FIELD INVESTIGATION FOR FLEXIBLE PAVEMENT DESIGN

By T A Middlebrooks, *Principal Engineer*

AND

G. E. Bertram, *Engineer*

U S Engineer Department

SYNOPSIS

This report reviews the method used by the U. S Engineer Department for making bearing tests on airport runways and subgrades with loads and bearing areas comparable to those of present day military planes The relative effect of the stresses produced by a large military plane and by a heavy loaded truck is illustrated.

Load-deformation results are given for bearing tests made (1) on the surface, the base course and the confined subgrade of a bituminous stabilized project, (2) on a good, a fair, and a failed section of an asphalt pavement of a commercial airport, and (3) on a poorly, a partially, and a well consolidated subgrade

The report also discusses briefly the value of laboratory tests to determine the effect of moisture changes on stability and the plans of the Department to inaugurate a series of tests to determine the relationship between field bearing tests and the laboratory bearing test developed by the California State Highway Department.

The Engineer Department has undertaken an investigation of flexible pavement design in conjunction with and as a guide in the nation-wide airfield construction program being conducted by the Department. Much valuable assistance in design practice has been given by the various highway research and construction agencies, but due to the magnitude of the wheel loads for which runways for military airfields are designed, it has been necessary to conduct special research on the load carrying capacity of flexible type pavements.

The effects of the areas of large airplane tire footprints on the stresses produced in a pavement subgrade as compared to those induced by heavy-duty truck loadings can best be illustrated by a stress diagram. Accordingly, the shearing stresses and vertical stress differences for a uniformly distributed load on circular areas of 12-in. and 24-in. diameter are shown in Figure 1. The shearing stresses and vertical stress differences have been computed without regard to the stress distortion produced by the surface and base course and their boundaries, and is based on a homogeneous, isotropic and elastic subgrade. Although the exact stress values cannot be taken as absolutely correct, the differences are valid It will be noted that the one-tenth unit load shearing stress occurs at almost twice the depth for the 24-in. area as for the 12-in. area and that the maximum vertical stress difference is some 5 in deeper in the case of the 24-in. diameter.

In order properly to evaluate the effect of these stress differences on flexible pavement design, it was decided to conduct a series of full scale load bearing tests on pavements and subgrades. Consideration was given to the possibility of extrapolating the results of tests on small size bearing areas, but this was abandoned since it was found that loads and contact areas comparable to the planes could reasonably be used, thereby eliminating one major variable. The relationship between unit bearing capacity and diameter of bearing plate is shown in Figure 2 for a cohesive soil. The curve represented by the solid line was obtained from tests conducted by the Public Roads Administration at Arlington Farm and the dashed line represents Engineer Department tests The general agreement between the curves is

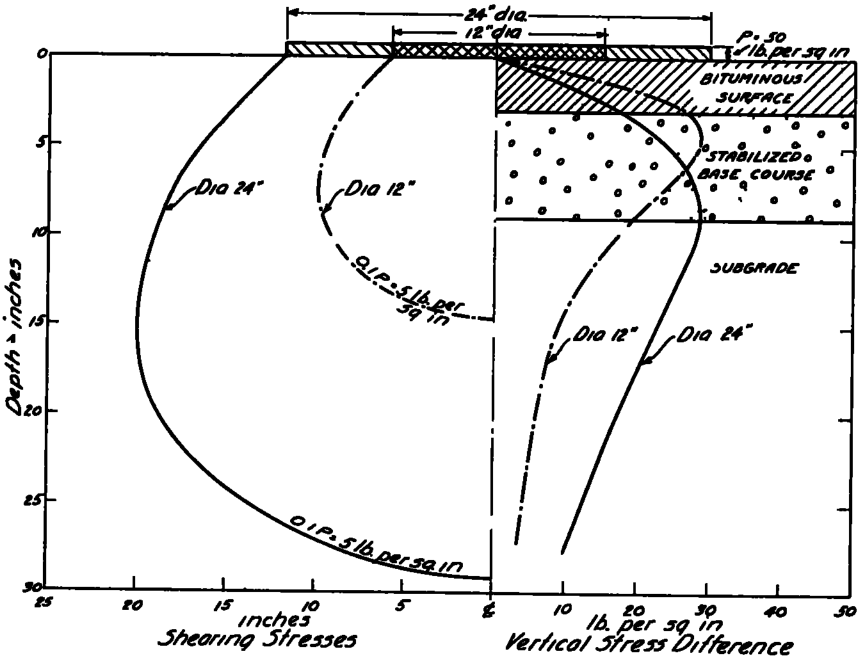

Figure 1. Effect of Increased Bearing Area on Subgrade Stresses

Figure 2. Relation Between Bearing Plate Diameter and Supporting Value of Soil.

good, however, it is believed that neither curve should approach tangency, but should in general, continue to show a decrease in bearing strength with increased area. On the basis of the relationship shown by the curves, the 30-in. diameter bearing plate was selected for all subgrade loading tests.

