National Center for Asphalt Technology
NCAT
at AUBURN UNIVERSITY

Balanced Mix Design for Texas and Oklahoma

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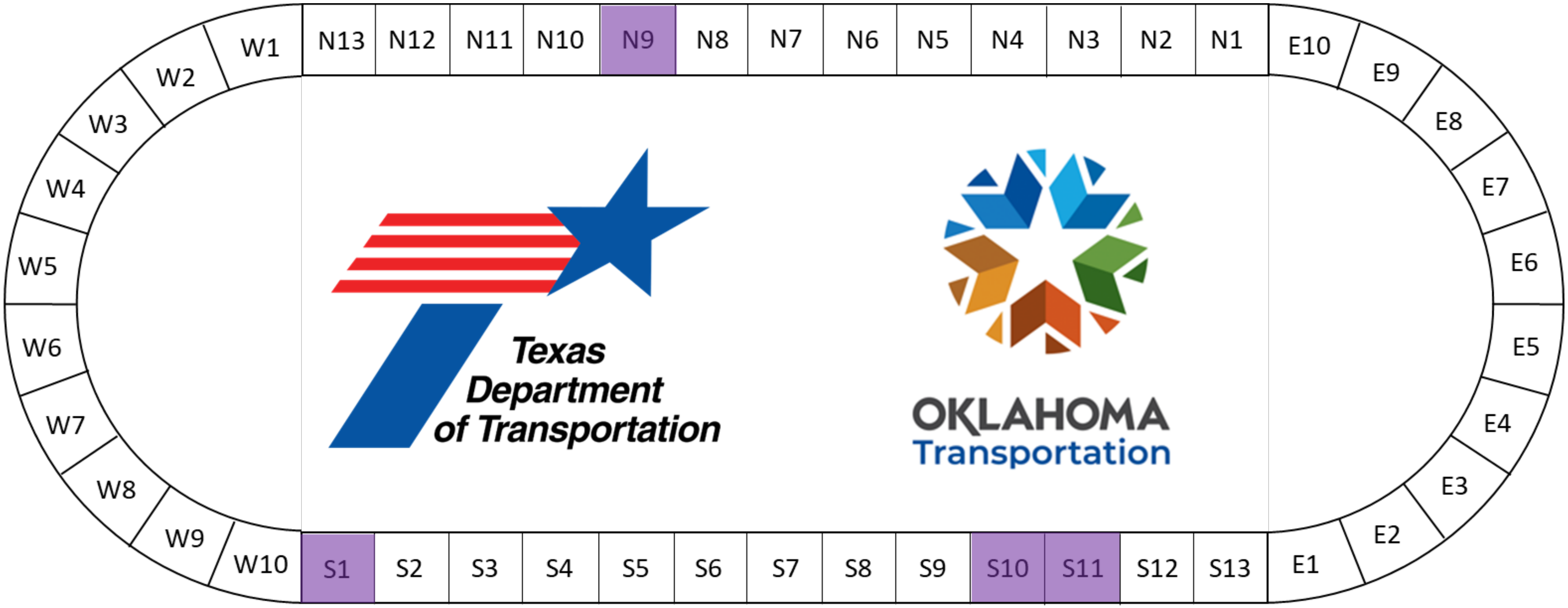
SEVENTH RESEARCH CYCLE

NCAT TEST TRACK CONFERENCE

Balanced Mix Design (BMD) Experiments



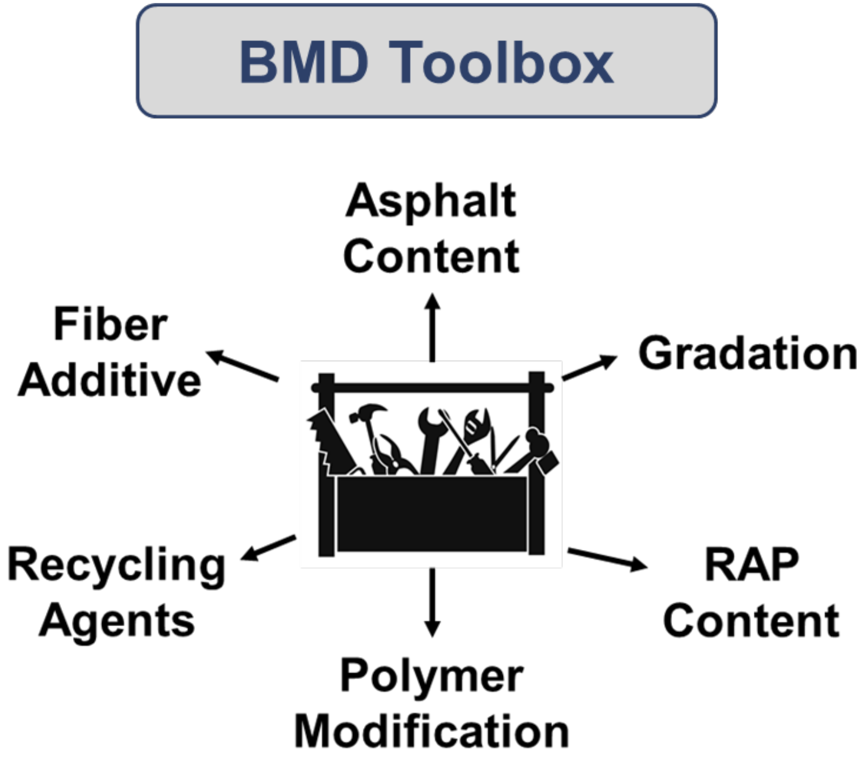
Texas BMD Experiment

- Objective: performance comparison of asphalt mixes designed with a BMD approach versus the traditional volumetric approach
- 2.5-inch mill-and-inlays over existing pavements with 15 to 20% cracked lane area
- Mix designs
  - 12.5 mm SP-C surface mix (50 gyrations)
  - PG 70-22 SBS modified binder
  - 20% RAP binder replacement ratio
  - S11 volumetric mix
  - S10 BMD mix (HWTT + OT)

