UNCLASSIFIED

AD NUMBER
AD882234
LIMITATION CHANGES
TO: **Approved for public release; distribution is unlimited.**
FROM: **Distribution authorized to U.S. Gov't. agencies only; Administrative/Operational Use; MAR 1971. Other requests shall be referred to Air Force Weapons Laboratory, Attn: DEZ, Kirtland AFB, NM 87117.**
AUTHORITY
AFWL ltr, 29 Apr 1985

THIS PAGE IS UNCLASSIFIED

AD 882234

AUTHORITY: AFWL ltr, 29 Apr 85

AD882234

AFWL-TR-70-133

AFWL-TR
70-133

2

PAVEMENT DESIGN FOR VARIOUS LEVELS OF TRAFFIC VOLUME

D. L. Cooksey

D. M. Ladd

US Army Engineer Waterways Experiment Station

AD NO. ____

DDC FILE COPY

TECHNICAL REPORT NO. AFWL-TR-70-133

March 1971

AIR FORCE WEAPONS LABORATORY

Air Force Systems Command

Kirtland Air Force Base

New Mexico

26

AFWL-TR-70-133

AIR FORCE WEAPONS LABORATORY
Air Force Systems Command
Kirtland Air Force Base
New Mexico 87117

AFWL-TR-70-133

PAVEMENT DESIGN FOR VARIOUS LEVELS OF TRAFFIC VOLUME

D. L. Cooksey
D. M. Ladd
US Army Engineer Waterways Experiment Station

TECHNICAL REPORT NO. AFWL-TR-70-133

FOREWORD

This report was prepared by the US Army Engineer Waterways Experiment Station, Vicksburg, Mississippi, under MIPR 68-10. The research was performed under Program Element 62301F, Project 5713, Task 5-1.

Inclusive dates of research were January 1968 through December 1970. The report was submitted 31 December 1970 by the Air Force Weapons Laboratory Project Officer, Major Guy P. York (DEZ).

This technical report has been reviewed and is approved.

GUY P. YORK
Major, USAF
Project Officer

CLARENCE E. TESKE
Lt Colonel, USAF
Chief, Aerospace Facilities Branch

JEAN M. MARCHAND
Lt Colonel, USAF
Chief, Civil Engineering Division

ABSTRACT

(Distribution Limitation Statement No. 3)

The design of a flexible pavement airfield requires that the traffic volume be considered as one of the parameters. Criteria are presented that allow the airfield designer to design an airfield for any anticipated traffic volume by decreasing the basic design thickness for less-than-capacity traffic and increasing the basic design thickness for traffic volumes greater-than-capacity operation.

This page intentionally left blank.

CONTENTS

This page intentionally left blank.

SECTION I

INTRODUCTION

The thickness design for permanent military airfields in the United States has generally been based upon the anticipated 20-year traffic intensity, which is termed capacity operation. The thickness requirement for capacity operation is considered to be 100-percent design thickness. Except for special traffic areas, such as channelized traffic areas, permanent-type facilities have generally been designed for the 100-percent thickness.

In a limited war situation, it is neither feasible nor economical to construct a pavement for a 20-year design life. In the theater of operations, paved airfields or airfields surfaced with expedient materials (landing mat, membrane, etc.) are normally built for a life of several months to several years. As a tactical mission, it then becomes important to construct an airfield in a minimum amount of time with a minimum of construction materials. To provide guidance to accomplish such a mission, it was necessary to improve existing engineering criteria, which reflect reductions in thickness, that could be used for other-than-capacity operational designs.

The basic tool for designing flexible pavements for less-than-capacity operation is a plot prepared by the U. S. Army Corps of Engineers entitled "Percent of Design Thickness Versus Coverages" (reference 1). Since this plot was based on only a small amount of data obtained prior to 1949 and since there was no unanimous agreement as to the location of this curve with respect to the coordinate axes, it was felt that a study of all currently available data should be conducted to improve the usability of these criteria.

The purpose of this report is to present the results of a project conducted for the investigation and development of data upon which to base adequate engineering criteria for design of flexible pavements that will be subjected to less-than-capacity operation.

An office study was therefore conducted to review and analyze existing traffic test data as presented in numerous technical reports in order to fulfill the test objective.

SECTION II

CURRENT CRITERIA

A procedure has existed for several years for designing or evaluating airfields for various intensities of traffic. This traffic has always been expressed in terms of coverages, where a coverage represents that number of contiguous aircraft wheel passes required to load a designated portion of a pavement one time. The criteria used for designing or evaluating pavements for various coverage levels are shown in a plot of coverages versus percent of design thickness (figure 1). To use this plot, the 100-percent design thickness is determined and then adjusted to the thickness required for other coverage levels. The 100-percent design thickness has been designated as that thickness required for capacity operation or for 5000 coverages. Therefore, thickness requirements for coverage levels other than 5000 coverages are determined by increasing or decreasing the 5000-coverage thickness by the percent design thickness value read from figure 1.

