STRUCTURAL BEHAVIOR OF CONCRETE AIRFIELD PAVEMENTS—THE TEST PROGRAM

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SYNOPSIS

The great increase in weight of certain types of aircraft, and the tendency to concentrate the loads on a minimum number of wheels presents problems in the design of runway pavements that require investigation.

The rigid pavement laboratory at Cincinnati of the Corps of Engineers has performed tests to determine the effect of impact of a landing wheel of variable load on a rigid pavement, to measure the reactions of a pavement under a set of idealized conditions as assumed by Westergaard's theory, and to study the effect of accelerated traffic on rigid pavements. Impact effects were studied by means of flight tests and drop tests, wherein the reactions both in the plane and in the pavement were correlated. Static loading tests were employed to check the validity of theoretical assumptions, and later to correlate the effects of repeated loading to the results observed in traffic tests. Accelerated traffic tests with wheel loads ranging from 20 to 60 kip have been conducted on thirty-seven designs, and all preparations have been made to traffic test nineteen basic designs with a 150 kip wheel load.

The paper is a description of the procedures and methods employed in testing. It establishes for record the basis for future presentation and discussion of results.

The years immediately before the war and those since its beginning have witnessed a tremendous development of all types of military aircraft. Not the least spectacular of these developments is the advancement of the heavy land-based bomber and cargo ship. Today we read of building pavements for 150 kip wheel loads, a six-fold rise in as many years from a wheel load standpoint. Experts in aircraft design speculate sagely that it would not be safe to guess that heavy aircraft of the future will weigh less than a million pounds.

These heavy aircraft, when used as bombers, must possess long range and large bomb carrying capacity. This demand, coupled with the structural difficulties of multiple landing gear, has resulted in a marked tendency on the part of plane designers to concentrate the loads of planes on the minimum number of wheels, thereby multiplying the need for heavier and heavier pavements.

The Corps of Engineers has met the challenge of these designs by accelerated testing of extrapolated designs. The investigations for rigid pavements have been centered largely in the Ohio River Division, where its unit, the Cincinnati Testing Laboratory, has been designated as the Engineer Department's Rigid Pavement Laboratory.

REVIEW OF THE TEST PROGRAMS

Originally three general types of tests were undertaken; static loading tests on concrete slabs, both existing and specially prepared, to measure stress-deflection and the ultimate strength properties of these slabs; observation of tire imprints, acceleration, photographs of tires and other effects produced by a plane upon landing on a concrete runway; and, drop tests to discover if the stresses resulting from a dynamic force such as that of a plane on landing, are equal or differ from those resulting from an equivalent static force.

From October 10, 1941 to December 5, 1941, a series of static loading tests were conducted on an existing hangar apron at Wright Field, which was constructed by the Quartermaster Corps in 1929. In the period from December 23, 1941 to September 1, 1942, static loading tests were conducted on nine prepared slabs of various designs at Wright Field. On October 8, 1941, flight tests were conducted at the Dayton Municipal Airport, Vandalia, Ohio, using a B-26 Martin medium bomber. In addition, observations were made during the trial flights of the B-19 Douglas bomber during its stay at Wright Field January to November, 1942. Dynamic loading tests were conducted on two of the prepared slabs at Wright Field during the period from August 24, 1942 to September 3, 1942.

In addition to the tests at Wright Field, the Chief of Engineers approved a service behavior test to be conducted at Godman Field, Fort Knox, Kentucky, starting March 7, 1942. These tests proved to be of short duration, largely because of the total inadequacy of an existing 5-in. concrete pavement. To fulfill the request for information, these tests were continued, starting May 5, 1942, on the runway and turnaround button at Northern Field, Camp Forrest, Tennessee. In both of these cases, destruction of the pavement was brought about by the traffic of a Model A-3 "Tournapull" hauling a LeTourneau Model N.U. Scraper unit, capable of being weighted to wheel loads of 60,000 lb.

The mounting weight of aircraft and early results indicating that existing designs were truly optimistic, gave impulse to the need for more comprehensive studies. On June 25, 1943 the Chief of Engineers authorized the construction and testing of an oval track which, for the first time, combined the observations of static and traffic tests at one location. This track, known officially as Lockbourne No. 1, was built in the late summer and fall of 1943, at the Lockbourne Army Air Base near Columbus, Ohio. Traffic tests were begun as soon as weather permitted in the spring of 1944, and were completed in December of that year.

In that the Army Air Forces again raised their sights, it became necessary to investigate rigid pavement designs for wheel loads up to 150 kip. On September 1, 1944 the Chief of Engineers directed the construction and testing of an experimental mat, known officially as Lockbourne No. 2. This mat, located adjacent to the track, was built in the fall of 1944, and will be tested as soon as weather permits in the spring of 1945.