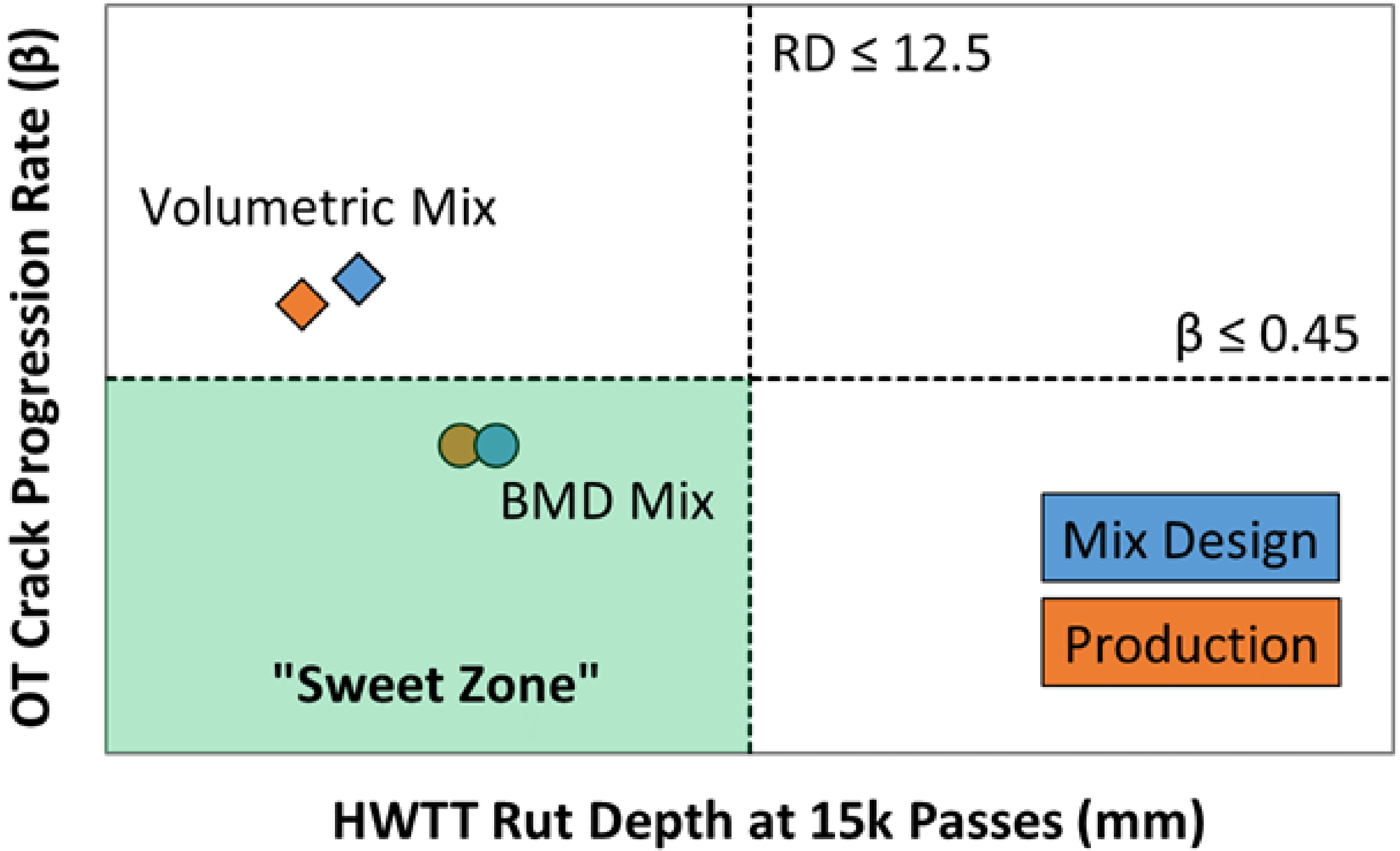
Mix Design Modifications for S10 BMD Mix

- Coarser gradation
- Higher VMA and V_{be}
- Improved cracking resistance
- Mix design volumetrics

Mix Property	S10 BMD	S11 Volumetric
Binder Content, %	5.5	4.7
Air Voids, %	4.0	4.0
VMA (G_{se}), %	16.6	15.0
V_{be} (G_{se}), %	12.6	11.0
VFA (G_{se}), %	76	73

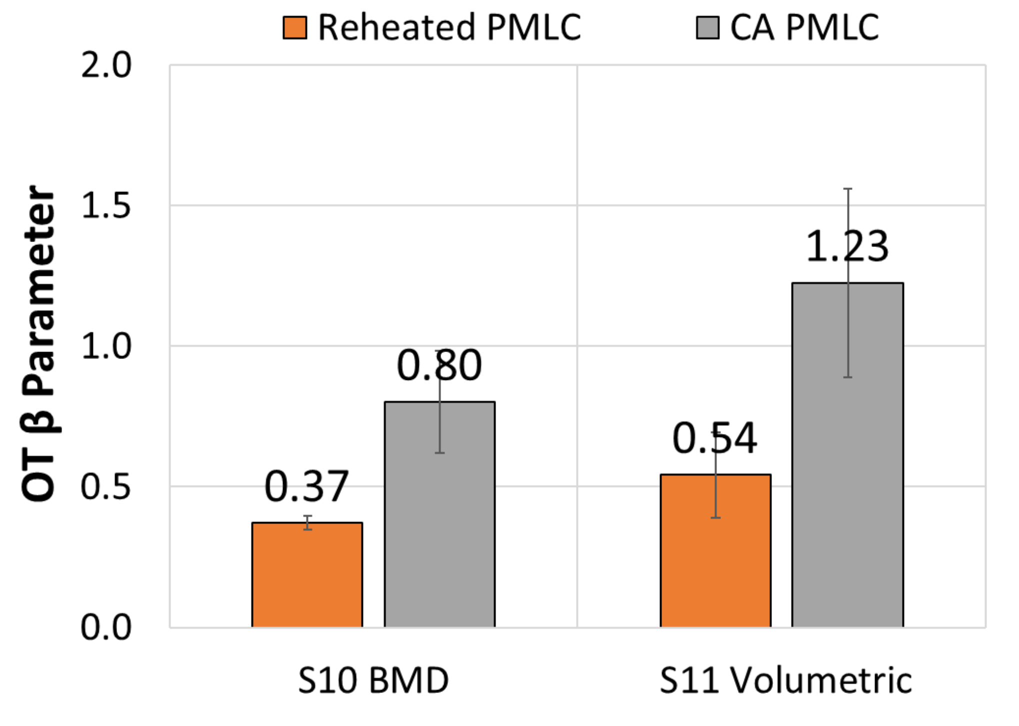


BMD Performance Testing

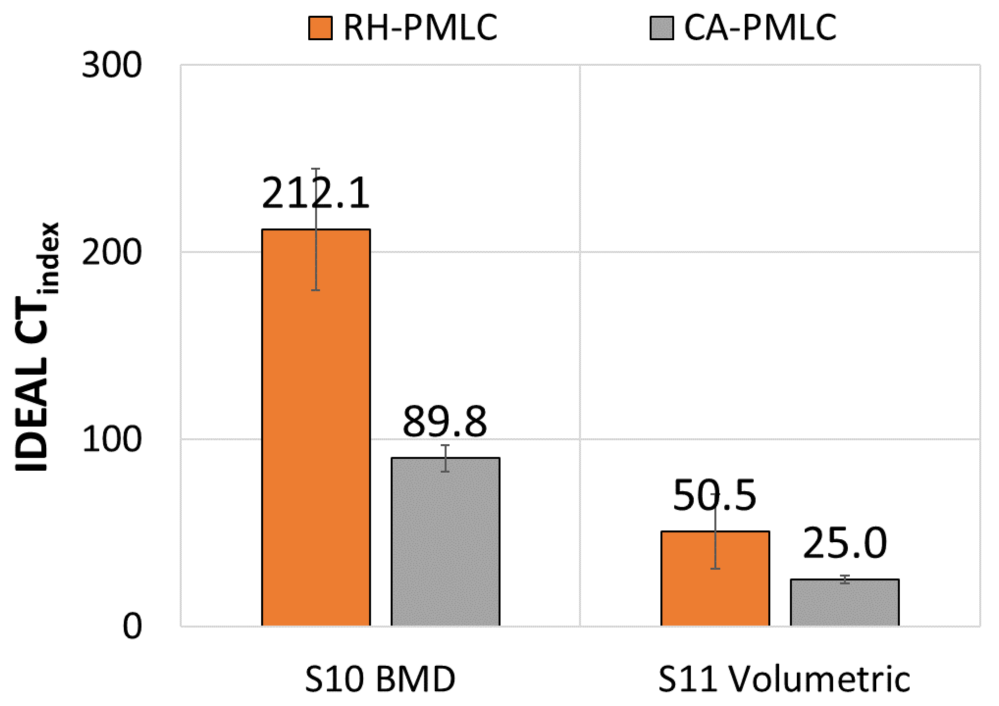


Impact of Mix Critical Aging (8 hours at 135°C)