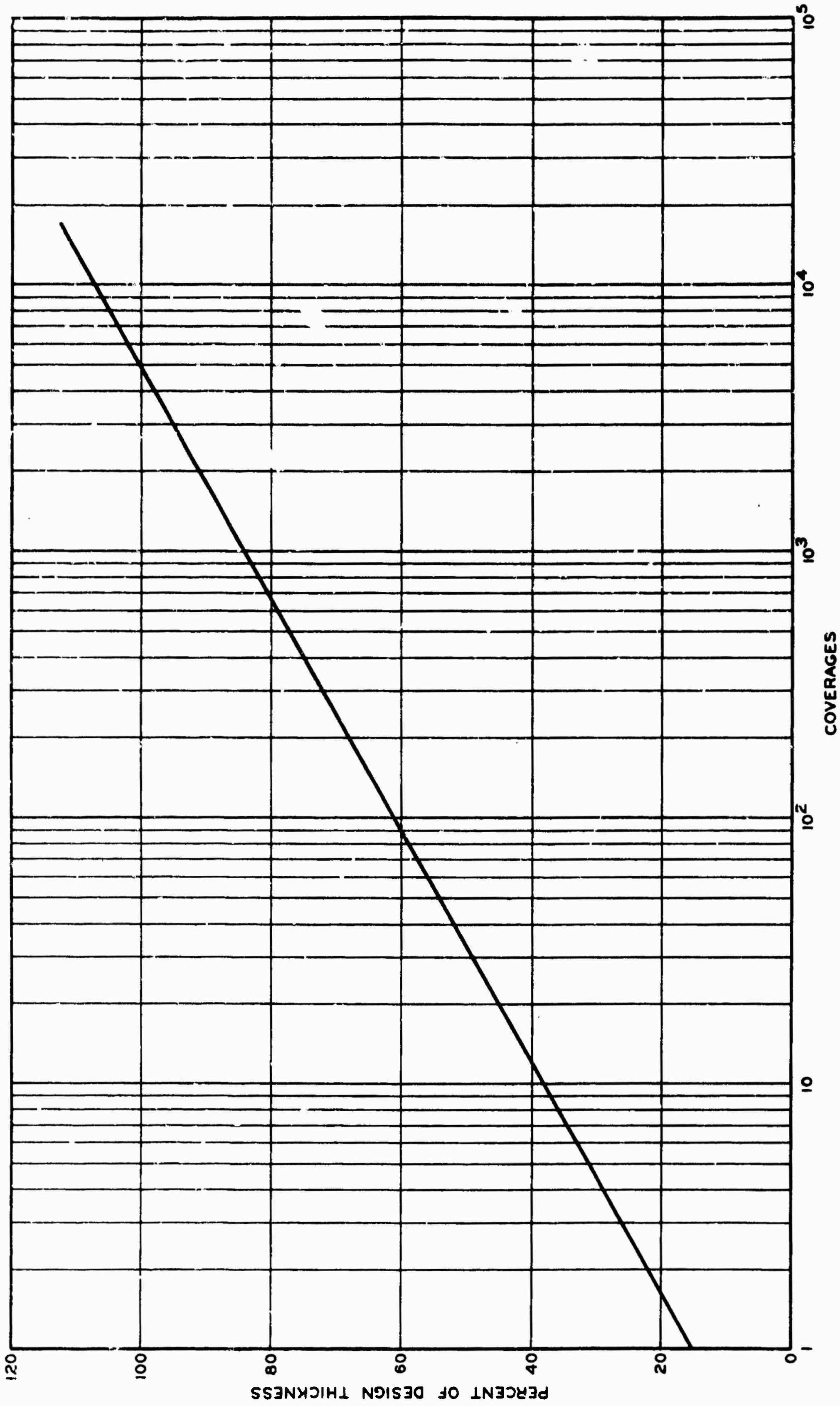


Figure 1. Current Thickness Adjustment Curve

SECTION III

DISCUSSION OF DATA

In order to accomplish the purpose of this project, it was necessary to select and analyze data from those failed pavements that could be related to current pavement design methods and procedures. The available traffic test data were reviewed regardless of the origin or mode of failure. However, the final analysis was performed using only selected data from that reviewed. The data selected for use in the analysis were data that resulted from subgrade failures, consisted of only one loading intensity, and represented pavement systems constructed using typical construction materials. Only subgrade failures were considered because the current thickness design procedures are based upon protecting the subgrade from failure. Since pavement structures are designed for only one loading intensity, it was necessary to consider only those failures produced by one loading condition. The design of a pavement for various coverage levels is accomplished by reducing only thickness requirements and not material requirements; therefore, those pavement failures obtained on materials not meeting quality standards were eliminated.

The data that met the above requirements are presented in tables I and II. Shown in these tables are the source of the data, loading, subgrade strength (CBR), coverages at failure, thickness above subgrade, gear arrangement, and tire contact area.

