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AIRCRAFT-PAVEMENT COMPATIBILITY STUDY

F. H. Griffis, et al

Army Engineer Waterways Experiment Station

Prepared for:

Federal Aviation Administration
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16. Abstract

An economic analysis was performed to relate pavement upgrading cost to penalty cost associated with adding gears and wheels to aircraft in order to provide adequate flotation for present-day pavement design criteria. A basic assumption was made that the *Widebody Jets* and a 15-million-lb aircraft (Categories I and II aircraft, respectively) would use the projected 26 major hub airports by the year 1985. Three gear types were designed for Categories I and II aircraft: current-flotation compatible with present pavement criteria; median-compromise design considering present pavement criteria and optimal gear for aircraft structure; and optimal-gear optimized for aircraft structure with no regard for pavement flotation requirements. Costs were based on each gear type for both categories of aircraft. Pavement data were surveyed for all projected 1985 major hub airports. Rigid and flexible pavement thicknesses were determined for Categories I and II aircraft; thicknesses were calculated both for new construction and for overlay of selected pavement areas where the aircraft might operate. Aircraft costs were developed as associated with carrying landing gear weight and volume in excess of the optimal gear. Pavement upgrading costs were determined and cost comparisons were made. Recommendations and devices were presented relative to policy decisions on pavement criteria.

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PREFACE

This project was conducted by the Soils and Pavements Laboratory, U. S. Army Engineer Waterways Experiment Station (WES), Vicksburg, Mississippi, for the Federal Aviation Administration under IAA. This report covers work done from May 1971 to November 1973.

The project was conducted under the general supervision of Mr. J. P. Sale, Chief of the Soils and Pavements Laboratory. Sections 1 and 2 and 6 through 10 were prepared by MAJ F. H. Griffis, Jr. Sections 3 through 5 were prepared by Mr. M. A. Gamon under the supervision of Mr. Paul C. Durup, Group Engineer, Aeromechanics Group of the Structures Division of Lockheed-California Company, Burbank, Calif., under Contract DACW 39-73-0041, dated 27 November 1972, between WES and the Lockheed-California Company.

During this period of the project, Directors of the WES were BG E. D. Peixotto, CE, and COL G. H. Hilt, CE. Technical Director was Mr. F. R. Brown.

CONTENTS

CONVERSION FACTORS, U. S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

U. S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
inches	2.54	centimeters
feet	0.3048	meters
miles (U. S. statute)	1.609344	kilometers
square feet	0.09290304	square meters
square yards	0.8361274	square meters
cubic inches	16.38706	cubic centimeters
pounds (mass)	0.4535924	kilograms
tons (2000 pounds)	907.1847	kilograms
foot-pounds	1.355818	joules
pounds per square inch	6,894.757	pascals
pounds per cubic inch	27,679.90	kilograms per cubic meter
pounds per cubic foot	16.01846	kilograms per cubic meter

1 EXECUTIVE SUMMARY

The purpose of this study was to perform an economic analysis relating the pavement upgrading cost to the penalty cost associated with adding gears and wheels to aircraft in order to provide adequate flotation for present-day pavement design criteria. Adequate flotation as used here implies distributing the total weight of the aircraft over a larger area to keep pavement stresses within acceptable limits. Specifically, the question answered by this study is "Should the FAA policy on pavement strength stated in paragraph 5 'Maximum Pavement Strength for FAAP Participation' of Order 5320.2 dated July 18, 1966,* be changed due to the advent of the *Widebody Jets* (B747, DC10, L1011) and the possible addition of an aircraft weighing up to 1.5 million lb** to air carrier fleets by 1985?" The basis for the answer of this question was purely economic; environmental, sociopolitical, and energy factors did not enter into the trade-off criteria. The basic assumption that the *Widebody Jets* and the 1.5-million-lb aircraft would use all projected 26 major hub airports in 1985 was not challenged in this study.

1.1 Aircraft Cost Development

To conduct this study, a contract was let to Lockheed-California Company, Inc., to develop two hypothetical aircraft types. The Category I aircraft corresponded to the present *Widebody Jets* and the Category II aircraft corresponded to a projected 1.5-million-lb aircraft to be operational by 1985. Three gear types were designed for both the Categories I and II aircraft. Type 1, referred to as the current gear, is a gear type with flotation compatible with present FAAP/ADAP maximum design criteria. Type 2, referred to as the median gear, is a compromise gear type designed with consideration of the present FAAP/ADAP pavement criteria but also considering the optimal gear designed with respect to

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* The cited paragraph is restated here for easy reference. "The maximum pavement strength for which FAAP [Federal-Aid Airport Program which has been superceded by the Airport Development Aid Program (ADAP)] funds may be applied at any airport may not exceed that required for 350,000 pound dual tandem gear airplane."

** A table of factors for converting U. S. customary units of measurement to metric (SI) units is presented on page 4.

the aircraft structure. Ideally, this median gear lies midway between the two with respect to flotation requirements. The type 3 gear, quite naturally, is the gear type optimized with respect to the aircraft structure with no regard to pavement flotation requirements and is referred to as the optimal gear.

Gear types during this portion of the study were optimized with respect to cost instead of weight.

The model used for the gear designs is the property of Lockheed-California Company. The optimization procedures, from Table 1 in the text, minimize acquisition, maintenance, and flight operation costs of wheels and tires with respect to total weight, vertical load, and tire pressure; brakes with respect to total weight, rejected takeoff, landing kinetic energy, service energy, and number of brakes; bogie beam with respect to total weight, vertical load size, and labor as a function of total number of gears; gear strut, braces, and actuators with respect to total weight, takeoff gross weight, number of gears, and material as a function of gear weight; and gear-support structure with respect to total weight, takeoff gross weight, number of gears, and gear location. Figure 1 shows the gear designs for the Category I aircraft and Figure 2 shows the gear designs for the Category II aircraft as taken from Tables 9 and 12 in the text, respectively.

In conformance with the same contract, Lockheed-California Company surveyed pavement data at all projected major hub airports in 1985. The definition of a major hub airport is one that enplanes more than one percent of the domestic enplaned passengers. FAA Pavement Evaluation Forms for each of the projected 1985 major hub airports are included in this document as Appendix A. In addition to providing a basis for designing the overlay thicknesses required for the pavement costing section of this report, Appendix A provides a central source of pavement data for the subject airports. Table 13 of the text describes the source of the pavement data and, as a check on the validity of the data, each airport engineer was presented a copy for verification. The extreme right-hand column of Table 13 indicates whether or not the airport engineer in question responded to the verification request.

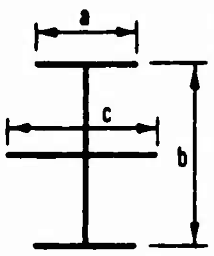
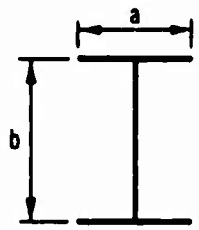
ITEM	CURRENT-PAVEMENT GEAR	MEDIAN-PAVEMENT GEAR	OPTIMIZED GEAR
GEAR CONFIGURATION	6-WHEEL BOGIE	4-WHEEL BOGIE	4-WHEEL BOGIE
TIRE VERTICAL LOAD, POUNDS	38,630	57,950	57,950
TIRE PRESSURE, PSI	200	200	215
TIRE DIAMETER, INCHES	44.8	56.1	53.8
BOGIE SIZE, INCHES a	42.3	44.5	42.4
b	97.7	59.9	57.1
c	56.4	-	-
BOGIE CONFIGURATION			

Figure 1. Gear designs for Category I aircraft

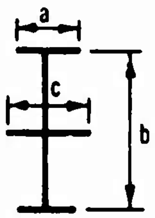
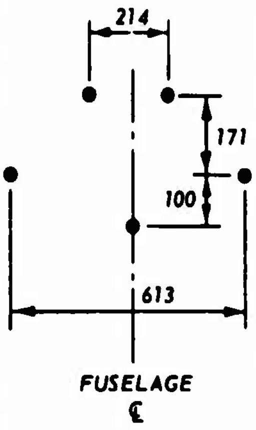
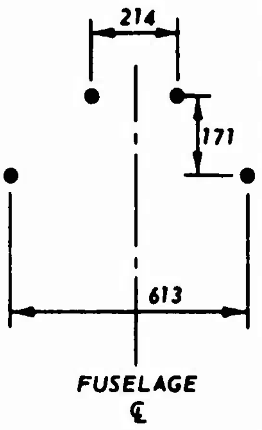
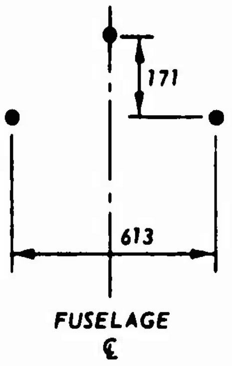
ITEM	CURRENT-PAVEMENT GEAR	MEDIAN-PAVEMENT GEAR	OPTIMIZED GEAR
GEAR CONFIGURATION	FIVE 6-WHEEL BOGIES	FOUR 6-WHEEL BOGIES	THREE 6-WHEEL BOGIES
TIRE VERTICAL LOAD, POUNDS	47,500	59,375	79,167
TIRE PRESSURE, PSI	150	200	250
TIRE DIAMETER, INCHES	56.2	56.9	58.4
BOGIE SIZE, INCHES a	52.2	52.8	54.1
b	120.5	121.8	124.9
c	69.6	70.3	72.1
			
GEAR LOCATIONS, INCHES			

Figure 2. Gear designs for Category II aircraft

The final requirement for the contract was to develop the aircraft cost associated with carrying landing gear weight and volume in excess to that optimized with respect to the aircraft structure and with no regard to the pavement strength. These costs arise from four sources:

o Acquisition cost
o Maintenance cost
o Flight cost
o Lost revenue cost

The first three costs were considered in the landing gear design since the design was based on the least cost design. The lost revenue cost was based upon the lost payload of the aircraft. Several assumptions were made to determine this payload. Figure 3, taken from Figure 25 of the text, is a graphic illustration of the probability assumptions.

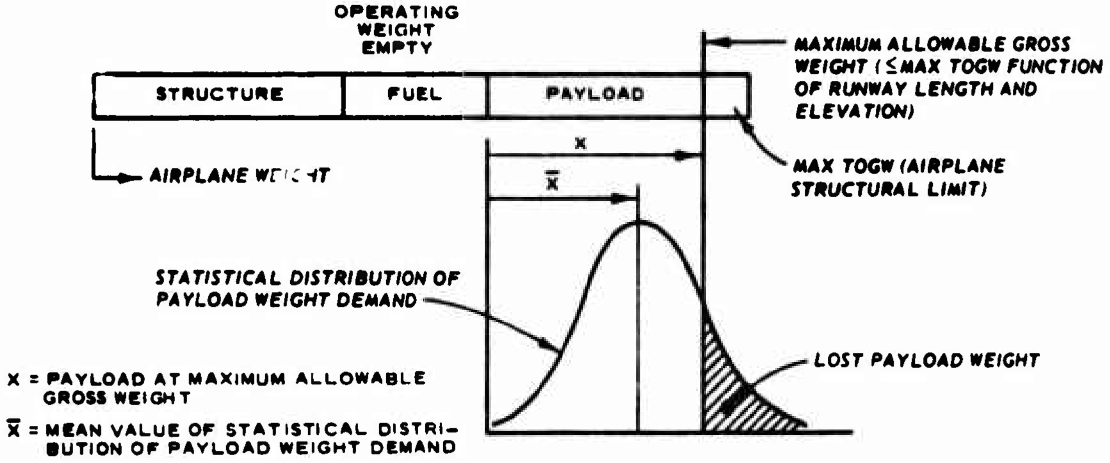


Figure 3. Determination of lost payload

Basically the assumptions include an average weekly payload $\bar{X}$, a normal distribution of payload weight about $\bar{X}$, and a coefficient of variation of 60 percent. The equations used in the lost revenue model were:

$$\begin{aligned}(\text{Total revenue, \$}) = {} & (\text{Passenger miles}) \times (\text{Yield/passenger mile}) \\ & + (\text{Cargo ton mile}) \times (\text{Yield/ton mile})\end{aligned}$$

(Total weight, lb) = (Passenger miles × 200 lb/passenger) + (Cargo ton mile × 2000 lb/ton) ÷ (Flight distance)

(Average yield ($/lb)) = (Total revenue) ÷ (Total weight)

multiplied by 52 weeks per year to arrive at an annual expected lost revenue by aircraft type by distance-block under various landing gear/operational empty weight (OEW) assumptions. This lost revenue is then summed over all the distance-blocks analyzed for the projected 26 major hub airports to determine the total annual lost revenue from operations out of the major domestic hub airports. Tables 17 and 18 of the text give the computed lost revenue from each projected 1985 major hub airport for the Categories I and II aircraft, respectively.

Table 19 lists the total acquisition, operation, maintenance, and lost revenue costs in 1985 dollars for the Categories I and II aircrafts. The total point estimate costs relative to the optimal gear configurations are shown below.

	Current Pavement Gear	Median Pavement Gear
Category I Aircraft	$ 6,673,397	$ 1,929,880
Category II Aircraft	68,777,864	35,160,820
Total Aircraft Cost	75,451,261	37,090,700

1.2 Pavement Cost Development

Because of spatial and temporal variables, a statistical approach was used to develop the total pavement upgrading costs. Since the Dallas-Fort Worth Regional Airport has been designed for a 1.5-million-lb aircraft, it was excluded from the analysis. An assumption was made that two major runways, the associated taxiway systems, and the entire apron area at the remaining 25 projected 1985 major hub airports would be overlayed with either a rigid or a flexible pavement; the pavement type was determined from historical records. Land-acquisition costs were not considered in this analysis.

The initial step in developing the unit price for each pavement upgrading project was to determine the relationship of the pavement cost to the total upgrading cost. Bid tabulations for 14 major airport paving projects published during 1971-1972 in Engineering News Record were analyzed. Upgrading costs were broken down into seven categories and the mean percentage of category cost to total upgrading cost, along with each standard deviation, was computed using small sample statistics. The mean $\bar{X}$ and the standard deviation σ of each category as a percentage of the total upgrading cost are as follows:

Category	$\bar{X}$	σ
Excavation	13.10	11.08
Pavement	72.79	9.81
Subsurface Structures	7.13	5.70
Wiring	1.74	2.27
Lighting	2.21	4.47
Painting	0.37	0.67
Miscellaneous	2.66	4.92

Although some rather large variances occur in the categories other than pavements, this is inconsequential. The average price of pavement as a percentage of the total contract price is 72.79 percent with a coefficient of variation of 14 percent.

An analysis of variance showed that one could not conclude that there was no significant difference between the percentage of rigid pavement price and the percentage of flexible pavement price to total contract price. Thus, a grouped analysis determined the ratios of pavement price to total price used in this study. These parameters are shown below:

Pavement Type	$\bar{X}$	σ
Rigid	77.51	8.03
Flexible	68.06	9.60

The pavement unit prices were developed, in as far as possible, on the basis of the price per square yard per inch (SYIN). Bid tabulations for numerous projects were collected on a regional basis as were FAA Forms 5100-1. The bid tabulations list the square yard (SY) price, whereas the FAA Form 5100-1 records the depth of each pavement layer. Prices were assumed to decrease hyperbolically with increased thickness within an acceptable range.

Equations used for determining unit prices were:

PCC:

C = Price per SY ÷ thickness

Bituminous:

C = Price per SY ÷ thickness

or, when bid tabulations were listed in price per ton,

$$C = \text{Cost per ton} \times \frac{1}{2000 \text{ lb/ton}} \times 150 \text{ lb/cf} \times 9 \text{ sf/SY} \times \frac{1}{12 \text{ in./ft}}$$

The last equation explicity assumed an asphaltic concrete density of 150 lb/cf. In those cases where the price of aggregate and asphalt cement were given separately, an asphalt content of 5 percent was assumed. The rate of application of asphalt prime coats was assumed to be 0.3 gal/SY and tack coats at 0.1 gal/SY. A list of national average prices for pavement products taken from Table 22 of the text is given below.

Pavement Product	Cost Units	Number of Observations	Mean Price	Standard Deviation
Portland Cement Concrete (P501)	$/SYIN	46	0.94	0.34
Bituminous Surface Course (P401)	$/SYIN	21	0.54	0.14
Crushed Aggregate Base (P209)	$/SYIN	8	0.19	0.03
Bituminous Base (P201)	$/SYIN	13	0.59	0.22
Prime Coat (P602)	$/SY	9	0.07	0.02
Tack Coat (P603)	$/SY	23	0.03	0.02

The prices in SYIN used for each of the projected 1985 major hub airports were derived in order of priority according to the following sources:

(1) Project bid data at a particular airport if two or more tabulations were available (this requirement was for some statistical credibility).

(2) Regional averaged bid data for those regions supplying adequate data.

(3) Nationwide averages as listed above.
The prices used for the 1985 major hub airports are listed in Table 23 of the text in 1972 dollars.

Third step in developing the pavement cost was to design the pavement cross section required for the Categories I and II aircraft. FAA design criteria were used for the design at a standard 100,000 aircraft pass level. Only those areas assumed required for operations were considered for design. Design curves and associated rationale are included in Section 7 of the text.

Pavement areas for costing purposes were selected subjectively by this evaluator. Pavement areas were scaled from the sketch drawings shown on the airfield evaluation forms in Appendix A. Most drawings were adequately scaled for the calculation of areas. For those that were not scaled, suitable assumptions were made with respect to the areas involved. From a macro point of view, this was adequate.

