GROUP A

MATERIALS CHARACTERIZATION

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Materials characterization has long been an integral part of the pavement design process. Many of the tests currently used to characterize paving materials are empirical in nature and, as such, do not measure fundamental properties of these materials. This is due in large part to the lack of development of a pavement design procedure based on a mechanistic model of the pavement system. As a consequence, arbitrary test procedures have been developed to evaluate materials for use in empirical procedures.

The current interest in developing a rational approach to pavement design has created a need for using more fundamental approaches to characterize paving materials. The selection of methods of material characterization is integrally related to the mathematical model chosen to represent the pavement system. Therefore, the materials engineer should consider the mathematical model that will be used to predict the pavement response when he selects appropriate test methods.

Characterization of paving materials is a complex problem. The rate dependency, environment, effect of stress state, and effect of time on the material properties all add to the complexity of the problem. Characterizing a material under laboratory conditions is relatively easy compared with realistically characterizing the true material response in a pavement system over a long period of time. Stresses, strains, temperature, rates of strain, levels of stress, and other critical factors that influence material characteristics vary not only in the three-dimensional space domain but also in the time domain. Thus, the testing method and conditions under which the test is performed in the laboratory must be chosen with great care to represent realistic conditions of these materials in service.

A unique characterization of paving materials is not possible. All material characterizations used in representing paving materials must by necessity be a compromise between rigor and practicality. Usually the compromise is based on average or limiting conditions that are believed to be critical with respect to pavement behavior. Sensitivity analyses should be performed and the results evaluated so that they can be used to guide the engineer in selecting the most representative conditions. This implies that the mathematical model chosen to represent the pavement structure is capable of doing so with reasonable accuracy.

The development of mathematical models requires certain assumptions with regard to the behavior of the material. If the behavior of the material is not in agreement with the assumptions made, revisions will have to be made of the governing model. In many instances it may be necessary to approach the problem on an iterative basis. That is, it will be necessary to evaluate a pavement system with a simplified theory as a first-order approximation to determine the general states of stress and strain in the system. These results can then be used to guide the investigator or engineer in selecting the necessary conditions for further characterization of the materials. More sophisticated pavement analyses can be made with the refined material properties and new conditions for material evaluation until a satisfactory degree of accuracy is obtained. This method has been applied reasonably accurately by using elastic theory to evaluate pavement systems composed of viscoelastic materials.

For practical design procedures, tests for characterizing material properties must be suitable for testing on a production basis by highway department personnel. Testing procedures must be such that testing errors do not camouflage the true properties of the materials. Equipment for production testing must be inexpensive so it can be purchased or developed by highway departments and other agencies charged with pavement design.

The members of Group A were drawn from a broad background of experience and disciplines ranging from material scientists from the aerospace industry, to specialists in the field of mathematical modeling techniques, to practicing highway engineers. This broad spectrum of backgrounds resulted in a lively exchange of ideas and a blending of viewpoints.

CURRENT STATE OF KNOWLEDGE

The current state of knowledge with regard to material characterization is nicely summarized in the paper by John A. Deacon. As he points out, the response of paving materials is influenced by rate of loading, temperature, environment, and stress state. Because a three-dimensional state of stress exists in the material beneath a pavement subjected to a moving load, it was agreed that the test procedure used should be multiaxial in nature, with provisions made for changing the ratio of principal stresses in the test. The triaxial cell was considered to be a reasonable testing device to use in characterizing material properties, at least for the present time.

Based on current knowledge and a consideration of the current capabilities for solving layered systems problems, a promising method for material characterization appears to be the use of linear viscoelastic parameters. By testing these materials with a creep, a cyclic load, or some other type of test, we can evaluate the necessary parameters for characterizing the material for use in a linear viscoelastic layered system model such as the one developed by Moavenzadeh and now under verification by the Federal Highway Administration.

Discussions in the work sessions indicated that the response of pavement systems could be estimated to a reasonable engineering degree of accuracy by using an iterative procedure in which successive approximations of the secant modulus are an input parameter for the elastic layered system model. The secant modulus used in this method is measured with the cyclic load triaxial test. This approximate method has already been applied to pavement design problems by a number of investigators. It was also brought out in these discussions that rutting can be estimated by using a linear viscoelastic layered system model, as were the appropriate parameters to describe the linear viscoelastic properties. Furthermore, with further extensions of the theory, fatigue cracking may also be predicted by using viscoelastic theory.

