Compaction Requirements for Flexible Pavements

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This paper presents the results of an analytical study made to develop criteria for determining the degree of compaction required at different depths in soils beneath flexible pavements to prevent consolidation of the soil under wheel loads and consequent deformation of the pavement.

Data obtained from observations of airfield pavements in actual service and from reports of accelerated traffic tests on carefully controlled test sections were tabulated, and from these tabulations correlations were developed between the compaction effort applied to flexible pavements by aircraft traffic and the densities resulting from this compaction effort at various depths.

The established CBR relations were used to integrate the effects of wheel load, tire pressure, assembly configuration, and depth below pavement surface into a compaction index, C_i, for purposes of this study. Correlations between C_i and the densities required to prevent further compaction are presented.

IN 1942, when the Corps of Engineers adopted the California Bearing Ratio method
r use in designing flexible pavements for airfields, the CBR procedures specified
boratory compaction of soil samples under a 2,000-psi static load. This compac-
on gives densities of the same order as those obtained by AASHO Method T99 for
ndy and gravelly soils, but much higher densities for clayey soils. The CBR meth-
also specified a field compaction test using a tamper that imparted a compaction
fort considerably greater than imparted by AASHO T99 compaction. Personnel of
e Corps of Engineers and consultants to the Corps anticipated that higher densities
uld be needed in soil components of airfield pavements than were produced by the
SHO T99 compaction test, but did not consider the CBR procedures entirely suit-
le for this purpose. From laboratory tests performed in the Corps' Flexible Pave-
ent Laboratory, Soils Division, at the Waterways Experiment Station, Vicksburg,
ssissippi, it was determined that a modification of AASHO T99 would be better suit-
to the Corps' problems and would require less new test equipment. The Corps' de-
n manual published in June 1942 specified a laboratory compaction test similar to
SHO T99, but with modifications which increased the weight of the hammer from 5
10 lb, the height of fall from 12 to 18 in., and the number of layers compacted from
o 5. These changes increased the compaction effort almost fivefold.

Also, based primarily on judgment of Corps personnel and consultants, compaction
uirements were specified in 1942 as 95 percent of modified AASHO maximum density
all base courses, subbases, and for the top 6 in. of subgrades. In most soils 95 per-
t of modified AASHO density is equal to or higher than 100 percent of AASHO T99
ximum density; therefore, these specifications represented a definite upgrading of
npaction requirements from those used for highways, which were normally 95 per-
t of AASHO T99. Compaction of fill was specified to be 90 percent of modified
SHO compaction, but no specifications were established for cut sections except in
top 6 in.

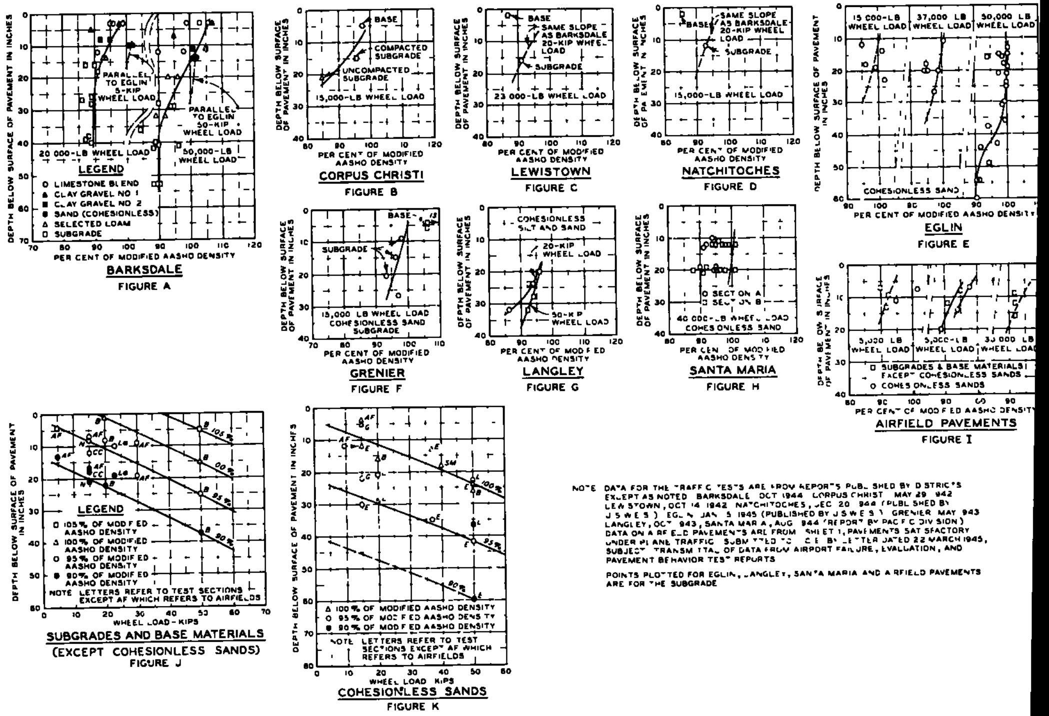
In 1945, a study was made of the degrees of compaction existing in certain acceler-
d-traffic test sections. These studies showed a definite relation between degree of

compaction, wheel load, and depth from the surface of the pavement to the layer being studied. It was assumed that if this density had been built into the structure during construction of the test sections, no appreciable densification would have occurred under traffic. As a result of these studies, the Corps has established in a sense, a "design" of the ultimate compaction necessary. For the "design," the compaction that wil be induced in each layer by the airplane traffic is determined, and this degree of compaction is required to be obtained during construction.

Unfortunately, the studies which led to these developments were documented only i letter reports between the Waterways Experiment Station and the Office, Chief of Engineers, and thus the test data have not been generally available. However, in 1959, th Corps published a report (24) which contains all the data collected by the Corps on the subject. The authors of this paper were directly connected with the studies. This paper summarizes data (24) and shows how the procedures developed by the Corps can b applied to civil airfields and highways.

Early Studies

Figure 1, taken from a 1945 unpublished letter report, shows plots of the degree o compaction that developed in several accelerated-traffic tests at various depths belo

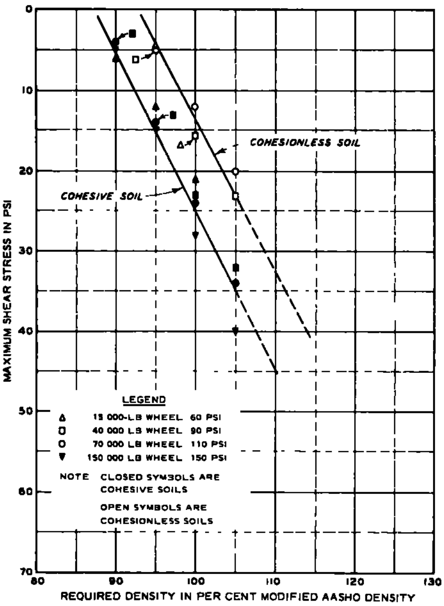


NOTE DATA FOR THE TRAFFIC TESTS ARE FROM REPORTS PUBLISHED BY DISTRICTS EXCEPT AS NOTED BARKSDALE OCT 1944 CORPUS CHRISTI MAY 29 1942 LEWISTOWN, OCT 14 1942 NATCHITOCHES, DEC 20 1944 (PUBLISHED BY U S W E S) EGLIN JAN 5 1945 (PUBLISHED BY U S W E S) GRENIER MAY 1943 LANGLEY, OCT 1943, SANTA MARIA, AUG 1944 (REPORT BY PACIFIC DIVISION) DATA ON AIRFIELD PAVEMENTS ARE FROM SHEET 1, PAVEMENTS SATISFACTORY UNDER PLANE TRAFFIC SUBMITTED TO O C E BY LETTER DATED 22 MARCH 1945, SUBJECT TRANSMITTAL OF DATA FROM AIRPORT FAILURE, EVALUATION, AND PAVEMENT BEHAVIOR TEST REPORTS

POINTS PLOTTED FOR EGLIN, LANGLEY, SANTA MARIA AND AIRFIELD PAVEMENTS ARE FOR THE SUBGRADE

Figure 1. Compaction study data.

the pavement surface. It is apparent that the density developed by traffic decreased with depth in a logical manner when the densities were expressed as a percentage of the maximum densities obtained in the laboratory compaction test. This pattern appeared in all the accelerated-traffic tests (Fig. 1A-H) and in the airfield pavement u der actual traffic (Fig. 2). Another feature indicated by these results is that the co sionless sands appear to plot about 5 points higher (in percentage of compaction) tha the other soils. Figures 1J and 1K are summary plots obtained by reading the dept



igure 2. Required density versus maximum shear stress.

at which 90, 95, 100, and 105 percent compaction were measured and plotting the depth against wheel load. The lines of equal percentage of compaction were fitted to the plotted points visually. These summary plots were used to establish the following compaction requirements which appeared in the Corps of Engineers' engineering design manual published in 1946.

Through the succeeding four years, personnel of the Flexible Pavement Laboratory were engaged in producing CBR versus thickness design curves for multiple-wheel gears and for higher tire pressures by theoretical resolution of the single-wheel curves. These same concepts were applied to the compaction requirements, and it was found that a definite relation existed between the required degree of compaction and the maximum shear stress (τ_{max}) as computed by the theory of elasticity. Figure 2 shows the relation. In 1950, the relation shown in Figure 2 was used to translate the compaction requirements for single wheels (Table 1) into compaction requirements for a range of single, dual, and twin-tandem assemblies. Although tire pressure was not dicated in the 1946 requirements, the tire pressures for the various loads were approxiately those shown in the legend of Figure 2, and these values were used for the translations. ranslations were produced for 100- and 200-psi tire pressures for single-wheel loads. For e dual and twin-tandem assemblies, the tire pressure was varied to give a contact area of 7 sq in. for each tire. Figure 3 shows the compaction requirements produced by theoret-

TABLE 1

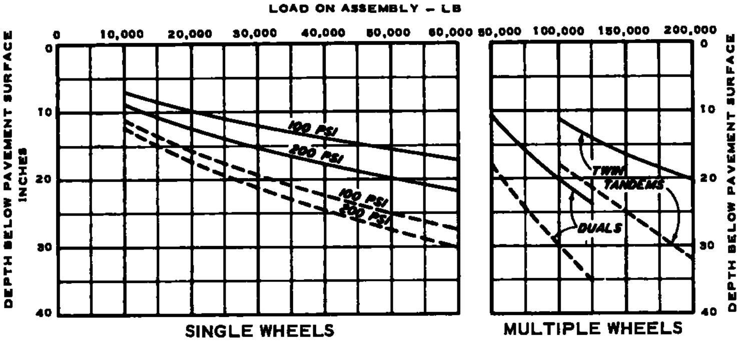
1946 COMPACTION REQUIREMENTS

heel Load (lb)	Depth in Inches Below Pavement Surface to Which Indicated % of Modified AASHO Density Should Extend			
	All Subgrades Except Cohesionless Sands		Cohesionless Sands	
	100%	95%	100%	95%
5,000	-	-	-	12
15,000	-	12	12	24
40,000	12	18	24	36
60,000	18	30	30	48
50,000	30	54	48	78

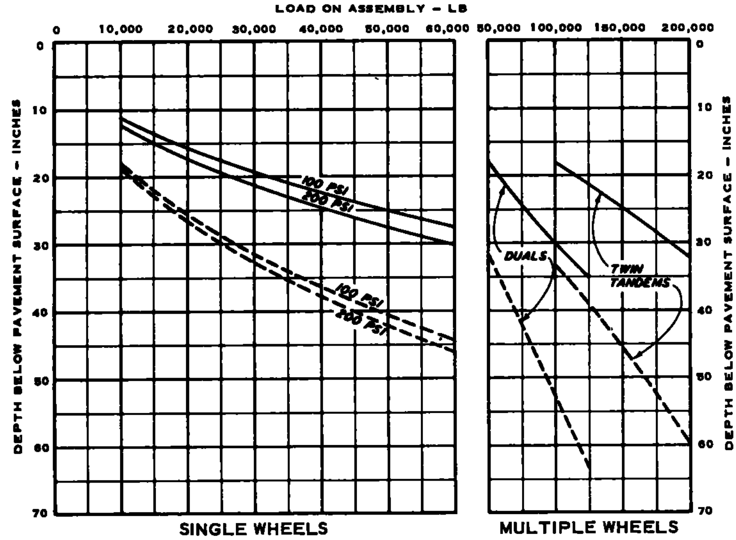
l resolution of the 1946 criteria. These requirements appeared in the Corps' engiring design manual in 1951.