Since the total cost varies linearly with the surface area, a sensitivity analysis with respect to area and other parameters was performed. Based on most historical evidence, only two types of overlays were considered: full-depth bituminous overlays, FAA Item P-401; and portland cement concrete overlays, FAA Item P-501. A total expected area of 29,939,536 sy was calculated with 32.2 percent consisting of runway area, 23.4 percent consisting of taxiway, and 44.4 percent consisting of apron area. These statistics are shown in Table 24 in the text.

A comparison of the total aircraft cost and the total pavement price was made in terms of equivalent anuual cost in 1985 dollars.
To develop the total pavement upgrading cost, the unit price p , in dollars per SY, was developed by summing the products of the price per SYIN and the designed thicknesses for each pavement section of each projected 1985 major hub airport with each product divided by the ratio of the pavement cost to the total upgrading cost as developed earlier.
The total pavement cost in 1972 dollars was obtained by multiplying unit price for each pavement section by the area of that section and summing over all of the projected 1985 hub airports. These prices are

listed by airports in Tables 25 and 26. These calculations were made for each category airplane and each gear type relative to a zero cost for not upgrading.

The basic equation for determining the equivalent annual pavement cost in 1985 dollars can be expressed simply as

$$x = p \times A \times (1 + i)^n \left[\frac{i\,(1 + i)^m}{(1 + i)^m - 1} \right]$$

where

x = equivalent annual cost of pavement upgrading in 1985 dollars
p = average total cost of upgrading per sy
A = pavement area to be upgraded in sy
i = interest rate in percent
n = number of years to construction (or bond issuance)
m = amortization period of the pavement structure in years

Some basic value assumptions were necessary in order to make comparisons using this 5-space function. Expected values for p of \$7.36, \$7.77, \$7.45, and \$12.82 in 1972 dollars were computed for the Category I median and optimal gears and Category II median and optimal gears, respectively. The computed value for A was 29,939,536 SY . Assumptions for the remaining independent variables were:

i = 5 percent
n = 13 years (since construction must be concluded in 1985 for the comparison to be valid)
m = 20 years

Since these assumptions are most certainly to be challenged, a thorough sensitivity analysis was performed for each assumption and procedures are presented for recomputing x using the challenger's own assumptions. Tables 27 and 28 in the text list the most probable equivalent annual pavement upgrading cost (MPC) for each projected 1985 major hub airport for the Categories I and II aircraft, respectively. The totals are repeated below for convenience:

	Median Gear	Optimal Gear
Category I Aircraft	$33,328,803	$35,218,395
Category II Aircraft	33,749,362	58,097,736

Due to the extreme difficulty of predicting construction cost in the future, three separate costs were developed for each gear type. An assumption was made that a probable coefficient of variation existed in both unit price and area to be paved calculation of 20 percent. Based on this assumption, a lowest probable cost (LPC) of pavement upgrading was computed assuming a 20 percent low-side calculation in both p and A and a highest probable cost (HPC) was computed assuming a 20 percent high-side calculation in both p and A . However, the original assumptions for i , n , and m were not changed.

Again, the reader is reminded that a device for changing these variables is presented herein also. One should note that, while these analyses were performed for the pavement upgrading cost, only a single point estimate of the aircraft penalty cost has been made. This should be considered in examining conflicting alternatives.

1.3 Cost Comparisons

The purpose of this section is to present economic justification for either modifying or not modifying FAA Order No. 5320.2 with regard to pavement strength. This presentation first considers only the Category I aircraft since the possibility exists that the Category II aircraft will not be operational in 1985.

Category I aircraft. Based on the equivalent annual cost analysis using the MPC for pavement, the total equivalent annual costs are:

o Current Gear	$ 6,673,379
o Median Gear	35,258,683
o Optimal Gear	35,218,395

It is obvious from this listing that the optimal alternative is not to modify the present policy if one only considers the Category I aircraft. If one uses the LPC for pavement, the decision remains unchanged as shown below:

o Current Gear	$ 6,673,379
o Median Gear	13,943,790
o Optimal Gear	12,666,249

These results are illustrated in Figure 44 of the text.

Categories I and II aircraft. A basic assumption inherent in the following analysis is that a pavement structure upgraded for the Category II aircraft would be adequate for the additional Category I aircraft concurrently. The state-of-the-art in pavement analysis is in its infancy concerning mixed traffic and pavement deterioration prediction. Based on the equivalent annual cost analysis using the MPC for pavement, the total equivalent annual costs are:

o Current Gear	$75,451,243
o Median Gear	70,840,062
o Optimal Gear	58,097,736

Based on this total annual cost listing, the present policy should be changed to permit the optimization of the gear to the Category II aircraft. However, in this instance, if one assumes the HPC for pavement, a conflicting alternative arises as shown below:

o Current Gear	$ 75,451,261
o Median Gear	103,239,690
o Optimal Gear	113,842,221

There is considerable logic behind the assumption that the MPC will be exceeded in the pavement upgrading for the Category II aircraft. In all probability, the paved area will exceed that computed in this report. The unit price differential may or may not increase. Thus, it is extremely critical to the decision maker that a proper determination be made as to whether or not the Category II aircraft will be operational in 1985; whether or not it will operate at all 26 projected major hub airports or perhaps only at 7 to 10 regional airports; and other operational assumptions.

Other variable considerations. Numerous figures and equations are presented in the text to permit the user of this document to change parameters and develop his own policy derivation. Assuming that the MPC calculations are correct and n = 13 years, Figure 4 presents a

o Current Gear	$ 6,673,379
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o Optimal Gear	12,666,249

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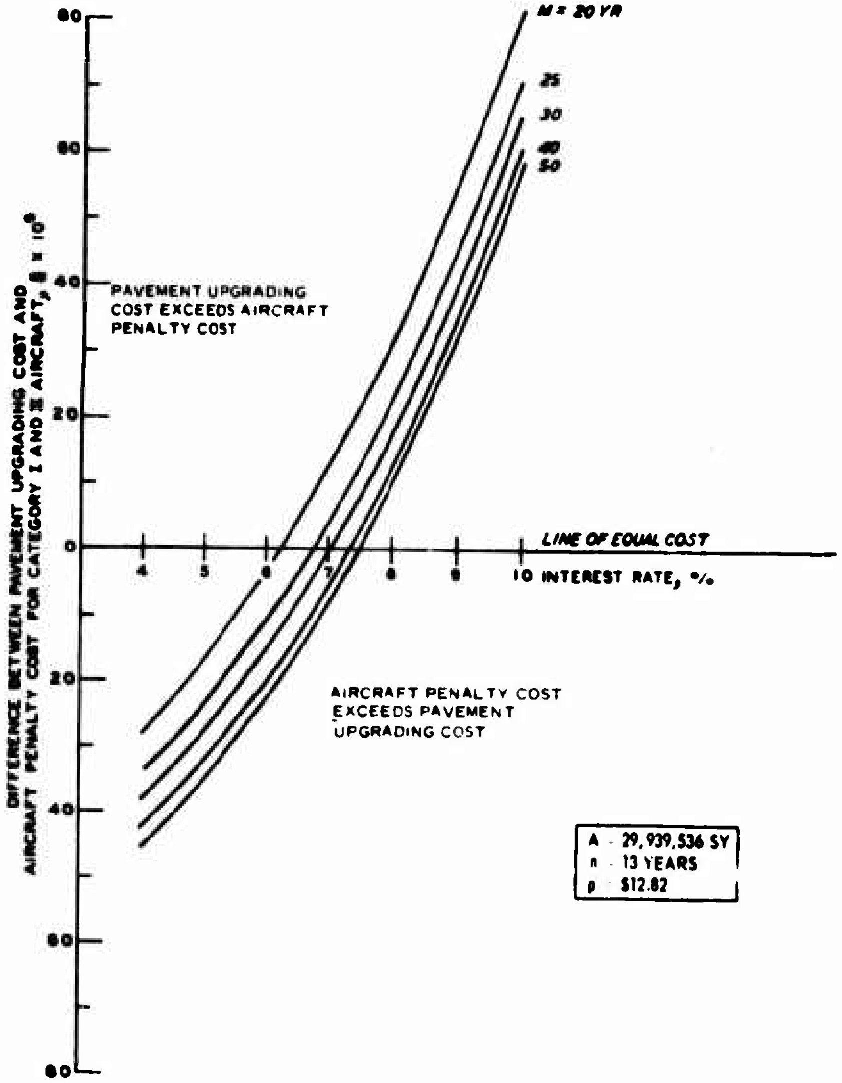

Figure 4. Effects of variations of pavement life m and inflation factor i

convenient method for changing the assumptions for i and m , two elusive parameters. Figure 4 is based on Figure 54 of the text.

1.4 Recommendations

The following recommendations resulted from this study. They are based on the authors' calculations and assumptions. Devices are presented in this report to permit the decision to change these assumptions and calculations and the possibility exists that the recommendations should change based on further developments.

(1) If only the Category I aircraft will be in operation at each of the 26 projected major hub airports in 1985, the current FAAP/ADAP criteria should not be changed.

(2) If the Categories I and II aircraft (implied also is the Category II aircraft alone) will be in operation at each of the 26 projected major hub airports in 1985, the current FAAP/ADAP criteria should be changed to permit the gear to be optimized to the aircraft. The possibility of operating the Category II aircraft at from 7 to 10 regional airports should be investigated.

1.5 Additional Value of This Report

In addition to providing a useful device exclusive of additional cost for examining various policy decisions, this report provides:

(1) A consolidation of airport layouts and pavement structures as of 1972.

(2) An algorithm for designing aircraft gear types on a minimum cost basis.

(3) Pavement design curves for heavy aircraft.

(4) Methodology for complex cost analyses.

2 INTRODUCTION

2.1 Background

Since 1958, the Federal Aviation Administration (FAA) has adopted a policy of limiting pavement design for large jet aircraft to an equivalent 350,000-lb gross weight on a twin-tandem gear configuration. However, to remain within acceptable stress limitations, the B747 has 4 main gear bogies with 16 wheels, and the DC10 series 10 and the L1011 have been designed with larger wheels at greater spacing to remain within the same flotation criterion. The penalty cost associated with conformance to these restrictions has been hypothesized, but quantification has not previously been made public.

As aircraft begin exceeding 0.5-million-lb gross weight, intrinsic penalties obviously tend to occur. For instance, the DC10 series 20 and 30 have two additional wheels under the fuselage. The wide spacing required on the four main gears of the B747 places the gears beneath the engines, thereby decreasing the torque available for ground turning. This greatly impedes the ground maneuverability. As the aircraft industry moves toward aircraft in the 1.5- to 2.0-million-lb gross weight class, even greater penalties intuitively seem plausible.

2.2 Scope

The scope of this study is illustrated in Figure 5 and consists of three parts. First, a contract was let to Lockheed-California Company to design landing gears for two categories of aircraft. Category I consisted of a representative of the relatively new series of commercial jet aircraft, in Lockheed's case, the L1011. Category II consisted of a projected 1.5- to 2.0-million-lb aircraft. These category identifications will be used throughout this report to identify the two types of aircraft. For each of these types of aircraft, Lockheed designed three representative landing gears. The first gear type was constrained by the criterion that states that the gear shall cause no more distress to the pavement than a 350,000-lb aircraft with a dual tandem gear structure with intended spacings similar to a DC8-63F aircraft. The second type of gear is one that is optimized with respect to the aircraft

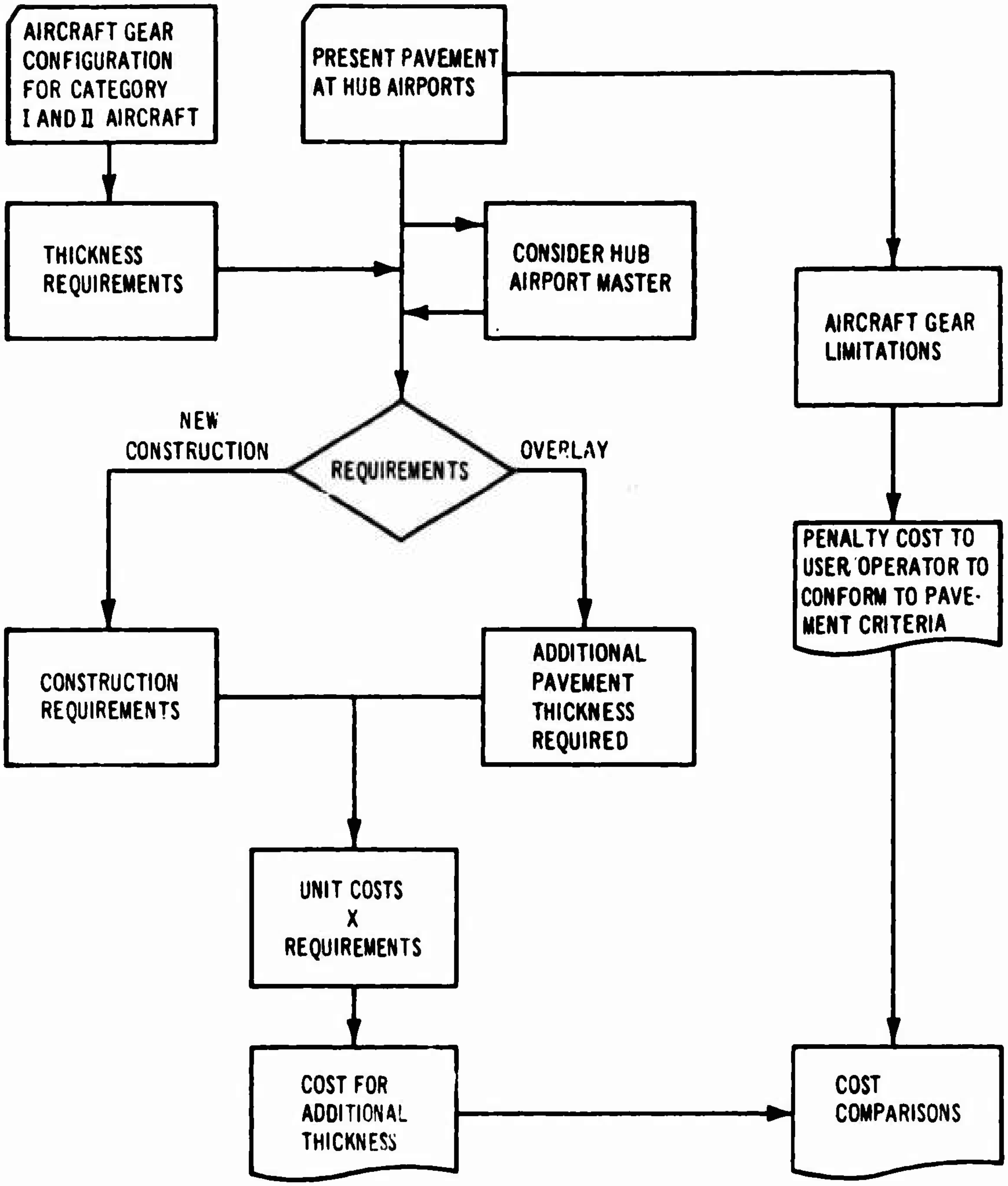

Figure 5. Scope of aircraft pavements compatibility study

without pavement constraints. The third type of gear is a compromise or median gear, causing a pavement distress somewhere between the other two gear types. In addition, Lockheed was required to project the major hub airports that would be servicing the two categories of aircraft in the year 1985 and from derived city pairs, develop the economic penalties associated with the three gear types for both categories of aircraft.

Based on the gear configurations and parameters provided by Lockheed, the U. S. Army Engineer Waterways Experiment Station (WES) analyzed the airport master plans for the projected major hub airports and decided whether new construction or overlays were required to accommodate the six combinations of aircraft. Pavement cross sections were then designed for each major hub airport and total pavement areas computed. Pavement cost data were obtained from FAA Regional Offices in the form of bid tabulations and associated cross-sectional designs. Lockheed provided FAA with condition surveys of each airport.

The final phase of the study consisted of performing a cost analysis at each major hub airport with respect to equivalent annual cost.

2.3 Purpose

The purpose of this study was to determine an optimal policy with respect to cost to be used in the aircraft gear load and pavement system. By increasing flotation to support a given load through an increase in wheels and design of gears, economic penalty is imposed on the user/operator of the aircraft. This, however, reduces the required thickness of pavement. On the other hand, permitting unrestricted flotation to support a given load increases pavement thickness requirements and consequently construction costs which are ultimately paid by the user/operator. An economic analysis was performed to find the optimal policy with respect to increased flotation versus increased pavement thickness. Specifically the question answered by this study is "Should the FAA policy on pavement strength stated in paragraph 5 'Maximum Pavement Strength for FAAP Participation' of Order 5320.2 dated

July 18, 1966,* be changed due to the advent of the *Widebody Jets* (B747, DC10, L1011) and the possible addition of an aircraft weighing up to 1.5 million lb to air carrier fleets by 1985?"

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* The cited paragraph is restated here for easy reference. "The maximum pavement strength for which FAAP [Federal-Aid Airport Program which has been superceded by the Airport Development Aid Program (ADAP)] funds may be applied at any airport may not exceed that required for 350,000 pound dual tandem gear airplane."

3 LANDING GEAR OPTIMIZATION

3.1 Mathematical Model

3.1.1 General discussion. The landing gear optimization scheme was based upon functional relationships that predict the weight and costs of the landing gear system. It has been noted that volume requirements for additional wheels are significant as far as bulk cargo space is concerned; however, volume has been ignored for the purpose of this analysis since the emphasis of this study is on passenger aircraft. Table 1 gives an overall summary of the functional relationships, showing the variables that affect the various gear system costs and weights.

