Failure Criteria For Flexible Airfield Pavements

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● IN THE development of the Corps of Engineers' flexible pavement design procedures, it has been customary to study both failed and unfailed pavements and then to set the design criteria at a level so that the failures would be eliminated.

In the early work of the Corps of Engineers' Flexible Pavement Laboratory, attempts were made to define the word "failure." It became apparent, however, that any reasonable definition of failure would have to consider a stated amount of maintenance, because maintenance is an accepted feature in any type of failure. Since it appeared hopeless to reach agreement on an "acceptable amount of maintenance," attempts to ascribe a specific definition to the term "failure" were abandoned, and now the term is used loosely to refer to an unsatisfactory condition in the pavement of sufficient severity to warrant attention.

The loose definition of failure given in the preceding paragraph is not satisfactory for use in developing design criteria for flexible pavements, which is the principal mission of the FPL, and it has been necessary to develop definitions of conditions which could be accepted as satisfactory and unsatisfactory so that design criteria could be set at the proper level. It has generally been found desirable to avoid the term "failure," except in the loose sense noted above, and to use terms which are descriptive of the behavior or the condition.

The major causes of unsatisfactory conditions in flexible pavements that have been studied by the FPL are (a) inadequate thickness of subbase, base, and pavement, (b) inadequate compaction in the subgrade, subbase, and base, (c) inadequate durability in the bituminous layers, and (d) inadequate stability in the bituminous pavement under traffic during hot weather. It is recognized that unsatisfactory conditions can develop in flexible pavements for reasons other than those listed, but these are not discussed in this paper.

THICKNESS

The FPL considers that the thickness of base and pavement above a given layer is inadequate if detectable shear deformation occurs in the given layer. Shear deformation is defined as change in shape with no change in volume, sometimes referred to as plastic movement or plastic deformation. Shear deformation usually occurs after pore pressures develop. During traffic, materials move out from under the wheel paths, creating a depression in the traffic lane and an upheaval outside the traffic lane. Typically, the bituminous pavement is cracked in the traffic lane. The thicknesses shown on the CBR design curves for a given CBR are intended to prevent all shear deformation in the layer with the given CBR.

Determination of the occurrence of shear deformation in a given layer can be made by a study of deflection measurement, in-place CBR tests, cracking of the pavement, upheaval of the surface, and position of the layers.

Deflection

Deflection is defined as the downward movement under load. Deflections are generally measured at the surface in the accelerated traffic tests conducted by the FPL under standing loads at intervals throughout the period of the traffic tests. Deflections at the level being considered (usually subgrade) are desired, but surface deflections can be used if the overlying layers are of high quality and adequately compacted so that little compression occurs under the load.

Curves of deflections versus coverages can be used to determine if shear deformation is occurring. Figure 1 shows idealized curves. Curves A and B, which show a decreasing or constant deflection with coverages, are typical of conditions where no shear defor-

mation occurs. Curves C and D are believed typical of cases where shear deformation occurs. Case D indicates a severe overload; case C indicates the conditions desired in an accelerated traffic test. This curve shows a small increase in deflections versus coverages during the early stages followed by sharp increase in deflection at a substantial number of coverages. Generally, in the traffic tests conducted by the FPL, which have been made with airplane loads, deflections have been in excess of 0.25 in. when shear deformation developed.

In-place CBR

In-place CBR test, and probably any strength test, can be used to indicate the development of shear deformation in any layer if the tests are made at intervals throughout traffic. Where no shear deformation occurs, the CBR value will remain constant or increase with traffic; where shear deformation occurs, the CBR will show a significant drop.

Cracking

The cracking that develops in a bituminous pavement when shear deformation occurs follows a typical pattern. In the early stages, the cracks are generally parallel to the direction of traffic. As repetitions are continued, transverse cracks occur and a blocky or alligator pattern occurs. Closely spaced cracking indicates shear deformation in a layer near the surface; widely spaced cracking indicates shear deformation in a deep layer.