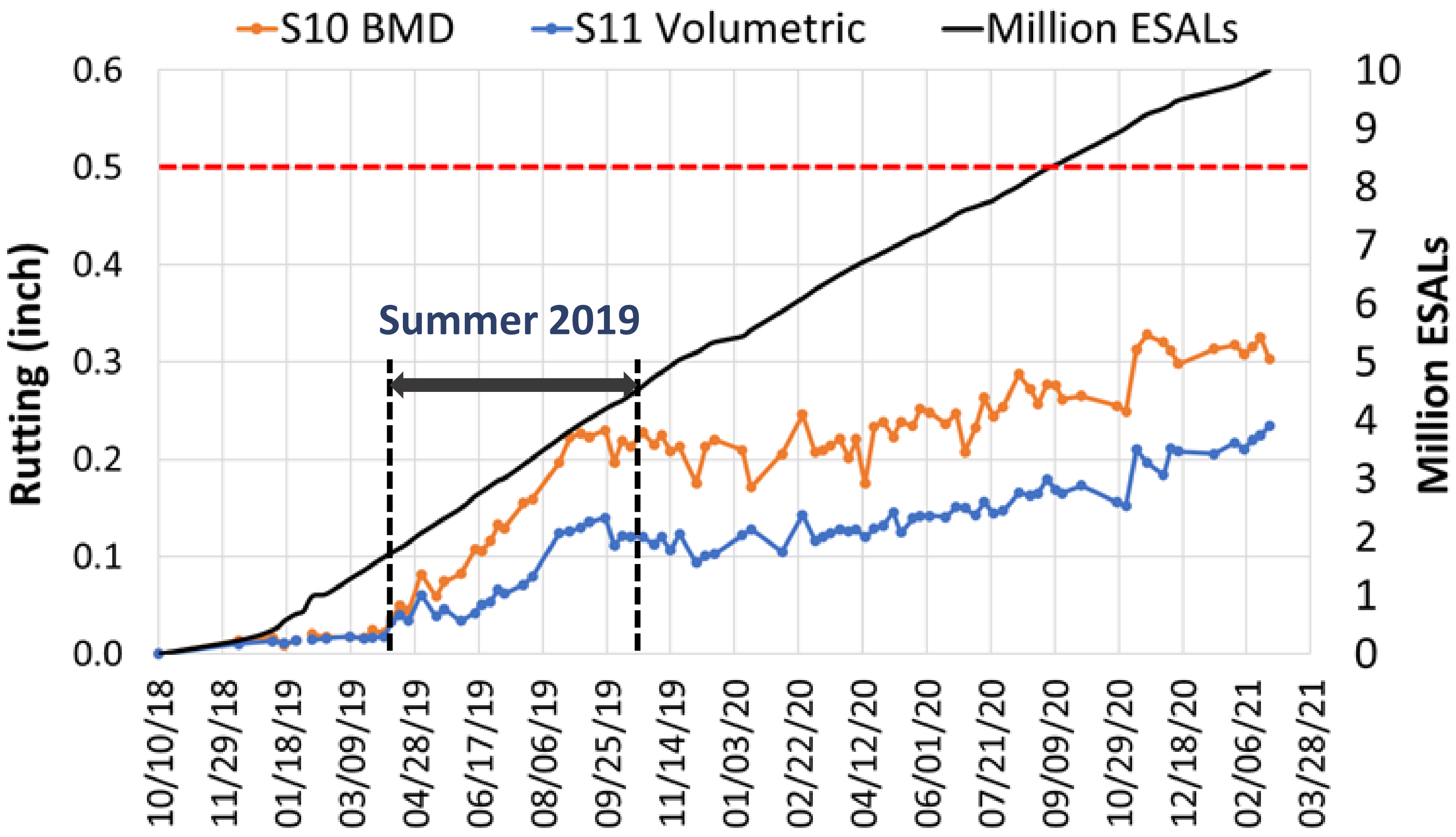
OT Crack Progression Rate (β)



IDEAL Cracking Tolerance Index (CT_{Index})



