Laboratory Evaluation of High Binder Replacement with Recycled Asphalt Shingles (RAS) for a Low N-Design Asphalt Mixture

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Outline

- RAS Background
- Research Methodology and Objectives
- Sample Preparation and Materials
- Experimental Program
- Results and Analysis
- Summary and Conclusions

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Recycled Shingles in Illinois

- Recycled asphalt shingles (RAS) are considered as a valuable supplement in HMA
- Potential for savings in paving projects and environmental benefits
- Current use of RAS in Illinois[1]:
  - 3,234 tons in IDOT projects
  - 4,440 tons in City of Chicago projects
  - 14,054 tons in Tollway projects
  - US total estimated: **701,000 tons** in 2009 and **1,099,000 tons** in 2010 (Hansen, 2012-NAPA survey)

Lippert and Brownlee (2012) – Use of RAS in IL

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Why RAS?

- The composition of RAS (good stuff in RAS)
- Sufficient RAS supply in the market

Material	% by Weight
Coating filler (limestone or fly ash)	32-42
Granules (painted rocks and slag)	28-42
Asphalt binder	16-25
Back dust (limestone and sand)	3-6
Fibers (paper, cotton rag, fiberglass)	2-15

Major Concerns with RAS

- Highly oxidized asphalt binder
  - Poor relaxation potential (usually characterized by m-value)
  - High PG Grades 100-150
- Low temperature cracking resistance due to brittleness of hardened binder
- Fatigue performance at intermediate temperatures when used at large quantities

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Research Objectives and Methodology

- The objective is to evaluate the effects of RAS on the critical performance properties of asphalt mixture
- A laboratory experimental program was conducted to assess fracture, fatigue, modulus, and permanent deformation characteristics of an asphalt mixture at high binder replacement levels

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Mix Designs with RAS

- Mix design initially contained 7.5% RAS and 37.5% RAP (N30 at 2.0% air voids)
- Different versions of the mix were produced with varying percentages of RAS

Mix Design*	Coarse RAP (%)	Fine RAP (%)	RAS (%)	ABR(%)	Binder Type
2.5% RAS	20.0	22.5	2.5	48	PG46-34
5.0% RAS	20.0	20.0	5.0	56	PG46-34
7.5% RAS	20.0	17.5	7.5	64	PG46-34 and PG58-28

*All mix designs were prepared and initially tested by S.T.A.T.E Testing

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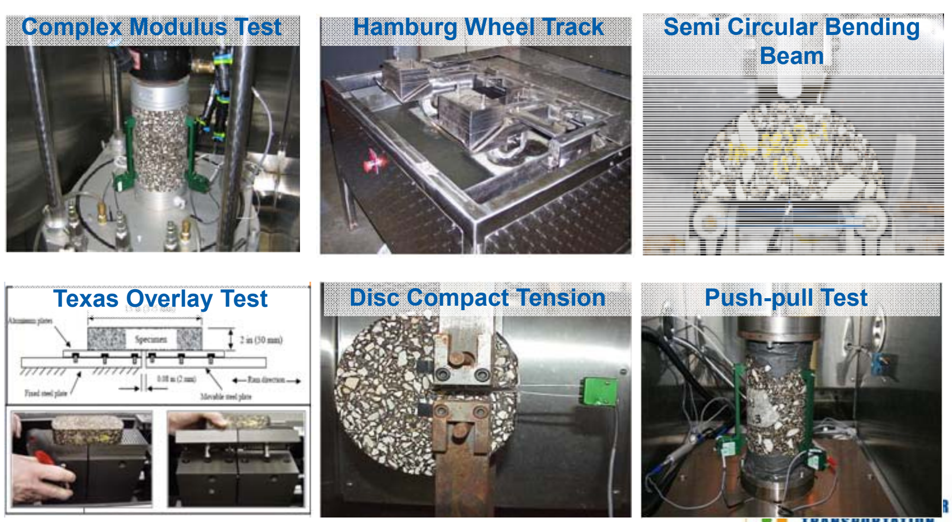
Experimental Program