Table I

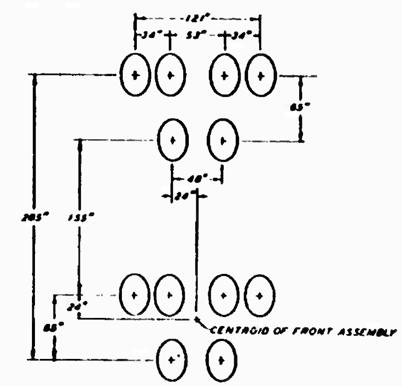
SINGLE-WHEEL TEST DATA

Reference No.	Test Point	Wheel Load kips	Tire Contact Area, in.^{2}	Thickness above Subgrade in.	CBR	Coverages at Failure
2	1	200	1501	39.0	6.0	150
2	2	200	1501	44.0	9.0	1700
2	3	200	1501	18.0	16.0	10
2	4	200	1501	20.5	18.0	60
2	5	200	1501	23.5	15.5	360
2	6	200	1501	30.0	17.5	1500
2	7	200	1501	49.0	8.0	1300
3	8	15	250	10.0	8.0	3760
3	9	15	250	10.0	9.0	3760
4	10	50	285	15.0	3.7	6
4	11	50	285	24.0	4.4	200
4	12	30	285	15.0	3.7	120
5	13	30	150	12.0	14.0	216
5	14	30	150	12.0	7.0	178
5	15	30	150	12.0	6.0	203
6	16	10	91	5.0	6.0	40

Table II

MULTIPLE-WHEEL TEST DATA

Reference No.	Test Point	Type of Assembly	Wheel Spacing in. c-c	Assembly Load kips	Tire Contact Area, in.^{2}	Thickness above Subgrade in.	CBR	Coverages at Failure	Remarks
7	1	Twin	37	70	330	10	20.0	2000	* The 12-wheel assembly, shown below, represents one main gear of a C-5A aircraft.
7	2	Twin Tandem	31 x 63	150	262	14	16.0	1000	
5	3	Twin Tandem	31½ x 60	120	150	16	12.0	312	
5	4	Twin Tandem	31½ x 60	120	150	16	5.0	90	
5	5	Twin Tandem	31½ x 60	120	150	16	15.0	1500	
4	6	Twin Tandem	44 x 58	240	290	33	3.8	40	
4	7	Twin Tandem	44 x 58	240	290	33	4.0	40	
4	8	Twin Tandem	44 x 58	240	290	41	4.0	280	
4	9	12 Wheel	*	360	285	15	3.7	8	
4	10	12 Wheel	*	360	285	24	4.4	104	
4	11	12 Wheel	*	360	285	33	3.8	1500	
4	12	12 Wheel	*	360	285	33	4.0	1500	



SECTION IV

DATA ANALYSIS

The analysis of data in this study was aimed at revising existing criteria for designing flexible pavements for various coverage levels. The following equation from reference 8 is currently used to design pavements for capacity operation:

$$t = \sqrt{\frac{P}{8.1\ CBR} - \frac{A}{\pi}} \qquad (1)$$

Where:

t = thickness of pavement structure above subgrade, in.

P = single or equivalent single-wheel load, lb

CBR = measure of the soil strength

A = tire contact area, sq in.

To determine the design thickness for other-than-capacity coverage levels, the capacity operation thickness is simply multiplied by the percent design thickness as determined from figure 1. The equation for determining pavement thickness then becomes:

$$t = f\sqrt{\frac{P}{8.1\ CBR} - \frac{A}{\pi}} \qquad (2)$$

Where:

f = design thickness, percent

The objective of this analysis was to analyze the available traffic data in order to provide a revised percent design thickness factor. Calculations were made to determine the percent design thickness factor for all test data. This was accomplished by dividing the actual thickness of the pavement structure tested by the thickness required by equation 1. The results of these calculations are shown in tables III and IV. The percent design thickness values calculated were then plotted versus the number of coverages that brought about failure of the test section.

Figure 2 presents the single-wheel data used in this analysis. The curve presently used for percent design thickness determinations was placed on this figure. As can be seen, this curve represents the data very well as an average curve.

Figure 3 presents the twin-tandem-assembly data. In drawing the curve, more reliability was given to points 2, 6, 7, and 8 than points 3, 4, and 5. (Test points refer to numbers from table II.) Points 3-5 were obtained from a test section that had been previously trafficked. Although these tests were run on an area of the section that had not received a significant amount of test traffic, some miscellaneous traffic had been placed on the area and would therefore result in somewhat more coverages than indicated.

Figure 4 represents the results of traffic tests using a 12-wheel landing-gear assembly. A curve was drawn slightly above these points in order to provide some conservatism.

As can be seen, the results of the single-wheel study developed a straight line, and the results of the multiple-wheel study are curves. It was considered, therefore, that the single-wheel criteria should also be represented by a curve. The single-wheel curve was redrawn and is shown in figure 5 with the twin-tandem and 12-wheel curves.

Only one twin-wheel data point was available for use in this study. This point would plot between the twin-tandem and 12-wheel curves. Logic indicates that this point should fall between the single-wheel and twin-tandem curves. Since only one point was available, no curve was provided for twin wheels.

The design curves to be used to obtain the percent design thickness have been developed using the load on one landing-gear assembly of an aircraft. In actual practice, however, designs are to be based upon the load on all main-gear tires. Therefore, the percent design curves (figure 5) show not only the landing-gear type used to develop the curves, but also the total number of aircraft main-gear tires represented by the gear type. Use of the criteria, therefore, is accomplished by determining the equivalent single-wheel load and the percent design thickness for all main-gear tires. However, where it is shown that some combination or grouping of tires other than all main-gear tires will produce a greater thickness requirement than the main tires, then the other combination or group will be used. Use of the criteria for aircraft having a number of wheels other than shown requires interpolation between the curves.

