




# SEAUPG 2004 Conference - Baton Rouge Presented By Brian Egan - Tennessee DOT




## Fatigue Characteristics of RAP in Surface Mixtures



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## RAP in Surface??




- TDOT did not allow RAP in Surface Mixture (D-mix)
- RAP stockpiles getting bigger !!
- Concern was FATIGUE with "oxidized" RAP asphalt, consistency of RAP, and CA siliceous content
- U. of Tennessee, Phase 1, Laboratory Phase in November 2002 (finished April 2004), Prof. Baoshan Huang, Graduate Student William Kingery

## Research Approach

- Existing Mix Designs
- Laboratory Testing (w/ simulated aging)
  - Indirect Tensile Strength Test (IDT)
  - Semi-Circular Bending (SCB) Test
  - Beam Fatigue (Flexural Bending Test)
  - APA Rut Test- was discontinued, but replaced with SCB Notched specimens
  - Binder Extraction, Recovery and Test



## Mix Designs and Materials



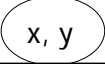


- Two aggregates (siliceous)
  - Crushed Limestone and Gravel
- Two asphalt binders
  - PG 64-22 and PG 76-22
- Three percentages screened RAP
  - 10%, 20% and 30%



## Test Matrix

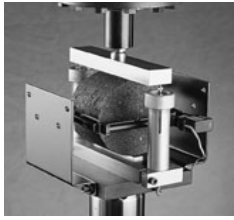

Aggregate	Asphalt Cement	RAP (%)	IDT	SCB IDT	SCB Fatigue	SCB Notched Fatigue			Flexural Beam
						0.5"	1.0"	1.5"	
						x,y	x,y	x,y	
Limestone	PG 64-22	0	x,y	x,y	x,y	x,y	x,y	x,y	x,y
		10	x,y	x,y	x,y	x,y	x,y	x,y	x,y
		30	x,y	x,y	x,y	x,y	x,y	x,y	x,y
	PG 76-22	0	x,y	x,y	x,y	x,y	x,y	x,y	x,y
		10	x,y	x,y	x,y	x,y	x,y	x,y	x,y
		30	x,y	x,y	x,y	x,y	x,y	x,y	x,y
Gravel	PG 64-22	0	y,z	y,z	y,z	y,z	y,z	y,z	y,z
		10	y,z	y,z	y,z	y,z	y,z	y,z	y,z
		30	y,z	y,z	y,z	y,z	y,z	y,z	y,z
	PG 76-22	0	y,z	y,z	y,z	y,z	y,z	y,z	y,z
		10	y,z	y,z	y,z	y,z	y,z	y,z	y,z
		30	y,z	y,z	y,z	y,z	y,z	y,z	y,z

Note: Each Test will be conducted on triplicate samples  
 IDT - Indirect Tensile Strength  
 SCB - Semi-circular Bending  
 x - un-aged  
 y - long-term aged  
 z - long-term aged Freeze Thaw cycle

