

Subtask 2-2.3 Age Hardening – Field Validation Sites

Mike Farrar
Western Research Institute

July 24, 2007
ETG meeting
Denver, Colorado



Principal researchers:

Fred Turner, Mike Harnsberger, Shin-Che Huang,
Troy Pauli, Mike Farrar, Will Grimes

Goals

- Develop a rapid FTIR method to map chemical moieties, related to oxidative age hardening, on the face of a core (slicing cores & extraction/recovery is too time and labor intensive)
- Review and establish correlations between carbonyl, sulfoxide and aromatic moieties, and low and high temperature rheological properties
- Map rheological properties based on correlation with chemical moieties

Goals Cont.

- Revisit the Global Aging System
 - Compare GAS predicted hardening to actual hardening at the validation sites
- Revise the GAS or develop a new long-term age hardening model

Goals Cont.

- FTIR application to sealer/rejuvenator and OGFC
 - Can FTIR **microscopy** provide insight into:
 - The extent of sealer/rejuvenator infiltration?
 - The extent of diffusion/mixing at the asphalt sealer/rejuvenator interface?
 - The reduction in oxidation below the seal or OGFC?

What is the Global Aging System?

- Published 1995 (AAPT, Vol. 64) [Mirza and Witczak]
- Predicts change in asphalt viscosity in pavement with time and depth
- Based on statistical analysis of data from 40 field projects
- Integral part of NCHRP 1-37A Mechanistic-Empirical Pavement Design Guide

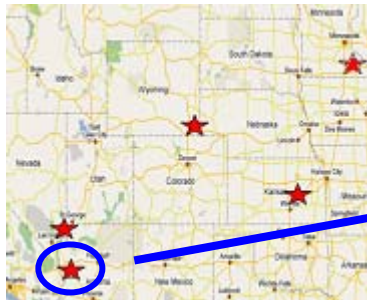
Global Aging System cont.

- Short-term aging model
 - Predicts mix/laydown viscosity
 - $f(\text{original viscosity, hardening code})$
- Long-term aging model
 - Predicts aged viscosity at assumed depth of 0.25”
 - $f(\text{mix/laydown viscosity, time, MAAT, and temperature})$
 - Optional adjustments for air voids and change in air voids with time
- Depth model
 - Predicts aged viscosity with depth
 - $f(\text{aged viscosity, MAAT, and depth})$

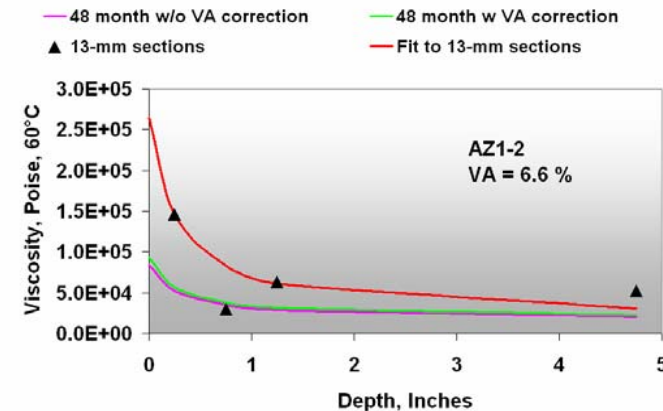
Global Aging System Limitations

- Does not apply to:
 - Modified asphalt
 - Waxy asphalt
 - Blown asphalt
- Air void adjustment factor is based on limited data and considered “optional”
- The model does not address solar radiation effects
- Several recent studies suggest the long-term model needs adjustment/modification [Al-Azri et al. 2006; Farrar et al. 2006; NCHRP 567, Christensen and Bonaquist, 2006]
- Does not take into account sealer/rejuvenator, or OGFC effects
- Not based on fundamental properties

