SECTION VIII

PROBLEMS OF ROAD AND RUNWAY CONSTRUCTION

SUB-SECTION VIII a

TEST SECTION

VIII a 2

STRESSES AND DISPLACEMENTS IN A HOMOGENEOUS SOIL

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SYNOPSIS

This paper describes the construction of a homogeneous clayey silt test section, the installation of pressure cells and deflection gages in the homogeneous soil mass, and the tests performed. The object of the study is to obtain information on stresses and deflection. No test data are shown as tests are still in progress. In general, the test setup and test procedures are proving satisfactory.

INTRODUCTION

As a part of a long-range program for the improvement of the present method of design of flexible pavements for airfields, the Corps of Engineers, Department of the Army, is currently engaged in a series of studies to obtain basic information concerning the behavior characteristics of soils under load. The purpose of this paper is to furnish information to interested engineers on the rather elaborate setup of test equipment which has been made in order to accomplish one phase of the study described in the preceding sentence.

The tests are being performed by personnel of the Waterways Experiment Station, Vicksburg, Mississippi. Testing began in July 1947 and probably will be completed by March 1948. Since testing was not completed at the time of writing this paper, no data are presented.

At the present time the Corps of Engineers uses the CBR method for determining total base and wearing course thickness for flexible pavements. The design curves used in the CBR method are based on empirical data 1), 2), 3) . For this reason, each modification or extrapolation of the curves necessitated by an increase in load, tire pressure or by a new type of airplane landing gear must be proved by a full scale field test. To eliminate this undesirable condition, the Corps of Engineers is engaged in these studies as a part of an overall program to develop a more rational method of design.

After considerable paper study and attempts to analyze available stress distribution data from three test sections, Stockton No. 1, 4) Barksdale 5), and Marietta 6), where layered systems had been used, it was concluded that a layered system (wearing course, base, and subgrade) was too complex for analysis. It was decided, therefore, to study first the simplest possible case, the measurement of stresses and displacements produced by loads simulating airplane wheels in a homogeneous soil mass. After data from this simple case were assimilated, layered systems of increasing complexity would be tested.

DESCRIPTION OF TEST SECTION AND TEST INSTALLATION

As shown on fig. 1 the test section is 26 ft wide, 50 ft long, and 12 ft deep with side slopes of 1 on 1. The bottom 2 ft of the section consist of pervious sand to insure against capillary saturation. Pressure cells were installed in the section to measure induced stresses in a vertical, two horizontal, and two diagonal directions, and deflection gages were installed to measure vertical deflections. In each of the test sections previously referenced, it was necessary to space the cells and gages installed in a given type of subgrade over a relatively wide area to obtain the desired variables of thickness, type of base, and other features. Unexpected variations occurred in the subgrade in these installations which made analysis of the data difficult. An attempt was made to eliminate this condition, as far as possible, in the design of the test section reported herein. The same installation of cells and gages was tested at several depths of fill by constructing the maximum depth initially and cutting off successive layers of the fill as testing progressed. As shown on fig. 1 the major installation of the cells and gages was at a depth 5 ft below the initial height of the test section. A few pressure cells were also installed at a depth of 2 ft below that of the major installation to obtain a limited amount of information at depths of 6 and 7 ft below the level at which the load is applied. The lower installation will also provide check readings on cells in the major installation at the same depths but at later dates in the test program. If satisfactory check readings were secured, it could be assumed that no serious change in soil structure occurred during the testing period. All pressure cells in the major installation are of the WES (Waterways Experiment Station) type and are 12 in. in diameter except for a few which are 3 in. in diameter.

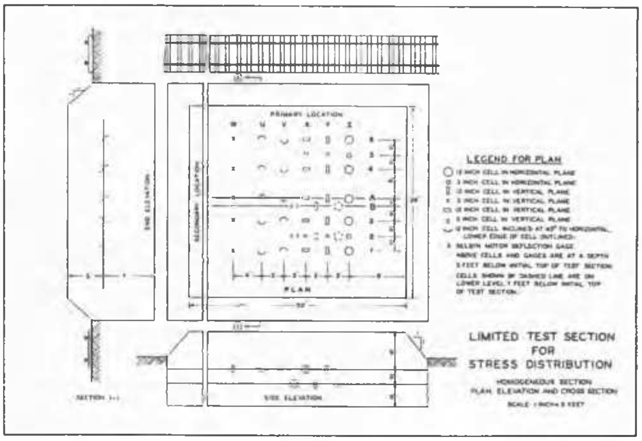

FIG. 1

PHOT. 2

PHOT. 1

PHOT. 3

The deflection gages are of the selsyn motor type. In order to assist in analyzing the data a control cell was placed in a protected position on the surface of the test section and read at suitable intervals. At a secondary location (not shown in the layout on fig. 1) deflection gages of the California, cantilever, and selsyn motor type and pressure cells of the Carlson and WES type were installed for purposes of comparing instrument performance. The WES type pressure cell and the selsyn and cantilever type deflection gages are described in detail in a paper titled "Instrumentation for Field Measurements of Deflections and Pressures for Airport Pavements", by John M. Griffith and E.H. Woodman, and submitted as a companion paper.

