Pavement Evaluation and Overlay Design: Summary of Methods

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Methods of pavement evaluation and overlay design are summarized and compared.

A general framework for pavement maintenance and rehabilitation is shown in Figure 1, and Figure 2 lists a number of available alternatives. Maintenance refers to those processes—both preventive and corrective—that do not involve major alterations in the pavement structure. Rehabilitation encompasses the areas of reconstruction, overlays, and recycling and their combinations and can be used to restore or to improve the serviceability of the pavement structure.

To assist the engineer in deciding what pavement maintenance or rehabilitation to do and when to perform it, pavement performance must be measured on a systematic and continuing basis. In this performance evaluation, both the functional and the structural performance of the pavement system should be considered.

Functional performance describes how well the pavement serves the user, and structural performance is related to its ability to sustain load (which in turn affects its ability to serve the user). If the pavement becomes too rough, for example, it will be difficult for the user to operate the vehicle and functional performance will be unsatisfactory. However, although these characteristics are related, there is currently no well-defined relationship between structural distress and functional performance. Thus, at present, judgment must be used in deciding when structural deterioration will lead to a level of functional performance below that considered reasonable by the user of the facility (which obviously will vary among vehicles, users, and types of facilities).

For street and highway pavements, particularly, it is appropriate to separate the performance-evaluation process into two phases (Figure 1). In the first, termed the network-monitoring phase, condition surveys are used to provide a basis for segregating those pavements that clearly do not require maintenance or rehabilitation from those that may and for which further information is required.

The second phase is composed of more detailed or diagnostic investigations that can provide the data required to determine an appropriate strategy. These include measurements of physical condition (surface characteristics and structural response) and assessment of special problems such as drainage difficulties or thermal cracking.

Visual condition-evaluation procedures described in this Record in the papers by Shahin, Darter, and Kohn for airfield pavements and by Phang for highway pavements are a necessary part of the network-monitoring process and can serve as a guide to the type of maintenance or rehabilitation to be accomplished. Also, as noted by Phang, these surveys can assist in the overall investment-programming process for maintenance and rehabilitation.

The use of visual condition surveys is well established and should be a part of the maintenance and rehabilitation methodology of every organization that has responsibility for pavements.

Structural performance can be measured by a number of nondestructive testing devices that have been developed in recent years and are being used as a part of the overlay-design methodologies of many organizations. The majority of these devices provide some measure of surface deflection. The various devices currently in use are summarized below.

Method by Which Load is Applied	Device	Organization by Which Used
Slow-moving wheel	Benkelman beam	Asphalt Institute, College Park, Maryland
	Traveling deflectometer	California Department of Transportation
	Deflectograph	U. K. Transportation and Road Research Laboratory, Crowthorne, England, and National Institute for Transport and Road Research, Pretoria, South Africa
Vibratory load	Light vibrators Road rater	Kentucky Department of Transportation
	Dynaflect	Utah Department of Transportation, Louisiana Department of Transportation and Development, and the Federal Highway Administration (Austin Research Engineers, Inc.)
	Heavy vibrators	U.S. Army Corps of Engineers Waterways Experiment Station
Falling weight	Falling weight deflectometer	Shell Research B. V., Amsterdam

There is some concern about the use of light vibratory loading for measuring the structural response of heavy-duty pavements. When light vibrators (e.g., Dynaflect and road rater) are used for such pavements, careful interpretation of the results is required, such as that incorporated in the procedure developed for the Federal Highway Administration by Austin Research Engineers (ARE) that recognizes the stress sensitivity of pavement materials and is described by Treybig in another paper in this Record.

One of the purposes of structural evaluation is to provide data for the design of pavement overlays.

Overlay-pavement design can be accomplished by using tests of representative samples of pavement components, deflection measurements at the pavement surface, or a combination of both.

Figure 3 represents a general framework for overlay designs based on deflection measurements. In this type of system, performance considerations are usually limited to a single factor (such as fatigue cracking, rutting, or riding comfort). Each method makes the assumption that, if the specific design factor being considered is adequately controlled, other forms of distress or performance will also be controlled. For example, it may be assumed that, if fatigue cracking is minimized, protection against rutting will be adequate and riding comfort will be satisfactory.

