PERFROMANCE EVALUATION OF ASPHALT PAVEMENT MIXES IN IDAHO CONTAINING HIGH PERCENTAGES FOR RECYCLED ASPHALT PAVEMENT (RAP)

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Outline

- Background
- Objectives
- Laboratory Characterization
- Findings

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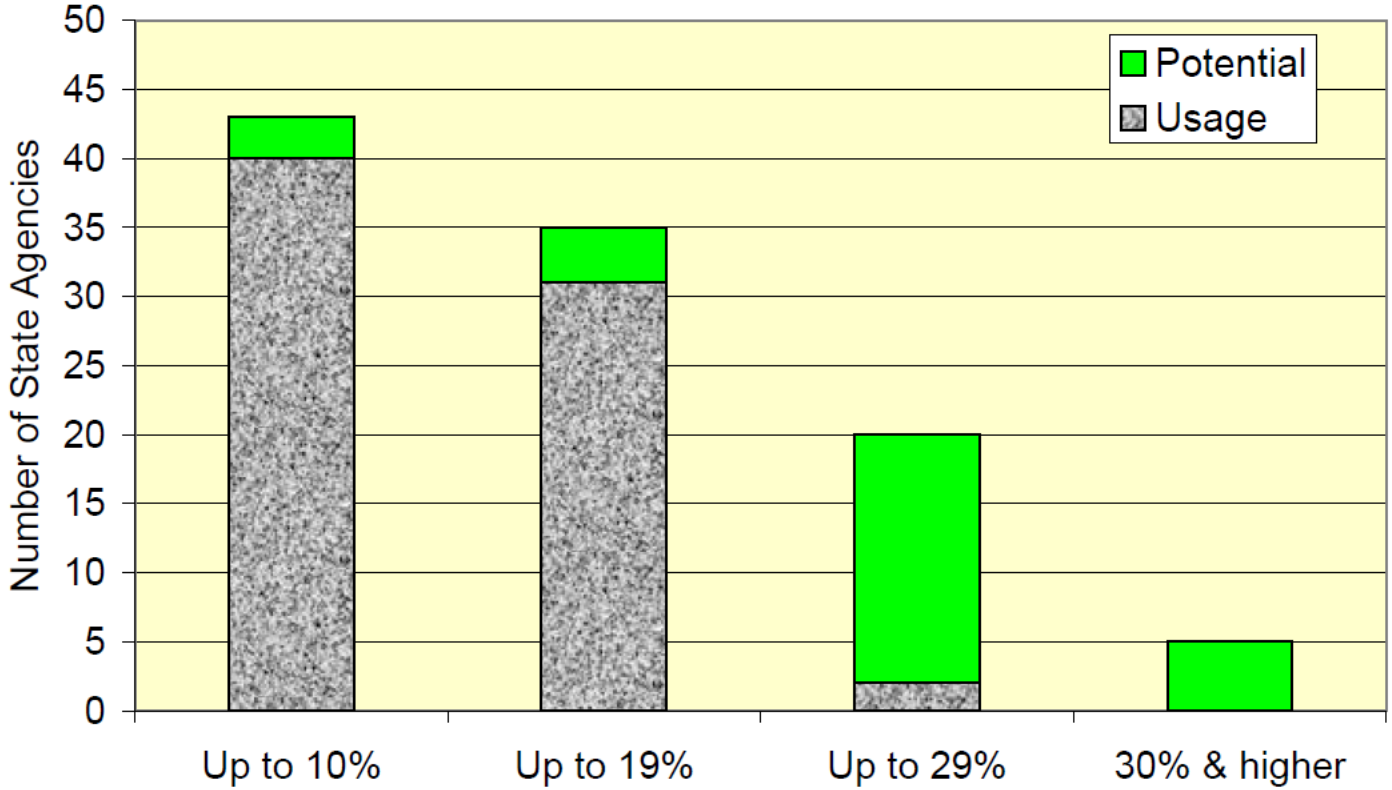
Background

- Benefits of using RAP in HMA
  - Economics
    - Aggregates
    - Binder
  - Environment
    - Resources
    - Petroleum
    - Landfill
    - Energy
    - Emission

Background

- Status of the use of RAP in HMA



Copeland et al. 2011

Mix Design-Virgin Binder Selection

- ITD Binder Adjustment
  - Replacement <=17%. No adjustment
  - 17%<Replacement<= 30. One grade lower
  - Replacement>30 %. Blending chart.
    - Based on assumption of complete blending between RAP binder and virgin binder

Dynamic Modulus

- Dynamic modulus increased with increasing RAP percentage, and RAP significantly affects dynamic modulus values at intermediate and high temperature (Li 2008, McDaniel 2012, Qazi 2011)

Performance-Rutting

- **Consensus Conclusion:**
  - Rutting resistance increased as the increase of percent of RAP (Hajj 2009, Qazi 2011, Santos 2010, Yu 2010, Colbert 2012)
  - Aged RAP binder increase the stiffness of mixture

Fatigue Cracking

- Most studies show that RAP mixtures had reduced fatigue life or more brittle behavior (Huang 2011, Shu 2008, Yu 2010, NCHRP 9-12)
- A few studies, however, showed that mixtures with RAP had better fatigue life (Santos 2010, Hajj 2009, McDaniel 2012)
- Fatigue life of stiffer mixes depends on the thickness of layer (Sousa 1998, Hassan 2009)

Thermal Cracking

- Fracture Energy (Li 2008)
  - Decrease as RAP content increased, indicating lower low-temperature fracture resistance
- Fracture temperature (Hajj 2011)
  - Thermal stress retained specimen test (TSRST) test
  - similar TSRST fracture temperature between 0 and 15% RAP mixes
  - several degree warmer for 50% RAP mixes , indicating decreased thermal cracking resistance
- Using soft binder could help improve thermal cracking resistance

Moisture Susceptibility

- Mixtures with RAP could have acceptable resistance to moisture damage, or addition of antistripping additive could help mixtures with RAP gain TSRs above 0.80 (Hajj 2009, NCHRP 9-46, Yu 2010, Loria 2011)

*www. pavementinteractive.com

Background

- We can not wait for 20 years to see the performance
- Need to determine the performance before pavement with high RAP percentage is built
- Key is to select materials properties from lab to relate to field performance for performance evaluation and also mix design

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Objective

- **Verify the guideline by ITD on the use of RAP in HMA to lead to same performance in the laboratory**

- **Evaluate the effect of RAP on pavement performance**

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Material Procurement

- Plant Loose Mixes and Field Cores
  - US95 Garwood to Sagle, 30% RAP by binder replacement
- Lab Mixes
  - Binder:
    - PG58-28 (Control), PG52-34
  - Aggregates:
    - Nominal Maximum Size is 19mm

