MEASURING THE LOAD SUPPORTING VALUE OF FLEXIBLE PAVEMENTS

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SYNOPSIS

This paper presents laboratory and field data showing the decrease in unit strength as the area of the testing plate increases The laboratory tests were made on 4 ft by 4 ft samples compacted to various thicknesses in steel boxes Each layer or combination of layers was tested successively with four circular plates having areas of 36, 72, 144 and 216 sq in Load readings were taken at various deformations between 0 and 25 in after a static load had been applied for 2 min The experiments were on soil compacted so as to contain a minimum of air voids and on soil-aggregate mixtures compacted to maximum density at optimum moisture content Seven sets of tests were made

The field tests were made on a subgrade prepared for airport runways The upper 12 in of the subgrade was compacted to practically 100 per cent of maximum density at optimum water content and tests made as soon as compaction was completed In addition to the four plates used in the laboratory a fifth plate having an area of 432 sq in was added Loads were applied and deformations determined as in the laboratory In making these tests a strip of subgrade about 5 by 15 ft was smoothed off, the various bearing plates bedded with a plaster of paris mixture upon the subgrade at intervals of about 3 ft, and tested successively Eleven sets of tests were made

Both the laboratory and field tests indicate that the unit-strength-plate area relation is shown by a curve parabolic in form

Since the laboratory and field curves are almost identical in form it is thought that the laboratory set-up is suitable for the determination of the load bearing values of flexible surfaces

In designing flexible pavements, which consist of stabilized soil subbases and bases topped with a bituminous surface, the engineer must take two major factors into consideration The first deals with the stability or durability of the stabilized soil or soil aggregate mixtures. The tests used in this connection measure the resistance of the layers to volume changes when submitted to the actions of drying, freezing and capillarity The second deals with the load-supporting value of the pavement. To be able to design adequately and economically, we need to know the rate at which stabilized layers increase the natural subgrade strength, the deformation at which to make strength tests, and the variations in strength with plates of different sizes. This paper is limited to presentation of some data relative to the last two phases

Engineers recognize that the unit load-bearing value of this class of pavement decreases as the size of the loaded area increases. However, the rate at which this decrease takes place is not well established In connection with the design and construction of runways on two airports this year we had an opportunity to make a good many load-bearing tests, both in the laboratory and in the field.

The design for one of the airports specified at least 12 in. of densified soil on the upper portion of the subgrade, a 5-in sand-gravel-clay base and a 2-in. hot mixed bituminous wearing surface, while the other called for a 6-in. compacted subgrade, an 8-in sand-gravel-clay-emulsified asphalt base, and a 2-in hot-mixed bituminous surface. No load-bearing requirement was specified on either project but at least 75 lb. per sq in. with a 432-sq. in plate at ¼-in. deformation was expected.

LABORATORY TESTS

Since the natural subgrade on one of the airports was known to be very weak, it was considered necessary to make some laboratory tests to determine the rate at which its strength could be increased by replacing some of the upper portion with a selected densified soil. The tests were planned in such a manner as to obtain information on the unit strength-testing area relationship.

To conduct the tests we used one 4-ft. by 4-ft. steel mold 12 in deep with attached bottom and 4-ft by 4-ft molds 6 in. deep without bottoms The circular testing plates had areas of 36, 72, 144 and 216 sq in. The loads were applied by means of a pipe testing machine and deformations were determined with two gages graduated in 0 005 in. Deformation readings were taken at approximately 0 08, 0 16, and 0 24 in Loads were applied at the rate of about 8,000 lb per min and 2 min. were allowed to elapse after the application of the load before load-deformation readings were taken Special attention is called to the fact that all layers were compacted with an air tamper and contained a minimum of air voids (1 to 3 percent)

An outline of the tests made is as follows:

Four subgrades of various strengths were prepared and placed successively in the 12-in. mold Each was first tested with a 36-sq. in. plate. Next a 6-in layer of a selected soil, compacted to maximum density at optimum moisture content, was placed above each of the subgrades and tested with the four plates (Tests 1, 2, 3, and 4, Table 2). After this two 6-in sand-gravel-clay mixtures were prepared, compacted to maximum density at optimum moisture content, and tested above one of the subgrades (Tests 5 and 6, Table 2) Finally a 12-in layer of selected soil was tested above one of the subgrades (Test 7, Table 2) The superimposed layers were not fastened to the subgrades. For the sake of clarity, the selected soil layers were designated as subbases and the sand-gravel-clay layers as bases All the subgrades were prepared from one soil by varying the water content The deformations reported represent the total testing plate settlements.