Table III

SINGLE-WHEEL DATA CALCULATIONS

Test Point	Wheel Load kips	Tire Contact Area, in.^{2}	Thickness of Test Section above Subgr, in. t'	CBR	Coverages at Failure	Thickness for Capacity Operation, in. t	Percent of Design Thickness
1	200	1501	39.0	6.0	150	60.4	64.6
2	200	1501	44.0	9.0	1700	47.6	92.4
3	200	1501	18.0	16.0	10	32.7	55.0
4	200	1501	20.5	18.0	60	29.9	68.6
5	200	1501	23.5	15.5	360	33.4	70.4
6	200	1501	30.0	17.5	1500	30.6	98.0
7	200	1501	49.0	8.0	1300	51.1	95.9
8	15	250	10.0	8.0	3760	12.3	81.3
9	15	250	10.0	9.0	3760	11.2	89.3
10	50	285	15.0	3.7	6	39.7	37.8
11	50	285	24.0	4.4	200	36.3	66.2
12	30	285	15.0	3.7	120	30.2	49.7
13	30	150	12.0	14.0	216	14.7	81.6
14	30	150	12.0	7.0	178	21.9	54.8
15	30	150	12.0	6.0	203	23.6	50.2
16	10	91	5.0	6.0	40	13.3	37.6

Table IV

MULTIPLE-WHEEL DATA CALCULATIONS

Test Point	Assembly Load kips	Equivalent* Single-Wheel Load, kips	Tire Contact Area, in.^{2}	Thickness of Test Section above Subgr, in. t'	CBR	Coverages at Failure	Thickness for Capacity Operation, in. t	Percent of Design Thickness
1	70	41.8	330	10	20.0	2000	12.7	78.7
2	150	63.3	262	14	16.0	1000	20.2	69.3
3	120	47.8	150	16	12.0	312	21.1	75.8
4	120	47.8	150	16	5.0	90	33.7	47.5
5	120	47.8	150	16	15.0	1500	18.4	87.0
6	240	125.3	290	33	3.8	40	63.1	52.3
7	240	125.3	290	33	4.0	40	61.4	53.7
8	240	144.0	290	41	4.0	280	66.0	62.1
9	360	61.6	285	15	3.7	8	44.3	33.6
10	360	77.4	285	24	4.4	104	45.6	52.5
11	360	94.3	285	33	3.8	1500	54.5	60.6
12	360	94.3	285	33	4.0	1500	53.1	62.1

* Values derived from equivalent single-wheel load curves in figure 6.