RAP Characterization

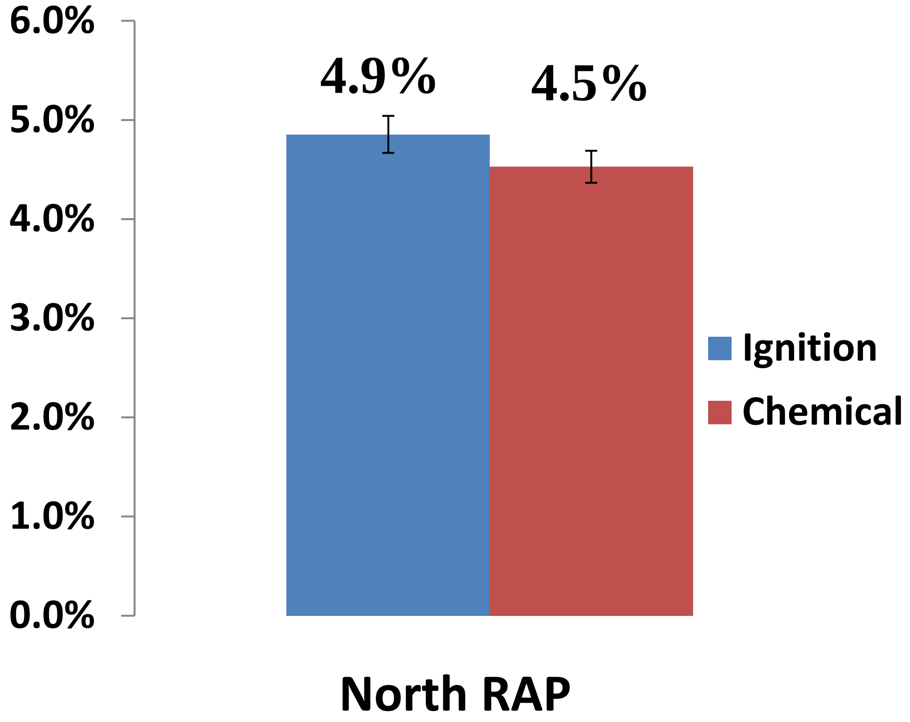
- Binder Content
- RAP Aggregate Gradation
- Bulk Specific Gravity of RAP Aggregate
- PG of Extracted RAP Binder

RAP Characterization

- **Fractionated**
  - Coarse RAP and fine RAP are separated by No.4 Screen
    - 0.53:0.47 for the North RAP
- **Recombined after homogenization in a concrete mixer**

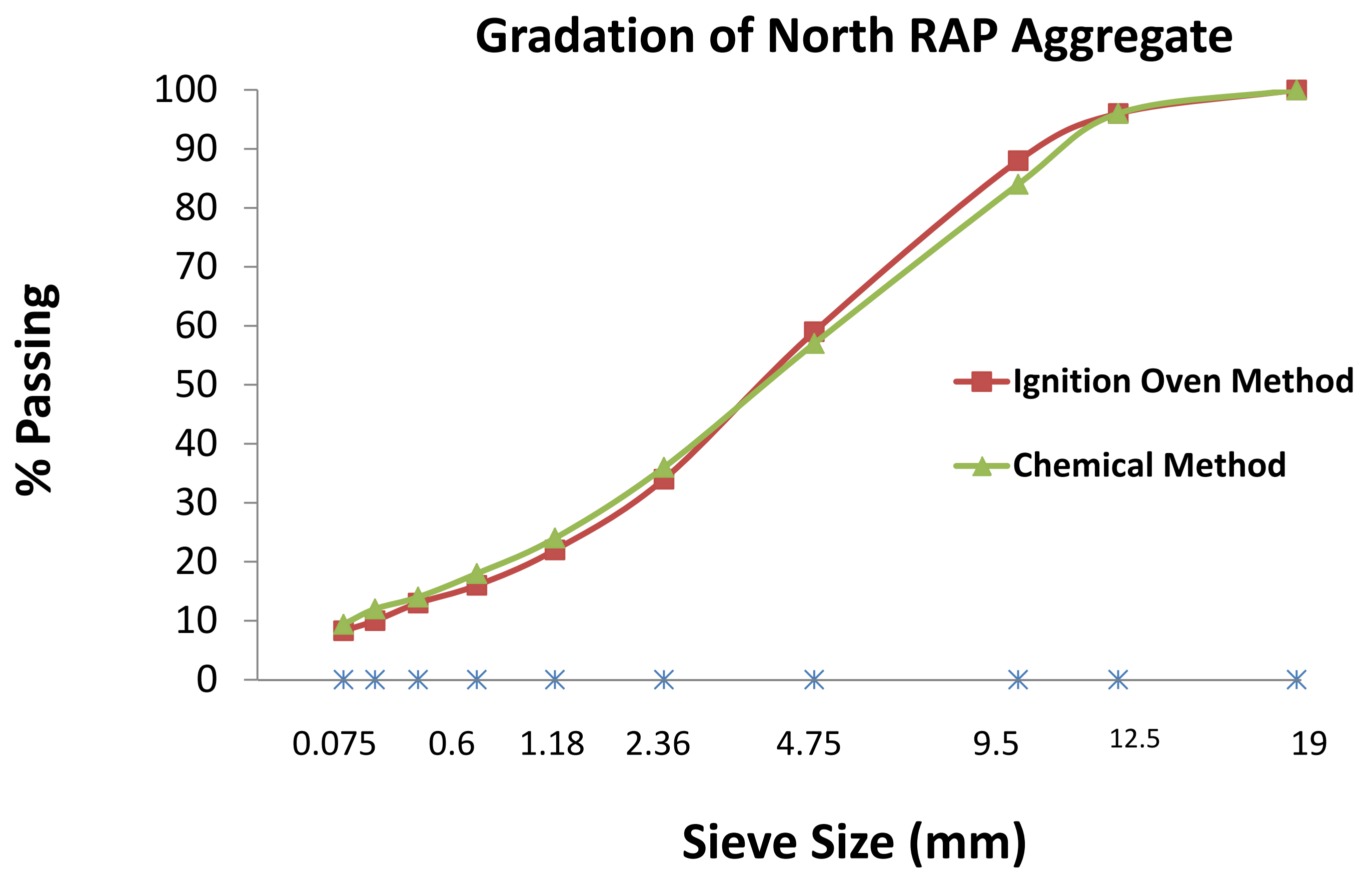
RAP Binder Content

- Ignition Oven (AASHTO T308)
- Chemical Extraction (AASHTO T164)



Gradation of RAP Aggregate

- **AASHTO T30 "Mechanical Analysis of Extracted Aggregate"**



Bulk Specific Gravity of RAP Aggregate

- Ignition Oven : AASHTO T308
  - Coarse Aggregate: AASHTO T85
  - Fine Aggregate: IT 144

North RAP Aggregate	1	2	3	Average	Std	COV
Coarse RAP aggregate	2.604	2.604	2.611	2.606	0.004	0.15%
Fine RAP aggregate	2.618	2.628	2.635	2.627	0.009	0.33%
Combined	2.619					

Results of PG of Extracted Binder

- Chemical Extraction and Recovery:
  - AASHTO T164-11 & AASHTO T170

- RAP Binder: PG 75.8-23.6

	PG of Recovered North RAP binder					
	1	2	3	Average	Std	COV
High Temperature	76.9	74.9	75.5	**75.8**	1.0	1.3%
Low Temperature	-22.7	-24.6	-23.6	**-23.6**	1.0	4.2%