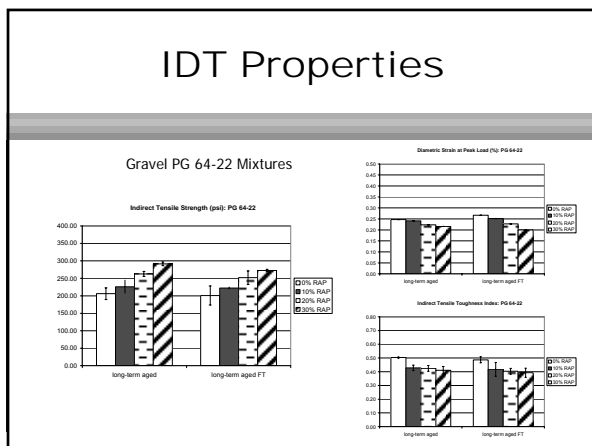
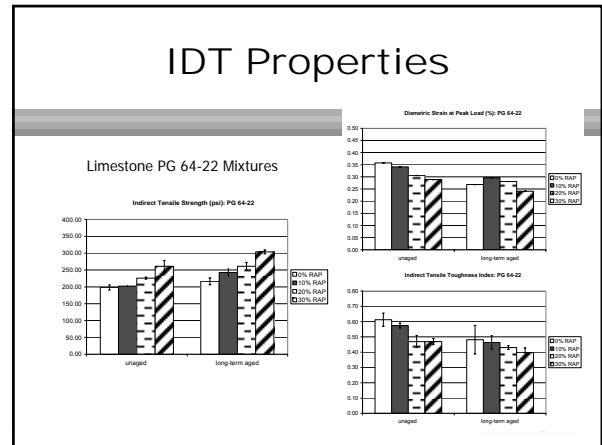
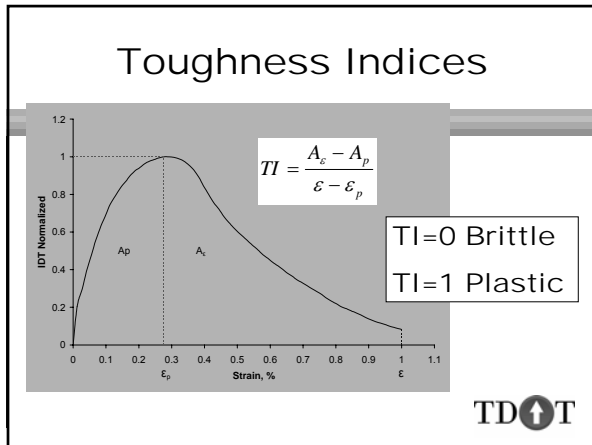
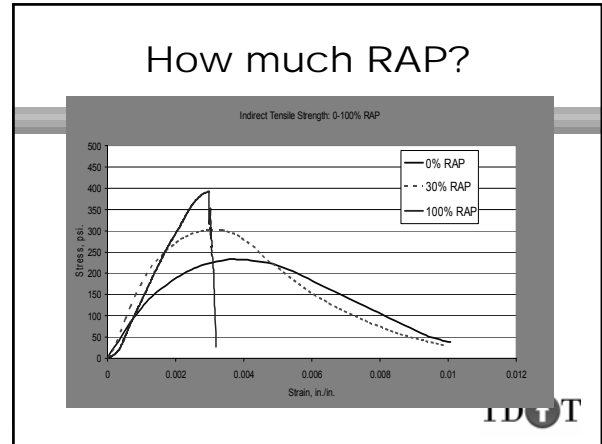
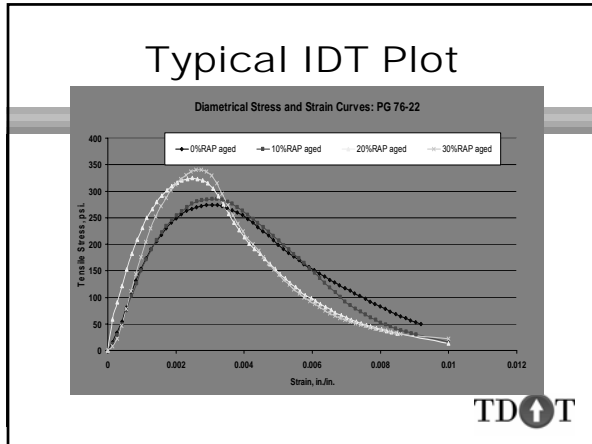



## Indirect Tensile Strength (IDT)

- 4" Samples
- ASTM D4123 @ 25°C
- Specimen loaded at 2 in./min.
- Load and deformation continuously recorded and indirect tensile strength and strain were calculated

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- ### Results from IDT
- Inclusion of RAP:
    - Increased Tensile Strength
    - Decrease post failure characteristics
  - Laboratory long-term aging:
    - Higher Tensile Strengths
    - Lower diametric strain
    - Lower toughness indices
  - Freeze Thaw Cycle Decreases ITS
- TDOT