The subgrade strengths with corresponding water content are given in Table 1. The subbase samples contained 17 4 percent water and the bases contained 5 7 and 6 3 percent water, respectively

TABLE 1
DATA ON SUBGRADES

Subgrade No	1	2	3	4
Water Content	23 8	19 9	18 9	18 0
Load-Bearing Value with a 72-sq in plate at ¼-in deformation	15	24	78	127

In Table 2 are given the load-bearing values obtained with all combinations and testing plates It should be observed that these combinations give a wide range of strengths For example, with a 216-sq in. testing plate the strengths vary from 25 to 100 lb per sq. in In preparing this table only the strengths at ¼-in. deformation are given They were calculated from curves constructed with the three load-deformation determinations made during each test

In Table 3 the strength of each plate, in each combination, is expressed as a percentage of the strength obtained with a 72-sq in. plate These data were used in constructing Figure 1. This figure shows that if a flexible surface has a

TABLE 2

LOAD-BEARING VALUES WITH VARIOUS TESTING PLATES AT ¼-IN DEFORMATION

Plate area, square inches	Load-bearing values in lb per sq in						
	Test No						
	1	2	3	4	5	6	7
36	51	79	118	167	89	88	205
72	42	68	108	145	70	72	164
144	30	44	78	112	52	52	123
216	25	42	59	83	44	48	100

TABLE 3

STRENGTH RESULTS IN TABLE 2 EXPRESSED AS PERCENTAGES OF THE 72-SQ IN PLATE STRENGTH

Plate area, square inches	Percentages							
	Test No							
	1	2	3	4	5	6	7	Average
36	121	117	114	115	122	125	120	120
72	100	100	100	100	100	100	100	100
144	71	65	72	77	72	75	75	72
216	60	62	55	57	67	61	61	61

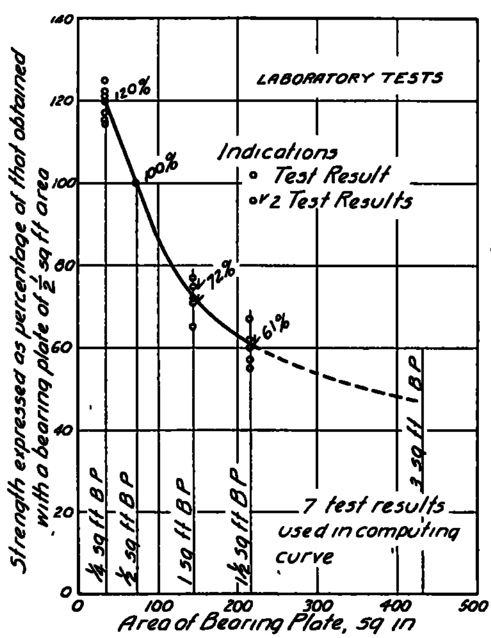

Figure 1. Curve Showing Variation in Load Bearing Value in Relation to Bearing Plate Area at ¼-in. Deformation.

The data for this curve are given in Table 3.

load-bearing value of 100 lb. per sq. in. when tested with a 72-sq. in. plate, it will give a strength of 120, 72, and 61 lb, when tested with plates having areas of 36, 144, and 216 sq in., respectively.

FIELD TESTS

During the construction of runways on one of the airports load-bearing tests were made on the improved subgrade at 11 different locations In addition to the plates used in the laboratory, another, having an area of 432 sq. in., was added. Heavy dirt movers were used as resistances and loads were applied by a hydraulic jack, equipped with a gage Deformations were measured 1 in. from the center of the plates with gages graduated in 0.005 in Readings were taken and loads applied as in the laboratory tests.

In making a set of tests a strip of subgrade about 5 ft. by 15 ft was cut fairly smooth with a blading machine and nails set, even with the ground, about 3 ft apart along the center of the 5-ft. dimen-

sion The proper size paper was next set on each nail and a wet mixture of cement and plaster of paris spread on The plates were lowered on the mortar and well seated as quickly as possible. After about 30 min. tests were made with the small plate. The upper end of the jack ram was provided with a ball and socket arrangement to insure vertical application of loads. The deformation gage was carried by a 4-in. by 4-in angle iron 6 ft long, which in turn was supported at its ends by 4-in. by 4-in wooden blocks. The wooden blocks were always at least 24 in. from the perimeter of the plates and the tires of the loaded vehicles. Previous tests on this soil had shown that with a 22,000-lb. load the 216-sq. in. plate produced a deformation of about 0.01 in. at a distance of 24 in. from its perimeter. The tires of the dirt mover with a load of 17,000 lb. per wheel produced about the same deformation at the same distance away from the points of contact with the surface as did the plate.

The results of all tests are shown in Tables 4 and 5 and Figure 2 In constructing this curve all of the results from the 11 sets of tests were plotted, but in locating the curve only 7 sets of points were used, as shown. The average of all the tests with any one plate is practically the same as shown on the curve, but some of the tests were eliminated, due to the fact that it proved almost impossible to select 15-ft. strips of uniform strength throughout. Attention is called to the fact that Figure 2 is very similar to Figure 1.