In the period following 1951, it was necessary to produce plots such as those shown Figure 3 for many different gear loadings. In the course of this work, ample evice was found that the compaction that will be produced in a given layer by traffic is unction of the total load, arrangement of tires, tire pressure, number of repetitions, d depth to the given layer. Theoretically, the characteristics of the material between the surface and the given layer should also influence the compaction, but apparently the differences in the materials in the average flexible pavement are not enough to significantly influence compaction.

The determination of the exact relations between the compaction induced in the give layer and each of the variables listed above would require a multiplicity of carefully controlled test sections. A major discovery by personnel of the Flexible Pavement



ALL SUBGRADES AND BASE COURSE MATERIALS EXCEPT COHESIONLESS SANDS



COHESIONLESS SANDS

LEGEND

100% MOD. AASHO DENSITY
95% MOD. AASHO DENSITY

DUAL WHEELS SPACED 37.5 IN. CC. TWIN TANDEMS SPACED 31"x60" CC.; BOTH EQUIPPED WITH TIRES INFLATED TO GIVE A CONTACT AREA OF 267 SQ. IN. PER TIRE AT ALL LOADS.

NOTE: IN NO CASE SHALL THE COMPACTION IN A BASE COURSE OR THE TOP 6 INCHES OF A SUBGRADE BE LESS THAN 95% MOD. AASHO (100% FOR COHESIONLESS SANDS). ALSO ALL FILLS WILL BE COMPACTED TO 90% MOD. AASHO DENSITY BELOW THE ZONES OF GREATER REQUIRED COMPACTION.

Figure 3. Subgrade and base course compaction requirements.

Laboratory was that the design CBR could be used as a compaction index to combine the parameters listed. In preparing compaction requirements for the various gear loads it was found that an almost constant relation exists between the degree of compaction required in a given layer by the Corps and the design CBR indicated by the Corps' CBR design curves for that layer. Table 2 illustrates the constancy of th relation. The values shown in Table 2 were obtained by selecting a range of loads

TABLE 2

REQUIRED CBR VALUES FOR VARIOUS WHEEL LOADS[1]

	Single Wheels			Multiple Wheels			
ASHO Density	Wheel Load (kips)	CBR for Indicated Tire Pressure 100 psi	CBR for Indicated Tire Pressure 200 psi	Assembly Load (kips)	CBR for Dual Wheel Loads	Assembly Load (kips)	CBR for Twin-Tandem Wheel Loads
			(a) Cohesionless Sands				
00% Mod.	10	8.1	7.1	50	9.2	100	9.5
	20	8.1	7.2	75	8.6	125	8.9
	30	8.0	7.7	100	8.5	150	9.4
	40	8.0	7.5	125	8.5	175	8.9
	50	8.0	7.4	-	-	200	9.2
	60	8.0	7.5	-	-	-	-
95% Mod.	10	3.7	3.3	50	4.1	100	4.7
	20	3.6	3.4	75	4.0	125	4.6
	30	3.6	3.3	100	3.7	150	4.5
	40	3.5	3.3	125	3.6	175	4.2
	50	3.6	3.3	-	-	200	4.1
	60	3.6	3.6	-	-	-	-
			(b) Other Soils				
0% Mod.	10	15	13	50	16	100	16
	20	15.5	13.5	75	14.5	125	15
	30	16	14	100	15	150	15
	40	15.5	14	125	15	175	15.5
	50	16	13.5	-	-	200	16
	60	16	13.5	-	-	-	-
5% Mod.	10	8.1	7.1	50	9.2	100	9.5
	20	8.1	7.2	75	8.6	125	8.9
	30	8.0	7.7	100	8.5	150	9.4
	40	8.0	7.5	125	8.5	175	8.9
	50	8.0	7.4	-	-	200	9.2
	60	8.0	7.5	-	-	-	-

verage CBR: (a) Cohesionless Sands, 100% Mod. AASHO Density = 8.3; 95% = 3.8; (b)
her Soils, 100% Mod. AASHO Density = 15.0; 95% = 8.3.

d gear configurations, reading the depth at which 95 and 100 percent compaction
uld be required from Figure 3, and then reading from the respective CBR curve the
R that would be required at that thickness. For example, Figure 3 indicates that
any material other than cohesionless sand, 100 percent compaction would be re-
ired at a depth of 7 in. for a 10,000-lb, single-wheel load, 100-psi tire pressure.
e Corps' CBR design curves (Fig. 2 of Appendix, (2)) indicate that a design CBR
15 would be required for the 10,000-lb wheel load at a depth of 7 in. The other
ues shown in Table 2 were obtained in the same manner. This over-all factor
ich combines the parameters of load, tire arrangement, tire pressure, number of
etitions, and depth to the layer under consideration was labeled "Compaction Index,"
to avoid the confusion that would exist if the initials CBR were used. With this
nbination factor the variables are reduced to two, percentage of compaction and
npaction index, and all pertinent data can be plotted in one plot and brought to bear
the problem even though the data from individual tests do not cover the full range
he variables.

Following this discovery, a review was made of all available data (4 - 25). Data
e considered pertinent only where information was available on the density, depth,

TABLE 3

ACCELERATED TRAFFIC TEST COMPACTION RESULTS

Depth from Surface in.	Plasticity Index	Per Cent Mod AASHO Density	Compaction Index*
A. Source of Data	Pavement Mix Design Study for Very Heavy Gear Loads; Pilot Test Section (DRAFT), Jan 1957		
Assembly Load:	240,000 lb		
Assembly Type	Twin tandem, spacing 31 x 60 in., 267-sq-in. contact area		
4.0	NP	104.7	81.0
10.5	NP	105.9	50.4
14.5	NP	105.8	40.0
35.0	28	92.0	13.8
38.0	28	89.2	12.0
58.0	28	83.2	6.6
4.0	NP	106.2	81.0
8.0	NP	103.8	60.5
14.0	NP	104.1	40.5
B. Source of Data	Unpublished data from Columbus AFB test section, 1958		
Assembly Load	212,000 lb		
Assembly Type	Twin twin, 37-62-37-in. spacing, 267-sq-in. contact area, bicycle-type gear		
4.0	NP	105.0	83.0
12.0	NP	103.6	44.0
17.0	NP	101.0	30.0
21.0	NP	104.8	23.0
25.5	18	106.9	17.5
31.5	P	101.7	13.5
C. Source of Data:	Investigation of Effects of Traffic With High Pressure Tires on Asphalt Pavements, TM 3-312, May 1950		
Assembly Load	30,000 lb		
Assembly Type:	Single, 200-psi tire pressure		
16.0	23	100.3	12.5
12.0	23	99.3	19.0
12.0	23	98.1	19.0
12.0	23	98.2	19.0
12.0	23	97.4	19.0
12.0	23	97.0	19.0
Assembly Load·	120,000 lb		
Assembly Type·	Twin tandem, 31 x 60 in.		
13.0	23	99.0	22.5
13.0	23	99.0	22.5
13.0	23	100.5	22.5
13.0	23	93.8	22.5
12.0	23	95.3	25.0
D. Source of Data·	Investigation of the Design and Control of Asphalt Paving Mixtures, TM 3-254		
Assembly Load.	15,000 lb		
Assembly Type:	Single, 50-psi tire pressure		
1.5	7	93.0	50.0
1.5	7	92.0	50.0
3.0	7	98.0	30.0
3.0	7	95.0	30.0
3.0	7	105.0	30.0
5.0	7	93.0	18.5
3.0	NP	103.0	30.0
4.0	NP	98.0	24.0
6.0	NP	96.0	15.0
6.0	NP	97.0	15.0
6.0	NP	97.0	15.0
6.0	NP	99.0	15.0
6.0	NP	96.0	15.0
6.0	NP	96.0	15.0
0.8	NP	108.0	70.0
2.0	P**	94.0	41.0
2.0	P	95.0	41.0
2.0	P	96.0	41.0
2.0	P	98.0	41.0
6.5	7	93.0	14.0
6.5	NP	99.0	14.0
6.5	NP	93.0	14.0
6.5	NP	99.0	14.0
6.0	NP	98.0	14.0
6.0	NP	100.0	15.0
7.0	NP	95.0	13.0
6.5	NP	100.0	14.0
6.5	NP	103.0	14.0
6.5	NP	102.0	14.0
6.5	NP	100.0	14.0
6.5	NP	102.0	14.0
9.0	28	93.0	9.3
9.0	28	96.0	9.3
9.0	28	95.0	9.3
9.0	28	94.0	9.3
9.0	28	95.0	9.3
9.0	28	96.0	9.3
9.0	28	94.0	9.3
9.0	28	94.0	9.3
9.0	28	96.0	9.3
9.0	28	96.0	9.3
9.0	28	95.0	9.3
9.0	28	94.0	9.3
9.0	28	92.0	9.3
9.0	28	95.0	9.3
9.0	28	92.0	9.3
9.0	28	96.0	9.3
11.0	28	94.0	7.0
11.0	28	95.0	7.0
11.0	28	95.0	7.0
D. (Continued)			
Assembly Load:	37,000 lb		
Assembly Type·	Single, 100-psi tire pressure		
1.5	7	93.0	98.0
3.0	7	98.0	63.0
3.0	NP	99.0	63.0
5.0	NP	93.0	45.0
2.0	NP	100.0	82.0
6.0	NP	102.0	39.0
2.0	P	79.0	82.0
2.0	P	88.0	82.0
2.0	P	98.0	82.0
2.0	P	94.0	82.0
2.0	P	96.0	82.0
7.25	7	91.0	32.5
8.0	7	89.0	30.0
7.25	NP	101.0	32.5
8.0	NP	101.0	30.0
8.0	NP	101.0	30.0
9.0	NP	91.0	26.0
7.5	NP	101.0	31.5
8.5	NP	100.0	28.0
9.5	NP	102.0	24.0
6.5	P	95.0	35.5
13.0	28	91.0	17.0
13.0	28	90.0	17.0
13.0	28	98.0	17.0
13.0	28	93.0	17.0
13.0	28	97.0	17.0
13.0	28	90.0	17.0
13.0	28	96.0	17.0
13.0	28	97.0	17.0
13.0	28	96.0	17.0
11.0	28	82.0	20.0
11.0	28	91.0	20.0
D. (Continued)			
Assembly Load·	60,000 lb		
Assembly Type:	Twin, 37 in. c-c, 360-sq-in. contact area		
3.0	7	87.0	61.0
3.0	7	89.0	61.0
3.0	NP	100.0	61.0
2.0	P	93.0	75.0
2.0	P	94.0	75.0
2.0	P	94.0	75.0
2.0	P	83.0	75.0
2.0	P	94.0	75.0
8.75	7	95.0	24.0
9.5	7	89.0	21.0
9.5	7	79.0	21.0
8.75	NP	98.0	24.0
8.75	NP	102.0	24.0
8.75	NP	95.0	24.0
9.5	NP	97.0	21.0
10.5	NP	101.0	19.0
9.0	NP	101.0	23.0
9.0	NP	101.0	23.0
9.0	NP	97.0	23.0
10.0	NP	100.0	20.0
11.0	NP	99.0	18.0
11.0	NP	99.0	18.0
4.9	NP	103.0	43.0
16.0	28	97.0	12.5
16.0	28	93.0	12.5
16.0	28	95.0	12.5
16.0	28	91.0	12.5
16.0	28	96.0	12.5
16.0	28	93.0	12.5
16.0	28	88.0	12.5
16.0	28	96.0	12.5
16.0	28	96.0	12.5
16.0	28	88.0	12.5
16.0	28	95.0	12.5
16.0	28	96.0	12.5
16.0	28	93.0	12.5
16.0	28	92.0	12.5
16.0	28	92.0	12.5
16.2	28	95.0	12.3
11.0	28	96.0	18.0
11.0	28	93.0	18.0

