Journal of Traffic and Transportation Engineering(English Edition)
2014,1(1):49-54

A dissipated energy comparison to evaluate fatigue resistance using 2-point bending

Cinzia Maggiore[1,*], Gordon Airey[1], Paul Marsac[2]

[1] *NTEC, University of Nottingham, Nottingham, United Kingdom*

[2] *IFSTTAR, Nantes, France*

Abstract: Fatigue is the main failure mode in pavement engineering. Typically, micro-cracks originate at the bottom of asphalt concrete layer due to horizontal tensile strains. Micro-cracks start to propagate towards the upper layers under repeated loading which can lead to pavement failure. Different methods are usually used to describe fatigue behavior in asphalt materials such as: phenomenological approach, fracture mechanics approach and dissipated energy approach. This paper presents a comparison of fatigue resistances calculated for different dissipated energy models using 2-point bending (2PB) at IFSTTAR in Nantes. 2PB tests have been undertaken under different loading and environmental conditions in order to evaluate the properties of the mixtures (stiffness, dissipated energy, fatigue life and healing effect).

Key words: fatigue resistance; dissipated energy; 2-point bending; fracture mechanics approach

1 Introduction

Asphalt is a viscoelastic material, thus it dissipates energy under mechanical work (loading and relaxation). Usually, in an elastic material the energy is stored in the system when the load is applied, all the energy is recovered when the load is removed; in this case the unloading and the loading curves coincide. Viscoelastic materials are characterized by a hysteresis loop because the unloaded material traces a different path to that when loaded (phase lag is recorded between the applied stress and the measured strain); in this case the energy is dissipated in the form of mechanical work, heat generation, or damage(Rowe 1993; 1996).

The area of the hysteresis loop represents the dissipated energy in a load cycle and the following equation can be used to calculate its value in a linear viscoelastic material:

$$W_i = \pi\sigma_i\varepsilon_i\sin(\varphi_i) \quad (1)$$

where W_i is dissipated energy in cycle i; σ_i is stress level in cycle i; ε_i is strain level in cycle i; φ_i is phase angle in cycle i.

* **Corresponding author**: Cinzia Maggiore, MEng, Marie Curie Researcher.
E-mail: evxcmm@nottingham.ac.uk

During a fatigue test, the stiffness reduces, the fatigue process starts and micro-cracks are induced in the material; therefore the dissipated energy, W, varies per loading cycle and it, usually, increases for controlled stress tests and decreases for controlled strain tests.

The aim of this study was to compare different dissipated energy methods to evaluate flexural fatigue of bituminous mixtures by 2-point bending (2PB) tests undertaken at IFSTTAR in Nantes (France).

2 Testing procedure and material

2.1 2PB

The 2-point bending test is widely used for measuring fatigue resistance and stiffness for asphaltic paving materials. For this laboratory activity, fatigue tests were carried out at IFSTTAR in Nantes (France). The methodology consists of applying a continuous sinusoidal waveform at the top of a trapezoidal specimen. The specimen is glued between two plates (at the top and at the bottom) and the fracture usually occurs at 1/3 of the height, where the bending moment is a maximum. Usually four specimens were tested at each strain level. Fig. 1 shows the 2PB equipment at IFSTTAR; the trapezoidal specimen is mounted as vertical cantilever; sinusoidal constant displacement is applied at the top of the specimen, while the bottom base is fixed.

As mentioned before, fracture usually happens at 1/3 high from the bottom because that area is the most stressed in the specimen as shown in Fig. 2.

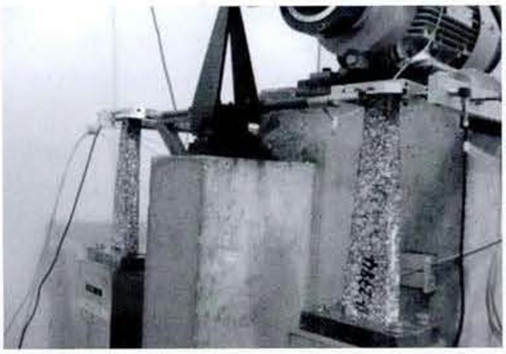

Fig. 1 2PB at IFSTTAR

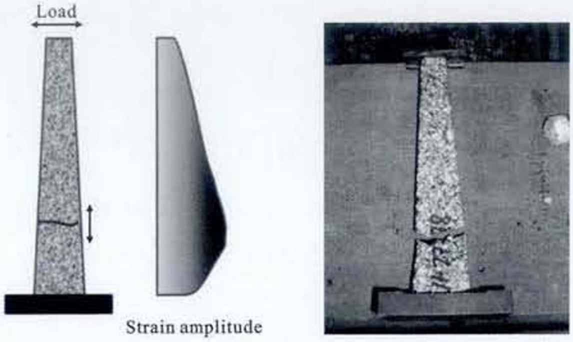

Fig. 2 Failure mode

The initial stiffness is usually chosen between the 50^{th} and the 100^{th} load application. Traditionally, a fatigue test ends when the stiffness has decreased to half of its initial value (Rowe 1993; SHRP-A-404 1994).

2.2 Material

A 10 mm dense bitumen macadam (DBM) or asphalt concrete was chosen for the experimental work. A 100 pen binder was chosen for the mixture. The aggregate type selected was a crushed limestone. The aggregate gradation curve is shown in Fig. 3, four lines are presented: the upper, the lower limits and the mid-point curve from the British Standards and the aggregate gradation.

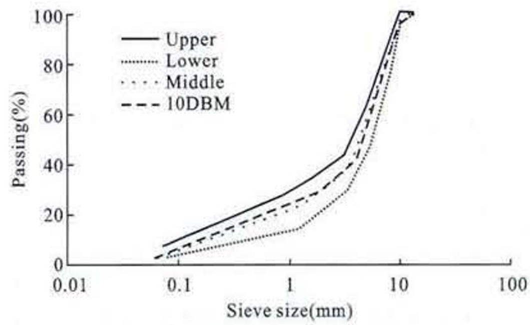

Fig. 3 Aggregate gradation curves

3 Experimental resutls

Fatigue tests were undertaken in controlled strain mode. Testing conditions were as follows: temperature 20 ℃; frequency 15 and 25 Hz; sinusoidal loading; strain levels between 120 and 190 $\mu\varepsilon$