TESTS AND TEST DESIGNS

Static, Flight and Drop Tests

Static Loading Tests, Apron Series. Dead load was applied by use of a jacking frame, consisting of four 24-in. I-Beams 32 ft. long, supported on timber cribs spaced 22 ft. center to center. This frame is constructed in two units, each of which can be used separately or combined into a single frame. Concrete blocks, weighing 1 ton each, piled upon this frame, are used for dead weight. (See Fig. 1.) Two Simmons calibrated hydraulic jacks of 30 ton capacity, and one Watson-Stillman calibrated hydraulic jack of 250 ton capacity, were available to apply the load from the jacking frame to the pavement. A 10-ton diesel powered caterpillar crane was used to

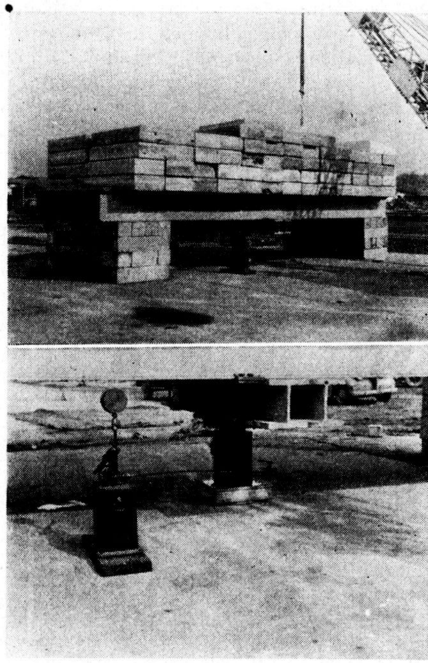

Figure 1. Photograph of the assembly used for applying static loads to pavements.

handle the equipment. The load on the pavement, in each case, was applied through a rigid grill to a circular bearing plate, under which was placed a $\frac{1}{4}$-in. thick rubber mat. Increments of load were selected such that each increment was one-eighth the estimated load carrying capacity of the slab. Each increment of load was applied and held until all deformation of the slab had ceased in an interval of time fixed by the difference of the square of a unit number of minutes; for example, 25 to 36 min., or 49 to 64 min., etc. The deformation of the slab was measured by five Ames dial gages (1/10,000-in.) supported by a 2-in. angle, 14 ft. long, which in turn was supported by small concrete pedestals grouted to the slab. The load was increased by increments until the slab failed, at which time a sketch of the crack pattern was made. The slabs were tested in corner, edge, center and joint loading with 8- 12- 18- 24- and 30-in. diameter bearing plates. The apron pavement consisted of a 7-in., lightly reinforced, uniform slab, with free joints. The mesh was No. 6 gage wire spaced 6 in. by 6 in. placed in the midplane of the pavement, which in turn was placed upon the natural subgrade.

Static Loading Test, Prepared Slab Series. These tests were similar in character to those in the apron series but differed in many details. First, a series of three slabs 30 ft. by 12.5 ft., split by a dummy groove joint into two slabs 15 ft. by 12.5 ft., were cast on a natural subgrade. These slabs were of 6- 8- and 10-in. uniform thickness, respectively. As the tests on these slabs proceeded, it was soon found that the results were being influenced by the dissymmetry of the slab, caused both by shape and the dummy joint. It was decided therefore, to construct all remaining slabs 40 ft. by 20 ft. each split by a free joint into two units 20 ft. by 20 ft.; a layout is shown on Figure 2. The resulting symmetry proved to be beneficial both to check observations and to compare results with available theory. As a result of the experience gained on the apron series, it was decided to isolate the dial gage supports from the slab as well as to increase the number of observed deformations. This idea developed, until with the latest tests, an independently supported framework held 18 dial gages, resulting in more complete and more correct observations of deformation. In addition, soil pressure cells and hydrostatic pressure cells, of the Waterways Experiment Station Type, were placed into the subgrade of these slabs before the slab was cast, and records of the pressure as indicated by these cells were

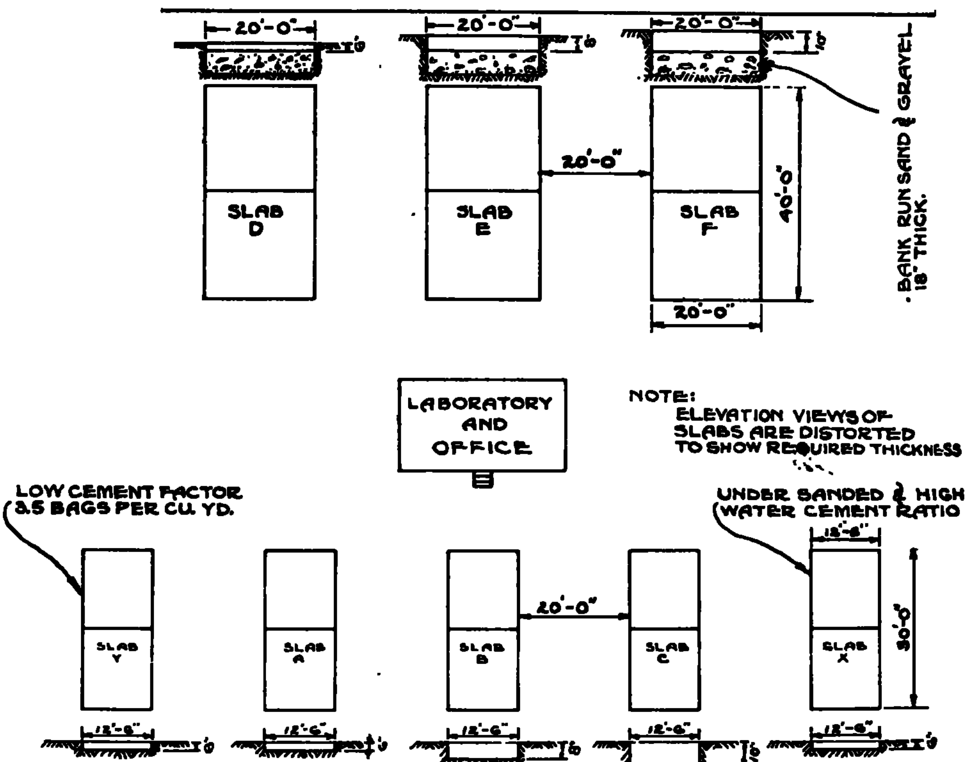

Figure 2. Layout of Test Slabs, Wright Field

made both before and during the loading period. These pressure cells were located so as to coincide in position with the deformation gages on the surface. In addition, strain gages known commercially as the Type A, SR-4 Metalectric Strain Gage, (Baldwin-Southwark Company, manufacturers), were arranged in rosettes of three at selected points on the top surface of the concrete test slabs. These gages were placed just before the slab was loaded, and the strains indicated thereby were recorded during the period of loading. Thermohms were placed at three levels and at one location within the test slabs, which permitted a record of temperature during the curing period and during each test. Nine slabs were constructed and tested. A summary of the salient properties of these slabs is given in Table 1.