Table 1

Landing Gear Optimization Functional Relationships

Item	Factors Affecting Weight	Factors Affecting Costs		
		Acquisition	Maintenance	Flight Operation
Wheel and Tire	Vertical Load and Tire Pressure	Total Weight	Vertical Load and Pressure	Total Weight
Brake	Rejected Takeoff and Service Energy		Landing Kinetic Energy, Number of Brakes	
Bogie Beam	Vertical Load, Size (from Pavement Stress Curves)		Labor Function of Number of Gears	
Gear Strut, Braces, and Actuators	Takeoff Gross Weight, Number of Gears		Material Function of Gear Weight	
Gear Support Structure	Takeoff Gross Weight, Number of Gears, Gear Location			

The functional relationships were derived from historical airplane weight and cost data, empirical design guides available in the literature, specific detailed weight and cost data on Lockheed airplanes, and calculations. The specific relationships are discussed in the following sections.

3.1.2 Functional weight relationships.

a. Wheel and tire weights. Wheel and tire weights are related to the vertical tire load and tire pressure as shown in Figure 6. This figure was derived from the tire data presented in Reference 1 for current airplane tires and the wheel weight data in Reference 2. The wheel weights are for aluminum forgings from Curve 7 of Reference 2. Figure 6 is an average of all the Type VII and some "New Design" tire data, using the rated tire load (32 percent deflection) and corresponding loaded

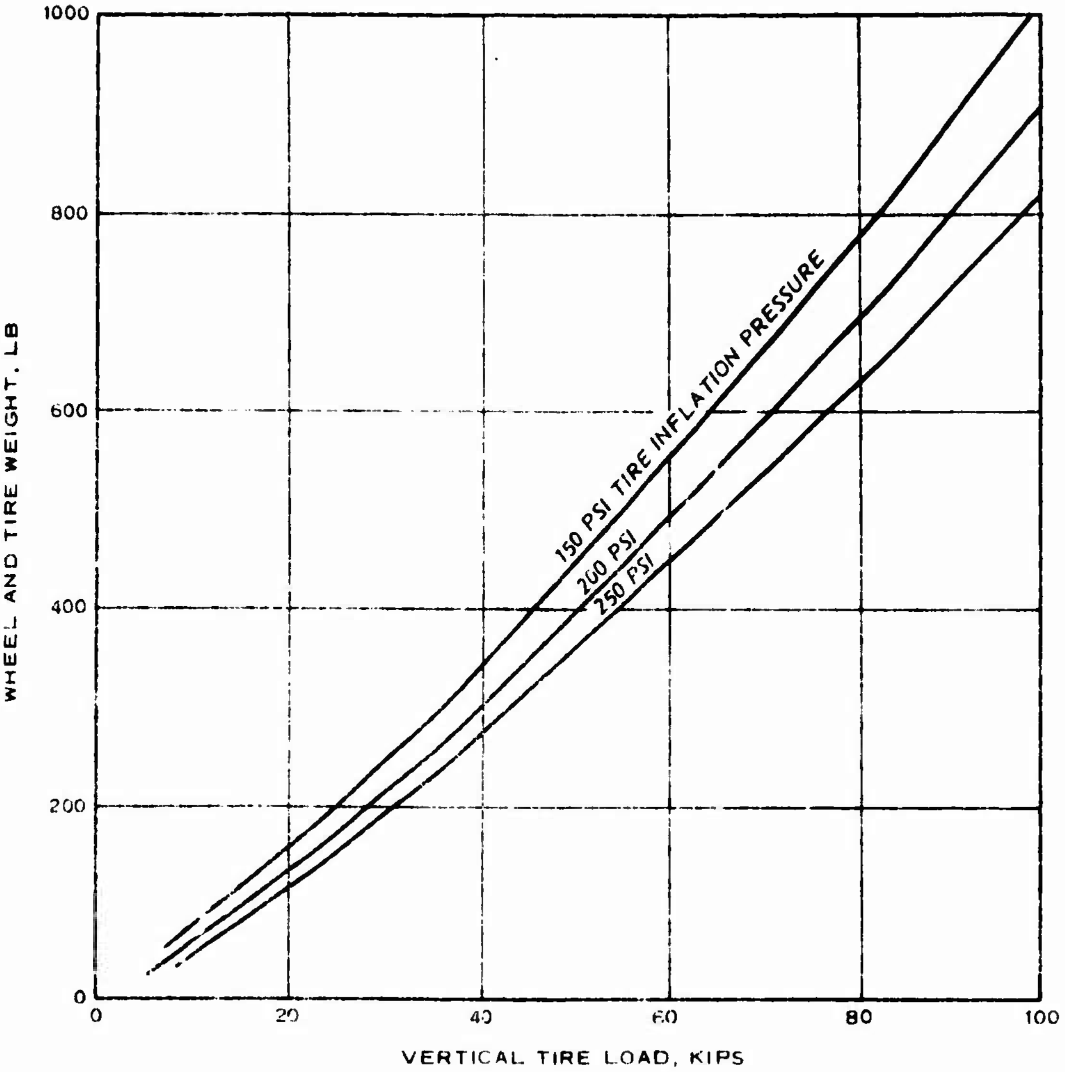


Figure 6. Wheel and tire weight versus vertical load

inflation pressure and tire weight. In general, for a given load, a lighter combined wheel and tire weight result from a higher inflation pressure, since this allows a smaller diameter tire (and smaller surface contact area).

It is also of interest to note from Figure 6 that multiple small tires are more efficient than fewer large tires. For example, 240,000 lb can be carried by six 40,000-lb rated tires weighing 1800 lb (at 200 psi) or by four 60,000-lb rated tires weighing 1976 lb. This represents a weight saving of almost 9 percent by changing from four to six tires.

Figures 7 and 8 show the relationship between tire load and outside diameter and between tire outside diameter and rim diameter. Again these are statistical averages of the actual data from Reference 1. These curves were needed to determine the minimum possible bogie size (function of tire outside diameter) and to determine brake width (function of rim diameter).

b. Brake weight. The total brake weight for the airplane was determined from Figure 9, which is reproduced from Reference 2. Data are shown in Figure 9 for rejected takeoff (RTO) kinetic energy and for service energy with a brake life of 1000 landings. The higher weight from the two curves was used to design the brake. One thousand landings represent a relatively long service life, so that the RTO curve tended to control the design of the brake weight. Since current widebody transport airplanes are being designed with this brake life, the 1000-landing curve was used for this study. (Shorter brake-life curves lie between the two shown, giving lighter brake weight.)

For any given gear configuration, it must be ascertained if the above-determined brake weight can be physically located within the wheels provided. Figure 10 from Reference 2 shows the heat sink volume corresponding to different brake weights. Figure 11, from Reference 2, shows the heat sink volume available per inch width for different rim diameters. From Figures 10 and 11, the resulting brake width can be calculated for a given configuration. From the data in Reference 1, the rim width averages about 0.54 times the diameter. Therefore, both the wheel width and the brake width are calculated. As long as the brake width is not more than a few inches larger than half the wheel width, the configuration is acceptable.

The brake data above are all based on conventional steel heat sink brakes. Other more exotic brake

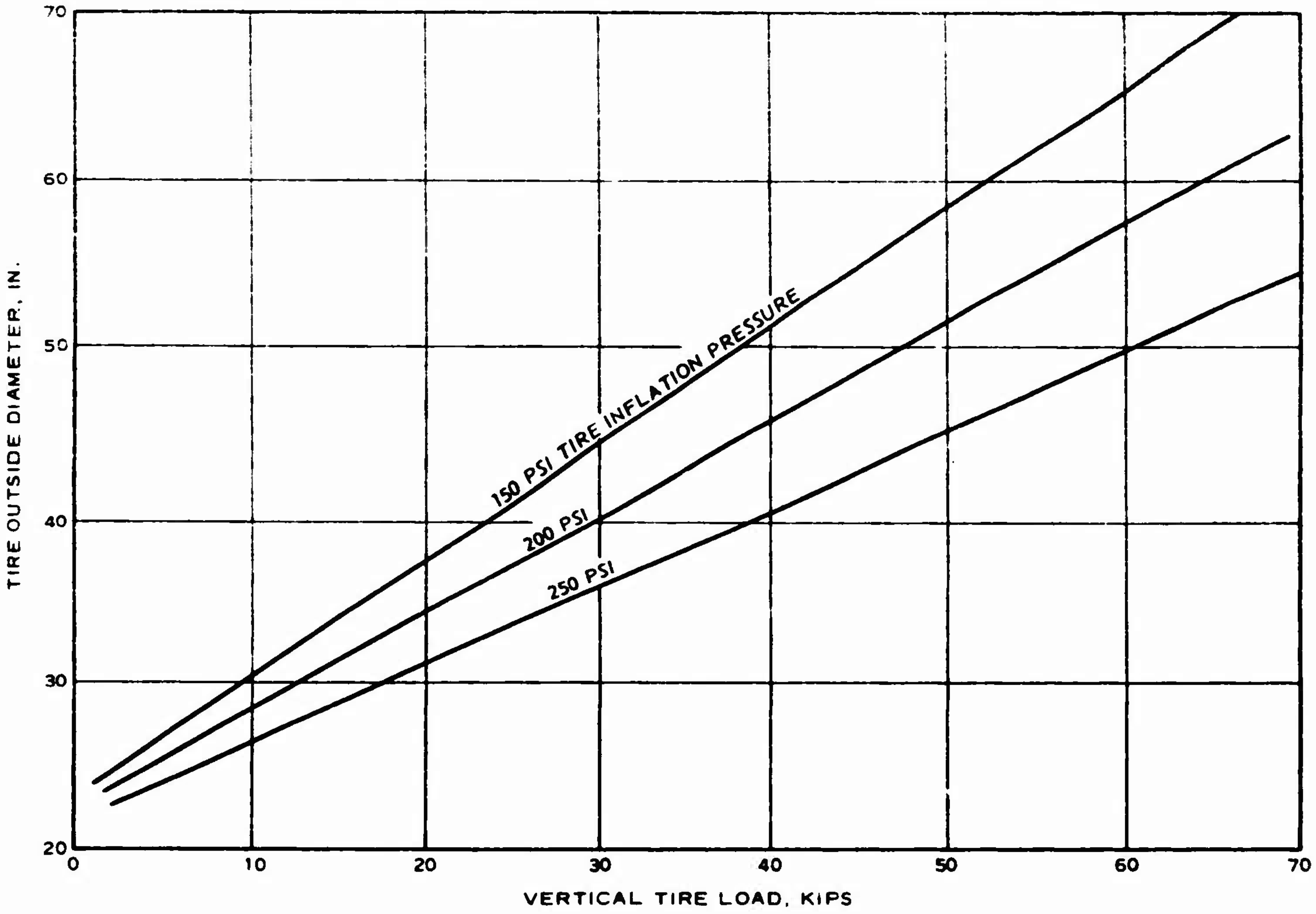


Figure 7. Tire outside diameter versus load

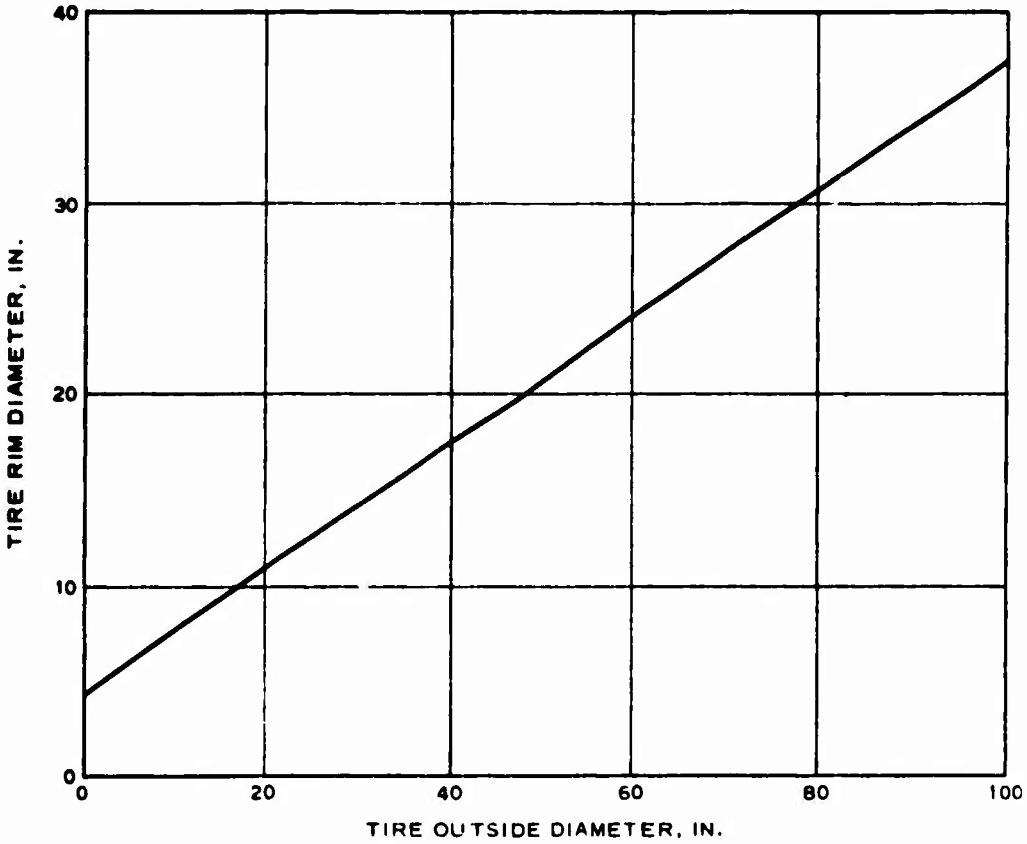


Figure 8. Rim diameter versus tire diameter

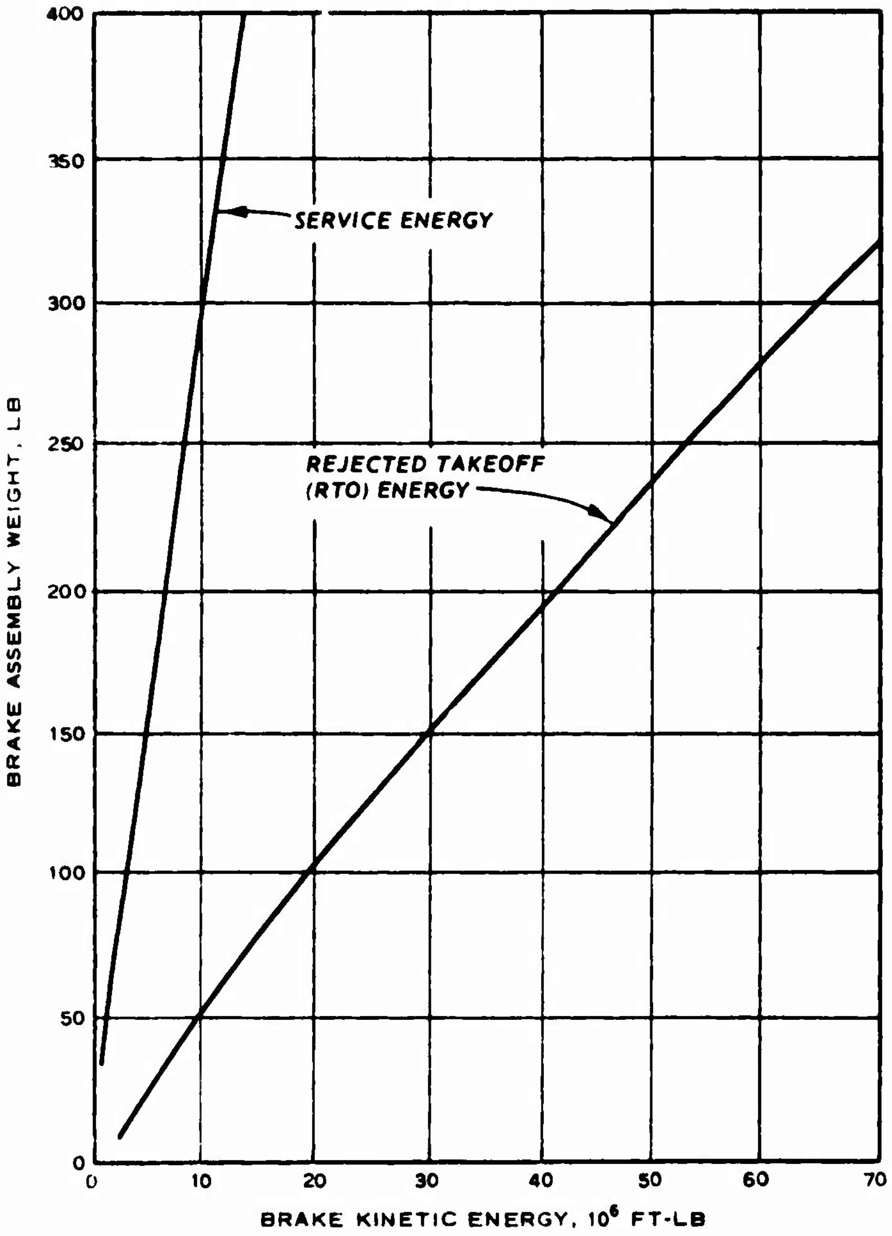


Figure 9. Brake assembly weight versus brake energy (from Reference 2)

