GROUP E

TRAFFIC-INDUCED FRACTURE

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VERTICAL LOADING

Repeated Applications

For fractures induced by vertical loading, the phenomenological state of the art is sufficient and capable of introduction to practice. The block diagram of a fatigue subsystem shown in Figure 1 provides a possible framework for implementation. It is believed that a more detailed mechanistic approach, based on fracture mechanics principles, is needed for analysis of fatigue. Such an approach is achievable in the near future and could be introduced into practice.

Needed Research: Phenomenological Approach—The phenomenological approach to fatigue is that one developed by Monismith, Deacon, Pell, and others. The state of the art is briefly summarized by Deacon in Part III of this Special Report. The proposed design subsystem includes the use of the results of fatigue testing of asphalt concrete beam specimens, the characterization of materials of the pavement section by using cyclic load triaxial testing within the environmental and load ranges expected during the service life of the pavement, and the prediction of stresses by using the available solution to the layered, two-dimensional, elastostatic boundary value problem. This method, it is claimed, has the capability of predicting the time to first cracking of the asphalt concrete layer caused by repeated traffic loadings.

The method has been used in several instances, both for analyses of existing in-service pavements and for the design of proposed pavement facilities.

To develop an accepted design method requires the following:

1. Verification—If it is felt that a method is capable of introduction into practice, no further research is indicated except that necessary to show that the method works. This can be done by using the subsystem to explain known occurrences of fatigue distress or by using the subsystem to monitor the behavior of designed pavements.
2. Sensitivity analysis—Many of the items considered at this workshop directly affect the fatigue subsystem. The function of sensitivity analyses proposed is to determine the level of effect on the fatigue life prediction of variation in the inputs to the subsystem. This kind of information is required by the user of the subsystem in allocating his efforts in the acquisition of the data required by the process.

In the long term, to develop a more acceptable, reliable design method requires the following:

1. Verification—Verification functions here in the same manner as for the short term.
2. Knowledge of mode of loading effects—The applicability of laboratory fatigue test results to fatigue life prediction of real pavements requires knowledge of the mode of loading (ranging from controlled stress to controlled strain) that exists in the field.

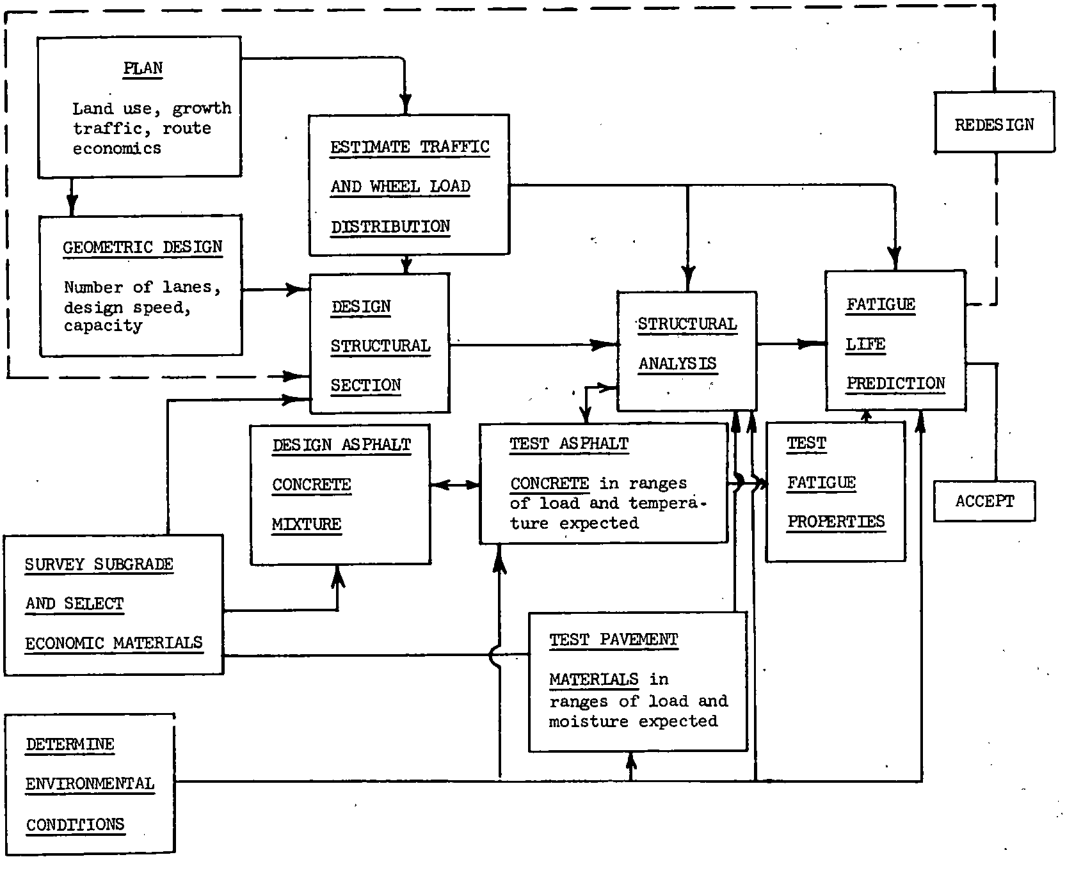

Figure 1. Fatigue subsystem.