As shown in Figure 3, by using deflection data and condition-survey information, homogeneous analysis

Figure 1. General framework for pavement maintenance and rehabilitation.

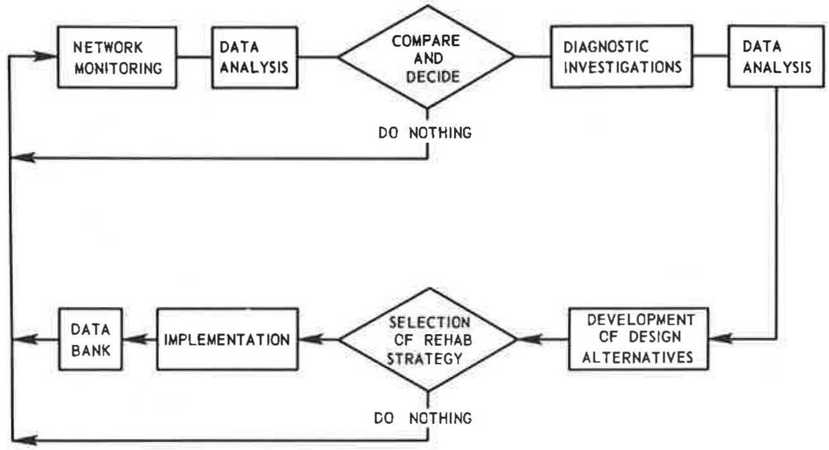
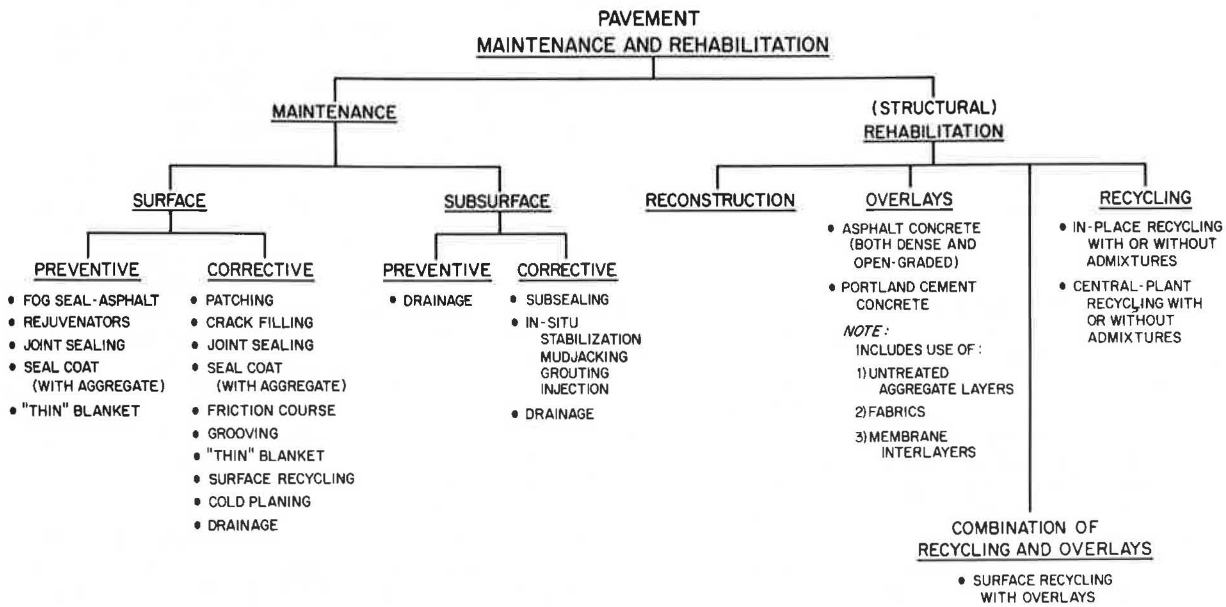


Figure 2. Maintenance and rehabilitation alternatives.