Rutting



S10 BMD
S11 Volumetric
Million ESALs
Summer 2019
Rutting (inch)
Million ESALs
0.6
0.5
0.4
0.3
0.2
0.1
0.0
10
9
8
7
6
5
4
3
2
1
0
10/10/18
11/29/18
01/18/19
03/09/19
04/28/19
06/17/19
08/06/19
09/25/19
11/14/19
01/03/20
02/22/20
04/12/20
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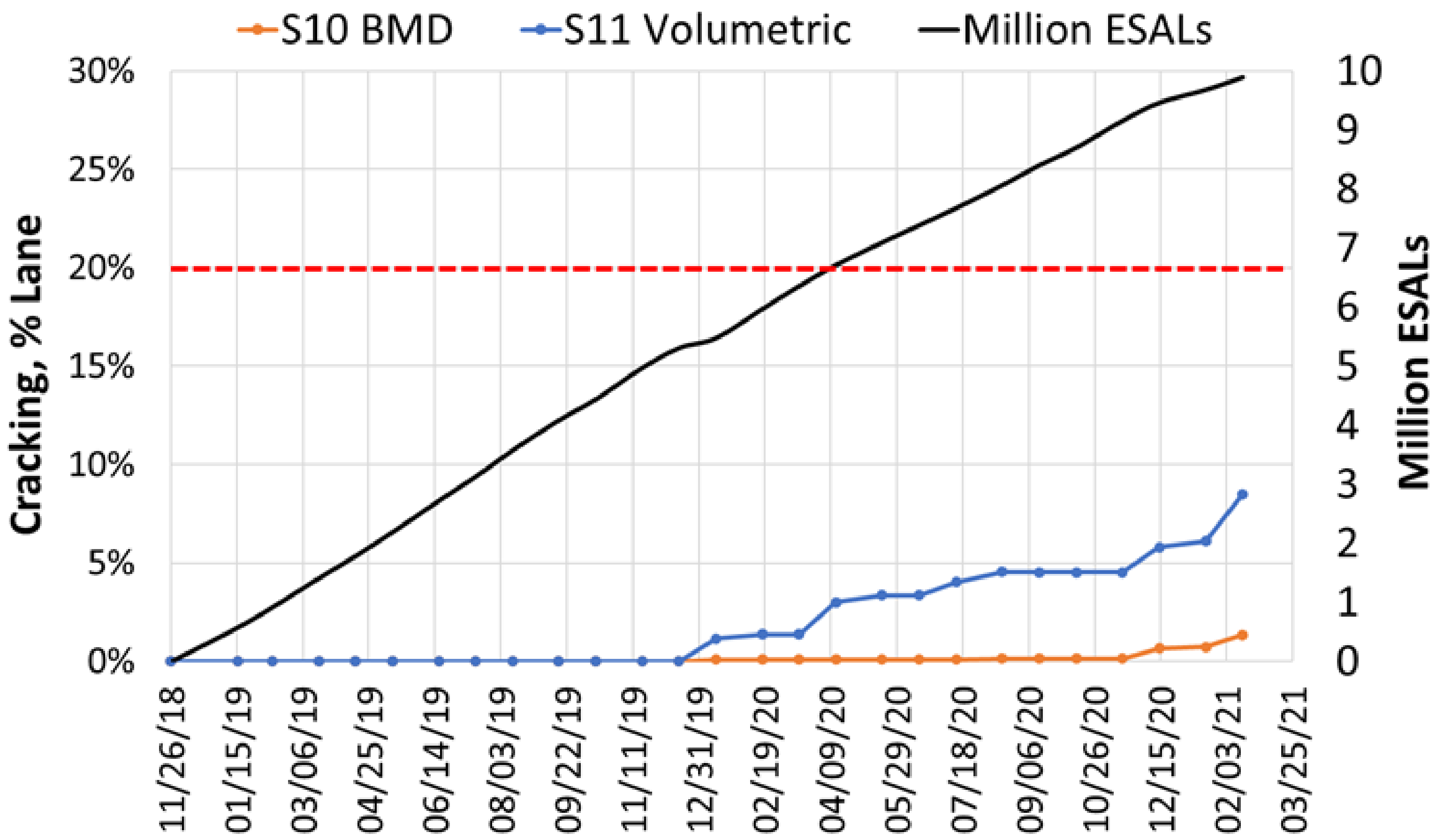
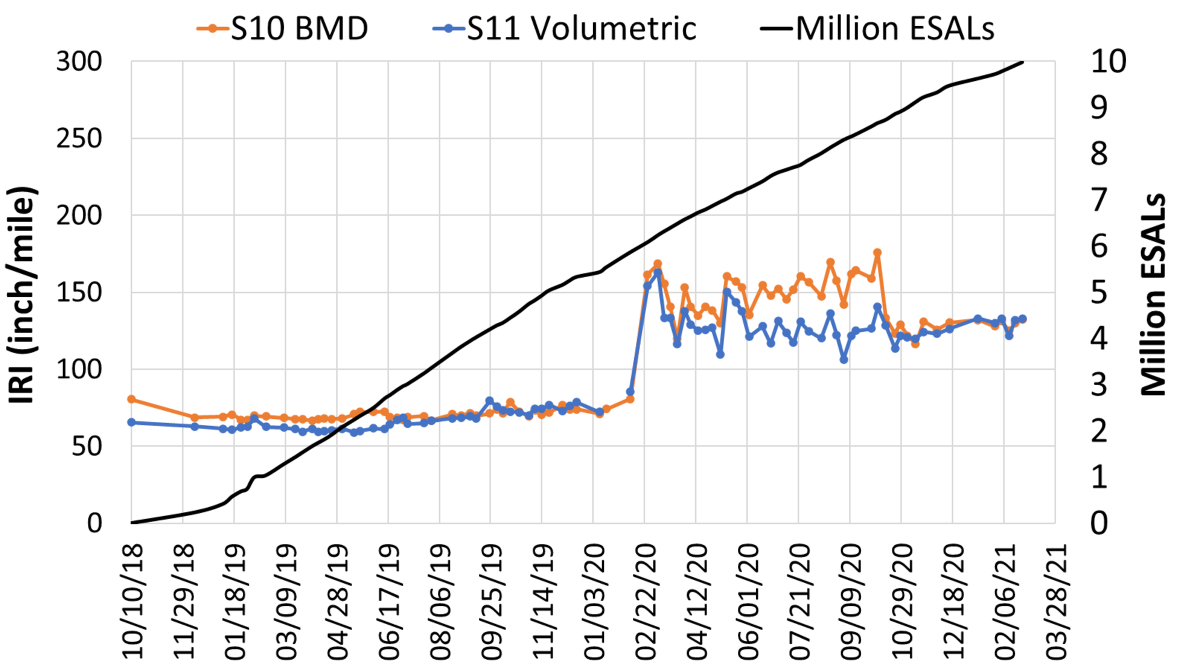
07/21/20
09/09/20
10/29/20
12/18/20
02/06/21
03/28/21

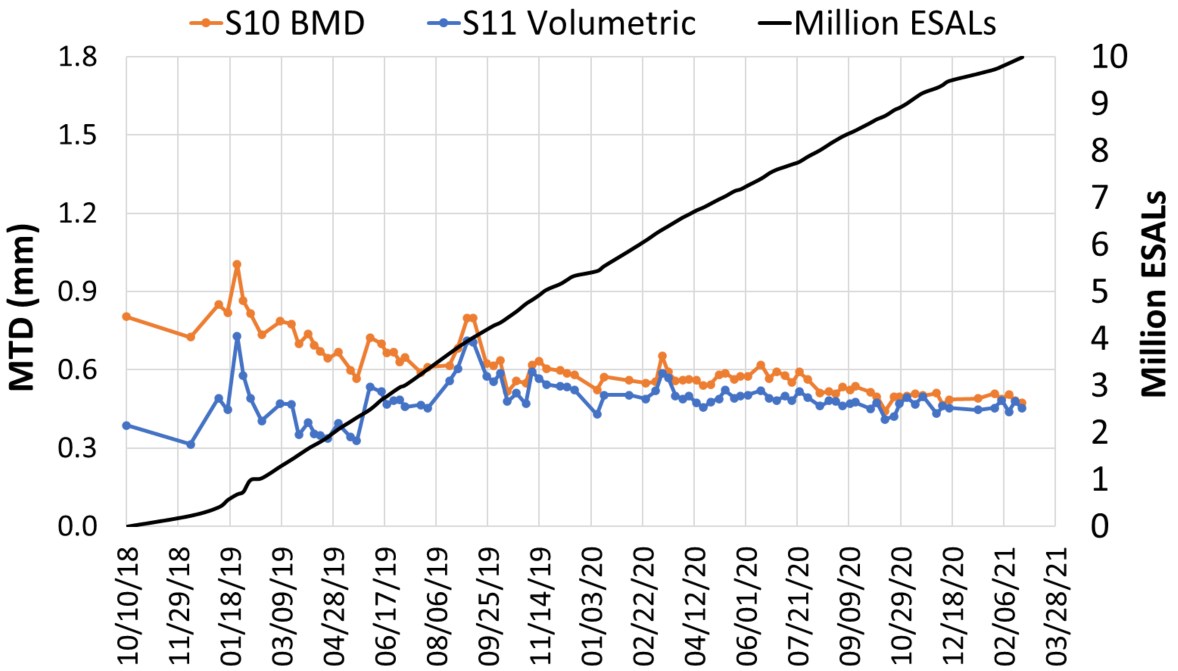
Cracking



S10 BMD
S11 Volumetric
Million ESALs
Cracking, % Lane
30%
25%
20%
15%
10%
5%
0%
10
9
8
7
6
5
4
3
2
1
0
Million ESALs
11/26/18
01/15/19
03/06/19
04/25/19
06/14/19
08/03/19
09/22/19
11/11/19
12/31/19
02/19/20
04/09/20
05/29/20
07/18/20
09/06/20
10/26/20
12/15/20
02/03/21
03/25/21