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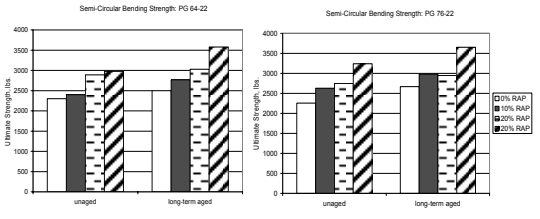
## Semi-Circular Bending Test

- Compacted in SGC, 6" diameter, 1" thick
- Dynamic/cyclic loading and single loading
- Frequency sweep testing for Modulus and phase angle



TDOT

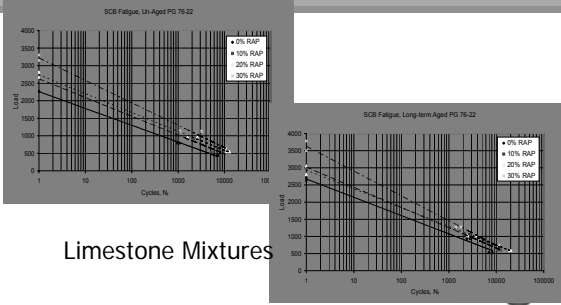
## SCB Tensile Strength Test



Limestone Mixtures

TDOT

## Semi-Circular Fatigue Test



Limestone Mixtures

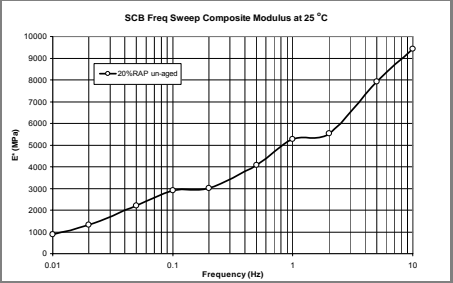
TDOT

## Results from SCB Fatigue Test

- Inclusion of RAP increased lab fatigue life at high stress levels
- Lower stress levels (similar to highway conditions) and higher percentages of RAP tend to have lower fatigue life
- Long-term aging increased fatigue life
- Freeze Thaw Cycle decreased fatigue life

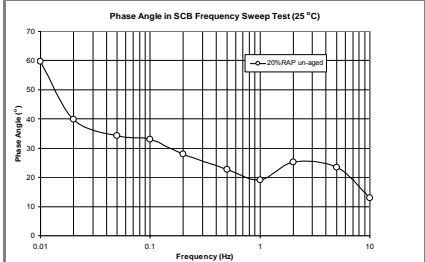
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## SCB - Frequency Sweep Composite Modulus



