Florida Department of Transportation Research

Base Course Resilient Modulus for the Mechanistic-Empirical Pavement Design Guide

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Elastic modulus determination is often used in designing pavements and evaluating pavement performance. The Mechanistic-Empirical Pavement Design Guide (MEPDG) has become an important source of guidance for pavement design and rehabilitation. MEPDG recommends use of modulus over structural number for pavement base layer thickness design. For the MEPDG Level-2 and Level-3 material parameter inputs, modulus is entered as a single linearly elastic parameter. However, modulus is nonlinear with respect to several critical factors, such as effective confinement stress, loading strain, and moisture. These nonlinear dependencies must be properly understood for the accurate and effective application of modulus in pavement design. However, MEPDG does not offer a standard procedure for determining this single elastic modulus value.

Resonant column apparatus during calibration.

University of Florida researchers undertook a study to fill this gap, focusing on laboratory characterization of base modulus nonlinearity. They developed a nonlinear response model using laboratory data for pavement analysis and a practical linear design methodology to determine nonlinear equivalent linear effective design modulus values for whole base layer using a newly developed nonlinear response model analysis. This approach enables a single modulus to be input into the MEPDG model which approximates the nonlinear aspects of the base layer.

Fixed-free and free-free resonant column tests were conducted to characterize nonlinearity of shear modulus in the strain range of 10-5% to 10-1%, including small-level strains, under various confinement and moisture conditions. Modulus was linear at strains lower than 10-5%, but nonlinear at higher ranges. Nonlinearity with respect to strain increased with increasing moisture. The suction effect increased shear modulus in the strain range 10-5% to 10-1%, but the effect was very significant at strain levels less than 10-3%. A procedure to calculate approximate shear modulus values at known water content, confinement, and strain magnitude was developed.

Using the laboratory nonlinear modulus characterization data as material parameter inputs, the researchers developed a stress-and-strain-dependent nonlinear response model for base layer analysis with the aid of Plaxis software (a product of Plaxis bv). The maximum surface deflection obtained from nonlinear analysis served as the matching factor between nonlinear and linear methods, and a methodology to determine equivalent effective elastic modulus for a base layer was proposed.

The researchers found that base layer nonlinearity has no apparent affect on cracking performance, but it could affect rutting performance as pavement structure thickness and moisture content decrease. Subgrade nonlinearity appears to influence the determination of subgrade strain values very significantly. Thus, development of new performance criteria compatible with nonlinearity may be required for accurate rutting performance analysis.

Project Manager: David Horhota, FDOT Materials Office
Principal Investigator: Dennis R. Hiltunen, University of Florida
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