Age hardening at the Arizona validation site and comparison to the GAS



Field validation sites



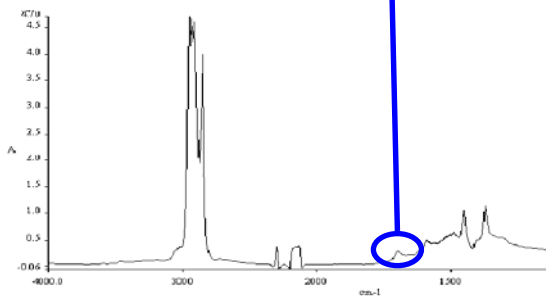
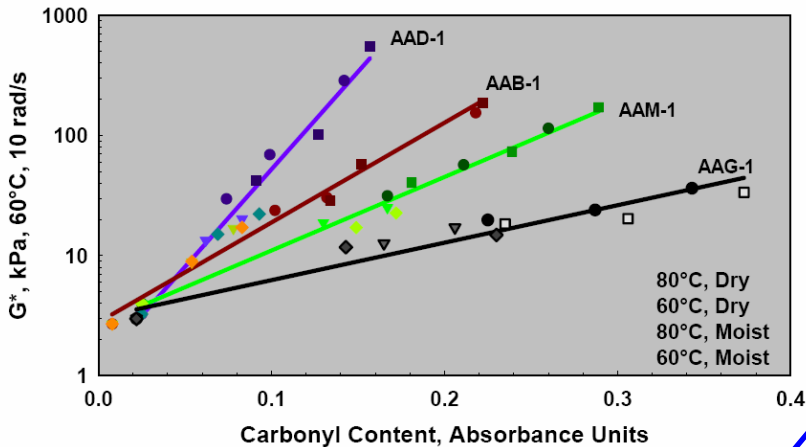
■ Global Aging System ... key finding

- The GAS significantly under predicts the change in asphalt stiffness with time and depth for the four year old pavements at the Arizona site, especially in the top 13 mm

Farrar, M. J., P. M. Harnsberger, K. P. Thomas, W. Wisler. Evaluation of Oxidation in Asphalt Pavement Test Sections after Four Years of Service. Proceedings of the International Conference on Perpetual Pavement, September, 2006, Columbus, Ohio.

Alternate approach

RELATIONSHIP BETWEEN CARBONYL CONTENT AND COMPLEX MODULUS OF ASPHALT



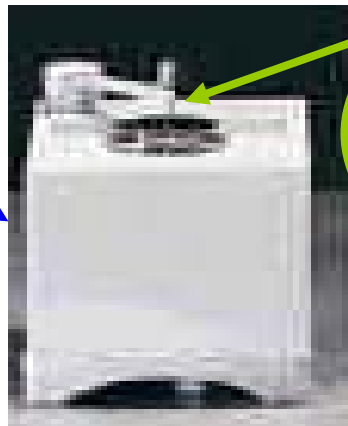
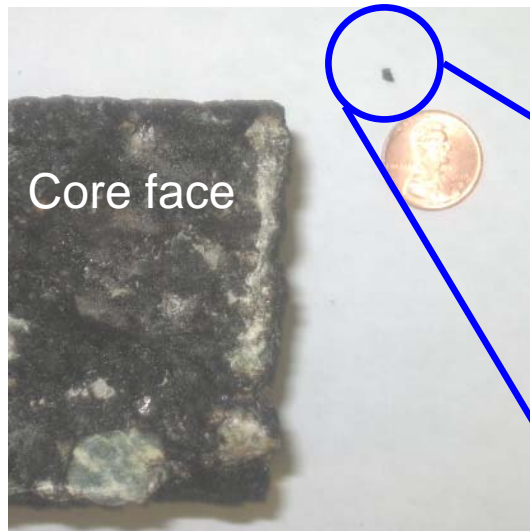
- Quantitative FTIR
 - Liquid Cell ... common method
 - Mass of asphalt is known
 - Somewhat time consuming
 - Typically no aggregate

