Crack Accumulation in Pavement Systems

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Cracking is recognized as one of the indicators of damage in pavement systems. Although the cracking per se, does not generally contribute significantly to the total damage (or decrease in serviceability) incurred by pavements, it tends to promote faster increases of the other indicators of damage (rutting and roughness). The process of crack formation is mostly due to the repetitive nature of the loading, i.e., it is a fatigue process. Because of the variability in the loading patterns, in the material properties, and in the operating environment, crack formation and accumulation is a stochastic process. Consequently it was necessary to study the reliability of the system with respect to fatigue crack accumulation.

Two methods of approach were adopted for the study of fatigue cracking. They both use a three-layer visco-elastic model for the determination of the stresses and strains developing within the pavement for a stochastic operating environment.

The first method is based on a modified form of Miner's law. The approaches based on Miner's law present the advantage of simplicity. Their principal limitations are that the predicted fatigue life is generally a function of the geometry and the loading conditions. The data obtained in the laboratory constitute a good approximation to a limited type of pavement systems. The necessary formulations relating the statistical characteristics of a cracking indicator to those of the operating system are derived. The expected value of the damage D(t) is given by the following equation.

$$E[D(t)] = \sum_{K=1}^{L} \left\{ \frac{\bar{n}_K}{\bar{N}_K} + \frac{\bar{n}_K}{\bar{N}_K^{\,3}} \; \sigma^2_{N_K} \right\}$$

where $\bar{n}_K$ is the mean number of Poisson loads in a period of time K; $\bar{N}_K$ is the mean number of loads to failure in that period and $\sigma^2_{N_K}$ is the corresponding variance. A simiilar expression is derived for the variance of the damage D(t). The examples of application show the sensitivity of the results to the various assumptions of correlations between the material properties at small deformations and the fatigue properties. In particular the effects of the quality control yield some counter intuitive results in some instances.

The second method of approach is based on the Fracture Mechanics concepts of stress intensity factors and crack propagation laws. This approach can be viewed as a generalization of Miner's law. While the latter bases the prediction of cracks development on the initial configuration of the system, the Fracture Mechanics approach incorporates the changes of configuration. A simplified

extension to viscoelastic systems is presented and discussed.

The modified Miner's law is preferred in the short range because of its simplicity and the availability of data, while the approaches based on Fracture Mechanics concepts are preferred in the long range because of their completeness.