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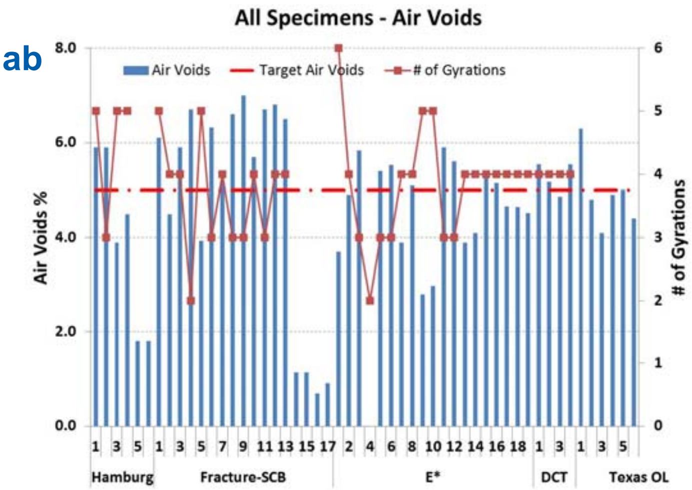
Specimen Preparation

- Gyratory compacted lab specimens and field cores were used
- Target air voids were achieved within **3-5 number of gyrations**



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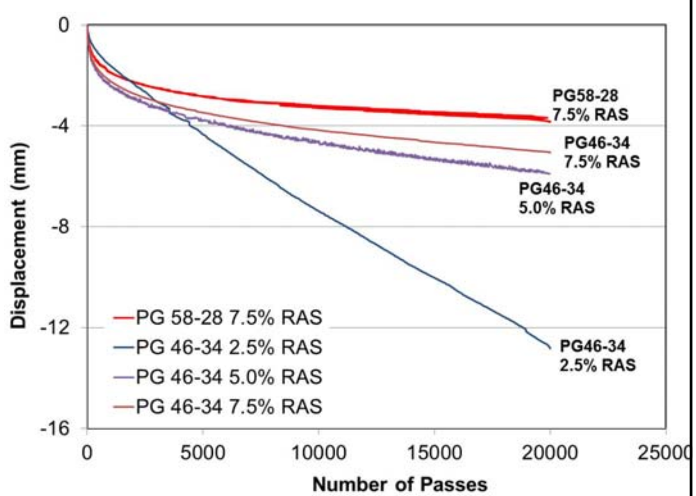
Hamburg Wheel Track

(AASHTO T324-11)

- Rutting results were all passing the IDOT criteria (mix designs were acceptable)
- RAS (as expected) improved the rutting resistance



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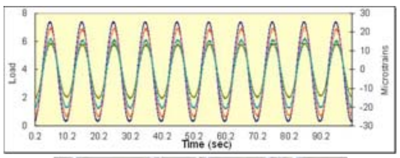
Complex Modulus Testing

(AASHTO TP62-03)

- Complex modulus testing were conducted for all lab compacted mixes to evaluate:
  - Stiffness of the mixes with RAS



Test Temperature (°C)	Test Frequency (Hz)	Mixes
-10	0.1, 0.5,1,5, 10,25	All Lab Compacted Mixes
4	0.1, 0.5,1,5, 10,25	
21	0.1, 0.5,1,5, 10,25	
38	0.1, 0.5,1,5, 10,25	