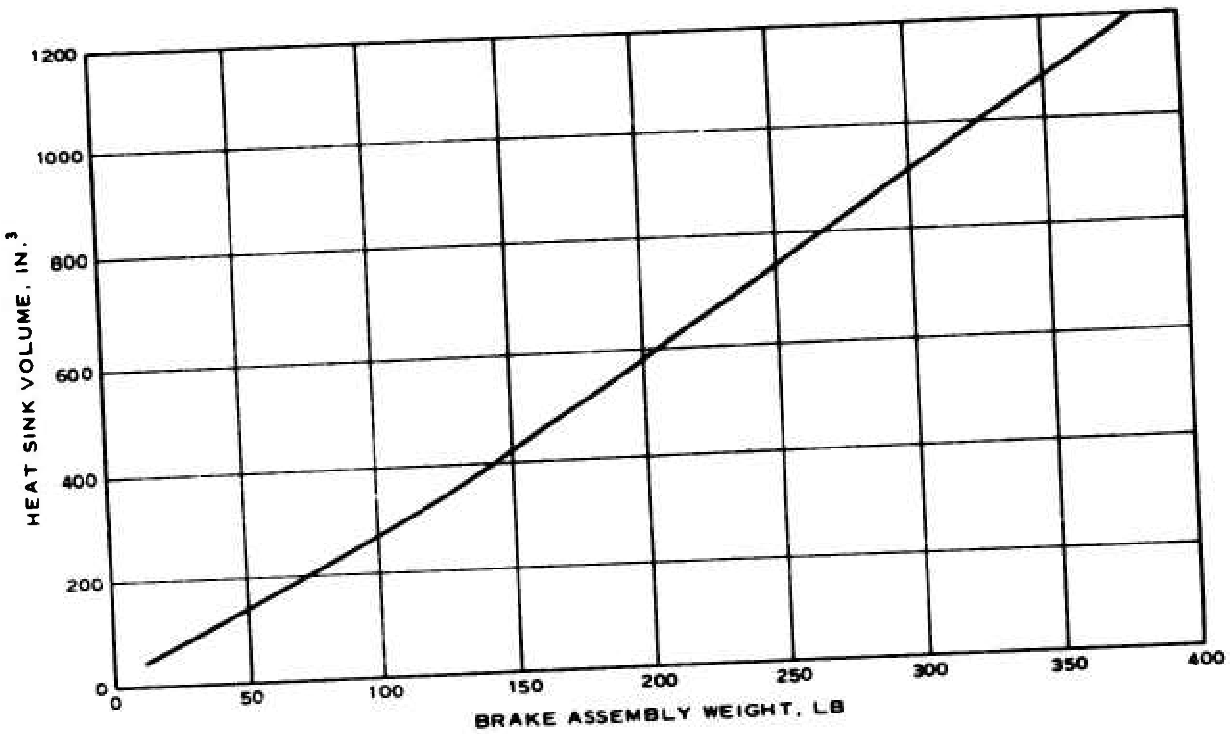


Figure 10. Heat sink volume versus brake weight (from Reference 2)

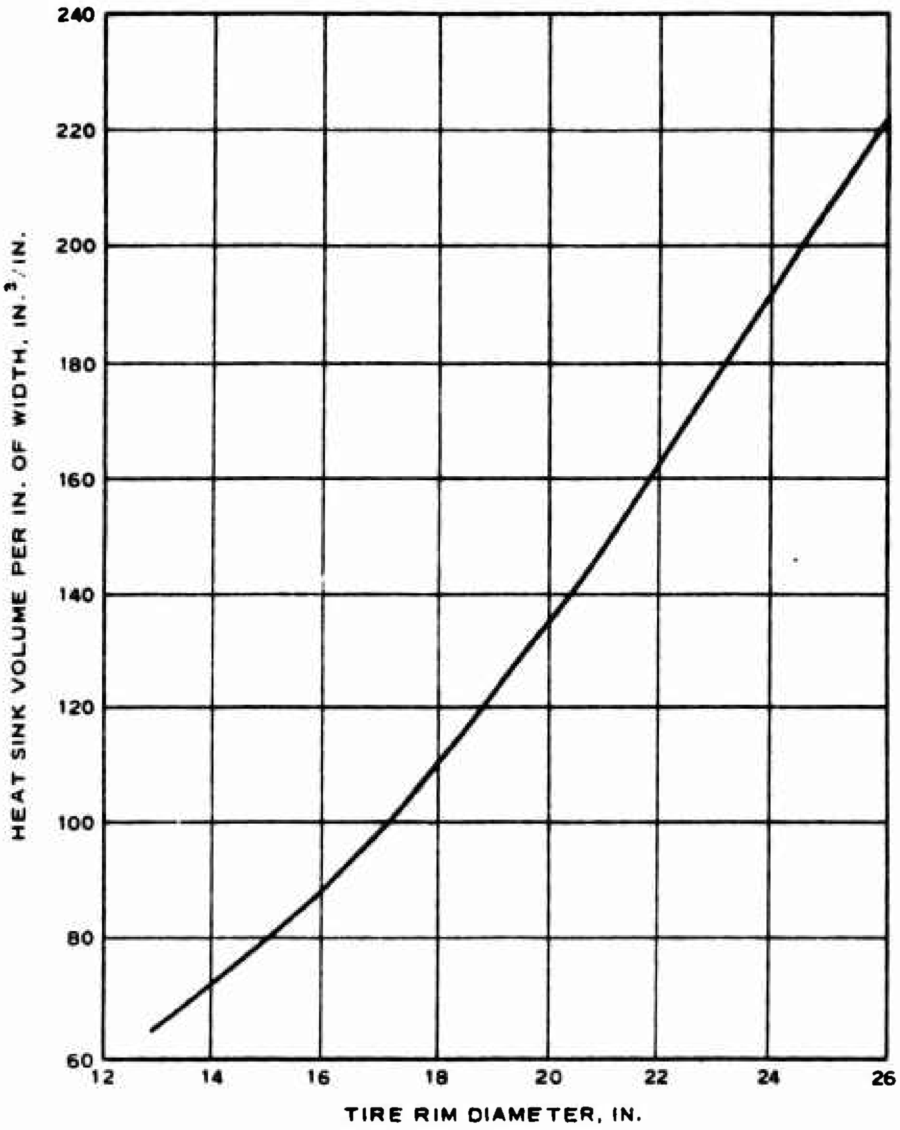


Figure 11. Heat sink volume per inch width versus rim diameter (from Reference 2)

materials are potentially lighter but have yet to prove themselves in service. Since this brake model assumed that the total airplane brake weight is independent of gear configuration (only a function of airplane energies), the type of brake heat sink assumed did not affect the selection of the optimum gear or the weight and cost penalties associated with designing to different pavement strength levels. The brakes only affected configuration selection in that certain configurations were eliminated because the brake size was too large for the available wheel space.

c. Bogie beam weight. Figures 12 and 13 show the weight of the bogie beam and axles per gear as a function of the vertical wheel load and bogie size ratio. The bogie size ratio in each curve is the ratio by which the existing Model -4 four-wheel bogie or Model -6 six-wheel bogie dimensions was multiplied to obtain the desired bogie size. The dimensions of the existing bogies are shown in Figure 14 (axle widths are measured to tire center lines).

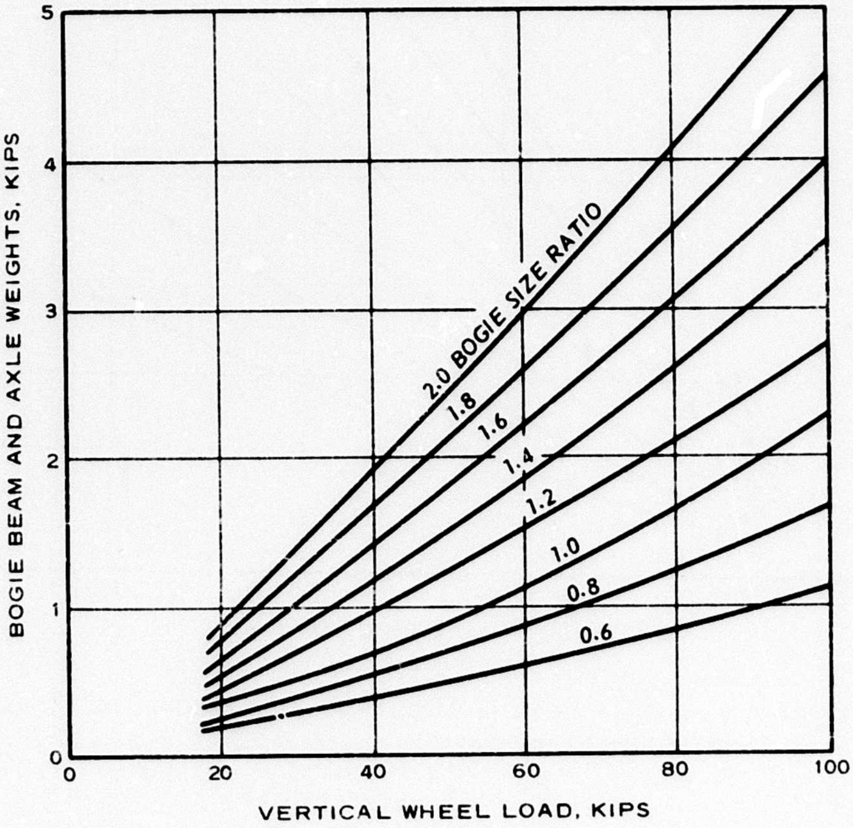


Figure 12. Bogie beam and axle weight versus vertical wheel load, 4-wheel bogie

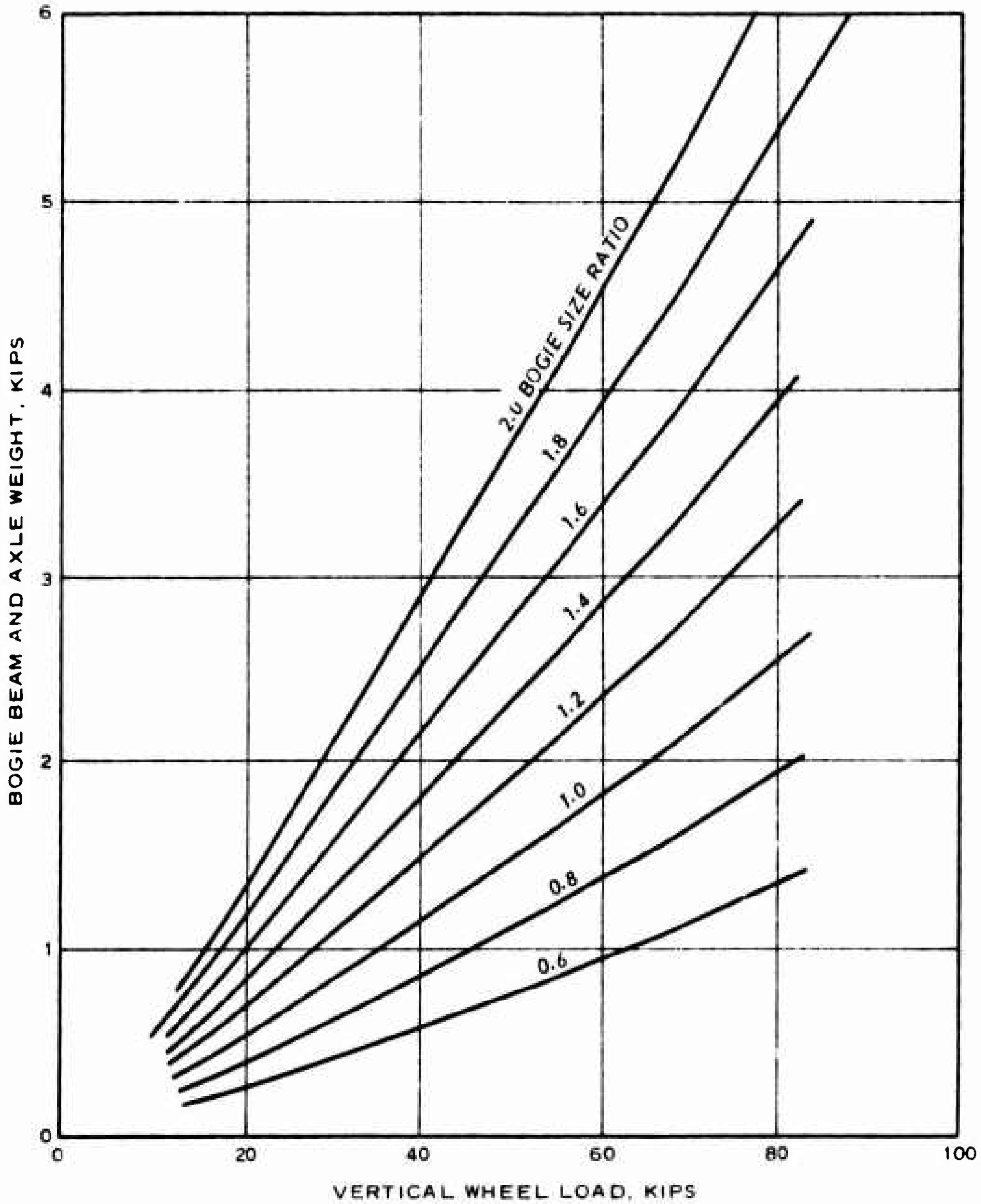
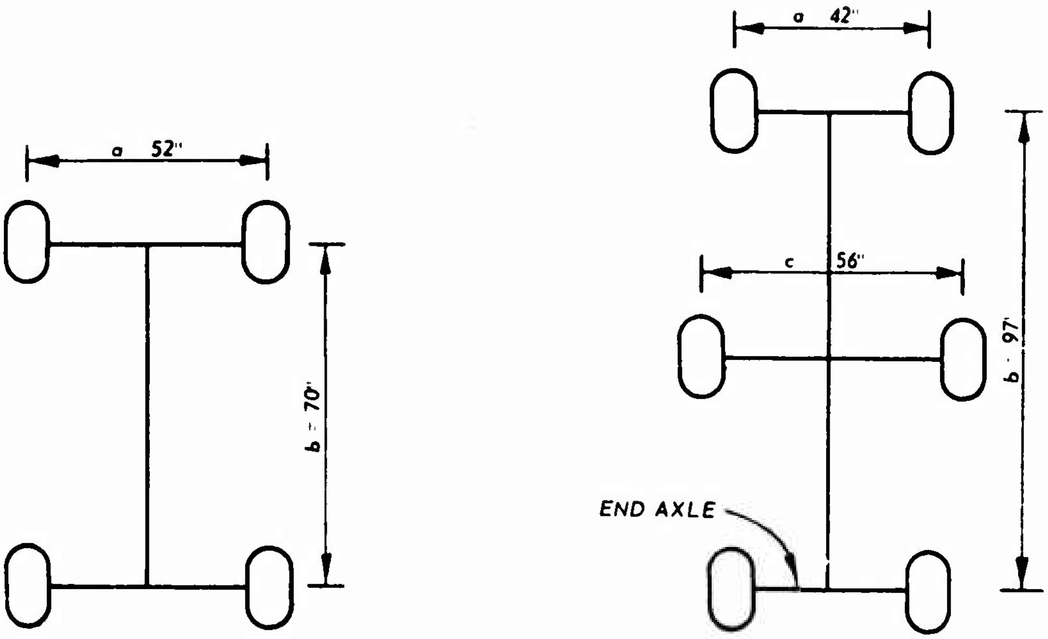


Figure 13. Bogie beam and axle weight versus vertical wheel load, 6-wheel bogie



a. 4-WHEEL BOGIE (MODEL-4)   b. 6-WHEEL BOGIE (MODEL-6)

Figure 14. Dimensions of 4- and 6-wheel bogies

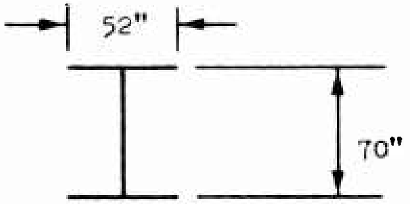
A basic assumption in this design procedure was that the bogies always have the same proportion as the designs above and only the overall scale changed. When using Figures 12 and 13, the bogie size ratio and wheel vertical load were known, and the bogie weight was determined. Figure 12 for the four-wheel bogie was derived from known weight and size data for the Model -4, B747, DC8, and C141. Figure 13 was based on Model -6 bogie weight and the same growth relationships as in Figure 12.

This study showed that for a given total gear vertical load, four- and six-wheel bogies of the sizes shown above have about the same weight. Intuitively, one would expect the six-wheel bogie to weigh more, but the smaller vertical loads at each wheel location (2/3 smaller loads) more than compensate for the extra axle and larger beam length. Table 2 shows a simple weight comparison between the above two bogies designed for the same total gear load, assuming that the beam is designed by bending and the axles by shear. Note that the six-wheel bogie configuration is 5 percent lighter than the four-wheel design. Models -4 and -6 weight data support the conclusion that four- and six-wheel bogies weigh

Table 2

Four- and Six-Wheel Bogie Weight Comparison

Four Wheel



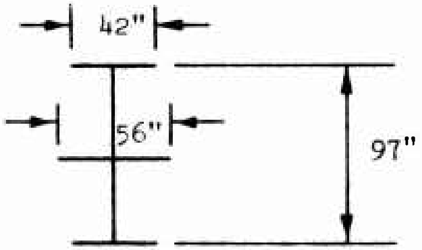
Vertical Load at Each Wheel = 1.000

Beam Weight = 0.706

Axle Weight 0.147 ea = 0.294

Total Weight = 1.000

Six Wheel



Vertical Load at Each Wheel = 2/3

Beam Weight = 0.707 (2/3) (97/70) = 0.652

End Axles = 0.147 (2/3) = 0.098 ea = 0.196

Center Axle = 0.147 (2/3) = 0.098

Total Weight = 0.946

about the same for a given total gear vertical load.