Mix Design

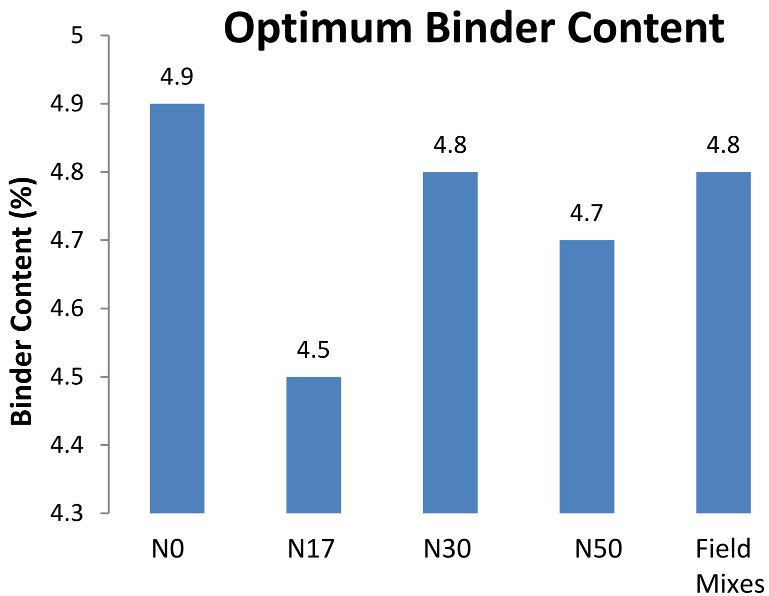
- **Lab Mixes**
  - Four different RAP percentages
    - 0, 17, 30, and 50% (N0, N17, N30 and N50)
  - Duplicate field mix in terms of aggregate gradation
    - US-95, Garwood to Sagle, Chilo STG
  - Class of Mixture
    - 3/4’’, SP5, Traffic 10-30 (ESALs)

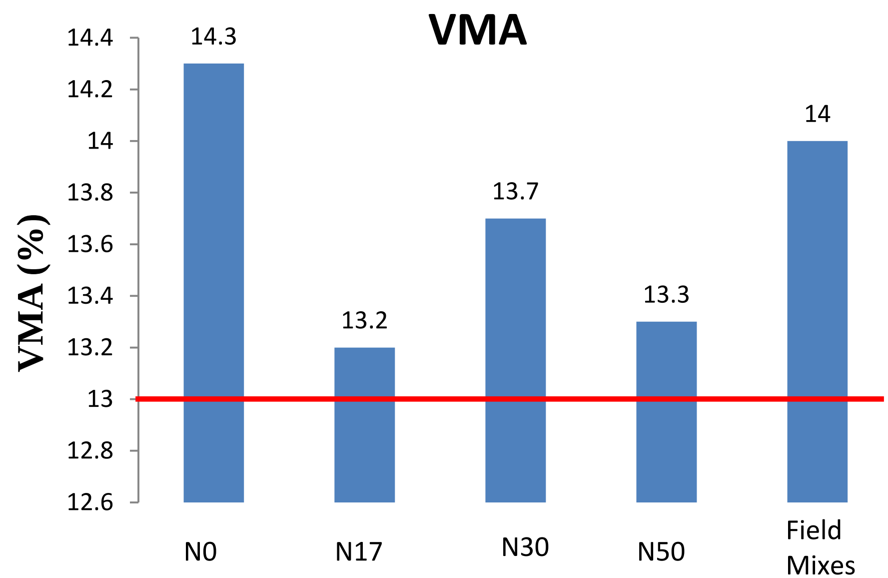
PG of Blended Binder for Mixes

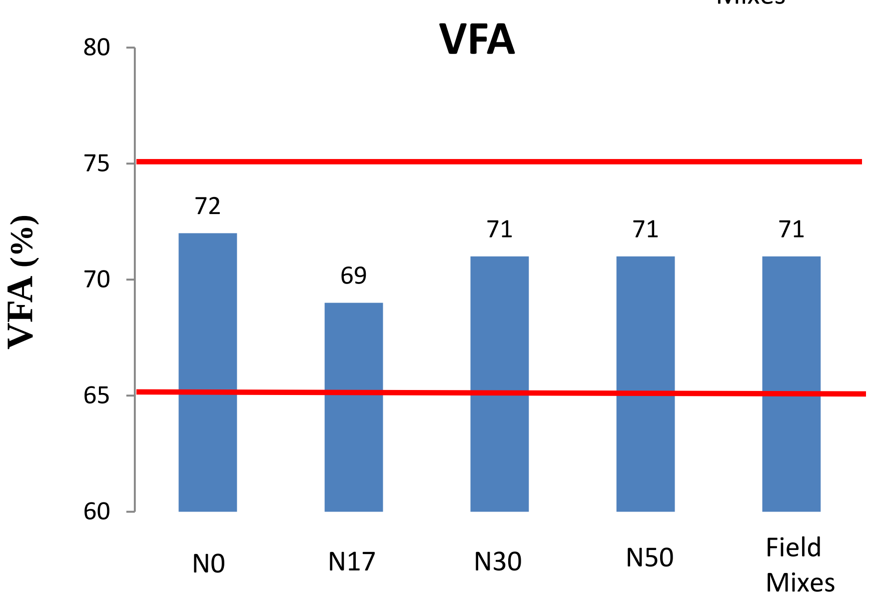
- Assuming 100% blending between the RAP binder and virgin binder

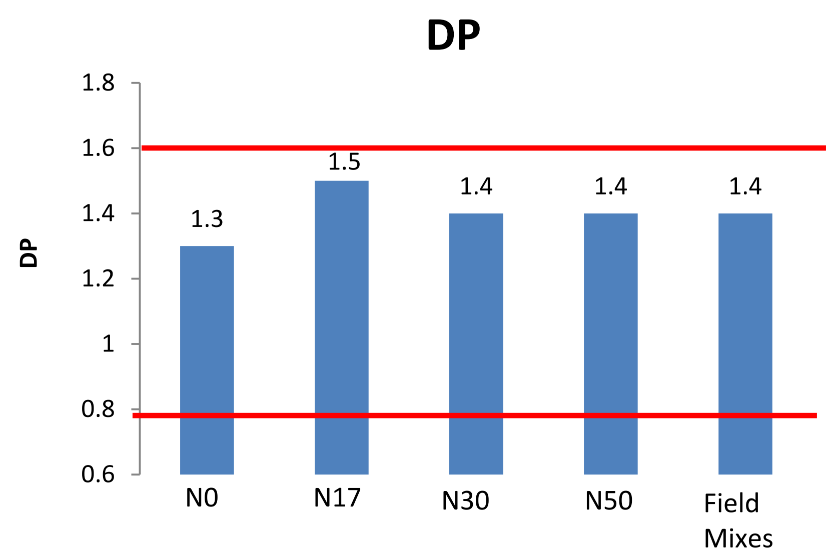
% RAP	Virgin Binder	RAP binder	Blended Binder	Target PG of binder
0	58-28	-----	58-28	58-28
17	58-28	75.8-23.6	61.0-27.3	
30	52-34		59.1-30.9	
50	52-34 (40-34)		63.9-28.8	

