Abridgment

Design of Pavement With High-Quality Structural Layers

George M. Hammitt, U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi

It is generally recognized and field observations have verified that the performance of a pavement is related to the quality and thickness of the layers making up its structure. Present criteria generally require minimum thicknesses based on the use of specified materials (hereafter referred to as conventional materials or conventional pavements) that have been shown by experience to give satisfactory performance. However, experience in accelerated testing of full-scale pavement sections has shown that the use of materials more durable and stronger than conventional materials permits a reduction in the thicknesses required for equal performance. The quality of the materials used can be improved by either selective use of existing materials or chemical or bituminous stabilization (hereafter simply referred to as stabilization) of them. Stabilization can be used to transform locally available materials of either specified or marginal quality into acceptable or high-quality materials, thereby reducing the required thickness of the locally available material. These reductions in thickness requirements often offset the additional expense of stabilization. The performances and possible economic advantages of stabilization have therefore been fairly well defined. The basic problem underlying further advancement of the state of the art is that of developing a method for incorporating the increase in performance into design considerations.

The purpose of this study was to develop design criteria and construction procedures for airport pavements incorporating structural layers of high-quality materials.

The study was accomplished as follows:

1. Two specially designed test sections of pavement composed of items representing a range of stabilization efforts were constructed and trafficked to failure under controlled, accelerated conditions.
2. Data from the specially designed test sections and from previous studies of test sections composed of stabilized and high-quality materials were compiled and used as input to an analysis of construction and performance characteristics of pavements incorporating high-quality materials.
3. The results of the analysis were used to formulate design criteria and construction procedures.

SUMMARY OF WORK ACCOMPLISHED

Two specially designed test sections, including four items surfaced with asphalt concrete (AC) and two items surfaced with portland cement concrete (PCC), were evaluated. Simulated aircraft traffic was applied with 890 and 1070-kN (200 000 and 240 000 lbf) dual-tandem assemblies. Visual observations of the behavior of the items were recorded throughout the traffic period and supplemented by photographs and rod and level readings. After completion of the trafficking, additional tests were conducted by excavating trenches across the traffic lanes.

Data from previous studies that incorporated stabilized and high-quality unbound materials (15 AC-surfaced items and one PCC-surfaced item) were also used in this study. Single-wheel loadings of 220 and 330 kN (50 000 and 75 000 lbf), dual-tandem loadings of 710 and 890 kN (160 000 and 200 000 lbf), and a 12-wheel loading of 1600 kN (360 000 lbf) were used in trafficking these items. The general approaches and methods of testing were nearly identical for all test sections.

FLEXIBLE PAVEMENT ANALYSIS

Two methods of analysis were applied to the data from the AC-surfaced items, one based on elastic layer theory and the other on comparisons of performance. The theoretical method involved the use of computerized models to predict the performance of each item. The response parameters used as input to the models included the resilient modulus as determined from resilient triaxial tests, the average modulus as determined from unconfined compression tests, and the tensile modulus as determined from indirect tensile tests. The performance predictions were made based on computed subgrade stresses and surface deflections and on limiting subgrade strain criteria. The results of the analysis showed that the stiffness of the stabilized materials in the various items was considerably lower than the resilient stiffness of the laboratory specimens. It was not possible to develop a correlation between the laboratory material characterization and the field material properties; thus, a theoretically based design procedure could not be perfected.

The comparative-performance method involved a comparison of the results from the various items with conventional flexible pavement criteria. The subgrade strength, environmental conditions, and loading conditions were held relatively constant in the items, while the quality of the material in the items was varied, which made a direct comparison of material quality and pavement performance possible. To account for the differences in performance of the items, equivalency factors were developed that consist of the ratio of the required thickness of a conventional base or subbase layer to that of a layer of the high-quality material.

The approach used in developing the equivalency factors was to compute the thickness of conventional flexible pavement that would perform in the same manner as the test item with the high-quality layer. The conventional flexible pavement was then assumed to have the minimum requirements of 7.6 cm (3 in) of AC and 15.2 cm (6 in) of base with the remainder of the structure being subbase, and the ratio of the thickness of the high-quality material to that of the conventional base or subbase calculated. After the equivalency factors were calculated for all the test items, values were selected to represent several

types of soil, depending on the type of material or stabilizing agent. In all cases, the resulting high-quality material must meet specified strength and durability requirements before the equivalency factor can be used in design. The equivalency factors are shown below.

