A COMPREHENSIVE STRUCTURAL DESIGN FOR STABILIZED PAVEMENT LAYERS

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SUMMARY REPORT 98-13 (S)

SUMMARY OF

RESEARCH REPORT 98-13

PROJECT 3-8-66-98

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Foreword

Research Report 98-13 presents a design procedure for the structural design of stabilized pavement layers. The system is directed primarily at the prevention of tensile failures in the surface and subbase layers of a three-layer pavement structure and can be applied to take full advantage of those highway materials which possess cohesion or tensile strength. The report is the thirteenth in a series which describes work completed on Project 3-8-66-98, "Evaluation of Tensile Properties of Subbases for Use in New Rigid Pavement Design."

Introduction

In recent years the use of pavements involving one or more layers of stabilized materials has increased. Most pavement design methods do not provide adequate means for the structural design of stabilized layers, and, in fact, the thickness of these layers in some methods is often influenced only by depth of frost penetration or some minimum thickness established from experience. The structural design of a subbase for a rigid pavement is based primarily on the improvement in the support value for the surface layer and generally does not consider the stresses and strains in either the subbase layer or subgrade. On the other hand, flexible pavement design procedures generally include some consideration of subbase strength characteristics but do not assess the contribution of each layer to the ability of the total pavement structure to withstand the expected traffic. For these pavements to be used effectively, there should be a design method which is based on fundamental considerations and emphasizes the contribution of each individual layer to the behavior of the total pavement structure.

Report 98-13 presents a design method for selecting the thickness of each layer in a pavement structure that will insure adequate tensile resistance to a large number of applications of vehicle loads.

Design Approach

The design approach is composed of a series of design equations and several techniques for characterizing the properties of the materials proposed for use in the pavement layers. The formalized design system (Fig 1) is broken down into three phases. The first is concerned with characterization of the highway materials in the laboratory and requires techniques for estimating fundamental material properties. The second phase involves special considerations of such factors as temperature, loading rate, and repeated load applications and includes consideration of minimum allowable stress and strain values for each of the highway materials, based on repeated load studies. The culmination of the design process occurs in the third phase, where the minimum design criteria established in the second phase are used with design equations to obtain the required layer thickness.

The hypothetical pavement design section adopted for this design system, illustrated in Fig 2, consists of three layers, i.e., a surface course, a subbase course, and the subgrade. The pavement is assumed to be loaded by two 4500-pound loads uniformly distributed over circular areas and located 12 inches apart, center to center. This loading represents the present single axle legal load limit, 18,000 pounds.

Design Applications

Linear elastic layered theory was used in the development of the design equations for estimating tensile stresses and strains in the surface layer, tensile stresses and strains in the subbase layer, and compressive strain in the subgrade. Separate equations are presented in the report for use in the design of high modulus portland cement concrete pavements and for the design of flexible pavements and low modulus portland cement concrete pavements. The equations are lengthy and can best be solved in a computer; however, nomographs were developed for solution of the equations for

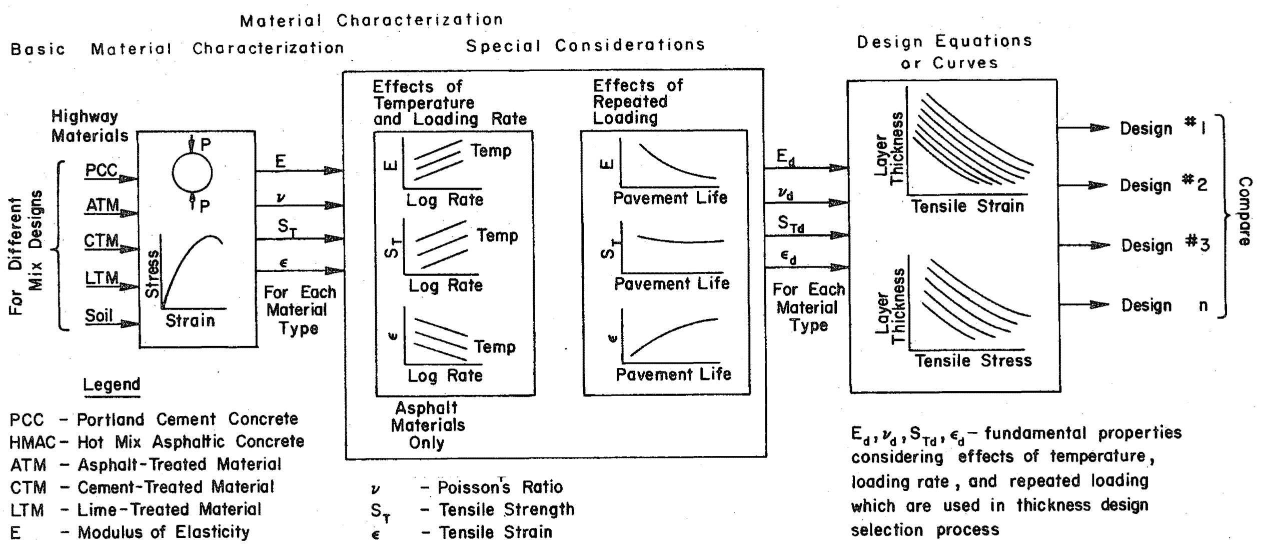

Fig 1. Block diagram of a system for structural design of stabilized pavement layers.