Further corroboration is contained in Figure 15, which is a reproduction of Figure 5 of Reference 3 shown here for illustration. This study shows that the six- and four-wheel (twin-tandem) designs are about the same weight, with the six-wheel generally slightly lighter on conventional flexible pavements without stabilized layers. Therefore, the bogie weight curves used in this study (Figures 12 and 13) assumed that at a bogie size ratio of one and the same total vertical gear load, four- and six-wheel bogies weighed the same. (However, for the same total vertical gear load and a bogie size ratio of one, the six-wheel bogie will produce a lower pavement stress.)

Concerning Figures 12 and 13, it was stated earlier that the bogie size ratios must be known to determine the bogie weight. These ratios were determined for a given gear configuration by pavement stress design criteria. Figures 16 through 19 show the relationships for 4- and 6-wheel gears and for both current and median pavements. Current pavement is defined as the pavement thickness requirement for the projected Category I aircraft (Model -6 with a six-wheel bogie at 488,000 lb). Median pavement thickness is halfway between the current pavement thickness and the greater thickness required for an optimized gear (without regard to pavement thickness) on the projected Category II (1.5-million-lb) airplane. These thicknesses are shown in Table 3.

Table 3

Pavement Thickness Criteria

	Pavement Thickness, in.	
Pavement Type	Rigid	Flexible
Current	11.9	33
Median	14.5	42
Optimized	17.1	51.2

For a given gear configuration, with known tire vertical load and tire pressure, Figures 16 through 19 give the bogie dimension a , which is the length of the end axles, measured between the tire center lines. The bogie size ratio is then given simply by dividing the value for "a" by 52 for four-wheel bogies and by 42 for six-wheel bogies. Thus, the size ratios needed for Figures 12 and 13 were determined.

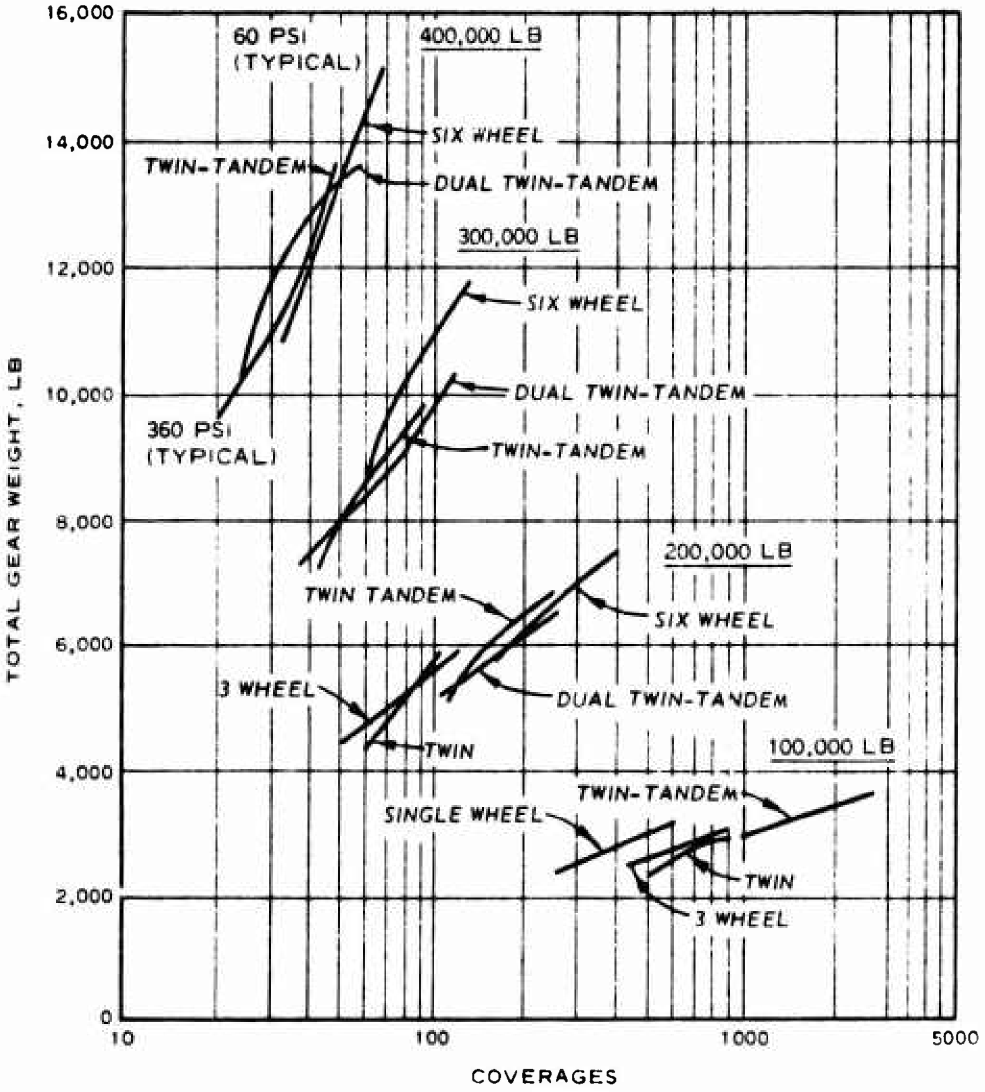
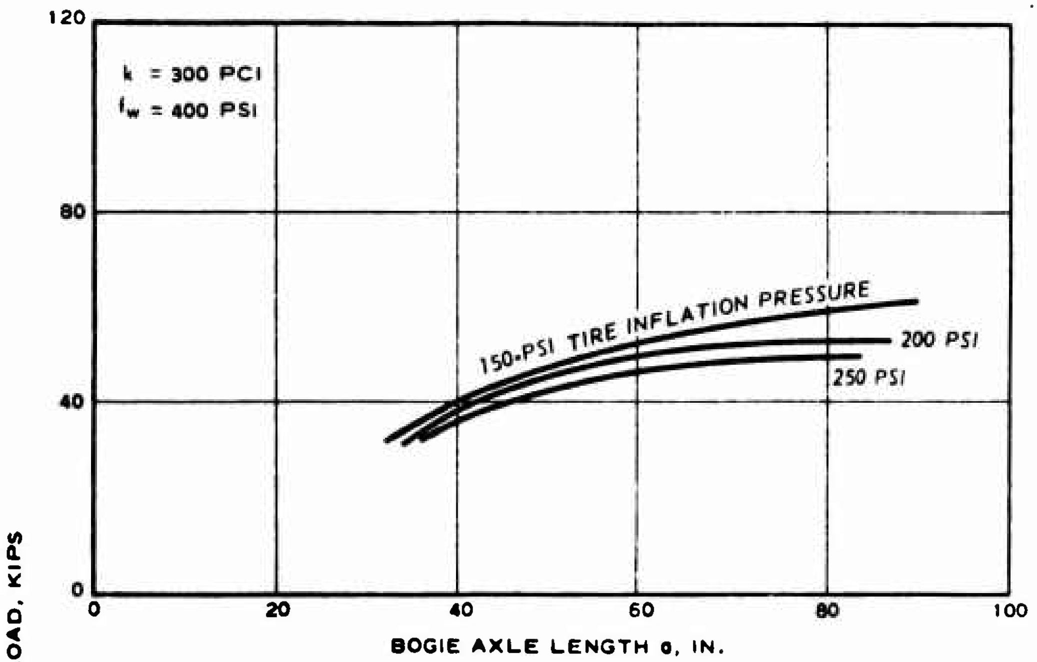
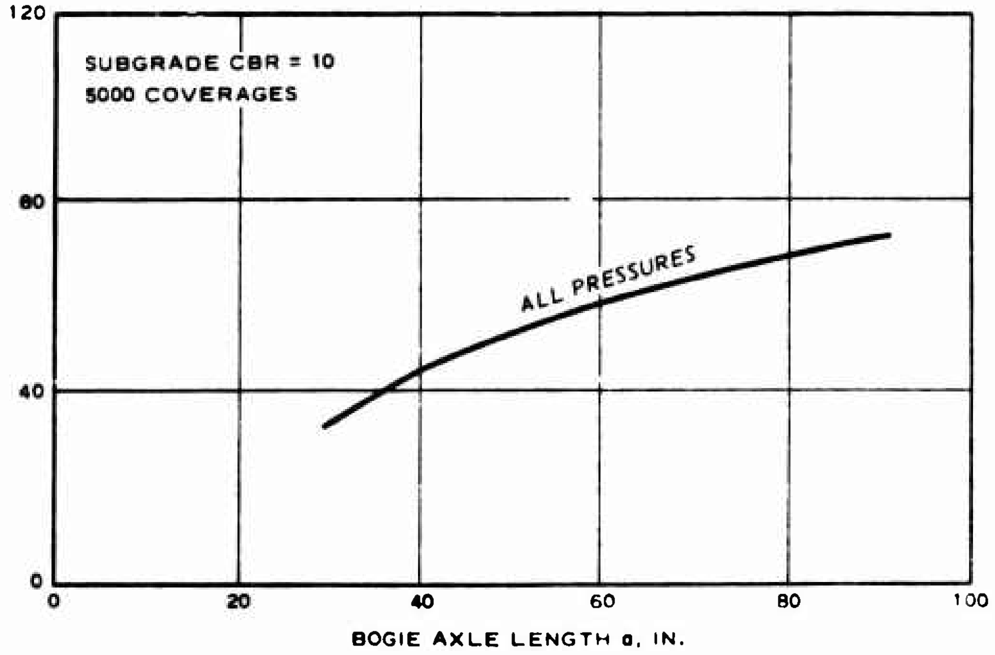


Figure 15. Total gear weight versus coverages for conventional flexible pavement (from Reference 3)