Results of Mixes







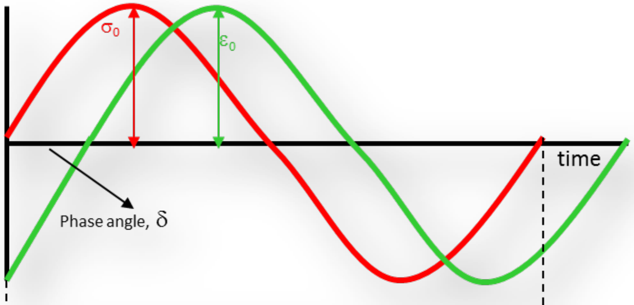


Lab Performance Evaluation

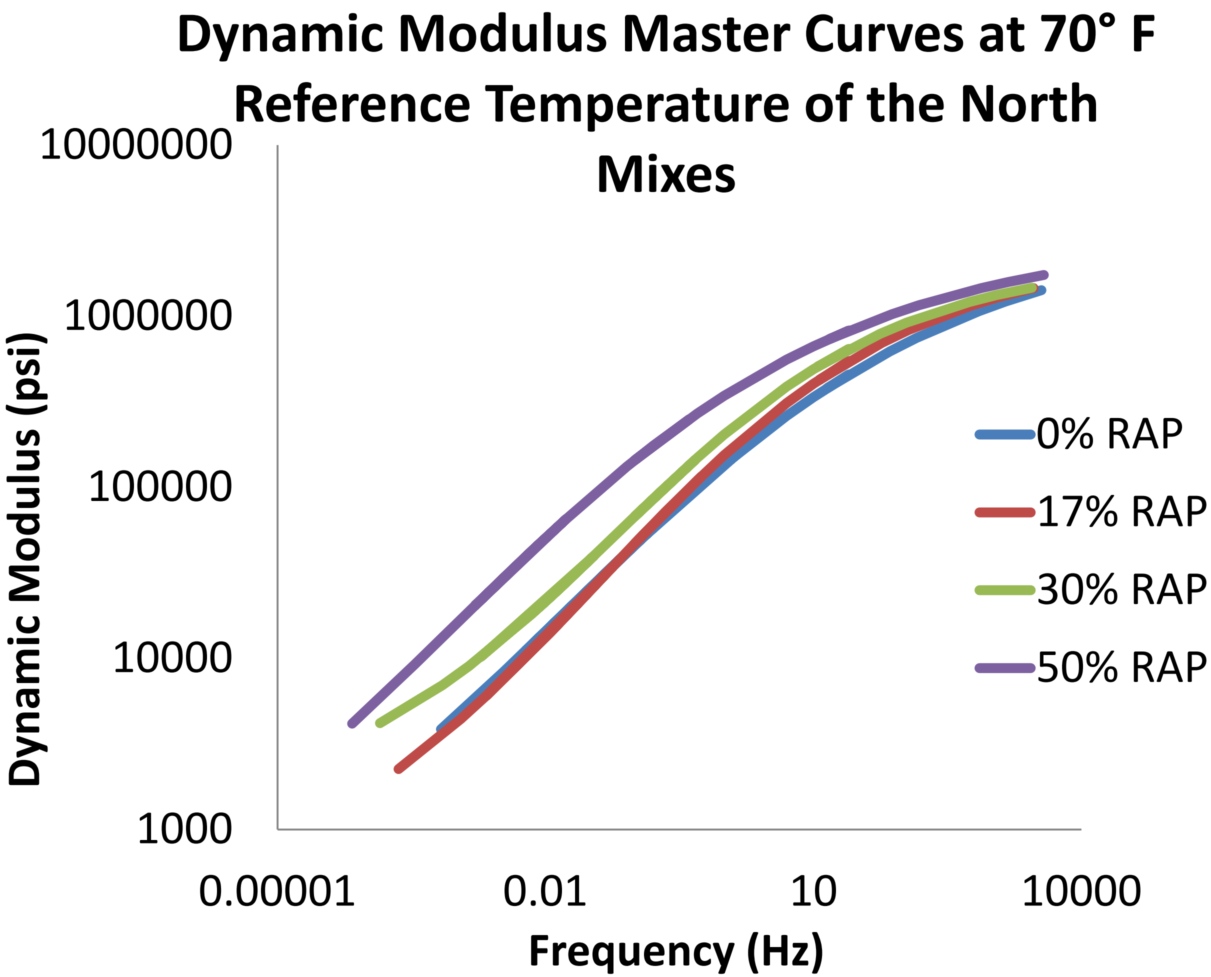
- Modulus
- Rutting
- Fatigue Resistance
- Low Temperature Thermal Cracking

Dynamic Modulus Test (E*)

- Sample Preparation for E*
  - Mixing
  - Short term aging 140 F, 16hour aging
  - 2-2.5 hours aging at compaction temperature
  - Compaction
  - Core and cutting with air voids within 6.5%-7.5%
  - Testing temperatures (40^o F, 70^o F, 100^o F, 130^o F)
  - Loading frequencies(0.1Hz, 0.5Hz,1Hz, 5Hz, 10Hz, 25Hz).



E*- Master Curves-Mixes

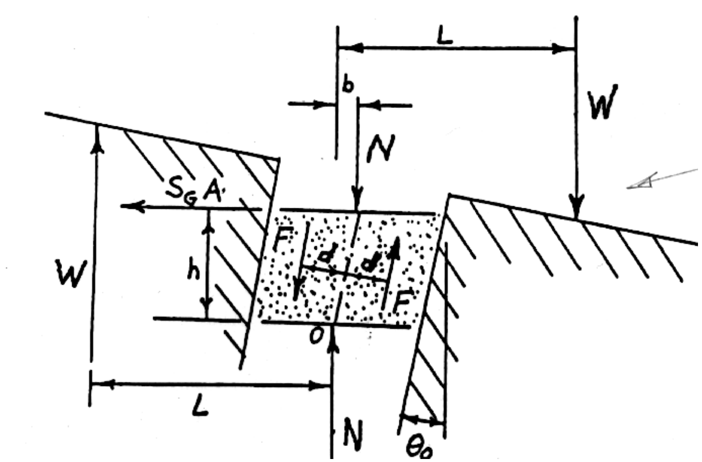


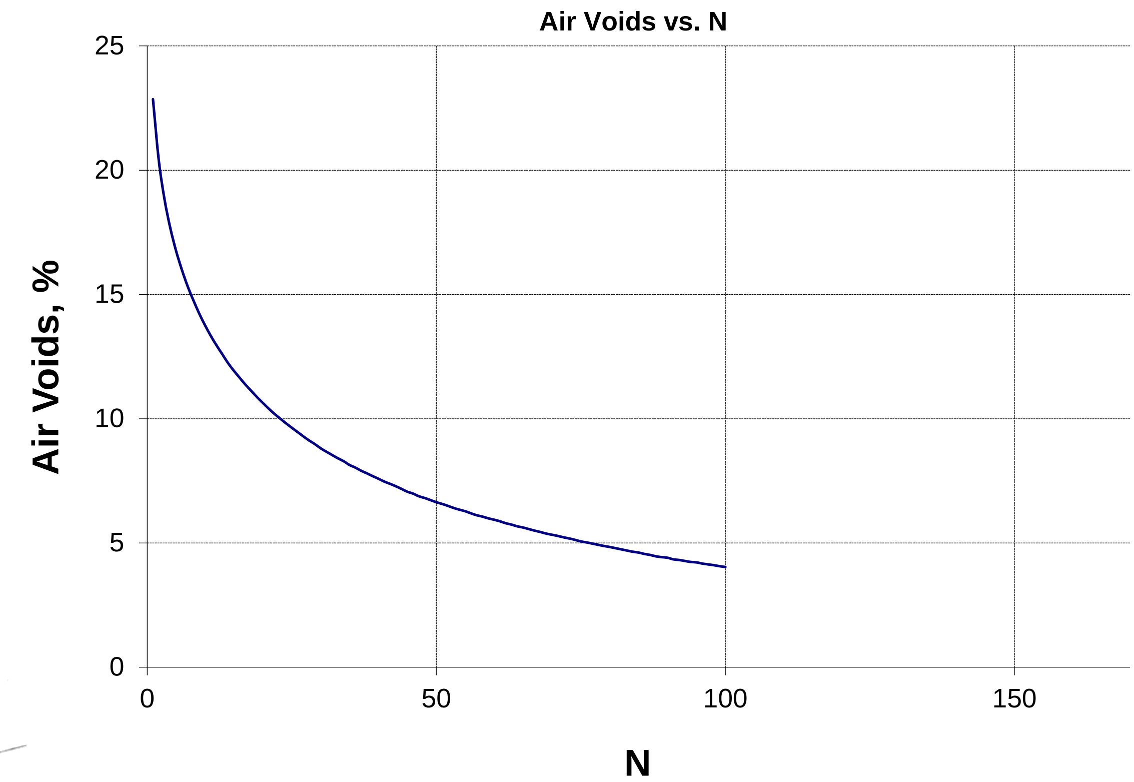
% RAP	Virgin Binder
0	58-28
17	58-28
30	52-34
50	52-34 (40-34)