More rapid FTIR method that includes aggregate

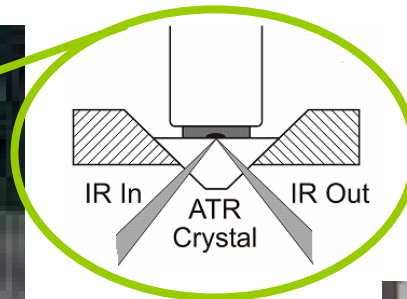
FTIR absorbance spectrum



Rapid Quantitative FTIR



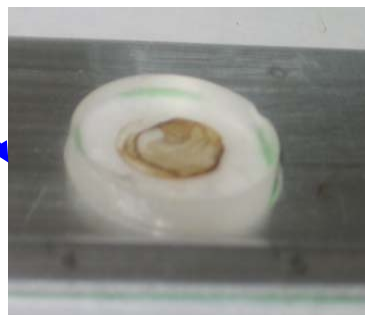
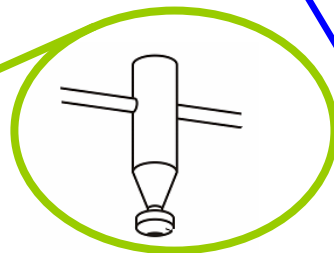
Attenuated Total Reflectance (ATR)



FTIR microscope (transmission)



Micro-ATR

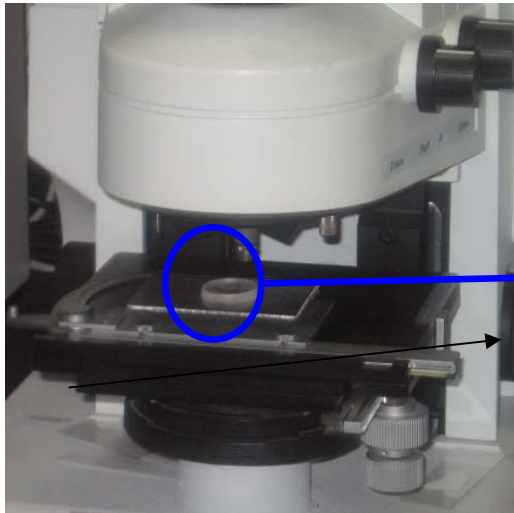


Sample cast on KBr plate

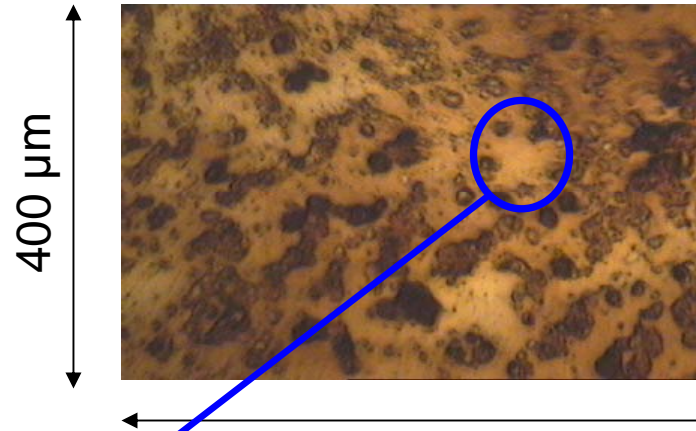


FTIR (transmission)

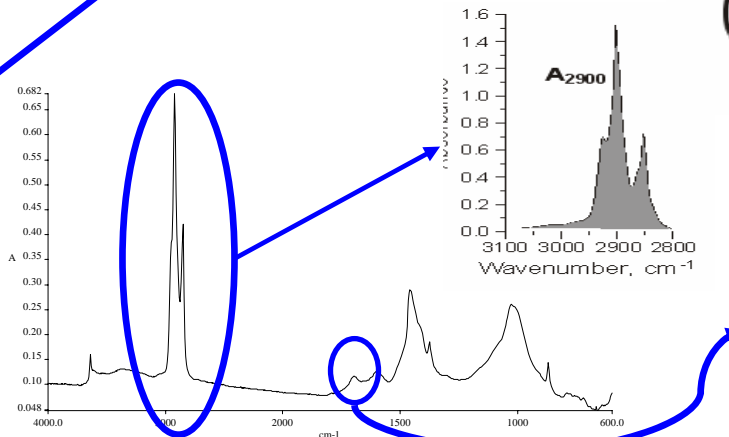
FTIR Microscope (transmission)