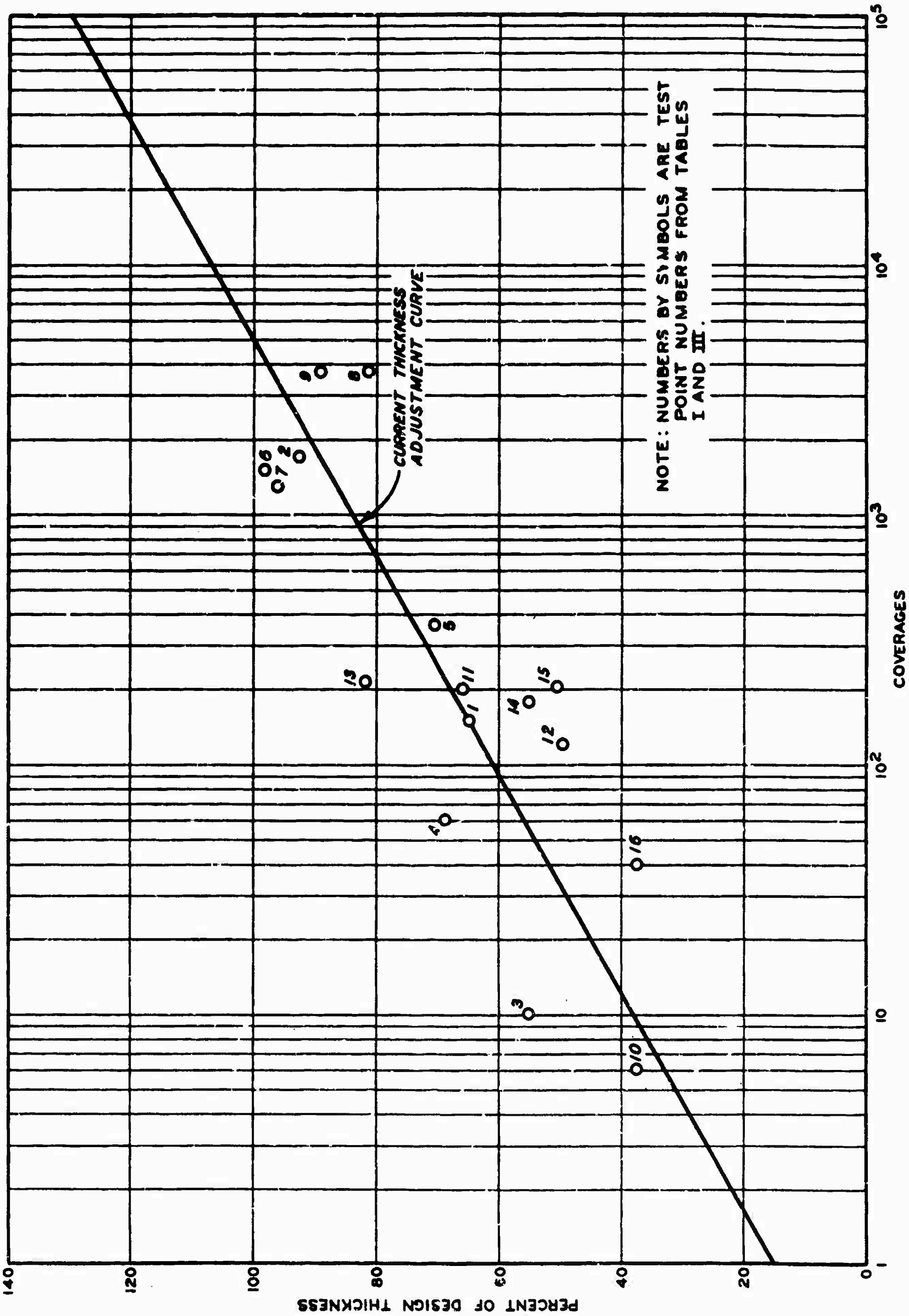


Figure 2. Comparison of Single-Wheel Test Data and Current Thickness Adjustment Curve

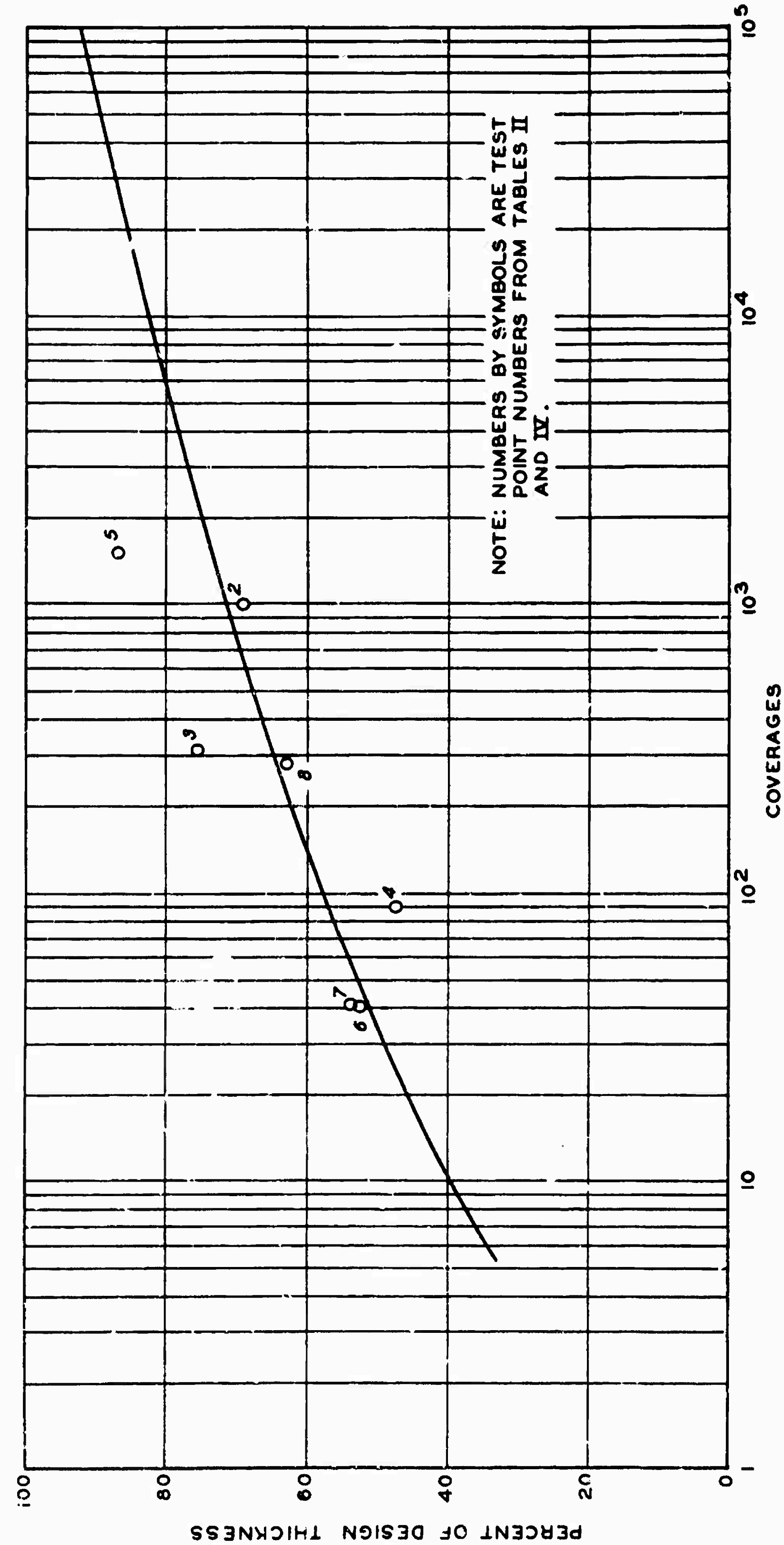


Figure 3. Results of Twin-Tandem-Assembly Traffic Tests with Proposed Thickness Adjustment Curve

