INSITU SHORING SYSTEM And Containment Wall



Underground Infrastructure

Extend the service life and rehabilitate existing underground infrastructure.



Manhole Sealing

Manhole Sealing/Rehabilitation

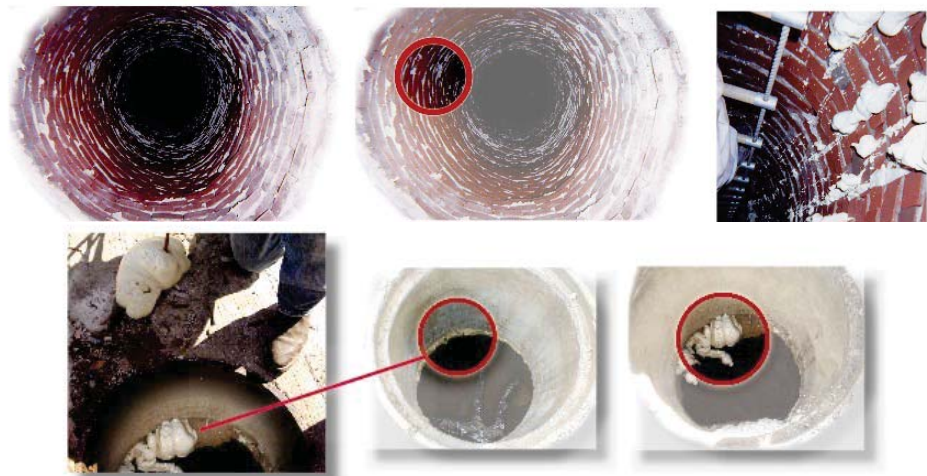
Rehabilitate and restore structural integrity
Quickly eliminate soil erosion and seepage concerns.

Leak Sealing and restoration

Seal eroded and deficient manholes and lateral lines.

Soil Erosion Control

Extend the service life and rehabilitate aging infrastructure without excavation.



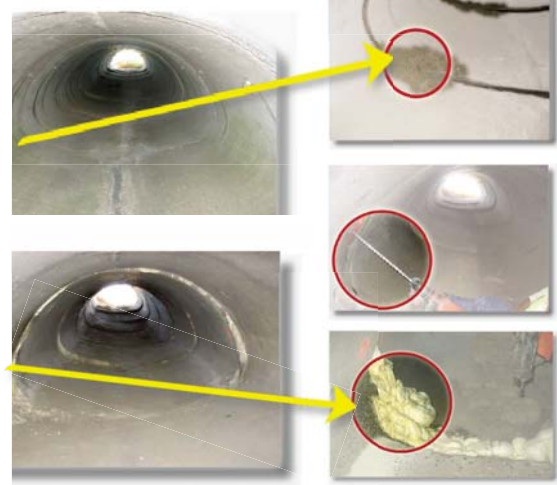
Sewer Main Sealing

Lateral Line Sealing/Encapsulation

Rehabilitate and restore structural integrity.
Quickly eliminate soil erosion and seepage.



Infrastructure Stabilization/Soil Erosion Control



erosioncontrol



emergencyinfrastructure



Dam and spillway

Rehabilitate and restore structural integrity. Quickly eliminate soil erosion and seepage concerns.

Sea and lake wall

Seal eroded bulkhead and wall joints and eliminate water and soil seepage/erosion.

conduit and outfall

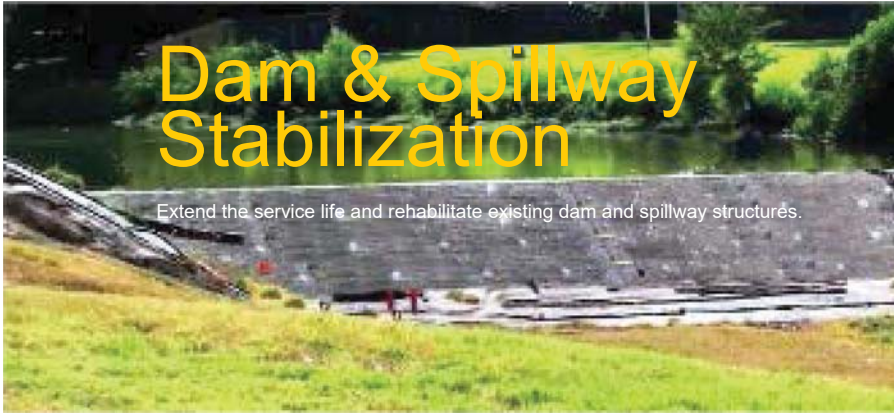
Extend the service life and rehabilitate existing conduit and outfall structures quickly, safely.

emergencyinfrastructure



Dam & Spillway Stabilization

Extend the service life and rehabilitate existing dam and spillway structures.



Thank You!

QUESTIONS???

THOUGHTS???



Use of Visual Distress Survey and Deflection Data for Rehabilitation Decisions in Idaho

57th Idaho Asphalt Conference

October 26, 2017, Moscow, Idaho

Presented By:

Deb Mishra, Ph.D., P.E.

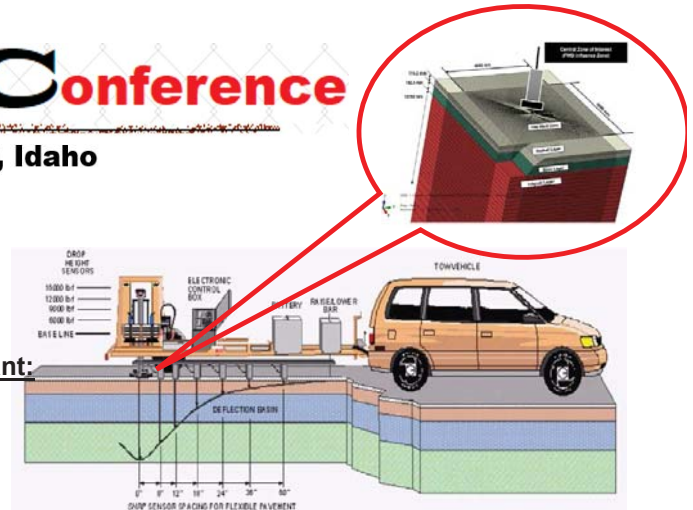
Assistant Professor

Dept. of Civil Engineering
Boise State University

Graduate Research Assistant:

Md. Fazle Rabbi

Grad. Research Assistant
Dept. of Civil Engineering
Boise State University



57th Idaho Asphalt Conference

October 26, 2017, Moscow, Idaho

1

Initial Version of Paper Presented at the 96th Annual Meeting of the Transportation Research Board



Use of Visual Distress Survey Data and Deflection Basin Parameters for Network-Level Pavement Rehabilitation Decisions in Idaho

96th Annual Meeting of the Transportation Research Board

Author:

Deb Mishra, Ph.D., P.E.

Assistant Professor

Dept. of Civil Engineering
Boise State University

Co-Author:

Md. Fazle Rabbi

Grad. Research Assistant
Dept. of Civil Engineering
Boise State University

Co-Author:

John Arambarri, PE,
Materials Engineer,
District 3
ITD

Co-Author:

Dan Harelson, PE,
Engineering Manager,
District 5
ITD



57th Idaho Asphalt Conference

October 26, 2017, Moscow, Idaho

2

Project Background and Scope

"Over the year the transportation department has routinely repaired the pavement but **even with this routine maintenance the pavement has reached the end of its life**; it's time to invest in a new surface".

-Dan Harelson,
ITD project manager

- ☐ Total length of I-15 In Idaho= 190 miles
- ☐ Replacing around 44 miles



Several sections were initially selected for Full-Depth Reclamation (CRABS); In-Depth Analysis of Structural Condition can lead to more educated decisions

Project No	Limits		Project Length		
	Start	End	Start	End	Length
1	Arimo Interchange	McCammon Interchange	39.8	47.5	7.7
2	Baseline	Bonneville	106.7	111.9	5.2
3	Chubbuck	Milepost 76.01	72.6	76.01	3.4
4	Lava Bed crossover	Baseline road	100.4	106.7	6.3
5	McCommon Interchange	South 5th Pocatello	47.5	66.8	19.3
6	Milepost 76.01	Burns Road	76.01	81.9	5.9
7	South Blackfoot	west Blackfoot	89.3	92.5	3.2
8	Sand Road	Blackfoot	85.6	89.3	3.7
9	West Blackfoot	Lava Beds	92.5	100.4	7.9



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3

Pavement Sections Analyzed

Projects: (District -3) Thank you John Arambarri!

- US-95 Payette NCL to Weiser River Bridge
 - MP 70.28 to 81.52
- SH-55 Pride Lane to Middleton Road
 - MP 7.1 to MP 15.6
- I-84, Sand Hollow to Caldwell
 - MP 17 to MP 26

Projects: (District -5)

- I-15, Sand Road to South Blackfoot
 - MP 85.6 to MP 89.3



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4

Objective and Motivation

1. Recurrent Pavement Distresses
2. Unprecedented Construction and Maintenance Costs
3. Frequent Traffic Interruption
4. Increased in User Costs

Full Reconstruction?
or
Partial Reconstruction?
or
Rehabilitation?
or
Successive Maintenance Approach??



What is the Probable Solution????

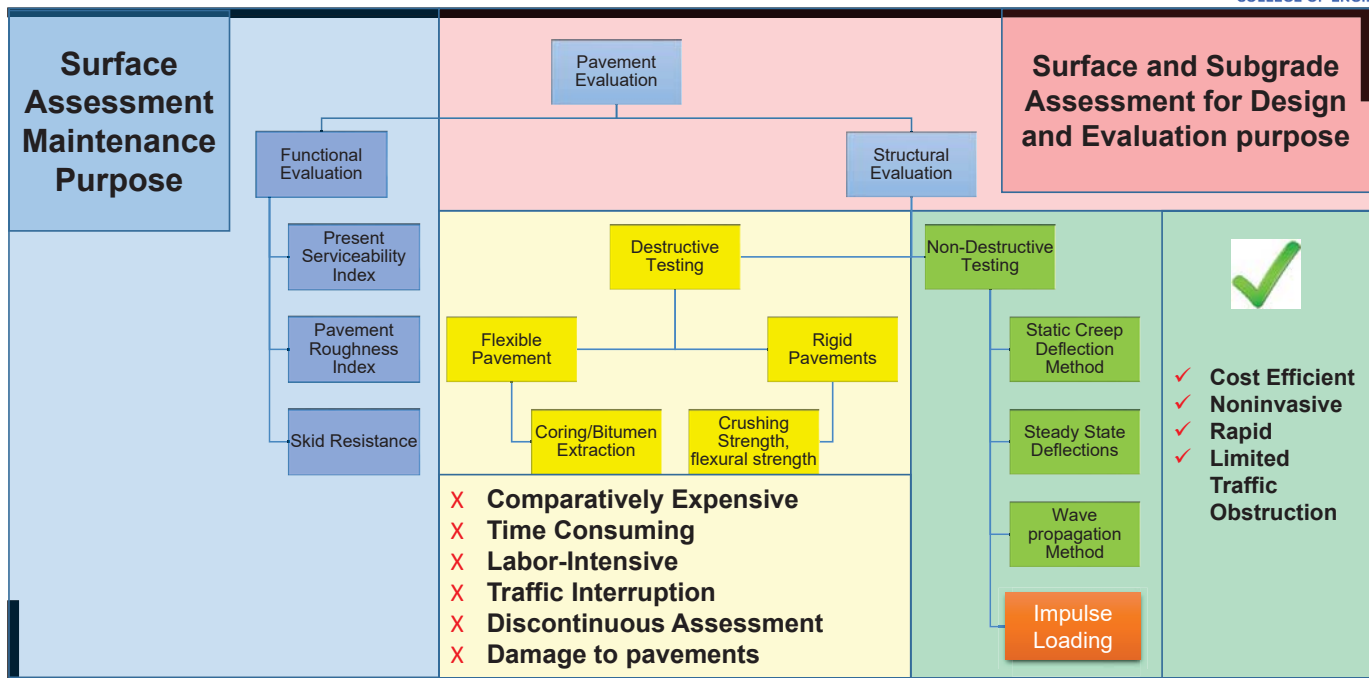


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en.wikipedia.org color.ngmexpo.com
www.qespavements.com www.fhwa.dot.gov/publications/transporter/96aug/index.cfm

5

Functional vs. Structural Pavement Evaluation



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6

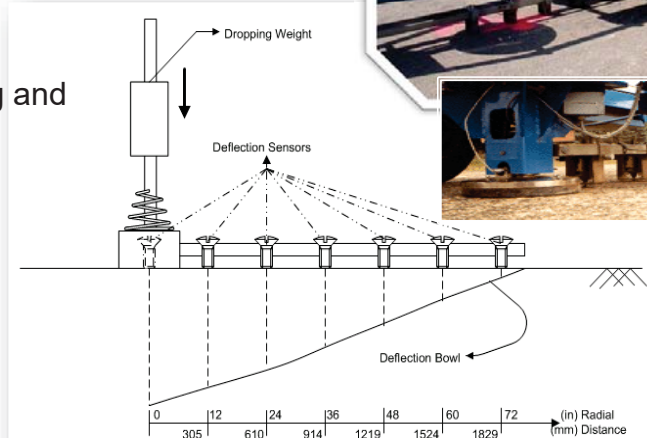
FWD (Impulse Loading Devices)

Falling Weight Deflectometer (FWD) is widely used to measure pavement surface deflections

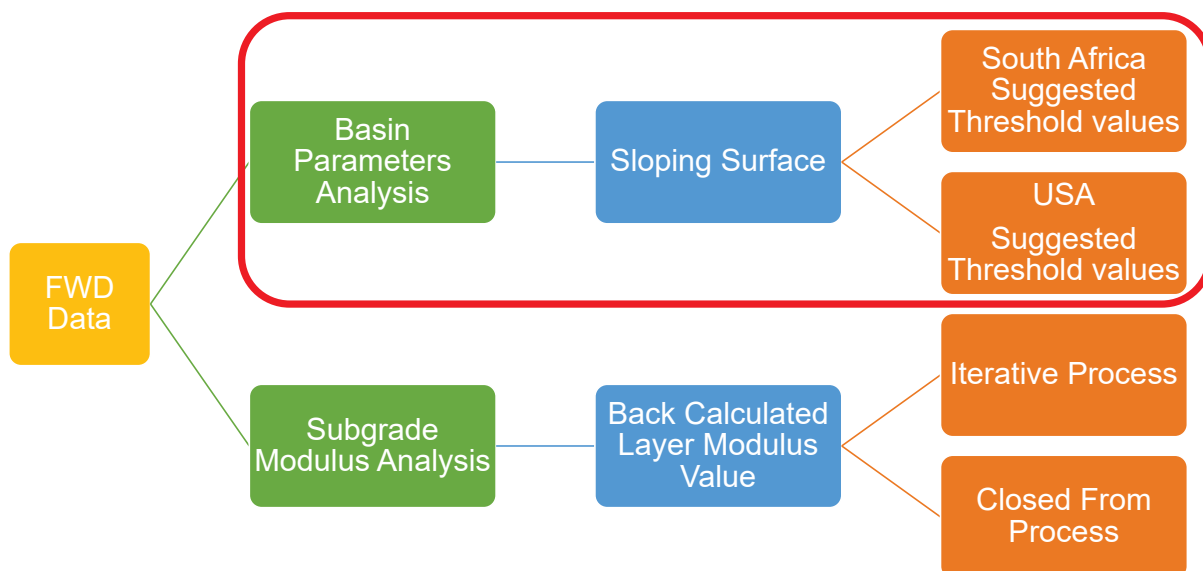
- FWD measures surface deflections by an **impact loading** to simulate a vehicular moving load.
- The system applies **controlled loading** and measures deflections.

Advantages:

- ✓ **Comparatively Fast**
- ✓ **Economical**



FWD Data Assessment Process

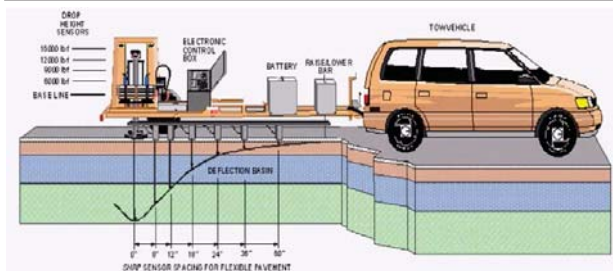


Backcalculation – A Challenge

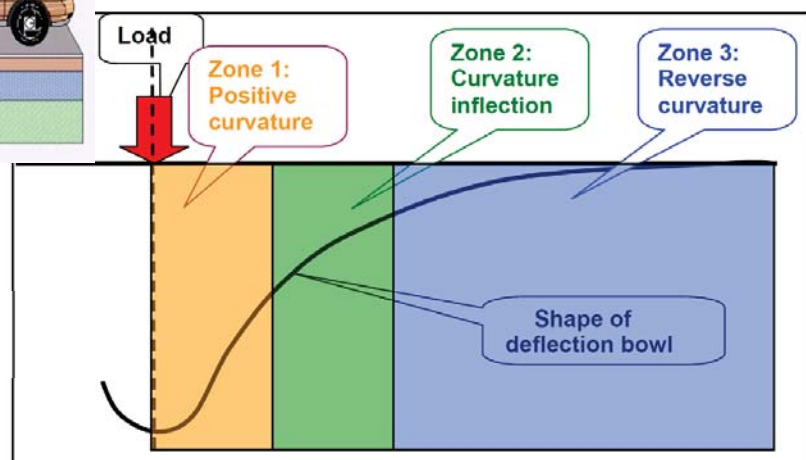
- ✓ Very powerful concept – needs good understanding of the procedure
- ✓ Pavement layer thicknesses – Important Input
- ✓ Not something that DOTs do on a daily basis

Is it possible to utilize FWD data at a network level without going through detailed back-calculation approaches?

Deflection Basin Shape – Relevant Inferences



Not a replacement for backcalculation ! Just a tool to help engineers



Deflection Basin Parameters Used in the US

Surface Curvature Index (SCI)

(also known as Base Layer Index, BLI)

$$SCI = D_0 - D_{300}$$

Middle Layer Index (MLI)

(also known as Base Damage Index, BDI)

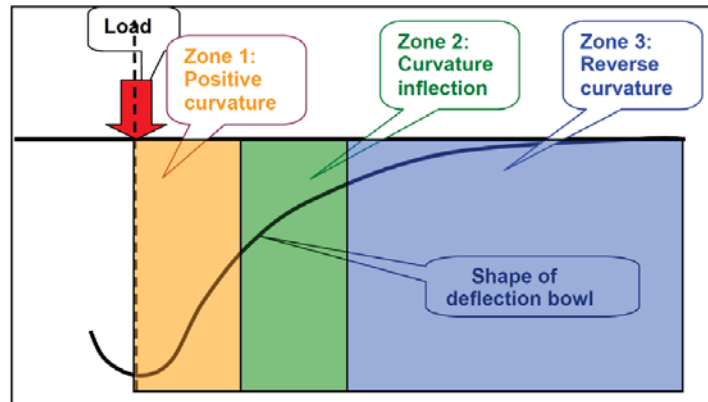
$$MLI = D_{300} - D_{600}$$

Lower Layer Index (LLI)

(also known as Base Curvature Index, BCI)

$$LLI = D_{600} - D_{900}$$

Shape of the deflection basin is governed by structural condition of individual pavement layers



Different Countries: Different Names



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Ref: Horak, E. (2008), "Benchmarking the Structural Condition of Flexible Pavements with Deflection Bowl Parameters"

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Deflection Bowl Parameters - South African Practice

Parameter	Formula	Structural indicator
Maximum Deflection	D_0 as measured	ALL Layers
Radius of Curvature (RoC)	$RoC = \frac{L^2}{2 \times D_0 \left(1 - \frac{D_0}{D_{200}}\right)}$ $L = 200 \text{ mm (for FWD)}$	Surface and Base Layer
Base Layer Index (BLI)	$BLI = D_0 - D_{300}$	Base Layer
Middle Layer Index (MLI)	$MLI = D_{300} - D_{600}$	Subbase/ Subgrade Layer
Lower Layer Index (LLI)	$MLI = D_{600} - D_{900}$	Subbase/ Subgrade Layer



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Ref: Horak, E., Emery, S., & Maina, J. Review of Falling Weight Deflectometer Deflection Benchmark Analysis on Roads and Airfields. In Proc. 11th Conf. on Asphalt Pavements for Southern Africa.

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Deflection Bowl Parameters and Thresholds

Base Type	Structural Condition Rating	Deflection Bowl Parameters (700 kPa)				
		Do (μm)	RoC (m)	BLI (μm)	MLI (μm)	LLI (μm)
Granular Base	Sound	< 625	> 90	< 250	< 115	< 65
	Warning	625 to 925	42-90	250-475	115-225	65-120
	Severe	> 925	< 42	> 475	> 225	> 120

Need to use consistent FWD load levels

Idaho Uses a Load Level of 12 kips for FWD Testing

Parameter	Formula	Structural indicator
Maximum Deflection	D_o as measured	ALL Layers
Radius of Curvature (RoC)	$RoC = \frac{(L)^2}{2D_o(1 - \frac{D_o}{D_{200}})}$ L= 200mm (FWD)	Surface and Base Layer
Base Layer Index (BLI)	$BLI = D_o - D_{300}$	Base Layer
Middle Layer Index (MLI)	$MLI = D_{300} - D_{600}$	Subbase/ Subgrade Layer
Lower Layer Index (LLI)	$LLI = D_{600} - D_{900}$	Subbase/ Subgrade Layer



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Ref: Horak, E., Emery, S., & Maina, J. Review of Falling Weight Deflectometer Deflection Benchmark Analysis on Roads and Airfields. In Proc. 11th Conf. on Asphalt Pavements for Southern Africa.

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Deflection Bowl Parameters & Thresholds

Deflection Basin Parameters Range		Remarks
SCI / BLI (mils)	< 4.00	Very Good Asphalt Layer
	4.00 - 6.00	Good Asphalt Layer
	6.00 - 8.00	Fair Asphalt Layer
	8.00 - 10.00	Poor Asphalt Layer
	> 10.00	Very Poor Asphalt Layer
MLI (mils)	< 2.00	Very Good Base Layer
	2.00 - 3.00	Good Base Layer
	3.00 - 4.00	Fair Base Layer
	4.00 - 5.00	Poor Base Layer
	> 5.00	Very Poor Base Layer
W ₆₀ (mils)	< 1.00	Very Good Subgrade Layer
	1.00 - 1.14	Good Subgrade Layer
	1.40 - 1.80	Fair Subgrade Layer
	1.80 - 2.20	Poor Subgrade Layer
	> 2.20	Very Poor Subgrade Layer



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Ref: Chang C, D. Saenz, S. Nazarian, I. N. Abdallah, A. Wimsatt, T. Freeman, and E. G. Fernando (2014) "TxDOT Guidelines to Assign PMIS Treatment Levels" (Table)

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Structural Evaluation of I-15, I-84, SH-55 & US-95 Sections using Deflection Basin Parameters

Different Pavement Sections Considered

1. US-95 Payette NCL to Weiser River Bridge
 - MP 70.28 to 81.52
 - FWD data collected in 2011
2. SH-55 Pride Lane to Middleton Road
 - MP 7.1 to MP 15.6
 - FWD data collected on 29 June 2016
3. I-84, Sand Hollow to Caldwell
 - MP 17 to MP 26
 - FWD data collected on 14 October 2015
4. I-15, Sand Road to South Blackfoot
 - MP 85.6 to MP 89.3
 - FWD data collected on 15 June 2011

$$d_{on} = \left(\frac{L_{norm}}{L_{applied}} \right) d_0 \quad [1]$$

Where: d_{on} = Normalized deflection
 L_{norm} = Normalized load
 $L_{applied}$ = Applied load
 d_0 = Measured deflection at selected sensor location

Normalized to "12000" lb Load

Functional Condition Assessment



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Condition Assessment Based on Rutting and International Roughness Index (IRI)


<http://pathweb.pathwayservices.com/idaho/> (edited)

Rutting Index	
Category	Rut Depth (in.)
Excellent	< 0.25
Good	0.25-0.37
Fair	0.38-0.50
Poor	> 0.50

Classification Based on IRI		
IRI Range	Criteria	Classification
	$IRI \leq 95$	Good
	$95 \leq IRI \leq 170$	Fair / Acceptable
	$IRI > 170$	Poor / Not Acceptable

Identifying the "source" of the problem is important for the selection of suitable rehabilitation measures

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Threshold Values used to Classify Pavements Based on Distress Extent and severity



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Distress Type	Distress Severity / Magnitude							
	I-15		I-84		US-95		SH-55	
	Value	Rating	Value	Rating	Value	Rating	Value	Rating
Cracking Index	2.6	Fair	3.8	Good	2.2	Poor	1.6	Poor
International Roughness Index (IRI, in/mi)	< 95	Good	56 (avg.)	Excellent	90.5 (avg.)	Good	156 (avg.)	Poor
Roughness Index (RI)	3.40	Good	3.95	Good	3.33	Good	2.51	Fair
Average Rut Depth (inch)	0.43"	Fair	0.24"	Good	0.46"	Fair	0.24"	Good

*The data was taken from ITD's visual distress survey database.