Smoothness and Texture





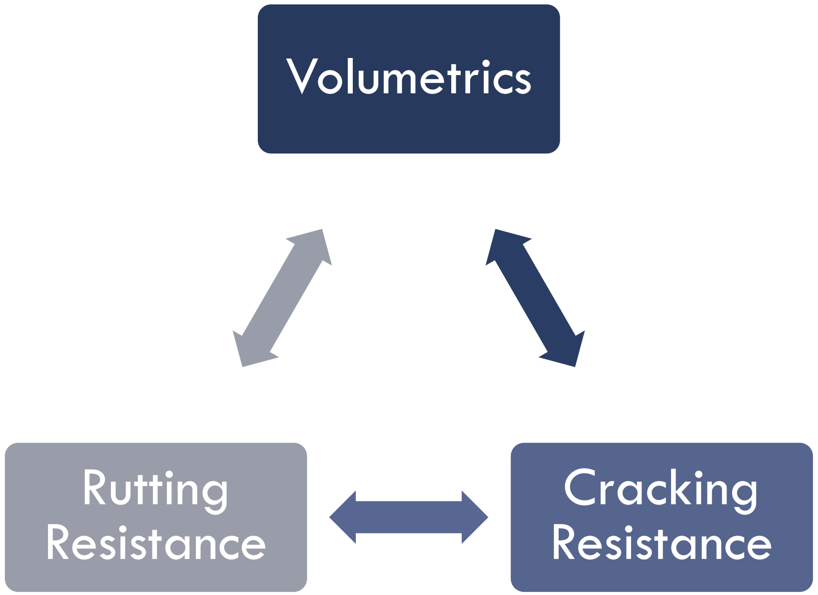
Conclusions and Recommendations

- Consistent performance test results from mix design and production testing
  - S10 BMD: passed HWTT and OT
  - S11 volumetric: passed HWTT, failed OT
- Significantly reduced cracking resistance after mix critical aging
  - S10 BMD > S11 volumetric
- Field performance after 10 million ESALs
  - More rutting in S10 than S11
  - More cracking & faster development rate in S11 than S10
  - In agreement with BMD performance test results
  - Similar smoothness, texture, and friction characteristics
- Traffic continuation to monitor longer-term performance

Oklahoma BMD Experiment

OKLAHOMA
Transportation

- Objective: implementation of mixture performance testing and criteria for BMD
- Section N9: 1.5-inch mill-and-inlay with a BMD mix
- Section S1: 5.0-inch mill-and-inlay with BMD surface and base mixes
- ODOT BMD approach
  - Performance-Modified Volumetric Design
  - HWTT for rutting evaluation
  - I-FIT → IDEAL-CT for cracking evaluation
  - Up to 15% RAP in surface mixes
  - 3 to 4% design air voids