TABLE 1

Slab Designation	Horizontal Dimensions	Thickness of Slab	Base Type	Character of Concrete
	ft.	*in.*		
A	30 by 12.5	6	Subgrade	Normal
B	30 by 12.5	8	"	Normal
C	30 by 12.5	10	"	Normal
X	30 by 12.5	6	"	Under sanded
Y	30 by 12.5	6	"	Low cement factor
D	40 by 20	6	18-in sand and gravel	Normal
E	40 by 20	8	" "	Normal
F	40 by 20	10	" "	Normal
I	40 by 20	8	Subgrade	Blend

Note: Slabs A, B, C, X and Y, split into two slabs 15 ft. by 12.5 ft. by a dummy groove joint.
Slabs D, E, F and I split into two slabs 20 ft. by 20 ft. by a free redwood joint.
All concrete was moist cured (burlap and straw) for 14 days.

Flight Tests. These tests are grouped in the Wright Field series, although the actual tests were conducted at the Dayton Municipal Airport at Vandalia, Ohio, insofar as that airfield was the only one in the vicinity having concrete runways at the time. These tests were conducted by the Army Air Forces with a crew from the Corps of Engineers doing the ground work. A Martin B-26 Medium Bomber, having a gross weight of 31,500 lb., was used. The process was one of measuring the tread mark left on the runway after each of a series of particularly severe landings. At the same time, high speed photographs of the tire during the landing contact were taken from the open bomb bay of the plane. A Kollsman Type B mechanical accelerometer was mounted on the fixed portion of the landing strut. This instrument records only the maximum acceleration. In addition, attempts were made to record the deformation of the strut and the radial deflection of the tire during the landing period by mounting tell-tails on the strut and wheel assembly which were photographed at the same time the tire was photographed. In addition to these studies, a few measurements were made of the wheel marks left in landing by the B-19 during its stay at Wright Field from January to November, 1942.

Dynamic Loading Tests. For these tests a drop test rig belonging to the Alighting Gear Section of the Army Air Forces at Wright Field was used. The rig, shown on Figure 3, with a B-26 shock strut and wheel assembly mounted to it, was dropped vertically on the slabs tested from measured heights of 6, 12, 18 and 24 in. The rig was positioned over the point of loading on the slab by means of the mobile framework shown on Figure 3. A 10-ton capacity crane was used to set the frame and to lift the drop test rig for the dynamic loading. The static weight of the rig could be varied from 5,000 to 15,000 lb. by adding weights in the basket: however, the maximum weight dropped was 10,000 lb. The dynamic loads applied in this manner were evaluated by means of the accelerations measured by the accelerometers mounted on the basket or mass of the assembly. Two types of accelerometers were used for these measurements, the Kollsman Type B accelerometer, described under *Flight Tests*, and an electrical resistance type constructed and calibrated by U. S. Waterways Experiment Station, Vicksburg, Mississippi. With this latter type of accelerometer a complete record of the acceleration of the mass could be obtained from the time the assembly was released till it came to position of stable equilibrium on the slab. An extensive series of tests was made on two of the prepared slabs; namely slab B (8 in. thick) and slab D (6 in. thick) (see Fig. 2). For these test series the following measurements were made simultaneously with the accelerations: Surface strains from SR-4 strain gages mounted on the surface of the slab, subbase reactions from pressure cells set flush with the base of the slabs, and tire print areas for maximum loads. These measurements were made for both static and dynamic loads applied by the drop test assembly.

Service Behavior (Traffic) Tests

Godman and Northern Fields. These early tests were made by observing the reactions of traffic of a Model A-3 Tournapull hauling a mechanically stabilized gravel base. A total of 17,761 passes was made with the equipment, with wheel loads varying from 26 to 42 kip. Although the test lane was still serviceable after this traffic, the cracks were extensive and failure was judged to have occurred. In both tests, sketches were made of the cracks as they