FIELD COMPACTION DATA FOR FLEXIBLE AIRFIELD PAVEMENTS

Depth from Surface in.	Plasticity Index	Per Cent Mod AASHO Density	Compaction Index*
A. Source of Data		Condition Survey, Report No. 2, Pope Air Force Base, Fort Bragg, North Carolina, MP 4-3	
Assembly Load		13,000 lb	
Assembly Type		Single, 100-psi tire pressure	
4.0	NP	95.0	37.0
3.0	NP	93.0	48.0
9.0	7	83.0	13.5
21.0	13	84.0	3.4
20.0	NP	85.0	3.8
8.0	NP	81.0	15.0
B. Source of Data.		Condition Survey, Report No. 5, Eglin Air Force Base, Valparaiso, Florida, MP 4-3	
Assembly Load·		30,000 lb	
Assembly Type.		Single, 100-psi tire pressure	
8.0	NP	101.5	27.0
15.0	NP	96.9	11.5
4.0	NP	97.2	52.0
16.0	NP	94.9	10.5
8.0	NP	98.2	27.0
Assembly Load		96,000 lb	
Assembly Type		Dual, 37 in. c-c, 267-sq-in. contact area	
20.0	NP	102.7	15.5
15.0	NP	98.5	22.5
24.0	NP	96.7	12.0
36.0	NP	92.0	6.8
C. Source of Data		Airfield Pavement Evaluation, Report No. 3, Boca Raton Airfield, Florida, TM 3-344	
Assembly Load·		62,000 lb	
Assembly Type		Dual, 37 in. c-c, 360-sq-in. contact area	
11.0	NP	96.0	17.8
25.5	NP	96.0	6.8
10.5	NP	94.0	18.5
24.0	NP	84.0	7.5
10.75	NP	91.0	18.1
10.0	NP	96.0	20.7
24.0	NP	91.0	7.5
11.0	NP	96.0	17.8
24.0	NP	93.0	7.5
D. Source of Data·		Condition Survey, Report No. 3, Lawson Air Force Base, Fort Benning, Georgia, MP 4-3	
Assembly Load·		13,000 lb	
Assembly Type		Single, 100-psi tire pressure	
3.0	6	89.0	48.0
3.0	11	89.0	48.0
3.0	NP	89.0	48.0
3.0	NP	89.0	48.0
3.0	NP	90.0	48.0
3.0	NP	89.0	48.0
3.0	NP	89.0	48.0
11.0	NP	89.0	9.75
11.0	NP	88.0	9.75
12.0	NP	93.0	8.5
12.0	NP	92.0	8.5
10.0	NP	90.0	11.0
10.0	NP	85.0	11.0
12.0	NP	85.0	8.5
E. Source of Data		Condition Survey, Report No. 4, Ardmore Air Force Base, Ardmore, Oklahoma, MP 4-3	
Assembly Load·		22,500 lb	
Assembly Type:		Single, 100-psi tire pressure	
3.0	10	102.0	57.0
3.0	6	98.0	57.0
16.0	11	92.0	8.5
14.0	8	89.0	10.0
F. Source of Data.		Airfield Pavement Evaluation, Report No. 6, Palm Beach International Airport, Florida, TM 3-344	
Assembly Load·		79,000 lb	
Assembly Type·		Dual, 37 in. c-c, 267-sq-in. contact area	
3.0	NP	99.0	81.0
3.0	NP	100.0	81.0
7.0	NP	95.0	42.0
4.75	NP	93.0	60.0
2.0	NP	94.0	96.0
4.5	NP	95.0	62.0
3.5	NP	98.0	75.0
3.0	NP	101.0	80.0
3.0	NP	103.0	80.0
3.25	NP	104.0	78.0
4.0	NP	100.0	69.0
6.0	NP	103.0	49.0
3.5	NP	99.0	75.0
13.0	NP	89.0	21.0
13.5	NP	92.0	20.0
13.0	NP	92.0	21.0
13.0	NP	90.0	21.0
13.0	NP	91.0	21.0
11.5	NP	92.0	23.0
F. (Continued)			
21.0	NP	102.0	12.0
33.0	NP	95.0	6.4
14.5	NP	92.0	18.5
26.5	NP	95.0	8.8
17.5	NP	89.0	15.0
29.5	NP	90.0	7.5
8.0	NP	82.0	36.0
20.0	NP	81.0	13.0
11.0	NP	93.0	24.5
23.0	NP	91.0	11.0
14.0	NP	97.0	19.0
26.0	NP	94.0	9.0
19.0	NP	95.0	13.5
31.0	NP	94.0	6.6
11.5	NP	98.0	23.0
23.5	NP	97.0	10.5
19.0	NP	95.0	13.5
31.0	NP	95.0	6.6
17.0	NP	93.0	15.5
29.0	NP	95.0	7.75
17.0	NP	100.0	15.5
29.0	NP	101.0	7.75
14.5	NP	97.0	18.5
26.5	NP	97.0	8.8
16.5	NP	98.0	16.0
28.5	NP	90.0	8.0
12.0	NP	95.0	22.5
24.0	NP	94.0	10.0
13.5	NP	101.0	20.0
25.5	NP	94.0	9.4
G. Source of Data·		Airfield Pavement Evaluation, Report No. 2, Sheppard Air Force Base, Wichita Falls, Texas, TM 3-344	
Assembly Load.		15,750 lb	
Assembly Type		Single, 100-psi tire pressure	
3.0	8	100.0	51.0
12.0	NP	87.0	9.8
3.0	NP	94.0	51.0
2.0	7	100.0	66.0
9 0	NP	89.0	14.5
2.5	NP	90.0	58.0
3.0	NP	97.0	51.0
20.0	7	79.0	4.3
14.5	11	94.0	7.4
23.0	18	89.0	3.3
13.0	18	85.0	8.8
15.0	28	89.0	7.0
2.5	NP	91.0	58.0
3.0	NP	87.0	51.0
2.5	NP	93.0	58.0
12.0	17	93.0	9.8
13.5	20	91.0	8.2
14.0	17	93.0	7.7
H. Source of Data		Airfield Pavement Evaluation, Report No. 4, Davis-Monthan Air Force Base, Tuscon, Arizona, TM 3-344	
Assembly Load		74,400 lb	
Assembly Type.		Dual, 37 in. c-c, 267-sq-in. contact area	
3.5	15	94.7	71.0
3.5	4	99.7	71.0
4.0	10	98.5	65.0
4.0	18	97.3	65.0
2.5	NP	97.9	85.0
4.0	NP	98.4	65.0
3.5	11	100.7	71.0
11.5	20	86.3	22.5
11.5	11	92.7	22.5
12.0	17	92.2	21.0
11.0	19	96.9	23.5
11.5	23	88.3	22 5
12.0	12	90.2	21.0
14.0	12	89.6	18.0
12.0	13	90.3	21.0
12.0	12	91.4	21.0
12.0	8	97.6	21.0
14.0	13	95.5	18.0
I. Source of Data		Flexible Pavement Behavior Studies, Interim Report No. 2	
Assembly Load·		15,000 lb	
Assembly Type		Single, 100-psi tire pressure	
15.0	NP	92.0	6.75
15.0	NP	94.0	6.75
15.0	NP	95.0	6.75
15.0	7	94.0	6.75
20.0	44	86.0	4.0
20.0	44	92.0	4.0
15.0	37	87.0	6.75
15.0	11	84.0	6.75
15.0	13	94.0	6.75
19.0	32	86.0	4.5
12.0	13	92.0	9.5
13.0	1	86.0	8.5
17.0	8	75.0	5.5
13.0	1	94.0	8.5
13.0	6	94.0	8.5
Assembly Load:		16,000 lb	
Assembly Type·		Single, 100-psi tire pressure	
11.0	17	79.0	12.0
11.0	16	91.0	12.0
19.0	20	69.0	4.8
24.0	20	73.0	3.2
19.0	18	74.0	4.8
24.0	18	72.0	3.2

(Continued)

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* The compaction index is the design CBR value for the corresponding load and depth.

TABLE 4 (Continued)