IRI values for the I-84, US-95, and SH-55 segments were extracted from reports prepared by ITD. IRI values for the I-15 segment are extracted from the visual distress survey database

Condition: Cracking Index	
Pavement Condition	Functional Class Interstate and Arterials
Good	CI > 3.0
Fair	2.5 ≤ CI ≤ 3.0
Poor	2.0 ≤ CI ≤ 2.5
Very Poor	CI < 2.0
Condition: Roughness Index	
Pavement Condition	Functional Class Interstate and Arterials
Good	RI > 3.0
Fair	2.5 ≤ RI ≤ 3.0
Poor	2.0 ≤ RI ≤ 2.5
Very Poor	RI < 2.0
Condition: Rutting	
Pavement Condition	Functional Class Interstate and Arterials
Good	0.00" – 0.24"
Fair	0.25" – 0.49"
Poor	0.50" – 0.74"
Very Poor	≥ 0.75"
Condition: IRI (inch/mile)	
Pavement Condition	Functional Class Interstate and Arterials
Excellent	<60
Good	60-99
Fair	100-139
Poor	140-199
Very Poor	≥200

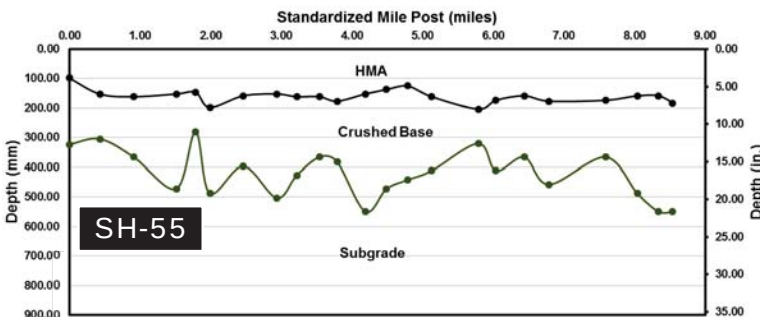
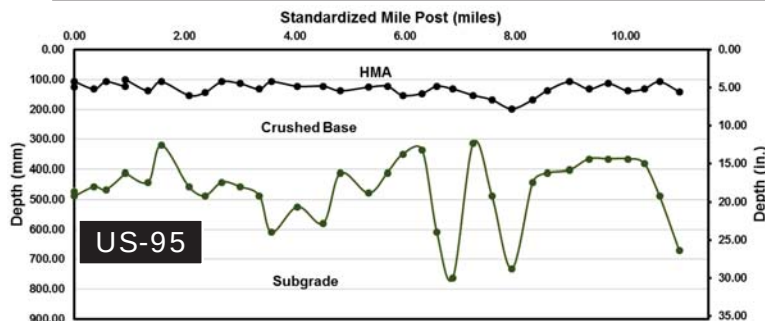


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Pavement Layer Profiles of US-95, SH-55 & I-15

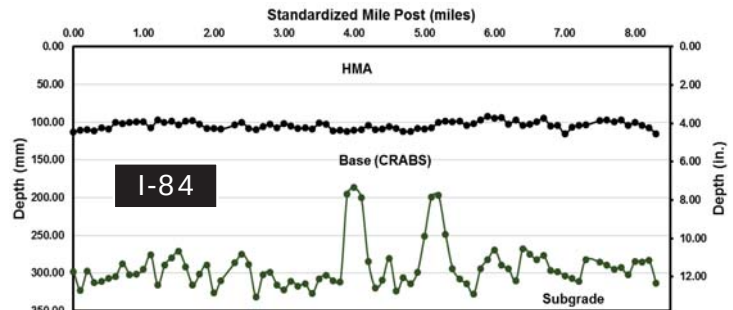


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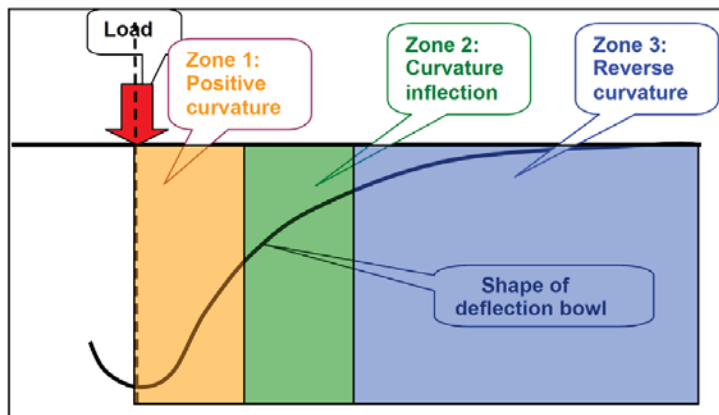
Pavement Layer Profiles

- (a) I-84 (Ground Penetrating Radar)
- (b) US-95 (Boring logs)
- (c) SH-55 (Boring logs)

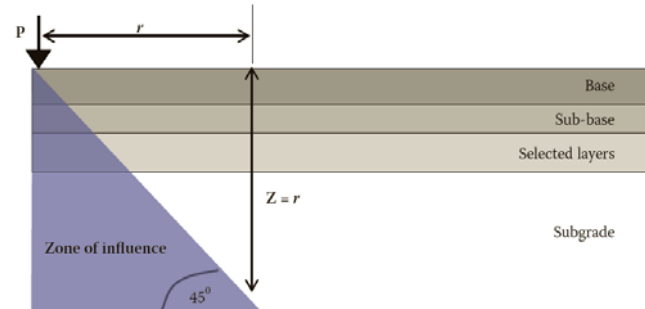


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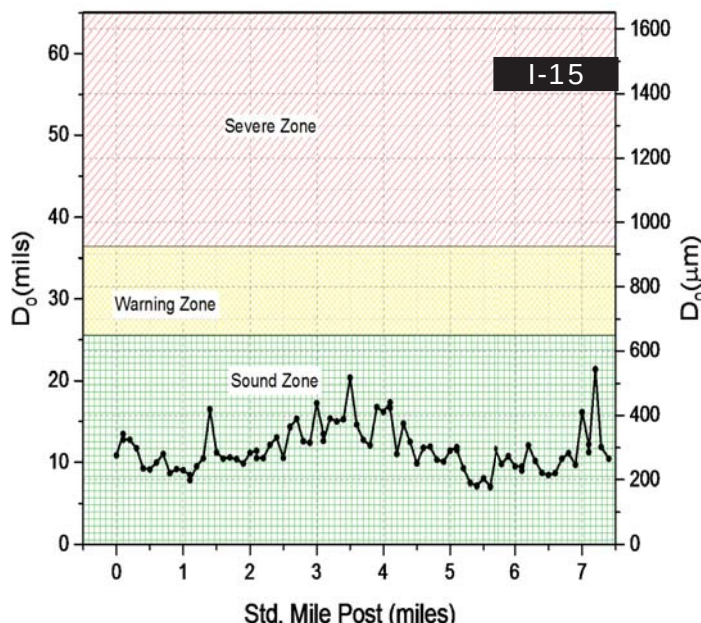
Inferences based on Deflection Basin – Zone 1



Inferences based on Shape of Stress Dissipation Curve



Pavement Assessment Based on Deflection Bowl Parameters



Base Type	Structural Condition Rating	Deflection Bowl Parameter
		D_0 (μm)
Granular Base	Sound	< 625
	Warning	625-925
	Severe	> 925

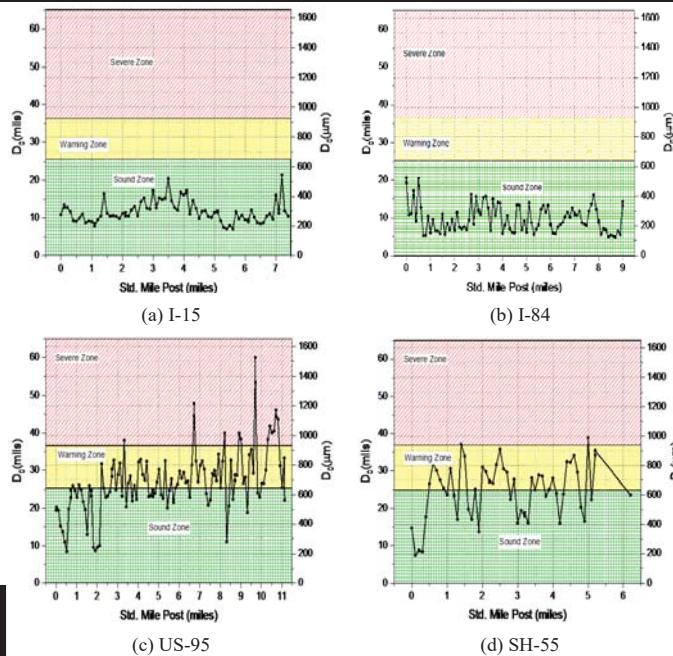
Deflection under the Load

Central Deflection as an Indicator of Overall Pavement Structural Condition

Pavement Assessment Based on Deflection Bowl Parameters



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Base Type	Structural Condition Rating	Deflection Bowl Parameter
		Do (μm)
Granular Base	Sound	< 625
	Warning	625-925
	Severe	> 925

Deflection under the Load

Central Deflection as an Indicator of Overall Pavement Structural Condition



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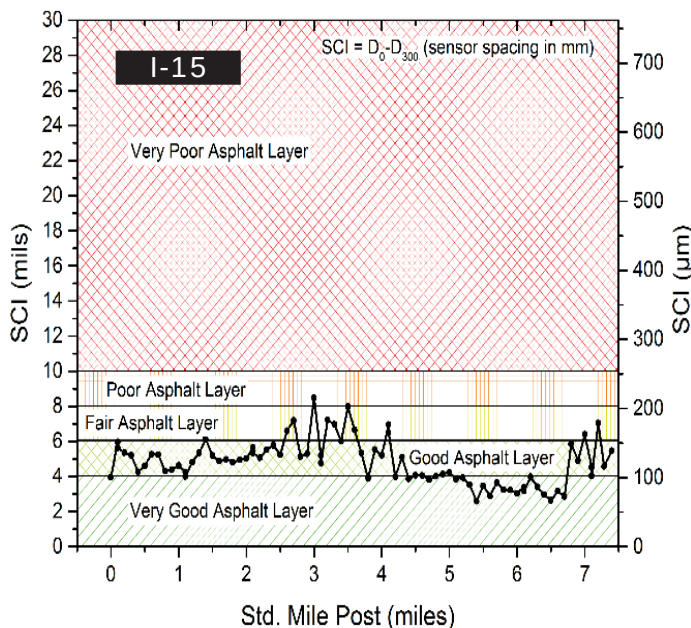
Ref: Levi, G. (2016), Horak, E., Emery, S., & Maina, J. Review of Falling Weight Deflectometer Deflection Benchmark Analysis on Roads and Airfields. In Proc. 11th Conf. on Asphalt Pavements for Southern Africa.

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Pavement Assessment Based on Deflection Bowl Parameters



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SCI (BLI)	Remarks
< 4.00	Very Good Asphalt Layer
4.00 -- 6.00	Good Asphalt Layer
6.00 -- 8.00	Fair Asphalt Layer
8.00 -- 10.00	Poor Asphalt Layer
> 10.00	Very Poor Asphalt Layer

Surface Curvature Index

Structural Condition Indicator for HMA Layer

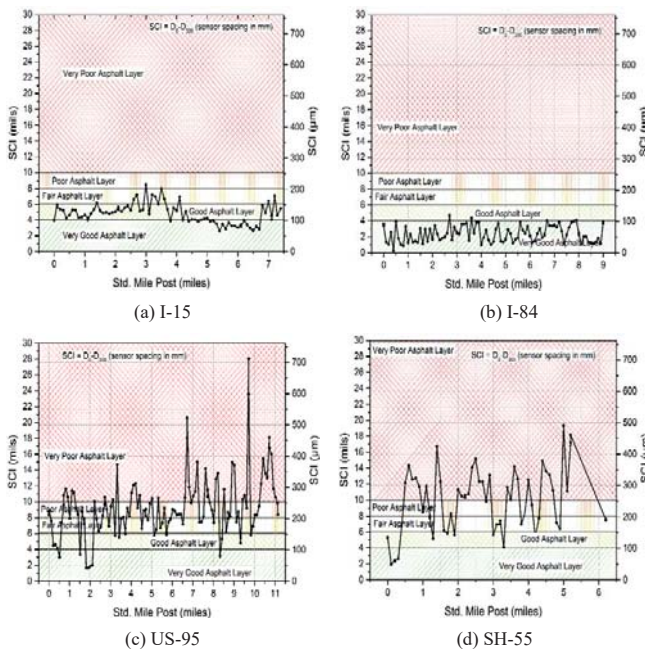


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Ref: Chang C, D. Saenz, S. Nazarian, I. N. Abdallah, A. Wimsatt, T. Freeman, and E. G. Fernando (2014) "Txdot Guidelines to Assign PMIS Treatment Levels" (Table)

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Pavement Assessment Based on Deflection Bowl Parameters



SCI / BLI (mils)	Inference
< 4.00	Very Good Asphalt Layer
4.00 -- 6.00	Good Asphalt Layer
6.00 -- 8.00	Fair Asphalt Layer
8.00 -- 10.00	Poor Asphalt Layer
> 10.00	Very Poor Asphalt Layer

Surface Curvature Index

Structural Condition Indicator for HMA Layer

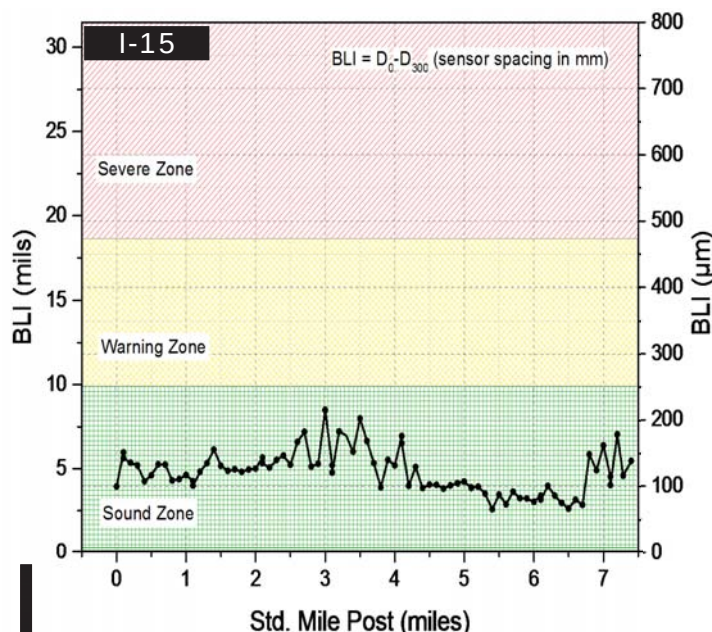


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Ref: Chang C, D. Saenz, S. Nazarian, I. N. Abdallah, A. Wimsatt, T. Freeman, and E. G. Fernando (2014) "Txdot Guidelines to Assign PMIS Treatment Levels" (Table)

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Pavement Assessment Based on Deflection Bowl Parameters



Base Type	Structural Condition Rating	Deflection Bowl Parameter
		BLI (μ m)
Granular Base	Sound	< 250
	Warning	250 - 475
	Severe	> 475

Base Layer Index

Numerically equivalent to SCI

However, used to Assess Base Layer Condition



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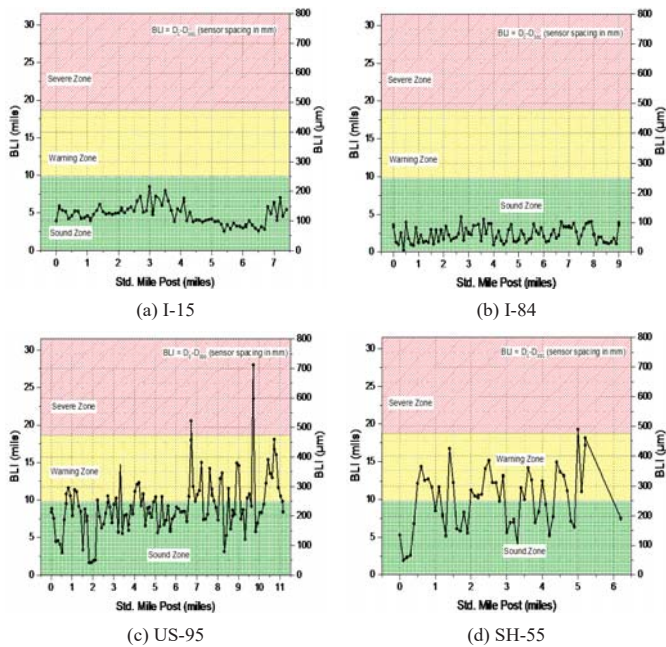
Ref: Horak, E., Emery, S., & Maina, J. Review of Falling Weight Deflectometer Deflection Benchmark Analysis on Roads and Airfields. In Proc. 11th Conf. on Asphalt Pavements for Southern Africa.

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Pavement Assessment Based on Deflection Bowl Parameters



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Base Type	Structural Condition Rating	Deflection Bowl Parameter
		BLI (μm)
Granular Base	Sound	< 250
	Warning	250 - 475
	Severe	> 475

Base Layer Index

Base Condition Indicator



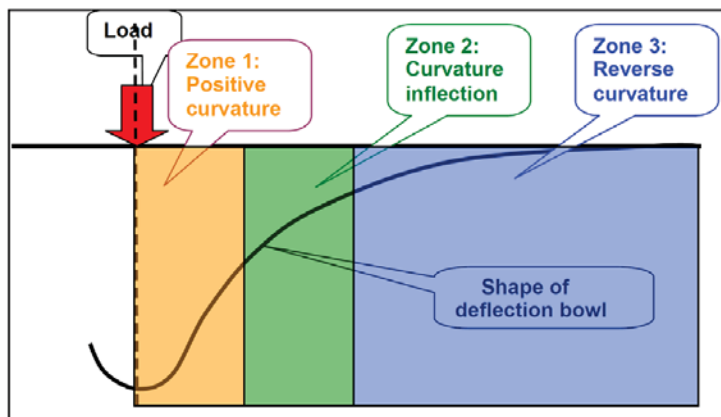
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Ref: Horak, E., Emery, S., & Maina, J. Review of Falling Weight Deflectometer Deflection Benchmark Analysis on Roads and Airfields. In Proc. 11th Conf. on 27
Asphalt Pavements for Southern Africa.

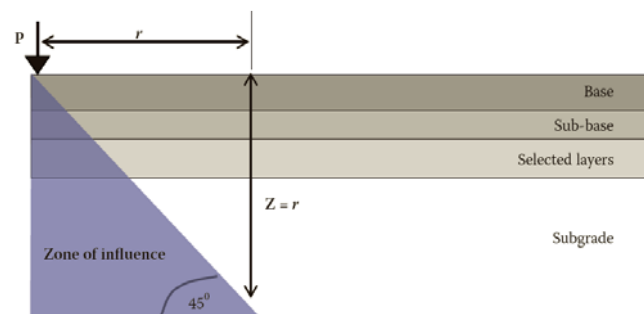
Inferences based on Deflection Basin – Zone 2



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Inferences based on Shape of Stress Dissipation Curve



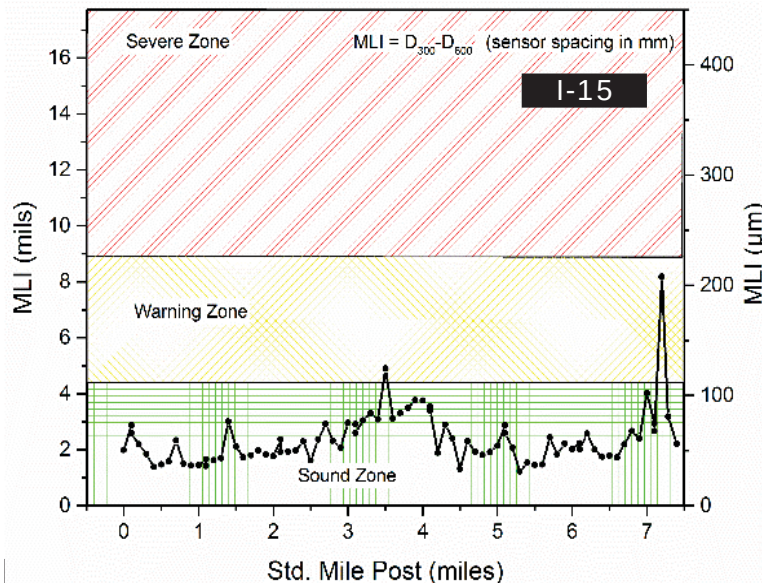
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Pavement Assessment Based on Deflection Bowl Parameters



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Base Type	Structural Condition Rating	Deflection Bowl Parameters
		MLI (μm)
Granular Base	Sound	< 115
	Warning	115-225
	Severe	> 225

Middle Layer Index

Inferences Concerning Intermediate Pavement Layers



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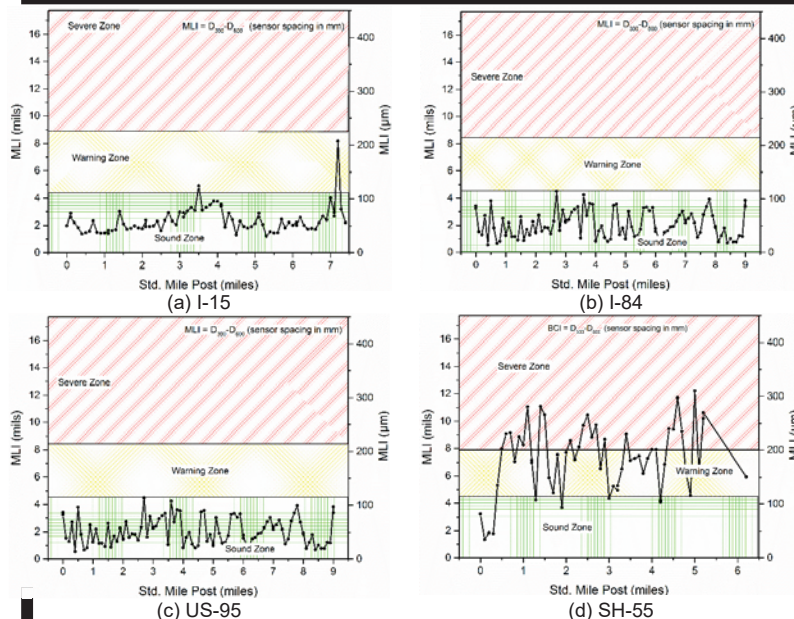
Ref: Horak, E., Emery, S., & Maina, J. Review of Falling Weight Deflectometer Deflection Benchmark Analysis on Roads and Airfields. In Proc. 11th Conf. on Asphalt Pavements for Southern Africa.

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Pavement Assessment Based on Deflection Bowl Parameters



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Base Type	Structural Condition Rating	Deflection Bowl Parameters
		MLI (μm)
Granular Base	Sound	< 115
	Warning	115-225
	Severe	> 225

Middle Layer Index

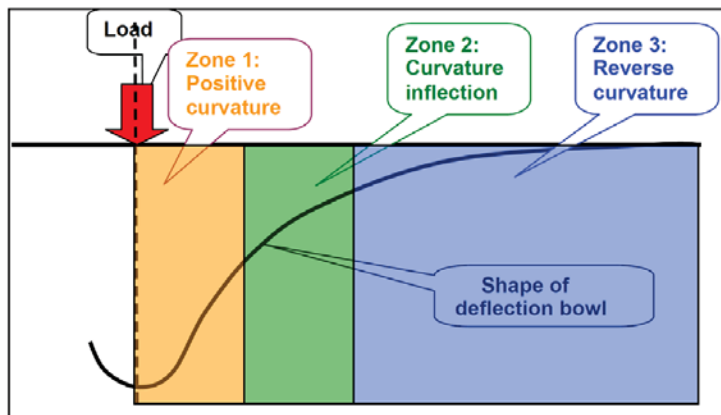


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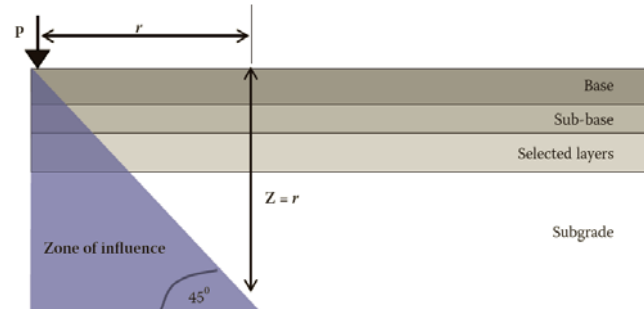
Ref: Horak, E., Emery, S., & Maina, J. Review of Falling Weight Deflectometer Deflection Benchmark Analysis on Roads and Airfields. In Proc. 11th Conf. on Asphalt Pavements for Southern Africa.

