LINEAR ELASTIC LAYER THEORY AS A MODEL OF DISPLACEMENTS MEASURED WITHIN AND BENEATH FLEXIBLE PAVEMENT STRUCTURES LOADED BY THE DYNAFLECT

SUMMARY REPORT 123-25(S)

SUMMARY OF
RESEARCH REPORT 123-25

PROJECT 1-8-69-123

Cooperative Highway Research Program
with U. S. Department of Transportation
Federal Highway Administration

TEXAS HIGHWAY DEPARTMENT

CENTER FOR HIGHWAY RESEARCH
THE UNIVERSITY OF TEXAS AT AUSTIN

TEXAS TRANSPORTATION INSTITUTE
TEXAS A&M UNIVERSITY

August, 1974

Linear Elastic Layer Theory as a Model of Displacements Measured Within and Beneath Flexible Pavement Structures Loaded by the Dynaflect

by

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Purpose

The principal purpose of the work described in this report was to investigate the suitability of the theory of linear elastic layered systems for use as a model of dynamic displacements occurring throughout the body of flexible pavement structures as the result of a vibrating load applied to the surface by a Dynaflect. It was envisioned that the theory, if found suitable, could eventually be introduced into the Texas Highway Department's Flexible Pavement Design System (FPS).

Loading and Measurements System

The Dynaflect applied an oscillating load varying sinusoidally with time at a frequency of 8 Hz and with a peak-to-peak amplitude of 1000 pounds. The resulting displacements, both horizontal and vertical, were measured at depths ranging from zero to 65 inches, and at horizontal distances from the load ranging from 10 to 216 inches, by means of geophones lowered into 1 3/4 in. diameter holes drilled vertically through the pavement structure, through an embankment, and one foot into the foundation material.

Pavement Test Facility

The pavements tested were a set of 27 statistically designed sections built at Texas A&M University's Research Annex in 1965. Normal Dynaflect surface deflections had been measured in 1966. The vertical and horizontal displacements at surface and subsurface elevations were measured in 1972. Since surface deflections were measured in both instances, and since only an occasional light vehicle traveled over the section in the six-year interim, data were available for studying long-term environmental effects on deflections in the absence of traffic.

Environmental Effects

Some discrepancies were discovered between the 1966 and the 1972 deflection data. After considerable study, discrepancies were ascribed to the entrapment of free water in pervious portions of the facility in the years 1966-1971, and the subsequent drainage of the water just prior to the start of the 1972 measurements program.

Also ascribed to the entrapped water was the swelling of a plastic clay embankment included in the facility, and the appearance of longitudinal cracks in sections supported by the embankment.

Side Studies

As a side study in the investigation, published data from other sources (an NCHRP project and the AASHO Road Test) were used to estimate the speed of a 1000-lb. (dead weight) wheel load that would induce the same deflection in a flexible pavement surface as the vibrating 1000-lb. Dynaflect load. The purpose here was to show the Dynaflect loading is clearly related to highspeed traffic loading.

In the second side study, published load-deflection data from the AASHO Road Test were used to establish the degree of linearity of the load-deflection relationship as a test of the hypothesis that the load supporting materials had linear elastic properties. In the analysis use was made of replication error as a practical yardstick for measuring the accuracy required of the linear elastic model.

Analysis of Vertical and Horizontal Displacements

Replication error was used for the same purpose in the analysis of the 1972 displacement data measured at the A&M Pavement Facility. In this analysis it was necessary to find values for the elastic moduli of eight materials that would satisfy the requirement that the differences between computed and measured displacements were, on the whole, of about the same size as the replication error. Although the time and funds available limited the analysis to a fraction of the data available, it is believed that enough evidence was mustered to support the findings.

Findings

The main report lists a number of findings of which the following are considered the most important.

1. According to an analysis of previously published data the 1000-lb. Dynaflect can be expected to produce a surface deflection of about 45% of the deflection caused by a static load of 1000 lbs., or the same deflection as a dual wheel load of 1000 lbs. dead weight moving at high speed (roughly 50-60 mph).

2. Finding 1 implies that either materials supporting the load possessed visco-elastic properties, or the effect on deflections of the inertia of these materials was greater than has usually been assumed.

3. Results of load-deflection tests made on flexible pavements at the AASHO Road Test a few weeks after construction, but before the first freeze of the winter season, indicated that the load supporting materials behaved, on the average, in a manner in agreement with the assumptions of linear elasticity. Variations from the average behavior were no greater than variations in the behavior of identical designs located in different traffic loops. However, shortly after a severe freeze-thaw cycle, the supporting materials behaved in a manner consistently contrary to the assumptions of linear elasticity.

4. Linear elasticity was found to be an acceptable model for the vertical and horizontal components of the displacement vector measured in 1972 within the body of seven selected sections of the A&M Pavement Test Facility, inasmuch as the combined prediction error in each component was about the same size as the corresponding combined replication error for the seven sections.

The **dynamic in situ moduli** determined in the analysis and used in calculating prediction errors are given below in pounds per square inch.

Asphaltic concrete	141,200
Limestone plus cement	469,800
Limestone plus lime	189,300
Limestone	86,000
Sandy gravel	49,200
Sandy clay	31,600
Plastic clay	12,400
Dense clay	47,500

Recommendation

It is recommended that a study be made to determine the feasibility of pre-computing and storing on tape an extensive table of stresses, strains, and displacements for use in accomplishing the double purpose of estimating in situ moduli, and of determining (in FPS) stresses, strains or displacements at critical points in trial designs. Such a table, computed from the theory of linear elastic layered systems, would be costly, but once computed and stored, the values would be available at minimal cost for use by researchers and designers alike.

Implementation Statement

This report presents evidence to show that linear elasticity apparently will, in an environment like that of most of Texas, predict the displacement vector field for flexible pavements with sufficient accuracy to warrant its trial, at an appropriate time, in the Texas Highway Department's Flexible Pavement Design System. How to make that trial is more difficult to define, but it seems fairly clear that one step toward implementation of the theory was made in 1973, with publication of Research Report 123-17, "The Optimization of a Flexible Pavement System Using Linear Elasticity." Another step in this direction, yet to be taken, would be to follow the recommendation stated in the preceding section. A third step toward implementation would be the standardization in Texas of a method for estimating the tensile strength of both water bound and stabilized materials. Finally, if full advantage is to be taken of the theory, the surface curvature index (SCI), would have to be replaced as an indicator of pavement life, by parameters consistent with fatigue theory.

The work involved in fully implementing linear elasticity as a subsystem of FPS may appear formidable, but the authors do not wish to infer that it should not be done.

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