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

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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

bituminous-concrete surface courses.

ACKNOWLEDGMENT

This paper is a summary of a report to the Federal Aviation Administration (1).

REFERENCE

1. W. R. Barker and W. N. Brabston. Development of Structural Design Procedure for Flexible Airport Pavements. Federal Aviation Administration, Rept. FAA-RD-74-199, Sept. 1975; NTIS, Springfield, VA, ADA-019-205.

Pavement Design: Prestressed, Steel Fibrous, and Continuously Reinforced Concrete

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Three Federal Aviation Administration reports on the use of prestressed, steel fibrous, and continuously reinforced concrete for airport pavements are summarized. The technical literature describing the construction, testing, and performance of prestressed concrete was reviewed, and the design criteria that have been best validated by experimental evidence selected. A design procedure based on the selected criteria was formulated, the recommended construction procedures described, and load-deflection measurements made on an instrumented highway test road at Dulles International Airport in Virginia to further develop or verify the design criteria. Four full-scale test sections of steel fibrous concrete were constructed and tested under controlled, accelerated traffic conditions, two field placements of this material were planned and constructed, and the efforts of other agencies with this material were monitored. A field study of a continuously reinforced concrete pavement at O'Hare International Airport in Chicago was made. This study involved (a) evaluation of existing pavements and overlays, (b) synthesis of data and methods for design of these pavements, (c) formulation of design procedures and construction specifications, (d) collections of response and performance data for an actual pavement subjected to actual aircraft loadings, and finally, (e) the development of a design procedure that can be implemented now and is compatible with Federal Aviation Administration procedures for other types of pavement.

PRESTRESSED CONCRETE PAVEMENTS

Prestressing to strengthen concrete has been used widely and successfully for bridges, buildings, storage tanks, and pressure pipes for the past 25 years; however, only a modest interest and a limited investment of research funds have been directed at prestressed concrete for pavements, particularly for airports. As a result, the current state of the art in the design and construction of such pavements is not highly developed. Since the construction of the first prestressed concrete pavement on record on a bridge approach at Luzancy, France, in 1946, only about 100 prestressed pavement test sections and test slabs are known to have been built. These have been about evenly divided between airports and highways. The most recently constructed sections of prestressed pavement are one on an access road to Dulles International Airport in Virginia and one in Pennsylvania that were designed and constructed by the Federal Highway Administration (FHWA) and the Pennsylvania Department of Transportation respectively.

The gross masses of current and proposed commercial aircraft have reached such proportions and the flight operations such intensities that as much as 40.6 cm (16 in) or more of plain concrete may be required to provide an adequate pavement. In view of the increased concern for more effective use of resources, there is a basis for renewed interest in the search for resource-saving methods of constructing pavements. The desire to thoroughly evaluate a possibly expanded role for prestressed pavements stems primarily from the three basic advantages such pavements offer over conventional rigid pavements.

First, it has been demonstrated, both analytically and by testing, that prestressed pavements permit a substantial reduction in pavement thickness (50 percent or more), with corresponding savings in construction materials and possibly in costs. Second, prestressed pavements can be designed with fewer joints, a characteristic that results in quieter and smoother rides and eliminates the need for costly sealing and resealing programs. Third, the smaller number of joints and the lower probability of crack formation (both load and nonload associated) can be projected into the likelihood of extended pavement life and reduced maintenance requirements.

There are, however, potential disadvantages associated with prestressed pavements that must also be considered. First, there is an increase in the complexity of construction that leads to higher costs, which offsets the savings of materials, although there are strong indications that improved construction techniques, which would result from increased use of prestressed pavements, will help to minimize these costs. Second, the joints that are required in a prestressed pavement are expensive to construct and, due to the large horizontal movements, difficult to maintain. However, through the use of improved materials and construction techniques, more durable joint systems will probably be developed.

There are data from only a relatively few full-scale test pavements, laboratory tests on small-scale models, and observations of the performance of a limited number of operational airport pavements available for use in extending and refining the design and construction procedures. A review of the approaches to design used in the construction of the various prestressed pavement test sections showed that few attempts have been made to develop these designs by analytical techniques. Generally, pavement thicknesses and amounts of prestress have been selected on an arbitrary basis. Most highway pavement test sections have been 15 cm (6 in) thick with only longitudinal prestressing, while airport pavements have been up to 22.8 cm (9 in) thick, with both longitudinal and transverse prestressing. Frequently, such empirical designs have been subjected to static load tests after completion of construction to evaluate the load-carrying capability of the pavement. Also, frequent attempts have