EXPERIMENTAL EVALUATION OF SUBGRADE MODULUS AND ITS APPLICATION IN MODEL SLAB STUDIES

By

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SUMMARY REPORT 56-16 (S)

SUMMARY OF
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Foreword

Research Report 56-16 describes an experimental evaluation of the modulus of subgrade reaction k and its application in the solution of small-dimension slabs-on-foundation based on a discrete-element model representation of slabs (Ref 2). A small-dimension slab test on a layered system is described in this report and the experimental results are compared with the discrete-element solution of the slab using the composite k-value for the layered foundation determined from the plate load tests. The k-value for the clay soil evaluated in this study was used by Agarwal and Hudson (Ref 1) to investigate the validity of the discrete-element representation of slabs with the results from small-dimension slab tests.

Introduction

Highway and airport pavements are complex structures supported on foundations of soil. The subgrade which provides support to the pavement slab finally absorbs the traffic loads. Therefore, it is important that the soil support to the pavement structure be determined and represented as accurately as possible for any theoretical or experimental approach to the problem. In modeling a pavement slab by a finite-element representation, Hudson and Matlock (Ref 2) represent the soil support k by linear springs based on Winkler's foundation, which can be evaluated by conventional plate load tests. Kelly (Ref 3) has examined a slab model representing the soil support by nonlinear load-deflection characteristics of foundation.

The purpose of this report is to describe a useful method of evaluating a representative value of the soil support k, for use in investigating the behavior of a small-dimension slab on a layered system.

Experimental Program

A testing program was developed to evaluate the k-value of a clay subgrade and a layered system consisting of a thin asphalt stabilized layer over the clay subgrade. Plate load tests were used with circular rigid plates whose diameters ranged from 2 to 9 inches. The small-dimension slab tested on clay (Ref 1) was subsequently tested on the layered system.

The tests were conducted in a wooden box (2-foot cube) and the loads were applied through a mechanical screw jack and measured by a proving ring in the plate load tests and by a load cell in the slab test. Deflections were measured by dial gages while strains at various points in the slab were measured by rosettes fixed to the surface of the slab. The 9 by 9-inch instrumented slab was tested under a static load of 200 pounds applied at the center of the slab. In order to have a cursory look at the behavior of the slab on the layered system under cyclic loading, the static slab test described earlier was continued for ten repetitions of load to the maximum measured deflection recorded in the first cycle. The data from the slab test were recorded in digital form. Complete details of the test setup are available in Research Report 56-15 (Ref 1).

Analysis of Test Data

The load-deflection data of the plate tests on the clay subgrade are shown in Fig 1. The plate diameter influences the load-deformation characteristics of the clay soil and the pressure required to produce a given plate deflection increases as the plate diameter decreases. For pressures reaching ultimate bearing capacity of soil, the effect of plate diameter ceases. Similar observations were made from the load-deflection data for the layered system as described in the report. Using the data shown on Fig 1, the k-value for the clay can be calculated using tangent and secant moduli approaches. The initial straight line portion of the load-deflection curve gives the initial tangent modulus k.

From the load-deflection data for the plate tests on the layered system, an increase in k-value was obtained by using a thin layer of asphaltic material over the clay subgrade.

Burmister's elastic layered theory was used to predict the load-deflection curve for the layered system by using the value of the modulus of elasticity, E_1, of the asphaltic material determined from indirect tensile tests on specimens of the

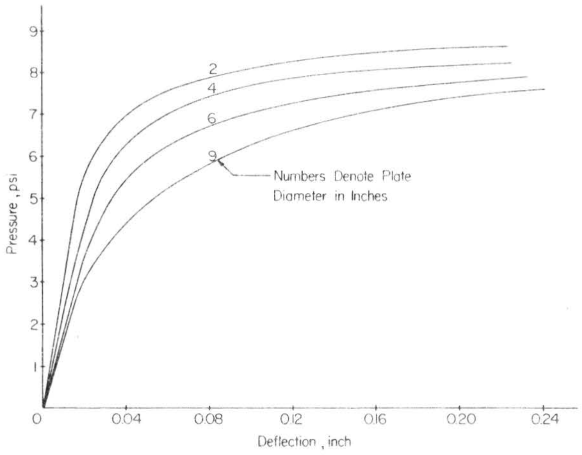

Fig 1. Average pressure-deflection curves for plate load tests on clay, Series A, B, and C.

asphaltic material. The predicted curve was compared with the load-deflection curve obtained from the plate load tests. Comparison is good for deflections up to .03 inch. Beyond that, the predicted deflections are higher than the measured ones.