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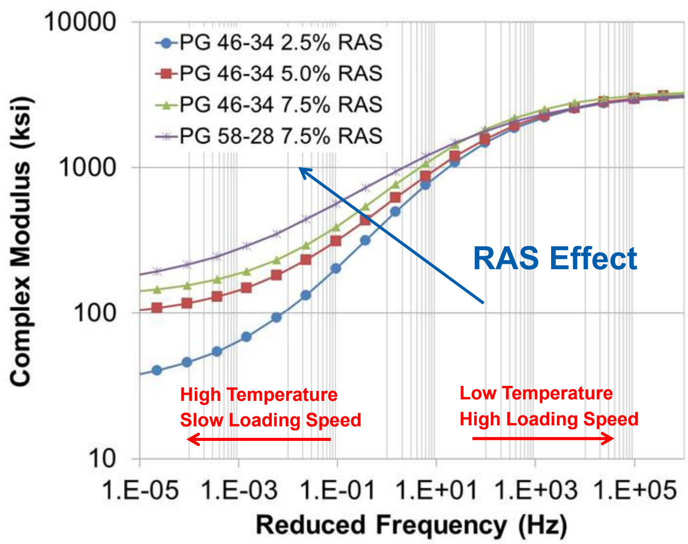
Complex Modulus Testing

(AASHTO TP62-03)



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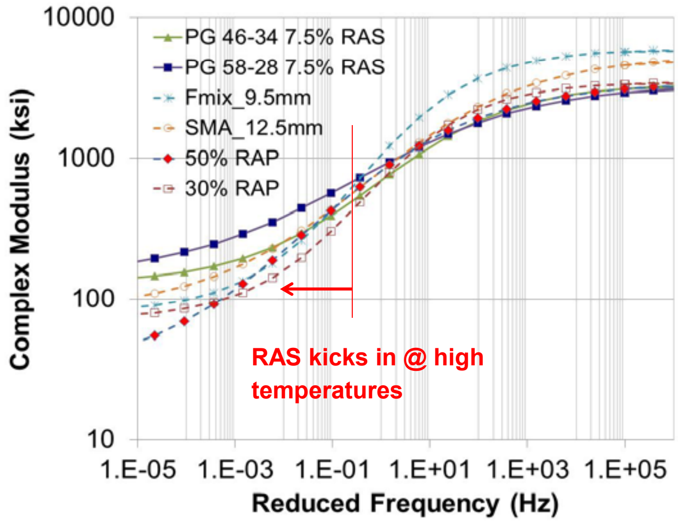
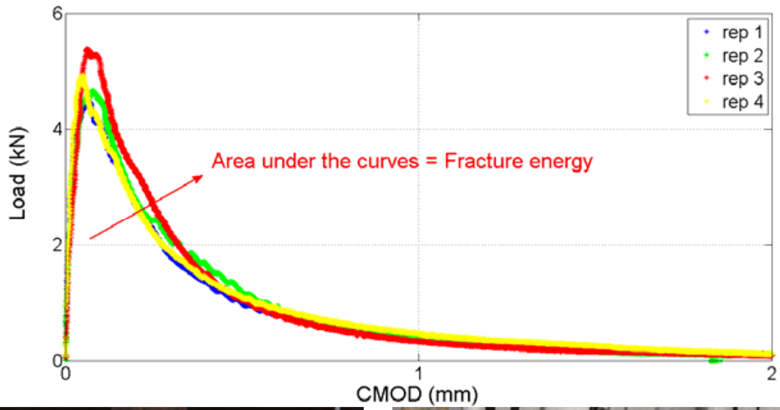
Complex Modulus Testing