sections that have uniform stiffness characteristics can be identified for further analysis. For each of these sections, representative or design deflections can in turn be established; these are selected to represent the variability of in situ conditions and can be adjusted to a particular season of the year. Representative deflections can be used to estimate the remaining life of a pavement, although little information is currently available to establish the reliability of such predictions. Generally, however, these deflections are used to determine an overlay design by estimating future traffic and selecting the overlay thickness from an appropriate design relationship that is a function of the materials used in the existing pavement and the pavement deflection before overlay. These design relationships have usually been established on the basis of field observations and reflect the reduced deflection resulting from the addition of the overlay.

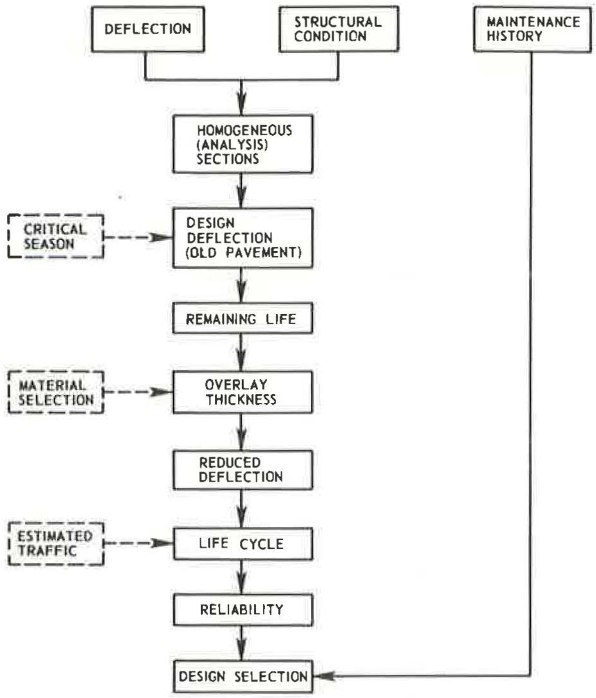
Although such a procedure is comparatively simple, it must be adequately qualified with respect to type of pavement. Moreover, extensive correlations are necessary to extrapolate to increased loading conditions, different materials, and different environments from those for which a specific procedure was developed.

There are also a number of recently developed procedures that follow in some manner the framework shown in Figure 4. It is believed that these procedures can improve the overlay-design process and minimize some of the deficiencies noted above. These procedures build on already established procedures and incorporate the results of recent pavement research. Nondestructive pavement evaluation (for example, deflection measurements) and condition surveys must be made in these procedures. In addition, some measure of the stiffness properties and distress characteristics of the various materials constituting the specific pavement structure are required.

The various procedures provide guidelines for the establishment of representative (analysis) sections, and the Shell and ARE methodologies discussed in the papers by Koole and Treybig, respectively, in this Record provide criteria based on statistical treatment of the deflection data.

In the Shell procedure; the Kentucky procedure described in the papers by Sharpe, Southgate, and Deen and by Southgate, Sharpe, and Deen in this Record; and the U.S. Army Corps of Engineers Waterways Experiment Station (WES) procedure described in the paper by Weiss in this Record, the material characteristics are deduced from the deflection measurements. In the

Figure 3. Framework based on deflection measurements for overlay design.



WES procedure, the expression for subgrade stiffness is estimated from the relationship: subgrade stiffness (in lbf/in^2) = 1500 × the California bearing ratio, which is only a very approximate relationship. For example, in its original development, the stiffness varied from 750 to 3000 times the California bearing ratio.

Of the procedures discussed in this Record, only the ARE method requires that in situ samples of materials be obtained and stiffness determinations be made in the laboratory. Moreover, this procedure uses both the deflection data and the laboratory-measured properties to ensure that the stiffness values obtained for the pavement components are reasonable.

The other procedures deduce in some manner the subgrade characteristics from deflection measurements by using the center deflection together with some offset value(s). For pavements that contain granular layers, the Shell procedure uses the same assumption relative to the ratio of base to subbase stiffness as used in its design methodology for new pavements. The others attempt to determine the subgrade stiffness through a form of solution of the multilayer elastic system that uses the surface deflection.

