SUMMARY REPORT 136-5(S)

ELASTIC MODULI DETERMINATION FOR SIMPLE TWO-LAYER PAVEMENT STRUCTURES BASED ON SURFACE DEFLECTIONS

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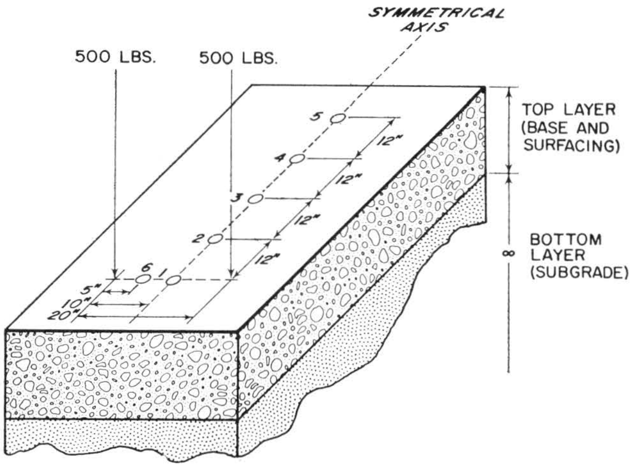

Relative position of Dynaflect loads and sensors. Vertical arrows represent load wheels. Points numbered 1 through 5 indicate location of sensors for standard test. Point 6 indicates the location of a desired additional measurement.

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Elastic Moduli Determination for Simple Two-Layer Pavement Structures Based on Surface Deflections

by

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This report presents a technique for determining the elastic modulus for each layer in a simple two-layered pavement structure. The thickness of the top layer is known (or measured) and the thickness of the lower layer is assumed to be infinite. The basic concept is to determine the set of values E_1 and E_2 (elastic modulus of pavement and subgrade, respectively) which will best predict a measured surface deflection basin in accordance with layered elastic theory.

The technique is somewhat similar to that developed previously in Study 1-8-69-123 by Scrivner, Michalak and Moore, the chief differences being that the present technique is more rapid and uses the "best fit" of the entire measured deflection basin rather than two arbitrarily selected points of the basin. It is more rapid because it employs the simple empirical equation developed previously in this study by Swift, instead of a conventional rigorous mathematical technique for two elastic layers like that developed by Scrivner, et al. The two techniques are similar in that they both assume a point load on a two-layer elastic pavement structure for which the thickness of the top layer is known. Both determine the elastic moduli for the two layers and assume that the layers have a Poisson's ratio of 0.5.

Methodology

Deflection predictions are based upon Swift's empirical equation given below:

$$\hat{w} = \frac{3P}{4\pi E_1}\left[\frac{1}{r} + \left(\frac{E_1}{E_2} - 1\right)\left(\frac{1}{x} + \frac{a^2}{2x^3} + \frac{3a^4}{2x^5}\right)\right]$$

in which $x = \sqrt{r^2 + a^2}$

$a = 2h \sqrt[3]{1/3\ (2 + E_1/E_2)}$

and P = magnitude of point load

r = horizontal distance from loading point

h = thickness of upper layer

E_1, E_2 = elastic modulus of upper and lower layers, respectively

$\hat{w}$ = predicted surface deflection at r

This equation closely approximates surface deflections computed using rigorous elastic theory with a Poisson's ratio of 0.5. In this equation, deflection is expressed as a function of the following five independent variables: P, r, h, E_1 and E_2. When deflections of a simple pavement structure of known thickness are measured with the Dynaflect, the first three independent variables are known and the last two are unknown. A computer program was developed which finds the set of values of E_1 and E_2 that best predicts the measured deflections, w. This set of values is assumed to represent the elastic moduli for the two layers.

Implications of Results

In fitting two-layer elastic systems to normal Dynaflect measurements, it is often difficult to distinguish between two alternate sets of elastic moduli which result in similar deflection basins. This problem occurs because there are many cases where two entirely different pairs of elastic moduli will provide nearly equal values of deflections in the range of the standard measurements (r values between 10 and 49 inches). Thus, two alternate sets of elastic moduli may appear to be equivalent solutions in a particular pavement evaluation problem. It was found that many such ambiguities can be eliminated simply by adding one additional measurement point to the normal five Dynaflect deflections.

This phenomenon does not imply that point load, two-layer, elastic deflection basins are not unique. In fact, Swift's "Two-Layer Elastic Deflection Chart," previously reported in this study, clearly demonstrates that each possible two-layer elastic case has its own unique characteristic deflection basin. However, the phenomenon does indicate that two alternate cases can become confused when the set of measurement points is not extensive enough.

Conclusions and Recommendations

1. Because the presented technique for determining elastic moduli for simple two-layer pavement structures fits the entire measured deflection basin, it is believed to be more representative of the true material properties, insofar as elasticity theory applies to such structures, than any other technique known to the author.

2. The five Dynaflect deflection measurements normally made in field testing are not sufficient to determine a unique set of elastic moduli for some two-layer highway pavements.

3. The apparent two alternate solutions for many existing flexible pavement structures could be resolved by making an additional deflection measurement closer to the loading point. It is recommended that the mechanics of accomplishing such a measurement be given immediate consideration for use in future deflection-based pavement evaluations.

Implementation Statement

A new computer program, "Two-Layer Elastic Moduli for Five Deflections," has been written to permit rapid inexpensive calculation of the elastic moduli of two-layer pavement structures, from routine field-measured pavement deflections. These insitu elastic modulus values are significant for pavement evaluation purposes and are expected to be required in future pavement design systems.

It is recommended that an observation be added to routine field deflection measurements in order to eliminate ambiguities found in the evaluation of some typical highway pavements.

The published version of this report may be obtained by addressing your request as follows:

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