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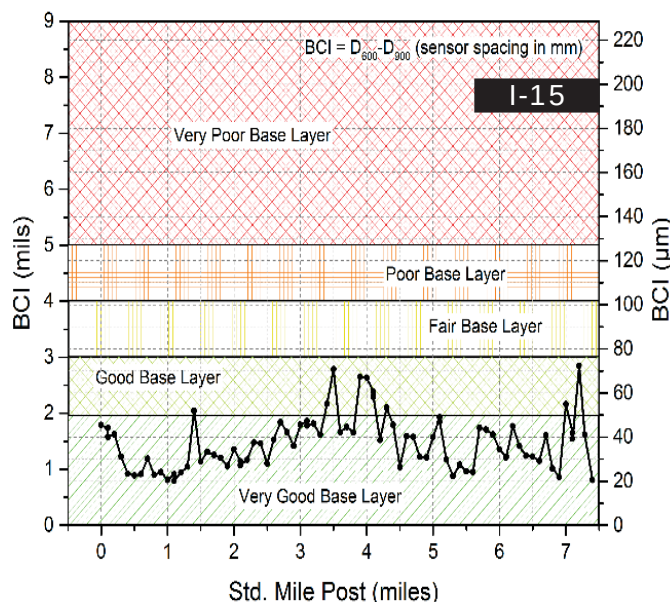
Inferences based on Deflection Basin – Zone 3



Inferences based on Shape of Stress Dissipation Curve



Pavement Assessment Based on Deflection Bowl Parameters



BCI / LLI (mils)	Inference
< 2.0	Very Good Base Layer
2.0 -- 3.0	Good Base Layer
3.0 -- 4.0	Fair Base Layer
4.0 -- 5.0	Poor Base Layer
> 5.0	Very Poor Base Layer

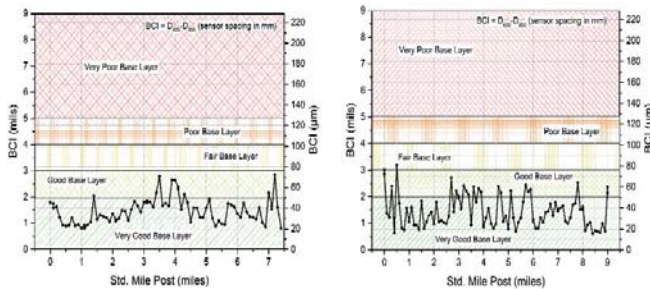
Base Curvature Index

Inferences Concerning Lower Pavement Layers

Pavement Assessment Based on Deflection Bowl Parameters

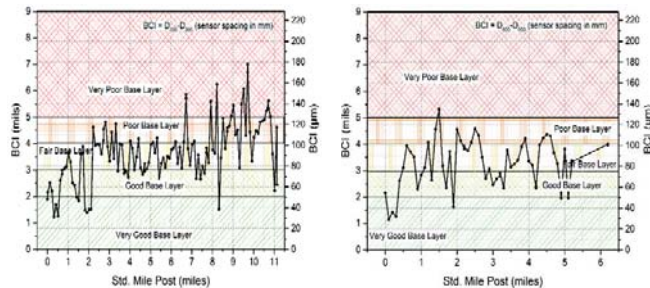


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(a) I-15

(b) I-84



(c) US-95

(d) SH-55

BCI / LLI (mils)	Inference
< 2.0	Very Good Base Layer
2.0 -- 3.0	Good Base Layer
3.0 -- 4.0	Fair Base Layer
4.0 -- 5.0	Poor Base Layer
> 5.0	Very Poor Base Layer

Base Curvature Index

Base/Subgrade
Condition Indicator



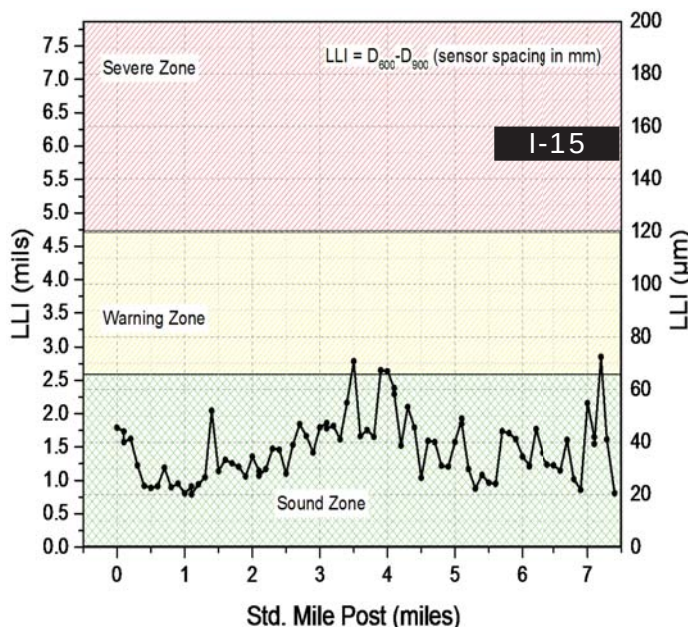
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Ref: Chang C, D. Saenz, S. Nazarian, I. N. Abdallah, A. Wimsatt, T. Freeman, and E. G. Fernando (2014) "Txdot Guidelines to Assign PMIS Treatment Levels" (Table 33 <http://pathweb.pathwayservices.com/idaho/>) (Picture)

Pavement Assessment Based on Deflection Bowl Parameters



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Base Type	Structural Condition Rating	Deflection Bowl Parameter
		LLI (µm)
Granular Base	Sound	< 65
	Warning	65 – 120
	Severe	> 120

Lower Layer Index

Subgrade Condition Indicator



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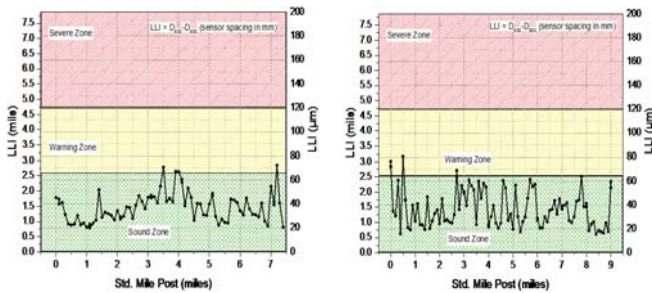
Ref: Horak, E., Emery, S., & Maina, J. Review of Falling Weight Deflectometer Deflection Benchmark Analysis on Roads and Airfields. In Proc. 11th Conf. on Asphalt Pavements for Southern Africa.

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Pavement Assessment Based on Deflection Bowl Parameters

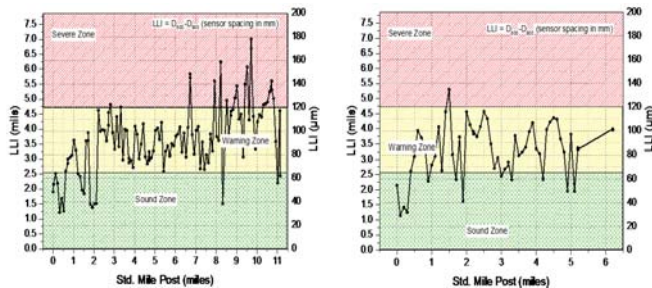


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(a) I-15

(b) I-84



(c) US-95

(d) SH-55

Base Type	Structural Condition Rating	Deflection Bowl Parameter
		LLI (µm)
Granular Base	Sound	< 65
	Warning	65 – 120
	Severe	> 120

Lower Layer Index

Subgrade Condition Indicator



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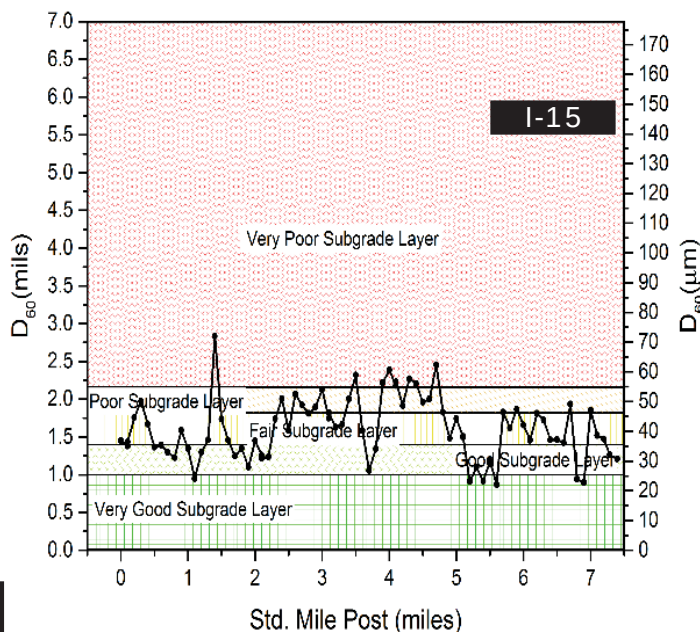
Ref: Horak, E., Emery, S., & Maina, J. Review of Falling Weight Deflectometer Deflection Benchmark Analysis on Roads and Airfields. In Proc. 11th Conf. on Asphalt Pavements for Southern Africa.

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Pavement Assessment Based on Deflection Bowl Parameters



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D (60")	Remarks
< 1.0	Very Good Subgrade Layer
1.0 -- 1.4	Good Subgrade Layer
1.4 -- 1.8	Fair Subgrade Layer
1.8 -- 2.2	Poor Subgrade Layer
> 2.20	Very Poor Subgrade Layer

Deflection at 60"

Structural Condition Indicator for Subgrade Layer



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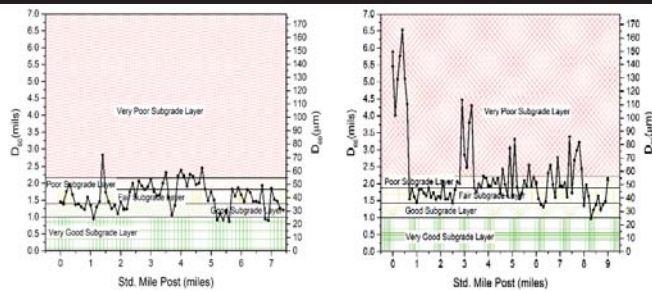
Ref: Chang C, D. Saenz, S. Nazarian, I. N. Abdallah, A. Wimsatt, T. Freeman, and E. G. Fernando (2014) "Txdot Guidelines to Assign PMIS Treatment Levels" (Table)

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Pavement Assessment Based on Deflection Bowl Parameters

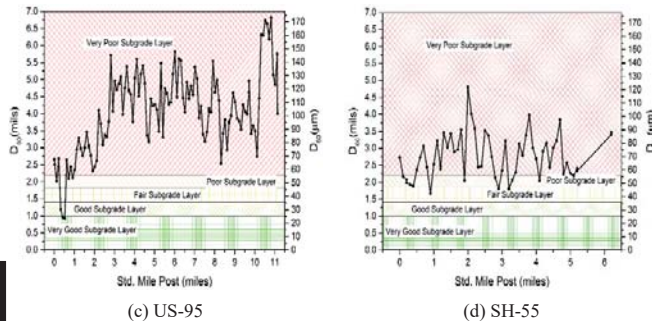


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(a) I-15

(b) I-84



(c) US-95

(d) SH-55

D (60")	Remarks
< 1.0	Very Good Subgrade Layer
1.0 -- 1.4	Good Subgrade Layer
1.4 -- 1.8	Fair Subgrade Layer
1.8 -- 2.2	Poor Subgrade Layer
> 2.20	Very Poor Subgrade Layer

Deflection at 60"

Structural Condition
Indicator for Subgrade Layer



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Ref: Chang C, D. Saenz, S. Nazarian, I. N. Abdallah, A. Wimsatt, T. Freeman, and E. G. Fernando (2014) "Txdot Guidelines to Assign PMIS Treatment Levels" (Table)

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Summary of Assessment Results



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Distress Type	Distress Severity / Magnitude							
	I-15		I-84		US-95		SH-55	
	Value	Rating	Value	Rating	Value	Rating	Value	Rating
Cracking Index	2.6	Fair	3.8	Good	2.2	Poor	1.6	Poor
International Roughness Index (IRI, in/mi)	< 95	Good	56 (avg.)	Excellent	90.5 (avg.)	Good	156 (avg.)	Poor
Roughness Index (RI)	3.40	Good	3.95	Good	3.33	Good	2.51	Fair
Average Rut Depth (inch)	0.43"	Fair	0.24"	Good	0.46"	Fair	0.24"	Good

Rehabilitation method should be selected based on detailed analysis of individual layer conditions

Distress Type	Structural Condition Assessed from FWD Data							
	I-15		I-84		US-95		SH-55	
	Percentage in Length	Rating	Percentage in Length	Rating	Percentage in Length	Rating	Percentage in Length	Rating
Surface	80	GOOD	100	GOOD	65	POOR	60	POOR
Base	100	GOOD	95	GOOD	40	GOOD	40	GOOD
Subgrade	25	POOR	25	POOR	75	POOR	65	POOR



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Summary of Assessment Results

Layer	I-15	I-84	US-95	SH-55
Surface				 
Base				
Subgrade				



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Research Outcome



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Research Does Pay Off !

...collaboration between one of their (ITD D5) engineers and Boise State University will result **in a savings of at least five million dollars from the original cost of the projects**. Dan Harelson ...asked Dr. Deb Mishra from Boise State University to review the consultant prepared pavement investigation report for the project and Dr. Mishra evaluated the data using a tool he has developed ... he concluded that the consultant evaluation was extremely conservative and that much less costly rehabilitation options are available. Dan and Dr. Mishra applied the analysis to several additional projects and reached the same conclusion in their regard. The analysis will result in a savings of over five million dollars ...

Report to Idaho Legislators


57th Idaho Asphalt Conference

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CIR Implementation on I-15

I-15 ARIMO TO MCCAMMON PROJECT
JUNE – FALL 2017

INTERSTATE 15

The Idaho Transportation Department will resurface approximately seven miles of Interstate 15 from Arimo to McCammon.

The interstate road surface is deteriorating and needs to be replaced. The resurfacing work will eliminate rough sections and soft spots in the road. As a part of this project, ITD will also upgrade the guardrail on I-15.

Through a method called Cold-in-Place Recycling, ITD will re-use the old pavement in the new roadway. This method reduces waste and lowers costs.

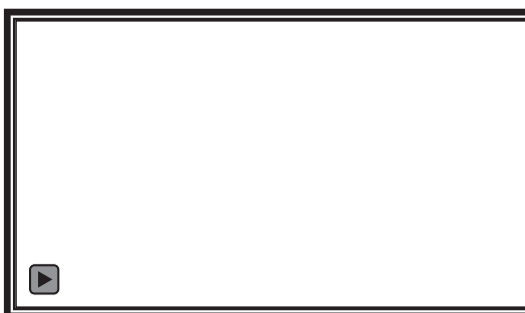
Traffic impacts:

- I-15 will be reduced to one lane in each direction in the project area.
- Both north- and southbound interstate traffic will travel on the same side of I-15.
- Some blasting of rock may be necessary early in the project to build crossover lanes for shifting traffic. The interstate may be closed for 15 to 20 minutes during the blasting.
- Oversized loads may be detoured. Check 511.idaho.gov for more details.
- The speed limit will be reduced.

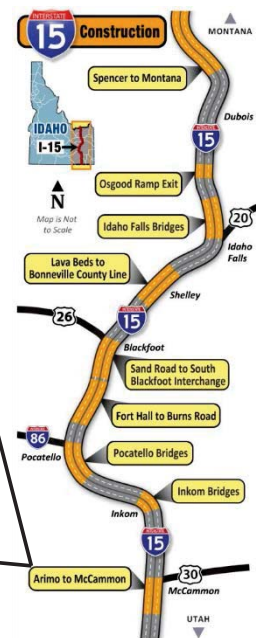
SIGN UP TO RECEIVE CONSTRUCTION UPDATES: TEXT INTERSTATE15 TO 22828 CALL (208) 239-3377

EMAIL: I-15CONSTRUCTION@ITD.IDAHO.GOV LEARN MORE: WWW.ITD.IDAHO.GOV/I-15CONSTRUCTION

DOWNLOAD THE I-15 APP FOR UP-TO-THE-MINUTE TRAVEL TIMES



"We are not bothering the traveling public as much and creating a road for cheaper that's actually gonna last longer" ---Scott Redding, ITD Resident Engineer


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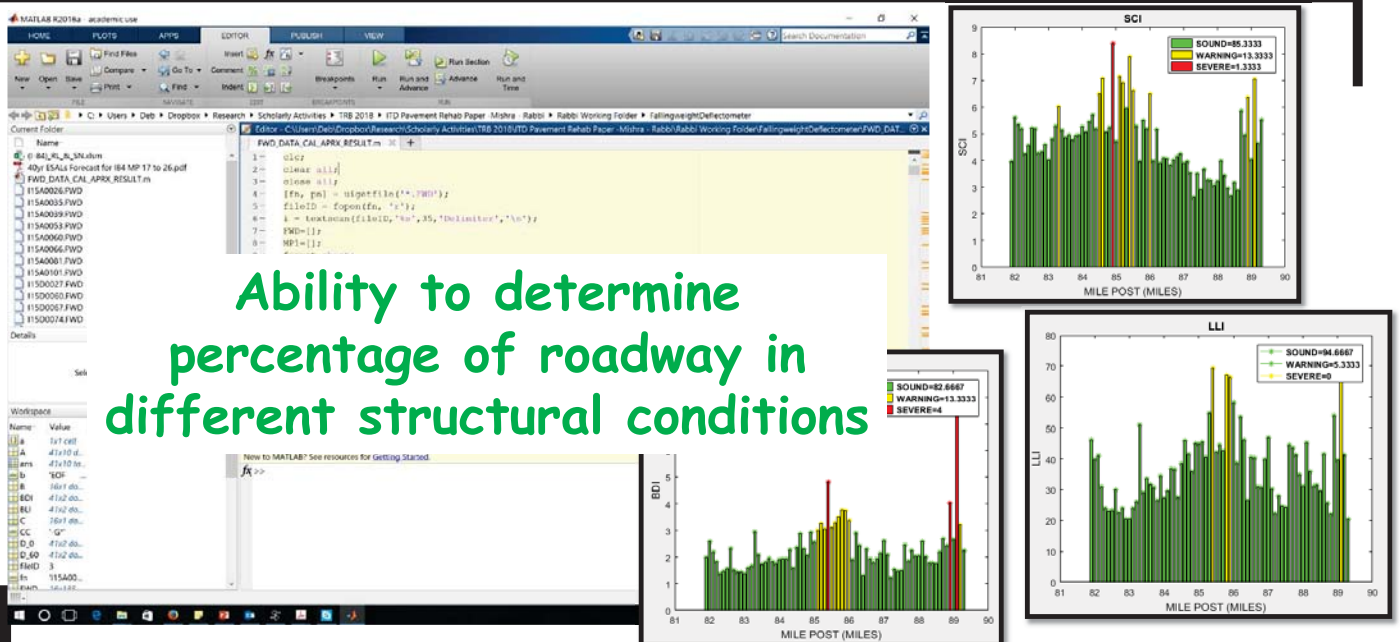
42

Developing a Tool for “Quick” Implementation



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MATLAB Tool for Rapid Analysis of FWD Data

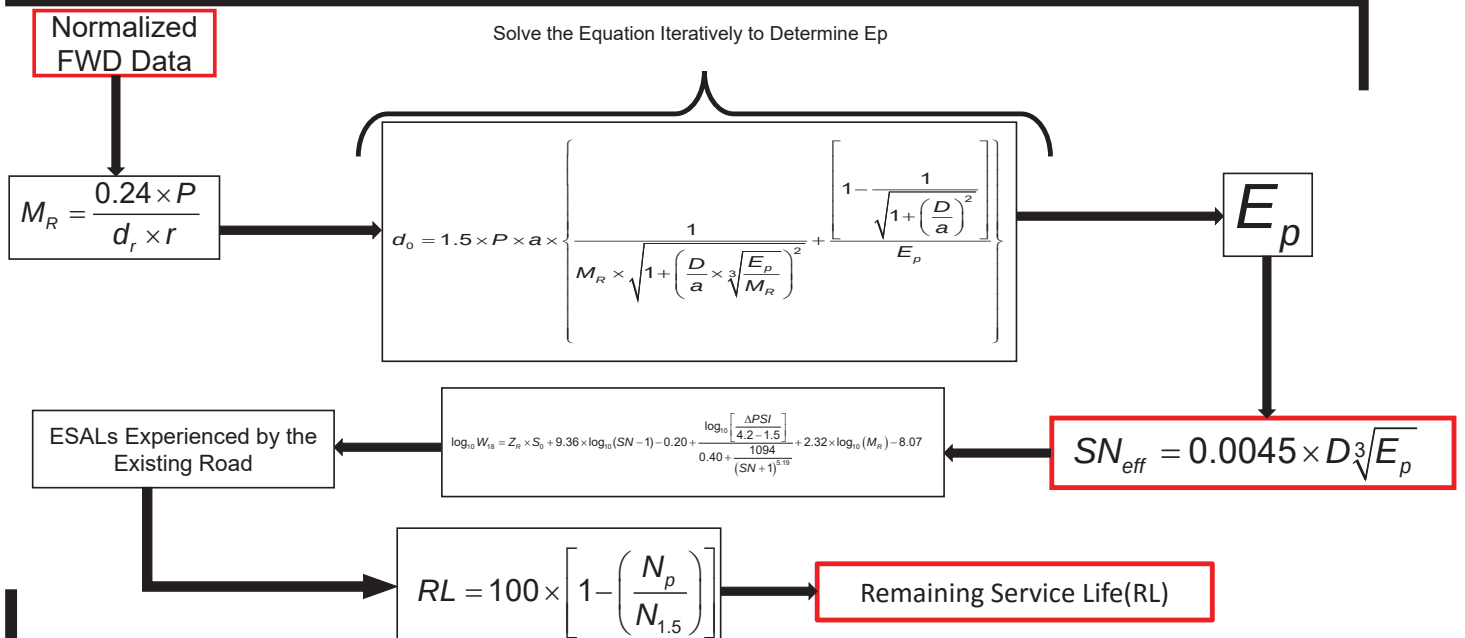


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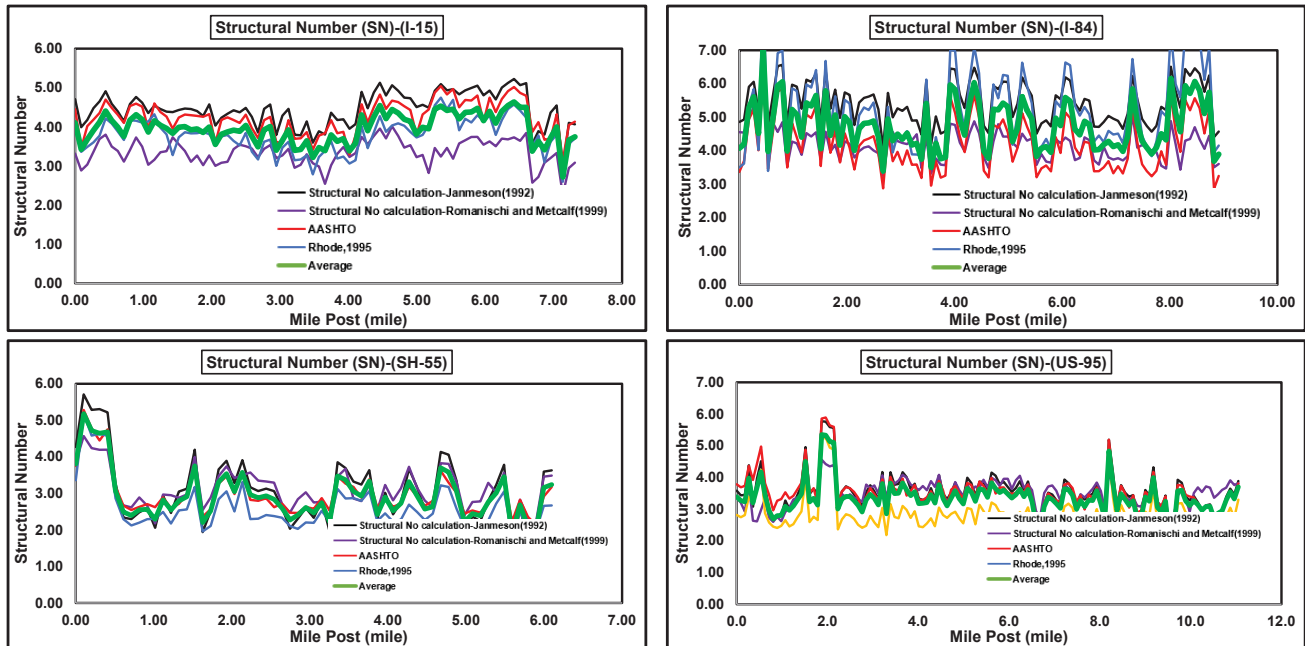
Network-Level Application of FWD Data

[Structural Number, Layer Modulus, Service Life]

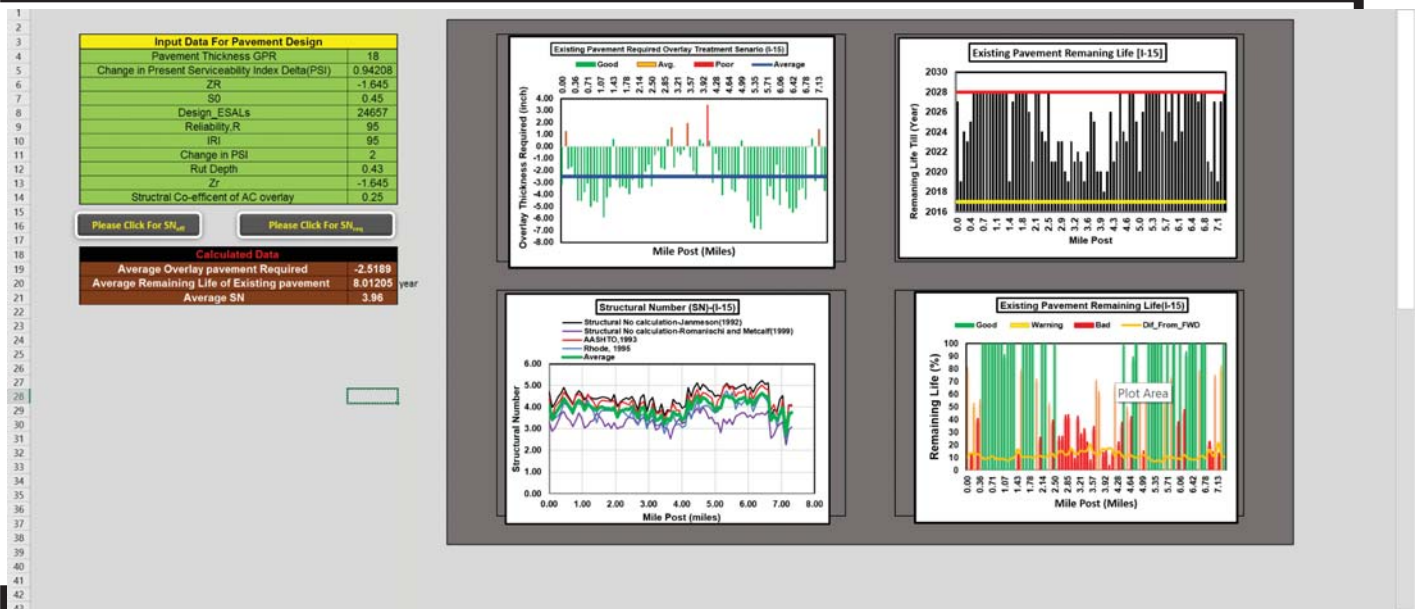
Structural Number & Remaining Life Calculations



Sample Representation of Network-Level Pavement Condition



Excel Tool for Network-Level Sn_{eff} Calculations



Mechanistic Validation of Deflection Basin Parameters using Finite Element Modeling

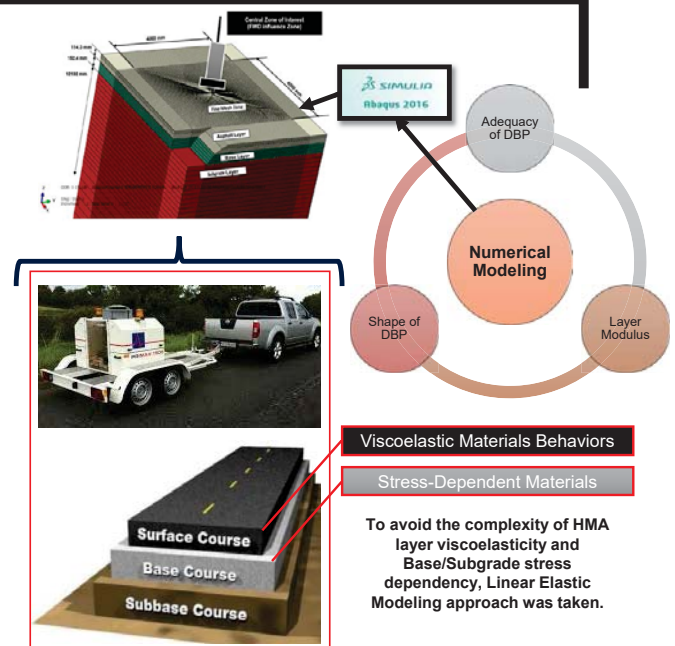
Numerical Pavement Modeling

Pavement Modeling Purpose:

- ❑ To determine the pavement responses like stresses, strains, and deflections due to the application of load.

