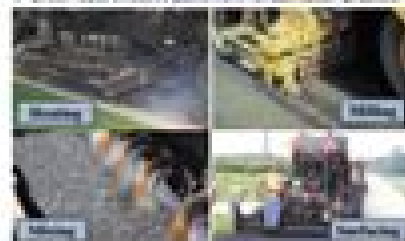


### INTRODUCTION

#### Hot In-place Recycling (HIR)

A Green and effective pavement rehabilitation practice



#### Advantages

- Up to 50% cost savings
- Less new material, both aggregate and asphalt
- No waste material
- Less transportation of material
- Up to 70% less emissions
- Fast, one pass process, Less road closure time

#### Asphalt Aging and Rejuvenation

- A critical element in HIR is binder rejuvenation
- Asphalt is composed of Asphaltenes (Main body) and Maltenes (Viscosity)
- Asphalt ages over time; Maltenes are lost mainly through oxidation and evaporation
- Rejuvenating agents (Rejuvenators) suit aging, replace maltenes and restore original properties

### RESEARCH OBJECTIVES

- This study aims at looking beyond initial performance and evaluating long term aging of recycled binders.
- Current Practice: Effectiveness of a rejuvenator is evaluated by softening curves established based on viscosity or penetration requirements
- Shortcoming: Not taking durability of recycled binder into account; Softening effectiveness and durability sometimes move in opposite directions
- Environmental aging of a recycled mix can be quite different from that of a virgin mix

### METHODOLOGY

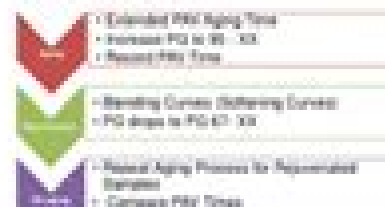
- Superpave Performance Grade Tests with Extended Aging Time
- Dynamic Shear Rheometer (DSR)
- Bending Beam Rheometer (BBR)
- Rotational Viscometer (RV)
- Rolling Thin Film Oven (RTFO)
- Pressure Aging Vessel (PAV): Simulates in-service aging



#### Material

- Two samples of PG58-10 asphalt binder
- Four rejuvenators (DRE, nPE, PMA, BOP)
- Standard PAV aging time is 20 hours. This time is extended to 60 hours to simulate long term aging
- Based on FDOT's experience with binders recovered from RAP (Reclaimed Asphalt Pavement) PG 58-10 was selected to represent a RAP binder
- PAV Time: The PAV aging time it takes each sample to reach high temperature PG of 58°C

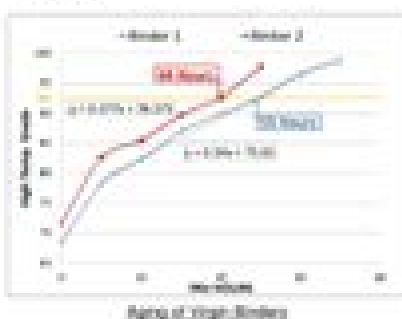
#### TESTING PROCEDURE



#### Time Stream of Testing Procedure

### RESULTS AND ANALYSIS

#### + Aging



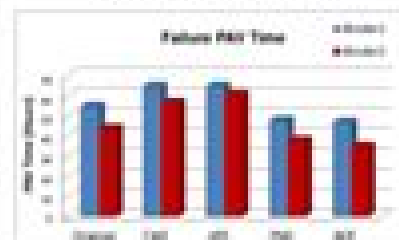
#### + Rejuvenation

The rejuvenator dosage required to soften aged asphalt samples to their original grade were determined as follows, based on softening curves

Rejuvenator Dosage to Soften Aged Asphalt Samples								
Asphalt Sample	Binder 1				Binder 2			
	100	200	300	400	100	200	300	400
Rejuvenator	100	200	300	400	100	200	300	400
Asphalt Grade	58	57	56	55	58	57	56	55

#### + Re-aging

Test Time (min)	High Temperature PG's									
	Binder 1					Binder 2				
	Original	100%	90%	80%	60%	Original	100%	90%	80%	60%
1	58.0	58.0	57.0	56.0	55.0	58.0	58.0	57.0	56.0	55.0
10	58.0	57.0	56.0	55.0	54.0	58.0	57.0	56.0	55.0	54.0
30	58.0	57.0	56.0	55.0	54.0	58.0	57.0	56.0	55.0	54.0
60	58.0	57.0	56.0	55.0	54.0	58.0	57.0	56.0	55.0	54.0
90	58.0	57.0	56.0	55.0	54.0	58.0	57.0	56.0	55.0	54.0



Longevity of the Original and Rejuvenated Samples Based on PAV Time

- Low Temperatures: Low Temperature properties were studied through BBR tests at standard aging (RTFO) (20hrs PMA) and ultimate aging conditions (60 hrs PMA)



### CONCLUSIONS

- Long term aging rate of samples recycled by different recycling agents can be very different. Among four rejuvenators tested, two (DRE and nPE) showed slow aging, while two others (PMA and BOP) accelerated it.
- The aging rate of virgin asphalt binder decreases after the first 20 hours of PAV aging. This trend was not observed in the recycled binders. They continued aging after 20 hours at almost the same rate.
- Recycled binders might age faster than virgin binders in the long term, even if they age at the same or slower rate during first 20 hours of PAV aging. This shows the importance of studying long-term aging beyond the standard PG system requirements.
- Properties of rejuvenators have a great influence of service life of recycled asphalt. The service life of samples recycled by proper rejuvenators was estimated to be up to 10 years more than those suffered by less effective products.
- The fastest aging occurred for the samples recycled by BOP, which is a bio-rejuvenator. Thus, it is important to consider long term aging when using such products as recycling agents.
- The low temperature creep stiffness of recycled binders was significantly lower than that of virgin asphalt binders.
- Future Work:
  - Studying aging of recycled mixes through Asphalt Pavement Weathering System (APWS)
  - Studying long term aging of mixtures containing PAV
  - Proposing modifications to HIR specifications to enhance longevity of HIR pavements using results from this study and future works.

### ACKNOWLEDGEMENT

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