

Fatigue Testing with Basis in Continuum Damage Theory

FHWA Fundamental Properties and
Modeling Expert Task Group Meeting
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Outline

- What is it and why do we care?
- What we have available for evaluation
- Evaluation plan
- Moving research results to delivery
- Feedback from the ETG

Introduction

- What, Why and Where?
- Janus Murzewski in 1957
- Dr. Richard Schapery - solid rocket fuels
- Several of the folks in this room

Objective

- FHWA-funded, competing and evolving approaches
- Evaluation of these approaches
- Practical applications
- Feedback from ETG

3 AC Characterization Techniques

- Reduced Cycles – ranking, endurance and AMPT
- Simplified VECD – ranking, endurance and input for FEP++
- DMA – materials ranking, compatibility and moisture sensitivity

Feature	Description of Feature for Each of Three Methods		
	Reduced Cycles	S-VECD	DMA
CDT Characterization Test	4 strain-controlled cyclic tests at 2 temperatures x 2 strain levels	1 frequency-temperature sweep dynamic modulus test and 1 controlled crosshead cyclic test at 1 temperature and 1 strain level	Strain-controlled or Stress-controlled
Material Tested	HMA	HMA	Sand asphalt
Total No. of Samples	4 tests total: 2 temperatures x 2 strain levels [YRK1]	6 specimens	4 tests total: 2 temperatures x 2 strain levels
Sample Geometry	Cylindrical, 150 mm high by 100 mm dia.	Cylindrical, 150 mm high by 100 mm dia.	Cylindrical, 50 mm high by 12 mm dia.
Testing Machine	AMPT or similar servo-hydraulic system	AMPT or similar servo-hydraulic system	Dynamic mechanical analyzer or similar rheometers
Analysis Software	Spreadsheet	Spreadsheet	Spreadsheet
Material Coefficients	$\alpha, T_g; k_1, k_2$, describing damage function	Prony coefficients and a, b describing damage function	Coefficients for reduced cycles or S-VECD method
Outcomes	Complete characterization of damage in HMA under fatigue loading over wide range of temperature, strain and loading frequencies; endurance limit values	Complete characterization of damage in HMA under fatigue loading over wide range of temperature, strain and loading frequencies, including prediction of N_f vs. tensile strain relationship and endurance limit	Simple, economical and complete characterization of damage in sand asphalt under fatigue loading over wide range of temperature, strain and loading frequencies.
Agency/Contractor Application	Evaluation of HMA fatigue resistance, pavement analysis and design, forensics, research	N_f vs. tensile strain relationship; Endurance limit as a function of temperature and frequency; Cracking performance prediction of asphalt pavement using VECD-FEP++; Material selection; Performance-based mixture design; New materials development; Performance-Related Specification; Mechanistic pavement design	Evaluation of local materials (binders and aggregates) for fatigue damage, healing, aging, and moisture damage; Screening of materials; A simple specification test for resistance to fatigue damage.

Evaluation

- Workshop?
- Materials?
- Expectations?
- Format?
- Scope?
- Outcomes?

Test	Temperature (°C)	Level	Replicates	Purpose
Linear viscoelastic (LVE) modulus, $ E^* $	3 to 4, typically ranging from 5 to 35°C	In linear strain range, typically 75 to 150×10^{-6}	3	LVE Characterization
Controlled Strain (actuator) Fatigue	10	L ¹	3	Reduced Cycle and DMA Characterization
	10	H ²	3	Reduced Cycle and DMA Characterization
	20	L ¹	3	Reduced Cycle, S-VECD and DMA Characterization
	20	H ²	3	Reduced Cycle, S-VECD and DMA Characterization
Controlled Stress Fatigue	15	M ³	3	Reduced Cycle and S-VECD Verification

¹ Low strain level chosen to yield N_f of approximately 1000 cycles

² High strain level chosen to yield N_f of approximately 10000 cycles

³ Moderate stress level chosen to yield N_f of approximately 5000 cycles

Goals

- Research into practice
- Inputs for pavement performance prediction
- Performance-based specifications
- Better understanding by practitioners

ETG Questions

- Is this an advantage?
- Is the testing plan appropriate?
- If so, what material sources may be considered?
- Should a workshop be planned?
- What is the scope and target audience?
- Should all 3 approaches be considered at this time?