The common structural models:

- ❑ Layered Elastic Models (All layers)
- ❑ Visco-Elastic Modeling. (HMA layer)
- ❑ Stress-Dependent Modulus (Base and Subgrade layers)



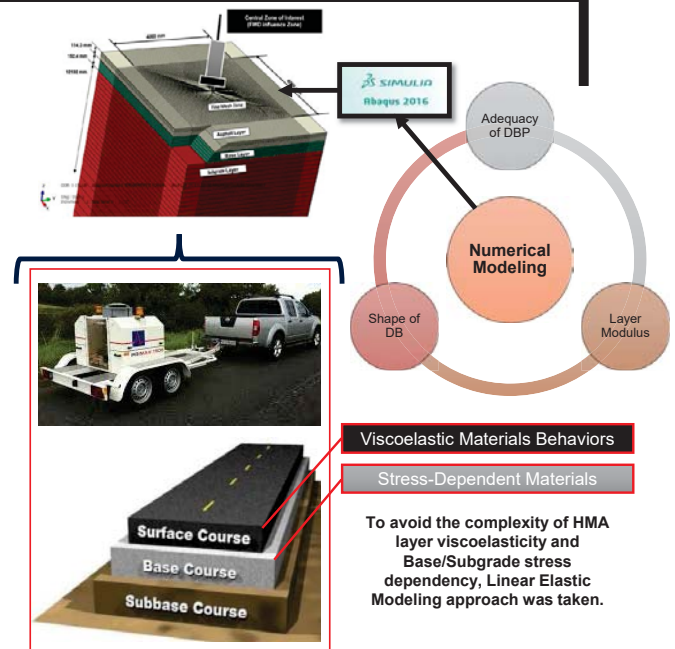
Numerical Pavement Modeling

Layered elastic model:

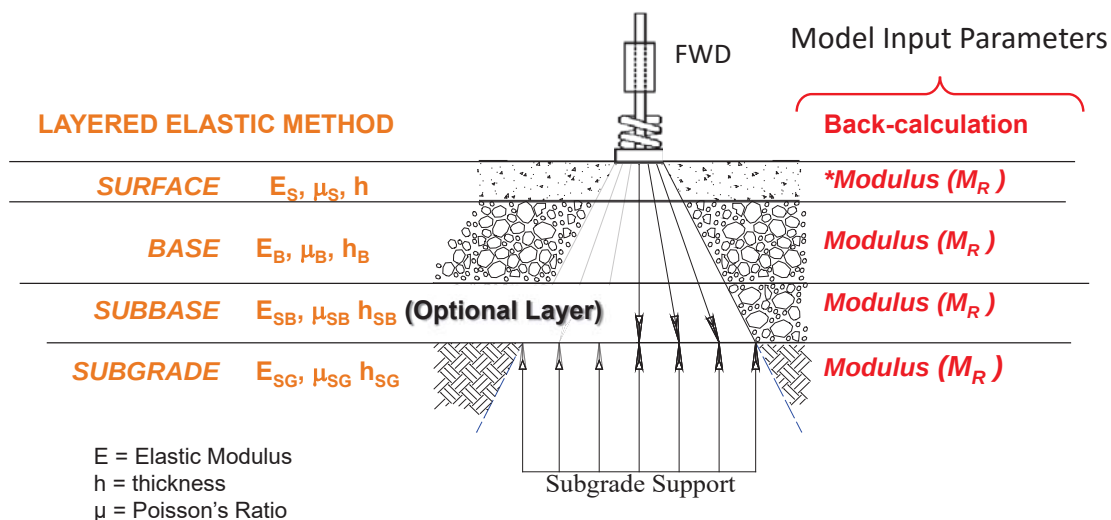
- ❑ Computation of **stresses, strains, and deflections** at any point in a pavements are **relatively simple**.
- ❑ For the modeling only **pavement layer configuration, elastic modulus and Poisson's Ratio** values are required.

Layered elastic models assumption:

- ❑ Pavement structural layer is **homogeneous, isotropic, and linearly elastic**
- ❑ The layer will **rebound to its original form** once the **load is removed**.



Flexible Pavement Typical Layer Input Parameters

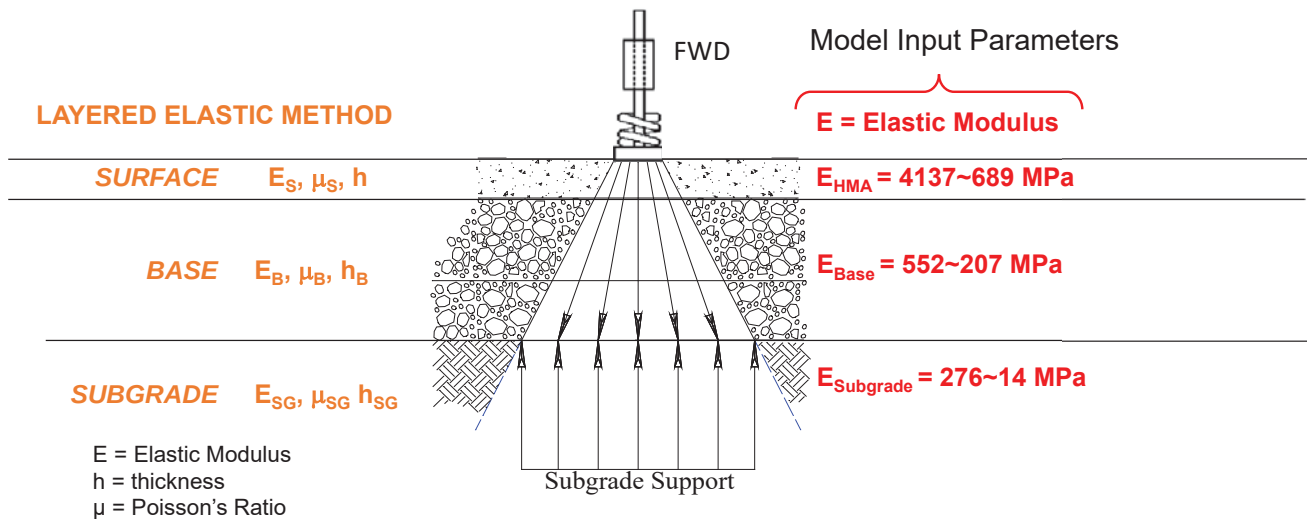


Flexible Pavement Typical Layer Input Parameters



BOISE STATE UNIVERSITY
COLLEGE OF ENGINEERING

Flexible Pavement Typical Layer Parameters Required as Input



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Ref: Rodney N. Joel, (2008), Civil Engineer / Airfield Pavement Airport Engineering Division, Presented to: 2008 Eastern Region Airport Conference (Picture Modified)

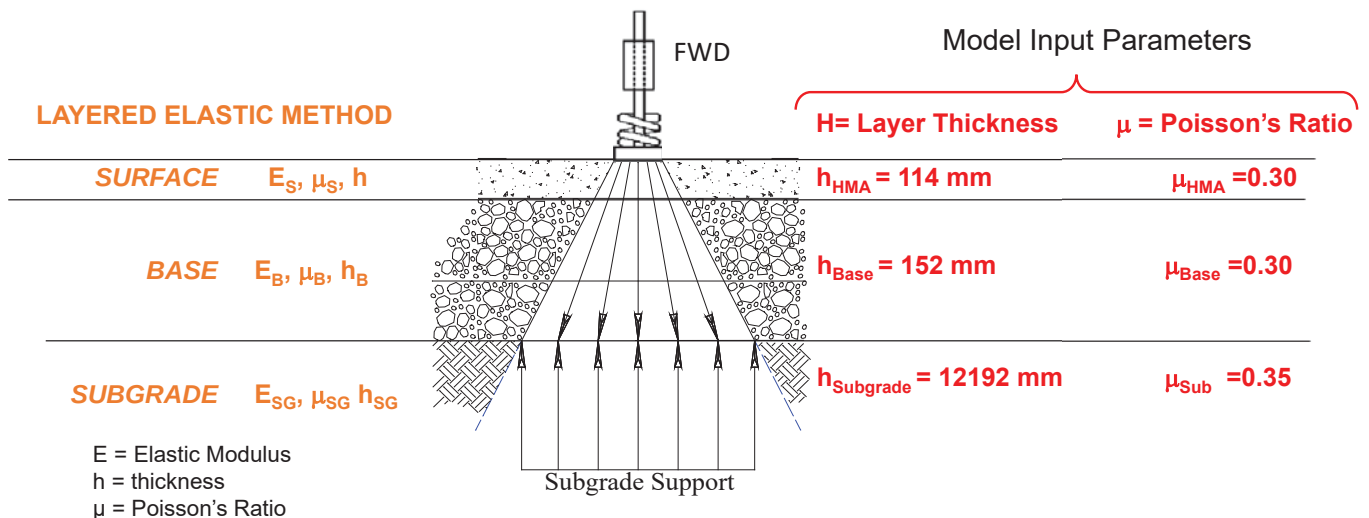
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Flexible Pavement Typical Layer Input Parameters



BOISE STATE UNIVERSITY
COLLEGE OF ENGINEERING

Flexible Pavement Typical Layer Parameters Required as Input



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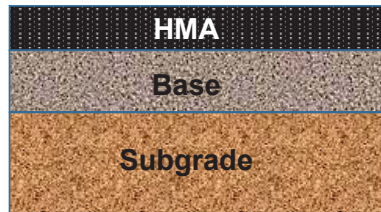
Ref: Rodney N. Joel, (2008), Civil Engineer / Airfield Pavement Airport Engineering Division, Presented to: 2008 Eastern Region Airport Conference (Picture Modified)

54

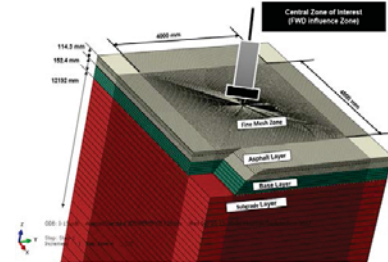
Details of the Numerical Model



The physical structure



The idealized model



The discretized (approximate) model

Advantages of 3-D Model

- Provides the complete stress and displacement fields for the analyzed domain
- Not limited to linear elastic analysis

Disadvantages of 3D-FEM

- Require long computation times
- Significant Pre-processing and post-processing requirements.
- Solution is mesh-dependent.
 - In theory, the solution can always be improved by refining the 3D mesh.
 - Improvement comes at the expense of time.

Model Dimensions

Length	26.0 m (85.3 ft.)
Width	18.0 m (59.0 ft.)
Depth	12.7 m (41.5 ft.)

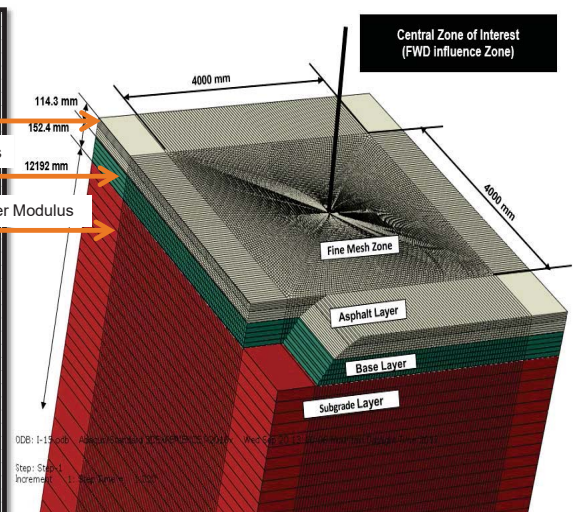
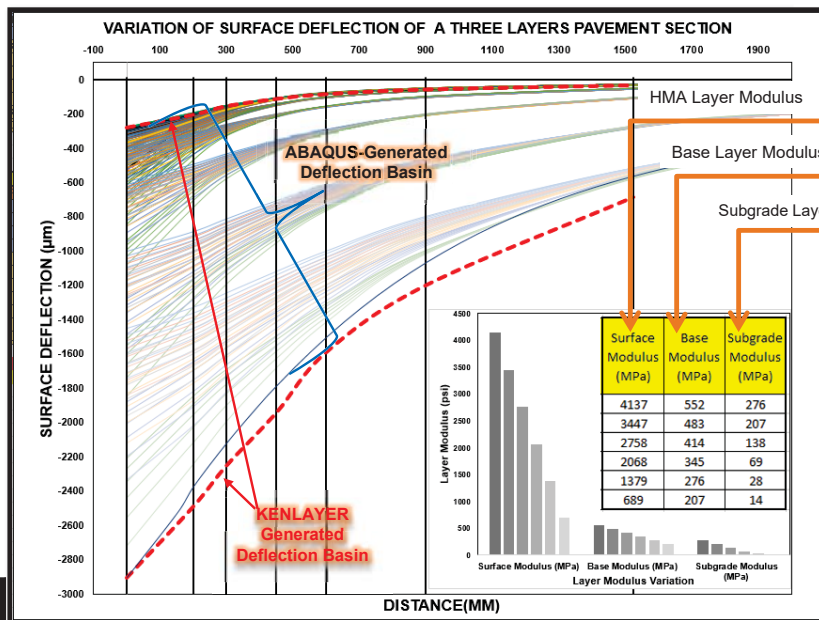


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Ref: Rodney N. Joel, (2008), Civil Engineer / Airfield Pavement Airport Engineering Division, Presented to: 2008 Eastern Region Airport Conference

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Model Optimization



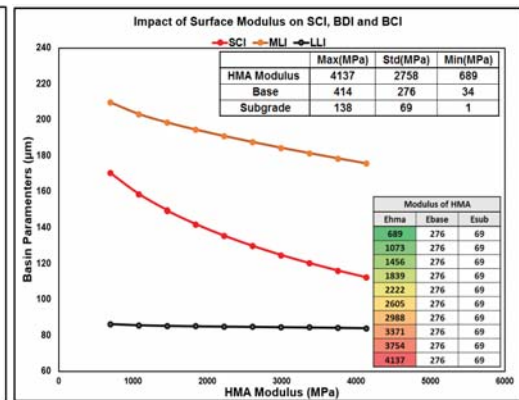
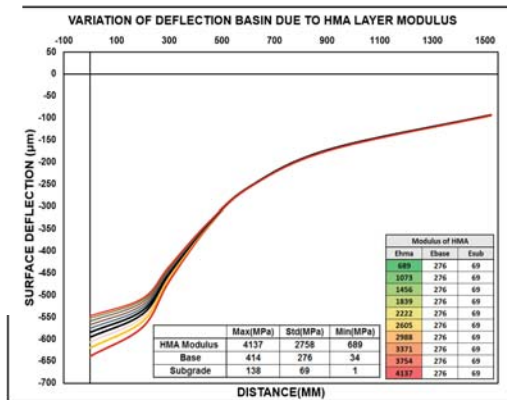
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Sensitivity Analysis Using the Control Pavement Section

Observation:

- ✓ Variation of SCI and MLI Significant
- ✓ Variation of LLI insignificant (~0)
- ✓ Effect are more prominent near the loading area.



Layer	Elastic Modulus (MPa)			PI (%)	SCI/BLI (µm)		MLI/BDI (µm)		LLI/BCI (µm)		SCI (µm)	MLI (µm)	LLI (µm)
	Min.	Max.	Control		Max.	Min.	Max.	Min.	Max.	Min.	PD (%)	PD (%)	PD (%)
HMA	689	4137	2758	+500	170	112	210	176	86	85	-34	-16	-1
Base	34	414	276	+1118	422	242	349	177	162	105	-43	-49	-35
Subgrade	17	138	69	+712	360	238	377	139	297	61	-34	-63	-79

**PI= Percentage Increase from minimum to maximum, PD= Percentage Decrease from maximum to minimum



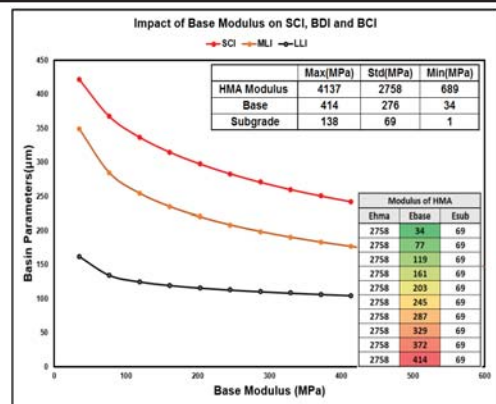
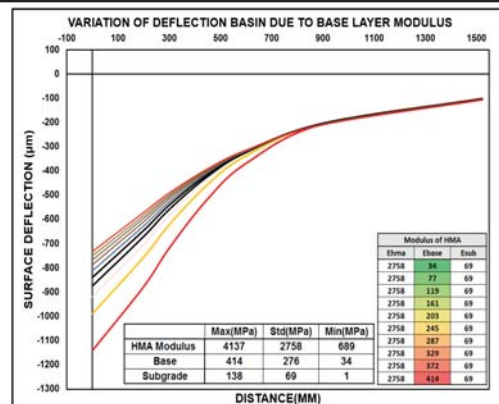
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Sensitivity Analysis Using the Control Pavement Section

Observation:

- ✓ Rate of change of slope noticeable in SCI, MLI and LLI
- ✓ SCI and MLI are highly influenced by changes in Base Modulus



Layer	Elastic Modulus (MPa)			PI (%)	SCI/BLI (µm)		MLI/BDI (µm)		LLI/BCI (µm)		SCI (µm)	MLI (µm)	LLI (µm)
	Min.	Max.	Control		Max.	Min.	Max.	Min.	Max.	Min.	PD (%)	PD (%)	PD (%)
HMA	689	4137	2758	+500	170	112	210	176	86	85	-34	-16	-1
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**PI= Percentage Increase from min. to max., PD= Percentage Decrease from max. to min.



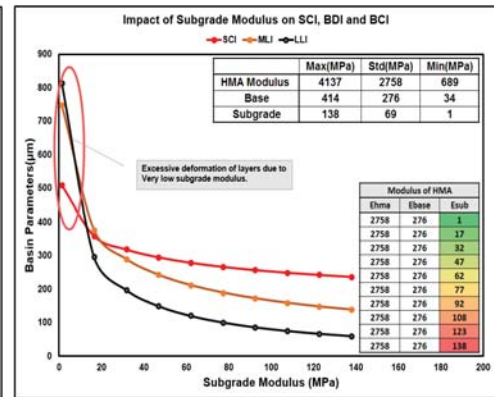
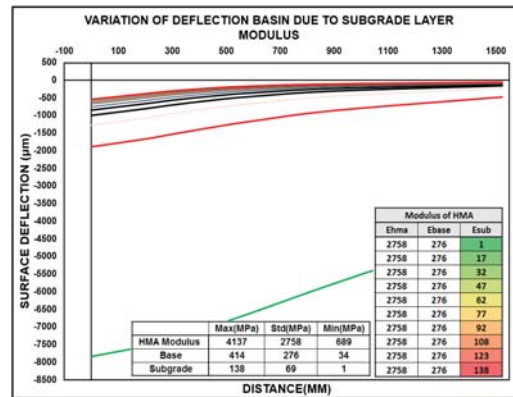
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Sensitivity Analysis Using the Control Pavement Section

Observation:

- ✓ Rate of change of slope noticeable in all three DBPs parameter such as SCI, MLI and LLI
- ✓ The variation of LLI are considerable high.
- ✓ Deflection of farthest sensor is highly influence by the variation of subgrade modulus.

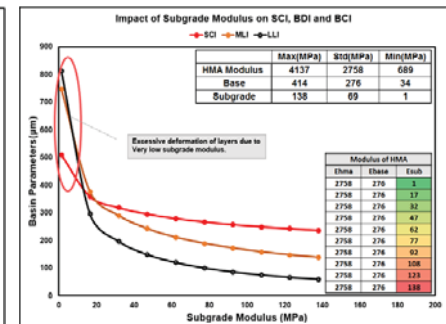
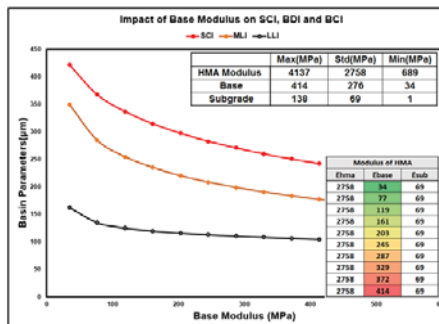
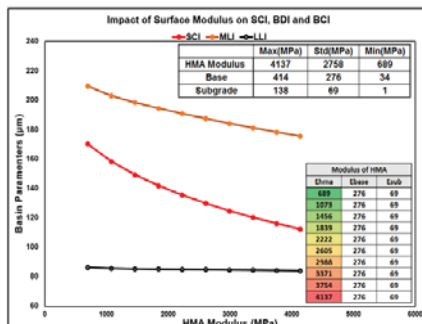


Layer	Elastic Modulus (MPa)			PI (%)	SCI/BLI (µm)		MLI/BDI (µm)		LLI/BCI (µm)		SCI (µm)	MLI (µm)	LLI (µm)
	Min.	Max.	Control		Max.	Min.	Max.	Min.	Max.	Min.	PD (%)	PD (%)	PD (%)
HMA	689	4137	2758	+500	170	112	210	176	86	85	-34	-16	-1
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**PI= Percentage Increase from minimum to maximum, PD= Percentage Decrease from maximum to minimum

Sensitivity Analysis Using the Control Pavement Section

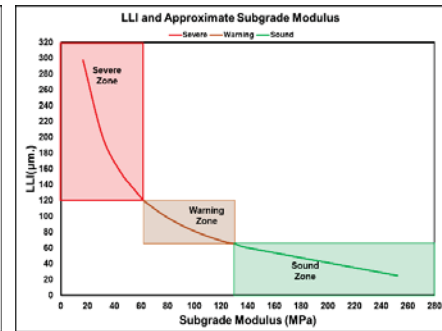
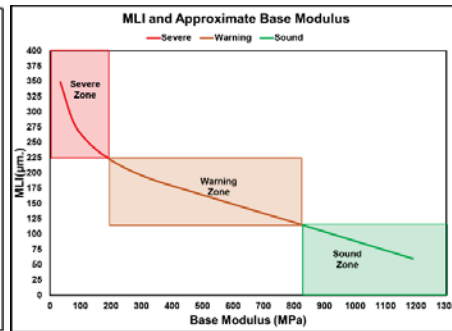
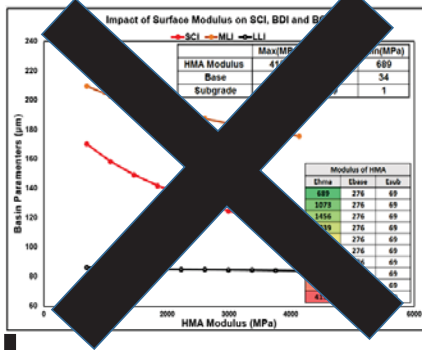
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Sensitivity Analysis Using the Control Pavement Section

Layer	Elastic Modulus(MPa)			PI (%)	SCI/BLI(μm)		MLI/BDI(μm)		LLI/BCI(μm)		SCI(μm)	MLI(μm)	LLI(μm)
	Mini.	Max.	Control		Max.	Mini.	Max.	Mini.	Max.	Mini.	PD (%)	PD (%)	PD (%)
HMA	689	4137	2758	+500	170	112	210	176	86	85	-34	-16	-1
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Sub.G	17	138	69	+712	360	238	377	139	297	61	-34	-63	-79



**PI= Percentage Increase f

Modulus variation between 100-600 ksi not capturing full SCI thresholds

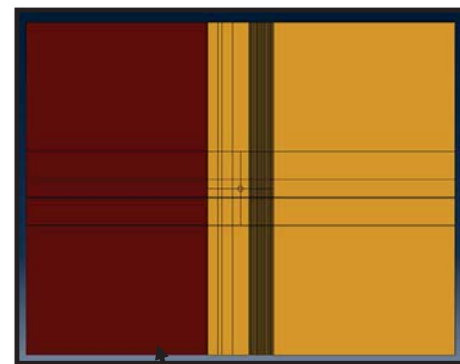
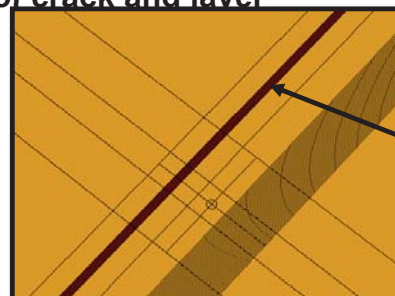


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Current Research Tasks

- ✓ Incorporation of viscoelastic behavior of HMA layer
- ✓ Preparation of a **synthetic database** of different pavement scenario and it's effect of DBPs.
- ✓ Investigate the effect of crack and layer thickness on DBPs



Soft spot

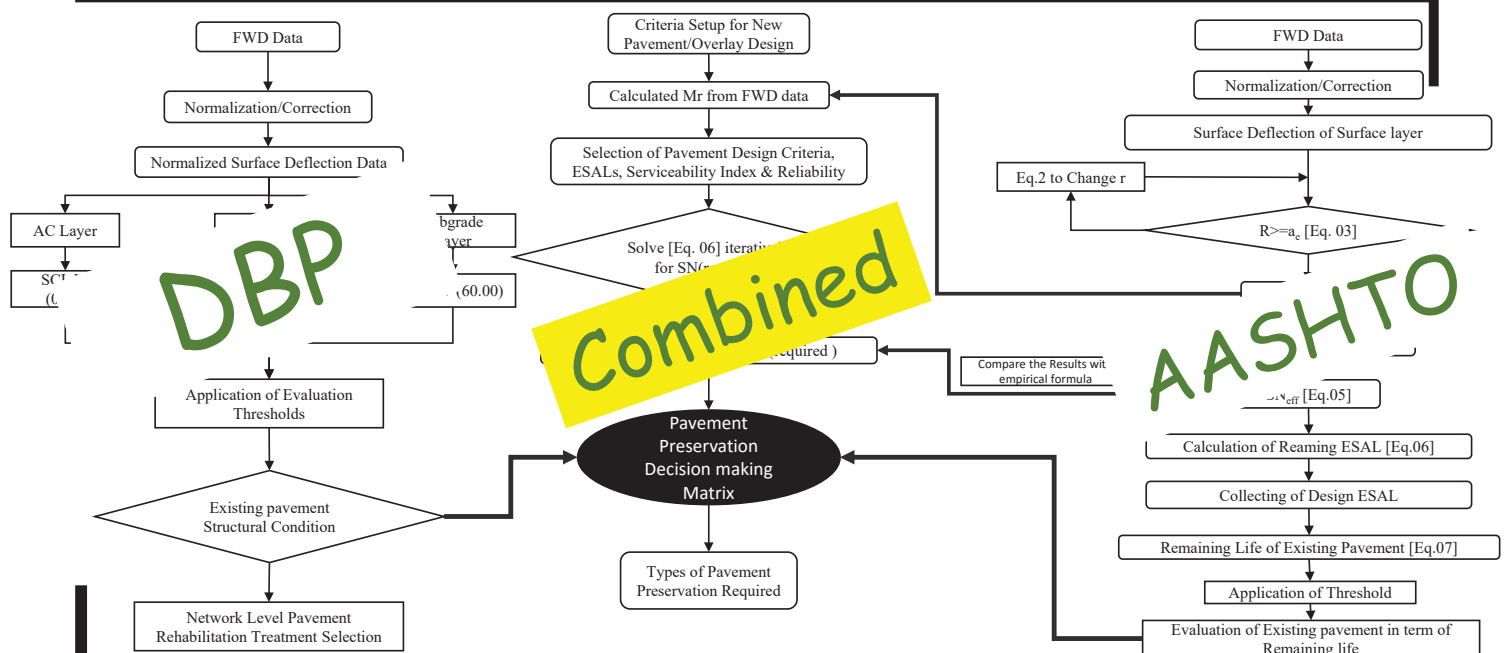


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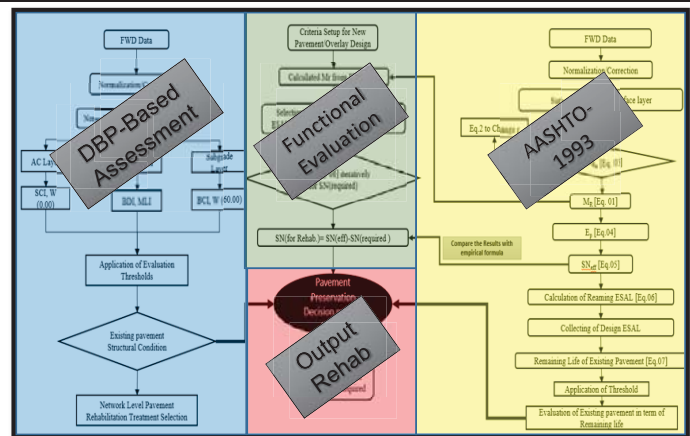
Moving Forward ...