The limited study conducted to investigate the effect of temperature on the stiffness of the asphalt stabilized layer shows that the k-value, which is a measure of layer stiffness, changes significantly with a change in temperature. For a change in temperature from 60° to 100° F, the k-value reduces from 550 lb/cu in. to 310 lb/cu in.

The recorded data of the slab test are processed as described in the report and the measured deflections and stresses for the loads of 100 and 200 pounds are compared with the analytical solutions of the slab using linear and nonlinear springs. The comparison is good near the loaded area but at corners (Fig 2) the computed deflections are 15 percent higher and at edges (Fig 3)

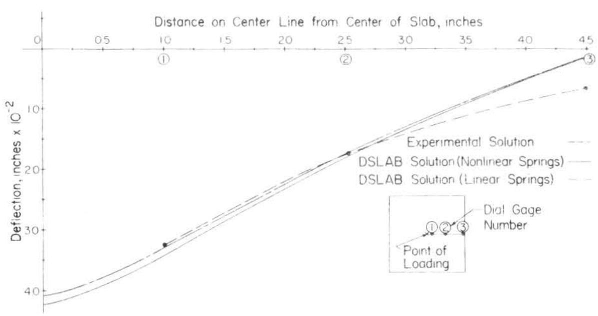

Fig 2. Comparison of experimental and analytical solutions for deflections of slab on points along its diagonal for a load of 200 lb applied at the center.

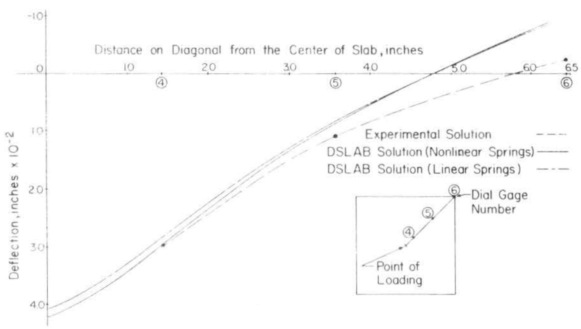

Fig 3. Comparison of experimental and analytical solutions for deflections of slab on points along its center line for a load of 200 lb applied at the center.

12 percent lower than the measured ones. Similarly, away from the vicinity of the point of loading measured and computed principal stresses differ considerably, as much as 16 percent. The comparison of the experimental and analytical solutions show that the use of nonlinear springs did not provide results which are significantly better than those from the use of the linear springs.

The effect of cyclic loading on the slab to the maximum measured deflection of 0.0362 inch produces some permanent deformation in the slab and by the tenth cycle the load appears to be stabilizing.

Conclusions

The following conclusions can be drawn from the study described in the report:

(1) The value of the soil modulus k varies inversely with the size of the plate used in the load tests and with the magnitude of the soil deformation.

(2) The addition of a thin layer of asphaltic material on the clay subgrade improves the k-value for the system by 40 percent and thus for the same load the slab deformed less on the layered foundation than on clay alone.

(3) The predicted load-deflection curves based on Burmister's elastic layered theory using the value of E_1 determined from the split tensile tests on the asphaltic material of the layer compared well with the load-deflection data of the plate tests for small amounts of deflection.

(4) Temperature significantly affects the modulus of elasticity of the asphaltic material which in turn affects the k-value for the layered system.

(5) Computed deflections and stresses in the slab are within 5 percent of the measured values in the interior of the slab near the point of loading. At the corners of the slab, computed deflections are 15 percent higher than the measured values, showing that a constant value of k is probably not fully representative of the actual conditions of subgrade existing at any point beneath the slab.

The full text of Research Report 56-16 can be obtained from R. L. Lewis, Chairman, Research and Development Commitee, Texas Highway Department, File D-8 Research, 11th and Brazos Streets, Austin, Texas 78701 (512/475-2971).

References

1. Agarwal, Sohan L., and W. Ronald Hudson, "Experimental Verification of Discrete-Element Solutions for Two-Dimensional Soil Structure Problems," Research Report 56-15, Center for Highway Research, The University of Texas at Austin, August 1969.
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KEY WORDS: clay (Taylor marl), deflection and stress, discrete-element solution, subgrade support, modulus of subgrade reaction k, plate load tests, small-dimension slab, static and cyclic load tests, temperature, two-layered system, experimental.