3. Development of a test method—The reduction of the laboratory effort required to produce a fatigue curve for a specific asphalt concrete is desirable. Efforts are under way in this area, but more verification is required.

4. Understanding of areal extent of first cracking—The difficult problem of what happens after the first crack has appeared in the pavement must eventually be solved. The nebulous term "percent cracking" must be defined and quantified and methods provided for its prediction.

5. Combination of temperature and loading—An examination is suggested of the possibility of "thermal fatigue" being additive to traffic-induced fatigue.

6. Use of stochastic models—The variability of every input to the subsystem, along with the uncertainty inherent at the design stage, requires that techniques be provided to allow the designer to consider their effects on his decisions.

Needed Research: Mechanistic Approach—The mechanistic approach used the fracture mechanics principles for crack initiation and growth mentioned in Moavenzadeh's paper in Part III and developed in a forthcoming AAPT paper by Majidzadeh. The effect of geometry, boundary conditions, and load time history are introduced in terms of a stress intensity factor. The model is also capable of considering variability in the material properties. Further research is needed in this area, specifically to incorporate random loading effects, localized elastoplastic effects due to excessive loading, and accumulation of cracking for performance analysis.

To develop an acceptable design method requires verification (data acquired in attempting to satisfy the need for verification of the phenomenological approach also serve for mechanistic approach), localized plastic flow-elastoplastic interaction, and random loading.

In the long term, to develop a more acceptable, reliable design method requires verification, combination of load effect and temperature effect, and stochastic loading.

As mentioned earlier, the mechanistic approach is not so well developed as is the phenomenological one. On the basis of a brief outline of its theory, Group E was impressed with the following possibilities for this approach:

1. Mode of loading effects are handled through the stress intensity factor that is calculated for both the laboratory test and the field condition;
2. The output appears in terms of areal extent of cracking; and
3. The method is based on a stochastic notion, that of the distribution of flaws within the asphalt concrete layer and, thus, must proceed stochastically.

At this point, we are faced with the problem of making a decision in the face of uncertainty. Until further work is done with the mechanistic approach, we are unable to assess the degrees to which its possibilities will be attained. At the same time, until we can assess the degree to which these possibilities can be attained, we are unable to firmly define what further work is required.

It should be noted that the mechanistic approach and the phenomenological approach pertain only to the blocks in Figure 1 labeled "test fatigue properties" and "fatigue life prediction." The considerations included in the other blocks are common information in both approaches. The verification work discussed earlier can serve its duality of purpose and should be carried out.

Single Application

In this category of fracture induced by traffic loading fall the considerations of the effects of abnormally large loads. At present we would attempt to ascertain the effects of one application of such a large load through either the bearing capacity approach such as that of McLeod or a punching shear approach such as that of Meyerhof. Some possibility exists for the development of the mechanistic approach to crack initiation and propagation discussed earlier, and this should approach a solution to this problem. (No research is suggested in this area.)

HORIZONTAL LOADING

The type of fracture induced by accelerating or decelerating vehicles or by articulated vehicles with a capability of rotating a single wheel around a vertical axis seems to be a problem of low priority in highway pavements of good construction. Problems associated with poor bond between the surface and the immediately underlying layer, however, can occur. This problem may be of more interest in airfield and other special paving situations (e.g., dock facilities for containerized cargo harbors). We suggest that some boundary value problem solutions exist for this problem, but some research should be initiated toward description of the failure mechanism.

OTHER RESEARCH TOPICS

Fatigue of Treated Material Layers in the Pavement Section

Because of limited time, Group E was not able to discuss an admittedly important topic, fatigue of treated material layers in the pavement section. Some information regarding the fatigue of asphalt-treated bases might be inferred from the accumulated knowledge regarding the fatigue of asphalt concrete. In the case of cement-treated bases, there does exist a fatigue-based design method for the selection of thickness of a layer of soil cement that meets the specifications of the Portland Cement Association.

Reflection Cracking

A most urgent need for research at this time is associated with reflection cracking. Although the problem is best known as associated with overlay design, the fracture of an asphalt concrete pavement due to the reflection of a crack in a cement-treated base is at least one example of its occurrence in new construction.

The need to develop a model that can explain the failure mechanism seems best measured by our inability to decide whether reflection cracking is or is not a traffic-induced fracture. Although we can accept that volume changes in an underlying material layer can contribute to the development of reflection cracking, we are uncertain what role is played by repeated traffic loading either in a flexural way or in a relative vertical movement way. This is considered an urgent research need.

CONCLUSIONS

The following items are of roughly equivalent priority and relevance to the development of design methods to preclude traffic-induced fractures:

1. The development of a model of the mechanism of reflection cracking;
2. The verification of the statement that there now exists a method for the design of asphalt concrete pavements; and
3. The development to the design stage of the mechanistic approach to fracture under repeated loading.