Framework for Rehabilitation Strategy Selection



Framework for Rehabilitation Strategy Selection

- ✓ This framework not only follows AASHTO-1993 guidelines, but also considers DBP evaluation along with the existing functional evaluation function process.
- ✓ Final results are presented as percent layer condition, SN and RL, which depict a complete picture of existing pavement conditions, and will assist engineers in selecting the best rehabilitation strategies.

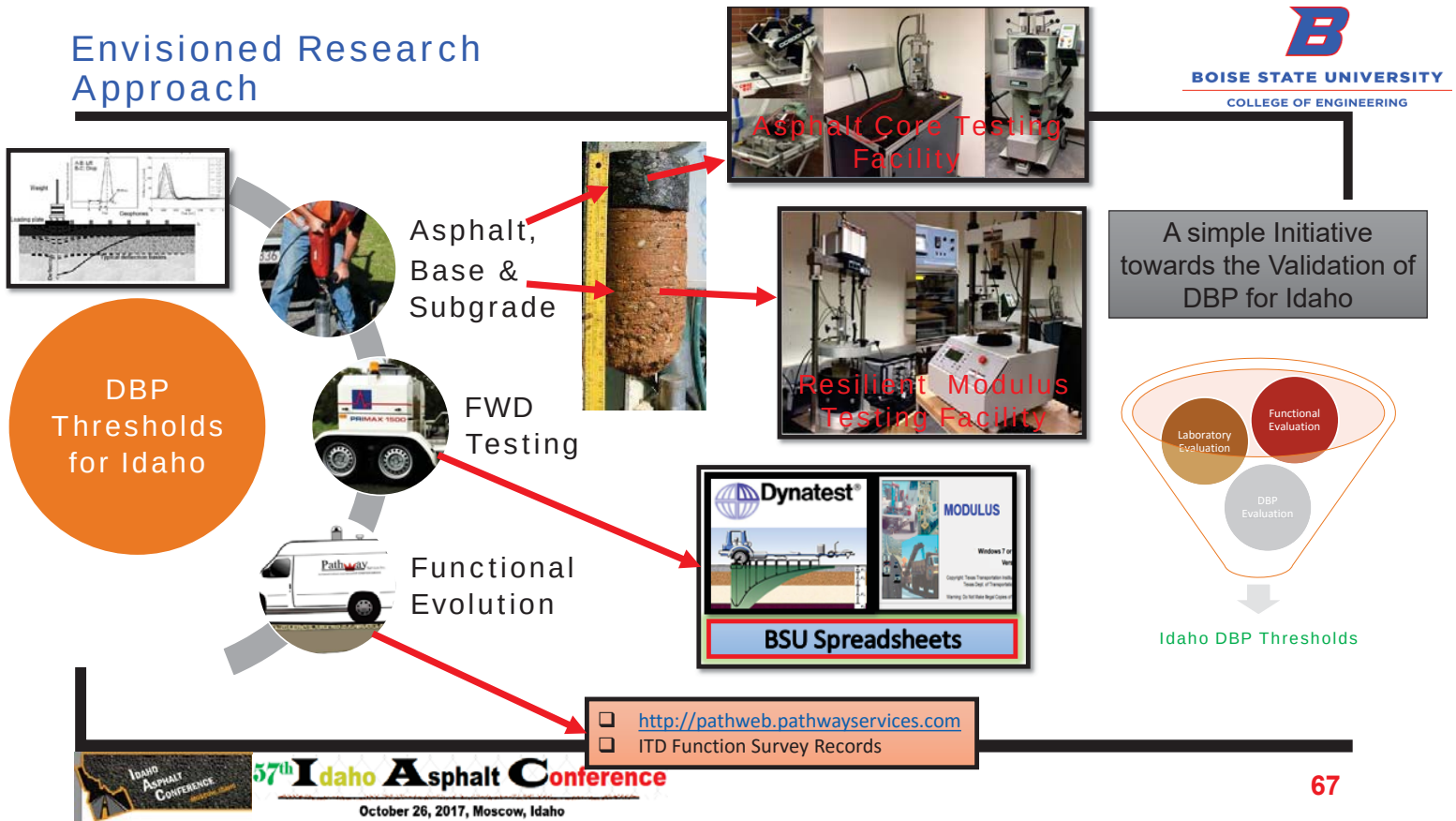


Futures Research Direction

- ✓ Collaborate with ITD to gather as much data as possible concerning pavement layer depths (from cores) and corresponding FWD data.
 - ✓ This will facilitate the validation of the DBP approach for different pavement depths
 - ✓ Possible modification of DBP thresholds
 - ✓ The FWD Data Analysis Tool (currently under development) will be available for use by ITD districts for rapid assessment of network-level pavement structural condition



Envisioned Research Approach



Acknowledgments

Dan Harelson
John Arambarri
Mike Santi
Dave Richards
Ed Bala
Dr. Mandar Khanal



Thank You

Deb Mishra, Ph.D., P.E.
Assistant Professor
Department of Civil Engineering
Boise State University; ERB 3137
Tel: (208) 426-3710
Email: debmishra@boisestate.edu

Thanks to all organizers and sponsors agencies



University of Idaho



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Using Your Paver as it was Intended

Presented by Todd Mansell, CAT Paving



Role of the Paver



- To meet specifications for grade, texture & smoothness

What Is Grade & Slope?



**Grade
(thickness)**



**Slope
(% crossfall)**

Mat Texture

Uniform texture all the way across the width



Understanding the Paver



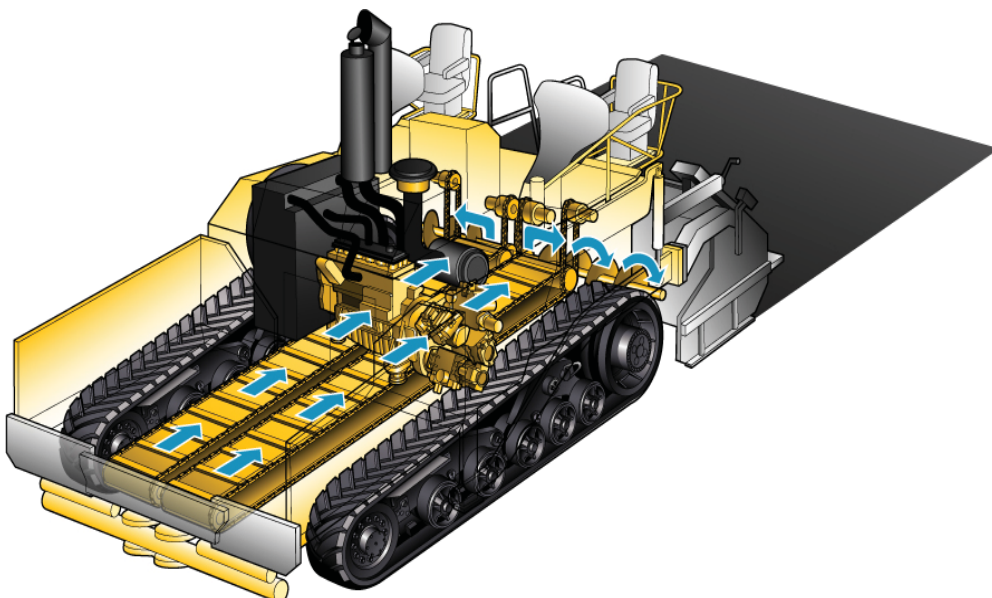
Tractor

- tows screed
- Accepts mix from trucks, MTV, etc.
- Pushes trucks
- Feeds mix to screed

Screed

- Floats on the mix
- Free to rise and fall according to many factors

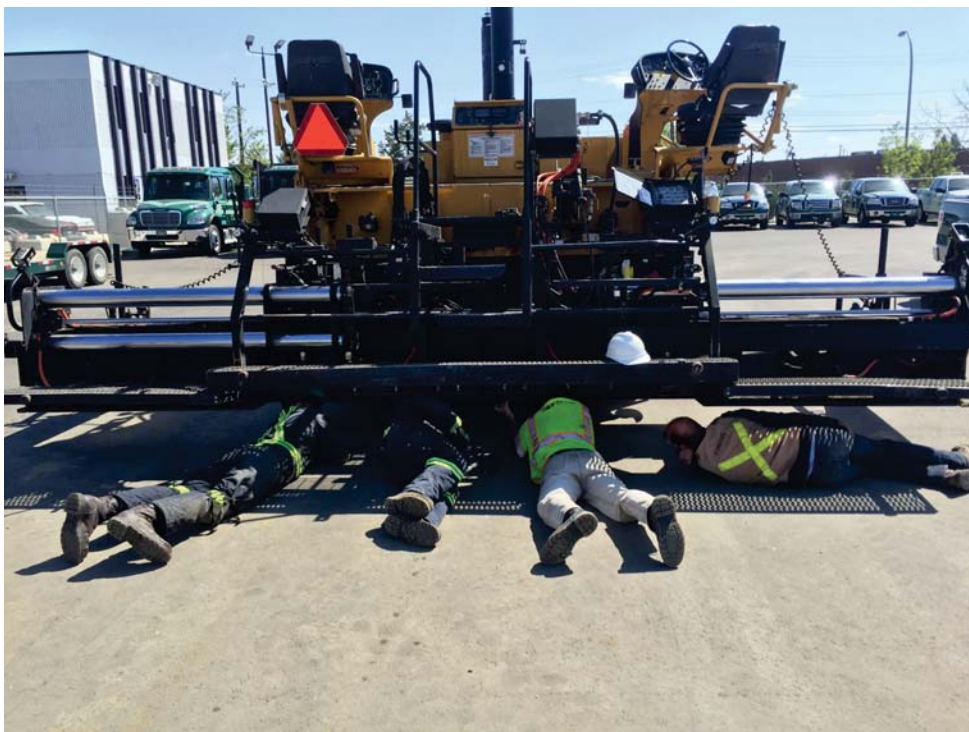
Tractor



Material Feed System

1. Hopper
2. Feeder bars
3. Adjustable height augers
4. Feeder sensors (not shown)

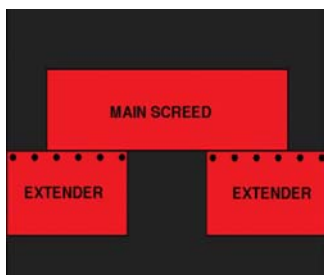
Screed



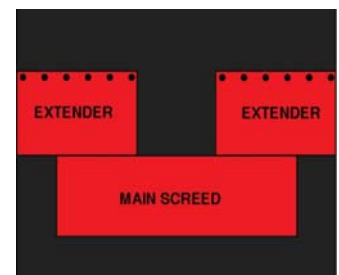
- Screed is hydraulic extendable to pave different widths
- Fixed-width screeds
- Which is best?

Front-mount and Rear-mount Screeds

Front-mount



Rear-mount

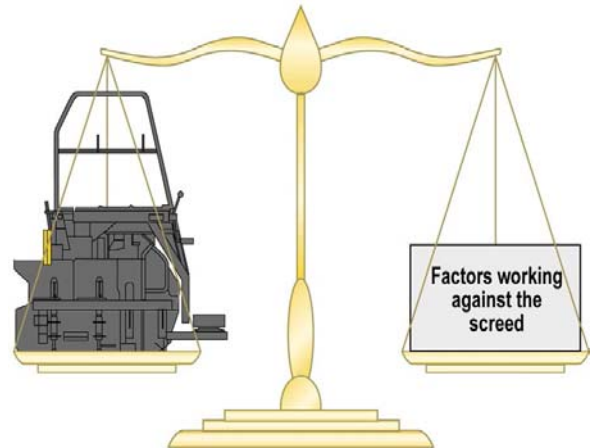


Direction
of paving

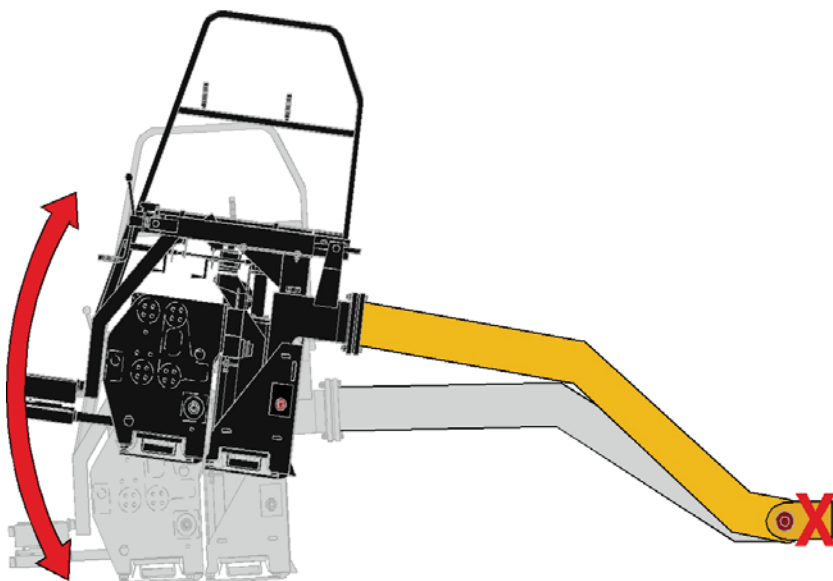
Free-Floating Screed



- Screed position determines mat thickness
- Screed position is constant as long as all factors remain constant



Tow Arm Geometry



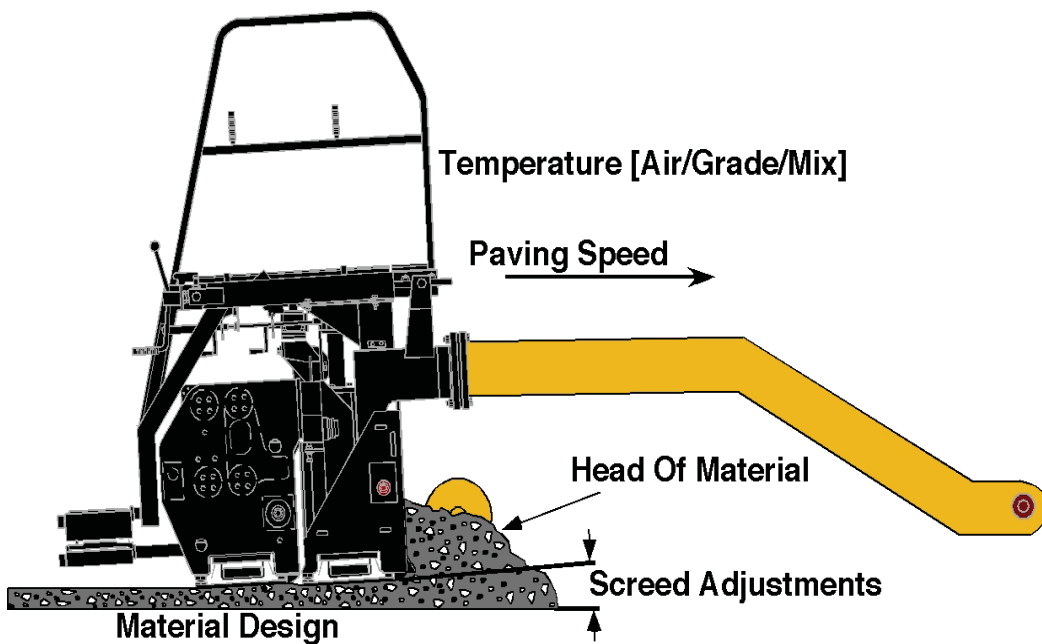
- Pinned to the tractor on left and right sides
- Pivot point at drop arm
- Screed rotates through an arc

How to Adjust Mat Thickness & Slope

- Use depth control cranks or “screws”
- Use tow points

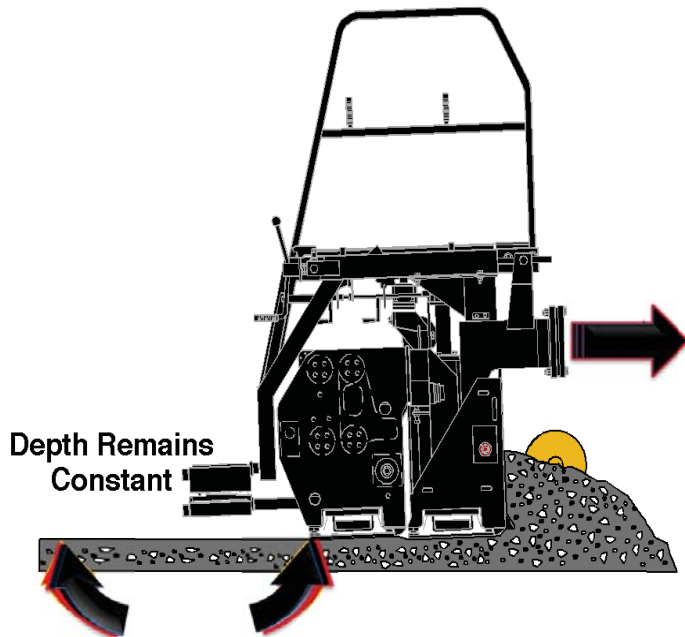


Factors Affecting the Screed



- Paving speed
- Head of material
- Screed adjustments
- Mix design
- Mix temperature
- Air temperature
- Grade temperature

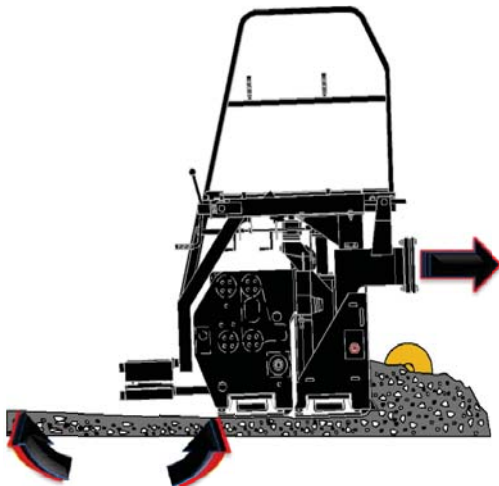
Factors Affecting Screed – Paver Speed



Constant Speed

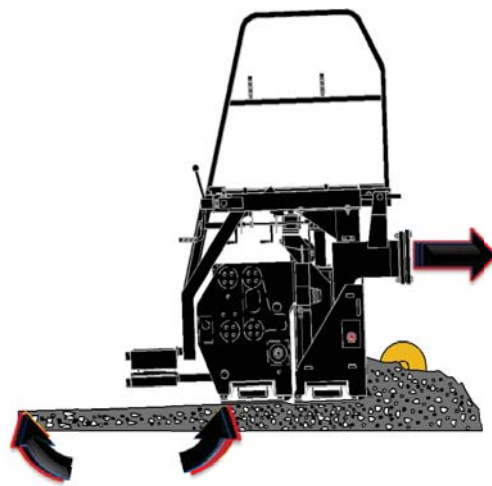
- Shear factor is constant
- Depth remains constant

Factors Affecting Screed – Paver Speed



Increased Speed

- Shear factor decreases
- Depth decreases



Decreased Speed

- Shear factor increases
- Depth increases

Factors Affecting Screed – Paver Speed

Real World Paving

- Do not panic
- Stay with the plan
- Get rid of trucks in an orderly fashion
- Establish a uniform trucking pattern
- Will help density & smoothness



Calculating Paver Speed



- Based on hot plant output and rate of mix delivery to job site (trucking & traffic)
- Goal = continuous paving

Calculating Paver Speed

CATERPILLAR® **PRODUCTION PLANNING**

Paver Speed Calculator

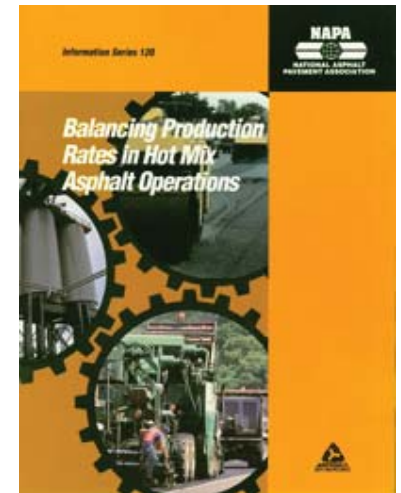
General Inputs

	ENGLISH UNITS	METRIC UNITS
Paving Thickness	2.00 in	50.8 mm
Paving Width	12.00 feet	3.658 meter
Material Density Uncompacted	140 lbs/ft ³	2243 kg/m ³

Paver Speed @ Given Production Rate

	250 tons/hr	227 tonnes/hr
Production Rate of Hot Plant	250 tons/hr	227 tonnes/hr
Calculated Paving Speed - 100% Efficiency	29.8 ft/min	9.09 m/min
Calculated Paving Speed - 95% Efficiency	31.3 ft/min	9.54 m/min
Calculated Paving Speed - 90% Efficiency	32.8 ft/min	10.00 m/min
Calculated Paving Speed - 85% Efficiency	34.3 ft/min	10.45 m/min
Calculated Paving Speed - 80% Efficiency	35.8 ft/min	10.91 m/min
Calculated Paving Speed - 75% Efficiency	37.3 ft/min	11.36 m/min

Effective Paving Speed **29.8 ft/min** **9.09 m/min**



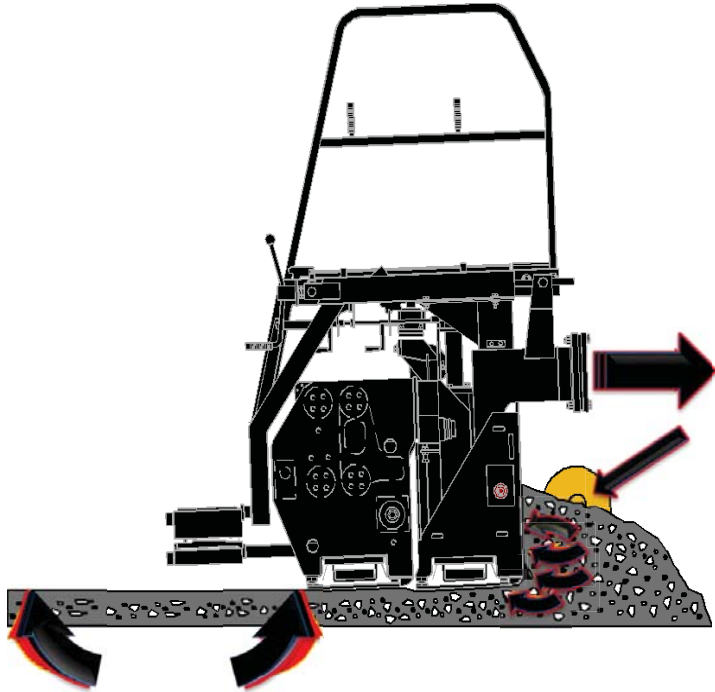
Controlling Paver Speed



Paving Speed

- Paving speed constant
- Feeder system set to match paving speed
- Changes in paving speed may require feeder system adjustments
- Resist temptation to “blow out trucks”

Factors Affecting Screed – Head of Material

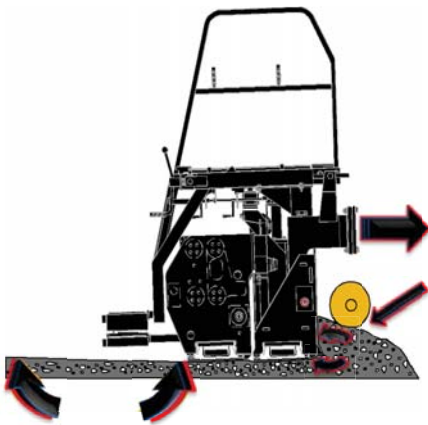


Correct Head of Material

- Half auger
- Constant resistance
- Constant depth

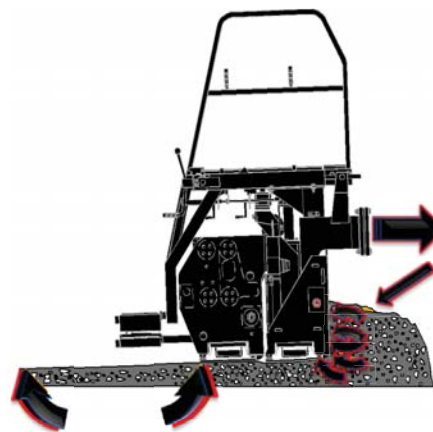


Factors Affecting Screed – Head of Material



Head of Material Decreased

- Resistance decreased
- Depth decreases



Head of Material Increased

- Resistance increased
- Depth increases

What's wrong with this picture?