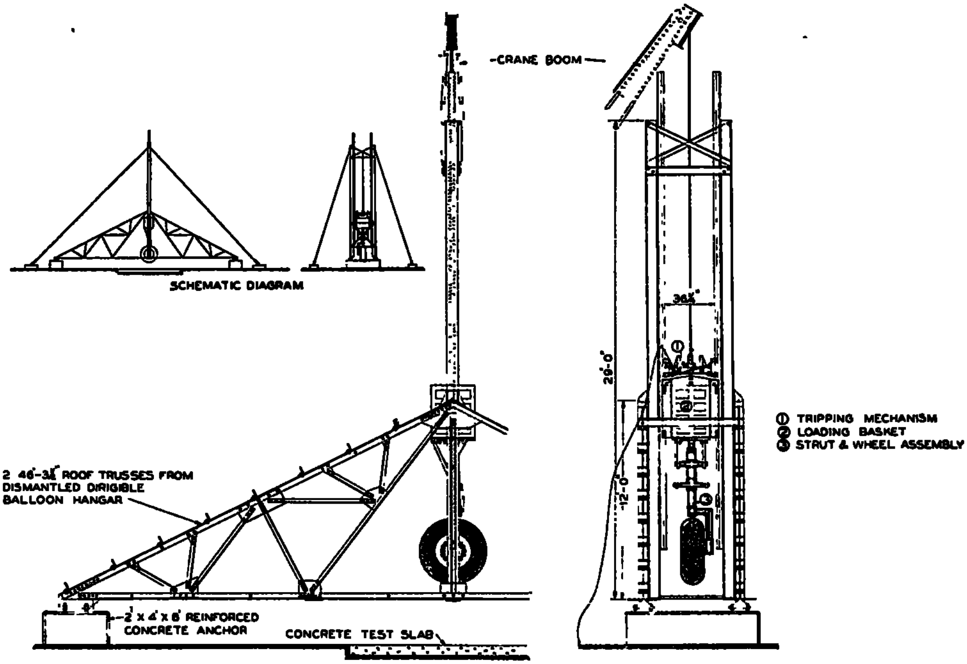

Figure 3. Wright Field Slab Tests Sketch of Assembly For Dynamic Loading Equipment

loaded Model N.U. Scraper on concrete pavement. This equipment is mounted on four 30-in. by 40-in. tires, with an inflation pressure of 45 psi. By loading the pan of the unit, wheel loads from 26 to 60 kip can be produced as desired. A photograph of this equipment is shown in Figure 4 (upper). These tests were started on the Godman Field apron, a 7–5–7 concrete slab. With the lightest wheel load (26 kip) 2260 passes of the equipment rendered the test section useless (see Fig. 4 (lower)), and the traffic portion of this test was considered finished. Insofar as the results had been so sketchy, the equipment was moved to Northern Field (Camp Forrest Airport) Tullahoma, Tennessee, where a test lane was located on the turnaround button at the Southwest end of the Northeast runway. The pavement here consisted of a 9–7–9 concrete slab on a 6-in.