Gyratory stability (GS)-Rutting

$$GS = \sum_{N_{G1}}^{N_{design}} S_e \, x \, d_e$$

$$S = \frac{R.e}{A.h}$$





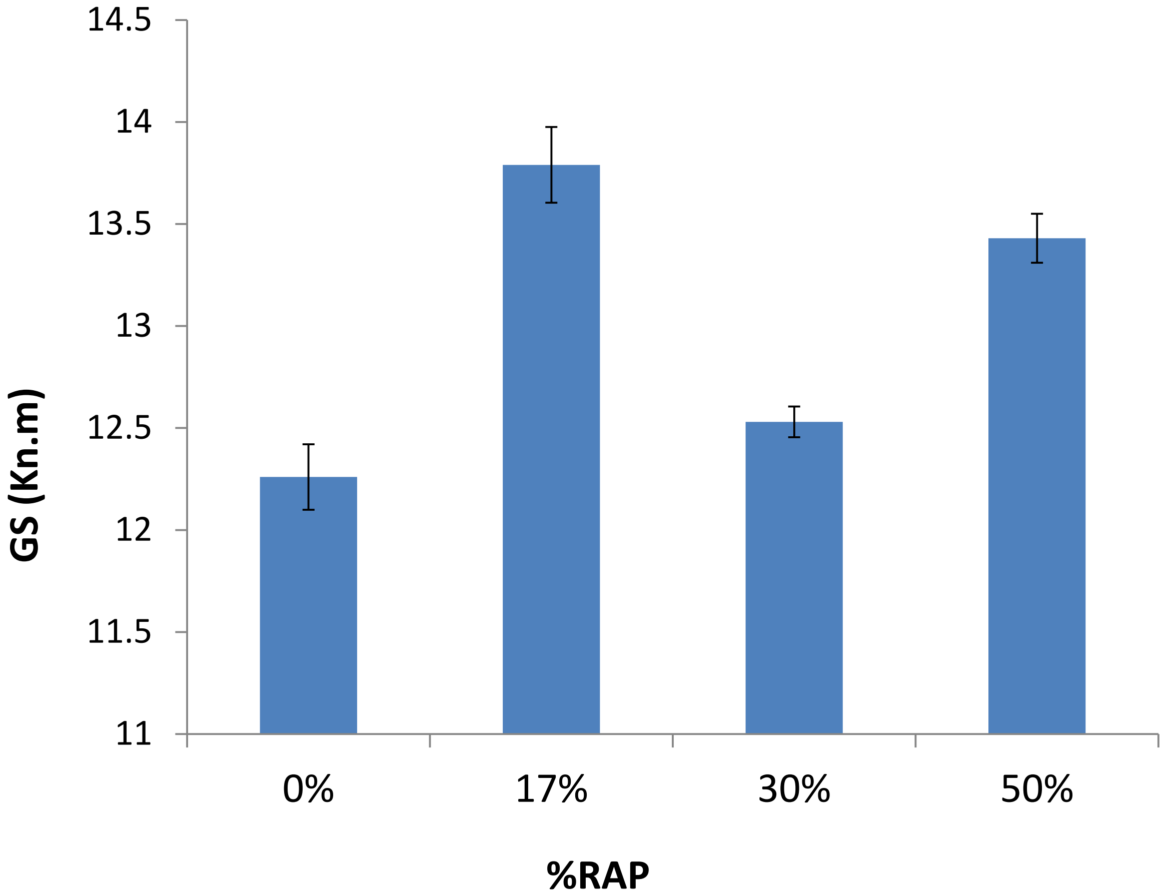
R = the resultant ram force

E = the average eccentricity for a given gyration cycle

A = the sample cross section, and

h = the sample height at any gyration cycle.

Gyratory stability (GS) - Rutting



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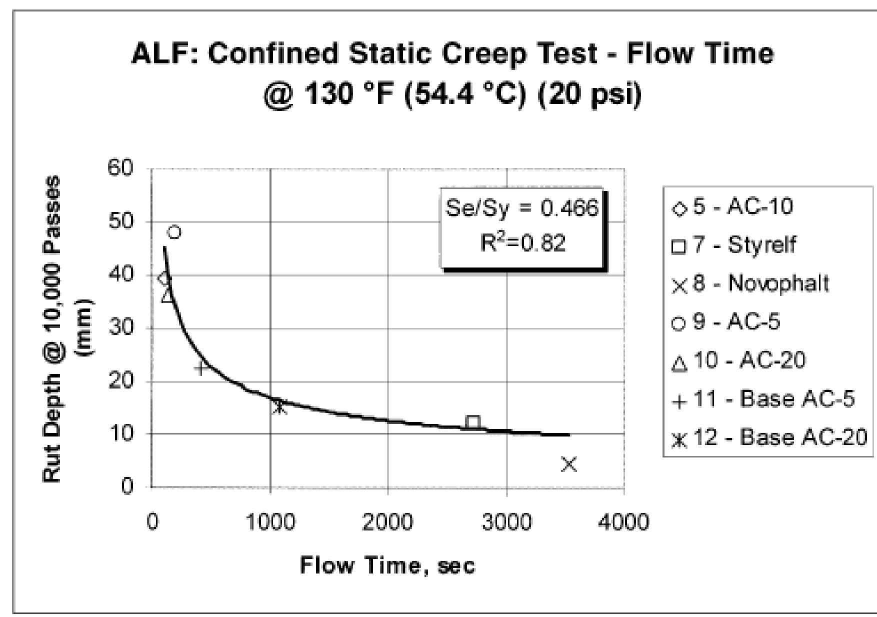
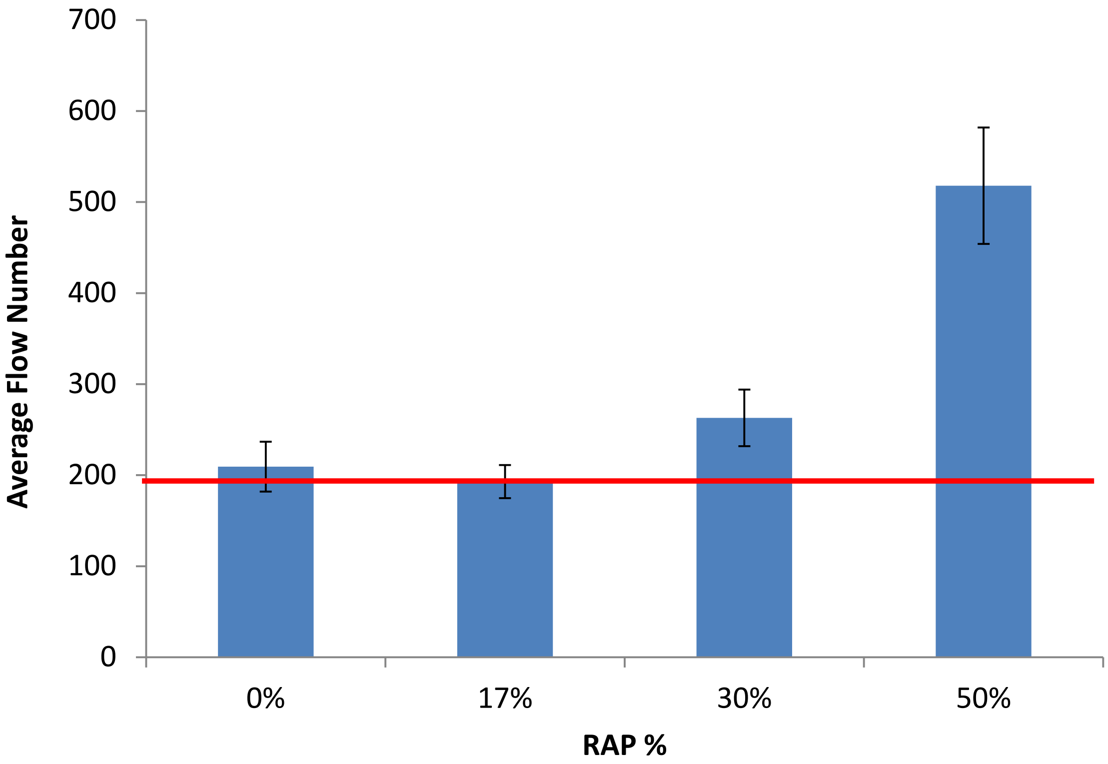
Flow Number Rutting