Characterization methods for granular (unbound) materials are in a poor state of development at the present time. It was agreed that, because of the unique characteristics of granular materials in tension and in compression, the behavior of the material must be considered in the actual pavement system. After considerable discussion, it was agreed that the probable states of stress for the material must be determined before the test procedures can be established.

Empirical tests as currently applied to paving materials are probably of little value in developing rational design methods unless they measure properties that can be used with elastic or viscoelastic layered system models. The important contribution in the future of empirical tests will probably be in the quality control area of materials engineering. Some current test procedures, such as the California resilience test, may have value for characterizing material properties for use in rational design methods. Triaxial tests performed by using repeated or creep loadings also appear to have much potential for evaluating some pavement materials.

RESEARCH NEEDS

Fatigue fracture of stabilized materials used in flexible pavements on a nationwide basis at the present time appears to be a more important cause of structural deterioration than is the accumulation of permanent, load-related deformations. This is not to imply that rutting of the pavement structure is not an important consideration. In certain areas rutting is probably as important as fatigue or even more important. Furthermore, rutting may become a more important consideration as we go to deeper asphalt concrete sections and as current practices are modified to reduce fatigue fracture.

Fatigue fracture was considered by Group A to require immediate and also long-term research studies. Considering the results of previous research in this area, we thought that emphasis should be placed on formation and propagation of cracks and overall characterization techniques that give results compatible with field observations. Because of time limitations, Group A did not delve into this subject in detail inasmuch as Group E had already considered this aspect of pavement design.

Characterization of rutting is a very complex problem. If the problem is solved reasonably rigorously, a linear viscoelastic or even a more complicated model must be used. An alternate approach to estimate rutting would be the use of an engineering method similar, for example, to that currently used to estimate fatigue life. In any case, much work will be required to develop and verify a suitable technique. The use of a linear viscoelasticity characterization probably offers the most straightforward method at the present time. Currently, a creep test is being used by some to evaluate the linear viscoelastic response. The application of this method to characterization of all materials, especially granular ones, remains to be verified for large numbers of load applications and field conditions.

Before any material characterization and accompanying theory can be accepted in a design procedure, careful verification of the theory will be required. Verification of the theory, including material characterization, can be done by the use of both accelerated, environmentally controlled, full-scale model studies and full-scale field tests. Serious doubts, however, were raised concerning whether a design procedure can be verified by the use of model studies. Therefore, the construction, instrumentation, and monitoring of full-scale field test sections are necessities and require immediate attention.

Another problem requiring immediate work is that of characterizing granular materials. A detailed study is needed of the applicability of currently used methods for characterizing the response of these materials when subjected to various states of stress. Based on this study, realistic methods should be selected or developed for characterizing granular materials. This problem, however, was not considered to be as pressing as those previously discussed. Work in the immediate future was considered to be necessary. Because of the complicated nature of the problem, a continuing program of research will probably be required over a relatively long period of time.

Finally, a closer examination of Poisson's ratio was considered desirable as a long-term research objective. Most present studies have indicated that the pavement response is not extremely sensitive to reasonable variations in this parameter. When characterization tests are carried out, however, every readily available opportunity should be taken to study this material property.

SUMMARY AND CONCLUSIONS

At the present time, material properties can be realistically characterized to a reasonable degree of accuracy for use in the more commonly applied layered system theories by means of a cyclic load test. Only a very few attempts have been made to use this or other approaches to characterize rigorously either granular materials or cumulative permanent deformations caused by the repeated application of wheel loadings. Considerable progress has been made in characterizing fatigue behavior of stabilized materials.

Fatigue fracture has been studied by applying repeated loads until failure occurs in both supported and unsupported beam specimens and also circular slabs resting on varying types of simulated subgrade supports. The results of these tests, however, indicate that a number of important questions still remain to be answered concerning fatigue behavior.

From the discussions of Group A the following research areas were determined to require immediate study:

1. Fatigue fracture of stabilized materials,

2. Verification of material characterization and design methods by full-scale model and field studies, and
3. Cumulative permanent deformations.

The characterization of unstabilized, granular materials was also considered to require a concentrated research effort, although the solution to this problem was not considered to be as critical as those areas listed.

As more knowledge of pavement behavior and response is gained, characterization procedures should be periodically reexamined and, if necessary, revised to yield a model that more nearly describes the actual behavior of the material. As more information from model and field studies is accumulated, the necessity may arise for the development of new tests and characterization procedures. For these reasons, the development of material characterization techniques and also the development of the pavement design method in general should both be considered as a continuing process.