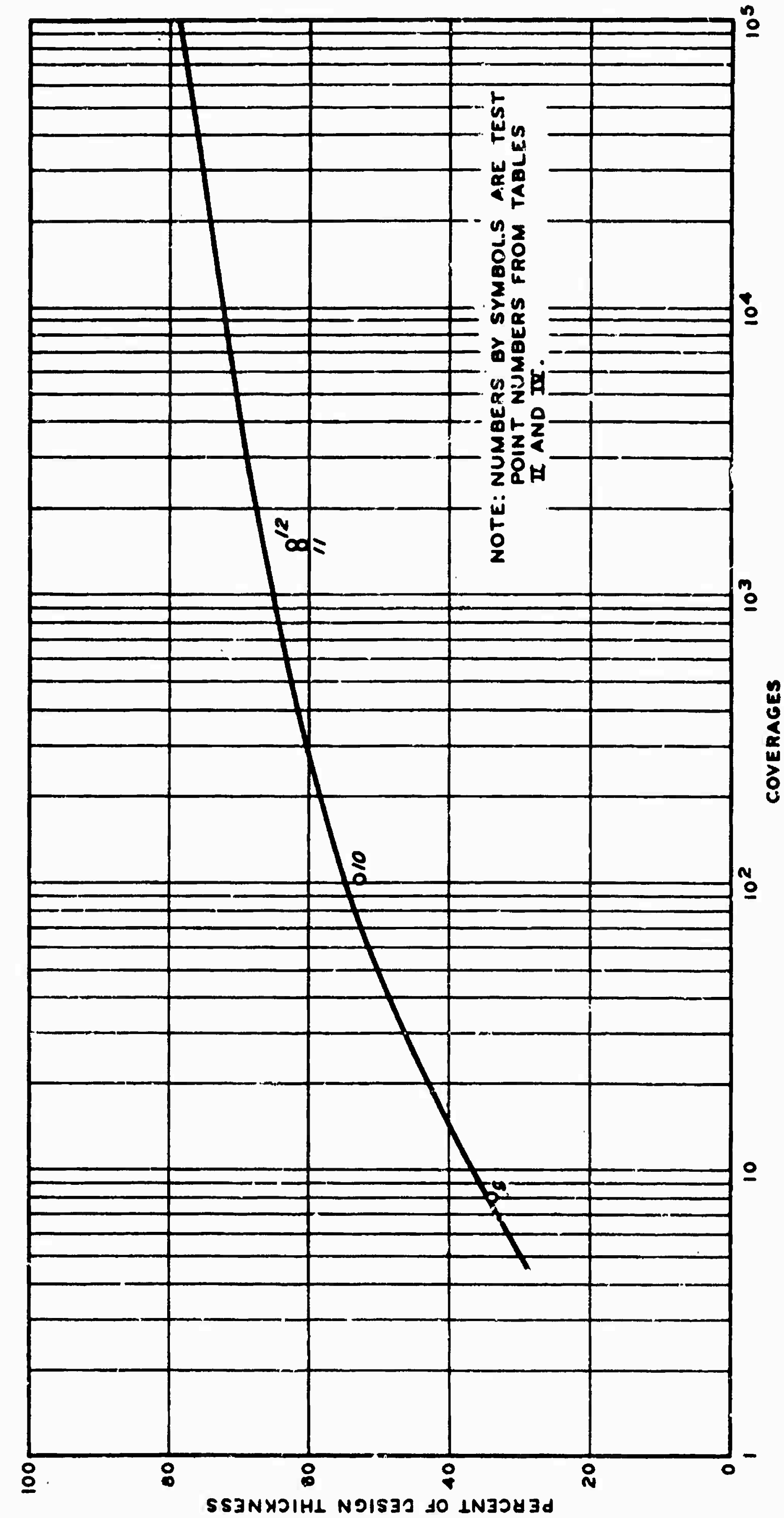


Figure 4. Results of 12-Wheel-Assembly Traffic Tests with Proposed Thickness Adjustment Curve