Head of Material – common issue



Dip



Bump

Controlling Head of Material



Controlling Head of Material

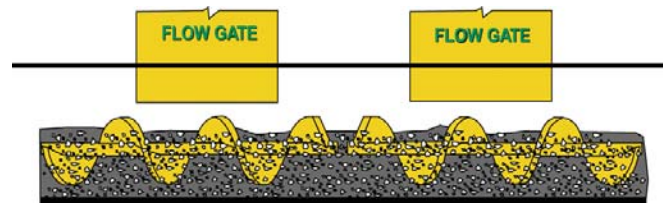
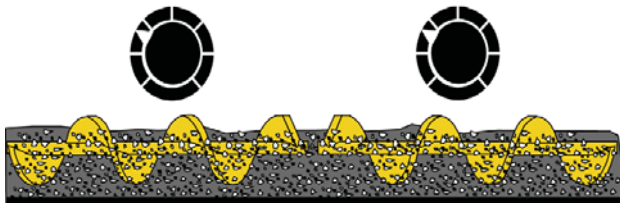
- Adjust gates/ratio
- Adjust auger speed
- Adjust auger height
- Position of sensors

Factors Affecting Screed – Head of Material

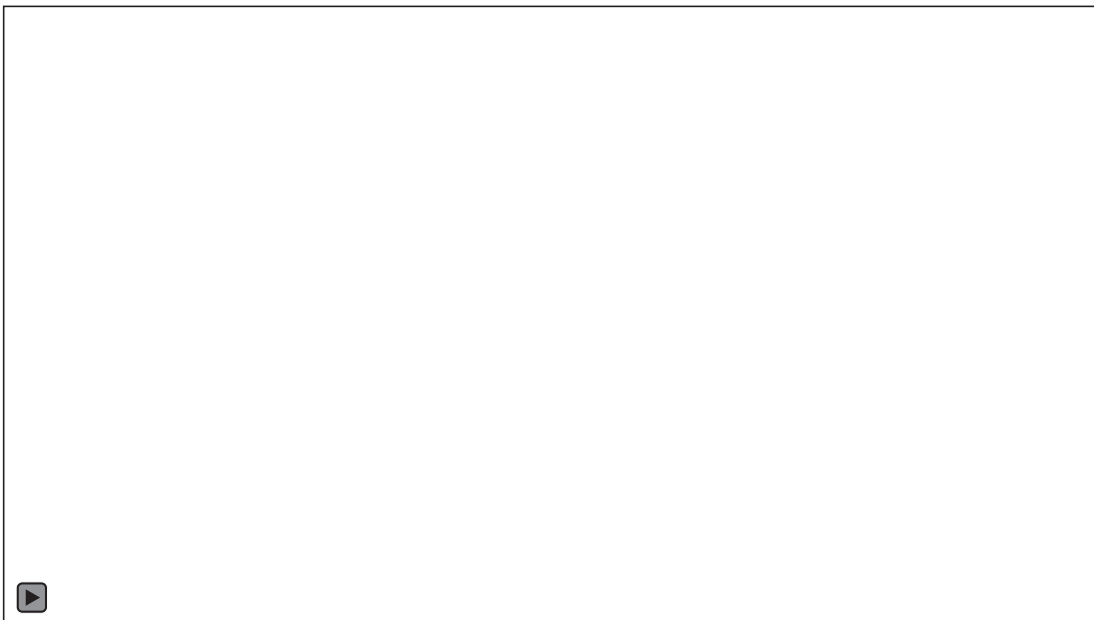


- Smooth, continuous movement from hopper to area in front of screed
- Uniform force against face of screed
- Don't run hopper low
- Proper setting of feed sensors

Adjust Mix Level to Half-auger

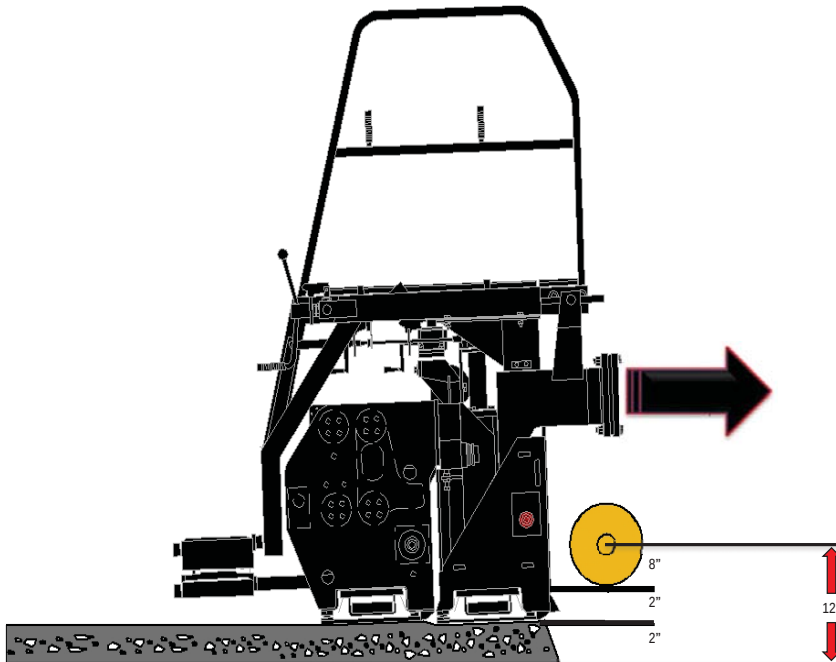


Factors Affecting Screed – Auger Speed



- Auger speed uniform
- 20-40 rpm
- Auger speed too high or too low can cause stripes in the mat

Factors Affecting Screed – Auger Height



- Start at 2" above level of mat
- Adjust up or down depending on mix type and appearance of mat



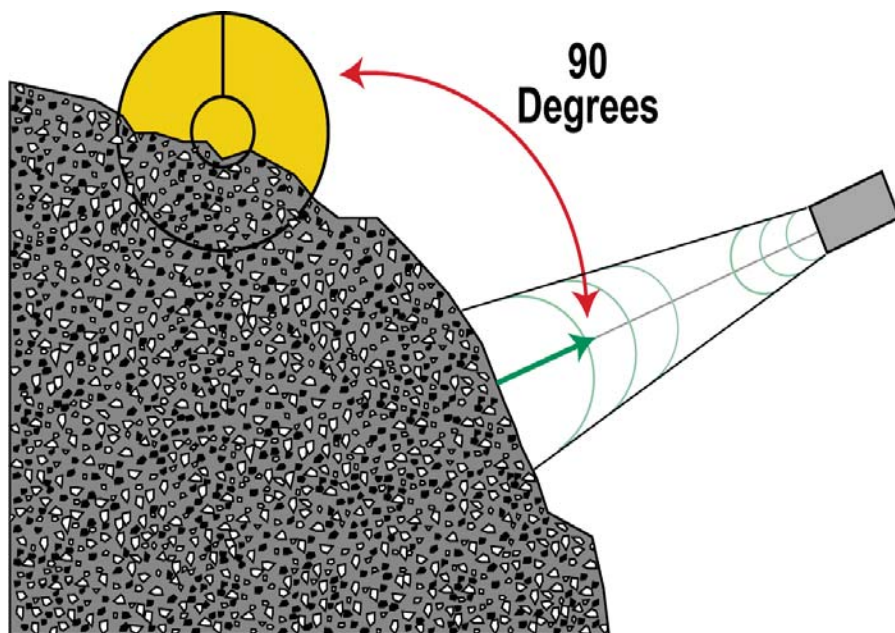
Factors Affecting Screed – Feed Sensors



- Mechanical or sonic
- Control level of material
- Position Sensor 18" from end of augers

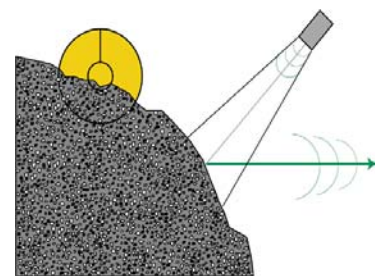


Factors Affecting Screed



Sonic Sensor Mounting Distance

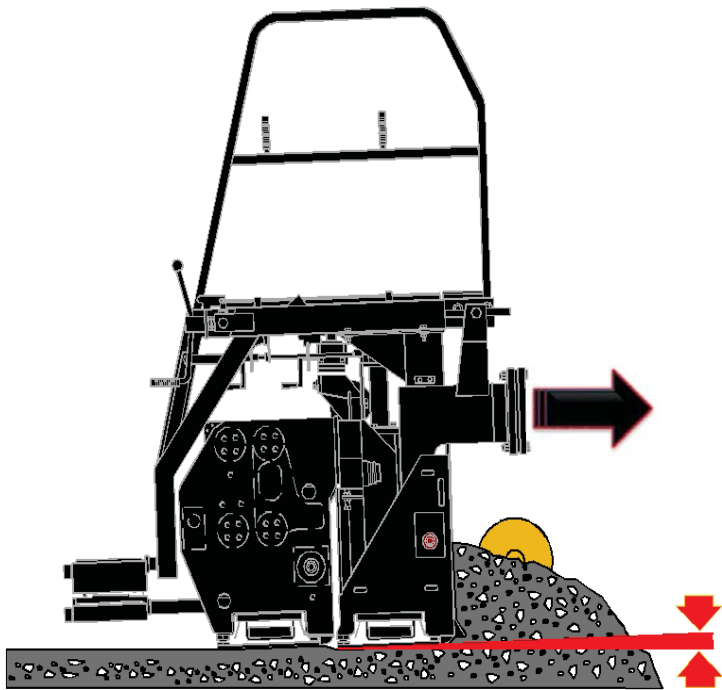
- Mounting position at 18"
- Working range of sonic sensor 12" – 32"



Paddle sensor at 18" and 45°



Screed Adjustments



Angle of Attack

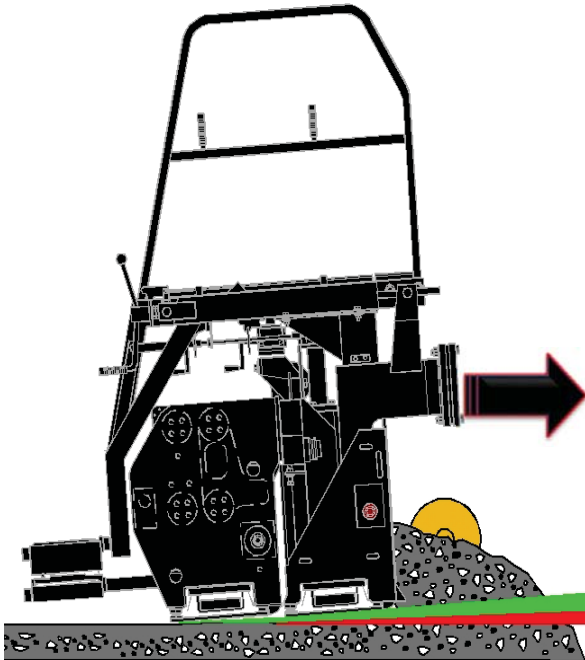
- Angle of attack is the relationship between the nose of the screed & the trailing edge of the screed
- Nose up attitude
- Screed reaches equilibrium

Screed Adjustments - Grade & Slope

- Use depth control cranks or “screws”
- Use tow points



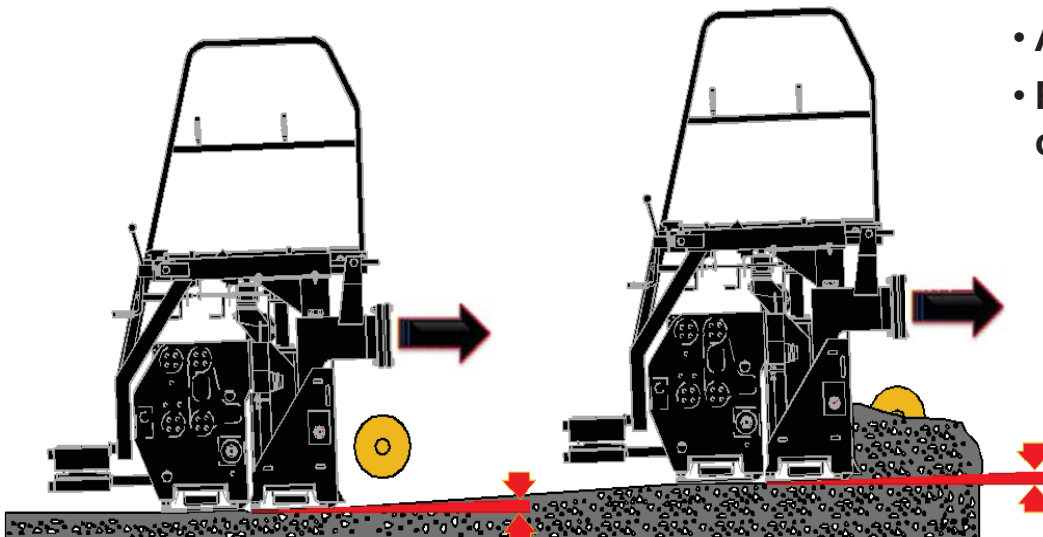
Screed Adjustments



Increase Angle of Attack

- More material passes under screed
- Screed rises to new level
- As screed climbs, angle of attack decreases
- Re-establish same angle, but at increased depth

Screed Adjustments

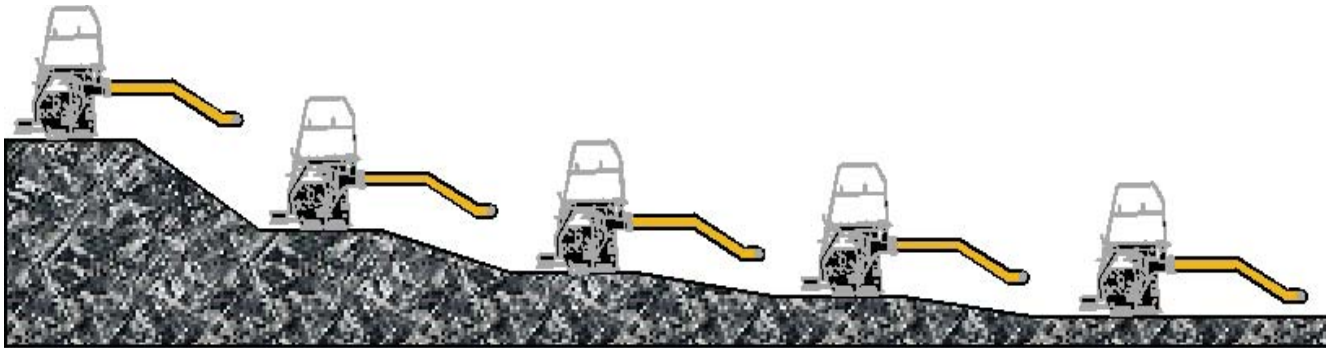


Screed Reaches New Height

- Achieves equilibrium
- Resumes original angle of attack

Screed Adjustments

- Screed reacts to change in angle of attack over 5 tow arm lengths
- 65% of change occurs in the first tow arm length
- 35% of change occurs in the last 4 tow arm lengths
- Factor improves rideability



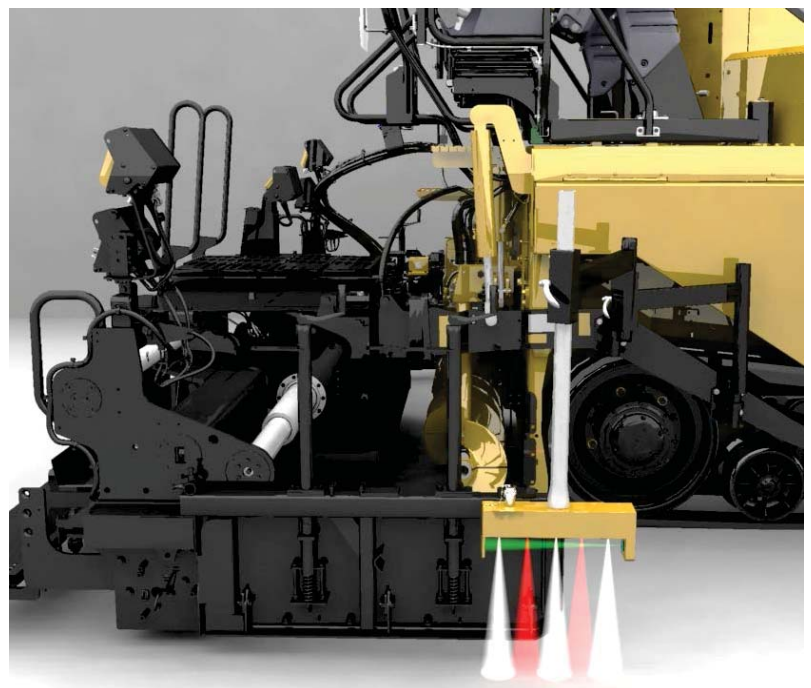
Automatic Grade Control



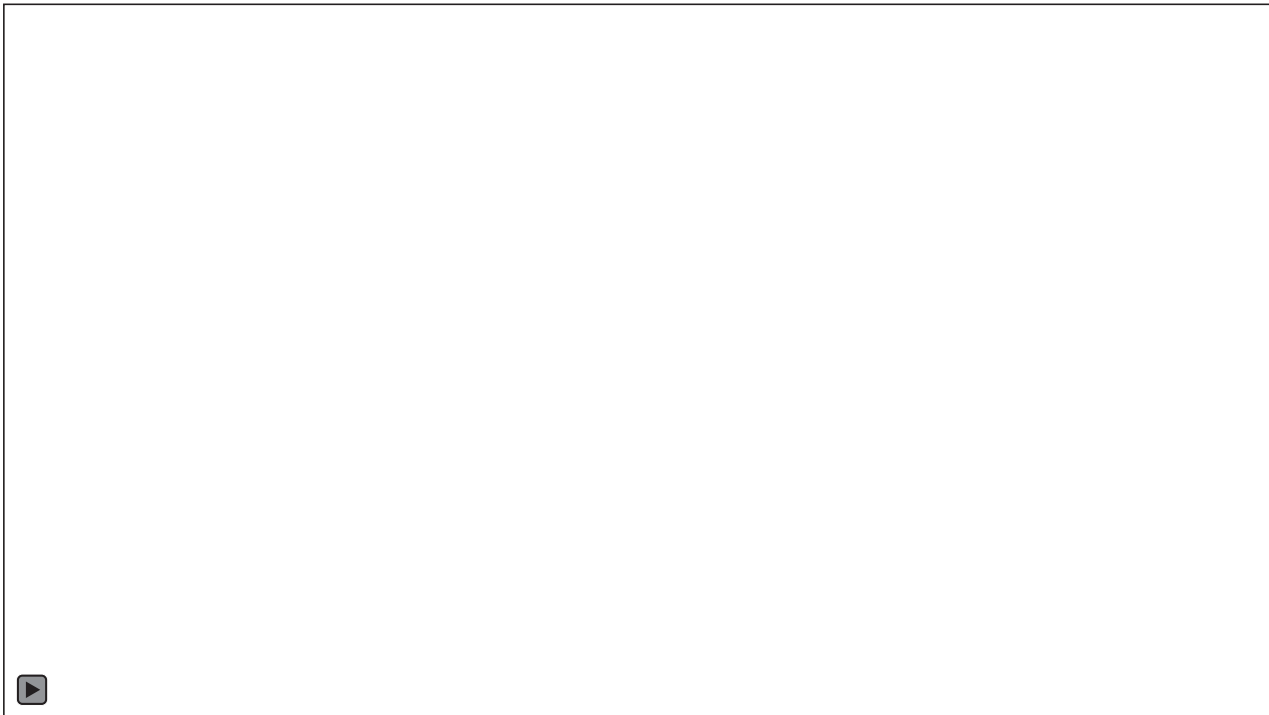
Joint Match (yield)

4:1 reaction

immediate



4:1 reaction for joint matching (yield)



Automatic Grade Control



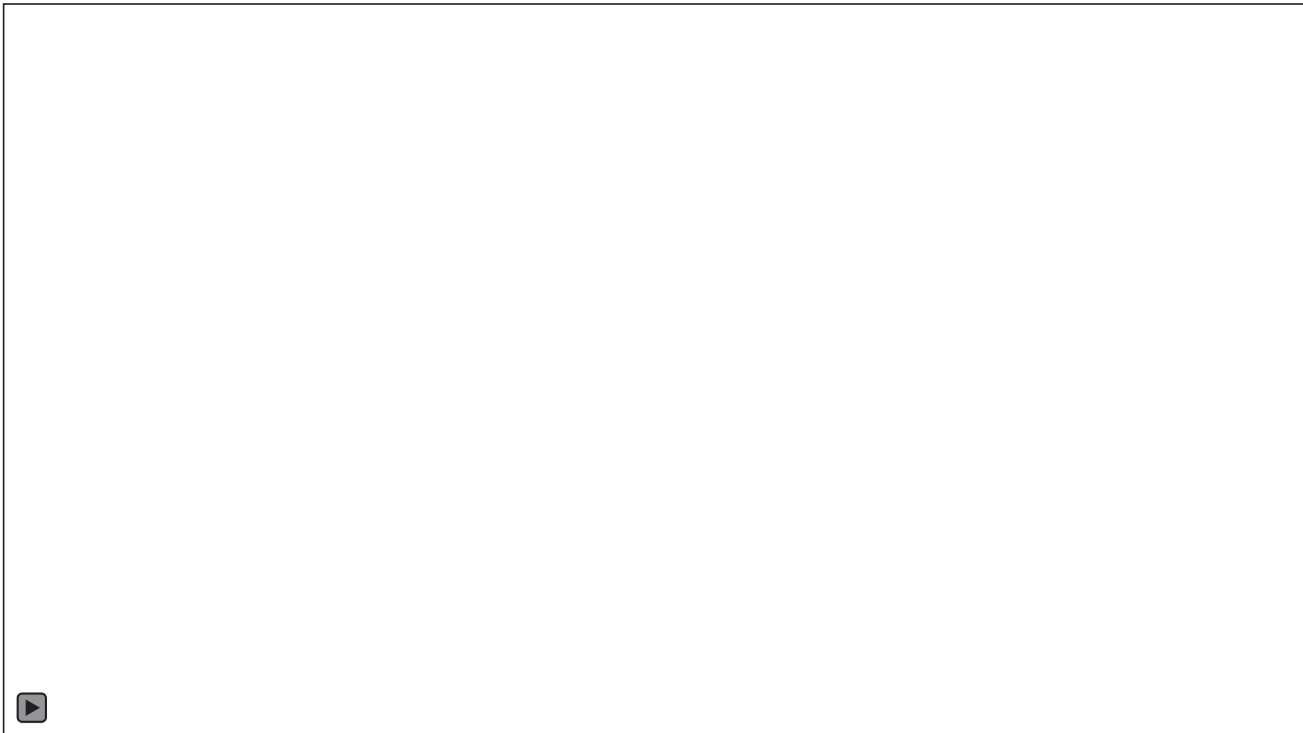
Smooth

1:1 reaction

5 tow arm lengths



1:1 reaction for smoothness



Proper Setup of Automatic Grade & Slope to Achieve Results

- 1. What does the Owner want? How was the job bid? Yield or Smoothness?**
- 2. What reference surfaces will I have for my automatic G&S system?**
 - Centerline, shoulder, milled surface, granular surface, other?**
- 3. Do I take off in automatic or manual? Why? Why not?**
- 4. Ski – sonic or contact? Single sensor?**
- 5. Do I run slope control?**

15 Steps to Setup & Take Off

PAVING BY THE NUMBERS

1. Heat the screed
2. Set the tow points
3. Set paving width
4. Set crown
5. Set extender height
6. Set extender slope
7. Lower screed and remove slack
8. Null the screed
9. Position end gates
10. Set auger height
11. Position feeder sensors
12. Set feeder controls
13. Fill auger chamber/place in auto
14. Set accessory functions
15. Pull off starting reference



QEXQ1403-04
(Replaces QEXQ1403-03)

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Goal: To have a smooth transverse joint & no mat defects *from the start*



Does this look like a good start?