- Laboratory Tests
  - Rutting (flow number) – repeated load @ high temperature



*NCHRP Report 465

Flow Number - Rutting



% RAP	Virgin Binder
0	58-28
17	58-28
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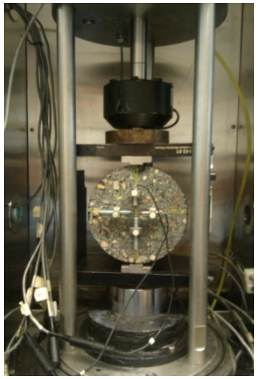
Design Traffic, Million ESAL	HMA[1]	WMA[1]
< 3	--	--
3 to < 10	50	30
10 to < 30	190	105
> 30	740	415

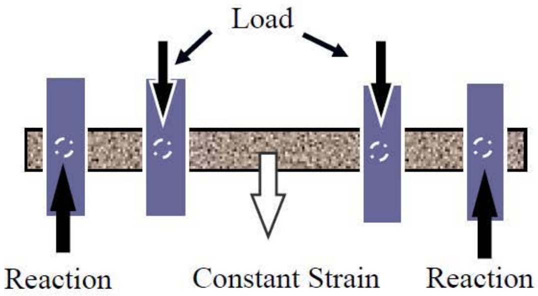
Fatigue Performance Test

- For fatigue, test methods in the lab can include
  - Stiffness

  - Indirect tensile strength

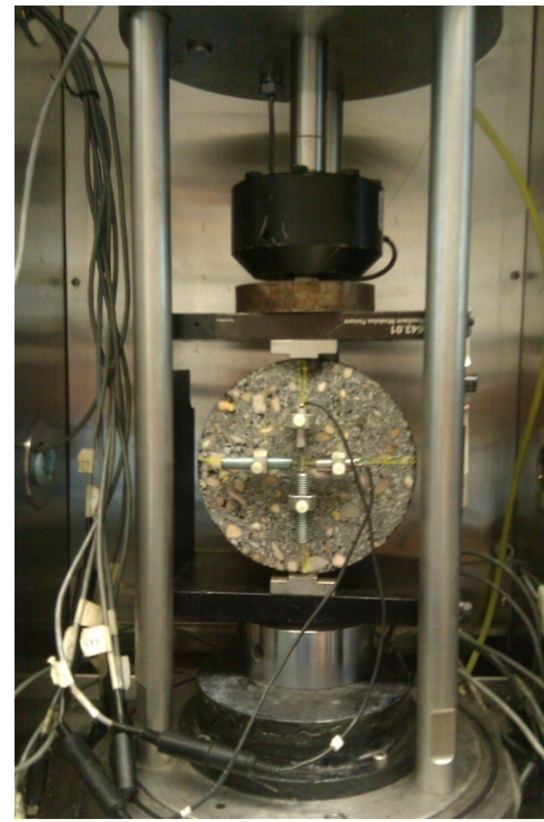


  - Beam fatigue

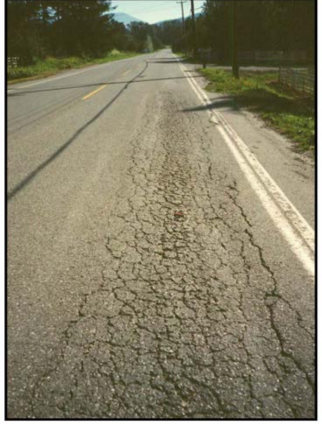


Fatigue Resistance

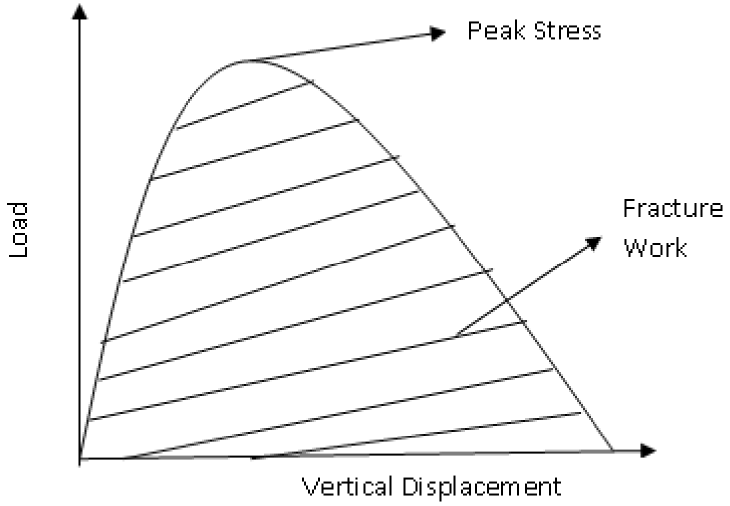
- **Long term aging**
  - 5 days at 185ºF
- **Test temperature**
  - Temperature: 68ºF
  - Displacement Control: 2inch/min
- **Properties**
  - Fracture Work Density
  - Vertical Failure Deformation