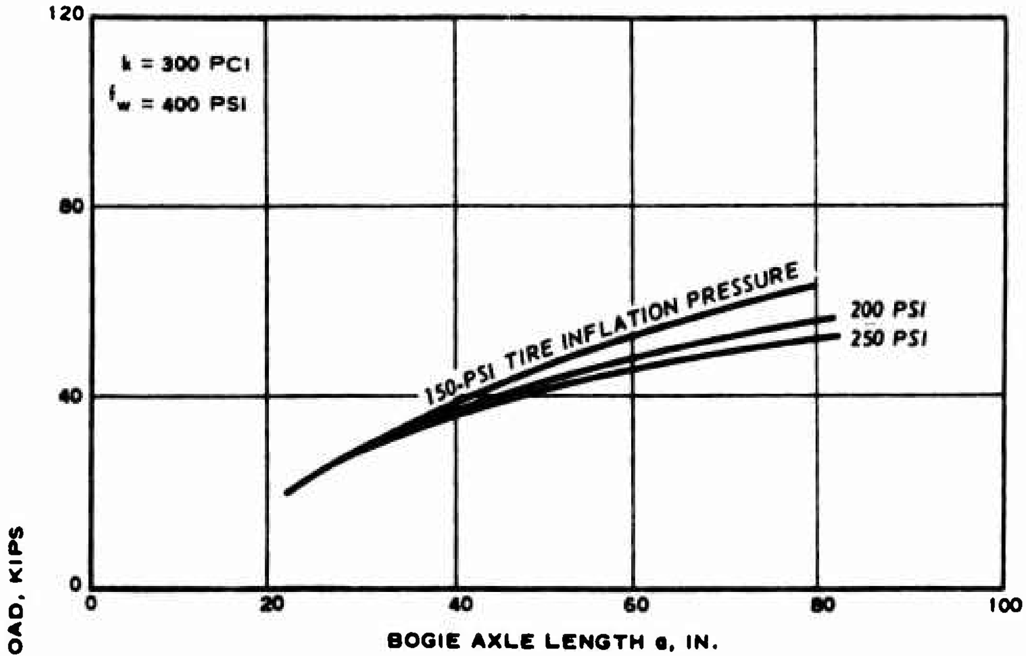


a. RIGID PAVEMENT

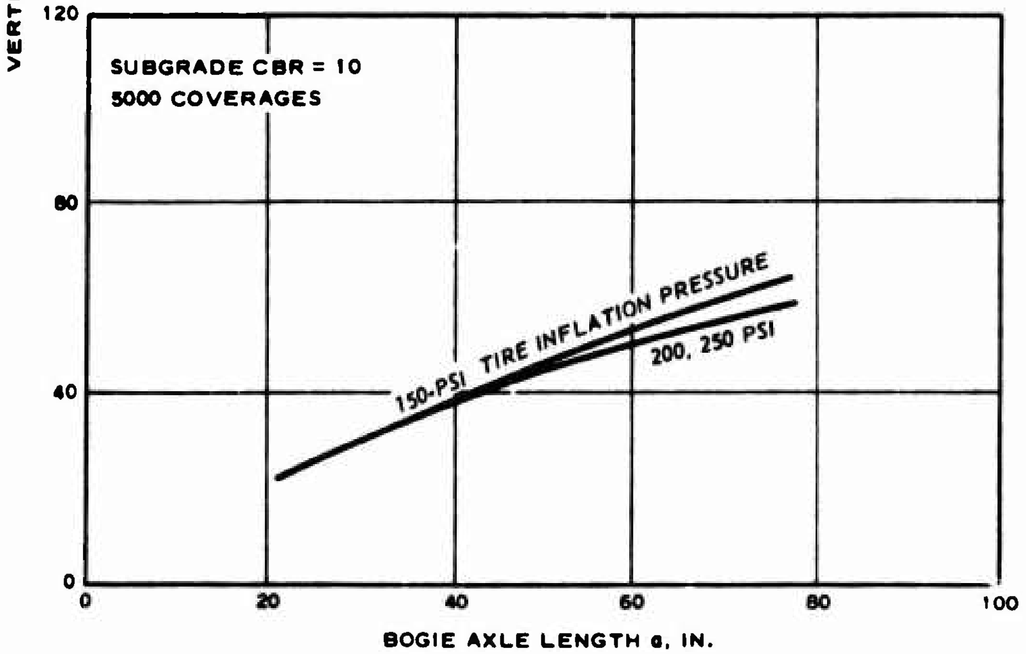


b. FLEXIBLE PAVEMENT

Figure 16. Bogie size versus wheel load, 4-wheel bogie, current pavement

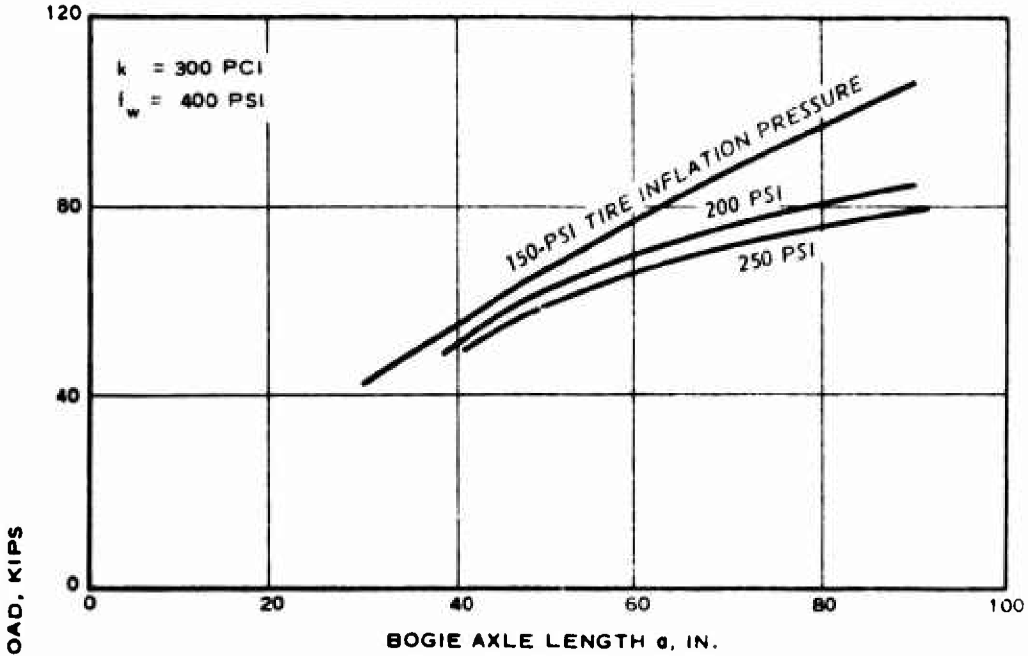


a. RIGID PAVEMENT

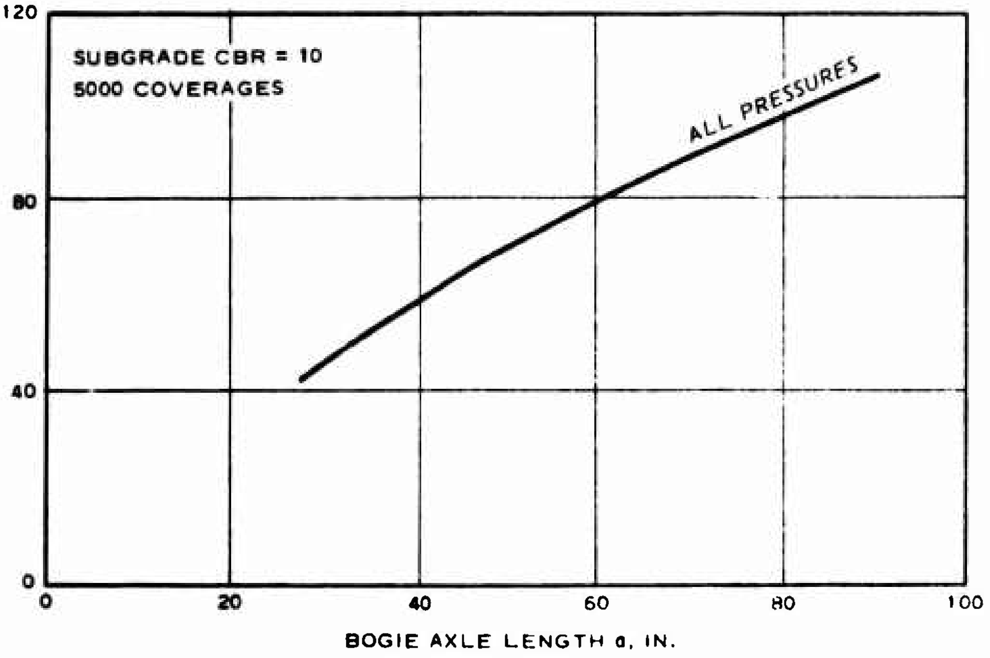


b. FLEXIBLE PAVEMENT

Figure 17. Bogie size versus wheel load, 6-wheel bogie, current pavement

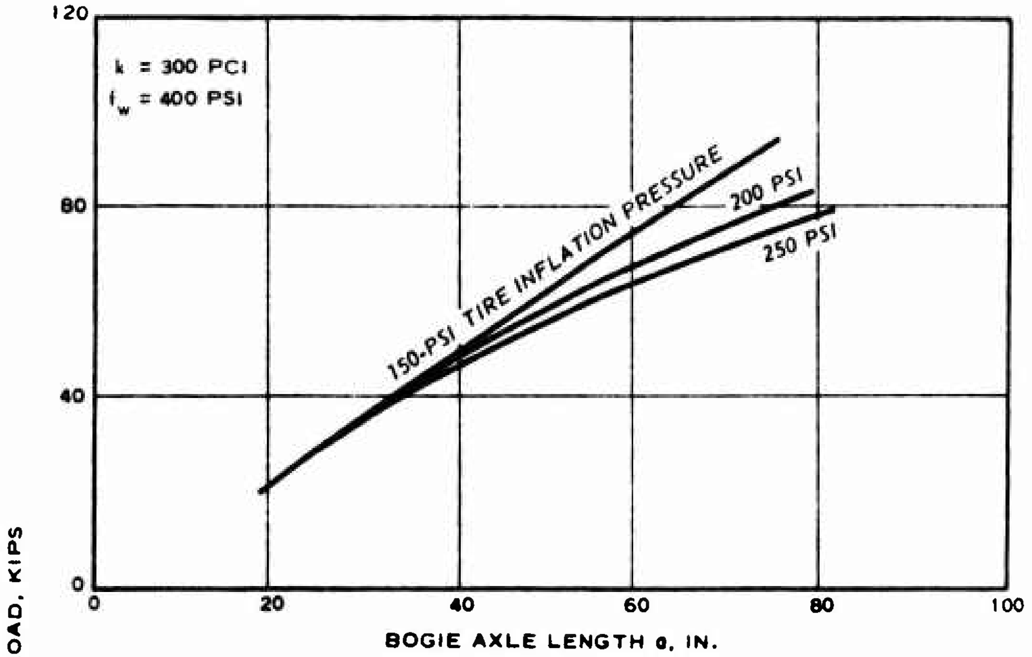


a. RIGID PAVEMENT

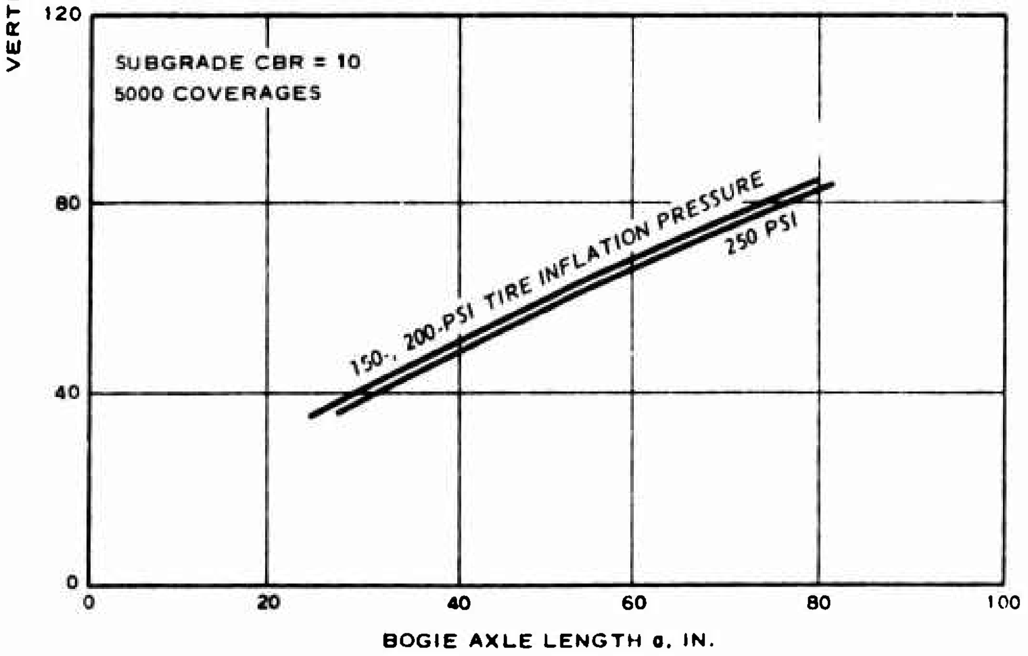


b. FLEXIBLE PAVEMENT

Figure 18. Bogie size versus wheel load, 4-wheel bogie, median pavement



a. RIGID PAVEMENT



b. FLEXIBLE PAVEMENT

Figure 19. Bogie size versus wheel load, 6-wheel bogie, median pavement

Figures 16 through 19 were based on computer program results that utilize the Portland Cement Association (PCA) method for rigid pavements and SEFL 1965A for flexible pavements. For rigid pavements, a subgrade modulus k of 300 lb/cu inch and a working stress f_w of 400 psi were used. For flexible pavements, a California Bearing Ratio (CBR) of 10 was used with 5000 coverages. The effect on pavement stress of the interaction between gears is not included in Figures 16 through 19; the relationships shown are for one landing gear only. FAA pavement design charts were not used since the charts are for specific fixed bogie dimensions and tire pressures, which are the variables in the present analysis. The assumed values of the pavement parameters were required only to provide a starting point for the design process.

Figures 16 through 19 were used to determine the bogie size for the gears designed for current pavement and those designed for the median pavement. For the optimum gear, designed to ignore pavement strength requirements, a different technique is required to determine the bogie size ratio needed in Figures 12 and 13. The bogie for this gear is simply sized as small as possible, while still providing adequate tire clearance. Utilizing the tire clearance calculation procedure from Reference 1, the following governing relations were obtained.

In Table 4, b is the length of the bogie beam, which is related to the outside diameter of the tire Do (obtained from Figure 7). With a as the end axle length, the bogie size ratio is readily determined.

Table 4

Optimum Gear Bogie Size Equations

Four Wheel	Six Wheel
$b = Do + 3.3$	$b = 2Do + 8$
$a = \frac{52}{70} b$	$a = \frac{42}{97} b$
Bogie Size Ratio = a/52	Bogie Size Ratio = a/42

Note that throughout the study, the same bogie proportions as the Models -4 and -6 four- and six-wheel designs were retained; only the overall scale was varied. This method of sizing the bogies did not bias the results significantly. For example, two current widebody transports with four-wheel bogies of different proportions (length-to-width ratios of 1.35 and 1.18) vary in rigid pavement thickness requirement by less than 0.2 inch at the same weight.

The landing gear optimization model considered four- and six-wheel bogies. In the airplane gross weight range employed for this study (0.5 to 1.5 million lb), main gear configurations with less wheels per gear were considered impractical for a number of reasons. The Category I airplane with a single wheel per gear and two main gears requires a rated tire load of 232,000 lb. The largest commercially available tire is a 56 by 16 high-pressure tire rated at 76,000 lb. If the tire diameter versus rated load trends for current tires, as shown in Figure 7, were followed for a 232,000-lb rated tire, the tire diameter would be 130 in. at 250 psi, and even larger at lower pressures. Providing storage space for such a large wheel-and-tire combination would be a formidable task, resulting in a significant structural weight penalty.

Single-wheel configurations have other inherent design deficiencies. If the wheel is mounted in a fork directly below the strut, the length of the landing gear is excessive. If the tire is mounted off center to allow for a more reasonable length gear, the off-center loading results in strut binding friction, approximately 15 percent of the static gear load. This friction deteriorates the taxi ride quality, since the gear is actually locked by the high friction for a high percentage of the time, causing the airplane to ride on tire deflection only. Single-wheel gear configurations are also less safe than multiple-wheel designs because the failure of a single tire can eliminate the braking and control capability of that gear.

The Category I airplane with two wheels per gear (total of four main gear wheels) requires a rated tire load of 116,000 lb. Such a tire would be 76 in. in diameter with a pressure of 250 psi, and over 100 in. at a tire pressure of 150 psi. These tire sizes are much greater than those that are commercially available. Two-wheel gear designs with such large tires are also very inefficient from a wheel storage viewpoint. For example, the two-wheel gear at 200 psi requires a storage volume for the tire envelope of 754,000 in.^{3}, compared to 350,000 in.^{3} for a four-wheel gear with the same load capability. If this added volume represented lost cargo space, then, at a cargo loading of 10 lb per cu ft, the added volume for the two-wheel gear on a

0.5-million-lb airplane would represent 4680 lb of cargo that could not be loaded. The following sketch (Figure 20) shows graphically the comparison between a four-wheel bogie design and a two-wheel design for the same load capability. Since the two-wheel design is considerably wider than the four-wheel design (93 in. compared to 62 in.), the added storage volume required for the two-wheel design can be readily visualized. Also shown in the sketch above is the position of the dual wheels with the gear compressed, which shows that the tire will interfere with the desired location of the lateral side brace. Therefore, to accommodate the

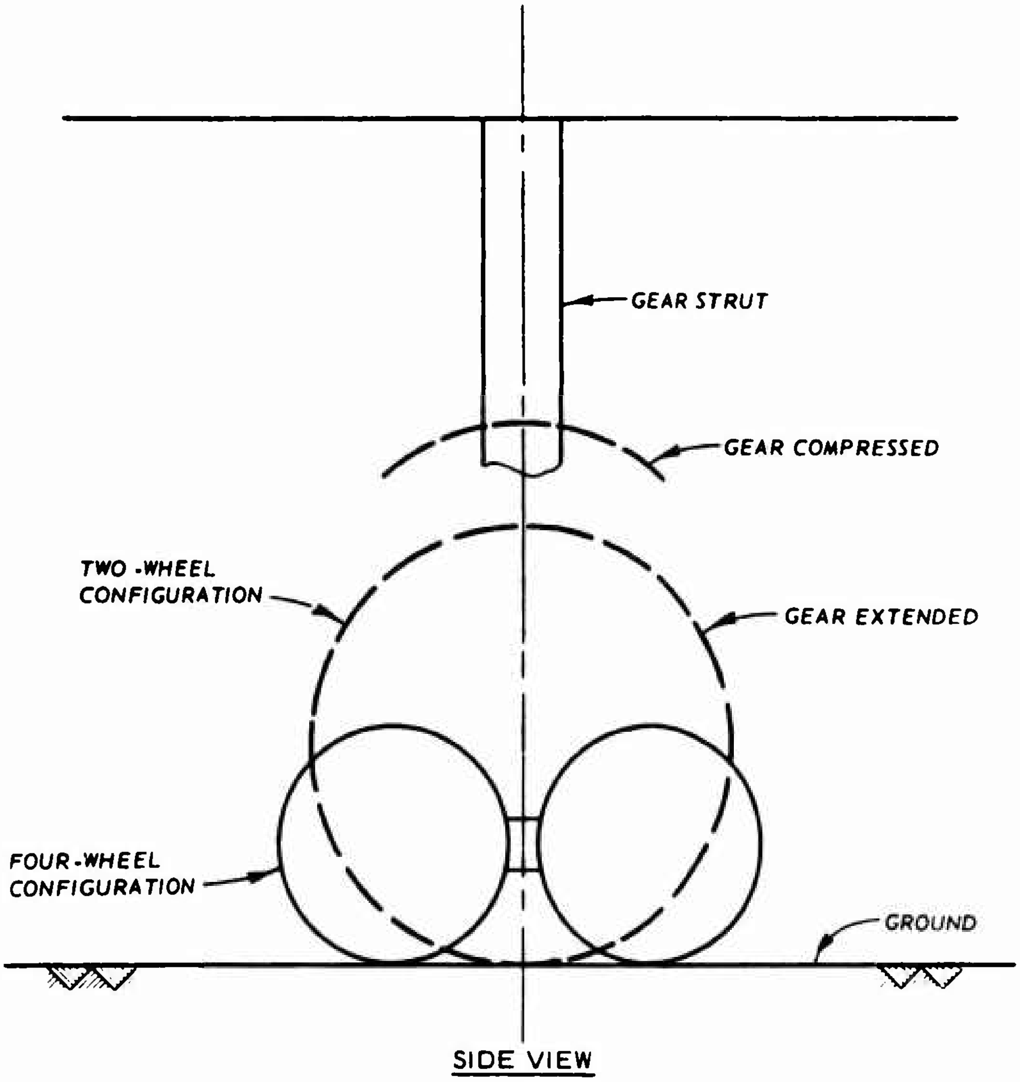


Figure 20. Comparison of two- and four-wheel bogie design

dual-wheel design, the side brace would have to be mounted higher than optimum, resulting in a weight penalty to achieve the required lateral gear strength.

The foregoing considerations were based on configurations with two main gears. It is possible to attain reasonable tire sizes by providing more main gears, each with two wheels. For example, two main gears with four-wheel bogies require the same tire size (and thus weight) as four dual-wheel main gears. However, the extra two main gears result in weight penalties both for the gears themselves and the added gear support structure (this point is amplified in Sections d and e following). These penalties (3900 lb) are much greater than the weight advantage of replacing the two bogies with four axles (1240 lb). Furthermore, it is much more difficult to store four two-wheel gears than two four-wheel gears. The foregoing disadvantages of single- and dual-wheel gears indicate that they should not be considered for installation in airplanes of the weight range under study. However, for airplanes of lower gross weights (around 200,000 lb), two-wheel gears become attractive, since only two main gears are required having reasonable tire sizes.

In reviewing gears with more than six wheels per gear, the most practical configurations are eight wheels mounted on four-wheel bogies and twelve wheels mounted on six-wheel bogies. For each of these configurations, the beneficial effect on pavement stress of the added wheels is reduced by the necessarily close proximity of the adjacent wheels on each bogie "arm." In addition, wheel, tire, and brake maintenance costs rise because of the inaccessibility of the inboard-mounted wheels (the outer wheels must be removed first to get at the inboard wheels). This problem can be alleviated somewhat by mounting two adjacent tires on a single wheel of greater width. However, this leads to difficulties in housing the necessary brake volume, since there are only half as many wheels for mounting the brakes. The brakes become excessively wide, resulting in a large number of rotors and inefficient brake heat dissipation resulting in additional weight penalties.

Because of the considerations above and because no eight- or twelve-wheel gears have been used in commercial operations, only four- and six-wheel gears were considered in this study.

d. Gear strut weight. The weight of the shock strut, braces, and actuators was compared to the airplane gross weight for about 15 different transport aircraft.

The weight used was the total gear system weight less the weight of bogie beams and axles and rolling stock (wheels, tires, brakes). These data showed an overall average for conventional tricycle (2 main gear, 1 nose gear) airplanes of 2 percent of the maximum takeoff gross weight. In addition, the data appeared to indicate a weight penalty for configurations with more than two main gears. This penalty is reflected in Figure 21, which shows a gear weight factor versus number of main landing gears. At two main gears, the factor is 1, and at four main gears, the factor is 1.16, or a 16 percent weight penalty. Thus, the weight of the shock strut, braces, and actuators is given by

$$W = 0.02 \text{ (TOGW) (Weight Factor, Figure 21)}$$

where TOGW is the takeoff gross weight of the aircraft. The weight penalty for multiple gears is probably due more to duplication of actuator systems than to heavier shock strut total weight.