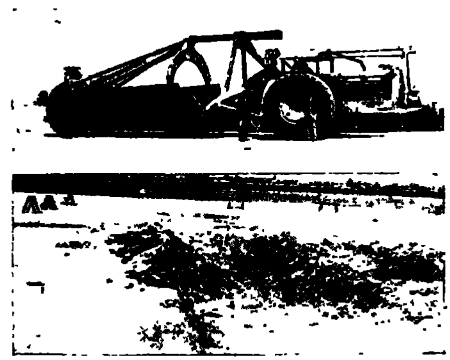

Figure 4. Service Behavior Test on Concrete Apron at Godman Field. Testing Equipment and View of Area in Monoliths D-11, D-12 and D-13 Showing Complete Disintegration of Pavement and Displacement of Subgrade. Note Upheaval of Slab in left center. Photo by Army Air Force.

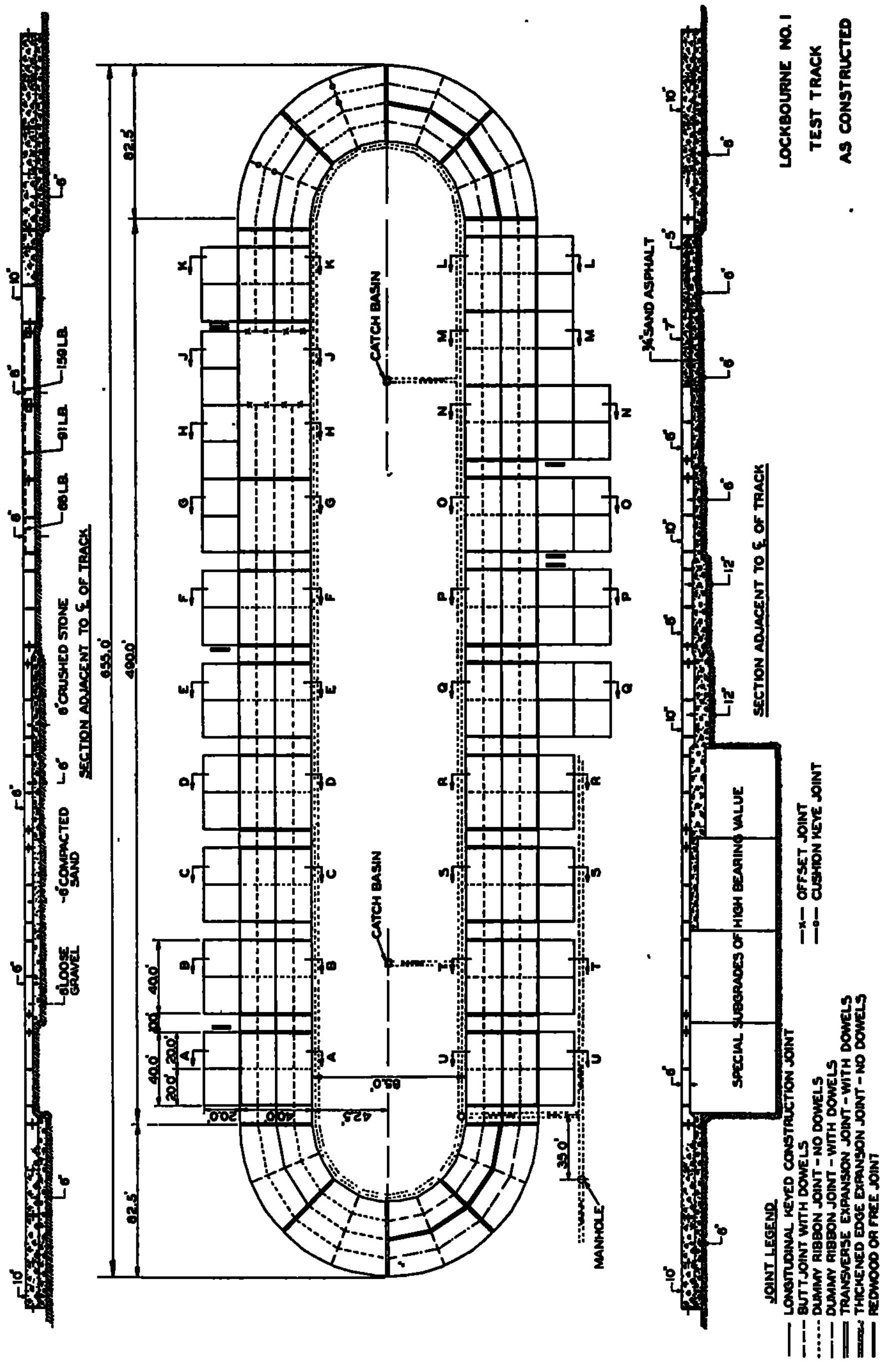
LOCKBOURNE NO. I
TEST TRACK
AS CONSTRUCTED
SECTION ADJACENT TO ℄ OF TRACK
6" LOOSE GRAVEL
6" COMPACTED SAND
6" CRUSHED STONE
159 LB.
91 LB.
65 LB.
655.0'
490.0'
82.5'
82.5'
CATCH BASIN
CATCH BASIN
MANHOLE
SECTION ADJACENT TO ℄ OF TRACK
3/4" SAND ASPHALT
SPECIAL SUBGRADES OF HIGH BEARING VALUE
OFFSET JOINT
JOINT LEGEND
LONGITUDINAL KEYED CONSTRUCTION JOINT
BUTT JOINT WITH DOWELS
DUMMY RIBBON JOINT - NO DOWELS
DUMMY RIBBON JOINT - WITH DOWELS
TRANSVERSE EXPANSION JOINT - WITH DOWELS
THICKENED EDGE EXPANSION JOINT - NO DOWELS
REDWOOD OR FREE JOINT