Depth from Surface in.	Plasticity Index	Per Cent Mod AASHO Density	Compaction Index
I. (Continued)			
Assembly Load:	17,500 lb		
Assembly Type:	Single, 100-psi tire pressure		
16.0	20	85.0	6.8
13.0	11	88.0	9.5
14.0	16	84.0	8.5
25.0	17	69.0	3.2
22.0	10	79.0	3.9
25.0	15	78.0	3.2
Assembly Load:	25,000 lb		
Assembly Type:	Single, 100-psi tire pressure		
15.0	20	87.0	10.0
24.0	20	79.0	4.7
15.0	20	90.0	10.0
24.0	20	83.0	4.7
20.0	9	83.0	6.4
26.0	9	85.0	4.0
17.0	2	90.0	8.3
13.0	9	106.0	12.3
15.0	14	94.0	10.0
15.0	7	84.0	10.0
15.0	7	104.0	10.0
14.0	15	75.0	11.0
15.0	5	75.0	10.0
J. Source of Data:	<u>Airfield Pavement Evaluation, Report No. 1, Campbell Air Force Base, Kentucky,</u> TM 3-344		
Assembly Load:	140,000 lb		
Assembly Type.	Twin tandem, 31 x 60 in. c-c, 267-sq-in. contact area		
12.5	29	89.0	22.5
24.5	P	72.0	11.0
32.0	36	91.0	7.75
40.0	P*	88.0	5.6
13.0	P	87.0	21.4
25.0	P	80.0	10.8
11.5	P	89.0	24.0
23.5	P	84.0	11.7
13.5	P	94.0	20.5
25.5	P	82.0	10.6
13.5	P	90.0	20.5
25.5	P	83.0	10.6
30.0	P	88.0	8.4
42.0	P	88.0	5.3
28.0	34	91.0	9.2
40.0	P	88.0	5.6
10.5	26	92.0	25.5
22.5	P	88.0	12.2
31.5	18	91.0	7.9
14.5	P	90.0	19.2
26.5	P	87.0	9.8
30.0	P	95.0	8.4
42.0	P	90.0	5.3
3.0	NP	89.0	98.0
3.5	NP	100.0	90.0
14.0	NP	96.0	20.0
4.5	NP	105.0	55.0
J. (Continued)			
3.0	NP	102.0	98.0
3.0	NP	98.0	98.0
3.0	NP	99.0	98.0
3.5	NP	99.0	90.0
12.5	NP	94.0	22.5
3.5	NP	98.0	90.0
13.0	NP	93.0	21.4
18.5	NP	96.0	15.5
3.5	NP	110.0	90.0
3.5	NP	93.0	90.0
14.0	NP	100.0	20.0
21.0	NP	94.0	13.5
2.5	NP	109.0	81.0
4.5	NP	101.0	55.0
14.0	NP	99.0	20.0
K. Source of Data:	Field Moisture Content Investigation Unpublished Data		
Field:	Ardmore Air Force Base		
Facility:	NS runway		
Assembly Load:	22,000 lb		
Assembly Type	Single, 100-psi tire pressure		
5.5	10	102.0	33.0
5.5	6	98.0	33.0
19.0	CL	89.0	6.25
Field:	Bergstrom Air Force Base		
Facility:	NW-SE runway		
Assembly Load·	15,000 lb		
Assembly Type:	Single, 100-psi tire pressure		
4.5	1	104.0	34.0
4.5	1	101.0	34.0
14.5	NP	92.0	7.0
19.5	44	86.0	4.25
24.0	44	85.0	3.0
4.5	1	101.0	34.0
14.5	NP	90.0	7.0
19.5	44	86.0	4.25
24.0	44	84.0	3.0
4.5	1	104.0	34.0
14.5	NP	89.0	7.0
19.5	44	94.0	4.25
24.0	44	94.0	3.0
4.5	1	104.0	34.0
14.5	NP	94.0	7.0
19.5	44	92.0	4.25
24.0	44	91.0	3.0
4.5	1	104.0	34.0
19.5	44	94.0	4.25
24.0	44	86.0	3.0
4.5	1	97.0	34.0
14.5	NP	95.0	7.0
19.5	44	92.0	4.25
24.0	44	92.0	3.0
K. (Continued)			
Facility:	Taxiway 1		
Assembly Load·	15,000 lb		
Assembly Type·	Single, 100-psi tire pressure		
4.5	3	104.0	34.0
14.5	7	94.0	7.0
19.5	39	86.0	4.25
24.0	39	85.0	3.0
4.5	2	100.0	34.0
14.5	8	91.0	7.0
19.5	38	84.0	4.25
24.0	38	82.0	3.0
Facility.	E-W runway		
Assembly Load:	15,000 lb		
Assembly Type:	Single, 100-psi tire pressure		
4.5	1	102.0	34.0
14.5	7	89.0	7.0
19.5	31	91.0	4.25
4.5	1	102.0	34.0
14.5	8	93.0	7.0
19.5	53	99.0	4.25
4.5	NP	108.0	34.0
14.5	4	90.0	7.0
19.5	38	94.0	4.25
Field.	Berry Air Force Base		
Facility:	West N-S runway		
Assembly Load:	15,000 lb		
5.5	2	102.0	27.5
14.5	37	87.0	7.0
24.0	37	69.0	3.0
5.5	2	106.0	27.5
14.5	11	84.0	7.0
24.0	11	85.0	3.0
5.5	2	108.0	27.5
14.5	20	82.0	7.0
24.0	20	89.0	3.0
5.5	2	109.0	27.5
14.5	29	91.0	7.0
24.0	29	90.0	3.0
Field	Blythe Air Force Base		
Facility:	N-S runway		
Assembly Load:	25,000 lb		
4.5	NP	98.0	43.0
10.5	NP	88.0	16.0
24.0	NP	82.0	4.6
4.5	NP	101.0	43.0
10.5	NP	92.0	16.0
24.0	NP	85.0	4.6
3.0	NP	94.0	59.0
6.5	NP	88.0	29.0
24.0	NP	86.0	4.6
4.5	NP	103.0	43.0
10.5	NP	92.0	16.0
24.0	NP	92.0	4.6
4.5	NP	100.0	43.0
10.5	NP	94.0	16.0
24.0	NP	88.0	4.6
K. (Continued)			
Field:	Campbell Air Force Base		
Facility	N-S runway		
Assembly Load	25,000 lb		
Assembly Type:	Single, 100-psi tire pressure		
6.25	NP	102.0	31.0
14.25	20	87.0	11.0
24.0	20	79.0	4.6
5.5	NP	101.0	35.0
14.5	20	90.0	10.6
24.0	20	83.0	4.6
5.5	NP	103.0	35.0
14.5	20	96.0	10.6
24.0	20	95.0	4.6
5.5	NP	106.0	35.0
14.5	20	87.0	10.6
24.0	20	91.0	4.6
10.0	20	90.0	17.0
Facility:	NE-SW runway		
Assembly Load:	15,000 lb		
Assembly Type·	Single, 100-psi tire pressure		
6.0	NP	99.0	25.0
15.5	15	88.0	6.4
Field:	Clovis Air Force Base		
Facility:	N-S runway		
Assembly Load	30,000 lb		
Assembly Type	Single, 100-psi tire pressure		
4.0	7	100.0	52.0
16.0	9	98.0	10.5
32.0	9	86.0	3.3
4.0	7	98.0	52.0
16.0	9	103.0	10.5
33.0	9	84.0	3.0
4.0	7	98.0	52.0
16.0	9	76.0	10.5
32.0	9	102.0	3.3
Field.	Davis Air Force Base		
Facility·	E-W runway		
Assembly Load·	65,000 to 75,000 lb		
Assembly Type:	Dual, 37 in. c-c, 267-sq-in. contact area		
6.0	15	95.0	45.0
14.0	20	86.0	18.5
23.0	20	92.0	10.25
6.0	4	100.0	45.0
14.0	11	93.0	18.5
24.0	11	76.0	9.6
Facility:	N-S runway		
Assembly Load	65,000 to 75,000 lb		
Assembly Type	Dual, 37 in. c-c, 267-sq-in. contact area		
6.5	10	99.0	42.5
14.5	17	92.0	17.75
24.0	17	89.0	9.6

from Surface in.	Plasticity Index	Per Cent Mod AASHO Density	Compaction Index
K. (Continued)			
Facility	Taxiway 4		
Assembly Load:	65,000 to 75,000 lb		
Assembly Type.	Dual, 37 in. c-c, 267-sq-in. contact area		
6.5	18	97.0	42.5
13.5	19	96.0	19.0
24.0	19	81.0	9.6
Facility:	Taxiway 3		
Assembly Load	65,000 to 75,000 lb		
Assembly Type·	Dual, 37 in c-c, 267-sq-in. contact area		
6.0	NP	100.0	45.0
14.0	23	88.0	18.5
24.0	23	83.0	9.6
Facility:	Taxiway 2		
Assembly Load:	65,000 to 75,000 lb		
Assembly Type:	Dual, 37 in. c-c, 267-sq-in. contact area		
6.5	10	98.0	42.5
14.5	12	90.0	17.75
23.0	12	76.0	10.25
Facility	Taxiway 1		
Assembly Load·	65,000 to 75,000 lb		
Assembly Type.	Dual, 37 in. c-c, 267-sq-in. contact area		
6.5	10	95.0	42.5
16.5	12	90.0	15.0
24.0	12	77.0	9.6
Facility:	Taxiway 9		
Assembly Load.	65,000 to 75,000 lb		
Assembly Type	Dual, 37 in. c-c, 267-sq-in. contact area		
6.0	10	91.0	45.0
14.5	13	90.0	17.75
26.0	13	93.0	9.5
Facility·	NW-SE runway		
Assembly Load·	65,000 to 75,000 lb		
Assembly Type.	Dual, 37 in. c-c, 267-sq-in. contact area		
14.5	12	91.0	17.75
23.0	12	82.0	10.25
6.5	NP	102.0	42.5
14.5	8	98.0	17.75
24.0	8	76.0	9.6
Facility·	N-S runway		
Assembly Load·	65,000 to 75,000 lb		
Assembly Type.	Dual, 37 in. c-c, 267-sq-in. contact area		
6.0	11	98.0	45.0
14.0	13	95.0	18.5
24.0	13	95.0	9.6
K. (Continued)			
Field	Dodge City Air Force Base		
Facility	Taxiway 4A		
Assembly Load:	15,000 lb		
Assembly Type·	Single, 100-psi tire pressure		
6.5	9	94.0	22.5
15.5	17	87.0	6.3
22.5	26	82.0	3.3
24.0	26	74.0	3.0
6.5	11	86.0	22.5
15.5	13	94.0	6.3
22.5	32	86.0	3.3
24.0	32	78.0	3.0
Field:	Douglas Air Force Base		
Facility:	Taxiway 5		
Assembly Load·	17,500 lb		
Assembly Type:	Single, 100-psi tire pressure		
5.5	3	93.0	29.0
14.0	NP	87.0	8.5
23.0	39	82.0	3.6
5.5	3	94.0	29.0
14.0	NP	86.0	8.5
23.0	36	81.0	3.6
Facility.	N-S runway		
Assembly Load	17,500 lb		
Assembly Type·	Single, 100-psi tire pressure		
5.5	NP	97.0	29.0
13.0	3	97.0	9.5
22.0	21	86.0	4.0
5.5	NP	94.0	29.0
11.0	3	89.0	12.0
21.0	21	89.0	4.3
5.5	NP	103.0	29.0
14.5	3	92.0	8.0
21.5	15	85.0	4.1
5.5	NP	97.0	29.0
14.5	3	85.0	8.0
21.5	21	88.0	4.1
5.5	9	101.0	29.0
13.5	11	95.0	9.0
21.5	11	85.0	4.1
5 5	9	102.0	29.0
11.5	11	91.0	11.3
17.5	24	80.0	5.9
5.5	9	98.0	29.0
11.5	11	94.0	11.3
16.5	24	87.0	6.5
5.5	9	98.0	29.0
10.5	11	91.0	12.8
18.5	24	84.0	5.4
K. (Continued)			
Field	Gainesville Air Force Base		
Facility	N-S runway		
Assembly Load	25,000 lb		
Assembly Type·	Single, 100-psi tire pressure		
4.5	9	107 0	43.0
16.5	29	92.0	8.8
4.5	13	104.0	43.0
14.5	20	85.0	10.6
28.5	22	89.0	3.4
4.5	8	103.0	43.0
14.5	21	90.0	10.6
24.5	20	82.0	4.5
Field.	Jackson Air Force Base		
Facility	NW-SE runway		
Assembly Load·	15,000 lb		
Assembly Type·	Single, 100-psi tire pressure		
4.5	8	104.0	34.0
11.5	13	86.0	10.0
24.0	13	89.0	3.0
4.5	8	103.0	34.0
11.5	13	92.0	10.0
24.0	13	90.0	3.0
Field:	Keesler Air Force Base		
Facility.	NW-SE runway		
Assembly Load·	15,000 lb		
Assembly Type	Single, 100-psi tire pressure		
4.5	NP	104.0	34.0
4.5	NP	103.0	34.0
4.5	NP	98.0	34.0
11.5	NP	101.0	10.0
4.5	NP	103.0	34.0
13.5	NP	99.0	8.0
Field.	Kirtland Air Force Base		
Facility.	Taxiway 2		
Assembly Load.	15,000 lb		
Assembly Type:	Single, 100-psi tire pressure		
4.0	5	106.0	38.3
13.0	5	95.0	8.5
4.0	4	102.0	38.3
13.0	6	94.0	8.5
4.0	3	108.0	38.3
13.0	4	93.0	8.5
Assembly Load:	30,000 lb		
Assembly Type:	Single, 100-psi tire pressure		
5.0	3	99.0	43.0
13.5	NP	90.0	13.3
24.0	NP	84.0	5.5
4.5	4	91.0	47.0
13.5	8	82.0	13.3
24.0	8	86.0	5.5
K. (Continued)			
Facility·	N-S runway		
Assembly Load	30,000 lb		
Assembly Type	Single, 100-psi tire pressure		
4.5	6	98.0	47.0
12 5	4	90.0	14.5
24.0	4	72.0	5.5
5.0	6	95.0	43.0
13.5	4	92.0	13.3
24.0	4	75.0	5.5
5.0	6	94.0	43.0
13.5	4	83.0	13.3
24.0		77.0	5.5
5.0	5	104.0	43.0
14.0	NP	95.0	12.6
5.0	5	99.0	43.0
11.5	NP	96.0	16.2
24.0	NP	85.0	5.5
Facility	NE-SW runway		
Assembly Load·	30,000 lb		
Assembly Type	Single, 100-psi tire pressure		
4.5	NP	104.0	47.0
14.5	3	74.0	12.0
24.0	3	75.0	5.5
4.5	NP	108.0	47.0
16.5	2	87 0	10.0
24.0	2	84.0	5.5
5.0	NP	103.0	43.0
16.5	3	90.0	10.0
24.0	3	76.0	5.5
4.5	NP	102.0	47.0
16.5	2	89.0	10.0
24.0	2	77.0	5.5
Facility	Taxiway 2		
Assembly Load·	75,000 lb		
Assembly Type	Dual, 37 in. c-c, 267-sq-in. contact area		
13 5	4	91.0	19.0
5.0	SC*	96.0	55.0
14.0	SC	86.0	18.5
5.0	SC	96.0	55.0
12.5	NP	94.0	20.5
5.0	SC-SM	104.0	55.0
12.5	SC-SM	90.0	20.5
5 0	SC-SM	97.0	55.0
12.5	SC-SM	92.0	20.5
5.0	SC	102.0	55.0
5.0	SC-SM	103.0	55.0
12.5	NP	94.0	20.5
5.0	SP-SM	100.0	55.0
13.5	NP	94.0	19.0
Facility:	Taxiway 1		
Assembly Load:	75,000 lb		
Assembly Type.	Dual, 37 in. c-c, 267-sq-in. contact area		
4.5	8	99.0	59.0
4.5	NP	99.0	59.0

(Continued)

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* Classification given where Atterberg limits are unknown.