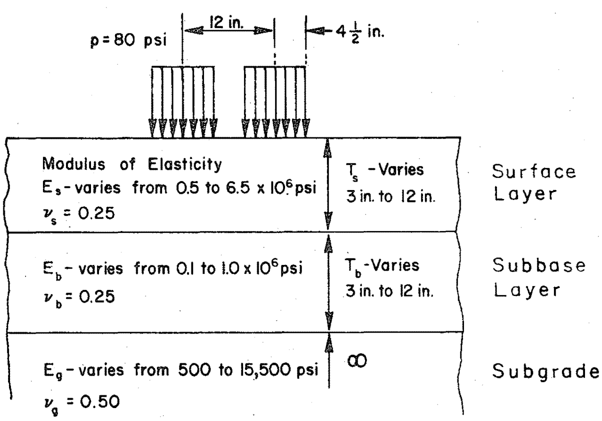

Fig 2. Hypothetical pavement section.

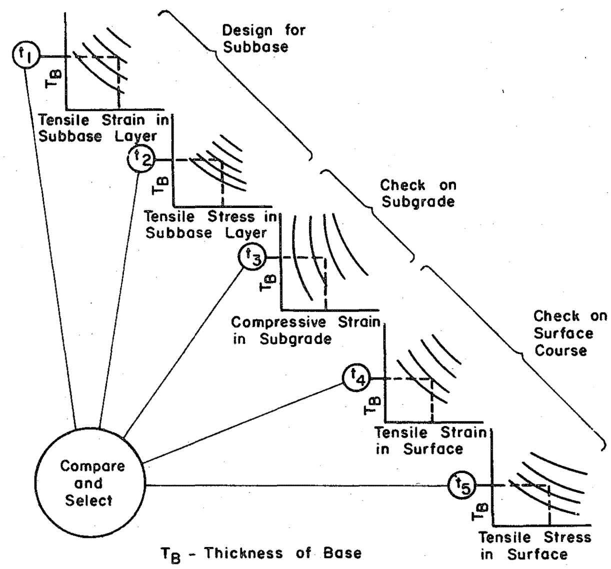

Fig 3. Process for selecting final base or subbase thickness.

application by those designers without access to computer facilities. Procedures for proper application of the design equations and nomographs are presented and include a method for selection of a critical design thickness. This selection procedure is illustrated in Fig 3 for a constant surface thickness and given material properties. The process is broken down into five separate designs. The first two design thicknesses are based on the allowable tensile stress or strain in the subbase layer. The third design is based on compressive strain in the subgrade to insure that lateral movement of the subgrade will not occur and that the integrity of the pavement system is maintained. The final two design thicknesses are obtained by checking to insure that the tensile stresses and strains produced in the surface layer do not exceed the allowable values for the surface layer materials.

All five subbase thicknesses are compared in order to select a critical design thickness that will satisfy all conditions. A typical design analysis might involve a number of iterative computations since changes in material types as well as different combinations of surface and base thicknesses can be evaluated in the process of selecting the most economical design section.

The application of the total design procedure to the structural design of various types of stabilized subbase layers is illustrated in example problems. A comparison of the results of the different design thicknesses indicates the effect of changes in material types and properties on the required subbase thicknesses.

Immediate Research Needs

Certain assumptions made in the development of the design system should be verified in the near future by research studies. One of the major research needs involves further development of limiting tensile-strain criteria for all pavement materials.

Other immediate research needs include development of compressive-strain criteria for a variety of subgrade types, additional studies to establish definite fatigue-strength-ratio criteria for different stabilized pavement-materials, and an evaluation of the effects of temperature on the fatigue strength and fatigue strain ratios for a wide variety of asphaltic materials, including hot-mix asphaltic concrete.

The time-temperature relationships for a variety of asphaltic materials should also be investigated to determine the effects of such variables as asphalt content, aggregate type, and asphalt cement type. In conjunction with this requirement there is a need for development of a temperature distribution theory to allow for estimation of temperatures in the various layers of a pavement.

Future Research Needs

The system presented in Report 98-13 should be augmented in the future by some of the following items.

(1) A systematic technique for estimating the stresses produced by the effects of temperature, so that these stresses can be superposed on the load stresses predicted by layered theory; a method of integrating the two systems should also be developed since temperature stresses occur over a relatively long period of time while stresses due to vehicle loads occur rapidly.

(2) Dynamic loading effects, with the ultimate aim of incorporating the effects of random loadings and dynamic loadings through research work in vehicle dynamics.

(3) Evaluation of the validity of the design approach by long-term observations of pavements designed in accordance with this design method and any of the other accepted base or subbase thickness requirements; in conjunction with this continuing pavement evaluation, provisions should be made for procedures by which the system could be updated on the basis of field data.

(4) Investigation of the cumulative damage of highway materials or the effects produced when materials or pavements are subjected to random loadings, including different stress levels and numbers of load applications; a cumulative design concept is required which will provide estimates of the life of a particular highway material based on its material properties and some random loading sequence.

(5) Additional material evaluation studies for a wide variety of highway materials, including a wide range of asphaltic materials, to include the use of lower quality materials in the design process, thereby allowing for a greater number of alternate designs from which a final design can be chosen.

(6) A systematic technique for estimating the effects of environmental variables on the design criteria, i.e., stresses and strains, including the effects of such factors as freezing, aging, and moisture on the material as well as fatigue properties; for example, during aging some highway materials increase in strength and stiffness but have a corresponding decrease in allowable tensile strains; in this case, the same vehicle load could produce different stresses in the pavement structure as the pavement material ages.

KEY WORDS: design, subbase, layered theory, tensile stress criteria, tensile strain criteria, modulus of elasticity, portland cement concrete, asphalt-treated materials, cement-treated materials, lime-treated materials, indirect tensile test, repeated loading, test temperature, loading rate, system, regression equations, nomographs.

The full text of Research Report 98-13 can be obtained from R. L. Lewis, Chairman, Research and Development Committee, Texas Highway Department, File D-8 Research, 11th and Brazos Streets, Austin, Texas 78701 (512/475-2971).