Photomicrograph

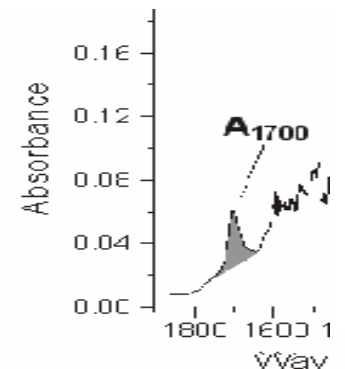


100 μm aperture

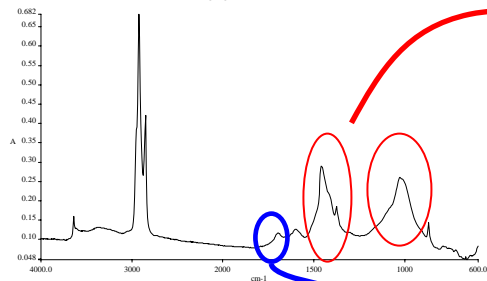
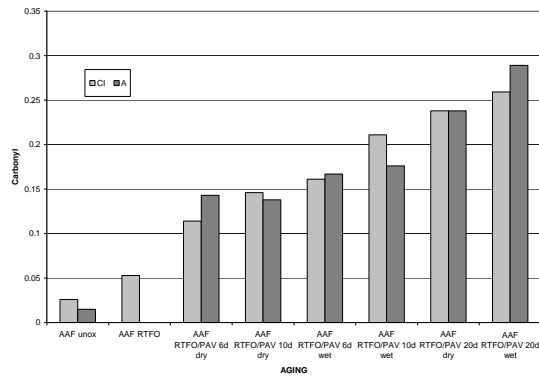
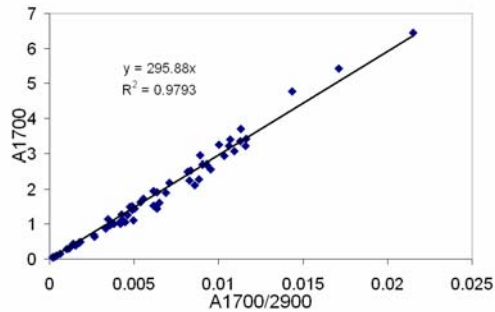


FTIR absorbance spectrum
(asphalt and aggregate)

$$\text{Carbonyl Index (CI)} = \frac{A_{1700}}{A_{2900}}$$



What have we found?