TABLE 4 (Continued)

Depth from Surface in.	Plasticity Index	Per Cent Mod AASHO Density	Compaction Index
K. (Continued)			
Field	La Junta Air Force Base		
Facility.	E-W runway		
Assembly Load.	17,500 lb		
Assembly Type	Single, 100-psi tire pressure		
9.5	9	104.0	14.7
15.5	20	85.0	7 2
24.5	17	69.0	3.2
9.5	9	108.0	14.7
15.5	20	85.0	7.2
24 5	17	84.0	3.2
7.0	14	100.0	22.0
14.0	10	91.0	8.5
7.0	14	102 0	22.0
13.0	11	89.0	9.5
22.0	11	79.0	3.9
9 5	8	98.0	14.7
15.5	10	89.0	7.2
Facility	Taxiway 5		
Assembly Load	17,500 lb		
Assembly Type.	Single, 100-psi tire pressure		
7.5	4	100.0	20.0
13.5	16	84.0	9.0
24.5	15	78.0	3.2
7.5	3	100.0	20.0
13.5	16	75.0	9.0
24.5	15	69.0	3.2
Field	Las Vegas Air Force Base		
Facility.	Taxiway 3		
Assembly Load	30,000 lb		
Assembly Type.	Single, 100-psi tire pressure		
7.0	6	100.0	30.0
15.5	16	82 0	11.0
24.0	16	73.0	5.5
6.5	11	109.0	33.0
15.5	8	76.0	11.0
24.0	8	80.0	5.5
Facility.	N-S runway		
Assembly Load	30,000 lb		
Assembly Type.	Single, 100-psi tire pressure		
6.5	NP	103.0	33.0
14.0	26	91.0	12.6
18.5	17	75.0	8.4
24.0	17	79.0	5.5
6.5	8	100.0	33.0
14.0	10	90.0	12.6
18.5	17	90.0	8.4
6.5	5	101.0	33.0
14.0	12	88.0	12.8
18.5	17	91.0	8.4
6.5	5	101.0	33.0
14.0	17	88.0	12.8
18.5	17	85.0	8.4
6.5	3	100.0	33.0
14.0	NP	89.0	12.6
18.5	8	86.0	8.4
K. (Continued)			
6.5	6	103.0	33.0
14.0	18	88.0	12.6
18.5	17	92.0	8.4
24.0	17	83.0	5.5
6.5	5	100.0	33.0
14.0	3	89.0	12.6
18.5	8	79.0	8.4
24.0	8	82.0	5.5
Facility	NE-SW runway		
Assembly Load:	30,000 lb		
Assembly Type	Single, 100-psi tire pressure		
6.5	8	100.0	33.0
13.5	NP	98.0	13.3
21.0	NP	89.0	5.9
6.5	6	96.0	33.0
13.5	11	91.0	13.3
24.0	11	83.0	5.5
6.5	5	97.0	33.0
13.5	1	93.0	13.3
20.0	1	99.0	7.4
6.5	8	99.0	33.0
13.5	NP	95.0	13.3
Field:	Lawson Air Force Base		
Facility.	Taxiway 6		
Assembly Load	15,000 lb		
Assembly Type	Single, 100-psi tire pressure		
4.5	3	84.0	34.0
12.0	1	86.0	9.5
14.0	1	75.0	7.5
4.5	3	88.0	34.0
12.5	1	94.0	9.0
14.0	1	77.0	7.5
Facility	Taxiway 4		
Assembly Load	15,000 lb		
Assembly Type.	Single, 100-psi tire pressure		
5.5	5	87.0	27.5
12.5	20	75.0	9.0
5.5	5	87.0	27.5
13.5	20	89.0	8.0
23.0	20	89.0	3.2
Facility	NE-SW runway		
Assembly Load:	15,000 lb		
Assembly Type	Single, 100-psi tire pressure		
4.5	6	89.0	34.0
12.5	NP	89.0	9.0
4.5	11	89.0	34.0
12.5	NP	88.0	9.0
4.5	NP	89.0	34.0
12.5	NP	93.0	9.0
4.5	NP	89.0	34.0
13.5	NP	92.0	8.0
K. (Continued)			
Facility.	NW-SE runway		
Assembly Load	15,000 lb		
Assembly Type	Single, 100-psi tire pressure		
4.5	NP	90.0	34.0
11.5	NP	90.0	10.0
4.5	NP	89.0	34.0
11.5	NP	85.0	10.0
Facility	NE-SW runway		
Assembly Load:	15,000 lb		
Assembly Type.	Single, 100-psi tire pressure		
4.5	NP	89.0	34.0
11.5	NP	85.0	10.0
Field.	Pope Air Force Base		
Facility:	NE-SW runway		
Assembly Load.	15,000 lb		
Assembly Type.	Single, 100-psi tire pressure		
6.5	NP	95.0	22.5
11.5	7	83.0	10.0
21.0	7	84.0	3.8
5.5	NP	93.0	27.5
10.5	NP	81.0	11.6
20.0	NP	85.0	4.0
Facility	NW-SE runway		
Assembly Load	15,000 to 25,000 lb		
Assembly Type.	Single, 100-psi tire pressure		
5.5	NP	98.0	35.6
15.5	NP	100.0	9.6
23.0	NP	76.0	5.1
6.5	NP	92.0	29.0
14.5	NP	98.0	10.6
Facility:	NE-SW runway		
Assembly Load	15,000 to 25,000 lb		
Assembly Type	Single, 100-psi tire pressure		
7.0	NP	99.0	27.5
16.0	NP	105.0	9.1
25.0	NP	96.0	4.3
7.5	NP	95.0	25.0
13.5	NP	105.0	12.0
23.0	NP	94.0	5.0
7.0	NP	94.0	27.5
16.0	12	89.0	9.1
26.0	12	88.0	4.0
Facility:	N-S runway		
Assembly Load.	15,000 to 25,000 lb		
Assembly Type	Single, 100-psi tire pressure		
7.5	NP	96.0	25.0
12.5	12	91.0	13.1
22.0	12	85.0	5.5
Facility:	Taxiway 1		
Assembly Load	15,000 to 25,000 lb		
Assembly Type.	Single, 100-psi tire pressure		
		100.0	35.6
K. (Continued)			
Facility	N-S runway		
Assembly Load:	15,000 to 25,000 lb		
Assembly Type.	Single, 100-psi tire pressure		
6.0	NP	91.0	31.7
15.0	NP	99.0	10.0
25.0	NP	90.0	4.3
Facility:	Taxiway 1		
Assembly Load.	15,000 to 25,000 lb		
Assembly Type.	Single, 100-psi tire pressure		
7.0	NP	102.0	27 5
12.5	NP	97.0	13.1
22.0	NP	98.0	5.5
Facility:	Taxiway 2		
Assembly Load.	15,000 to 25,000 lb		
Assembly Type.	Single, 100-psi tire pressure		
6.5	NP	100.0	29.0
10.5	6	92.0	16.0
20.0	6	77.0	6.4
7.0	NP	100.0	27.5
11.0	NP	109.0	15.1
21.0	NP	99.0	5.9
Facility	Taxiway 5		
Assembly Load	15,000 to 25,000 lb		
Assembly Type	Single, 100-psi tire pressure		
6.0	NP	91.0	31.7
11.0	16	91.0	15.1
21.0	16	81.0	5.9
Facility	Taxiway 1		
Assembly Load.	15,000 to 25,000 lb		
Assembly Type.	Single, 100-psi tire pressure		
6.5	NP	94.0	29.0
15.5	NP	104.0	9 6
25.0	NP	105.0	4.3
Facility	Taxiway 2		
Assembly Load.	15,000 to 25,000 lb		
Assembly Type	Single, 100-psi tire pressure		
6.5	NP	98.0	29.0
13.0	18	98.0	10.0
25.0	18	88.0	4.3
Facility	Taxiway 5		
Assembly Load	15,000 to 25,000 lb		
Assembly Type.	Single, 100-psi tire pressure		
6.0	NP	99.0	31.7
14.0	NP	102.0	11.1
7.0	NP	100.0	27.5
13.5	NP	108.0	12.0

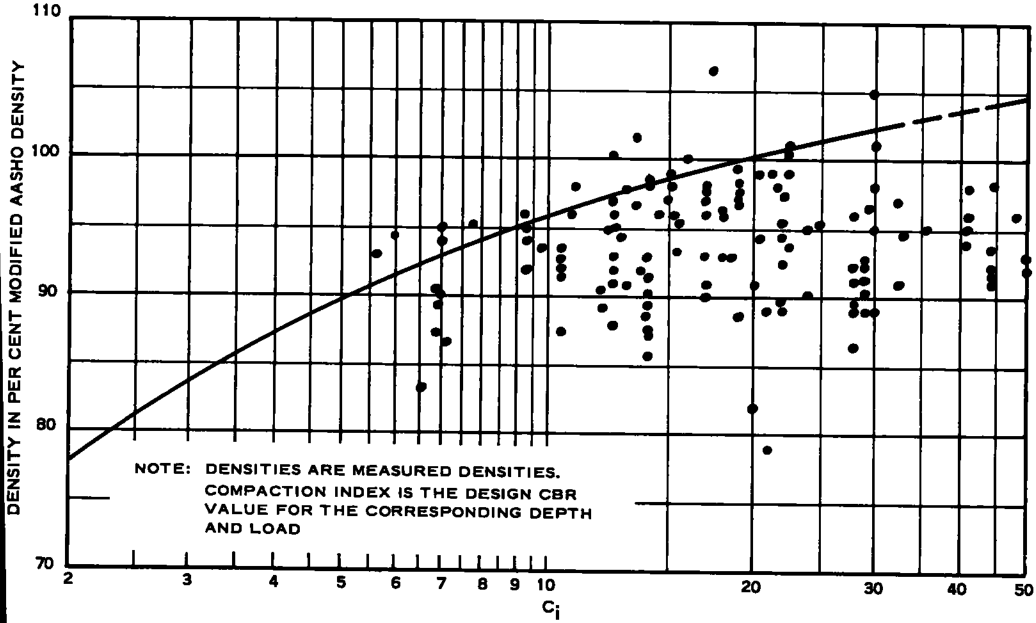
K. (Continued)