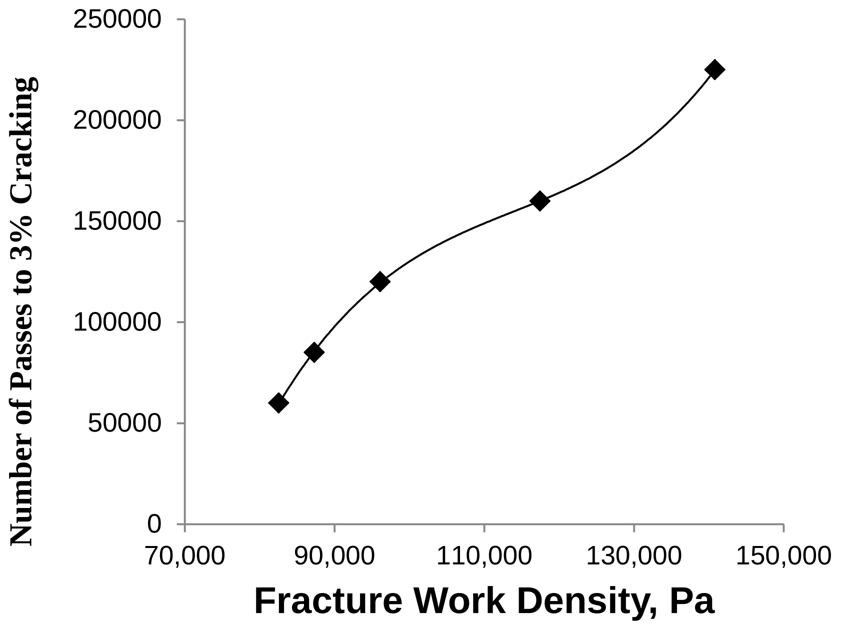


Fracture Work Density



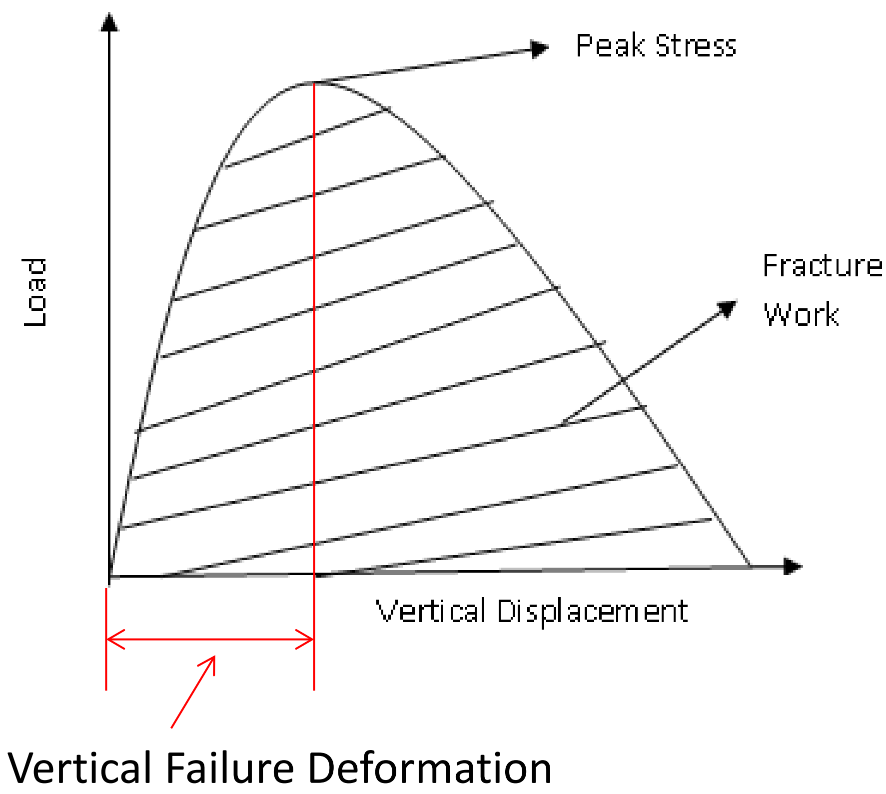
- Bottom-up fatigue cracking - fracture work from Indirect Tensile test at 68ºF (Wen et al. 2011)



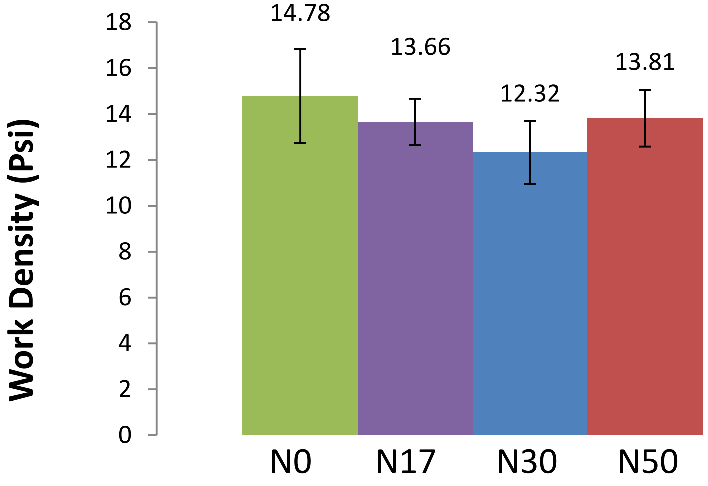


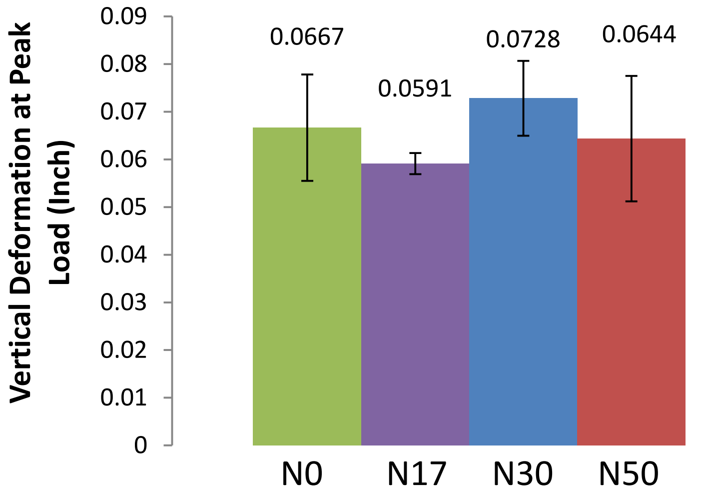
Vertical Failure Deformation

- Top-down cracking – vertical failure deformation (Wen et al. 2013) 12 out of 15 pair pavements match



Fatigue Results





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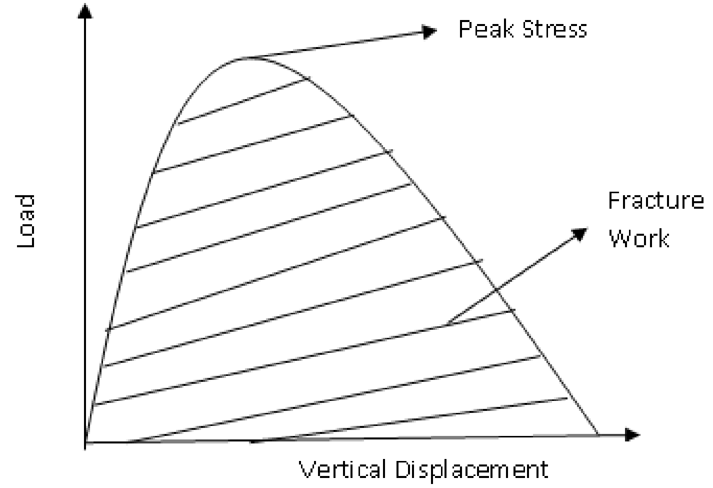
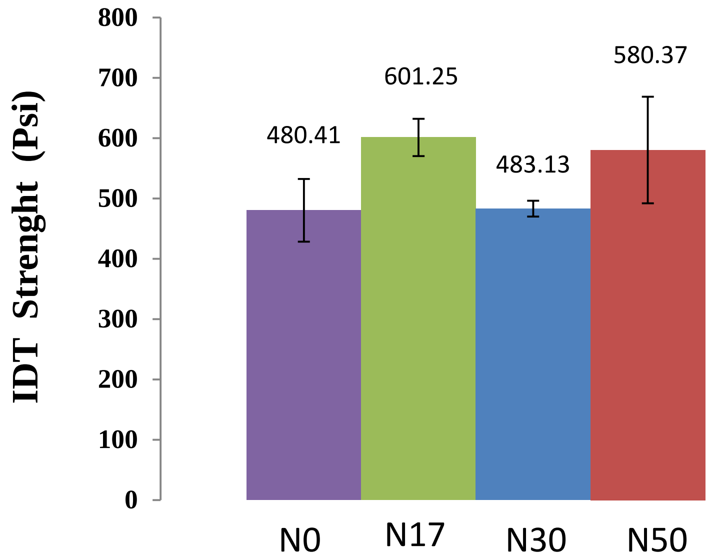
5.3 Low Temperature Thermal Cracking

