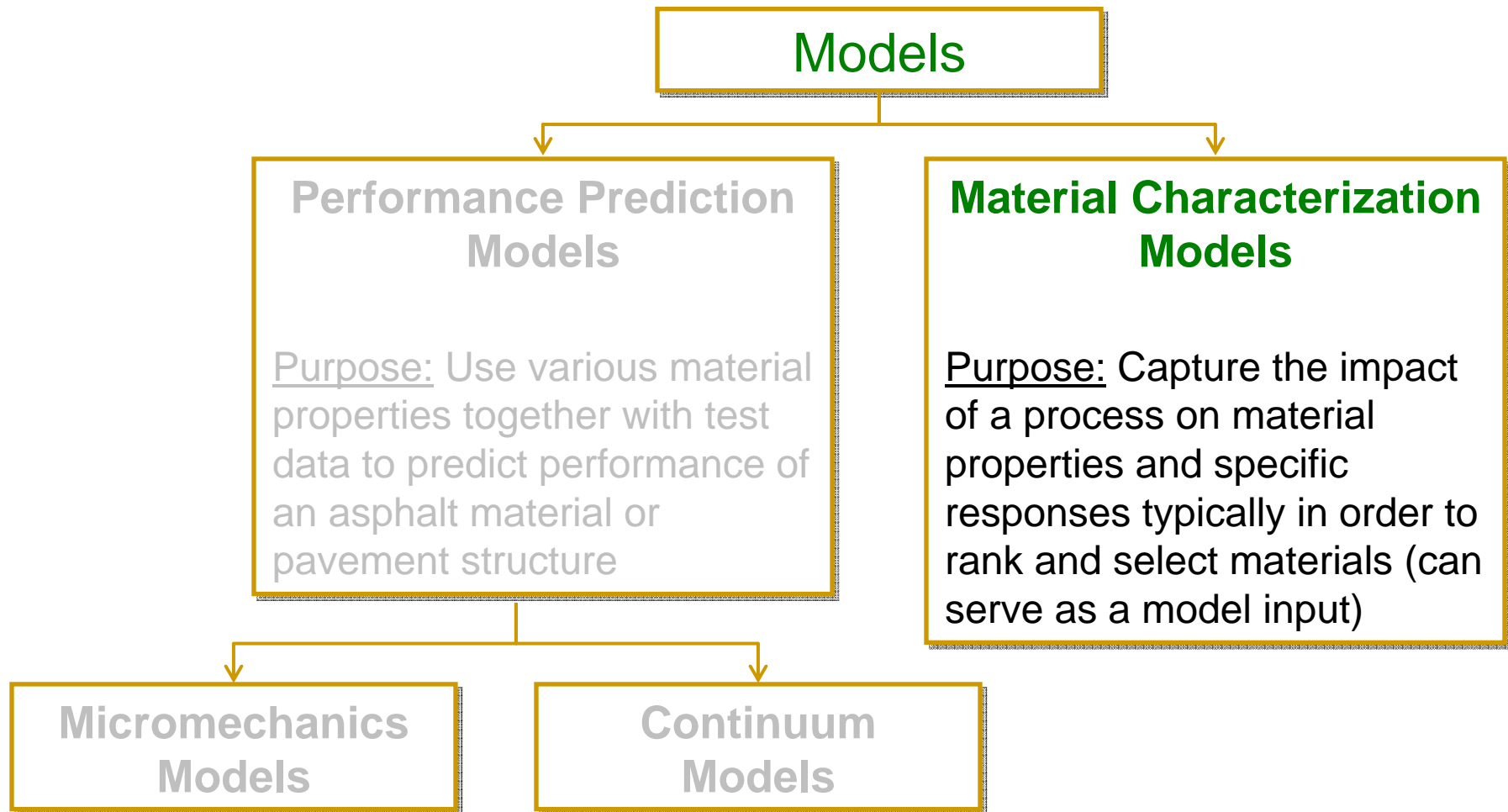

Asphalt Research Consortium

Material Characterization Models

Models ETG – Chicago, June 2008

Background



Material Characterization Models

■ Purpose

Capture the impact of a process or processes that alter the material properties and consequently the engineering response of the material or composite