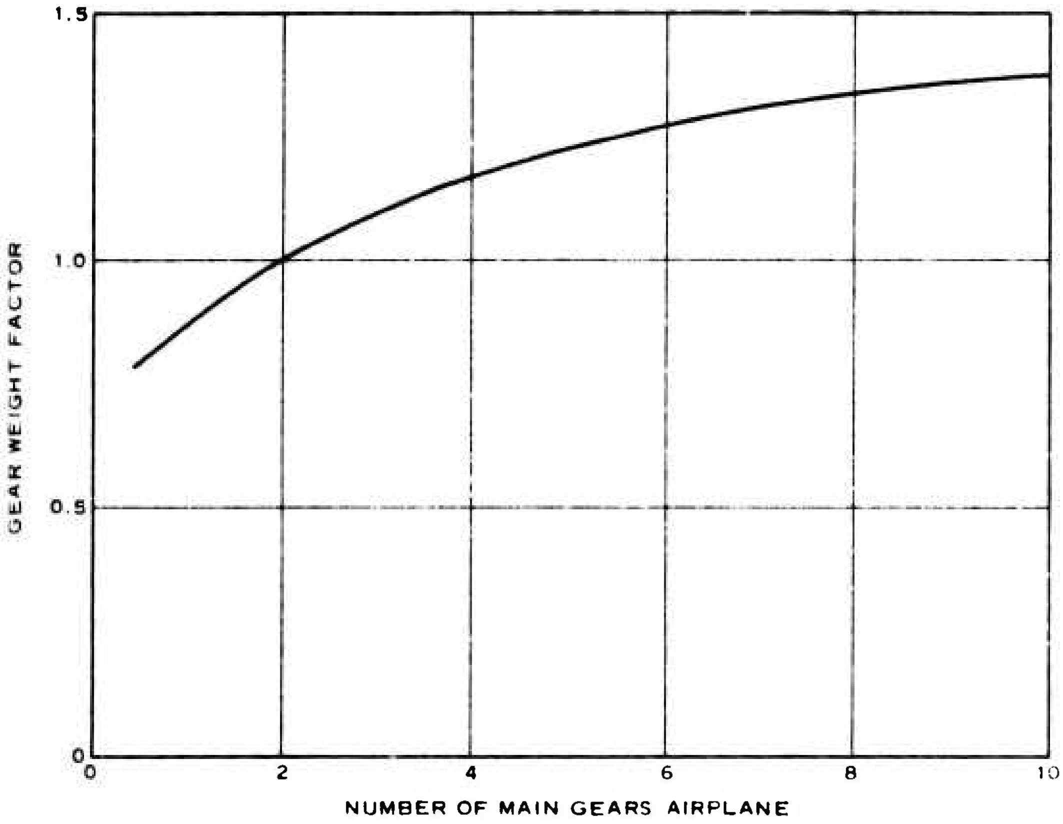


Figure 21. Gear weight factor versus number of gears

e. Gear support structure weight. The main landing gear support structure weight was compared to the airplane gross weight for the C130, C141, C5A, and Model -4 aircraft. These data indicated a basic weight ratio of 1 percent for two main gear equipped airplanes, with the weight penalty of Figure 21 also applicable in this case for airplanes equipped with more than two main gears. In addition, for fuselage-mounted main gears, there is approximately another 50 percent weight penalty for the gear support structure, relative to wing-mounted gears. Table 5 summarizes these effects for multiple-gear aircraft.

The data listed in Table 5 are based on configuring the airplane with only two main gears mounted in the wings and the remainder mounted in the fuselage. This arrangement is dictated by the size of the bogies. In conventional transports, the landing gear is mounted aft of the trailing edge of the wing with the bogie being stored in the fuselage.

Usually blisters are added to completely store the gear. A second wing gear mounted significantly outboard of the first gear would reduce inboard wing downbending and shear loads due to ground loading conditions by more uniformly distributing the ground reaction loads spanwise along the wing. However, when this advantage is compared with some of the more prevalent disadvantages and problems, the beneficial effect on structural weight is lost. These difficulties are:

(1) The maximum thickness is such that the bogie would not fit in the wing.

(2) Since the second wing-mounted gear would require that the wing box be cut, additional structure will be required to provide adequate torsional stiffness for flutter.

(3) In order to distribute the load approximately equally on all four main gears to compensate for runway crown and wing flexibility, a means of balancing the air pressure between the gears on the same side of the airplane would be needed.

(4) The second wing gears would use approximately 20 percent of the wing box volume which is normally used for fuel storage.

3.1.3 Functional cost relationships.

a. Acquisition costs. Landing gear system acquisition costs relative to gear system weight are estimated from Models -4 and -6 experience and from airplane depreciation rates for the DC10 and B747 given in Reference 4.

Table 5

Gear Support Structure Weight

⓪ Number of Main Gears	① Wing-Mounted Gears	② Fuselage-Mounted Gears	③ 1.5 × ②	④ Equivalent Main Gears ① + ③	⑤ Spt. Strength Weight Factor = ④ / ⓪	⑥ Gear Weight Factor (Fig. 17)	Total Spt. Str. Weight Factor ⑤ × ⑥
2	2	0	0	2.0	1.000	1.000	1.000
3	2	1	1.5	3.5	1.167	1.088	1.270
4	2	2	3.0	5.0	1.250	1.160	1.450
5	2	3	4.5	6.5	1.300	1.220	1.586
6	2	4	6.0	8.0	1.333	1.265	1.686

The acquisition costs on this basis are about 70 dollars/lb in 1973 dollars. These costs are then converted to a cost per lb per flight ($/#/flight) by dividing by 30,000 flights, which is determined from 20 years' operation at 1500 flights/year. Accordingly, the final acquisition cost is 4.31×10^{-3} $/#/flight, in 1985 dollars. The inflation rates employed are discussed in a later section.

b. Flight operation costs. Flight operation costs are also expressed in terms of $/#/flight and are composed primarily of fuel costs and crew labor costs. A value of 19.49×10^{-3}, in 1985 dollars, based on marketing studies, was used for the landing gear optimization studies of the Categories I and II airplanes.

The flight operation cost is about five times larger than the acquisition cost, expressed on the same basis; thus, the flight operation costs dominate. The total costs for acquisition and flight operation are 23.80×10^{-3} $/#/flight, in 1985 dollars. This figure was used for both airplanes to reflect the cost of carrying landing gear system weight. The value also correlates very well with the operating cost data for the DC10 and B747 published in Reference 4, when compared in terms of 1972 $/#/flight.

c. Maintenance costs. Referring to Table 1, it can be seen that the gear maintenance costs are divided into wheel and tire maintenance, brake maintenance, and maintenance on the remainder of the gear.

Figure 22 shows the tire maintenance cost relationship used in the study, in terms of $/wheel/landing (1985 dollars). The basic trend of increasing costs with tire load reflects the fact that increased tire loads require larger tire sizes (at constant inflation pressure and percent tire deflection) which, in turn, cost more to recap and replace. This trend is illustrated by the tire maintenance costs for 18 different airplanes ranging from 40,000 lb gross weight up to the B707 at over 300,000 lb. These data were obtained from Reference 5, which is a 1970 survey by Allegheny Airlines of landing gear maintenance costs as reported by 23 U. S. air carriers.

The maintenance cost increase with higher tire pressures reflects the fact that tire wear increases with tire pressure. This trend was also noted in Figure 3 of Reference 6, a landing gear maintenance cost study performed by American Airlines. Their study shows a rather drastic falloff of tire life (landings/tread) at tire pressures above 150 psi. Lockheed studies in

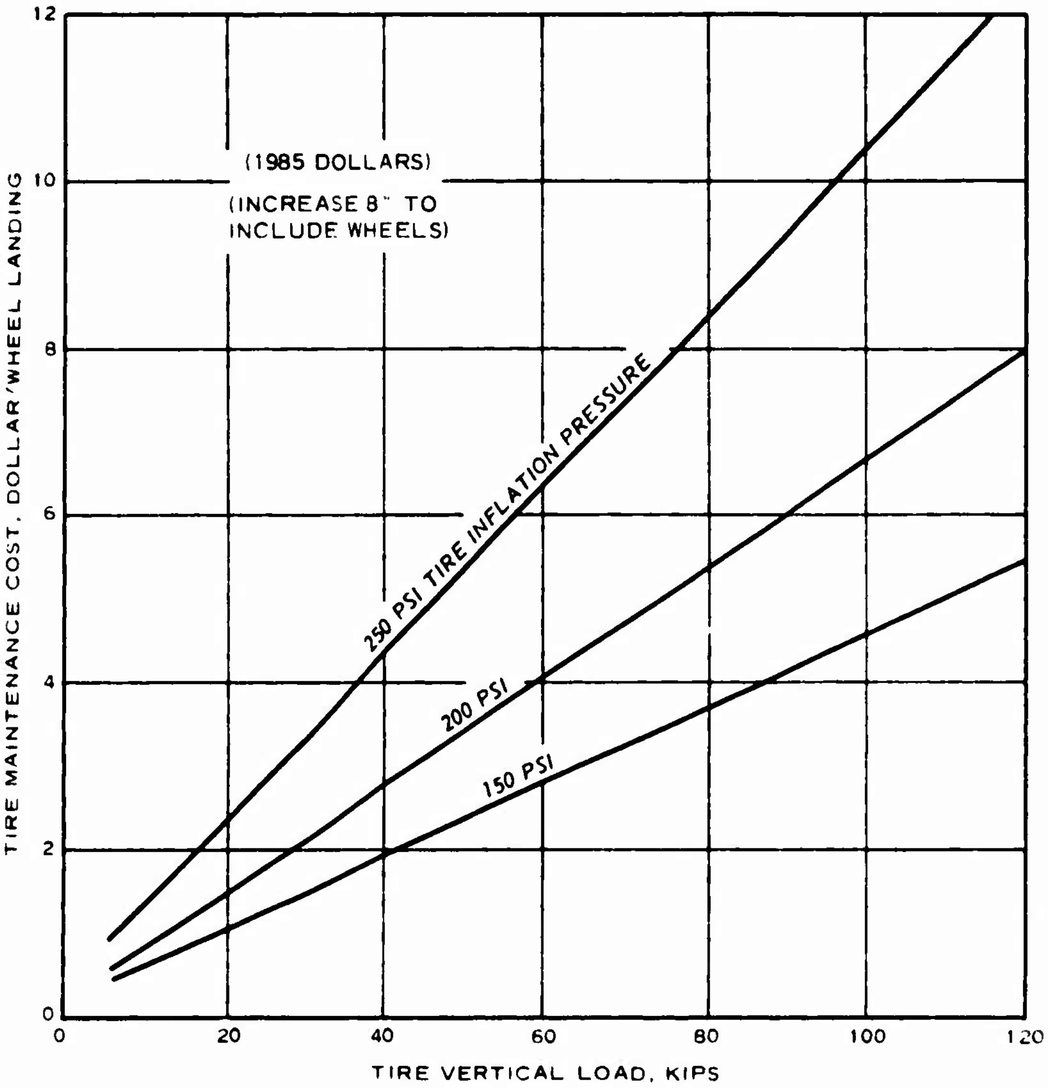


Figure 22. Wheel and tire maintenance cost versus wheel load (data from Reference 6)

support of the Model -4 showed similar effect, but not as severe as the Reference 6 data. Figure 22 was derived by using the Allegheny report data as representative of the cost for 150-psi tires (the average inflation pressure of the 18 airplanes making up the data base) and by estimating the increased cost at higher pressures from Lockheed data.

The increased maintenance cost at higher tire inflation pressures is the major negative factor associated with high tire pressures in the mathematical model of the gear system weight and costs. However, in Figure 6, it is shown that high tire pressure is desirable in reducing hweel and tire weight, which in turn will reduce flight operation and acquisition costs. Therefore, the tire maintenance costs tend to reduce the desirability of very high pressure tires. (Another negative factor resulting from the use of high tire pressures is the larger bogie size required for a given pavement thickness and wheel load, as seen in Figures 16 through 19. This is especially true for rigid pavements.)

Based on an Air Transport Association of America (ATA) System 32 (Landing Gear) maintenance cost analysis of the Model -4, performed by Lockheed's Commercial Maintainability and Reliability Department, the wheel maintenance costs can be included by increasing the tire maintenance values given in Figure 22 by 8 percent.

Brake maintenance costs are expressed in terms of dollars per ft-lb per landing ($/ft-#/landing), based on the airplane kinetic energy at landing weight and 1.2 times the airplane minimum speed in the landing configuration. Figure 23 illustrates the value of this cost to be a function of the total number of brakes per airplane. This reflects the fact that the total brake maintenance costs are due to both labor and material. The material cost is a function of brake weight only, which results from the landing kinetic energy, and the labor cost is a function of the number of brakes per airplane, not their size.

The data on brake maintenance costs from Reference 5 correlates well with landing kinetic energy. However, the corresponding Model -4 cost per landing data is 30 percent less than the data given in Reference 5. This appears to reflect a significant improvement in the state-of-the-art for determining brake maintenance costs, which is attributed to the previously mentioned 1000-landing brake-life criterion (in Figure 9) used to size the brakes. Since this criterion is representative of future heavy aircraft design philosophy,

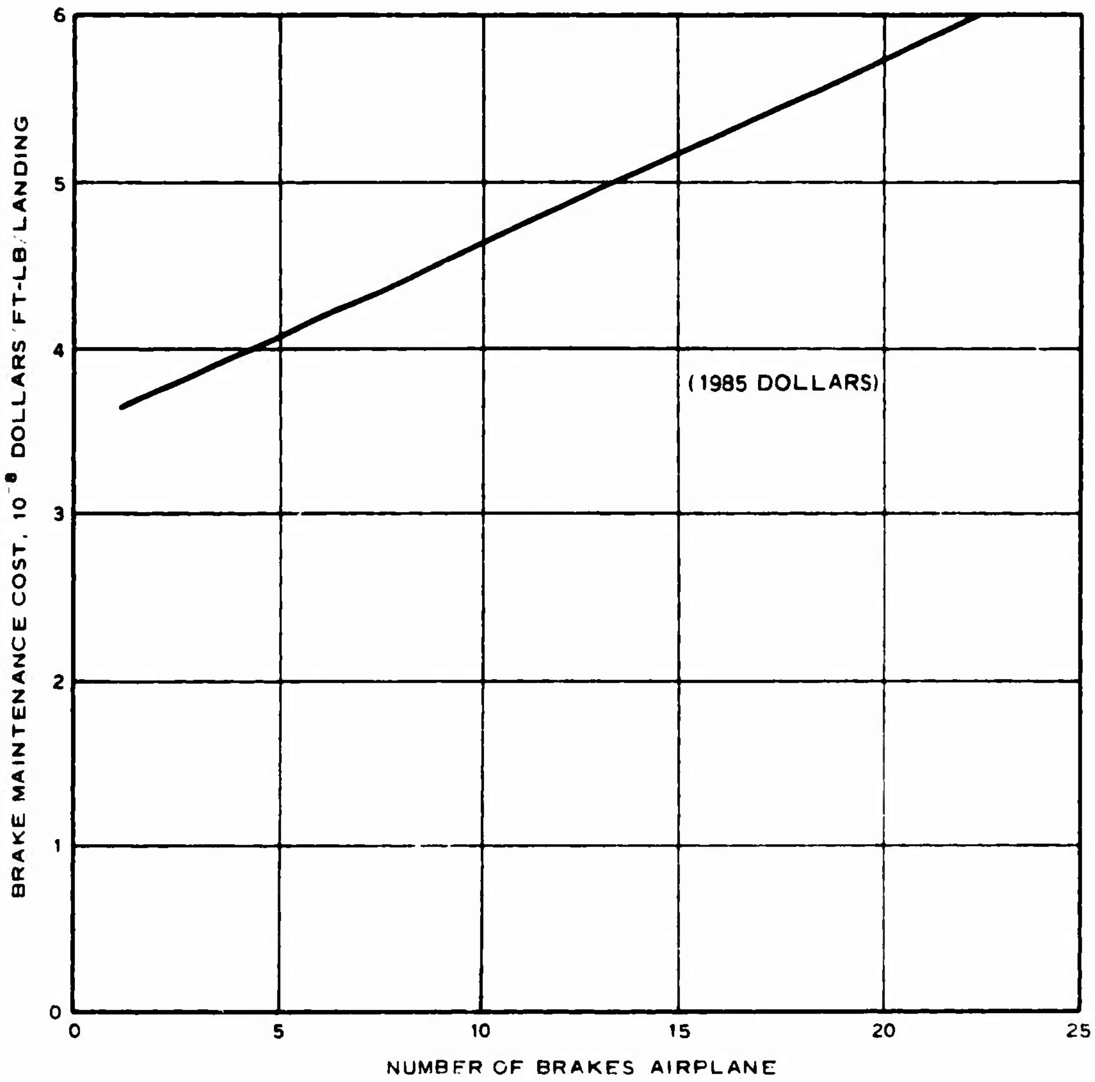


Figure 23. Brake maintenance cost versus number of brakes

the lower maintenance costs corresponding to that of the Model -4 values were used to derive Figure 23. The data in Figure 23 correspond to $1.06 per brake landing for the Model -4 in 1973 dollars. In summary, the ordinate of Figure 23 is multiplied by the airplane kinetic energy at landing weight and an approach airspeed of 1.2 times the airplane minimum speed in the landing configuration to obtain the brake maintenance cost in $/landing. Figure 23 reflects 1985 dollars.

The maintenance costs for the remainder of the landing gear system were calculated based on an ATA System 32 landing gear maintenance cost breakdown for the Model -4. The labor costs were assumed proportional to the number of gears, and the material costs proportional to the total gear system weight. The resulting costs, in terms of 1985 dollars, are

Labor Maintenance Cost = $7.31 per gear per landing

Material Maintenance Cost = $0.173 per 1000 lb per landing

<u>d.</u> Inflation rates to 1985. The inflation rates used between 1970 and 1985 are shown in Figure 24. These rates were obtained from a Lockheed corporate marketing study. The rates shown result in the overall inflation factors given in Table 6. The fuel inflation rate is used in the flight operating costs. The fuel costs are expected to take a 15 percent rise in 1973, and then level off at 5 percent to 1985.