- Rounded face at the joint
- Plunge cut too deep

Good Starting Point



- Cut straight starting joint
- Butt joint flat

- Tack butt joint
- Clean area where screed will rest

Measure Height of Starting Joint



- Calculate thickness of starter boards
- General rule vibratory screed: $\frac{1}{4}$ " compaction per 1" loose depth
- Example: Place 2- $\frac{1}{2}$ " loose to end up with 2" after rolling
- In this picture, need $\frac{1}{2}$ " boards



Step 1: Heat the Screed

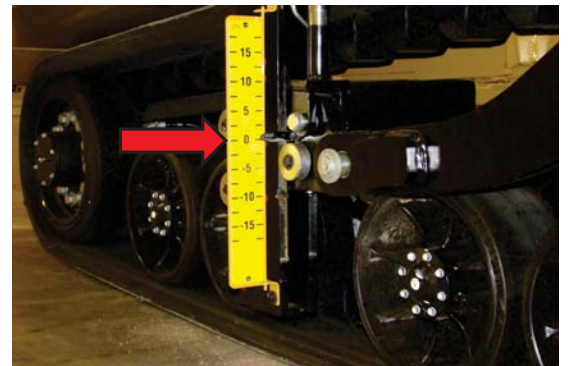


- Prevents sticking

Step 2: Position Tow Point Cylinders

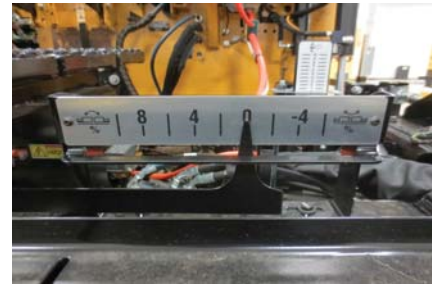
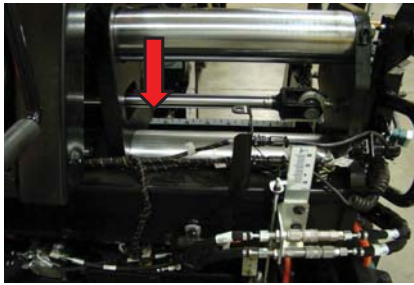


- Straight line-of-pull



Steps 3 through 6

3. Set paving width
4. Set crown
5. Set extender height
6. Set extender slope

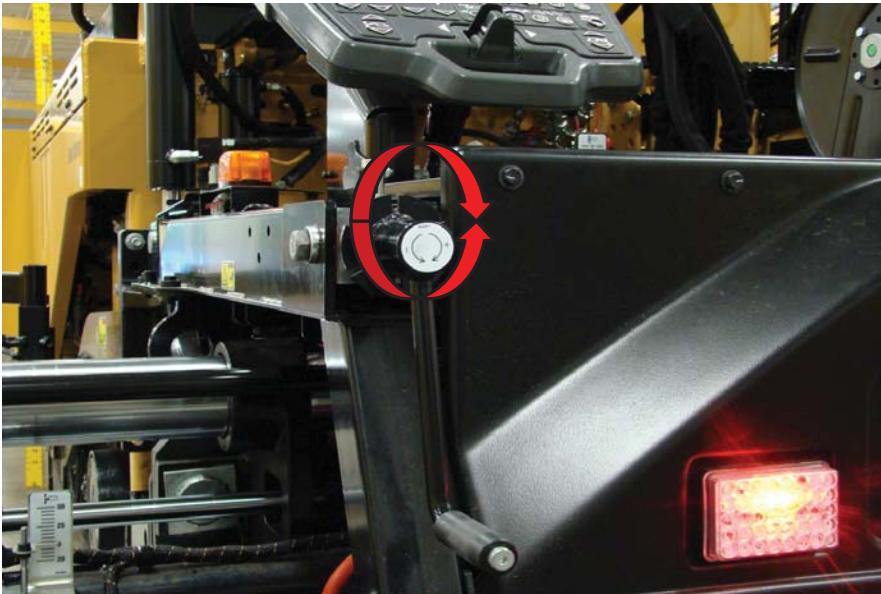


Step 7: Lower Screed



- Place starter boards = to desired mat thickness
- Lower screed onto starting boards in “float” position

Step 8: Null the Screed



- Nulling the screed removes all the tension in the screed
- Use depth screws on each side until no resistance is felt
- The screed must be “free-floating” on the mix

Steps 9 through 12

9. Position end gates
10. Set auger height
11. Position feed sensors
12. Set feeder controls (conveyor ratio dial and mix height dial)



Step 13: Fill the Auger Chamber



- Fill auger chamber with asphalt mix to $\frac{1}{2}$ auger height
- Use conveyors and augers
- Do not overfill

Steps 14 & 15

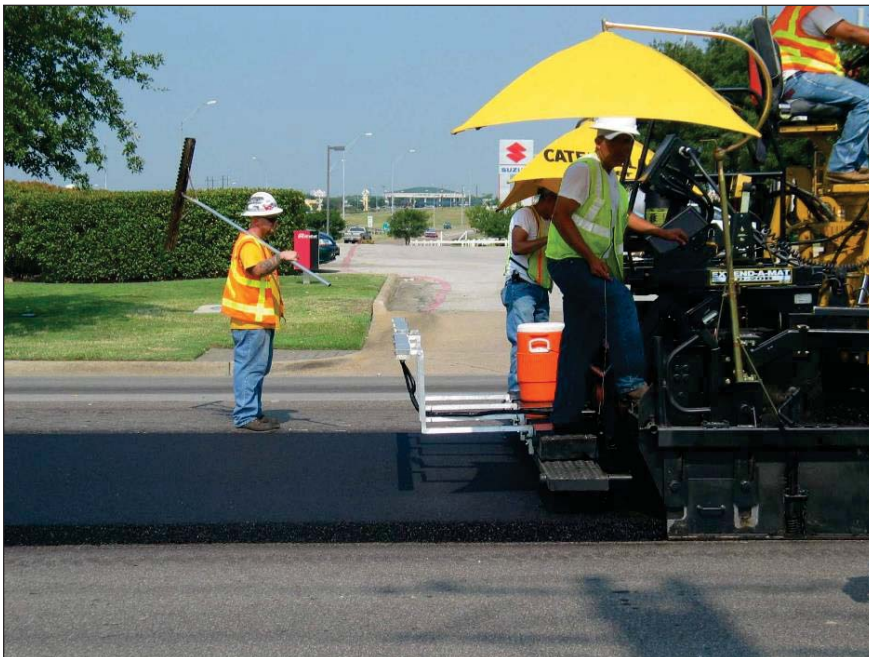


14. Setup automatic Grade & Slope control (if using)
15. Pull off starting boards and quickly get to paving speed

Longitudinal Joints & the Paver Setup



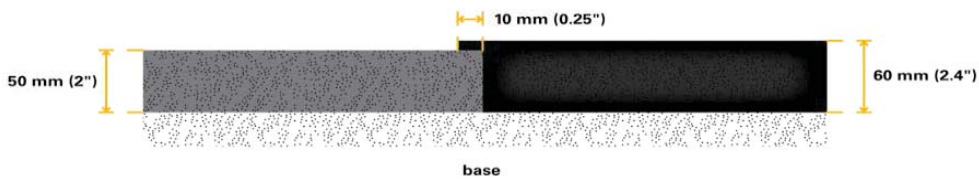
First Pass: Unconfined edge



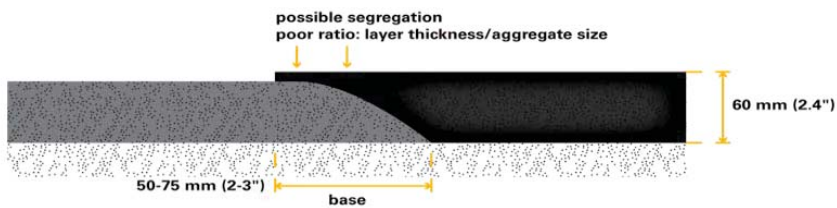
- Keep end gates down
- Get mix out to end gates
- Have sufficient auger extensions and tunnels

Joint Matching: End Gate Overlap

CORRECT SQUARE JOINT — END GATE DOWN



INCORRECT SQUARE JOINT — END GATE UP



- End gate down to create straight edge
- Overlap cold side 1/4in
- Correct pre-compaction height
- End gate up causes rounded edge, segregation and fractured aggregate

Lack of Mix at the Joint



- Joint separation normally caused by lack of mix prior to compaction -- incorrect overlap
- Can be excessive raking
- Can be lack of tack on face of joint

Dr. Ray Brown

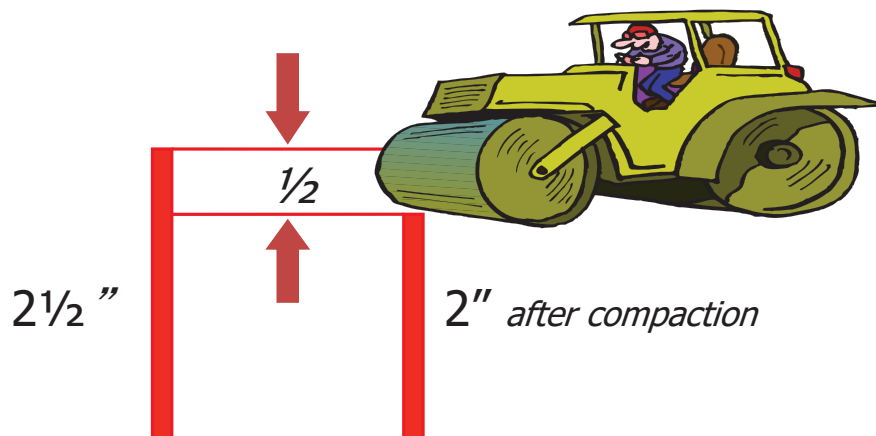
Proper Amount of Joint Overlap



$\frac{1}{2}$ " to 1" overlap



Fluff Factor (roll down) $\frac{1}{4}$ " per 1"



Have auger extensions and tunnels



What we're trying to avoid...



- Excessive head of material
- Segregation at end gate (joint)
- Lack of mix at joint

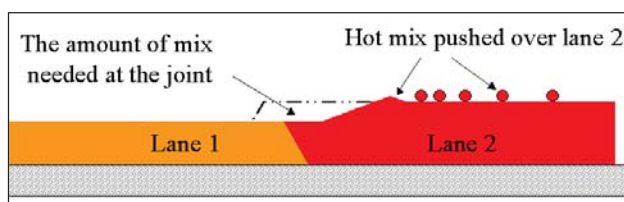
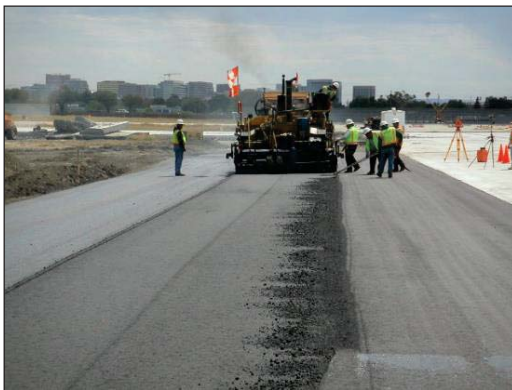
No Raking



- End gates set properly
- Correct overlap
- Correct height match
- Sufficient material to joint
- Rolls down to height match



Which side was paved first?



Don't do this!!



- Use a cut-off shoe when paving width is less than main screed width
- Or get a smaller paver and screed
- Impossible to match lanes

Cut-off shoe



- Used when paving width is less than main screed width

Wide-Width Paving



Variable Wide-width Paving



Variable Width ...

- Find widest section
 - flat screed or sloped extension?
 - set up balanced extensions whenever possible

Variable Wide-width Paving



Variable Width ...

- Add necessary screed extensions
- Check angle of attack and flatness
- Install screed heat plug-in

Variable Wide-width Paving



Variable Width...

- Find narrowest section
 - What is minimum extension width?

Variable Wide-width Paving



Variable Width ...

- Add maximum allowable auger extensions
- Add maximum allowable mainframe extensions

Variable Wide-width Paving



Variable Width ...

- Be prepared to shovel mix out to end gate at widest width
- Be prepared to shovel trapped mix when extension retracted for narrower width

Variable Wide-width Paving



Variable Width ...

- Position mechanical feed sensor
- Paddle 18" from end of auger shaft at 45 degree angle

Variable Wide-width Paving



Variable Width ...

- Aim sonic feeder sensor at material moving off front of the auger shaft
- 18" from target

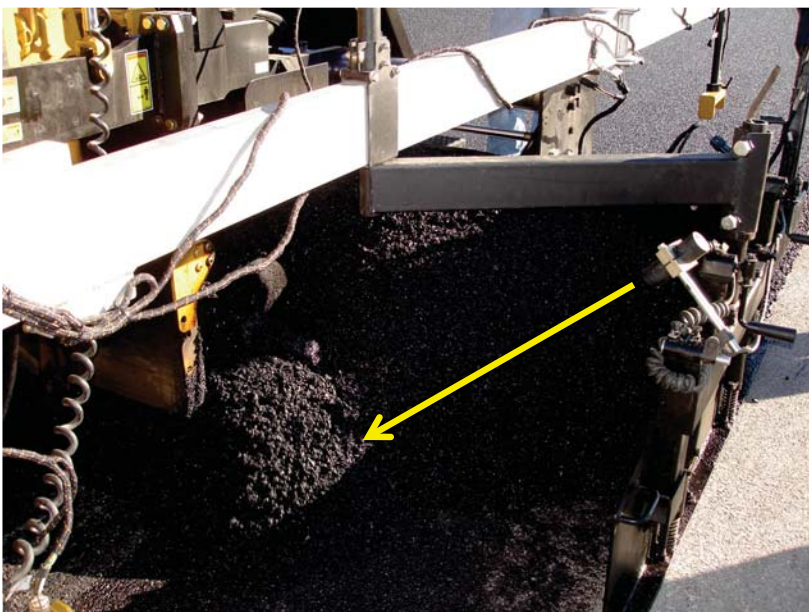
Variable Wide-width Paving



Variable Width ...

- Feeder system runs full speed when sonic sensor more than 30" from target
- Head of material erratic
- Throwing aggregate to create stripe

Variable Wide-width Paving



Variable Width ...

- Still rolling forward around mainframe extension
- Stripe moving toward edge of mat
- Need to re-aim sonic sensor when paving width changes

Fixed Wide-width Paving

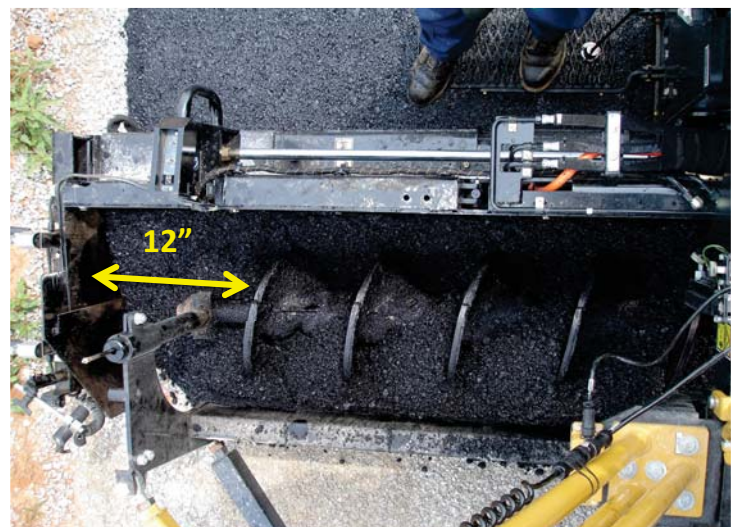


- Install wide-width kit for extra auger and mainframe extension

Fixed Wide-width Paving



- Maintain head of material at half an auger all the way out



- Always cover auger extensions
- Helps guide mix out to end gate

Wide-width Paving



What Not To Do...

- Excessive head of material
- Averaging ski improperly installed
- Feeder sensor in wrong position

Wide-Width Paving

Checklist to Review with Crew...

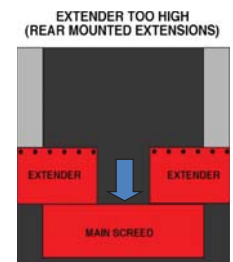
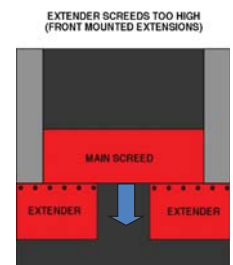
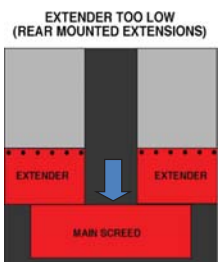
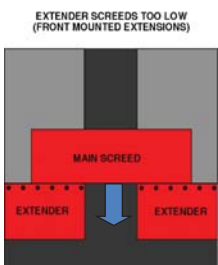
- Confirmed maximum paving width (variable width)
- Confirmed minimum paving width (variable width)
- Installed necessary bolt-on screed extensions
- Installed maximum allowable auger and mainframe extensions
- Reviewed feeder sensor position(s)
- Installed wide-width kit (fixed width paving)
- Reviewed grade control set-up inside paving width
- Reviewed grade control set-up outside paving width

Mat Texture – Angle of Attack



- Angle of attack of main screed and extenders should be set to produce a uniform mat texture
- Extenders have an independent angle of attack on hydraulic extendible screeds

Mat Texture - extender height lines



Mat Texture – on/off augers...feed sensors



- Aim feed sensors for continuous auger movement

Summary: Paver Setup & Operation

- Screed is “free-floating”
- Follow *Paving by the Numbers* setup (15 steps)
- Proper head of material is $\frac{1}{2}$ auger height
- Depth cranks are used to change mat thickness and slope
- 5 tow arm lengths for full change in thickness to take place
- Changes in paving speed usually requires a change to mix feed settings (conveyors, mix height dial)
- Increased head of material causes screed to rise up
- Decreased head of material results in screed dropping
- Continuous mix feed and constant paver speed = smoothness!!

Thank-you for your attention!

Questions?



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Compaction Theory and Best Practices

2017 Idaho Asphalt Conference

Moscow Idaho

October 26, 2017

Dave Johonson, P.E.

Senior Regional Engineer

Asphalt Institute

Understanding the Importance of Density

**“More emphasis must be placed on obtaining adequate density.”
– NCHRP Report 531 (2004)**

Carl Monismith – “...we could improve the life of our pavements in California a very substantial amount with the existing materials that we have if we just changed the compaction specification for the asphalt concrete. Right now we build pavements that have shorter lives than they should.” (AAPT 1997)

Importance of Compaction



“Compaction is the single most important factor that affects pavement performance in terms of durability, fatigue life, resistance to deformation, strength and moisture damage.” – C. S. Hughes, NCHRP Synthesis 152, *Compaction of Asphalt Pavement*, (1989)



“The amount of air voids in an asphalt mixture is probably the single most important factor that affects performance throughout the life of an asphalt pavement. The voids are primarily controlled by asphalt content, compactive effort during construction, and additional compaction under traffic.” – E. R. Brown, NCAT Report No. 90-03, *Density of Asphalt Concrete—How Much is Needed?* (1990)

Link Density to Pavement Durability

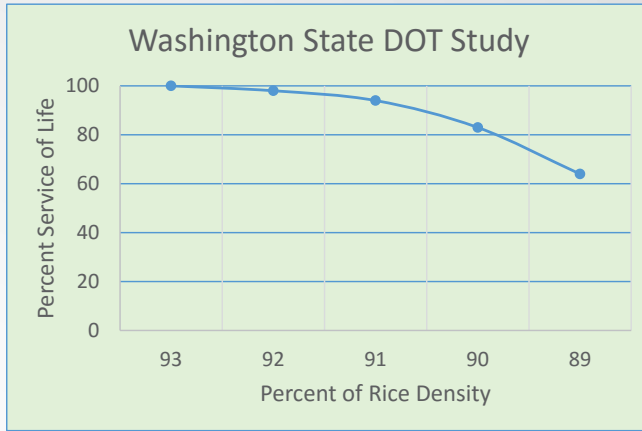
Improved Compaction =
Improved Performance

A **BAD** mix with **GOOD** density out-performed a **GOOD** mix with **POOR** density for ride and rutting.



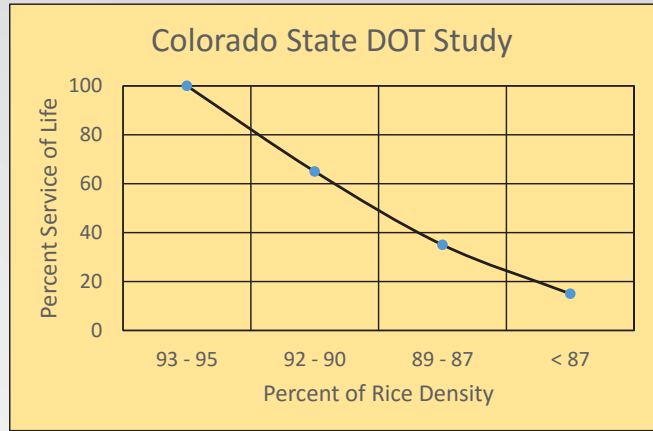
WesTrack Experiment

Density vs. Loss of Pavement Service Life



Thicker Pavements

TRR 1217, 1989

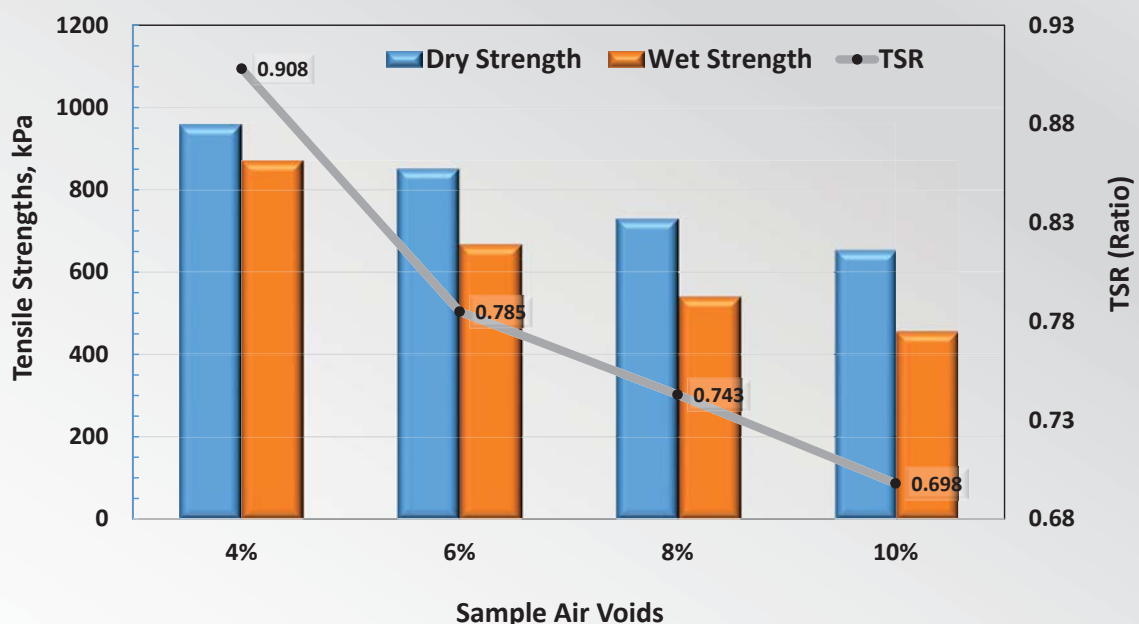


Typical Pavements

CDOT 2013-4, 2013

For both thicker and thinner, reduced in-place density at the time of construction results in significant loss of Service Life!