The field load tests were conducted with relatively simple equipment consisting essentially of a circular rigid bearing plate, a hydraulic jack equipped with a load indicating gauge, dial indicating gauges to measure the deflection or deformation of the bearing plate, and a suitable reaction load The dial indicating gauges are fastened to a bar, supported beyond the limits of possible influence from the loading of the plate. Various pieces of equipment were used for the reaction load for the test, depending on local availability. A truck trailer loaded with steel plate, two trucks, connected by a steel beam against which the load is placed; and a LeTourneau Tournapull loaded with earth have all been used as a load reaction for bearing tests

Very briefly, the procedure for the tests is as follows. After the equipment is assembled, a load of 5 lb. per sq. in is applied to seat the bearing plate firmly This load is released and the zero reading of the dial gauges is obtained Loads are then applied in 5 lb per sq in increments, allowing practically full deformation between each increment of load The loads are applied and released in the same manner. On special research projects two cycles of loading are employed, with the first cycle kept below the estimated yield point of the material

Tests have been made on special test sections and on various pavements in service The test sections have all been constructed by first rolling and compacting the natural subgrade, placing a uniform subbase under each section and then constructing the base course and surface.

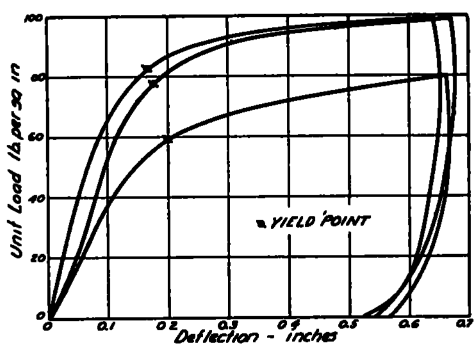

Figure 3. Comparative Test Data. Surface, Base Course and Subgrade

Separate test sections having different thicknesses of base and surface courses are included in the program Tests were also made of flexible runway pavements which have failed under service conditions On these latter investigations tests were made of both the failed and unfailed portions of the paving.

Results of these various investigations may be reported most briefly by reference to typical load-deformation diagrams obtained from typical test results Figure 3 shows typical load-deformation diagrams from tests on a bituminous stabilized base course project The curves shown are for surface, top of base course, and the confined subgrade. A decrease in bearing capacity with the removal of each layer is noted The yield points are somewhat less than 0.2 in for the various materials.

Results typical of the tests on service behavior of flexible pavements are shown on Figure 4. The three curves illustrate the load-deformation characteristics of an asphalt pavement on a commercial airport The tests in this case were made on sections representing paving in good condition, paving with small hair cracks, and paving which was failed to the extent that ruts have appeared in the surface due to

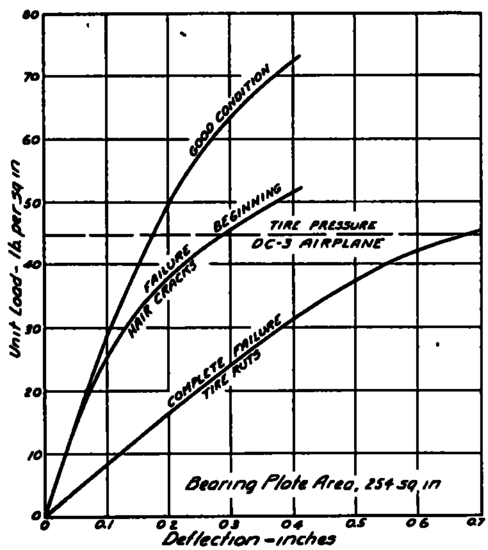

Figure 4. Condition Survey, Flexible Pavement at Commercial Airfield

the traffic of taxiing airplanes A unit pressure of 45 lb per sq in. comparable to the tire inflation pressure of the planes most frequently using the field produced deflections under the three conditions of 0.17 in, 0.28 in, and 0.67 in., respectively

Apparently the critical deflection for this soil lies somewhere between 0.17 and 0.28 in. for the number of repetitions to which it has been subjected. For a larger number of repetitions, the allowable deflection would be less. Although somewhat higher, the deflections compare fairly well with results of tests made by Stackhouse of the Washington State Highway

Department, in his excellent report on failures under logging truck traffic, in which he reports no service failure where the static deflection was less than 0 1 in. The cause of the failure in this case may be attributed to the subgrade as is the case in other instances which have been investigated by the Engineer Department In this connection, according to a recent report of Purdue University, 75 per cent of surface failures which they investigated were due to poor subgrade or base conditions. It is believed that subgrade failures are caused primarily by repeated excessive deflections which remoulds the soil directly under the base course and produces over a period of time a marked decrease in supporting power.

