Future Directions in Characterizing Strength and Deformation Properties of Pavement Layers

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The Committee on Strength and Deformation Characteristics of Pavement Sections is concerned with methods of measuring the strength and deformation properties of the layers that make up a pavement structure. These properties are used either to design new pavement structures or to diagnose the cause of existing problems so that the appropriate rehabilitation strategies can be chosen. The measurement can be destructive in nature, in which samples are tested in the laboratory, or nondestructive, in which the structure's transient response is measured for a range of known loading conditions. This area has been actively researched in recent years; however, one continuing source of disappointment has been the lack of acceptance and implementation of research results by the highway design community. This community faces many challenges in implementing advanced materials testing and design processes. Nevertheless, with the national move toward a more mechanistic pavement design process, already under development with a scheduled release date of 2002, there is much work to be done in summarizing where we are now and what future research is needed.

STATE OF THE PRACTICE

Currently, departments of transportation (DOTs) do not make use of rational design procedures, primarily because there is no reliable framework for predicting pavement performance using properties measured in the laboratory. The most popular tests in widespread use (i.e., California bearing ratio, Marshall) were ingeniously designed to give global properties. However, they are empirical, require much experience to implement, and are of little use in predicting pavement performance. In the next decade more mechanistic materials characterization procedures will be developed together with the framework for use of these values in performance prediction and design.

Nondestructive testing (NDT) technologies have made substantial progress in the past decade. Currently, the falling weight deflectometer (FWD) is commonly used; it applies a dynamic load through a circular plate that is lowered to the pavement surface. Sensors in contact with the surface measure the downward deflection of the pavement surface. This deflection bowl is then used to assess the structural condition and to identify weaknesses in any of the pavement layers. FWD-based design procedures are only beginning to be implemented within DOTs.

ISSUES AND CHALLENGES

As we move into the next millennium two prime issues face researchers. The first is related to building an implementation framework. The challenge is how to take complex and sophisticated laboratory testing and performance prediction models and implement them as routine procedures within the pavement design community. The first step toward implementation involves clearly demonstrating the benefits of the proposed improvements over existing methods for the variety of materials and pavement types designed.

The second challenge is ensuring that the procedures are practical and can fit within the organizational and time constraints under which pavement designers work. The second challenge involves integrating the laboratory and NDT equipment so that the same set of pavement properties are used in all phases of pavement design, quality control monitoring, and performance evaluation.

FUTURE DIRECTIONS IN MATERIALS CHARACTERIZATION

The new millennium will see the development of the next generation of laboratory test equipment to better characterize the materials from which pavements are constructed. This equipment will measure the resilient modulus, moisture susceptibility, permanent deformation, and fatigue cracking properties of the bound and unbound materials within the pavement structure.

Work will continue to express the resilient and performance-related properties of unbound soils and aggregates as a function of stress conditions. Recent studies have indicated the importance both of characterizing granular materials as transversely anisotropic materials and of measuring the stress dependency of the Poisson’s ratio. For asphaltic materials, agencies are beginning to characterize the resilient properties in terms of dynamic modulus, which is both frequency and temperature dependent. However, this characterization seems adequate only for low-temperature and rapid loading conditions. A more general approach will be developed with true nonlinear stress-strain relations, different rest times, medium and high temperatures, and slow loading rates.

Basic research will also be required to further understand and minimize the damaging effects of moisture on pavement materials. For asphalt concrete layers, the use of surface energy measurements on bitumen and aggregates will be directed at a better understanding of the stripping and crack growth phenomena. For granular materials, the impact of the quality and quantity of fine materials on suction and moisture susceptibility will be investigated.

For chemically stabilized material, work will focus on a better understanding of the factors governing long-term performance. The traditional strength-based designs have generally not resulted in optimum performance. Selecting the correct stabilizer type and content is an optimization problem in which the designer must balance the conflicting requirements of strength, shrinkage, and durability.

FUTURE DIRECTIONS IN MODELING

The next millennium will see the better integration of the materials characterization models with performance prediction models. Currently no reliable framework exists for predicting the permanent deformation performance of pavements. The conventional mu-alpha approach has not worked well, primarily because of the strong nonlinearity of the mu factor. Moreover, the effect of rest periods and stress path will need to be studied further and quantified. The decomposition of components into viscoelastic and viscoplastic constituents will be pursued in order to develop a more comprehensive pavement deformation model.

For fatigue cracking prediction, work will continue to improve the existing classical fracture mechanics theory. Studies involving microcracking formation and crack tip progression through the failure zone are expected to lead to a more complete understanding of cracking within the asphalt concrete layer. In view of the increasing interest in cracks forming at the asphalt surface and propagating downward, more studies combining thermal cracking and tire pressure effects will be conducted.

FUTURE DIRECTIONS IN NONDESTRUCTIVE TESTING

Future improvements in the NDT area will involve advances in current technologies such as the FWD and the implementation of new technologies such as ground-penetrating radar (GPR) and wave propagation techniques.

For deflection-based testing, work in the future will focus on improving both data collection and data processing capabilities. Researchers will continue to develop the next generation of NDT equipment, namely, the rolling deflectometer. Applying the test load through a rolling wheel and using noncontact sensors will eliminate stop-and-go testing and will allow operation at or near traffic speeds. The challenge for developers will be to improve the rolling deflectometer technology so that its accuracy approaches that of the traditional FWD. Further developments in analysis procedures will be directed toward improving the stability and capabilities of current programs. Enhanced computing power will enable the use of more complex and realistic pavement structures and materials models in the backcalculation procedures.

The last decade has seen the introduction of GPR technology into the highway area. This NDT technology can operate at highway speeds and monitors the electric properties of subsurface paving layers. These electric properties are influenced by material factors of critical importance to pavement engineers, namely, moisture content and density. Future research will be aimed at gaining a better understanding of these electric properties and how they relate to physical properties and also building improved software packages to convert GPR signals into useful information for engineers. Merging the GPR and traditional FWD technologies will be pursued to provide decision makers with a comprehensive NDT evaluation of existing facilities. GPR will also be investigated as a quality control tool for new pavements.

In recent years seismic technologies have also been automated and made available for everyday use. Seismic methods can be used both to diagnose specific distress precursors and aid in selecting rehabilitation treatments and to evaluate the effectiveness of treatments. This technology is capable of detecting voids and delaminations on concrete pavements and providing information about the quality and thickness of the surface layer and modulus of the base and subgrade. Seismic technology shows great potential, but it requires further work by the research community to make the data analysis more robust and user friendly. It is anticipated that seismic technologies will continue to be implemented by DOTs early in the next millennium.