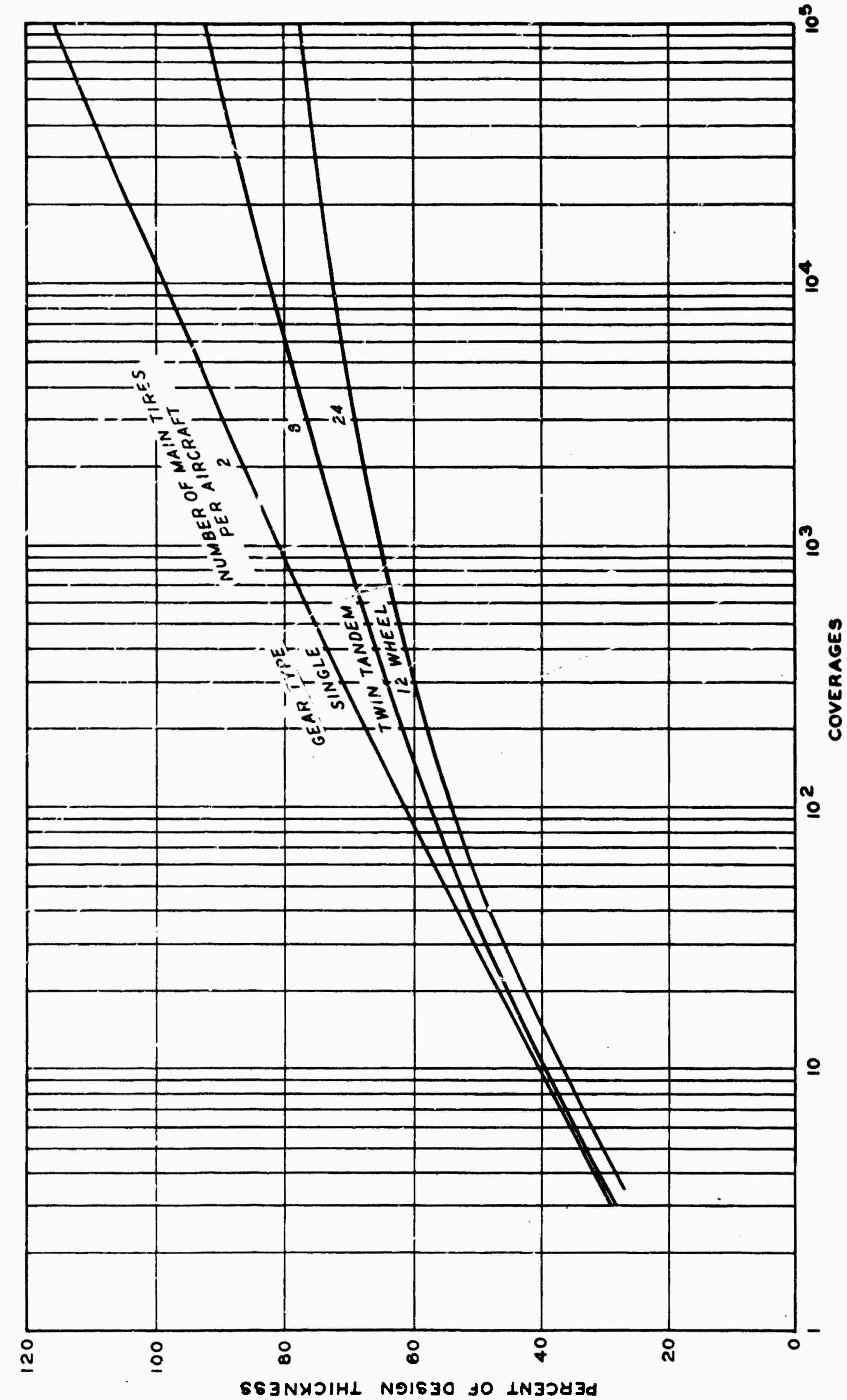


Figure 5. Flexible Pavement Thickness Adjustment Curves for Various Landing Gears