Mix Designs

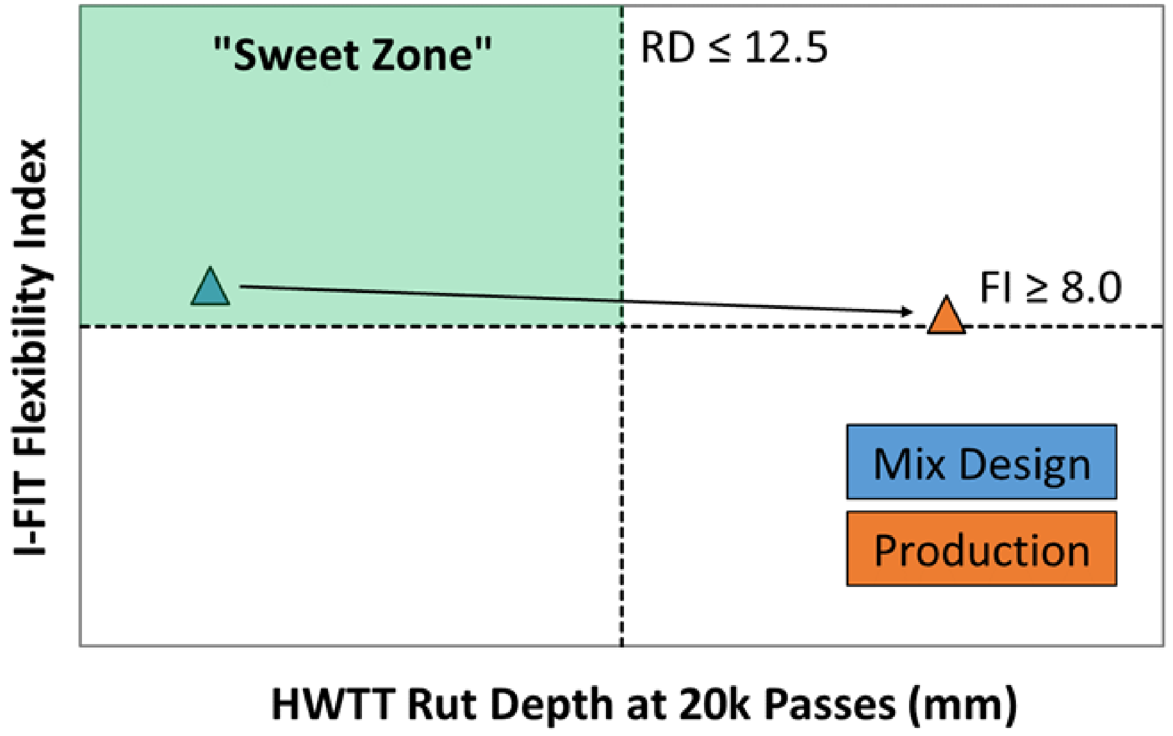
Section N9

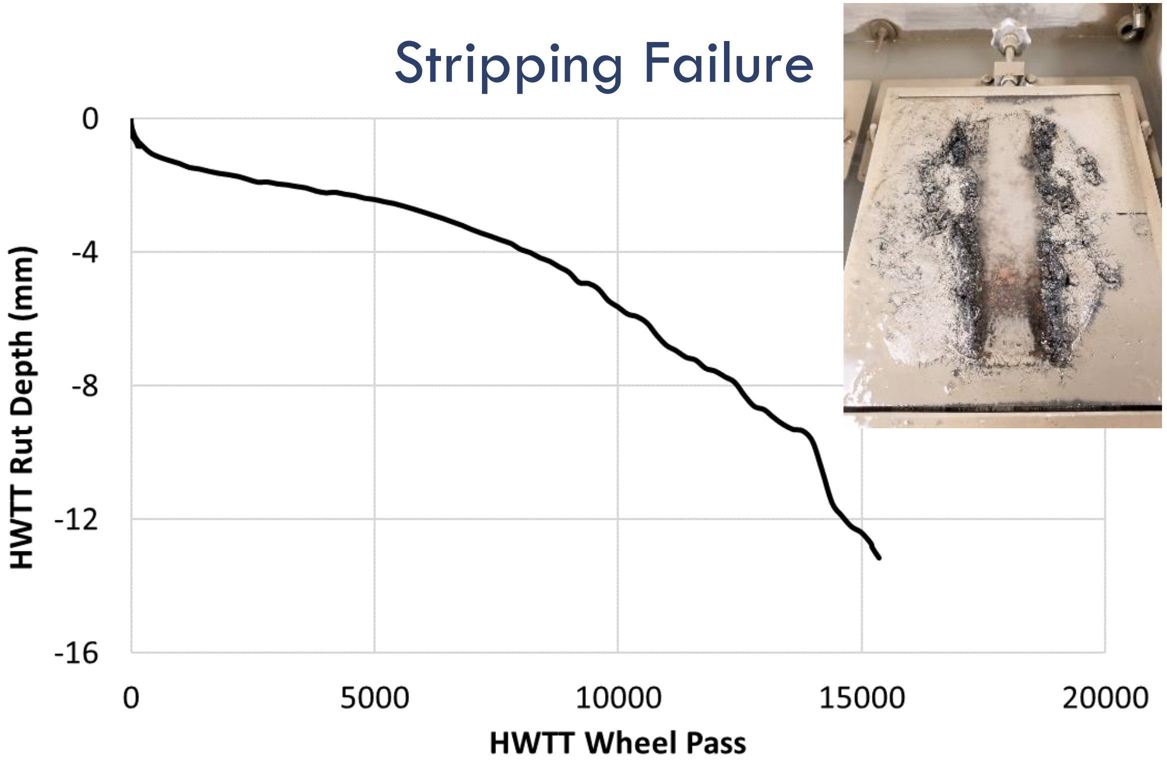
- ODOT S5 mix (9.5 mm NMAS)
- PG 76-28 SBS modified binder
- 15% RAP
- 5.6% AC, 15.5% VMA at 80 gyrations

Section S1

- Surface
  - ODOT S4 mix (12.5 mm NMAS)
  - PG 70-28 SBS modified binder
  - 12% RAP
  - 5.8% AC, 16.2% VMA at 65 gyrations
- Base
  - ODOT S3 mix (19 mm NMAS)
  - PG 64-28 SBS modified binder
  - 30% RAP + tall-oil based recycling agent
  - 5.2% AC, 14.0% VMA at 65 gyrations

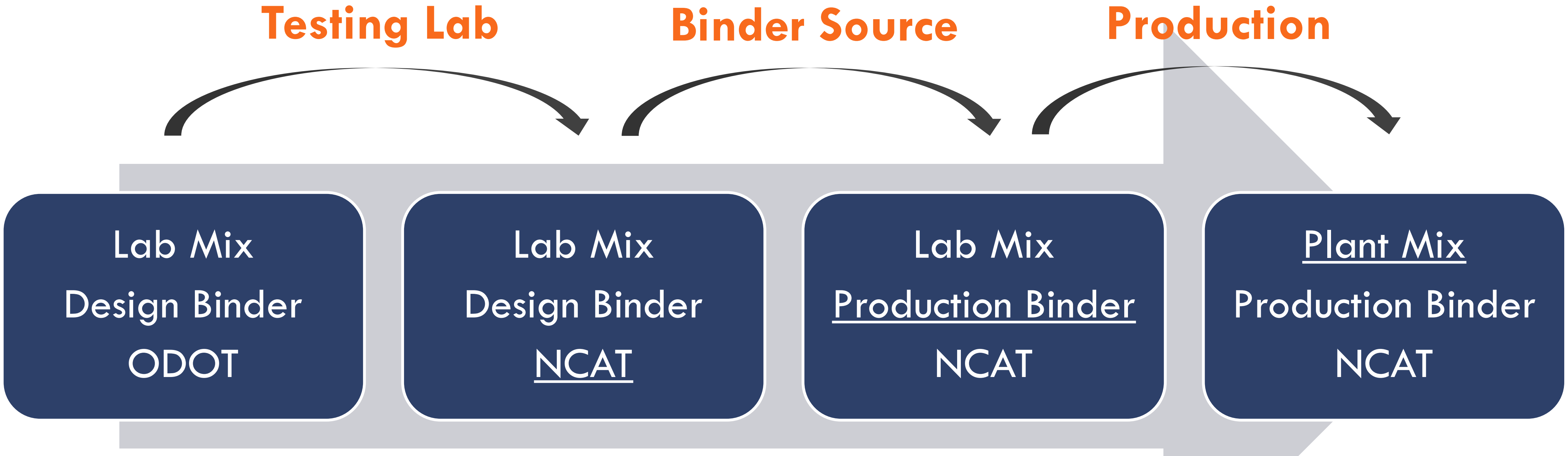
N9 BMD Performance Testing





No concern for rutting failure based on HWTT Corrected Rut Depth (CRD) analysis, IDEAL-RT and HT-IDT testing

