GROUP G

TRAFFIC-INDUCED PERMANENT DEFORMATION

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Permanent deformation due to moving traffic can be defined or at least limited to time-dependent distortion or volume change or both caused by densification of one or more layers within the pavement system. Deformation can take place in one or all layers although it is noticeable only at the surface in the form of ruts, lateral and longitudinal corrugations, shoving, and other movement. The first of these is of primary importance in this report; and, although the others are related, they may be more closely associated with mix design deficiencies.

IMPORTANCE AND RELATIONSHIP TO TOTAL DESIGN SYSTEM

Each of the main topics discussed by Groups A through I can be considered a box within the total framework. Figure 3, as presented by Hudson in Part III, shows that distortion or permanent deformation is one of the limiting distress response outputs of the pavement system. Finn, in his presentation, indicates that, from field observations, the distortion problem should receive second priority after fatigue cracking. Several speakers referred to pavement distress categories such as those referred to by McCullough in Figure 1 of his paper. Within this framework those items considered under permanent deformation are as follows:

1. Excessive loading,
2. Time-dependent deformation (creep),
3. Densification,
4. Consolidation, and
5. Swelling.

Of these, item 2 appeared to be of most concern, whereas items 3, 4, and 5 can be lumped together as volume change. Excessive loading is not the usual condition for design, and, therefore, was not considered further. However, it was felt that items 2 and 3 could be taken as the major causes of traffic-induced permanent deformation.

MATERIALS AND THEIR CHARACTERIZATION

Research and experience have shown the response of most pavement materials to be time-dependent and to be probably affected by the properties of materials themselves, their relationship or proximity to other materials in the system, and the usual factors of load, environment, and so forth. Conventional materials and their suggested form of characterization follow:

1. Asphalt mixtures—linear viscoelastic;
2. Granular bases or subgrades—assumed to be elastic or linear viscoelastic;
3. Cohesive subgrade—linear viscoelastic; and
4. Other materials including portland cement concrete and cement-treated base—assumed to be elastic.

Characterization of these materials in the laboratory for input parameters can best be accomplished by using a triaxial test apparatus. The types of tests deemed suitable would include at least the following:

1. Constant stress or strain (creep),
2. Sinusoidal, and
3. Repeated load.

It is recognized that one or more of these tests may be used to determine both the time-dependent and the volume change responses to loading and environment.

For the purposes of this workshop, it was assumed that other items that may contribute to surface deformation were not to be considered but were to be recognized. For example, construction deficiencies or local design considerations such as the use or lack of soil filters were not a key part of the discussions. However, it was recognized that improvement of various materials such as cement treatment was beneficial in preventing permanent deformation but that, if a systematic approach is used, these benefits will be a natural result of the material characterization and of subsequent analysis within the total framework of the pavement system.

STRUCTURAL ANALYSIS AND PREDICTIVE TECHNIQUES

Essential to the design or analysis process is a method of computing or determining pavement behavior in terms of stress, strain, deflection, or permanent deformation. Following is a brief summary of the status of present methodology.

Existing Techniques

The currently available methods based on stability criteria tend to preclude permanent deformation at least for conventional materials and designs. However, it is suggested that in the present California method, if the resistance value at the subgrade, R, is 10 and the asphalt concrete layer on top varies from 5 to 7 in., no traffic-induced permanent deformation is to be anticipated.

The group was of the opinion that in order to prevent traffic-induced permanent deformation the subgrade needed to be strengthened. To minimize the strain in the subgrade requires that the subgrade have a high bearing value (e.g., R = 10) or be stabilized.

Quasi-Elastic Method

This method developed by Shell suggests that, if the strain at the top of the subgrade does not exceed 6.5×10^{-4}, no permanent deformation could be anticipated for 10^6 repetitions of an 18-kip axle load. The AASHO Interim Guide and the Kentucky method are also based on similar principles.

Linear Viscoelasticity for Layered Systems

So that we can estimate the manner in which deformation accumulates in flexible pavements, a model is needed to account for the manner in which this deformation accumulates as a function of load, environment, and material variables. Specifically, the model should be able to account for the following variables:

1. Time-dependent behavior of materials;
2. Temperature-dependent behavior of materials;
3. Magnitude, duration, and number of repetitions of the loads; and
4. Influence of moisture changes.

A linear viscoelastic model of layered systems that can account for variables 1, 2, and 3 has recently been developed. The model is currently operational and requires that the creep properties of the materials be given in the form of creep compliance functions. It provides the total deflection and the permanent recoverable deformation. The influence of temperature and its variation can be accounted for only if the time-temperature superposition principle is assumed to be valid. The model can now account for randomness of load, temperature, and material properties in a simulative manner by using random number generators.

At the present time it is recognized that there may be a period of testing the technique through various validation procedures. These may include attempts to predict accumulated deformation by using a range of facilities capable of providing the necessary experimental data.

With regard to all three of these approaches, it can be recognized that the first and second are primarily methods of preventing excessive deformation in the form of rutting. However, the quasi-elastic approach has also been used in approximating the amount of rutting to be expected. The third method, based on linear viscoelastic theory, is an attempt to actually permit prediction of accumulated deformation.

MEASUREMENT AND DESIGN CRITERIA

It has been recognized that a measurement technique may be required to identify varying degrees of severity of permanent deformation. These may, in fact, be items such as rut depth, slope, and volume per station. The problem of relating these measurements to overall serviceability or performance is beyond the scope of the subject considered by this group, but it should be one of the long-range research objective. No specific recommendations are offered.

NEEDED RESEARCH

1. Laboratory procedures for characterizing the properties of granular materials used for pavement bases or subgrade or both should be developed. To accurately account for these materials in the pavement structure it will be necessary to characterize their time-dependent properties, if they exist. In addition, it is required that a predictive laboratory technique be developed to account for volume change in the pavement materials, which in turn must be separated from creep or time-dependent behavior.
2. It appears that a potentially valid procedure is available to predict permanent deformation based on linear viscoelastic theory. However, further verification of its validity must be accomplished through actual field measurements or other large-scale representative tests.
3. Once it becomes reasonably feasible to predict rutting or other traffic-induced permanent deformation, it will be necessary to relate these values to performance. It is recommended that a long-range objective be the determination of a deformation measurement system and the role that each degree of deformation plays in the overall performance such as in riding quality.