Tensile Strength & Moisture Susceptibility vs. Air Voids AASHTO T 283



Asphalt Institute Research

Literature Review on connecting in-place density to performance

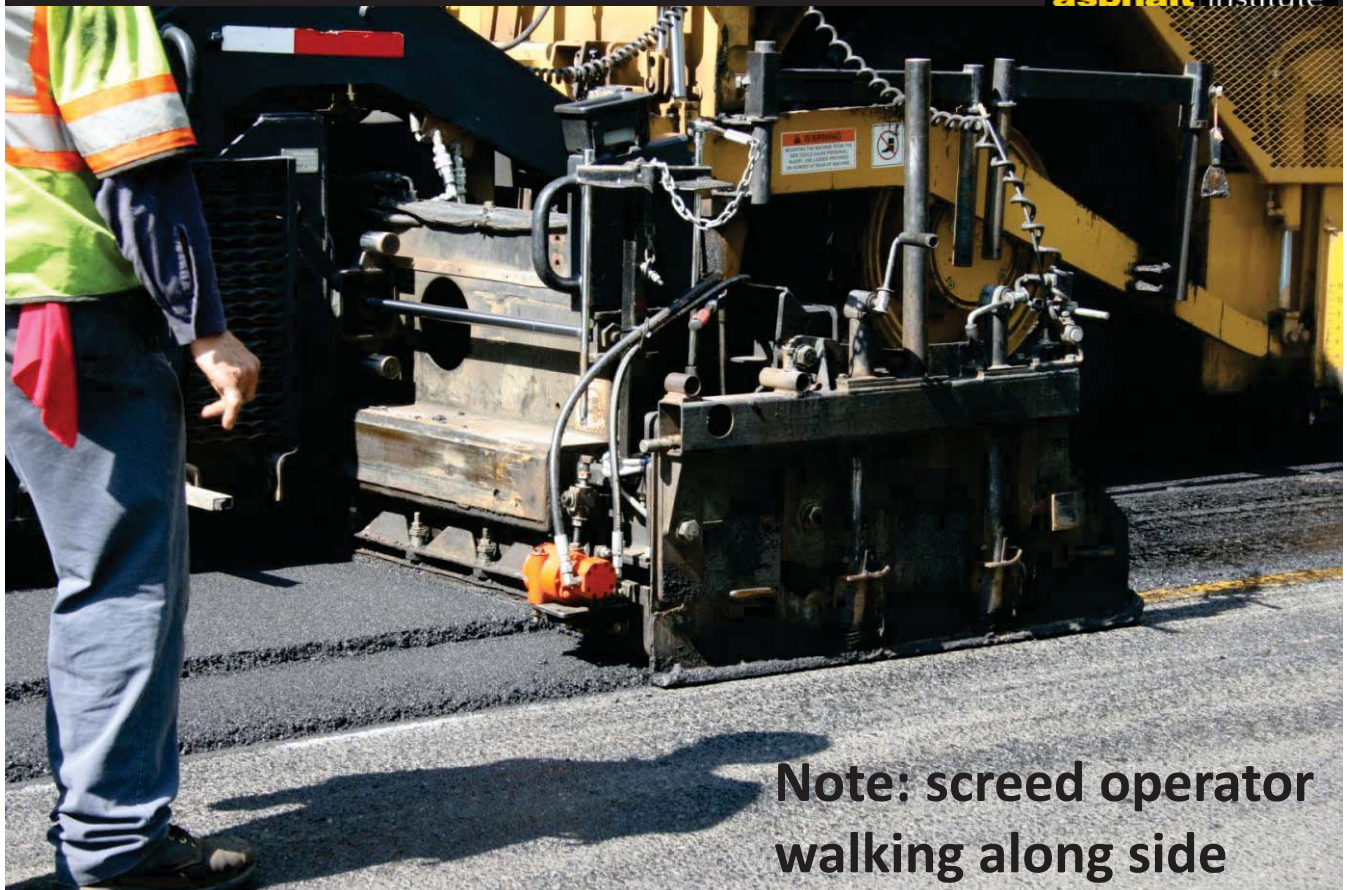
- 5 studies cited for fatigue life
- 7 studies cited for rutting
- “A **1% decrease in air voids** was estimated to improve the fatigue performance of asphalt pavements between 8.2 and 43.8%, to improve the rutting resistance by 7.3 to 66.3%, and to **extend the service life by conservatively 10%.**”

Research on Critical Air Void Level for Impermeability

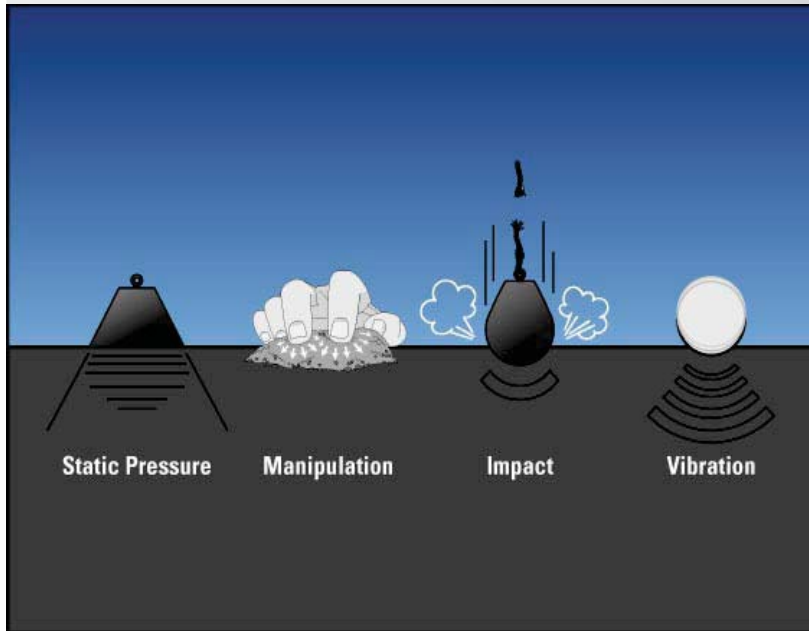
“...to ensure that permeability is not a problem, the **in-place air voids should be between 6 and 7 percent or lower.** This appears to be true for a wide range of mixtures regardless of NMAS and grading.” – NCHRP 531

Forces of Compaction and Roller Types

Vibratory Screed Should Always be “ON”



**Note: screed operator
walking along side**



Compaction forces

- Low force
 - Static pressure
 - Manipulation
- Higher forces
 - Impact
 - Vibration

Effect of Roller Type, Size, Passes

Roller type and size affects:

- Magnitude of the load
- Manner the load is imparted to the pavement

Number of passes:

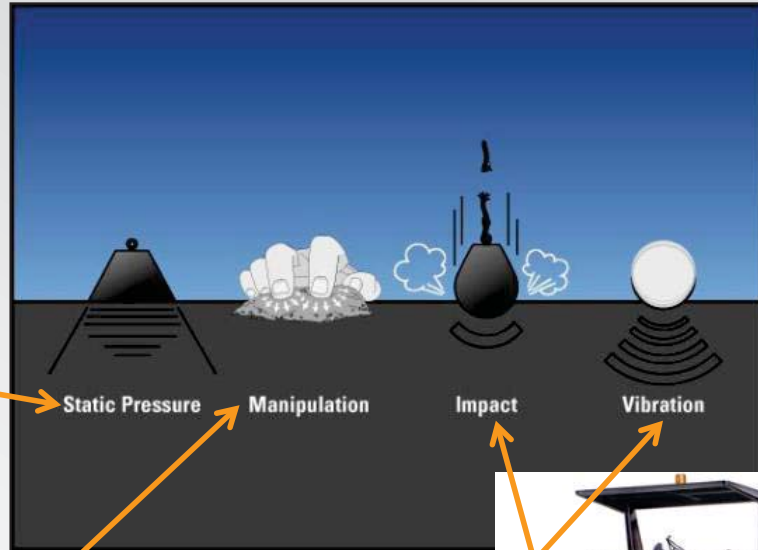
- Increases the density
- To break over point after a # of passes
 - Lowers compaction
 - If continued, damages mat



Static Steel-Wheeled



Pneumatic



Vibratory

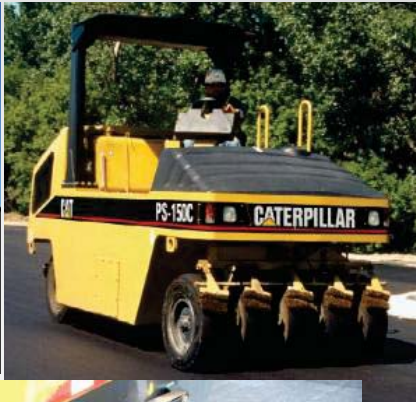
Static Steel-Wheeled Rollers



Static Pressure



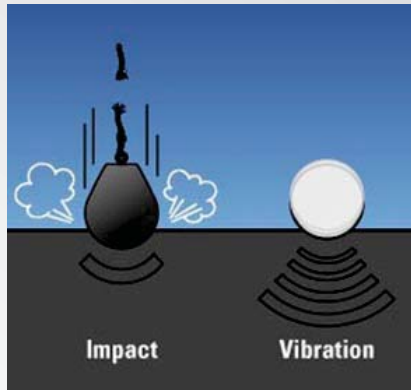
- 8 -14 ton rollers normally used for HMA compaction
 - Commonly use vibratory rollers operated in static mode
- Lighter rollers used for finish rolling
- Drums must be smooth and clean
 - Water spray & scraper bars
- For initial compaction, drive wheel must face paver must face paver



- Reorients particles through kneading action
- Tire pressures:
 - ~80 psi (cold) for compaction
 - ~50 psi (cold) for finish rolling
 - Range of tire pressures not to exceed 10 psi
- Used as Intermediate or as Breakdown Roller
- Tires must be hot to avoid pickup
- Tires must be smooth - no tread
- Not used for PFC mixes or SMA

Pneumatic Rubber Tired Rollers

- Many experts believe kneading action helps in providing a tighter surface that is more dense and less permeable compared to drum rollers.
 - Research supports this
- But must keep these away from the unsupported edge to avoid excessive lateral movement of mat.
- Use during intermediate rolling of the supported edge.
 - Not finish rolling



- Commonly used for initial (breakdown) rolling
- 8-18.5 tons, 57-84 in wide (“heavy” rollers)
 - 50-200 lbs/linear inch (PLI)
- Frequency: 2700-4200 impacts/min.
- Amplitude: 0.016-0.032 in.
 - For thin overlays (≤ 2 in.) use low amplitude or static mode
- Operate to attain at least 10 impacts/ft
 - 2-4 mph

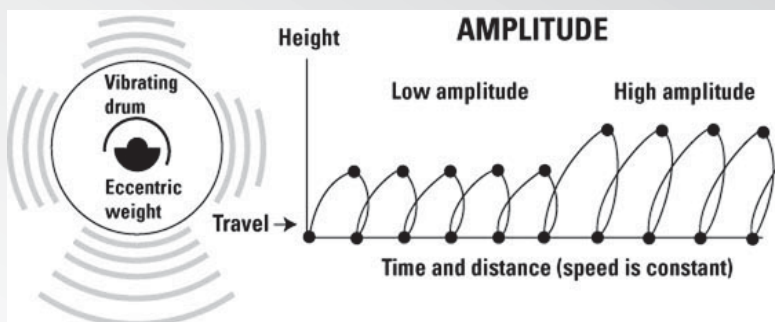
What Makes Vibratory Rollers More Effective?

- Movement of drum initiates particle motion
- When particles are moving
 - Resistance to deformation is reduced
- Force applied by weight of drum plus inertia
 - Produces a greater compactive effect
 - Achieving more compaction per pass than static rollers





Vibratory Rollers - Amplitude



- Spinning eccentric weight causes drum movement
- Falling drum adds to compactive force
- Distance drum moves is called amplitude
- Amplitude determines impact force

Low Amplitude

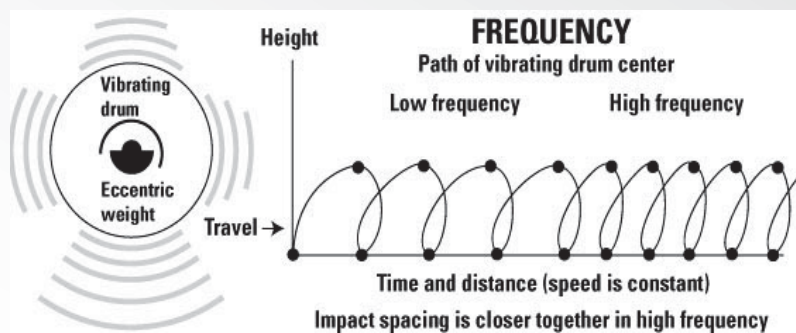


High Amplitude





- Frequency
 - Drum impacts per minute
- Match travel speed to frequency
- Best results when impact spacing is 10-14 per foot



Drum Impacts per Foot

Frequency	2 MPH	3 MPH	4 MPH	5 MPH
2000 vpm	11.36	7.58	5.68	4.55
2200 vpm	12.50	8.33	6.25	5.00
2400 vpm	13.64	9.09	6.82	5.45
2600 vpm	14.77	9.84	7.39	5.91
2800 vpm	15.91	10.61	7.95	6.36
3000 vpm	17.05	11.36	8.52	6.82
3200 vpm	18.18	12.12	9.09	7.27
3400 vpm	19.32	12.88	9.66	7.72
3600 vpm	20.45	13.64	10.22	8.18
3800 vpm	21.59	14.39	10.80	8.63
4000 vpm	22.72	15.16	11.36	9.10



- Amplitude too high
- Travel speed too fast
- Vibrating cool mat
 - Roll closer to paver
- Finish rolling too cool
 - Roll closer to intermediate roller
- Finish roller too light

Newer Roller Technology

- Technology
 - Intelligent Compaction
 - Vibratory Pneumatic
 - Oscillatory Rollers



Vibratory Pneumatic Roller

- Color-coded display in cab – real-time feedback
- Optimum # passes are achieved more consistently
- Analysis of data provides insight into critical factors of the compaction process
- Proof rolling of base or mapping of existing materials

Oscillatory Rollers

Bomag



Hamm



Sakai



CAT



- Aid in compacting difficult mixes
- Lower cessation temperature
- Contact suppliers for additional information

Roller Operations & Roller Procedures

- Roller Patters
 - Sequencing
 - Passes—A roller passing over one point in the may one time
 - Roller Speed
- Rolling Zone
- General Rolling Operations
- Dealing With Challenging Mixes

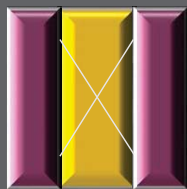
Traditional Roller Operations Sequencing

- Breakdown Rolling
- Intermediate Rolling
- Finish Rolling

- How many passes?
- How to be sure mix is rolled at correct temperature?
- How fast to roll?

Rolling Pattern

**Previously
Compacted Mat**

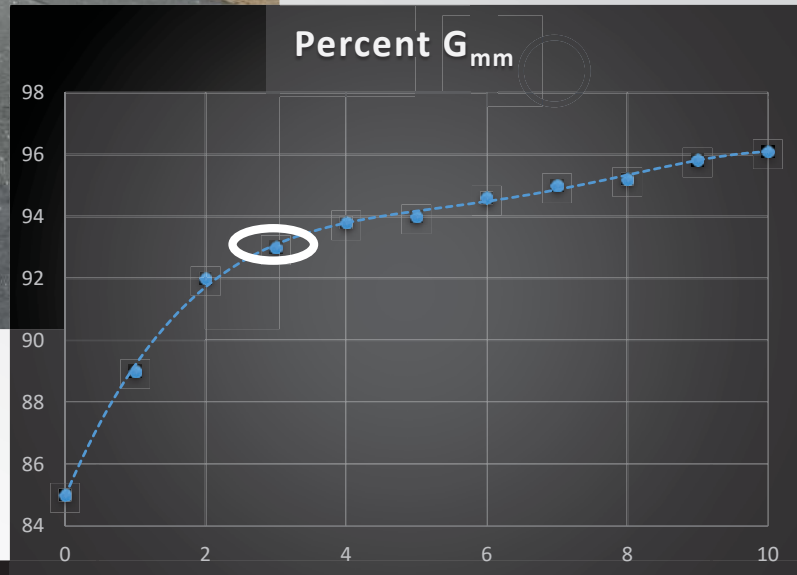


100 - 170 ft

- Roller width should overlap 6 inches
- Odd number of passes to advance
- Repeat uniformly



Goal: 93.5% G_{mm}



Select: 3 Passes
(Intermediate will get the rest of the density)

Rolling Pattern

- Speed and lap pattern for each roller
- Number of passes for each roller
 - One trip across a point on the mat
 - Set minimum temperature each roller finishes



IMPORTANT:

- Paver speed must not exceed compaction!!!
- Paver makes single pass
- Roller pattern requires 3-7 passes

- First roller behind paver
- Gets most of density
- Begin at highest temperature without huge mat distortion
- May have to work very close to paver for some mixes
- May be performed with two coordinated rollers



Breakdown Rolling



- Traditionally 3-wheel steel
- D/D vibratory most common
- Vibration most productive during breakdown
- Pneumatics
 - Used on base courses
 - Leveling courses
 - Forces mix into cracks
 - Compacts without bridging minor ruts
- Can leave marks – may be harder to roll out



- Final step in getting density and initial smoothness
- Mat hot enough to allow aggregate movement
- Mat already close to final density
- Too much force will fracture aggregate
- Typical roller type:
 - Traditionally pneumatic
 - Vibratory at low amplitude and/or static mode

Pneumatic Roller





Main purpose

- Minimal compaction
- Smoothness
- Removal of any marks
- Once smooth, stop rolling

Typical roller types:

- Tandem steel-wheel
- Pneumatic w/lower pressure
- Vibratory static mode only

General Rolling Procedures



For best results

- Roll at highest temperature without excessive displacement
- Stay close to paver
- Monitor weather
- Keep up but not too fast
 - Slower paver speed
 - Not faster roller speed

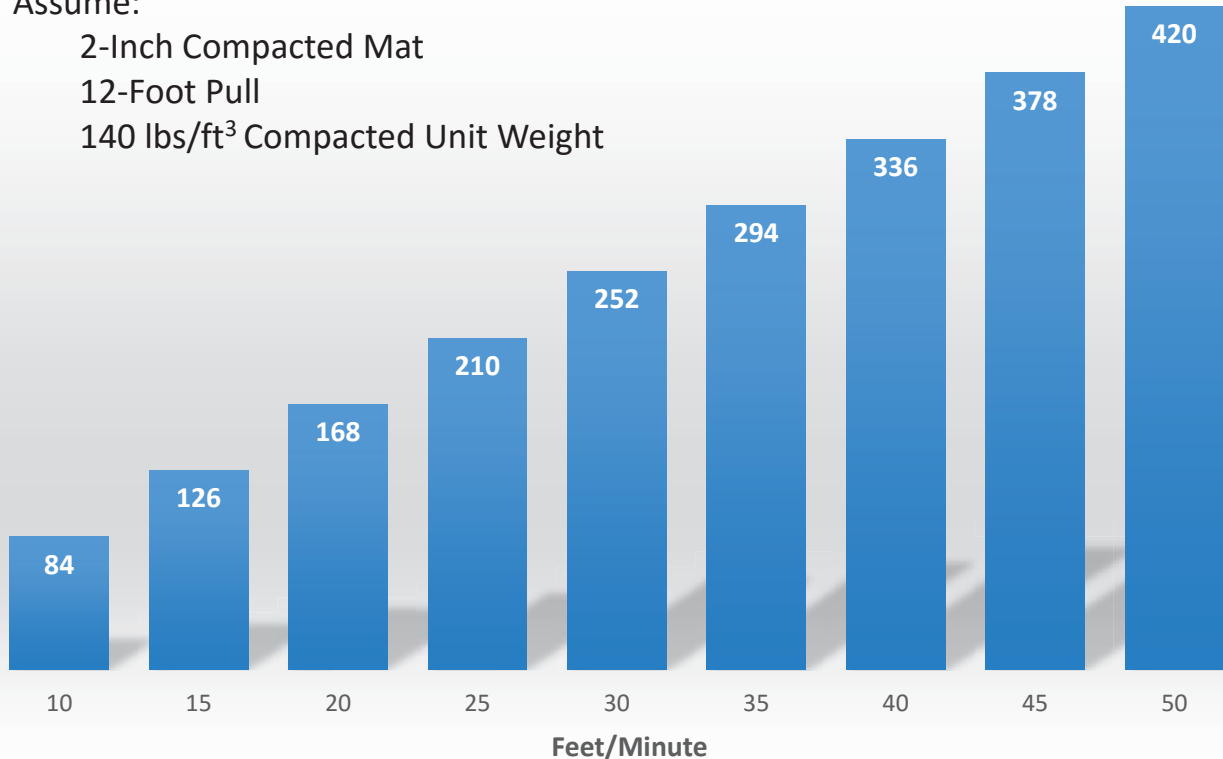
Assume:

2-Inch Compacted Mat

12-Foot Pull

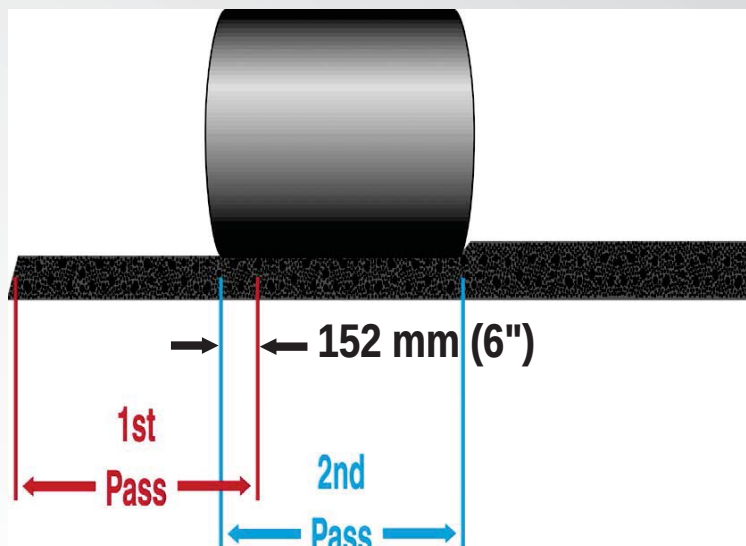
140 lbs/ft³ Compacted Unit Weight

Tons/Hour



General Rolling Procedures

Overlaps

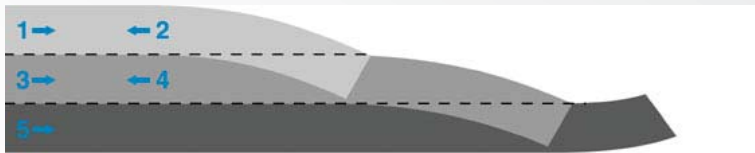


- 6" overlap assures uniform compaction
- Include overlap selecting drum width
- Roller should cover mat in no more than 3 passes



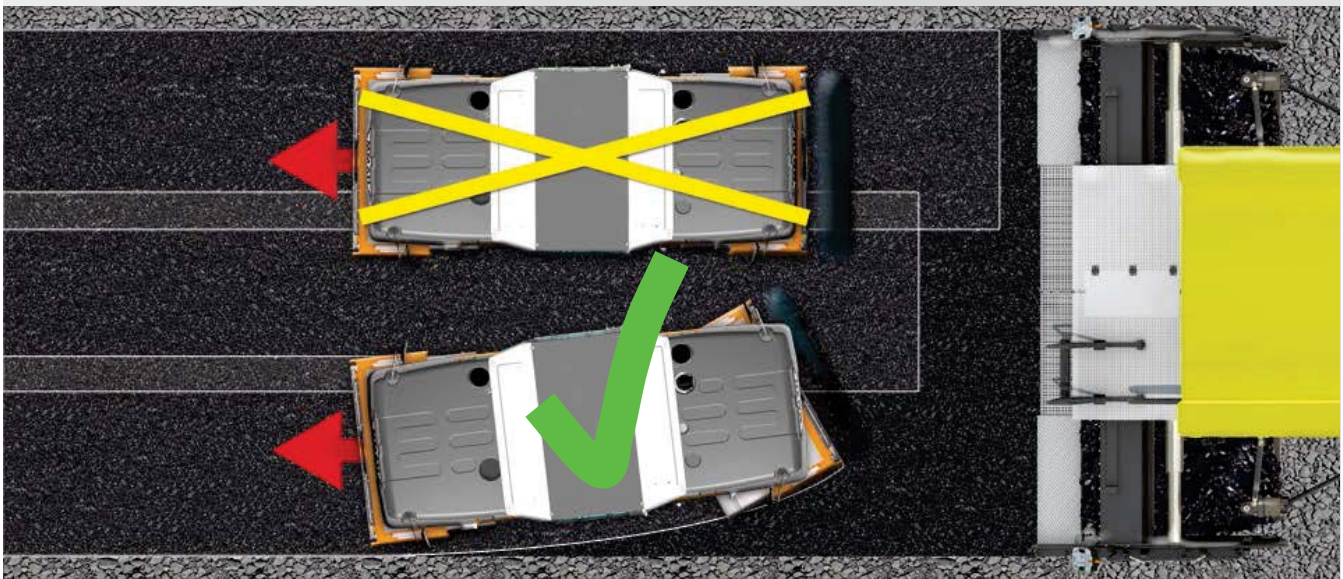
Reversing Directions

- Avoid straight stops
- Turn toward center of mat
- Don't turn drum while stopped
- Next pass should roll out any marks created by reversing



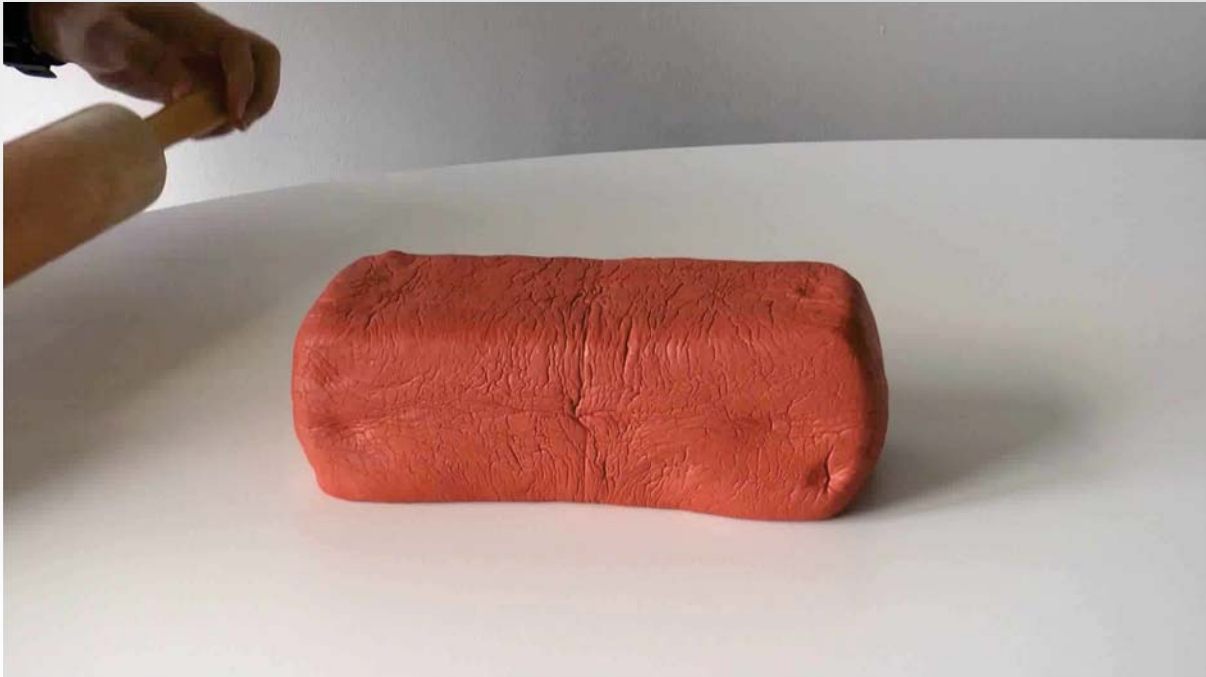
Reversing

Compact the Mat While It Is Hot!

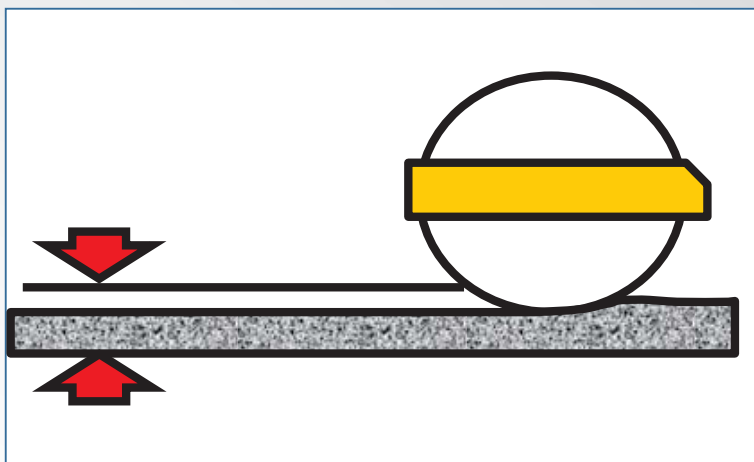


Stay Close to the Paver with Breakdown Rollers.

Always Stop and Reverse Directions at an Angle!



General Rolling Procedures



Rolldown

- Paver lays thicker lift
- Roller compacts to the design thickness
- Superpave mixes rolldown ~ 25%
- SMA, PFC & other open-graded mixes rolldown ~15%

- Compact mat when it is hot!
- Conduct a density control strip at the beginning of the project
 - Determine optimum roller pattern
 - Stick with roller pattern throughout project unless something changes in the conditions
- Reverse directions properly
 - Turn into stops
 - Do not turn while standing
- Do not stop roller on hot mat
- Use proper technique when compacting longitudinal joints
(See Asphalt Institute Webpage: asphaltinstitute.org)

Questions/Discussion

What is Achievable?