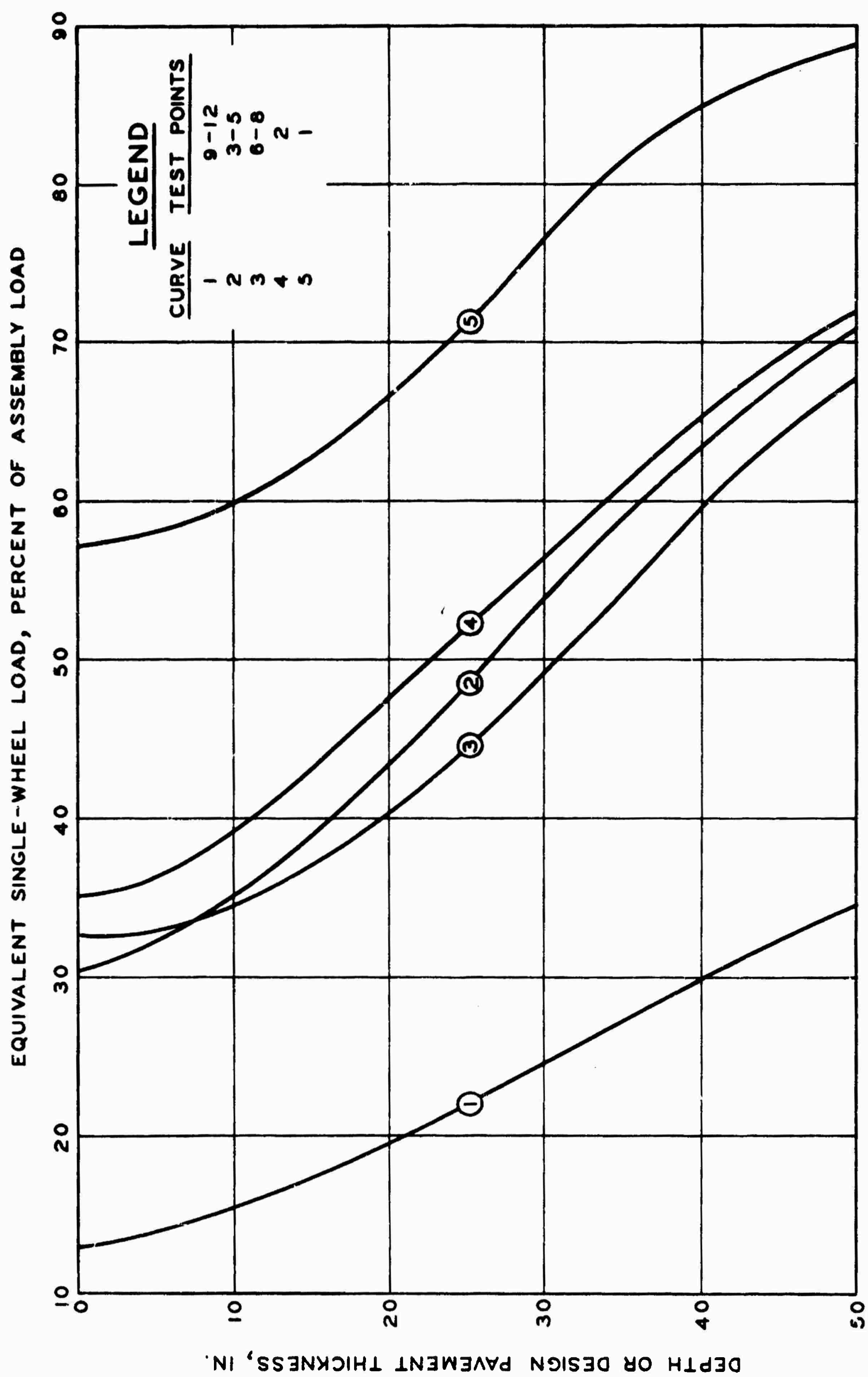


Figure 6. Equivalent Single-Wheel-Load Curves (Used for Table IV)

SECTION V

CONCLUSIONS

In the past, the design of flexible pavement airfields for various traffic volumes has been accomplished by use of a single curve as part of the design criteria. This curve has been modified and expanded into a family of curves, such that each curve represents an aircraft with a particular number of main tires. This family of curves represents the state-of-the-art for designing flexible pavements for various levels of traffic volume.

REFERENCES

1. Collection of Letter Reports on Flexible Pavement Design Curves, Miscellaneous Paper No. 4-61, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss., June 1951.

2. O. J. Porter and Company, Consulting Engineers, Accelerated Traffic Test at Stockton Airfield, Stockton, California (Stockton Test No. 2), Department of the Army, Corps of Engineers, Sacramento District, Sacramento, Calif., May 1948.

3. Flexible Pavement Behavior Studies, Interim Report No. 2, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss., May 1947.

4. Hammitt, G. M., II; Rice, J. L.; Multiple-Wheel Heavy Gear Load Pavement Tests, Analysis of Pavement Behavior, Technical Report S-70- , Report 4 (in preparation), U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

5. Investigation of Effects of Traffic with High-Pressure Tires on Asphalt Pavements, Technical Memorandum No. 3-312, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss., May 1950.

6. A Limited Study of Effects of Mixed Traffic on Flexible Pavements, Technical Report No. 3-587, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss., January 1962.

7. Design of Flexible Airfield Pavements for Multiple-Wheel Landing Gear Assemblies, Test Section with Lean Clay Subgrade, Report No. 1, Technical Memorandum No. 3-349, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss., September 1952.

8. Developing a Set of CBR Design Curves, Instruction Report No. 4, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss., November 1959.

This page intentionally left blank.

UNCLASSIFIED
Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY *(Corporate author)* US Army Engineer Waterways Experiment Station (WES) Vicksburg, Mississippi 39180	2a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED 2b. GROUP

3. REPORT TITLE

PAVEMENT DESIGN FOR VARIOUS LEVELS OF TRAFFIC VOLUME

4. DESCRIPTIVE NOTES *(Type of report and inclusive dates)*
January 1968-December 1970

5. AUTHOR(S) *(First name, middle initial, last name)*

D. L. Cooksey; D. M. Ladd

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
March 1971	26	8

8a. CONTRACT OR GRANT NO. MIPR 68-10	9a. ORIGINATOR'S REPORT NUMBER(S)
b. PROJECT NO. 5713	AFWL-TR-70-133
c. Task No. 5-1	9b. OTHER REPORT NO(S) *(Any other numbers that may be assigned this report)*
d.	

10. DISTRIBUTION STATEMENT
Each transmittal of this document outside the agencies of the US Government must have prior approval of AFWL (DEZ), Kirtland AFB, NM, 87117. Distribution is limited because of the technology discussed in the report.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	AFWL (DEZ) Kirtland AFB, NM 87117

13. ABSTRACT

(Distribution Limitation Statement No. 3)

The design of a flexible pavement airfield requires that the traffic volume be considered as one of the parameters. Criteria are presented that allow the airfield designer to design an airfield for any anticipated traffic volume by decreasing the basic design thickness for less-than-capacity traffic and increasing the basic design thickness for traffic volumes greater-than-capacity operation.

DD FORM 1 NOV 65 1473 REPLACES DD FORM 1473, 1 JAN 64, WHICH IS OBSOLETE FOR ARMY USE.

UNCLASSIFIED
Security Classification

UNCLASSIFIED
Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Civil engineering						
Airfield pavement design						
Flexible pavement						
Runway design						
Runway traffic volume						
Less-than-capacity runway design						

UNCLASSIFIED
Security Classification