TABLE 4

LOAD-BEARING VALUES OBTAINED WITH VARIOUS TESTING PLATES AT ¼-IN. DEFORMATION

Plate area, square inches	Load-bearing value in lb per sq in.										
	Test No.										
	1	2	3	4	5	6	7	8	9	10	11
36	111	100	136	153	223	250	167	189	275	172	252
72	100	90	119	125	196	240	135	132	189	152	185
144	97	62	113	94	105	163	111	97	146	97	142
216	74	53	96	78	101	145	100	88	123	77	116
432	62	39	71	40	93	111	72	64	98	90	98

TABLE 5

STRENGTH RESULTS IN TABLE NO 4 EXPRESSED AS PERCENTAGES OF THE 72-SQ IN PLATE STRENGTH

Plate area, square inches	Percentages										
	Test No										
	1	2	3	4	5	6	7	8	9	10	11
36	114	100	114	122	114	104	124	143	145	113	136
72	100	100	100	100	100	100	100	100	100	100	100
144	76	69	95	75	54	68	82	73	77	64	77
216	64	59	81	62	52	60	74	67	65	51	63
432	46	43	60	32	47	46	53	48	52	59	52

SOME OBSERVATIONS MADE IN CONNECTION WITH THE TESTS

In conducting the tests some related observations were made, which are added to this report.

1. The first observation deals with the

behavior of the surfaces under the various plates In general most of the deformation observed with the smallest plate is due to penetration, while with the large plate it is due to flexure. However, the permanent deformation is about the same for all plates at ¼-in deformation. In other words, the amount of permanent surface deformation produced is about

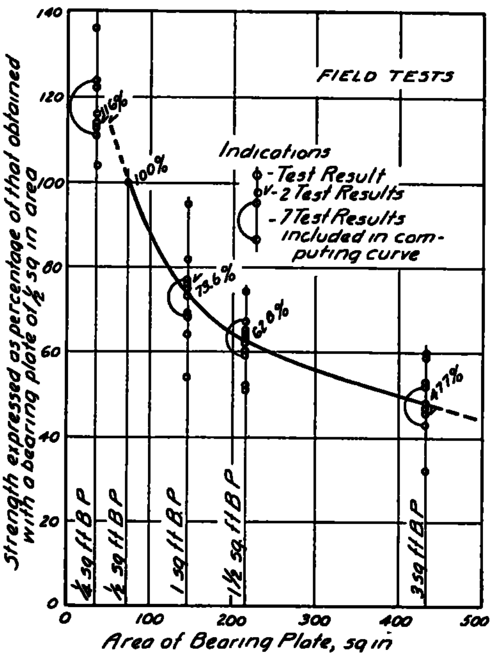

Figure 2. Curve Showing Variation in Load Bearing Value in Relation to Bearing Plate Area at ¼-in. Deformation.

The data for this curve are given in Table 5.

the same, regardless of whether the deformation is due to penetration, flexure, or a combination of the two. In these tests the permanent deformation averaged about 45 percent of the total deformation

2. When the deformation is carried beyond ¼ in a circular crack a few inches away from the perimeter of the plates appears and increases in width as the deformation increases. This is especially apparent with the larger plates Furthermore, the percentage of permanent deformation increases, very rapidly when the tests are made at deformations greater than ¼-in. Whereas, the permanent deformation was about 45 percent for the first ¼ in total deformation, it was about 60 percent for the next ¼ in

3 In these tests 6 in of well compacted suitable soils added about 17 lb. per sq in strength to subgrades at ¼-in. deformation with a 216-sq in plate, while 6 in of well compacted sand-gravel-clay mixtures added about 25 lb. Because of moisture changes, it is difficult to make reliable determinations of this type during construction We have obtained most satisfactory results by testing finished pavements. Tests are first made on top of the base, the base is then removed, and the subbase tested. Finally the subbase is removed and the subgrade tested.

4 So far we have not made load-bearing tests on top of the bituminous wearing surfaces Such tests would no doubt be of value but should be made when the surfaces reach their maximum temperature in the summer time. For the present we are using the strength added by the wearing surface as a part of the safety factor

CONCLUSIONS

1 Since the laboratory and field curves are amost identical it may be assumed that the laboratory set-up is suitable for the determination of the load-bearing values of flexible surfaces.

2. It is thought that the test data presented are sufficient in magnitude and cover a range wide enough to indicate a definite trend.

3. We believe that the empirical formula derived is sufficiently accurate to be used in connection with routine field testing. In actual work we use either the one-half or the one square foot plate and estimate the load-bearing value for the larger plates by use of the curve.