Figure 5

first occurred and then extended; photographs were not made because of the oil smeared onto the surface of the pavement by the equipment. Likewise, in both tests, deformations of the slab at the center and across the joints were rolled into position so that the deformation was indicated by the gage.

Lockbourne No. 1. The layout of the plan, and sections of this track are given on Figure 5. The general features of the plan to be

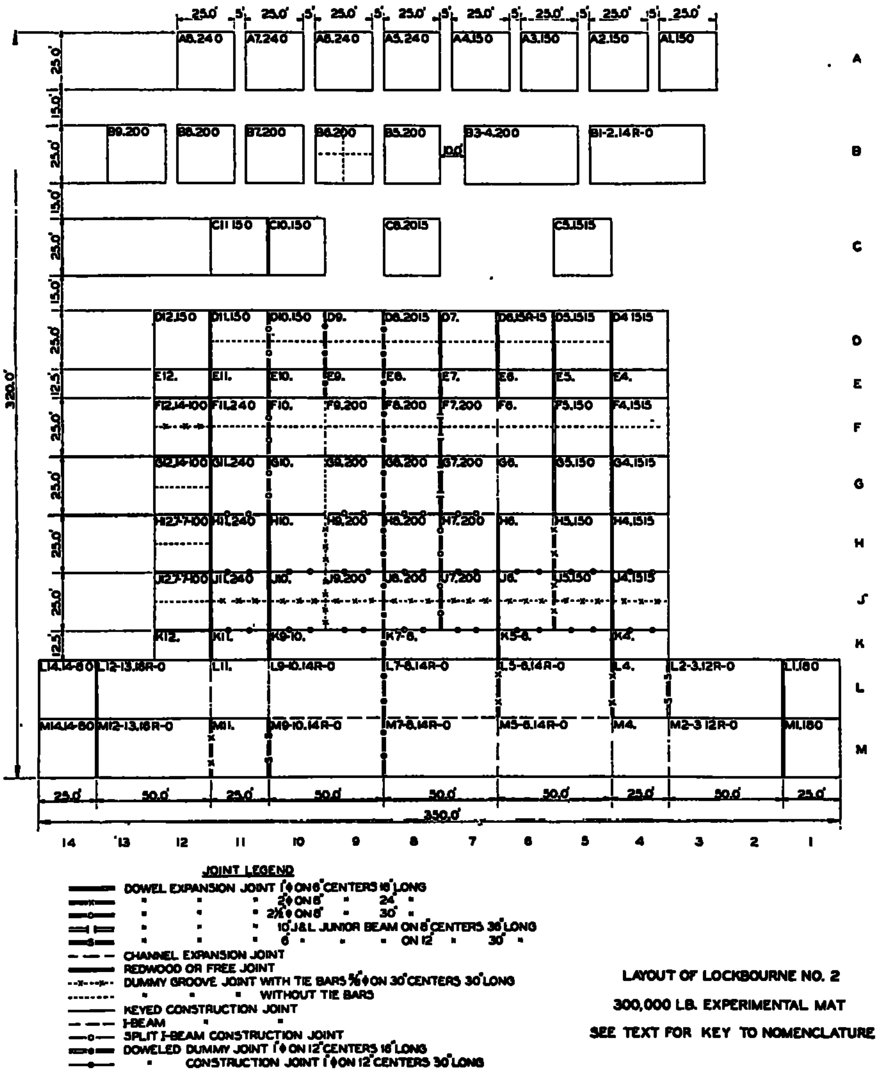

Figure 6

measured under the wheel load of the equipment at rest. These deformations were measured by means of a cantilever beam supported some distance from the point of loading. The dial gage was first set and the load carefully noted are: the two 20-ft. wide continuous traffic lanes, the adjacent 20 by 20-ft. slabs of design similar to those in traffic lanes for static load tests, and the special subgrades of high bearing value for sections R, S, T and U to evaluate subgrade quality. The subgrade for all the other sections is natural ground. The concrete units in each section are the same design and uniform in thickness providing combinations of 6-, 8- and 10-in. thick pavements on subgrade and on base courses 6- and 12- in. thick. This range in thickness of concrete and base treatment was originally considered adequate to bracket probable required designs for 37- and 60-kip wheel loads. On this basis it had been planned to test the inside traffic lane (Lane 1) with a 37-kip wheel load and the outside lane (Lane 2) under a 60-kip wheel loading. However, early breakup in Lane 1 under the 37-kip wheel load indicated the necessity of using a lesser wheel loading to evaluate the lighter designs. Therefore, sections A to K inclusive of Lane 2, were tested under a 20-kip wheel load traffic, to produce well developed cracking in the 6-in. slabs of these sections, after which a 7-in. concrete pavement was placed over the cracked slabs and transitions of Lane 2 from sections A to F inclusive, to carry the 60-kip wheel load traffic in this lane. During the course of traffic, many observations of deformation under static and moving wheel loads were made, as well as observations of curvature under stress, and permanent subsidence of pavement when under traffic. Attempts were made to distribute traffic uniformly, and as widely as possible over each lane. For the 37- and 60-kip wheel load traffic, the moving equipment previously described was used. A Model Super C Tournapull hauling a Model L.P. Scraper was used to provide 20-kip wheel load traffic. This equipment mounts 21-in. by 24-in tires fore, and 18-in. by 24-in. tires aft.

Lockbourne No. 2. A layout of this experimental mat is shown on Figure 6. Each test slab is designated by a letter and number showing location, followed by a decimal point, after which is an indicated design, first thickness of concrete, then thickness of base. "R" indicates general reinforcement and a dash separating numerals after the decimal point thickness of overlay. Transition slabs are designated by location only. For example, Slab G11.240 is located at "G", "11" is 24 in. thick and is directly on natural subgrade (no base). H4.1515 is a 15-in. slab on 15 in. of base course. M7-8.14R-0 is a 14-in. reinforced slab on no base; J12.6-6-100 is a three decker, a 6-in. slab on a 6-in. slab on a 10-in. slab with no base, etc. As built, drawings of steel layout are not yet available, insofar as construction has just been completed as this is written. Joint details are shown by legend; and these have been chosen to correct many of the faults revealed by previous tests. Special moving equipment to provide 150 kip wheel load traffic is now under construction. Gages and gage assemblies are being prepared and installed.

Auxiliary Testing. For all tests except the Flight Tests, great care was taken to obtain

TABLE 2

Slab Description	Thickness of Slab	Base Course	Character of Concrete	Load at Failure	Deformation of the Center of Loading at Failure
	in.			*tons*	*in.*
A	6	Subgrade	Normal	32.9	0.046
B	8	"	Normal	41.3	0.080
C	10	"	Normal	57.6	0.140
X	6	"	Undersanded	31.0	0.067
Y	6	"	Low cement factor	20.0	0.105
D	6	18 in. sand and gravel	Normal	57.5	0.318
E	8	" "	Normal	65.0	0.160
F	10	" "	Normal	90.0	0.150
Z	8	Subgrade	Blended (1 to 5)	80.0	0.160
Apron	7	"	Normal	112.5	0.153

Note: All tests shown are with center loading with a 30-in. diameter bearing area.

samples of the subgrade, base course, and concrete. Tests on these materials include:

On the Subgrade:

- Direct shearing tests on undisturbed samples.
- Consolidation tests (both quick and slow on undisturbed samples).
- California bearing ratio tests on undisturbed samples.
- Field bearing tests in place.
- Classification tests including limit tests, mechanical analysis, specific gravity, water content in place, etc.

On Base Course:

- Field bearing tests on the base in place.
- C.B.R. tests when possible.
- Classification tests.

Concrete:

- Tests on cement
- Modulus of elasticity both static and dynamic.
- Flexural strength.
- Compressive strength.
- Ring tests.
- Density.
- Absorption.

TEST RESULTS

In presenting an abbreviated story of the investigations of rigid pavements conducted by the Department, it has been necessary to omit many details to produce a digest of reasonable length. Likewise, any digest of results is not considered within the intended scope of this paper, and will be the subject of many discussions now in preparation by the members of the staff. A few isolated and independent results are presented, mainly, to give the reader something on which to taper off:—

Wright Field Apron Series. A comparison of the loads at failure under static loading is an indication of the following relationships for a uniformly thick 7-in. slab, having no joint transfer devices, and having been in use for 13 years.

Bearing capacity at an edge is $\frac{1}{3}$ of that for center loading.

Bearing capacity at a corner is $\frac{1}{6}$ of that for center loading.

Bearing capacity at a free joint is $\frac{1}{4}$ of that for center loading.

Wright Field, Prepared Slab Series. The end results of these static tests are shown in Table 2.