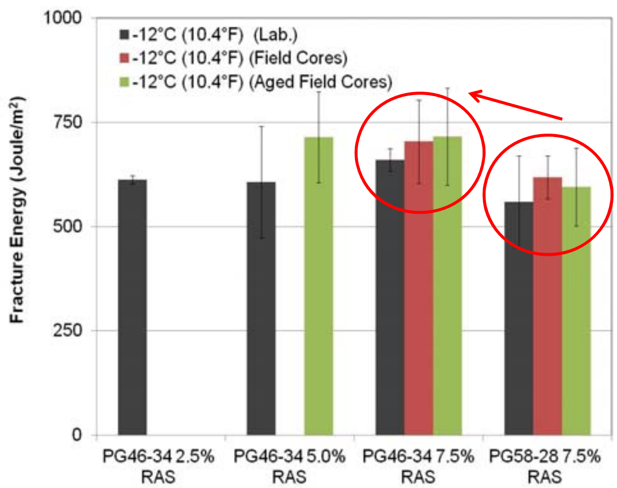
Low Temperature Fracture

- Test temperatures are 0 and –12°C
- Two types of fracture tests were conducted



Fracture Test Results

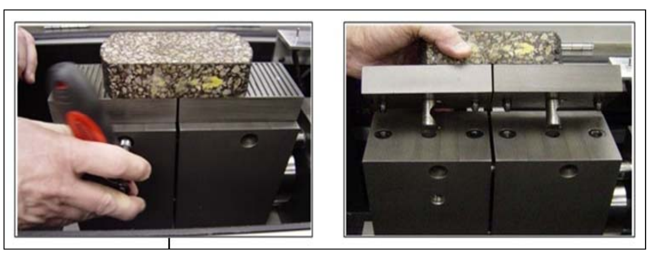
- Comparable results for lab and field cores at –12°C
- PG46-34 appears to be working well with 7.5% RAS



Fatigue Tests

- Cyclic loads or displacements until failure at or around room temperature

Texas Overlay



Push-pull

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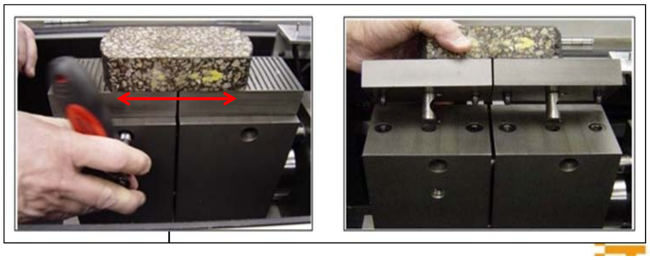
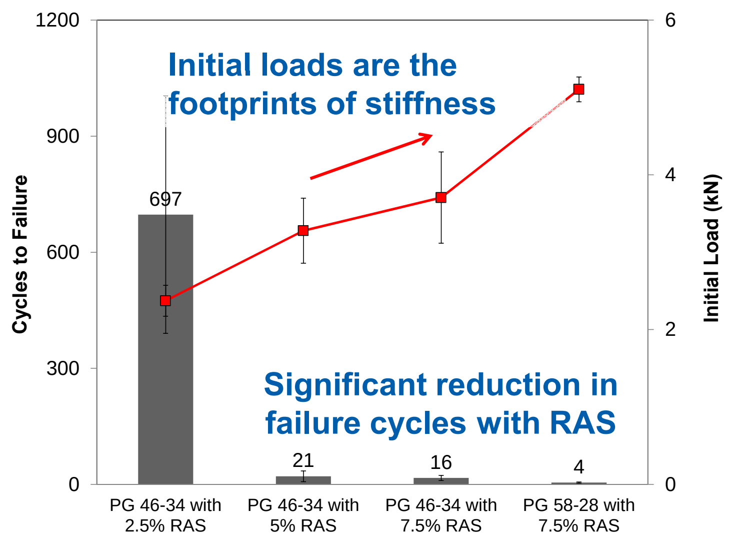
Texas Overlay Tester

- Texas overlay tester (aka TTI overlay test) was designed to measure reflective cracking resistance (Lytton and his co-workers)
- Cyclic displacements of 0.025 in at 0.1 Hz until specimens are fully broken



Texas overlay tests were conducted at TXDOT.