There is not yet adequate evidence to indicate that pavement properties can be ascertained from deflection-basin measurements. Thus, it is important that stiffnesses of in situ materials also be determined in the laboratory to permit comparisons to be developed. It is possible that, when such data become available, the technique of deducing properties from nondestructive test data will be proved valid but, until such evidence is available, laboratory testing should be an important part of the evaluation process.

It is important, until more data become available, to measure not only the stiffness of the subgrade but also the stiffnesses of the other pavement layers, particularly untreated and treated granular bases and subbases.

Various models are used to represent pavement response to load. In a number of the procedures that follow the framework shown in Figure 3, e.g., the WES dynamic-stiffness-modulus method, thickness-selection procedures based on existing methods are used as a part of the overlay-thickness-selection process.

In four procedures—those of Shell, WES, ARE, and Kentucky—the pavement is represented as a layered-elastic solid, and computer solutions such as the CHEVRON and BISAR programs are used to estimate stresses and deformations.

In the WES procedure, there is some attempt to consider dynamic effects as well, which would permit improved estimates of material properties to be deduced from the dynamic vibratory measurements made by using the heavy vibrator. However, this approach, while interesting, is not considered to be capable of implementation at present.

In using the methods of overlay design illustrated in Figure 4, distress criteria must be established for the various components of the pavement structure. For asphalt pavements, load-associated cracking (fatigue) of the asphalt-treated layer is controlled by the magnitude of the tensile strain that is repeatedly applied and rutting is controlled by limiting values of subgrade strain (Shell, Kentucky, WES, and ARE procedures), of stresses in the other layers (ARE procedure), and of strain in the asphalt-bound layer (Shell procedure). For portland cement concrete pavements, load-associated cracking is controlled by the magnitude of the repeatedly applied tensile stress.

In the Shell and ARE procedures, remaining life can be estimated in existing pavements by using the linear summation of cycle ratios as the cumulative-damage hypothesis. For this analysis to be effective, however, good traffic information is required! In addition, when this approach is used in designing an overlay for an existing pavement, one must be careful if the remaining life of the existing pavement approaches relatively small values (e.g., 10 percent or less). In this situation, as demonstrated in the Shell procedure, a thinner overlay may result if the existing pavement is considered to be part of the granular layer.

Both the Shell and ARE procedures make provision for the treatment of an existing, cracked asphalt concrete layer. In the Shell procedure, such a layer is treated as a part of the granular layer and, in the ARE procedure, different levels of stiffness modulus are assigned that depend on the extent of cracking.

The procedure illustrated in Figure 4 has not been limited to asphalt pavements in the WES and ARE procedures. The ARE procedure, particularly, includes provision for a range of types of existing portland cement concrete pavements.

