Evaluating Diffusion and Aging Mechanisms in Blending of New and Age-Hardened Binders during Mixing and Paving

UC PRC UNIVERSITY of CALIFORNIA | PAVEMENT RESEARCH CENTER Davis • Berkeley | CENTER

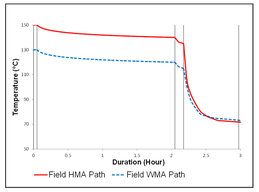
Yuan He, Zia Alavi, John Harvey, and David Jones

Paper No. 16- 4454

Caltrans

Introduction

- A number of studies have demonstrated that RAP does not behave as "black rock", but rather the RAP binder blends appreciably with virgin binder, ultimately producing a composite binder that will influence pavement performance, especially when the mix contains a high RAP percentage (more than 25%).
- It is important to understand the mechanisms of blending and its evolution during mix production and paving.



Objective

Investigate the extent of blending between virgin and RAP binders during mixing through compaction.

This was achieved through the following tasks:

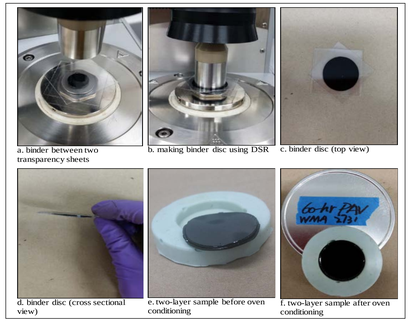
- ✓ Development of a testing protocol for preparation, conditioning, and testing of wafer composite binder specimens using a DSR.
- ✓ Testing wafer specimens conditioned at different stages over HMA and WMA time-temperature paths with a DSR.
- ✓ Modeling the blending of new and RAP binders based on diffusion law and considering aging.
- ✓ Prediction of representative diffusion and aging coefficients for composite binders based on comparing the estimated and measured values of shear modulus (G*).

Materials, Sample Preparation, and Testing

- ❑ New Binder: PG 58-22
- ❑ Age-Hardened Binder: PG87

(produced with aging of a PG64 binder in PAV for 60 hrs. at 100ºC with 2.1MPa air pressure)

Wafer binder specimen preparation and testing validation



Conditioning times and temperatures

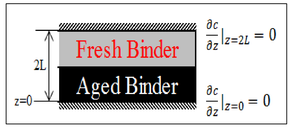
Phase	Level of Conditioning	
	HMA	WMA
Start Mixing	no conditioning	no conditioning
After Mixing	0.05hr at 150°C	0.05hr at 130°C
Silo+Trans_1	0.05hr at 150°C + 0.5hr at 140°C	0.05hr at 130°C + 0.5hr at 120°C
Silo+Trans_2	0.05hr at 150°C + 1hr at 140°C	0.05hr at 130°C + 1hr at 120°C
Start Paving	0.05hr at 150°C + 2hr at 140°C	0.05hr at 130°C + 2hr at 120°C
Finish Compaction	0.05hr at 150°C + 2hr at 140°C + 0.5hr at 135°C	0.05hr at 130°C + 2hr at 120°C + 0.5hr at 115°C

Blending Mechanism

- The change in rheological properties of wafer composite binders can be explained through the diffusion mechanism over time.
- The diffusion process involves transferring new binder molecules from regions of higher concentration to regions of lower concentration, without requiring bulk motion.
- The concentration of new binder in the RAP binder film around the aggregate increases as a function of time until equilibrium is achieved.

Modeling of the Blending Mechanism

$$\frac{\partial C}{\partial t} = D\frac{\partial^2 C}{\partial z^2}$$



Where:
D is the diffusion coeff. in m²/sec
C is the concentration in percentage
z is the position in m
t is time in sec.

$$\frac{2L}{G^*_{diffusion}(t)} = \sum_{i=1}^{n} \frac{h_i}{G^*(i,t)}$$

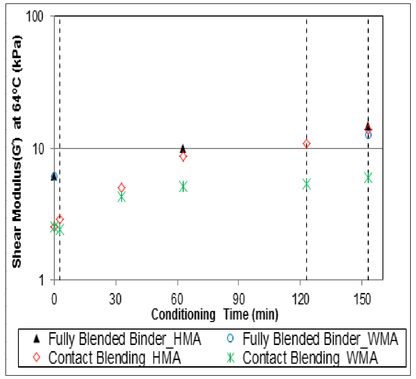
$$G^* = \frac{G^{*\,C}_{simulated\ RAP} \times G^*_{New}}{G^{*\,C}_{New}}$$

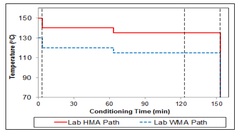
Incorporating aging effect during blending

$$G^*_{predicted} = G^*_{diffusion} + C \times t$$

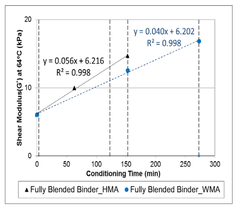
Where:
C is the aging coefficient, and
t is the conditioning time.

Evolution of Binder Rheological Properties



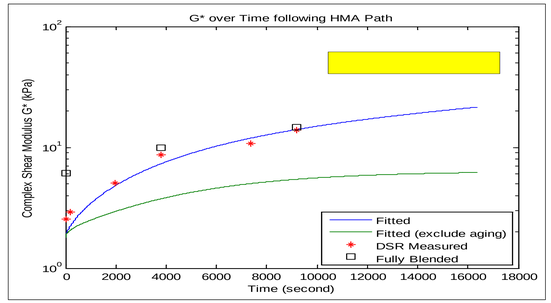


Determining aging coefficients

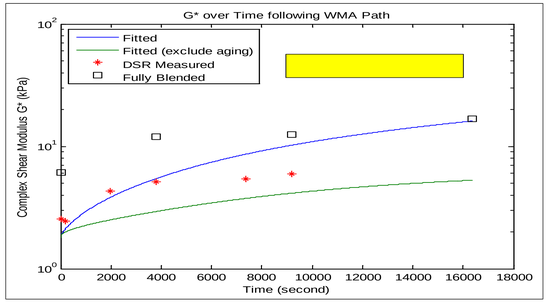


Prediction of Blending between New and Aged Binders

HMA production path



WMA production path



Summary and Conclusions

- The DSR wafer composite binder testing method was shown to be an effective approach for examining the level of blending between new and age-hardened binders.
- The diffusion mechanism in the blending process was shown to be temperature and time dependent.
- The diffusion coefficient increased with temperature.
- It is recommended that the DSR wafer method be further refined and standardized. It is also recommended that the method be used to evaluate the effect of different WMA technologies and/or rejuvenating agents on blending between new and RAP binders, and potentially to develop test methods and specifications.