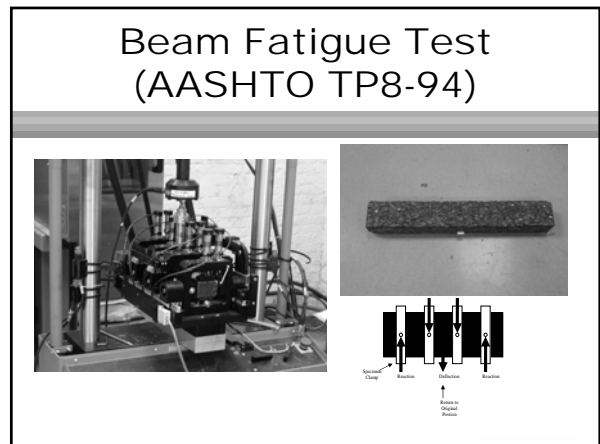
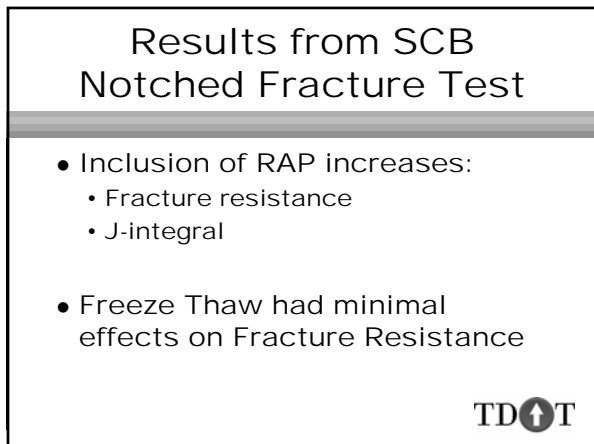
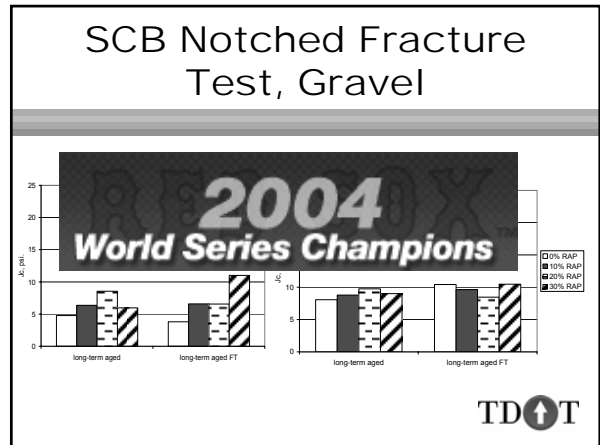
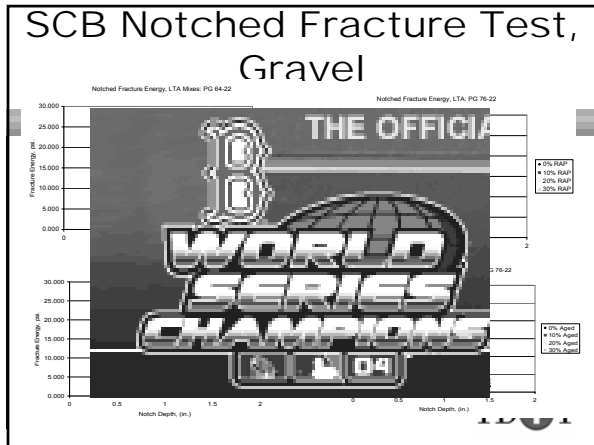
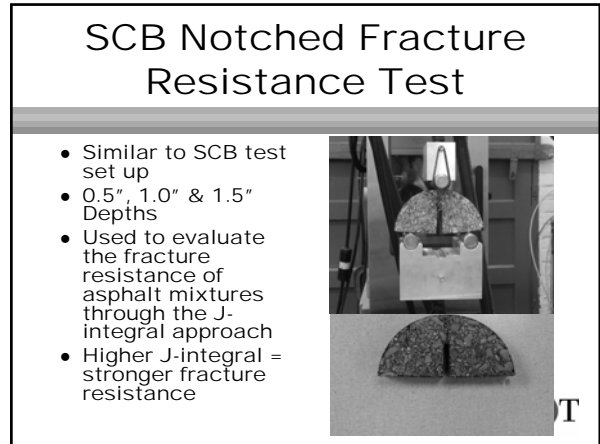
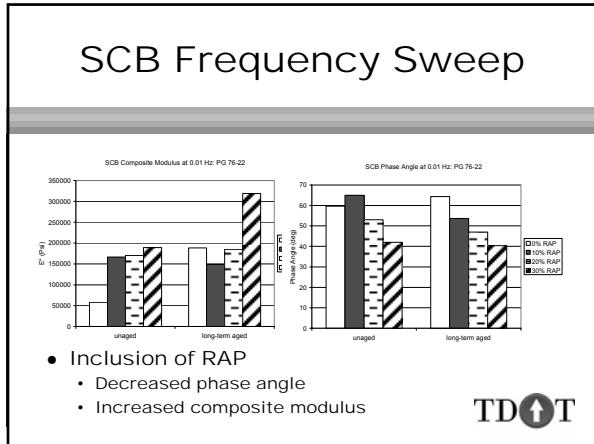
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## SCB - Frequency Sweep Phase Angle