Depth from Surface in.	Plasticity Index	Per Cent Mod AASHO Density	Compaction Index
Field:	Pueblo Air Force Base		
Facility:	E-W runway		
Assembly Load:	30,000 lb		
Assembly Type:	Single, 100-psi tire pressure		
4.5	3	102.0	47.0
13.5	24	92.0	13.3
24.0	24	85.0	5.5
4.5	3	99.0	47.0
13.5	20	94.0	13.3
24.0	20	87.0	5.5
4.5	4	98.0	47.0
13.5	20	89.0	13.3
24.0	20	88.0	5.5
4.5	4	95.0	47.0
13.5	20	82.0	13.3
24.0	20	93.0	5.5
4.5	4	102.0	47.0
13.5	20	88.0	13.3
24.0	20	92.0	5.5
Facility:	Taxiway 6		
Assembly Load	30,000 lb		
Assembly Type:	Single, 100-psi tire pressure		
7.5	2	100.0	27.9
14.5	9	89.0	12.0
24.0	9	84.0	5.5
7.5	1	97.0	27.9
14,5	18	89.0	12.0
24.0	18	86.0	5.5
Field:	Rocky Ford Air Force Base		
Facility.	E-W runway		
Assembly Load	16,000 lb		
Assembly Type	Single, 100-psi tire pressure		
5.0	NP	94.0	31.5
11.0	17	79.0	11 3
19.0	20	69.0	4.8
24.0	20	73.0	3.0
5.0	5	97.0	31.5
11.0	17	75.0	11.3
19.0	20	71.0	4.8
24.0	20	79.0	3.0
5.0	NP	101.0	31.5
11.0	17	83.0	11.3
19.0	20	77.0	4.8
24.0	20	76.0	3.0
5.0	NP	93.0	31.5
11.0	16	91.0	11.3
19.0	18	74.0	4.8
24.0	18	72.0	3.0
5.0	NP	99.0	31.5
11.0	16	91.0	11.3
19.0	18	74.0	4.8
24.0	18	73.0	3.0
5.0	NP	100.0	31.5
11.0	16	80.0	11.3
19.0	18	70.0	4.8
24.0	18	74.0	3.0
Field:	Santa Fe Air Force Base		
Facility:	N-S runway		
Assembly Load:	15,000 lb		
Assembly Type:	Single, 100-psi tire pressure		
4.5	12	101.0	34.0
12.5	10	78.0	9.0
4.5	11	103.0	34.0
12.5	10	78.0	9.0
4.5	12	104.0	34.0
12.5	17	82.0	9.0
Field:	Sewart Air Force Base		
Facility:	N-S runway		
Assembly Load:	25,000 lb		
Assembly Type	Single, 100-psi tire pressure		
18.5	29	93.0	7.3
24.0	29	91.0	4.6
17.5	24	90.0	8.0
24.0	24	98.0	4.6
14.5	30	86.0	10.6
24.0	30	94.0	4.6
24.0	29	83.0	4.6
17.5	33	89.0	8.0
24.0	33	98.0	4.6
17.5	43	83.0	8.0
24.0	43	72.0	4.6
Facility	Apron		
Assembly Load:	45,000 lb		
Assembly Type.	Dual, 28 in. c-c, 226-sq-in. contact area		
5.5	NP	101.0	33.6
21.5	41	88.0	7.5
29.0	41	90.0	4.8
5.5	NP	94.0	33.6
21.5	34	85.0	7.5
31.0	34	84.0	4.3
Facility	NW-SE runway		
Assembly Load.	45,000 lb		
Assembly Type.	Dual, 28 in. c-c, 226-sq-in. contact area		
5.5	NP	97.0	33.6
18.5	46	90.0	9.0
28.0	46	90.0	5.1
5.5	NP	104.0	33.6
22.5	50	98.0	7.0
28.0	50	92.0	5.1
Facility:	New taxiway		
Assembly Load:	45,000 lb		
Assembly Type.	Dual, 28 in. c-c, 226-sq-in. contact area		
5.0	NP	107.0	36.6
21.5	31	90.0	7.5
30.0	31	87.0	4.5
5.0	NP	108.0	36.6
20.0	36	91.0	8.25
30.0	36	96 0	4.5
Field:	Sheppard Air Force Base		
Facility:	NE-SW runway		
Assembly Load:	15,000 lb		
Assembly Type:	Single, 100-psi tire pressure		
5.5	8	100.0	27.5
12.5	NP	87.0	9.0
20.5	7	79.0	3.8
Facility:	E-W runway		
Assembly Load:	15,000 lb		
Assembly Type	Single, 100-psi tire pressure		
5.0	NP	94.0	31.0
17.0	11	94.0	5.5
Facility.	NE-SW runway		
Assembly Load:	15,000 lb		
Assembly Type:	Single, 100-psi tire pressure		
4.5	7	100.0	34.0
11.5	NP	89.0	10.0
Facility.	N-S runway		
Assembly Load.	15,000 lb		
Assembly Type.	Single, 100-psi tire pressure		
5.0	NP	90.0	31.0
16.5	18	85.0	5.8
5.5	NP	97.0	27.5
17.5	28	89.0	5.2
Facility:	Taxiway 5		
Assembly Load.	15,000 lb		
Assembly Type:	Single, 100-psi tire pressure		
5.0	NP	91.0	31.0
14.5	17	93.0	7.0
24.0	17	82.0	3.0
Facility:	NW-SE runway		
Assembly Load:	15,000 lb		
Assembly Type	Single, 100-psi tire pressure		
5.5	NP	87.0	27.5
16.0	34	91.0	6.0
Facility:	E-W runway		
Assembly Load:	15,000 lb		
Assembly Type:	Single, 100-psi tire pressure		
5.0	NP	93.0	31.0
16.5	30	93.0	5.8
Field.	South Plains Air Force Base		
Facility:	NW-SE runway		
Assembly Load.	12,000 lb		
Assembly Type	Single, 100-psi tire pressure		
4.0	7	92.0	35.0
12.0	13	92.0	9.0
4.0	3	102.0	35.0
12.0	12	98.0	9.0
4.0	NP	105.0	35.0
12.0	13	95.0	9.0
Field:	West Palm Beach Air Force Base		
Facility.	NW-SE runway		
Assembly Load:	35,000 to 95,000 lb		
Assembly Type.	Dual, 37 in. c-c, 267-sq-in. contact area		
5.5	NP	99.0	63.0
23.5	NP	102.0	12.1
33.0	NP	99.9	7.6
Assembly Type:	Dual, 44 in. c-c, 630-sq-in. contact area		
5.5	NP	100.0	41.0
16.5	NP	92.0	14.0
26.5	NP	100.2	8.5
9.5	NP	94.0	24.8
20.0	NP	89.0	11.8
29.5	NP	95.5	7.4
6.0	NP	92.0	37.0
12.0	NP	82.0	19.0
20.0	NP	85.9	11.8
Facility:	N-S runway		
Assembly Load.	35,000 to 95,000 lb		
Assembly Type	Dual, 44 in. c-c, 630-sq-in. contact area		
4.5	NP	94.0	48.5
13.5	NP	93.0	17.8
23.0	NP	96.5	10.0
Facility.	E-W runway		
Assembly Load:	35,000 to 95,000 lb		
Assembly Type	Dual, 44 in. c-c, 630-sq-in. contact area		
7.0	NP	94.0	33.8
17.5	NP	96.0	13.5
26.0	NP	99.0	8.6
6.0	NP	98.0	37.0
21.5	NP	94.0	10.8
31.0	NP	98.9	7.0
14.0	NP	98.0	17.0
23.5	NP	102.7	9.6
Facility:	Taxiway A3		
Assembly Load	35,000 to 95,000 lb		
Assembly Type:	Dual, 44 in. c-c, 630-sq-in. contact area		
5.5	NP	101.0	41.0
21.5	NP	94.0	10.8
31.0	NP	99.8	7.0
Facility	Taxiway A4		
Assembly Load:	35,000 to 95,000 lb		
Assembly Type	Dual, 44 in. c-c, 630-sq-in. contact area		
5.5	NP	103.0	41.0
22.5	NP	93.0	10.0
29.0	NP	99.8	7.6

(Continued)

TABLE 4 (Continued)

Depth from Surface in.	Plasticity Index	Per Cent Mod AASHO Density	Compaction Index
K. (Continued)			
Facility: Taxiway A3			
Assembly Load: 35,000 to 95,000 lb			
Assembly Type: Dual, 44 in. c-c, 630-sq-in. contact area			
5.5	NP	104.0	41.0
19.0	NP	99.0	12.2
29.0	NP	106.5	7.6
Facility: NE-SW runway			
Assembly Load. 35,000 to 95,000 lb			
Assembly Type· Dual, 44 in. c-c, 630-sq-in. contact area			
6.5	NP	100.0	35.0
8.5	NP	103.0	27.5
17.0	NP	97.0	14.0
26.5	NP	102.7	8.5
Facility· Taxiway A1			
Assembly Load· 35,000 to 95,000 lb			
Assembly Type: Dual, 44 in. c-c, 630-sq-in. contact area			
6.0	NP	99.0	37.0
18.0	NP	97.0	13.3
28.5	NP	95.2	7.8
Facility: Apron C			
Assembly Load: 35,000 to 95,000 lb			
Assembly Type: Dual, 44 in. c-c, 630-sq-in. contact area			
14.5	NP	94.0	16.5
24.0	NP	99.2	9.5
16.0	NP	100.0	15.0
25.5	NP	99.2	8.9
Field: Woodward Air Force Base			
Facility: Taxiway 3			
Assembly Load: 25,000 lb			
Assembly Type: Single, 100-psi tire pressure			
5.5	NP	91.0	35.5
14.5	NP	88.0	10.6
24.0	9	85.0	4.6
5.5	4	95.0	35.0
14.5	NP	88.0	10.6
19.5	9	92.0	6.7
24.0	9	87.0	4.6
Field: Yuma Air Force Base			
Facility: Taxiway 7			
Assembly Load: 30,000 lb			
8.0	NP	105.0	25.8
12.5	NP	103.0	14.5
24.0	NP	97.0	5.5
5.5	NP	104.0	38.7
12.5	NP	97.0	14.5
17.0	NP	94.0	9.6
Facility: N-S runway			
Assembly Load: 30,000 lb			
Assembly Type: Single, 100-psi tire pressure			
6.5	NP	104.0	33.0
15.5	NP	99.0	11.0
24.0	NP	93.0	5.5
6.5	NP	103.0	33.0
14.5	NP	99.0	12.0
18.0	NP	101.0	8.8
5.0	NP	100.0	43.0
13.5	NP	96.0	13.3
24.0	NP	96.0	5.5
6.0	NP	103.0	35.7
15.5	NP	103.0	11.0
24.0	NP	89.0	5.5
6.5	NP	100.0	33.0
16.5	NP	95.0	10.0
24.0	NP	89.0	5.5
7.0	NP	98.0	30.0
16.5	NP	93.0	10.0
24.0	NP	89.0	5.5



igure 4. Compaction requirements of cohesive (plastic) soils for flexible airfield pavements, Table 1 data.

ıd plasticity of the soil, and on the load, tire arrangement, tire pressure, and volume
traffic. Table 3 summarizes the data from certain carefully controlled test sections;
ese were considered of primary reliability. Table 4 summarizes data from airfields,
ich were considered of secondary reliability.

The data from Table 3 are plotted as diagrams of percent compaction versus com-
ction index in Figures 4 and 5. Since tolerable amounts of settlement from compac-
on have not been established, the points shown in Figures 4 and 5 cannot be separated
o "acceptable" and "nonacceptable" categories with a dividing line drawn between
em. The points in Figures 4 and 5 that plot toward the lower densities (for a given
mpaction index) represent cases where the amount of densification that occurred was
all. This could easily be due to a low volume of traffic or a moisture content con-
lerably dry (or wet) of optimum. The points that plot toward the higher densities,
wever, represent those cases where the volume of traffic was high and the moisture
nditions were proper for compaction to occur. A limiting line, set high enough so
t all points would fall below it, would be a completely safe limit; however, due to
inaccuracies involved in density sampling and in determining the proper reference
nsity (modified AASHO), it is felt that such a limiting line would be unduly conserva-
e. Also, some of the points lying in high positions may be due to unusually high den-
ies developed during construction, or to naturally high densities, rather than to traf-
. The lines shown in Figures 4 and 5 are intended to exclude the majority of the
nts. The shape of the curves was influenced to some degree by the pattern of den-
y-depth-load relations which was in use prior to the time this study was made.

In Figure 4, which treats cohesive soils, the material strength requirements and
sultant normal design practices affect the values at high compaction indexes. Load-
s applied to a test section or airfield that would plot in the high C_i range would pro-
e failure unless the materials involved had unusually high strengths (CBR values).
hesive materials at or near optimum moisture content do not normally have these
sually high strengths, but may have them at moisture contents well below optimum.
ollows that the data which were obtained for cohesive materials at high values of C_i
ld not have been in the proper moisture condition to give maximum compaction.