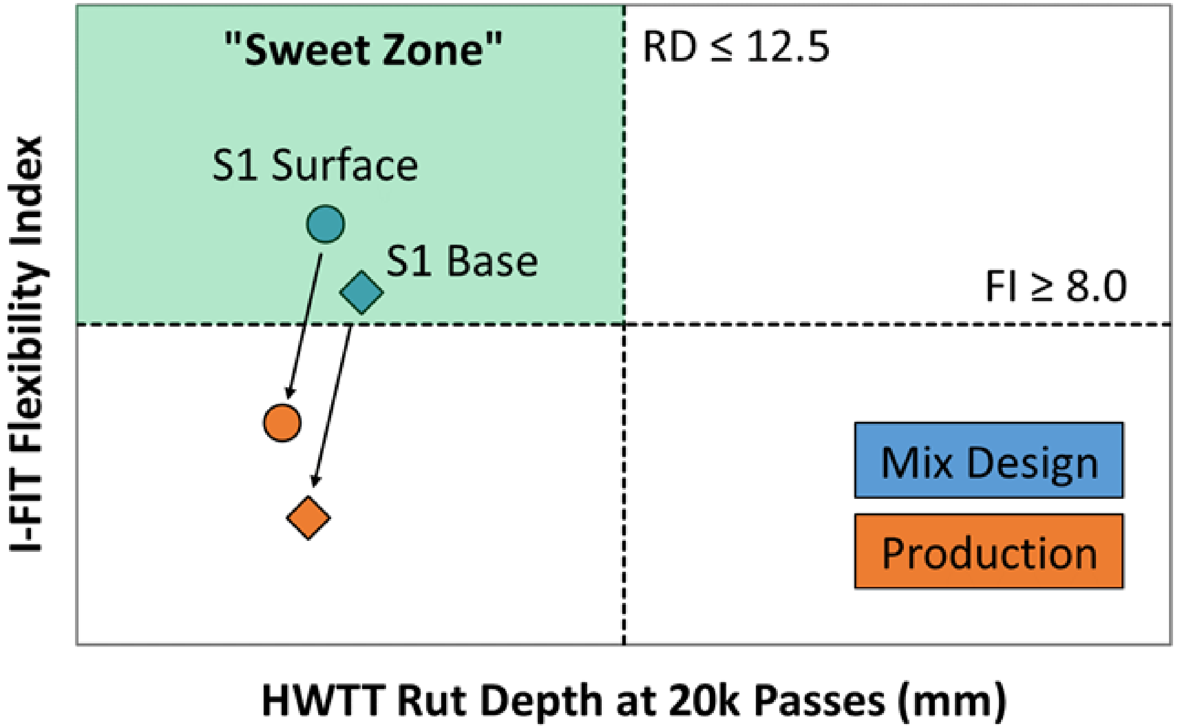
N9 Mix Design vs. Production Testing



Significant factors: between-lab variability, plant production

Insignificant factor: binder source

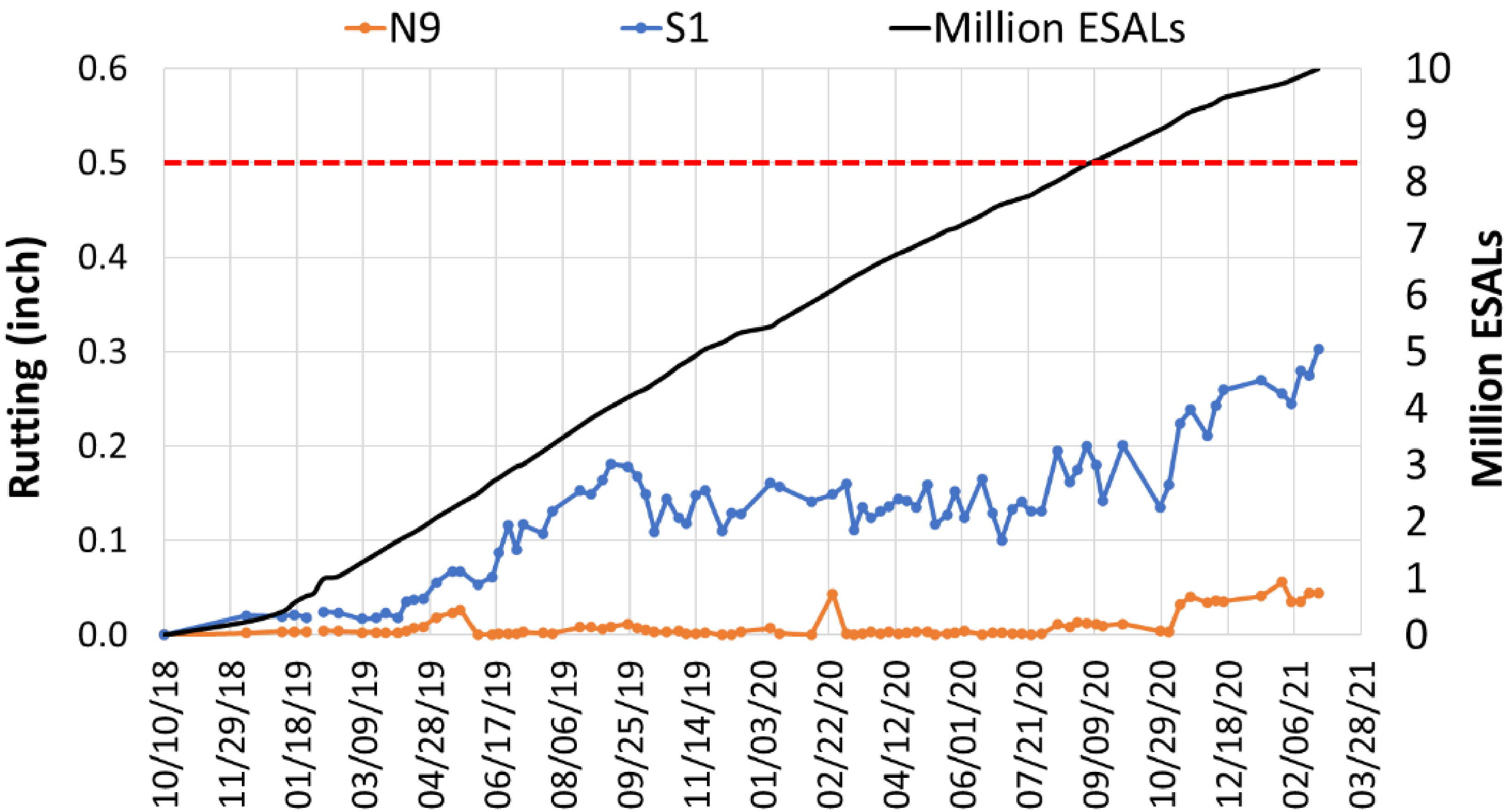
S1 BMD Performance Testing



Additional I-FIT Testing

- Significant factor: plant production
- Insignificant factors: between-lab variability, binder source