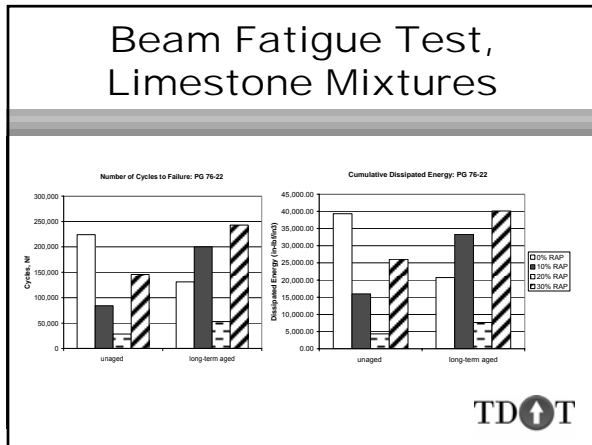
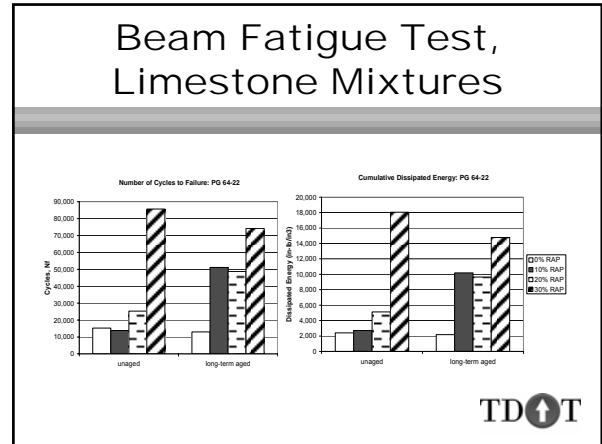
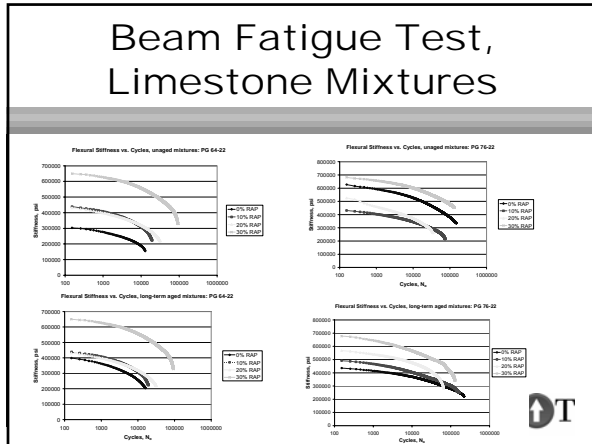


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- ## Results from Bending Beam Tests
- Inclusion of RAP increases:
    - Number of cycles to failure
    - Cumulative energy to failure
    - Therefore increasing resistance to fatigue failure
  - Freeze Thaw had minimal effects on Fracture Resistance

- ## Conclusions
- Freeze thaw cycle had little influence on the fatigue crack resistance
  - Inclusion of RAP may drop low temperature PG grade
  - 20% RAP is recommended for use in Tennessee surface mixtures
  - Further Field testing recommended to validate laboratory results

- ## Summary
- From this research, the addition of up to 30% RAP in some instances improved the "fatigue" resistance or was minimally detrimental

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## Phase 2 underway

- Evaluating 2 limestone and 2 gravel mixtures in the field, PG 64-22 and PG 76-22 of each
- 0, 10, 20, and 30 % RAP
- Aging through the plant and naturally
- Both limestone completed, gravel PG 64-22 completed
- 5 year field evaluation for mixture distresses



## Where is TDOT now?



- Processed RAP- *def.* RAP that has been crushed and screened or otherwise sized such that the maximum RAP particle size is less than the size specified for each mix before it enters the dryer drum/pugmill