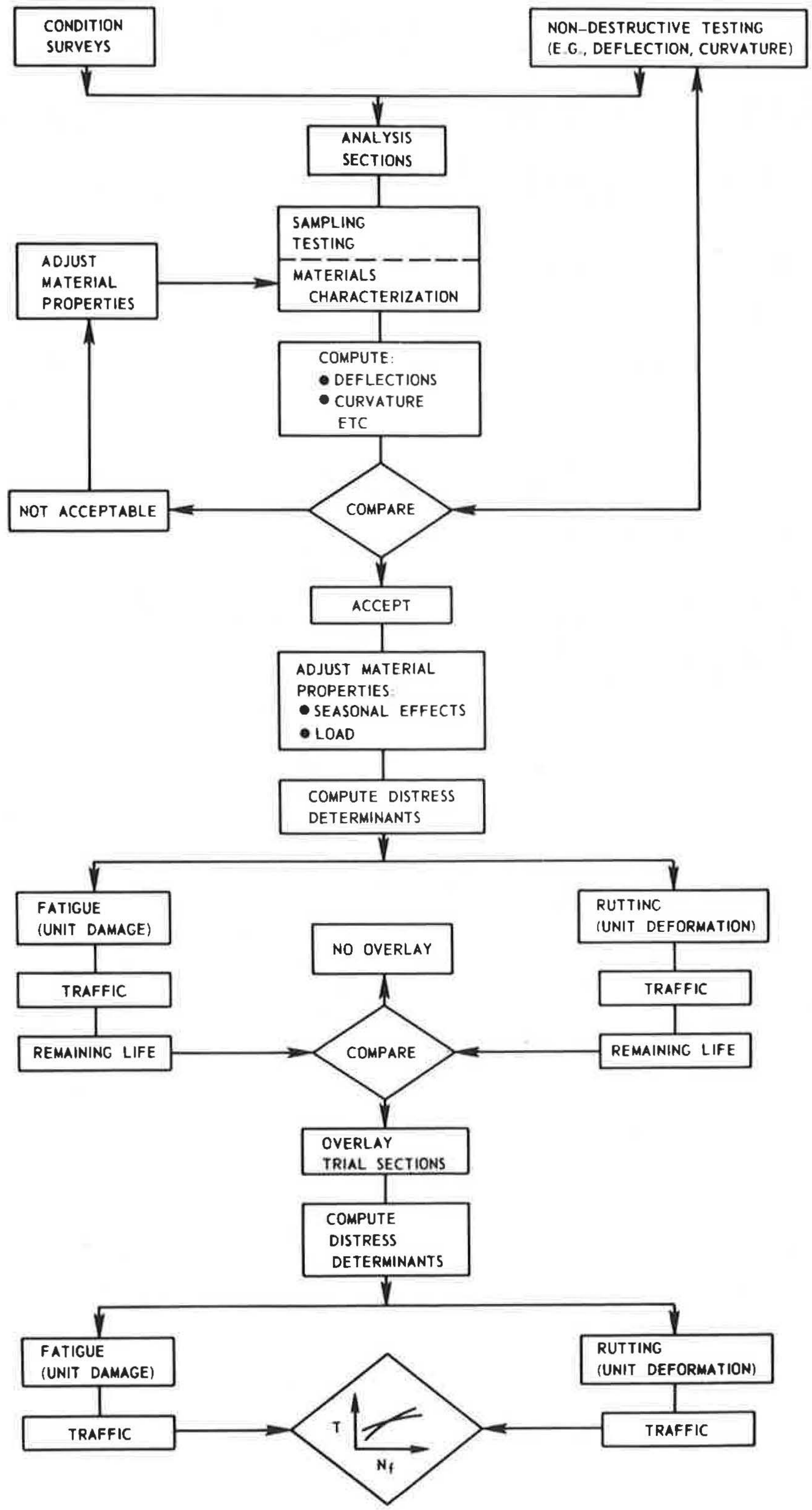
Although considerable progress has been made, there are a number of important problems that must be solved in order to develop improved evaluation and overlay-design techniques.

More effort should be directed toward developing comparisons between stiffness properties estimated by deflection or other nondestructive measuring techniques and laboratory-determined stiffness values. Of the methods compared here, only the ARE procedure uses laboratory tests on samples of in situ materials.

Considerable effort should be directed toward solving the reflection-cracking problem in overlays. Some attempt has been made in the ARE procedure, this must be considered a very crude first attempt and, while noteworthy, must be used with considerable caution.

There is a lack of performance data for overlays. Because this type of information requires time to accumulate, if it is not already being done, efforts should be directed immediately toward this aspect of performance evaluation.

Figure 4. Improved framework for overlay design.



However, there are also many positive features in the overlay-design procedures discussed in this Record. Well-defined techniques are available for the performance of condition surveys. Guidelines are available for the delineation of analysis sections (Figures 3 and 4) by using deflection measurements and statistical treatments of deflection area. It is evident that the general framework for overlay design that follows the format of Figure 4 and is embodied in the ARE, Kentucky, and Shell procedures for highway pavements and in the Shell and WES procedures for airfield pavements will lead to improved designs. Although there are limitations in this methodology, the potential for better-engineered pavements by using this emerging technology has already been demonstrated.

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