The test section is constructed of a clayey-silt soil, Corps of Engineers (Casagrande) classification CL, with a liquid limit of 36 per cent and a plasticity index of 13 per cent. The soil was compacted in 4-in. lifts by 8 passes of a 750 psi sheepsfoot roller. California Bearing Ratio tests made after construction but before testing show CBR values in the range of 9 to 12 per cent. The modulus of subgrade reaction at 0.05 in. deflection (Westergaard K-value) was found to be approximately 350 psi per inch. The moisture content and density of the soil were controlled very closely during construction to assure uniformity. The moisture content was at all times between 18.5 and 19.5 per cent of the dry weight. Tests performed after approximately 7 months of testing showed no appreciable change in the moisture, density, and CBR values. After construction, the dry density of the soil varied between 103 and 108 and averaged 105 lb per cu ft.

Uniform circular loads were applied to the surface of the test section by means of specially designed flexible plates developed for this project from basic ideas supplied by the Public Roads Administration. The plates are in two sizes: 500 sq. in and 1000 sq in. The faces of these plates are water-inflated rubber diaphragms as shown by photograph 1. The circular plate was chosen because it was simple to construct and because it facilitated computations and analyses. Theoretical studies indicated that a uniform circular load can be used to replace actual tires in this type of study with very little loss of accuracy. The loads are obtained by jacking against a loaded steel truss which spans the test section. The truss is mounted on wheels and can be moved on tracks the entire length of the test section. A view of the truss is shown in photograph 2.

As shown on fig. 1 there are 37 pressure cells and 5 deflection gages installed at the primary location. By means of a Baldwin Southwark SR-4 Strain Recorder it was possible to read all the pressure cells simultaneously. Some idea of the manner in which stress profiles were obtained may be gained from the following example. With a single load centered at the intersection of Lines A and Z (see fig. 1), the 12-in. cells in the Z line give values for the stress on a horizontal plane at offset distances of 0, 3, 4, 7, and 8 ft. By shifting the load 1 ft to the intersection of Lines B and Z the same cells furnish stresses at offset distances of 1, 2, 5, 6, and 9 ft. In this manner an entire stress profile on the horizontal plane was obtained with readings at 1-ft intervals from 0 through 9 ft. By repeating the process on the U, V, X, and Y lines, profiles of the stresses on planes at 45° and 135° with the horizontal and on 2 vertical planes at right angles to each other were obtained. From these observations the direction and magnitude of the principal stresses can be computed. This procedure gives the complete stress patterns under the single loads. For the twin loads the bearing plates are placed with respect to the cells so that only stress patterns on the planes of symmetry are secured. Deflection profiles were measured following the same method described for stress measurement.

Total loads of 15,000, 30,000, 45,000, and 60,000 lb were applied, in the order stated, by means of a single plate having 1,000 sq in. of area and by means of twin plates each having 500 sq. in of area. A view of the loading setup is shown in photograph 3. Since in both cases the load was uniformly distributed over an area of 1,000 sq. in., the contact pressures corresponding to the above loads were 15, 30, 45, and 60 lb per sq in. In each case the load was applied and released three times and the readings for each cell were averaged. The spacing between the twin loads was 7.5, 6.0, 4.5, and 3.0 ft and the loads were tested in that order of spacing. After testing was completed on the 5-ft elevation, the test section was cut down to an elevation of 4 ft. This process was repeated in 1-ft increments down to an elevation of 1 ft. In this way test values were obtained for depths 1, 2, 3, 4, and 5 ft. For the purpose of securing comparative test data between rigid and flexible plates a limited number of tests were made using a 30-in. (707 sq in.) rigid steel plate. These were compared with a like number of single load tests using both the 500 and the 1,000 sq in. flexible plates.

It should be pointed out that the principal testing program consisted of the measurement of induced stresses and deflections. These values were obtained by first reading the cell or gage in an unloaded condition (except for overburden) and then reading it with the load applied. The difference in these readings measures the effect of the imposed load. Studies that have been made recently of the data obtained from Stockton Test Section No. 2 indicate that the stresses existing in a subgrade prior to the application of an imposed load may play an important part in the ability of the subgrade to withstand the load. These stresses, which are total stresses acting in the soil over long periods, of time, appear to be of much greater magnitude than the stress caused by the weight of the overlying soil and pavement. It is believed that they are produced by compaction during construction and during application of traffic The study of the data from Stockton No. 2 was not made until after the cells for the test section reported here were obtained and prepared for installation. These cells are not designed to measure total stresses acting in the soil over long periods of time. An attempt is being made to obtain values for these stresses by taking cell readings at suitable intervals any applied load; however, it is recognized that the readings will not be as accurate as would be desired.

SUMMARY

In closing it can be stated that the bearing plates, loading truss, and pumping device are working satisfactorily. The section appears to be sufficiently uniform to be considered homogeneous. The deflection gages are operating well and the readings appear to be consistent and reasonable. In general the pressure cells are performing satisfactorily from the standpoint of measuring induced stresses. At the present time it is believed that the data from this section will add considerably to the knowledge of stress distribution in homogeneous soils and will be an important stepping stone toward gaining information of stress distribution in layered systems.

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