Rutting



N9
S1
Million ESALs
Rutting (inch)
Million ESALs
0.6
0.5
0.4
0.3
0.2
0.1
0.0
10
9
8
7
6
5
4
3
2
1
0
10/10/18
11/29/18
01/18/19
03/09/19
04/28/19
06/17/19
08/06/19
09/25/19
11/14/19
01/03/20
02/22/20
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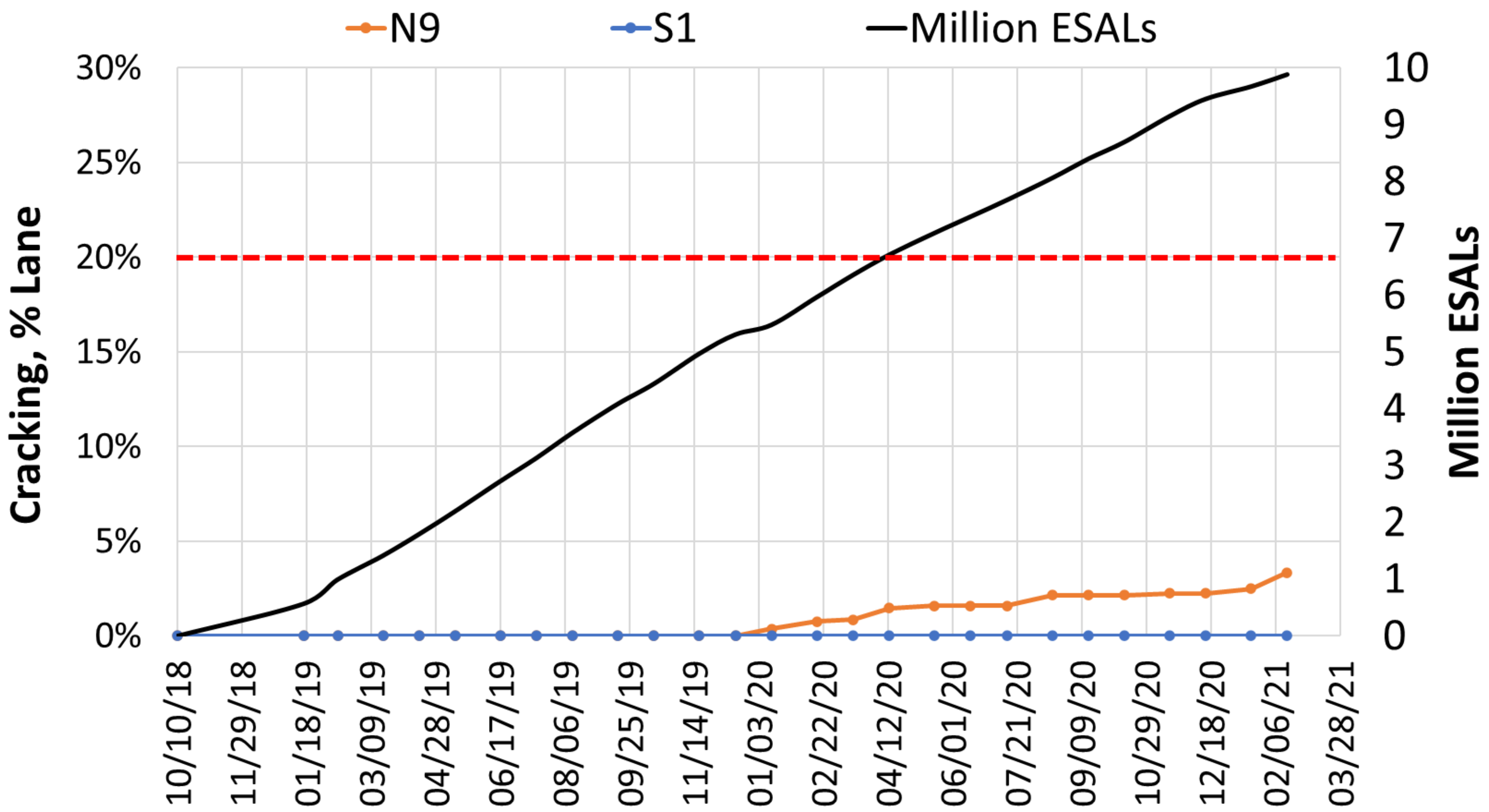
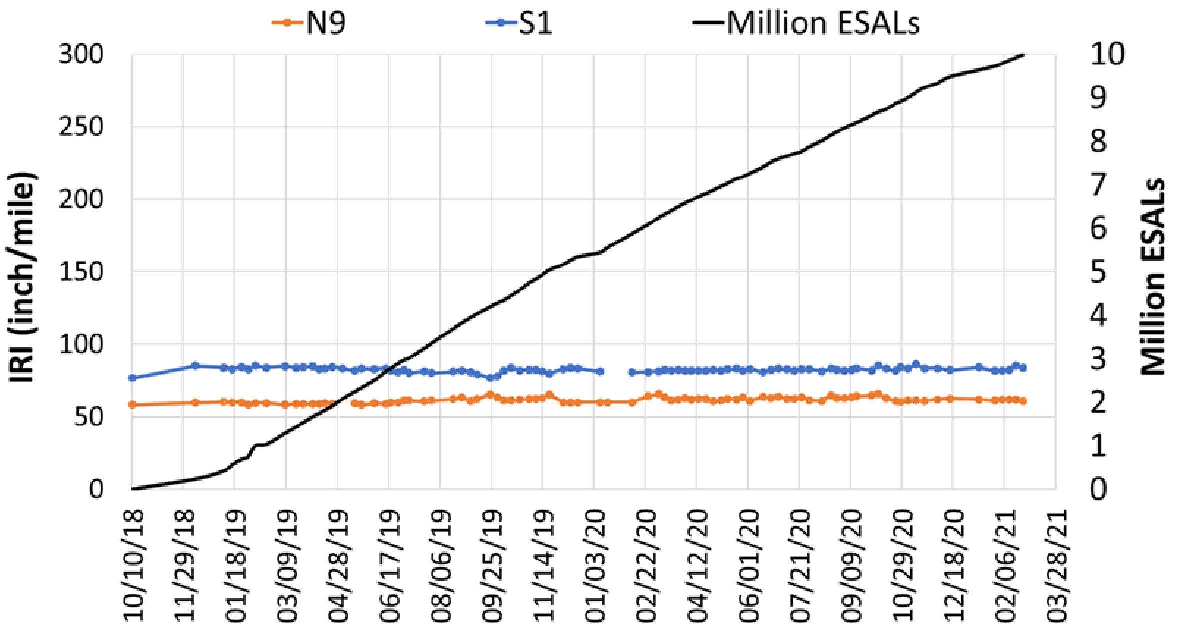
02/06/21
03/28/21

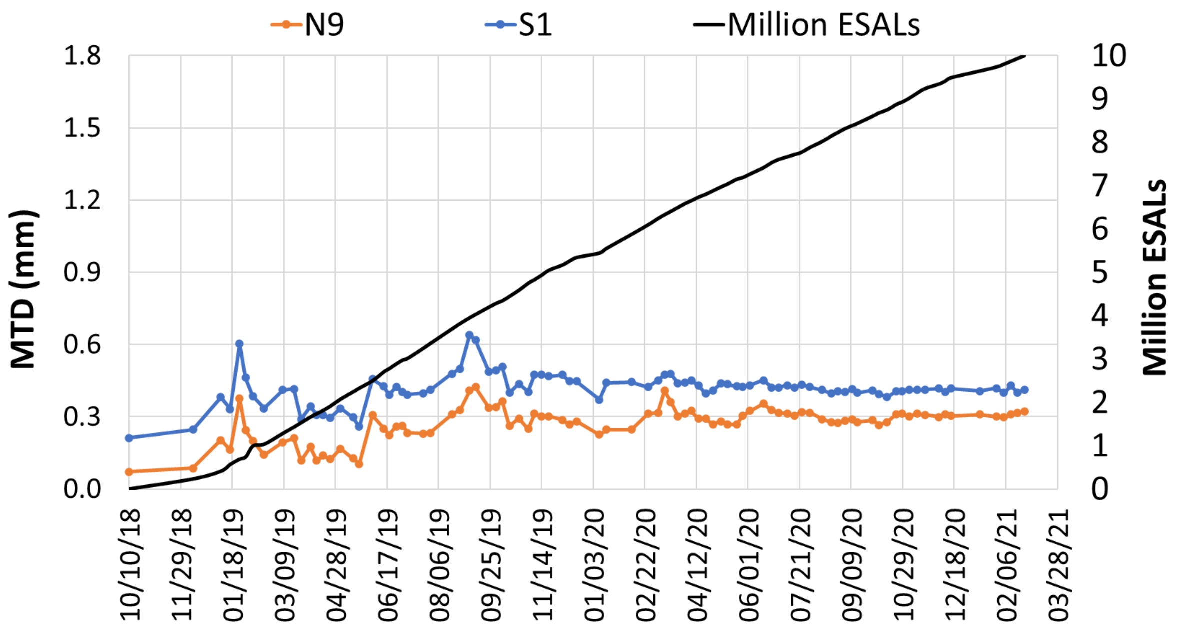
Cracking



Cracking in Section N9

Smoothness and Texture





Conclusions and Recommendations

- Production mixes failed mix design performance requirements
  - N9 failed HWTT due to stripping
  - S1 failed I-FIT and IDEAL-CT
- Alternative HWTT analysis to discriminate rutting and striping failure
- Significant impacts of between-lab variably and plant production on mixture performance test results
  - Round robin and training on specimen fabrication and testing
  - Performance testing during production
- Good field performance after 10 million ESALs
- Traffic continuation for S1 to monitor longer-term performance and verify IDEAL-CT criteria

Questions and Answers (f-yin@auburn.edu)

Thank You