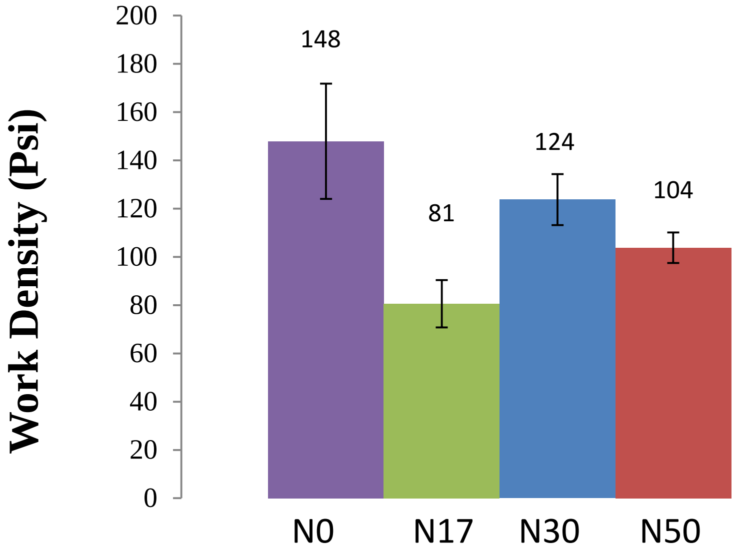
- AASHTO T322
  - "Standard Method of Test for Determining the Creep Compliance and Strength of Hot-Mix Asphalt (HMA) Using the Indirect Tensile Test Device"



- IDT Strength Test
  - Temperature: 14ºF
    - Fracture Work Density Correlates with Thermal Cracking
      - Wen et al. 2013, 15 out of 19 pair pavements match

Results of Low Temperature Cracking





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Findings

- With the increase of RAP percentage
  - Stiffness increases
  - Rutting resistance increases
  - Fatigue cracking resistance is not affected
  - Low temperature cracking resistance is affected
- The low temperature cracking resistance can be improved by change of PG grade or mix design
- Further verification is needed (South Idaho Mix)

Acknowledgements

The team would like to thank ITD for sponsoring this research and their support during the study

Washington Center for Asphalt Technology (WCAT)

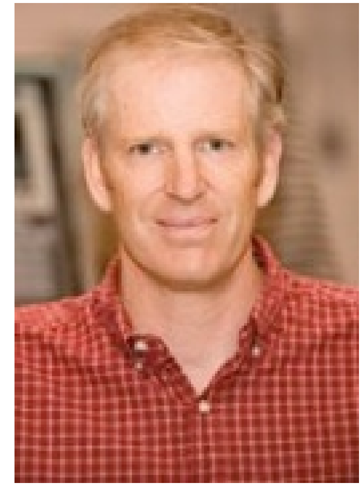
Haifang Wen, PhD, PE, Director
Assistant Professor
Washington State University

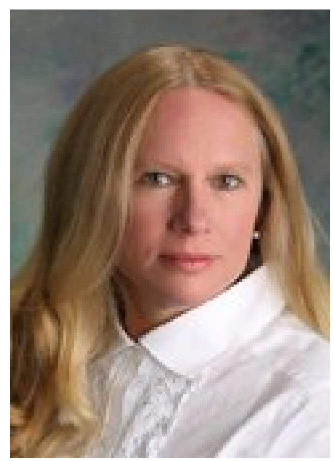
WASHINGTON STATE UNIVERSITY

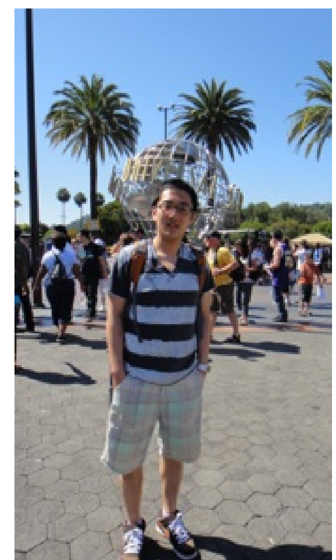
Background

- Established through partnership between
  - Washington State Department of Transportation (WSDOT),
  - Washington Asphalt Paving Association (WAPA), and
  - Washington State University (WSU)
- Funding also contributed by National Science Foundation (NSF)
- Website: wcat.cee.wsu.edu

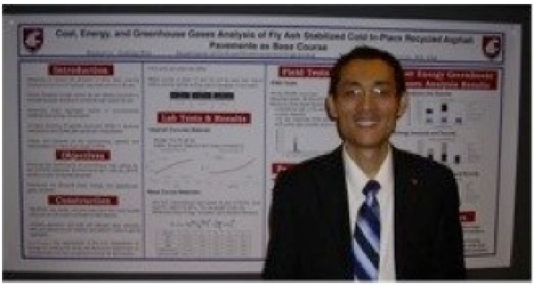
Members

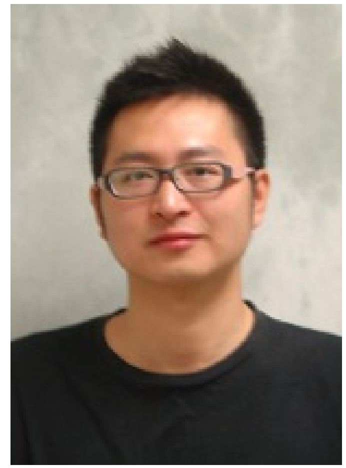


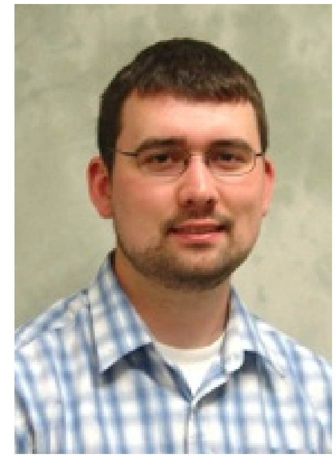




Graduate Students







WCAT Activities

- Education
  - Undergraduate and graduate students
- Industry services
  - Mix design and verification
  - Studies
- Research and development
  - NCHRP 09-49A, 04-36
  - FHWA EAR
  - National Science Foundation
  - WSDOT, ITD, WisDOT, Counties
  - University Transportation Centers
  - Industries

Laboratory Experiments

- WCAT is AASHTO accredited
  - Mix design
  - Mix verification
- Binder Tests
  - Extraction and recovery
  - Asphalt Content of Compacted Bituminous Mixtures using Ignition Oven or Solvent
  - Dynamic Shear Rheometer
  - Bending Beam Rheometer
  - Rolling Thin Film Oven
  - Pressure Aging Vessel
  - Rotational Viscometer (Brookfield)

Laboratory Experiments

- Mix performance tests
  - Dynamic Modulus Test - stiffness
  - Static Creep Test (Flow Time) - rutting
  - Repeated Load Test (Flow Number) – rutting
  - Indirect Tensile Test – fatigue and thermal cracking
  - Modified Lottman – moisture damage
  - Studded tire simulator

Thanks!

Questions?