Flight Tests. It was found that the force of acceleration of a wheel upon contact in landing is largely compensated by the uplift of the wing of the aircraft still in motion. The greatest load factor for the severest landing, by aircraft weighing more than 15 kip, was 2.1. For normal landings the load factor is usually less than 1.0, for very heavy aircraft 0.65 to 0.80.

Dynamic Loading Tests (Drop Tests). The character and speed of the impact of a landing aircraft produce stresses which do not differ from those produced by a statically equivalent force.

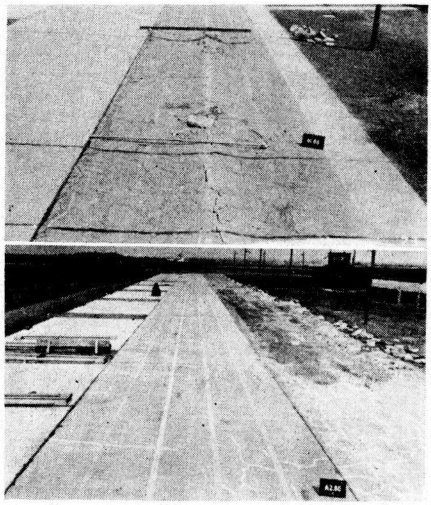

Figure 7. The progressive and complete destruction caused by an overtaxing wheel load. Note how the pavement has shifted on the base coarse; right of lower photograph. Lockbourne No. 1. A coverage is defined as two trips (passes) of the equipment shown on Fig. 4a.

(Upper) Transition between slabs C1.66 Sand D1.66 after 225 coverages of the 37,000 lb. wheel load. (2 May 1944)

(Lower) Lanes 1 and 2 of North Tangent after 370 coverages of the 37,000 lb. wheel load in lane 1. The cracks outlined in slab A2.60 are shrinkage cracks. (22 May 1944)

TABLE 3

Location	Subgrade					Base Course	Concrete	
	Liquid Limit	Plastic Limit	Natural Water Content	Foundation Modulus @ 0.05 in.	Undisturbed C.B.R.	% Undisturbed C.B.R.	Modulus of Rupture	Compressive Strength
Wright Field	34.2	18.5	15.5	100	7.7	115.0	745 psi	7,630 psi
Godman Field	39.9	24.3	20.2	120	7.1	None	650	6,000
Northern Field	43.9	27.2	20.7	140	16.1	13.7	700	7,800
Lockbourne No. 1	42.2	24.1	24.2	100	4.0	None	760	6,000

Service Behavior Tests. Figure 4 shows what happened to a 7–5–7 slab under a little traffic of a 26 kip wheel load. This early demonstration went a long way to prove the need for heavier pavements. It was estimated that the 9–7–7–9 pavement at Northern Field was adequate for wheel loads not to exceed 34 kip. Figure 7 shows two photographs taken at Lockbourne No. 1, which again illustrate the severe damage that can be caused by very little traffic of an overtaxing wheel load. The damaged sections shown are 6-in. slabs on 6 in. of various types of base course. It does not

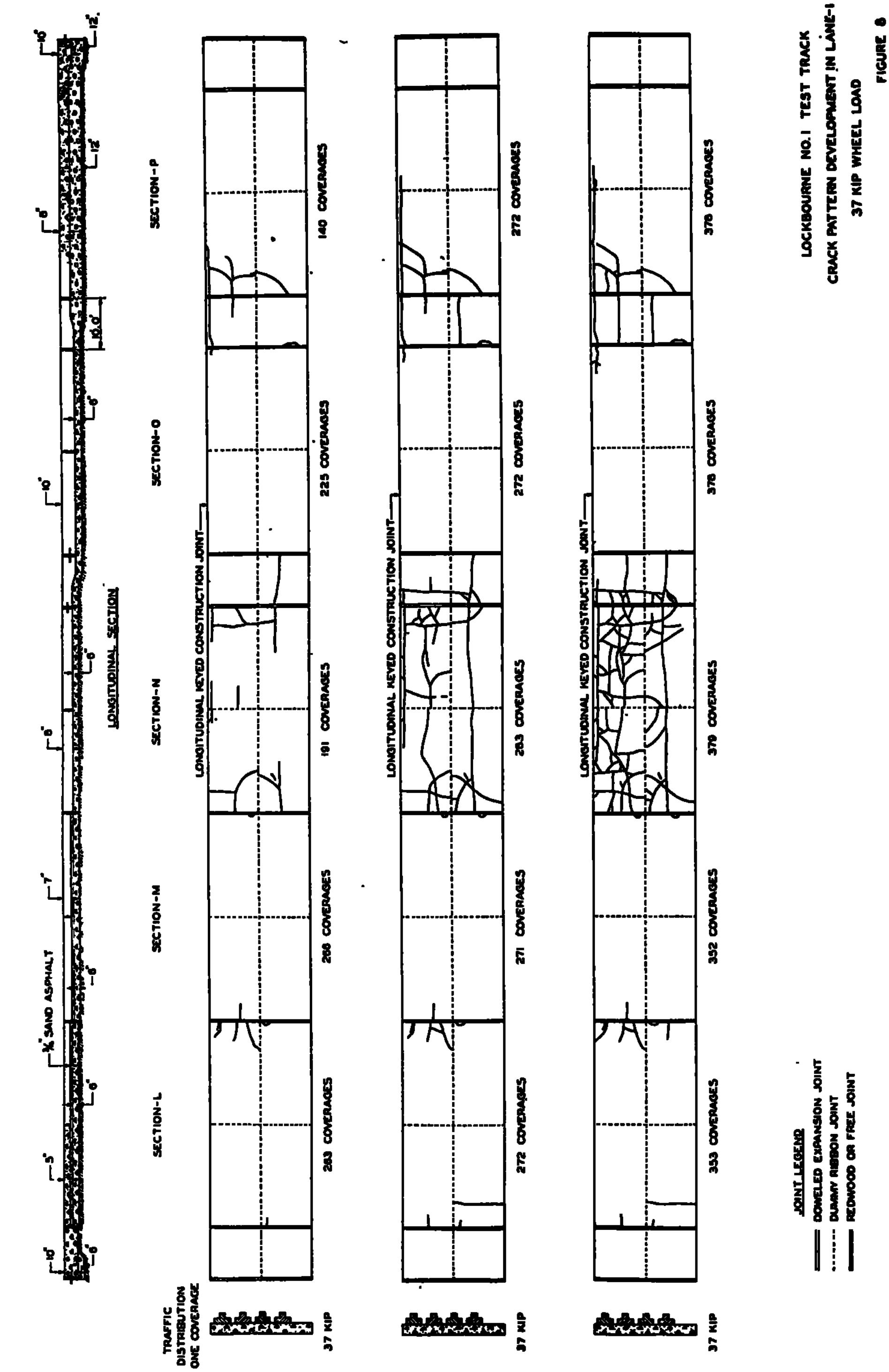
LONGITUDINAL SECTION
½" SAND ASPHALT
SECTION-L
SECTION-M
SECTION-N
SECTION-O
SECTION-P
LONGITUDINAL KEYED CONSTRUCTION JOINT
TRAFFIC DISTRIBUTION ONE COVERAGE
37 KIP
283 COVERAGES
268 COVERAGES
191 COVERAGES
225 COVERAGES
140 COVERAGES
272 COVERAGES
271 COVERAGES
263 COVERAGES
272 COVERAGES
272 COVERAGES
353 COVERAGES
352 COVERAGES
379 COVERAGES
378 COVERAGES
378 COVERAGES
JOINT LEGEND
DOWELED EXPANSION JOINT
DUMMY RIBBON JOINT
REDWOOD OR FREE JOINT
LOCKBOURNE NO. 1 TEST TRACK
CRACK PATTERN DEVELOPMENT IN LANE-1
37 KIP WHEEL LOAD
FIGURE 8