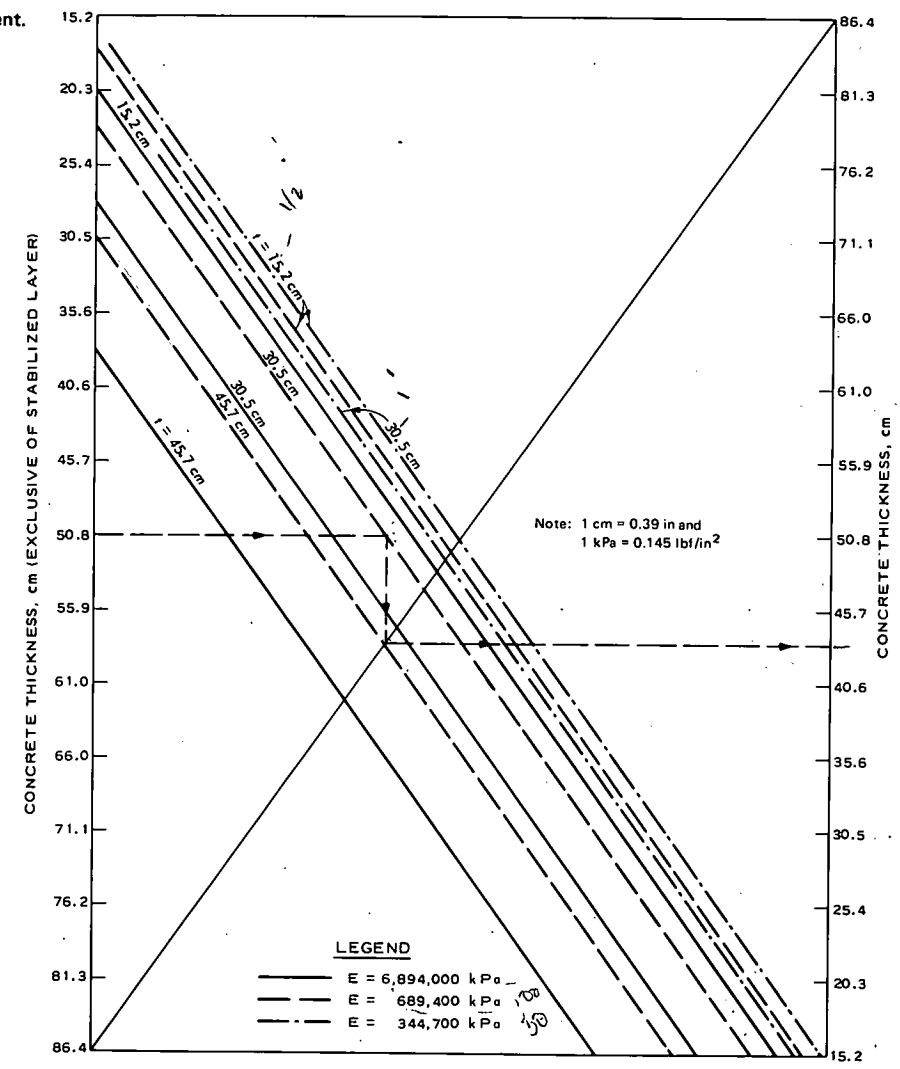
Material	Equivalency Factor Base	Equivalency Factor Subbase
Asphalt stabilized		
All-bituminous concrete	1.15	2.30
GW, GP, GM, and GC soils	1.00	2.00
SW, SP, SM, and SC soils	–	1.50
Cement stabilized		
GW, GP, SW, and SP soils	1.15	2.30
GC and GM soils	1.00	2.00
ML, MH, CL, and CH soils	–	1.70
SC and SM soils	–	1.50
Lime stabilized		
ML, MH, CL, and CH soils	–	1.00
SC, SM, GC, and GM soils	–	1.10
Lime, cement, and fly-ash stabilized		
ML, MH, CL, and CH soils	–	1.30
SC, SM, GC, and GM soils	–	1.40
Unbound crushed stone	1.00	2.00

Table 1. Examples of design procedure using equivalency factors for stabilized layers.

Procedure	Conventional Design	Equivalency Factors	Stabilized Design
Using cement-stabilized gravelly soil for base and subbase	7.6 cm AC, 15.2 cm base, and 45.7 cm subbase	1.0 for base and 2.0 for subbase	7.6 cm AC, 15.2 cm base, and 22.9 cm base
Using cement-stabilized gravel for base only	7.6 cm AC, 15.2 cm base, and 45.7 cm subbase	1.15 for base	7.6 cm AC, 17.8 cm base, and 50.8 cm subbase
Using surface mix for base and subbase	10.2 cm AC, 20.3 cm base, and 38.1 cm subbase	1.15 for base and 2.30 for subbase	10.2 cm AC, 17.8 cm base, and 16.5 cm subbase
Using cement-stabilized silty sand for subbase only	10.2 cm AC, 25.4 cm base, and 50.8 cm subbase	1.5 for subbase	10.2 cm AC, 25.4 cm base, and 34.3 cm subbase

Note: 1 cm = 0.39 in.