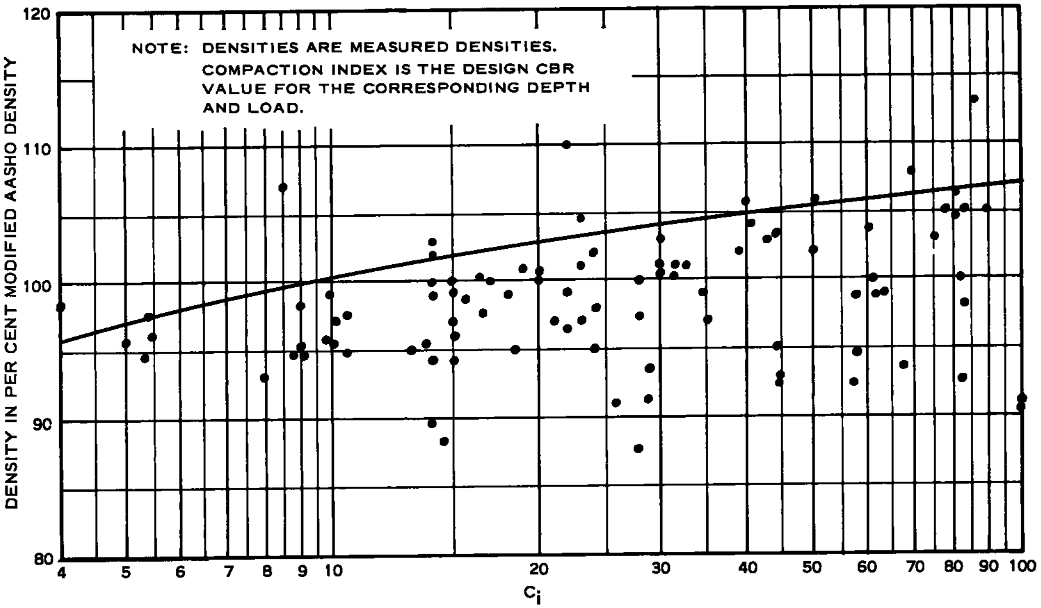


Figure 5. Compaction requirements of cohesionless (NP) soils for flexible airfield pavements, Table 1 data.

Therefore, data above a C_i of 50 have not been plotted, and some of the points immedi ately below a C_i of 50 must remain in question.

Figures 6 and 7 are plots of percent compaction versus compaction index for all th

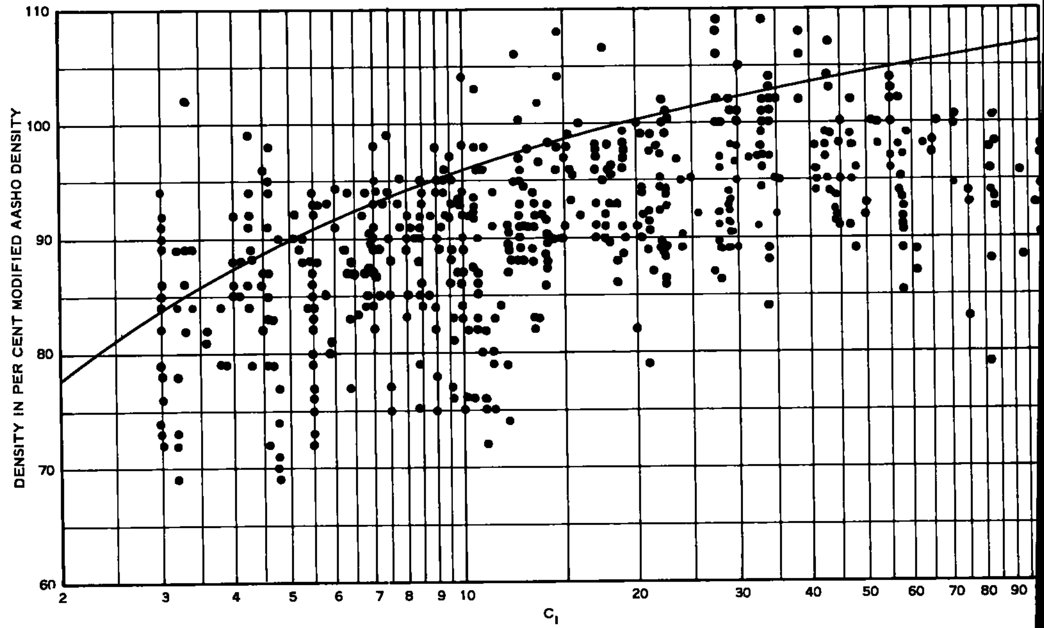


Figure 6. Compaction requirements of cohesive (plastic) soils for flexible airfie pavements, all data.

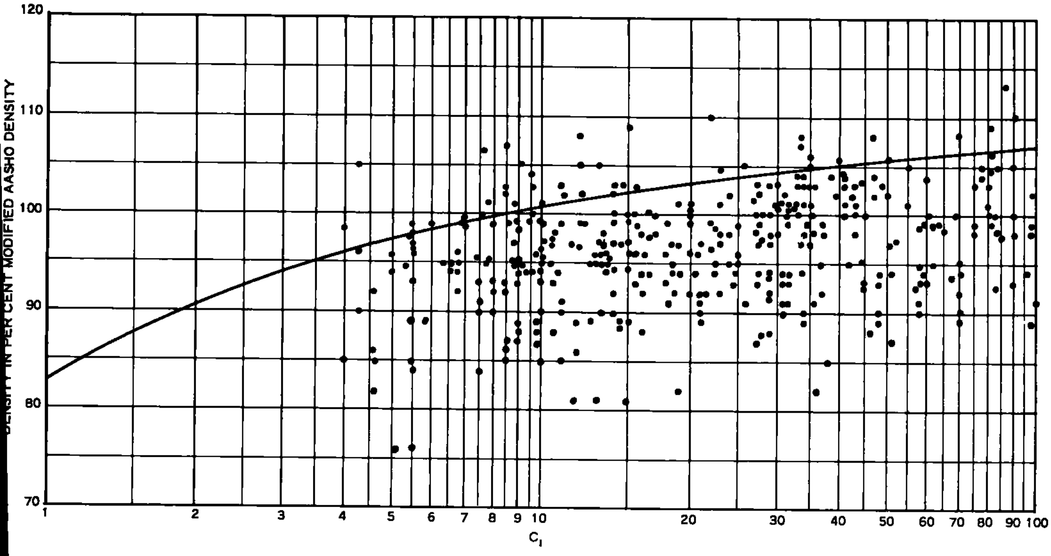
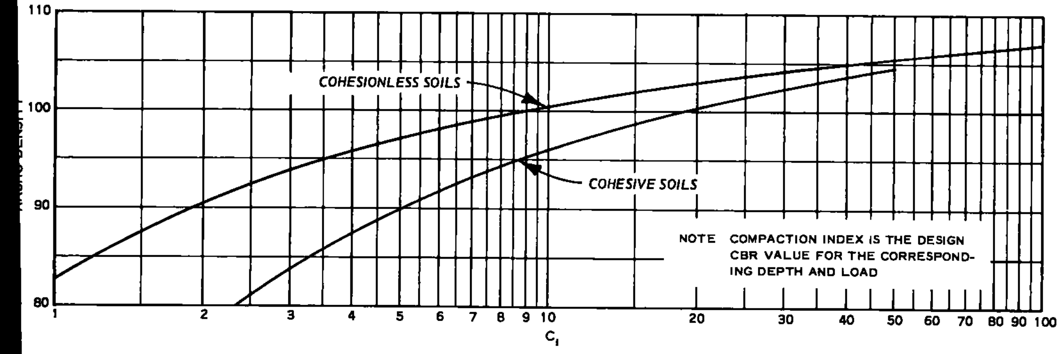


Figure 7. Compaction requirements of cohesionless (NP) soils for flexible airfield pavements, all data.

ata. The curves on these figures are the same as those shown in Figures 4 and 5.
Vhile at first glance it may appear that Figures 6 and 7 are an unrelated scatter of
oints, the plots have meaning if it is accepted that the required degree of compaction
ecreases with decreasing compaction index. On this basis the uppermost points in
ie right-hand portion in Figures 6 and 7 (the high C_i range) are considered to have re-
ulted from compaction by aircraft traffic. On the other hand, densities indicated by
ie uppermost points to the left were not necessarily the result of compaction by air-
raft traffic. For instance, 90 to 95 percent of modified AASHO maximum compaction
commonly required throughout fill sections, with 95 to 100 percent required in the
p 6 in. of the subgrade. Also it is possible in some cases for cut sections to be at
igher densities than those that will be produced by aircraft using the overlying pave-
ient. For these reasons, less importance should be attached to the high plotted points
the left-hand portions of Figures 6 and 7. The absence of points indicating high den-
ities in the very high C_i range in Figure 6 is due to the inability of cohesive materials
exhibit these unusually high strengths at optimum moisture contents, as discussed
reviously.

It was first thought that soil type as expressed by the plasticity index (PI) would be
sufficiently critical parameter that it might be treated in a number of ranges, such



NOTE COMPACTION INDEX IS THE DESIGN CBR VALUE FOR THE CORRESPONDING DEPTH AND LOAD

Figure 8. Compaction requirements for flexible airfield pavements.

TABLE 5

Material	Percentage Compaction
	Materials with Design CBR Values of 20 and Above
Base courses	Maximum that can be obtained, generally in excess of 100% of modified AASHO maximum and never less than 100%.
Subbases and subgrades	100% of modified AASHO maximum except where it is known that a higher density can be obtained practicably, in which case the higher density should be required.
	Materials with Design CBR Values Below 20
Select material and subgrades in fills	As shown below except that in no case will cohesionless fill be placed at less than 95% nor cohesive fill at less than 90%.
Subgrade in cuts	Subgrade in cuts must have natural densities equal to or greater than the values listed below. Where such is not the case, the subgrade must (a) be compacted from the surface to meet the tabulated densities, (b) be removed and replaced, in which case the requirements given above for fills apply, or (c) be covered with sufficient select material subbase and base so that the uncompacted subgrade is at a depth where the in-place densities are satisfactory.

Depth of Compaction for Select Materials and Subgrades

		Depth of Compaction in Feet for Per Cent Modified AASHO Compaction Shown								
		Cohesionless Materials				Cohesive Materials				
Type of Assembly	Gear Load, kip	100	95	90	85	100	95	90	85	80
Heavy Load Pavements										
Twin assembly, 37-in. spacing, 267-sq-in. contact area	50	2	3-1/2	5-1/2	7	1	2	3	4	5
	100	3	5-1/2	7-1/2	10	2	3	4-1/2	5-1/2	7
	150	4	6-1/2	9-1/2	12	2-1/2	4	5-1/2	7	8-1/2
Twin-twin assembly, 37-62-37-in. spacing, 267-sq-in. contact area	160	3-1/2	6	9	11-1/2	2	3	5	6-1/2	8
	240	4-1/2	8	11	15	2-1/2	4-1/2	6	8	10
	320	5-1/2	9	13	------	3	5-1/2	7-1/2	9-1/2	12
Light Load Pavements										
Single wheel, 100-sq-in. contact area	10	1	1-1/2	2	2-1/2	1/2	1	1	1-1/2	2
	20	1-1/2	2	3	3-1/2	1	1-1/2	2	2	2-1/2
	25	1-1/2	2-1/2	3-1/2	4	1	1-1/2	2	2-1/2	3
	30	1-1/2	2-1/2	3-1/2	4-1/2	1	1-1/2	2	2-1/2	3-1/2
Miscellaneous										
Single wheel, 100-psi tire inflation	10	1	1-1/2	2	2-1/2	1/2	1	1	1-1/2	2
	30	1-1/2	2-1/2	3-1/2	4-1/2	1	1-1/2	2	2-1/2	3
	50	2	3-1/2	4-1/2	6	1	2	2-1/2	3-1/2	4
	70	2-1/2	4	5-1/2	7	1-1/2	2-1/2	3	4	5

as nonplastic, 0-5 PI, 5-10 PI, 10-25 PI, etc. On analysis, however, it was found that distinctions could not be made between the various ranges of plasticity, and that only the separation into cohesive and cohesionless (plasticity index zero or NP) was warranted. This finding was partly due to the small differences between ranges and partly to the data being insufficient to establish such small differences.