Figure 8

overtax the imagination to conclude that such designs are totally inadequate for a 37-kip wheel load for the conditions at Lockbourne. Figure 8 shows the development of crack patterns for five designs in the south tangent of Lockbourne No. 1. This illustrates the clear definition of results, and demonstrates the wide performance difference that can be expected from adequate and slightly inferior designs.

To enable the reader to make elementary comparisons a summary of average physical properties of the materials involved is offered in Table 3.

CONCLUSIONS

It is becoming increasingly clear that the designs for concrete airfield pavements resulting from the more commonly accepted methods of analysis are optimistic. In general it can be predicted that there must be revision of the basis of design which, for heavy aircraft, will require greater added strength of pavement.

ACKNOWLEDGMENTS

The tests at Godman Field were conducted by the forces of the U. S. Engineer Office, Louisville, Kentucky. Although the tests at Northern Field were conducted by the laboratory staff, the force of the U. S. Engineer Office, Nashville, Tennessee helped in many respects. The Material Division (now the Air Technical Command) of the Army Air Forces has lent equipment and personnel, and rendered many services. Credit is due the staff of the Cincinnati Testing Laboratory and the Ohio River Division for having done the rest of the work. This work was done under and by the authority of the Office, Chief of Engineers.

AIRFIELD PAVEMENT EVALUATION

BY MESSRS. H. J. LICHTEFELD, *Engineer, Runways Section* AND R. M. HAINES[1], *Soils Engineer for Military Construction, Office of Chief of Engineers, U. S. Army*

SYNOPSIS

The Office, Chief of Engineers initiated the Airfield Evaluation Program for military airfields in August 1943 after numerous requests had been received from various commands of the Army Air Forces to determine if airfields would withstand the traffic of specific aircraft to assist in the reallocation of stations brought about by planned increases in training programs.

The evaluation program was considered to be an engineering study to determine the carrying capacity of the pavement as constructed. It encompassed field surveys and investigations in conformance with instructions issued by the Office, Chief of Engineers and consisted chiefly of tests on subgrade, base, and surfaces for both flexible and rigid type pavements. For bituminous pavements, the California Bearing Ratio (CBR) test was performed on undisturbed samples of the subgrade and base; in some instances the tests were made on the material in place. Such tests were made after the removal of the surface course from selected locations on the runway, taxiway, and apron facility. Extraction, gradation, and density tests were made on the surface course. Sections of the portland cement concrete pavement were removed and flexural strength determined by the third point loading method on beams cut therefrom. Plate bearing tests, using a 30-in. diameter plate, were made on subgrade materials. Sieve analyses, densities, and moisture contents of the subgrade and base materials were determined at the selected locations.

Conferences with Army Air Forces determined the desirability of interpreting the data and expressing the results so as to indicate a field evaluation and runway evaluation in terms of capacity operation and limited operation. The data and results of the tests obtained from the survey were applied to the principles in Chapter XX of the Engineering Manual for arriving at the load carrying capacities.

The Army Air Forces have been furnished the necessary information. Copies of the reports are on file at the three departmental laboratories and will constitute a valuable source of information for study in developing new features of design.

[1] Now Consulting Engineer, Dowagiac, Michigan.