Upheaval

Upheaval of the surface adjacent to the traffic lane is definite evidence of shear deformation, but the layer in which the shear deformation occurred cannot be determined from the surface. Also, traffic must be continued well beyond the point where shear deformation starts in order to develop sufficient upheaval to be measured.

Position of Layers

A cross-section of the face of a trench cut across the traffic lane can show whether or not a layer has been overstressed to the point where shear deformation occurred (see Fig. 2). A thinning of a layer in the traffic lane accompanied by a thickening of the layer outside the traffic lane is evidence of shear deformation in the layer. Also, upheaval of the subgrade outside the traffic lane is evidence of shear deformation in the subgrade. As noted above in the discussion of upheaval, traffic must be continued well beyond the initial development of shear deformation before it can be detected in a profile.

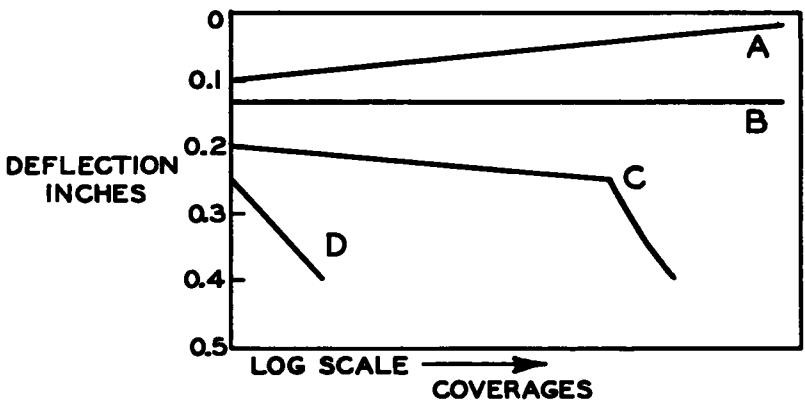

Figure 1. Relationship of deflection to traffic.

COMPACTION

Compaction is defined as a change in shape accompanied by a change in volume as opposed to shear deformation where no change in volume occurs, or simply as a reduction in voids. The compaction due to traffic is generally the only concern as the compaction due to the weight of the flexible pavement structure is generally negligible. Compaction results in a depression beneath the wheel path with no upheaval outside the traffic lane and typically with no cracking of the pavement. The shape of the depression is a clue to the layer that was densified. Compaction in a layer near the surface will produce a sharp depression; compaction at a depth produces a broader depression.

Compaction is not detrimental to a flexible pavement (except where the compaction produces pore pressures and a consequent reduction in strength with probable shear deformation resulting), but the depression which occurs is objectionable to the user if it becomes deep enough. Also, the ponding of water after rains in the depressions tends to shorten the life of the pavement. The acceptable amount of compaction would have to be stated by the user. The procedure used by the Corps of Engineers to design against compaction is to specify a density to be obtained during construction that will not densify any appreciable amount under traffic. Density design criteria were developed by sampling pavements that had been subjected to traffic and measuring the density that had developed. Some of the pavements had settled because of compaction. It is believed that had the compaction that developed under traffic been obtained during construction, densification under traffic would have been negligible.

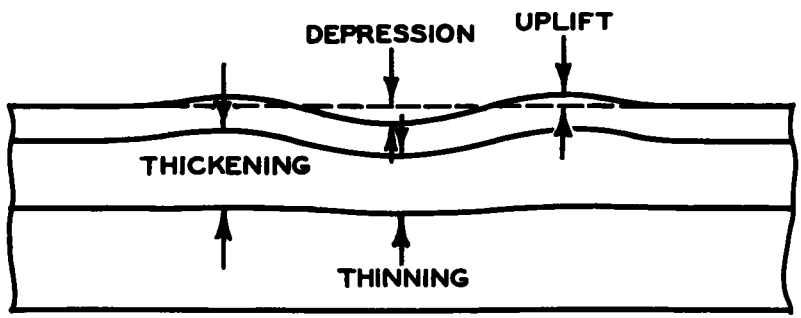

Figure 2. Effect of shear deformation.