■ Examples of Models

- rate of crack wetting and/or intrinsic healing of asphalt binders (*healing*)
 - fatigue characterization of FAM using DMA (*fatigue cracking*)
 - material characterization models for binders (*rheology of binders in mixtures, master curves*)
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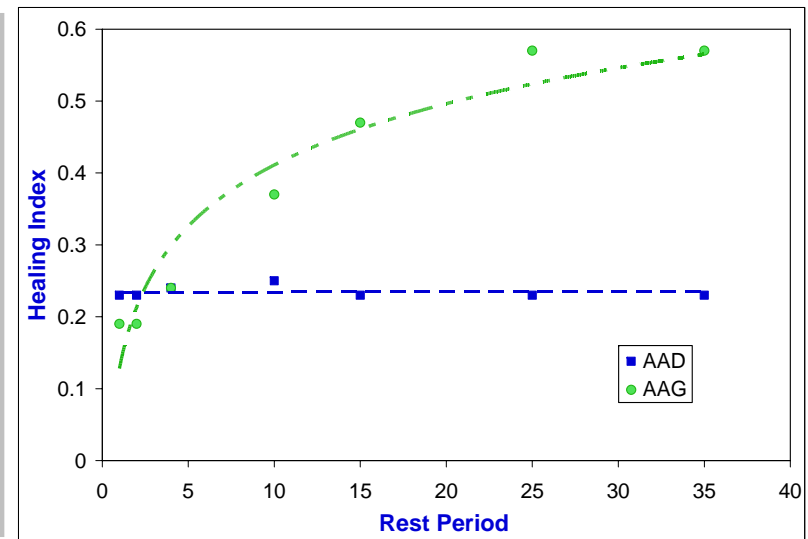
Material Characterization Models

Healing

■ Healing model and its components

$$R = \int_{\tau=-\infty}^{\tau=t} R_h(t-\tau) \frac{d\phi(\tau, X)}{dt} d\tau$$

- Healing function that describes relationship between % strength recovered and duration of rest period
- Typically obtained from mechanical fatigue tests with intermediate rest periods



Material Characterization Models

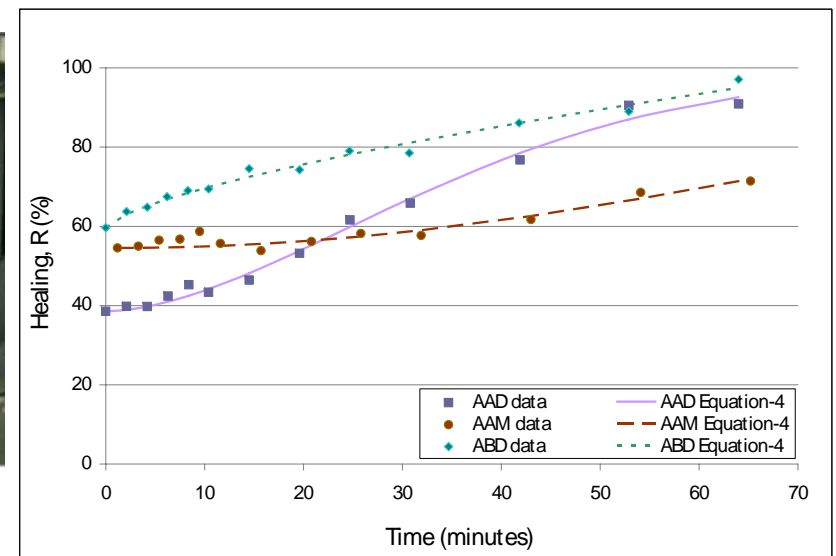
Healing

■ Healing model and its components

$$R = \int_{\tau=-\infty}^{\tau=t} R_h(t-\tau) \frac{d\phi(\tau, X)}{dt} d\tau$$

$$R_h(t) = R_0 + p(1 - e^{-qt^r})$$

- Intrinsic healing function and is a material property input in the model



Material Characterization Models

Healing

- Healing model and its components

$$R = \int_{\tau=-\infty}^{\tau=t} R_h(t-\tau) \frac{d\phi(\tau, X)}{dt} d\tau$$

$$\frac{d\phi(t, X)}{dt} = \dot{a}_b = \beta \left[\frac{1}{D_1 k_m} \left\{ \frac{\pi W_c}{4(1-\nu^2) \sigma_b^2 \beta} - D_0 \right\} \right]^{-1/m}$$

