ABSTRACT

VISCOELASTIC ANALYSIS OF FALLING WEIGHT DEFLECTOMETER DATA

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Dynamic modulus ($|E^*|)$ master curve is a fundamental material property for an asphalt pavement. It is also a key input to Pavement-ME, a pavement design and analysis software that can predict progression of distresses. Falling Weight Deflectometer (FWD) is a nondestructive test whose results are typically used for backcalculating layer properties of pavements in situ. Backcalculation of $|E^*|$ master curve of an in-service pavement using Falling Weight Deflectometer (FWD) data can lead to more accurate estimation of its remaining service life. Flexible pavements are multilayered structures, typically with viscoelastic asphalt layer followed by unbound/bound layers. Conventionally, multilayered elastic analysis is performed to obtain response of flexible pavements for design and inverse analyses, however, assuming asphalt pavement as a linear elastic material is an oversimplification of its actual behavior. It is well known that the asphalt pavements’ responses are both rate and temperature dependent. Appropriate characterization of individual layer properties is crucial for mechanistic analysis of flexible pavements. Hence, although elastic analysis is computationally efficient and well accepted in the engineering community, the theory cannot produce the viscoelastic properties of the asphalt concrete (AC) layer. Backcalculation of the entire $|E^*|$ master curve, including the time-temperature superposition shift factor coefficients, requires more data than the surface deflection time-histories of FWD drops. In theory, it should be possible to obtain the $|E^*|$ master curve provided that the data contain time changing response at different temperature levels.

The specific objectives of the study were to (i) develop a layered viscoelastic flexible pavement response model in the time domain, (ii) investigate whether the current FWD testing protocol generates data that is sufficient to backcalculate the $|E^*|$ master curve using such a model, (iii) if needed, recommend enhancements to the FWD testing protocol to be able to accurately backcalculate the $|E^*|$ master curve as well as the unbound material properties of in-service pavements. Two different approaches have been proposed to obtain comprehensive behavior of asphalt: (i) using series of FWD deflection time histories at different temperature levels and (ii) using uneven temperature profile information existing across the thickness of the asphaltic layer during a single or multiple FWD drops deflection histories. The models presented can consider the unbound granular material as both linear elastic as well as nonlinear-stress dependent material. Depending on the assumed unbound granular material property, and known temperature profile, several viscoelastic flexible pavement models were developed. The developed forward and backcalculation models for linear viscoelastic AC and elastic unbound layers have been referred to as LAVA and BACKLAVA, respectively. The developed forward and backcalculation models for linear viscoelastic AC and nonlinear elastic unbound layers have been termed as LAVAN and BACKLAVAN respectively in the study. LAVA and BACKLAVA algorithms assume a constant temperature along the depth of the AC layer. The algorithms were
subsequently modified for temperature profile in the AC layer and have been referred to as LAVAP and BACKLAVAP.

The major recommendations of the work are the estimated set of temperatures and number of deflection sensors where FWD tests should be conducted, in order to maximize the portion of the |E*| master curve that can be accurately backcalculated. The results indicate that there exists a range of temperatures (of FWD testing) at which the FWD response leads to better inverse solutions. The underlying (viscoelastic) forward solver is approximate and disregards dynamic effects which, in return, make it computationally efficient. A genetic algorithm based optimization scheme is offered to search for the pavement properties.