DURABILITY OF ASPHALT PAVING MIXTURES

The FPL studies on the problems of durability have been limited primarily to laboratory tests and to exposure tests, and to date no design criteria regarding durability have been developed from these studies. The CE design philosophy to obtain maximum durability is to use as soft an asphalt and as much of it as possible without obtaining a pavement that flushes during hot-weather traffic. This should not be construed, as it might be, to mean that CE-designed pavements involve high percentages of asphalt since the avoidance of flushing in pavements subject to large, high-intensity loads results in designs ordinarily considered quite lean.

STABILITY OF PAVING MIXTURES DURING HOT-WEATHER TRAFFIC

The preceding discussions of shear deformation and compaction were directed toward subgrade, subbase, and base course materials, but these types of behavior also occur in bituminous paving mixtures, although in a bituminous paving mixture shear deformation is generally termed "plastic flow."

Compaction and plastic flow can occur during traffic in other parts of the year than during hot weather, but the effect of temperature is so great that generally only the hot-weather traffic is considered. The FPL has simulated hot-weather traffic by testing only when pavement temperature is above 90 F. Also, the compaction that occurs in

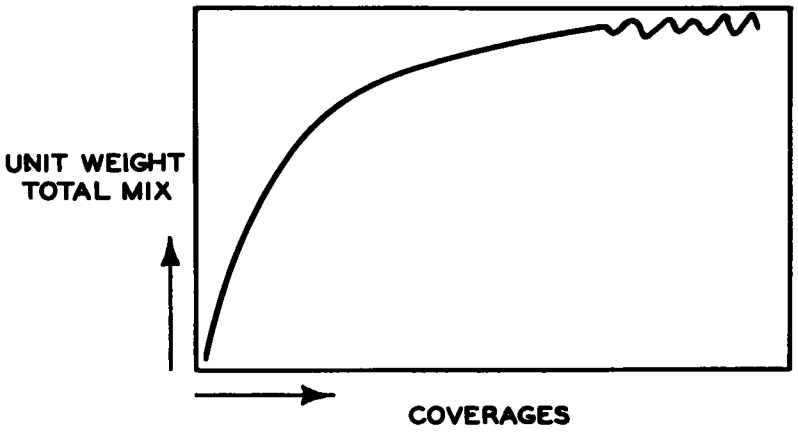

Figure 3. Relationship of density to traffic.

paving mixtures is usually ignored because depressions produced by compaction in paving mixtures are small.

In paving mixtures studied by the FPL, plastic flow does not occur until the mix has flushed; therefore, the most important tool for studying the development of plastic flow in paving mixtures is the measurement of density or voids at increments of traffic. Figure 3 is a typical curve of the relationship of density to traffic. Traffic produces densification to the point where the mix is flushed following which the density shows minor deviations but no further significant densification. If traffic is continued far enough, upheavals develop outside the traffic lane. Where the plastic flow is in the surface course, it can be detected by visual observations of trained observers almost as readily as it can be measured by density sampling. A surface course that is being subjected to plastic flow develops a typical wrinkling that is readily apparent at the edge of the traffic lanes and at any disconformity such as at an old core hole that has been refilled. Where the plastic flow is in the binder course or other underlying layer, sawing trenches with diamond saws becomes necessary so that the individual layers can be traced. A thinning of the layer in the traffic lane and a thickening outside the lane is definite evidence of plastic flow.

SUMMARY

In the preceding discussions, the causes of distress were neatly separated. This is rarely if ever the case in nature. When distress occurs in an actual pavement, both compaction and shear deformation are usually involved and it is necessary to attempt to separate the two. Compaction, though contributing to undesirable surface irregularity, increases the structural strength of a pavement (short of the point at which pore pressure develops) and becomes successively less under a given intensity of traffic. Shear deformation, on the other hand, becomes successively more pronounced in its resultant effects under a given intensity of traffic and has no beneficial effects.

It is important, therefore, to recognize the occurrence of shear deformation as a primary mechanism of failure regardless of the point at which resultant surface irregularities become intolerable for the use for which the pavement was designed. Also, if the behavior is to be used to improve the design criteria, it is necessary to establish the layer or layers which have been overstressed. This deformation requires careful observation and in most cases, sampling and testing.