## Where is TDOT now?

TDOT RAP USAGE POLICY			
MIX TYPE	% RAP	% RAP	100% of RAP aggregate Passing
	(NON-PROCESSED)	(PROCESSED)	
307 ACRL	0	0	-
313 TRB	0	0	-
307 AS	0	0	-
307 A	15	20	1 1/2"
307 B	15	25	1 1/2"
307 BM	15	25	3/4"
307 BM2	15	25	3/4"
307 C	15	25	3/8"
307 CW	15	25	3/8"
307 CS	0	15	5/16"
411 D	0	10/15	1/2"
411 E (SHLDR)	15	25	1/2"

\* ALL MIXES MUST STILL CONTAIN AT LEAST 65% VIRGIN AC, EXCEPT 411 D, SHALL BE 80% VIRGIN AC



## RAP in TDOT mixtures

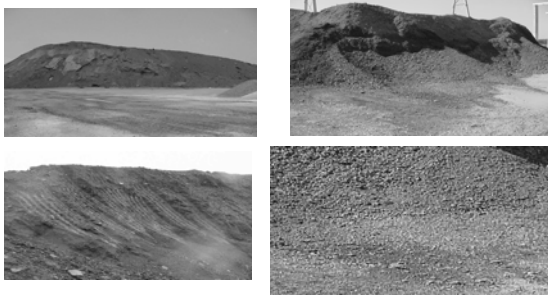
C-S mix 15 %	D mix	10-15%	E mix	25%
	BM-2 mix	25 %	BM-2 mix	25 %
	A mix	20 %		
	A-S mix	0 %		

% RAP allowed

Aggregate Base



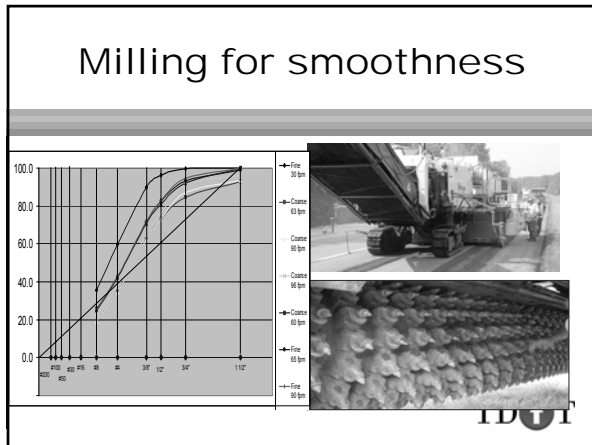
## RAP- Quality Control



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RAP in surface in SEAUPG States		
State	RAP	Comments
SC	20% low 10 % high 0% IS	<ul style="list-style-type: none"> <li>• max. 15% if batch plant</li> <li>•Max. size 2"</li> <li>•Max. Capillary viscosity 8,000 Poises</li> </ul>
VA	No limit, 15% (PG 76)	<ul style="list-style-type: none"> <li>•&gt;20%, bump down grade</li> <li>• Max. size 2"</li> </ul>
NC	50% 15% if RAS and >30 mil ESAL	<ul style="list-style-type: none"> <li>•15-25%, bump down grade</li> <li>•&gt;25%, approved by Eng.</li> <li>• Max. size 2"</li> </ul>

RAP in surface in SEAUPG States		
State	RAP %	Comments
KY	No Limit, 20% (PG 76-22)	<ul style="list-style-type: none"> <li>• RAP must be "polish resistant"</li> <li>• RAP stockpiles separate</li> <li>•If 21-30% bump down high grade, if &gt;30% recovery</li> </ul>
AL	15%	<ul style="list-style-type: none"> <li>• max. size 2"</li> </ul>
TN	15%, 10% if modified	<ul style="list-style-type: none"> <li>• max. size ½", processed and screened</li> </ul>

Thank You !  
Questions ?