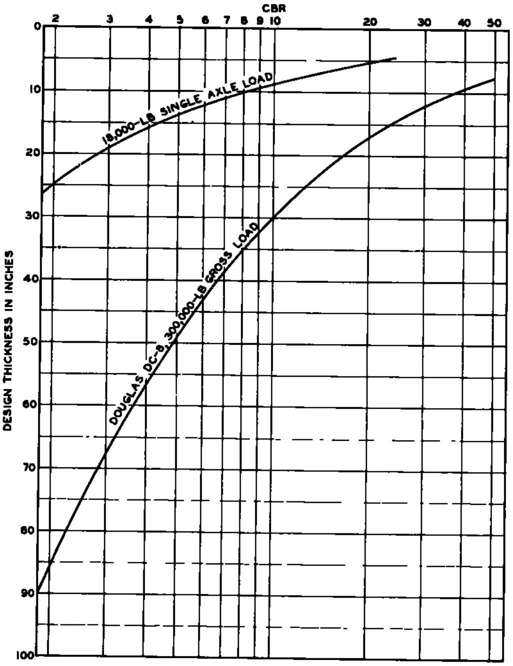
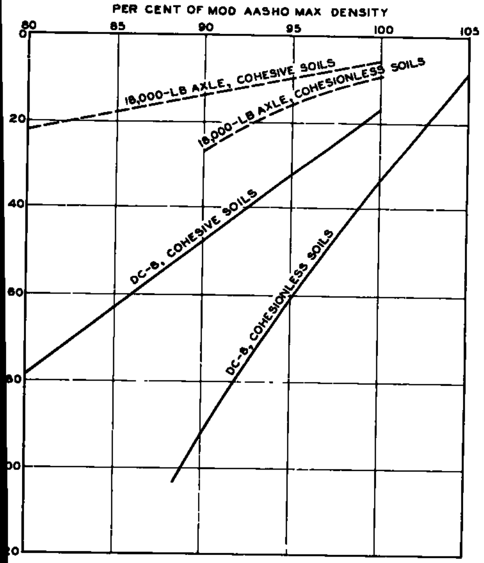


Figure 9. CBR design curves.

The percent compaction versus compaction index curves (shown for both soil ypes in Fig. 8) are the basis of the compaction requirements shown in Table 5. These are the requirements contained in he current (Aug. 1958) Corps of Engi-eers' design manual for pavement areas ubject to normal traffic distribution. The ompaction indexes from Figure 8 were sed with the respective CBR design curve o determine the depth to which the various egrees of compaction should be specified or subgrades with design CBR values less an 20. The depths are rounded off to e nearest half foot. As in previous issues of the manual, the minimum compacon requirements for fills are specified s 95 percent for cohesionless materials d 90 percent for other soils. These are relatively moderate compaction requirements. e values shown in Table 5 for 80 and 85 percent compaction are intended for use in e-luating the adequacy of the natural density in cut sections. Where the natural density less than the requirements, the soil must be compacted to the required density by lling from the surface of the cut (not effective unless the moisture content at the time of rolling is proper) or by removal and replacement in lifts.



ure 10. Example of density requirements.

As shown in Figure 8, indicated percentage of compaction for a compaction index of 20 and above (design CBR of 20 and above) is in excess of 100 percent. Compaction requirements for materials with design CBR values in excess of 20 (base courses, subbases, and high-strength subgrades) are given in Table 5 in a narrative form, rather than as a table, to emphasize the necessity for high degrees of compaction for these materials.

The compaction requirements indicated by the compaction index apply only to the problem of densification by traffic. The problem of the consolidation produced in subgrades and foundations by high fills is a soil mechanics problem.

Application to Civil Airfields and Highways

Figure 8 can be used to establish compaction requirements for civil airfields and for highways when CBR design curves are available. The procedures are illustrated by the following examples. Figure 9 shows CBR design curves for an 18,000-lb, single-axle load (from Fig. IV-2, very heavy traffic class, (3)), andfor a Douglas DC-8 plane at 300,000 lb (from Fig. 4, (1)). The compaction index in Table 6 was read from Figure 8, and the corresponding thickness from Figure 9. For example, the compaction index for 95 percent of modified AASHO maximum density from Figure 3 is 3.5 for cohesionless soils and 8.6 for other soils. The compaction index is converted directly to design CBR (compaction index of 3.5, design CBR of 3.5) and the thicknesses read from the proper curve in Figure 9. For example for the 18,000-lb axle load, the thicknesses indicated from Figure 9 are 17 in. for cohesionless soils and 10 in. for other soils.

TABLE 6

Compaction, %	Cohesionless Soils[1]			Cohesive Soils		
	Compaction Index	Thickness (in.)		Compaction Index	Thickness (in.)	
		18,000-lb Axle	DC-8		18,000-lb Axle	DC-
105	42	-	9	-	-	-
100	9	10	32	19	6	17
95	3.5	17	61	8.6	10	33
90	1.8	27	92	5.0	14	49
85	-	-	-	3.2	18	63
80	-	-	-	2.4	22	79

[1] PI = 0.

Figure 10 is a plot of the percent compaction versus depth given in Table 6. Norm ly, the curves in Figure 10 would be used to establish a step-pattern of compaction re quirements. For example, for the 18,000-lb axle load, 95 percent of modified AASH maximum density would be required to a depth of 14 in. from the finished surface of t pavement, and 90 percent to a depth of 18 in., in cohesive soils. In cohesionless soi 100 percent of modified AASHO maximum density would be required to a depth of 15 i from the finished surface of the pavement, 95 percent to a depth of 27 in. The depth would probably be shifted an inch or two to coincide with a lift. Also, 95 percent wou probably be specified for all cohesionless fills, and 90 percent for other fills.

SUMMARY

The design CBR, termed the "Compaction Index," C_i, provides a means of combi ing into a single parameter the variables of load, tire arrangement, tire pressure, volume of traffic, and depth from the surface to the layer being studied. The relatio developed by the Corps of Engineers Flexible Pavement Laboratory, between compac tion index and the required percentage of modified AASHO maximum density are presented. These relations can be used to develop compaction requirements for civil ai field and highway loadings. Examples of the procedures are given.

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Discussion

EDWARD A. ABDUN-NUR, Consulting Engineer, Denver, Colorado—In developing design compaction requirements from the actual observations on compaction of the various layers in airfields subjected to actual and to accelerated traffic, the authors have given the profession a very realistic approach to design criteria—badly needed in this field. They are to be highly commended for such a fine piece of work.

Figures 4 and 5 are most interesting in that they form the basis of the relationship between compaction requirements and compaction index, from which the requirements at different depths for different wheel loads, arrangements and tire pressures are later derived. Figures 6 and 7 are still more interesting in that they contain a much larger population, even though part of it may not be as reliable as that in Figures 4 an 5. These figures represent, in essence, the basic data from which all the final relationships and conclusions in the paper are drawn.

The authors have very carefully and capably given various reasons and explanations for the scatter of the data exhibited in these figures. Additional reasons and explanations that have also been factors in this scatter, can no doubt be enumerated. Howeve irrespective of any reasons and explanations, this scatter must be accepted as a norm physical picture of any universe being studied. The very orderliness that the authors have implied must exist in the data, and which their explanations tried to justify, simp does not exist in nature or on any project.

With this in mind, the writer questions plotting the curves in these figures at what appears to be the 85 to 95 percentile of the universe. The effect of using such a high level for a basis of design is to inject a factor of safety that is not needed and that will unjustifiably increase the cost of facilities designed to such standards. If to this is added the fact that such levels obtained from 85 or 95 percentile points are further used as minima, then the additional factors of safety interjected by this mechanis lose their practical justification.

It seems to the writer that a realistic approach would be to fit a curve around the average or mean of the data. This automatically allows for the scatter which is boun to result in the compaction on any construction job. If the ultra-conservative curves shown in these figures and the resulting increased cost are justified by other conside ations, then at least, the average requirement of compaction should be used instead o the minimum.

Control of compaction in a universe to a definite minimum is unrealistic, impracti cal, and nearly impossible of attainment on a construction project. The reasons for this have been developed by the writer for portland cement concrete in a paper delive ed at the 1961 Convention of the American Concrete Institute. They are just as applicable to soils, base courses, and bituminous concrete, except that the variations are of a different magnitude in each case. Control by maintaining an average compaction requirement that will assure a predetermined probability that no more than a predete mined percentage of the universe will fall below a given design figure is much more practical, represents the actual physical conditions on the job more realistically, an is obtainable. Such an approach has been used by the writer for several years, and h been recommended recently for compaction, as a result of the AASHO Road Test by W.N. Carey, Jr., J.F. Shook, and J.F. Reynolds in a paper presented at the 1960 Annual Meeting of the American Society for Testing Materials.

If such an average requirement is tied to the uniformity of a given contractor ope ation, a motivation can result that will improve the uniformity of the work far beyond that obtained by any degree of inspection.

W.H. CAMPEN, Manager, Omaha Testing Laboratories—Apparently the densities which are sufficient to produce required CBR values in subgrades, subbases and bases are not high enough to prevent further densification in the field by loaded tires. The authors therefore are proposing a method whereby the necessary degree of density can be specified for various depths of the layered systems under different wheel loads and tire pressures.

Based on the usual relationship between density and CBR the procedure recommended will result in higher values of CBR. Theoretically the thicknesses should therefore be reduced. Has this point been given consideration?

The writer notices also that the sandy or cohesionless subbases attain much higher densities, in respect to designed densities, than other types of subbases. In the writer's opinion the results are to be expected because it is well known now that the impact meth-od used in the laboratory in making the moisture-density test gives low results on cohe-sionless materials. A comparison of the results obtained with the impact method with those obtained by the inundation-vibration method on ordinary sand may show the former to be only 92 of the latter.

C.R. FOSTER and R.G. AHLVIN, Closure—The authors agree that Mr. Abdun-Nur's proposal to use statistical quality control methods in the control of compaction is a good one. The Waterways Experiment Station has made limited use of such methods in re-search work involving repetitive density sampling. The Corps of Engineers, however, s not geared to use of such methods in connection with specification compliance deter-minations, and it will be some time before adequate service test trials and education f field personnel will permit their use.

In regard to the analysis in the paper being discussed, it is doubtful that the methods Mr. Abdun-Nur proposes should be applied. As Mr. Abdun-Nur points out, scatter is ound to occur in the compaction on any construction job. The data being analyzed, owever, are for a multitude of jobs and not just one. Essentially, each plotted point n the figures to which Mr. Abdun-Nur refers (4-7), represents a separate job and herefore a separate universe in regard to the type of control proposed. An attempt to pply the same methods to the universe of universes represented by the data involves random treatment of unknowns and uncontrolled variables of such magnitude that the ariability is greater than the significant range in parameters. Also, such an attempt ould result in an average which would apply to a collection of subsequent constructions uch that half of these constructions would be satisfactory with a degree of conservatism anging upward from none, whereas the other would be unsatisfactory, ranging from ightly to greatly unsatisfactory.

Although the authors do not believe the methods proposed by Mr. Abdun-Nur apply to eir analysis, this in no way detracts from the merits of the methods, and one cannot il to recognize their advantages in regard to construction control.

Mr. Campen's question hews directly to the practical aspects of the interrelation of rength (CBR) and density, and reflects his intimate knowledge of the subject. A de-gn CBR value must be determined for each material used in a pavement structure, d design values necessarily depend on the density to be attained. It is, or has been, mmon practice to select design values from laboratory CBR test results based on a ven percentage of a standard density—frequently 90 or 95 percent of modified AASHO aximum density. Mr. Campen points out that where a higher density is required, a gher design CBR value may be selected.

Corps of Engineers' procedures specify a determination and plotting of CBR test re-lts for a range of moisture contents, densities, and compactive efforts from which sign CBR values are selected. Plots of data of this type permit selection of CBR de-gn values for any pertinent values of moisture content and density.

The authors are glad to have Mr. Campen's comment on the agreement of his exper-nce with theirs in regard to the ready attainment of higher densities in cohesionless terials.