Figure 1. Design criteria for rigid pavement.



Some examples of use are illustrated in Table 1.

Rigid Pavement Analysis

The basic analysis of the PCC-surfaced items consisted of a comparison of performance with present criteria that involved the use of the Westergaard analysis to determine the benefit derived from the stabilized layers. [This analysis was not concerned with high-quality unbound (nonstabilized) materials because the modulus of foundation reaction (k) is used to assess the strength of these types of materials in rigid pavement design.] This was accomplished by calculating the thickness of PCC pavement required to support the test traffic on nonstabilized material and comparing this thickness to the actual thickness of PCC used in the test items, thereby showing that the stabilized soil layer was equivalent to a particular thickness of PCC pavement.

The design criteria were developed by using Westergaard and elastic layer analyses. By using the Westergaard analysis, the stresses at the bottoms of the slabs in the test section were computed. These stresses were then used as input to the multilayered elastic analysis, and an equivalent thickness of PCC on a nonstabilized subgrade was computed. Finally, the elastic layer program was used to extend the data to other slab thicknesses, moduli of elasticity of the stabilized layers, and thicknesses of stabilized layers. The design criteria developed for rigid pavements are shown in Figure 1.

SUMMARY OF FINDINGS AND CONCLUSIONS

In the theoretical analysis of the AC-surfaced, high-quality structural layer items, a transfer from laboratory material characterization to field material properties was not accomplished; therefore, the design procedure developed was based on a comparison of performance with that of conventional flexible pavements. Experience gained during this portion of the study did show, however, the applicability of using elastic layer theory to establish correlations between computed pavement-response parameters and pavement performance.

The comparative-performance analysis of the flexible pavement items resulted in the development of equivalency factors that can be used to compute thickness requirements for pavements having high-quality layers. These equivalency factors together with existing conventional flexible pavement criteria constitute the design criteria for incorporation of high-quality structural layers in flexible airport pavements.

The comparative-performance analysis of the PCC-surfaced items also resulted in the development of a thickness design procedure. In this procedure, the thickness of PCC required without an underlying stabilized layer is reduced as the thickness and quality of the stabilized layer is increased. Construction techniques were developed for stabilized soil layers.

It is emphasized that the reductions in thickness for both flexible and rigid pavements apply only to quality stabilization that meets certain requirements for strength and durability.

Abridgment

Structural Design Procedure for Flexible Airport Pavements

Walter A. Barker, U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi

The structural deterioration of a flexible pavement is normally associated with cracking of the bituminous surface course and development of ruts in the wheel paths. The design procedure presented by Barker and Brabston (1) treats these two modes of deterioration through limiting values of certain response parameters or through accounting for cumulative damage according to Miner's hypothesis. The required response parameters, the subgrade strain and the tensile strains in the structural layers, are computed by using a layered elastic computer program; thus, the procedure can handle in a rational manner the possible variations in the properties of different pavement materials. The use of the cumulative-damage concept also permits including in a rational manner the variations in the bituminous-concrete properties and the subgrade strengths caused by cyclic climatic conditions.

The design system has subsystems of initial thickness, climate, traffic, material properties, performance, pavement response, and thickness modification. Each of the subsystems uses specific input and generates output that is used by the other subsystems. At present, the subsystems are simple, but the entire design system has been developed so that all the necessary information is available for the design of three types of flexible pavement: conventional, bituminous concrete, and chemically stabilized. These represent nearly all flexible pavements being constructed at this time.

CONCLUSIONS AND RECOMMENDATIONS

The Barker and Brabston procedure demonstrates that it is possible to handle in a rational manner a number of design parameters that are not now considered in the present Corps of Engineers and Federal Aviation Administration (FAA) design procedures.

The following recommendations are offered:

1. Existing test data should be used for a more extensive verification of the design procedure, and a sensitivity study should be conducted to identify the most critical variables.
2. The design procedure should be put into use on an experimental basis. During this experimental use, emphasis should be placed on obtaining feedback for its verification or modification.
3. Work should continue on the extension of the procedure to more realistically consider the traffic variables. The veriables thus far identified are wander, load, type and speed of aircraft, and time of operation.
4. The ongoing FAA state-of-the-art review should be used to begin a study of environmental effects on pavements. Initial efforts in this area should be toward the prediction of moisture conditions under pavement systems. Other areas of effort should be cold weather cracking, the effects of temperature on the modulus of bituminous concrete, and long-term deterioration of