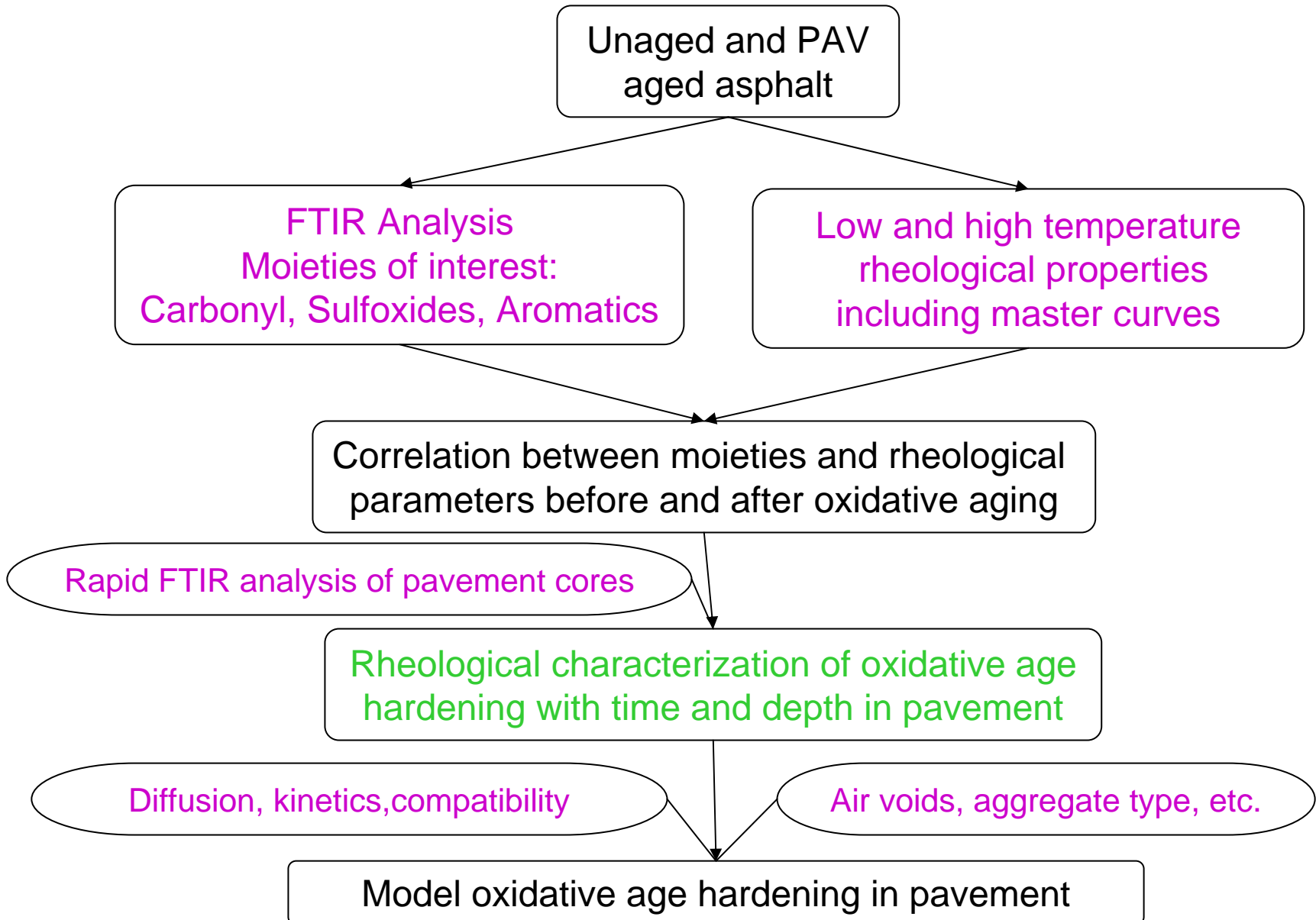
Normalization of carbonyl absorbance (A_{1700}) using (A_{2900}) appears feasible

$$\text{Carbonyl Index (CI)} = \frac{A_{1700}}{A_{2900}}$$

Preliminary analysis indicates aggregate absorption will not interfere with carbonyl absorbance

A_{1700}
Carbonyl absorbance

Work flow chart



References

REFERENCES

- Al-Azri, N. A., S. H. Jung, K. M. Lusford, A. Ferry, J. A. Bullin, R. R. Davison, and C. J. Glover. Binder Oxidative Aging in Texas Pavements: Hardening Rates, Hardening Susceptibilities, and the Impact of Pavement Depth. Paper accepted for presentation at the 2006 TRB January conference, Washington, D.C., 2006.
- Brown, A. B., J. W. Sparks, and O. Larsen. Rate of Change of Softening Point, Penetration, and Ductility of Asphalt in Bituminous Pavement. *Journal of Association of Asphalt Paving Technologists*, Vol. 26, 1957, pp. 66-76.
- Christensen, D.W., R.F. Bonaquist, National Cooperative Highway Research Program. *Volumetric Requirements for Superpave Mix Design*, NCHRP 567, 2006.
- Christensen, Donald W., T. Pellinen, and R.F. Bonaquist, Hirsch Model for Estimating the Modulus of Asphalt Concrete, *Association of Asphalt Paving Technologists (AAPT)*, Vol. 72, pp. 184-204 (2003).
- Coons, R. F., and P. H. Wright. An Investigation of the Hardening of Asphalts Recovered from Pavements of Various Ages. *Journal of Association of Asphalt Paving Technologists*, Vol. 37, 1968, pp. 510-528.
- Farrar, M. J., P. M. Harnsberger, K. P. Thomas, W. Wiser. Evaluation of Oxidation in Asphalt Pavement Test Sections after Four Years of Service. Proceedings of the International Conference on Perpetual Pavement, September, 2006, Columbus, Ohio.
- Mirza, M. W., and M. W. Witczak. "Development of a Global Aging System for Short and Long Term Aging of Asphalt Cements. *Journal of Association of Asphalt Paving Technologists*, Vol. 64, 1995, pp. 393-431.

Questions?