Texas Overlay Test Results



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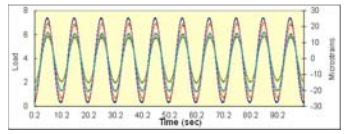
Push-pull Test Results

- Developed late 2000s by Richard Kim and his co-workers at North Carolina State University
- The main purpose is to characterize damage in asphalt concrete with repeated load applications
- Cyclic displacements generate uniaxial tension and compression in the specimen
- Tests are usually conducted at temperatures from 10 to 20°C and various strain levels (100 to 500 microstrains)



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Push-pull Test Matrix

- A rigorous test matrix was conducted at different strain levels and temperatures

Sample ID	ID #	Air Voids	Microstrain	Temperature (°C)
2.5% RAS PG 46-34	1	5.1	250	20
	2	4.7	350	20
	3	4.5	350	20
5.0% RAS PG 46-34	1	5.9	150	15
	2	3.0	250	20
	3	4.1	250	20
	4	2.8	350	20
	5	5.6	350	20
7.5% RAS PG 46-34	1	3.9	150	15
	2	5.1	250	20
	3	5.4	250	20
	1	5.8	350	20
	2	5.5	350	20
7.5% RAS	1	3.7	150	15

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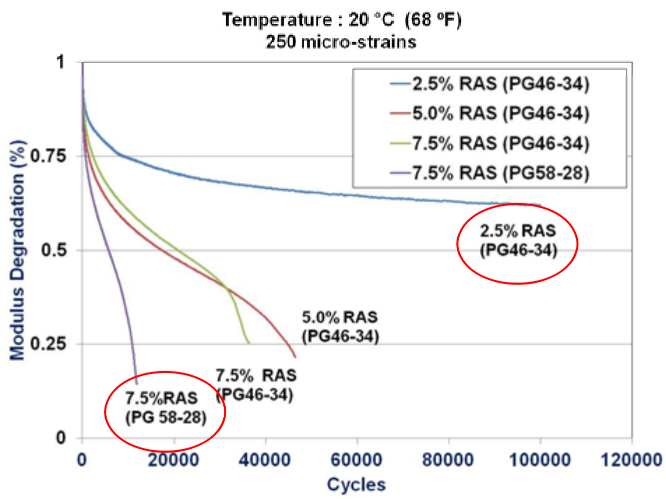
Test Results

20°C (68°F) & 250 microstrains

- Calculate the decrease (damage) in modulus at every cycle
- 2.5% RAS survived more than 100,000 cycles
- 7.5% RAS and PG58-28 are not working very well (insufficient bumping?)



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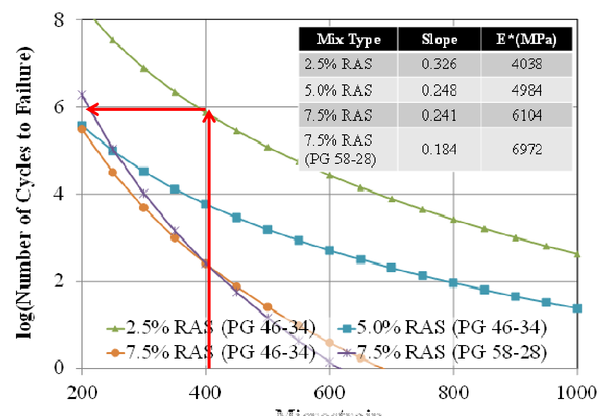
Fatigue Curves for RAS Mixes

- When data is sufficient, fatigue curves can be developed
- Some correlation was noticed between complex modulus parameters and fatigue
- Further research and more testing is needed to develop reliable fatigue curves



Calculate number of cycles to failure for a given microstrain

Summary and Remarks

- Permanent deformation resistance of the mixtures was improved in the presence of RAS
- Stiffness tests were reflecting the presence of RAS in the mix
- Fatigue life appears to be a problem with increasing RAS
  - 2.5% RAS and PG 46-34 showed the best performance in fatigue and fracture tests
- The improvement in performance and cracking resistance was noticeable when simply binder type was changed from PG 58-28 to PG 46-34

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