Wetting function can be determined from material properties such as the viscoelastic properties of the material

Material Characterization Models

Healing

■ Healing model – summary

$$R = \int_{\tau=-\infty}^{\tau=t} R_h(t-\tau) \frac{d\phi(\tau, X)}{dt} d\tau$$

A macroscopic healing parameter that can be used to rank healing characteristics of different materials using simple laboratory tests (binders, mastics, FAM, and mixtures)

A model that is based on the healing mechanism to relate fundamental material properties to macroscopic healing



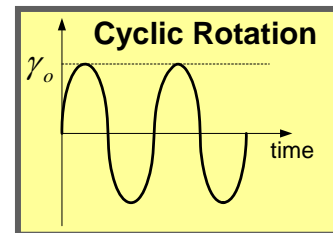
Material Characterization Models

Fatigue Cracking of FAM

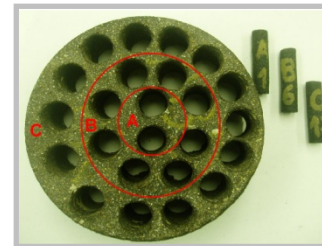
■ Fatigue cracking

$$\Delta R(N) = \left[(2n + 1)^{n+1} \left(\frac{G_R b}{4 \pi G_1 \Delta G_f} \right)^n N \right]^{\frac{1}{2n+1}}$$

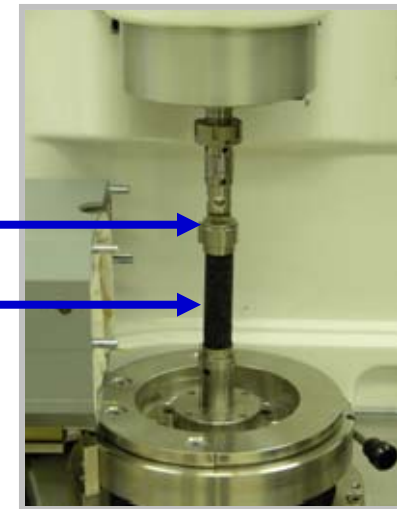
- Crack growth index as a relative measure of fatigue cracking
- This is a one dimensional analytical model based on fracture mechanics and can be extended to other modes of loading and/or materials (FAM or mixtures)



Loading



Specimen



Test Setup

Material Characterization Models

Fatigue Cracking of FAM

■ Fatigue cracking

$$\Delta R(N) = \left[(2n+1)^{n+1} \left(\frac{G_R b}{4 \pi G_1 \Delta G_f} \right)^n N \right]^{\frac{1}{2n+1}}$$

- Accuracy of the model is governed by the accuracy of parameters used in the model such as viscoelastic properties and rate of energy dissipation due to damage
- *Sub models* may be used to obtain accurate estimates for parameters in this model
- Examples include, model to distinguish non-linear response from incremental damage and a model to represent the non-linear viscoelastic response of a material

$$\frac{\varepsilon_0}{\sigma_0} \cos \delta_t = g_0 D_0 + g_1 \left\{ \hat{D}_\omega^* \cos \hat{\delta}_w + \alpha \sigma_0^\beta \hat{D}_{(1+\beta)\omega}^* \cos(\hat{\delta}_{(1+\beta)\omega} + \omega \beta t) \right\}$$

$$\frac{\varepsilon_0}{\sigma_0} \sin \delta_t = g_1 \left\{ \hat{D}_\omega^* \sin \hat{\delta}_w + \alpha \sigma_0^\beta \hat{D}_{(1+\beta)\omega}^* \sin(\hat{\delta}_{(1+\beta)\omega} + \omega \beta t) \right\}$$

Material Characterization Models

Rheology of binders in mixtures

- Binder / mixture rheology modeling
 - A universal phenomenological model
 - Loading time, temperature, & strain
 - Damage resistance modeling
 - Rutting
 - Stress, loading time
 - Fatigue
 - Energy, cycles
 - Thermo-volumetric Properties Modeling
 - Mixture Densification Modeling
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