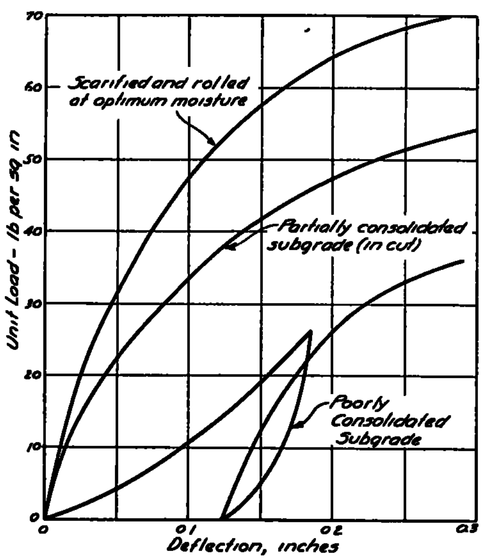

Figure 5. Effect of Subgrade Compaction

The strengthening of subgrades to gain support in bearing is the most essential and at the same time generally the most economical measure which can be taken In Figure 5, the two upper curves show the results of tests made on a subgrade being prepared for paving on a military airfield. The bearing capacity of the natural subgrade at a point of slight cut in the grade line is shown in the intermediate curve The same material scarified and rolled at optimum moisture is shown directly above An increase in bearing capacity of 14 lb. per sq. in. was obtained at 0 1 in. deflection and 16 lb. per sq. in. at 0 2 deflection by this operation. The lower load-deformation curve shows the results of a test loading on a very poorly compacted subgrade. The release of load causes practically no rebound and the second cycle of loading climbed abruptly until the point of previous maximum was reached Test data of this type clearly indicate the necessity for good compaction

The effect of the addition of a compacted layer to the subgrade to increase the bearing is as marked as the effect of rolling and compacting the subgrade itself. The load-deformation curves for a compacted subgrade with the addition of a 6-in. base course is shown in Figure 6. With the base course, the yield point of the layers was not reached and the test was run to the limit of the reaction load. The increase in bearing due to the base course was 26 lb. per sq. in at 0.1-in. deflection and 37 lb per sq. in. for 0.2-in deflection.

On all subgrade bearing tests no effort has been made in the field to simulate the worst possible conditions of saturation of the subgrade which will occur under operating conditions with the base and surface courses in place. An estimate of the decrease in bearing capacity, due to the change in moisture conditions, can be made by the use of quick triaxial or direct shear tests. Duplicate tests should be run on the samples; one test with the moisture conditions as present at the time of the bearing test, and the other with the sample saturated to represent the worst conditions to be expected. The bearing capacity should then be modified in direct proportion to the change in shearing strength. This procedure is based on the relationship between diameter of bearing plate, modulus of elasticity, unit load, and settlement formulated by Froehlich and used recently on work in connection with the design of the Third Set of Locks at Panama. In Panama, excellent correlation was obtained between field bearing tests and laboratory triaxial tests on soft rocks. All tests should be made on the subgrade in its compacted state to eliminate the effect of consolidation.

The reduction in bearing capacity due to capillary saturation may also be determined by means of the modified bearing test developed by the California State Highway Department and reported in Proceedings of the 18th Annual Meeting, Highway Research Board, December, 1938 (Vol. 18), by O J. Porter. The reduction in bearing is measured by the decrease in resistance to penetration of a standard piston on a compacted and soaked sample as compared to the compacted sample at optimum moisture Although this test is empirical in nature, the results which are reported in terms of bearing ratio have been correlated to service behavior of similar materials in the field. As this method is adaptable to the determination of most of the variables entering into foundation and base course design for flexible pavements, tests are presently being made to correlate this with bearing test results. It is intended, when the correlation is complete, to utilize the California procedure for the design of base course thicknesses.

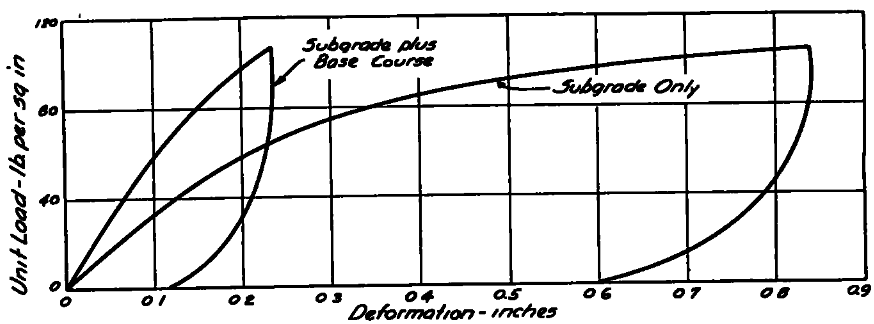

Figure 6. Subgrade and Base Course Bearing Tests

CONCLUSIONS

The results of the investigation to date warrant the following conclusions

(1) Field bearing tests or other methods of evaluating the load-carrying capacity of the subgrade and base course treatment are essential on every airport project

(2) Compaction of the subgrade should be accomplished over the entire runway area, both cut and fill, to produce the desired maximum bearing capacity.

(3) The maximum utilization should be made of local materials for base courses in flexible pavement design.

(4) Failures of pavements in service are largely attributable to inadequate subgrade and base course preparation

(5) Bearing capacity for the design of flexible pavement should be taken at a deflection which does not exceed the yield point of the soil in order that repeated application of load will not cause remoulding and a corresponding reduction in bearing capacity. On the basis of static tests, it appears that for general use this deflection should not be taken greater than 0 2 in. However, it must be recognized that for a large number of repetitions the allowable deflection will approach 0 1 in.