3.2 Gear Optimization Results

3.2.1 Category I airplane. The previously described gear optimization mathematical model is applied to the Category I airplane at 488,000-lb gross weight. Analyses of pavement stresses induced by the nose gear during landing rollout showed that pavement thickness requirements are less than those required for the main gear. Increasing the nose gear tire pressure above 200 psi, although reducing the size of the tire and wheel, did not result in cost savings. Accordingly, the gear optimization centered on evaluation of different main gear configurations. Because configurations with more than two main gears result in weight penalties, the analysis of the Category I aircraft was confined to two main gear configurations. Four and six wheels per gear were analyzed

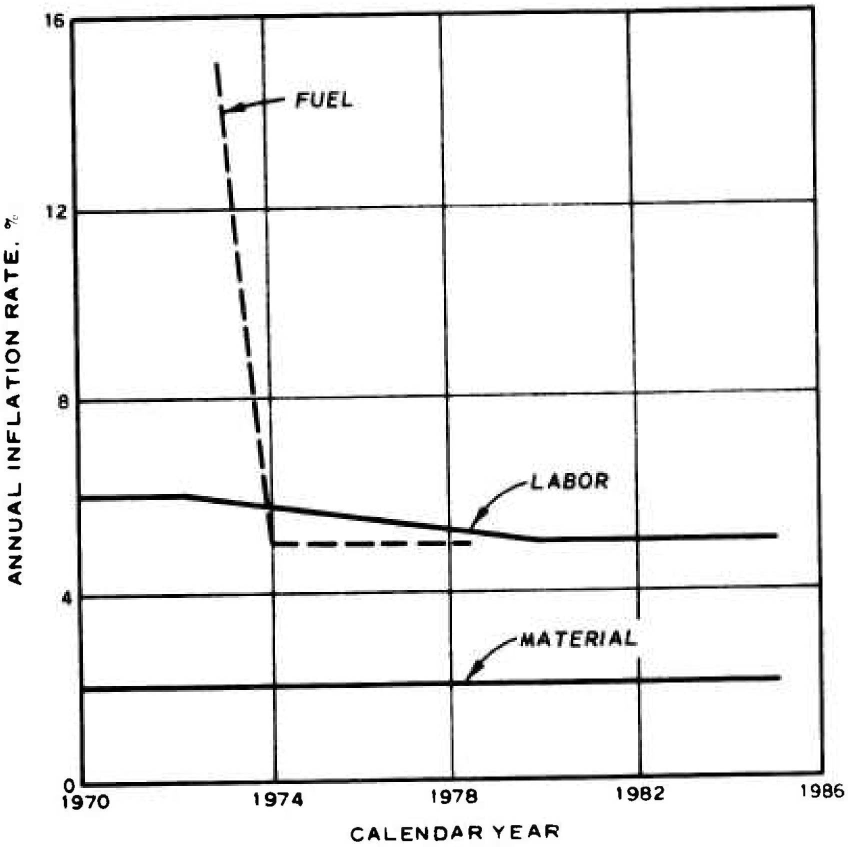


Figure 24. Annual inflation rates, 1970-1985

Table 6

Inflation Factors

Item	Time Span	Inflation Factor
Material	1970 - 1985	1.346
	1973 - 1985	1.268
Labor	1970 - 1985	2.321
	1973 - 1985	1.951
Fuel*	1973 - 1985	1.967

* Fuel rates prior to 1973 are not shown because the data were not required.

for all three pavement strength levels. In addition, five tire pressures (150, 175, 200, 225, 250 psi) were analyzed for each configuration. Thus, for each pavement strength level, ten landing gear configurations were investigated. The results, in terms of total landing gear system costs in $/flight, are shown in Table 7.

Table 7

Gear System Costs for Category I Airplane (1985 $/Flight)

Gear Configuration	Wheel Load, lb	Tire Pressure p, psi	Gear System Costs for Indicated Pavement Type*: Current	Median	Optimized
4-wheel	57,954	150	680.36	646.72	646.72
		175	690.49	643.53	643.53
		200	--	641.55	641.06
		215	--	644.00	640.38
		225	--	647.07	640.67
		250	--	656.38	644.25
6-wheel	38,633	150	652.56	652.56	652.56
		175	649.48	649.48	649.48
		200	647.21	647.21	647.21
		225	652.97	647.18	647.18
		250	662.52	651.34	651.34
Pertinent Pavement Thickness, in.:					
Rigid			11.9	14.5	15.3
Flexible			33	42(39)	39.6

* Underlined numbers indicate lowest cost gear configuration for each pavement strength.

Dashes in Table 7 represent configurations that cannot meet the pavement strength requirements. Some of the higher pressure four-wheel gears cannot meet the current pavement strength requirements. The pavement thicknesses for the three pavement strength levels are also shown in Table 7. The current and median pavement thicknesses are the same as in Table 3 of the previous section, but the thicknesses for the optimized gear are much less than those required for the Category II airplane shown in Table 3. Inasmuch as both the Category I and Category II airplanes would actually operate from the same 1985 pavements, the median pavement, in addition to the current pavement, would be the same.

The large difference in weight between the two airplanes is reflected in the variation in pavement thicknesses for the optimized gears for each of the airplanes. Thus with the most idealized gear configurations, large increases in airplane weight will require some increase in pavement thickness.

Note that the median gear flexible pavement thickness of 42 in. is the same as in Table 3, and is greater than the 39.6-in. thickness for the optimized gear. This apparent anomaly occurs because the median gear is actually sized by the rigid pavement criteria (14.5 in.), which for this gear is more critical than the flexible. Thus, the gear is good for flexible pavements of less than 42 in., in this case, 39 in. In other words, when the median gear is sized to both 14.5-in. rigid pavement and 42-in. flexible pavement, the rigid pavement requirement dominates and the resulting design is actually good for 39-in. flexible pavement.

The lowest cost gear configurations for each pavement strength criteria are underlined in Table 7. The four-wheel gear at 215 psi is the best optimized gear, the four-wheel design at 200 psi is the best median gear, and the best gear for operation on current pavements is the six-wheel design at 200 psi. The costs for the six-wheel gears are the same for all three pavement strength levels at pressures from 150 to 200 psi. For these gears, the bogie size is as small as wheel clearance requirements will allow; nevertheless, the gear is still good for current pavements. Since the six-wheel bogie cannot be made smaller to gain weight and cost benefits from thicker pavement, the costs of these gears are independent of pavement thickness for the range of pavement thicknesses used in the study. At higher tire pressures, this situation does not hold true. In this case the bogie must be larger than minimum to satisfy pavement strength requirements, so that a benefit is available when designing to thicker pavements (the bogie size can be reduced). However, at these higher pressures the costs are higher than at 200 psi because tire maintenance costs override the weight savings.

Table 7 indicates that the pavement thickness requirements for the optimized gear are not much greater than for the gear now installed on the airplane (the current pavement gear). Accordingly, for an airplane in the weight category of the Category I aircraft (around 500,000 lb), landing gears designed for current pavements are very nearly the same as that which can be achieved without pavement restrictions. This finding does not hold for the case of the Category II airplane.

The pertinent weight and cost penalty data for the Category I gears are shown in Table 8. All dollar figures are in 1985 dollars. The cost per lifetime is based on 30,000 flights, and the total fleet cost is based on 618 airplanes. This is an estimate of the projected fleet size for normal- and extended-range airplanes in this weight category involving domestic U. S. departures. The worldwide fleet size is approximately twice the above figure.

The data required for pavement stress analysis are shown in Table 9. The airplane gross weight is 488,000 lb, with 95 percent of this supported by the main gears, which are spaced 432 in. apart laterally.

3.2.2 Category II airplane. Procedures similar to those employed for determining the gear configurations for the Category I airplane were applied to the 1.5-million-lb airplane. Present-day practice for designing the nose gear for pavement flotation requirements is to configure the nose gear such that it will not impose greater stresses on the pavement during normal operations than will the main gear. This design philosophy is still valid for the Category II airplane. For the Category II airplane, the weight penalty associated with designing the nose gear for current pavement strength, relative to an optimized gear, is about 2 percent of the weight penalty for the main gears.

Table 8

Weight/Cost Penalties for Category I Airplane

Item	Current Pavement Gear	Median Pavement Gear	Optimized Gear	Difference Current-Optimized	 Median-Optimized
Gear Configuration	6 Wheel (200 psi)	4 Wheel (200 psi)	4 Wheel (215 psi)		
Total Gear Weight, pounds	24,084	23,934	23,720	364	214
Total Cost, \$/flt	647.21	641.55	640.38	6.83	1.17
Total Cost, \$/lifetime	19.416×10^6	19.247×10^6	19.211×10^6	204,900	35,100
Total Cost, \$/fleet/lifetime	11.999×10^9	11.895×10^9	11.872×10^9	126.6×10^6	21.7×10^6
Pavement Thickness, Inches				Optimized-Current	Median-Current
Rigid	11.9	14.5	15.3	3.4	2.6
Flexible	33	42(39)	39.6	6.6	6

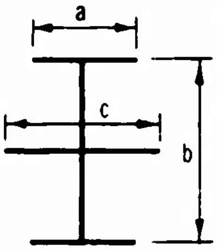
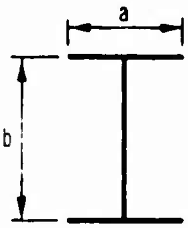
Table 8

Weight/Cost Penalties for Category I Airplane

Item	Current Pavement Gear	Median Pavement Gear	Optimized Gear	Difference	
				Current-Optimized	Median-Optimized
Gear Configuration	6 Wheel (200 psi)	4 Wheel (200 psi)	4 Wheel (215 psi)		
Total Gear Weight, pounds	24,084	23,934	23,720	364	214
Total Cost, $/flt	647.21	641.55	640.38	6.83	1.17
Total Cost, $/lifetime	19.416×10^6	19.247×10^6	19.211×10^6	204,900	35,100
Total Cost, $/fleet/lifetime	11.999×10^9	11.895×10^9	11.872×10^9	126.6×10^6	21.7×10^6
Pavement Thickness, Inches				Optimized-Current	Median-Current
Rigid	11.9	14.5	15.3	3.4	2.6
Flexible	33	42(39)	39.6	6.6	6

Table 9

Gear Parameters for Pavement Stress Calculations for Category I Airplane

<table>
<tr><th>ITEM</th><th>CURRENT-PAVEMENT GEAR</th><th>MEDIAN-PAVEMENT GEAR</th><th>OPTIMIZED GEAR</th></tr>
<tr><td>GEAR CONFIGURATION</td><td>6-WHEEL BOGIE</td><td>4-WHEEL BOGIE</td><td>4-WHEEL BOGIE</td></tr>
<tr><td>TIRE VERTICAL LOAD, POUNDS</td><td>38,630</td><td>57,950</td><td>57,950</td></tr>
<tr><td>TIRE PRESSURE, PSI</td><td>200</td><td>200</td><td>215</td></tr>
<tr><td>TIRE DIAMETER, INCHES</td><td>44.8</td><td>56.1</td><td>53.8</td></tr>
<tr><td>BOGIE SIZE, INCHES a</td><td>42.3</td><td>44.5</td><td>42.4</td></tr>
<tr><td>b</td><td>97.7</td><td>59.9</td><td>57.1</td></tr>
<tr><td>c</td><td>56.4</td><td>-</td><td>-</td></tr>
<tr><td>BOGIE CONFIGURATION</td><td> </td><td colspan="2"> </td></tr>
</table>

The most attractive nose gear configuration for the Category II airplane, for operating on current pavements, is four wheels on a common axle, as on the C5A. The wheels are 55 in. in diameter, with a load rating of 45,000 lb per tire, and an inflation pressure of 150 psi. The outer wheels are spaced 144 in. apart (compared to 92 in. for the C5A), and the inner wheels are spaced 51 in. apart (versus 33 for the C5A). For the optimized nose gear, the wheels are spaced closer (total axle width equals about 100 in.).

Since the weight penalty for designing the nose gear for current pavement strength is so small relative to the penalty for the main gears, the gear optimization scheme involves only finding the best gear configuration for the main gears. Seven different main-gear configurations, each at five different tire pressures (150, 175, 200, 250 psi), were investigated for each of the three pavement strength criteria shown in Table 3. Thus, 35 configurations were analyzed for each pavement strength level. The gear configurations analyzed included three six-wheel main gears; four, five, and six four-wheel gears; and four, five, and six six-wheel gears. Table 10 shows the total costs for these configurations at 150, 200, and 250 psi.

The lowest cost gears for each criterion are shown underlined in Table 10. The median gear is well defined in this case because there is a large spread in pavement thickness requirements between the current pavement gear and the optimum gear. The five and six gear, six-wheel-bogie wheel loads are of such a low magnitude that the bogie sizes are tire clearance limited as they are on the Category I airplane, so that at the lower tire pressures the costs are the same regardless of pavement strength requirements.

A comparison of the costs of the four-strut, six-wheel gears and the six-strut, four-wheel gears (both have the same total number of tires and, hence, the same tire vertical load) shows that the six-wheel bogie versions are less expensive. This is attributed to the weight penalties associated with the increased number of gears required for the four-wheel bogie versions.

Table 11 presents the pertinent weight and cost penalty data for

Table 10

Gear System Costs for Category II Airplane (1985 $/Flight)

			Gear System Costs for Indicated Pavement Type*		
Gear Configuration	Wheel Load, lb	Tire Pressure p, psi	Current	Median	Optimized
Three 6-wheel	79,167	150	--	2368.11	2342.30
		200	--	2371.72	2289.04
		250	--	2442.09	2263.19
Four 4-wheel	89,063	150	--	2382.49	2353.08
		200	--	2538.53	2315.75
		250	--	--	2304.84
Four 6-wheel	59,375	150	2432.92	2366.24	2366.24
		200	2537.55	2332.17	2332.17
		250	--	2366.15	2325.76
Five 4-wheel	71,250	150	--	2390.88	2390.88
		200	--	2414.13	2365.32
		250	--	2481.88	2366.44
Five 6-wheel	47,500	150	2410.68	2410.68	2410.68
		200	2447.10	2387.10	2387.10
		250	2522.55	2391.78	2391.78
Six 4-wheel	59,375	150	2550.24	2428.38	2428.38
		200	--	2414.55	2410.16
		250	--	2461.61	2419.03
Six 6-wheel	39, 583	150	2453.12	2453.12	2453.12
		200	2437.94	2435.95	2435.95
		250	2490.04	2447.80	2447.80
Pertinent pavement thickness, in.:					
		Rigid	11.9	14.5	17.1
		Flexible	33	42	51.2

---

* Underlined values indicate lowest cost gear for each pavement strength.

the three best gear configurations from Table 10. To determine the data given in Table 11, 30,000 flights/lifetime and a fleet size of 67 airplanes were used. This is the fleet size projected for 1985 for a Category II airplane to service U. S. domestic departures. The total worldwide fleet size is approximately twice this number. Table 11 shows that the Category II airplane gear system costs per flight are much larger than the corresponding figures for the Category I airplane ($147 versus $7). However, since the fleet size of the Category II airplane is much smaller (67 versus 618), the total fleet lifetime costs for the larger plane are only about two times the costs for the Category I airplane ($296 million versus $127 million).

The data required for pavement stress analysis are shown in Table 12. Ninety-five percent of the airplane gross weight of 1.5 million lb is distributed equally to each of the main gears. Likewise, the gear loads are distributed equally to each of the six wheels by providing the proper initial vertical offset between the center and end axles. With equal wheel loading, the six-wheel bogie pattern is such that the pavement stress under each wheel is virtually identical. For all configurations, two gears are wing-mounted, and the remaining 1, 2, or 3 are fuselage-mounted. In the case of the optimized gear, the tire size and load rating are greater than that of currently available tires. However, these larger capability tires would not require technical advances in the state-of-the-art to be feasible for a 1985 airplane.

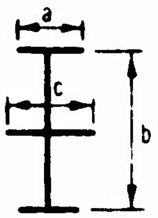
Table 11

Weight/Cost Penalties for Category II Airplane (1985 $)

Item	Current Pavement Gear	Median Pavement Gear	Optimized Gear	Difference	
				Current-Optimized	Median-Optimized
Gear Configuration	Five 6-Wheel Bogies	Four 6-Wheel Bogies	Three 6-Wheel Bogies	--	--
Total Gear Weight, pounds	93,353	89,288	84,566	8787	4722
Total Cost $/Flight	2410.68	2332.17	2263.19	147.49	68.98
Total Cost $/Lifetime	72.320×10^6	69.965×10^6	67.896×10^6	4.425×10^6	2.069×10^6
Total Cost $/Fleet Lifetime	4.845×10^9	4.688×10^9	4.549×10^9	0.296×10^9	0.139×10^9
Pavement Thickness, Inches				Optimized-Current	Median-Current
Rigid	11.9	14.5	17.1	5.2	2.6
Flexible	33	42	51.2	18.2	9

Table 12

Gear Parameters for Pavement Stress Calculations for Category II Airplane

<table>
<tr><th>ITEM</th><th>CURRENT-PAVEMENT GEAR</th><th>MEDIAN-PAVEMENT GEAR</th><th>OPTIMIZED GEAR</th></tr>
<tr><td>GEAR CONFIGURATION</td><td>FIVE 6-WHEEL BOGIES</td><td>FOUR 6-WHEEL BOGIES</td><td>THREE 6-WHEEL BOGIES</td></tr>
<tr><td>TIRE VERTICAL LOAD, POUNDS</td><td>47,500</td><td>59,375</td><td>79,167</td></tr>
<tr><td>TIRE PRESSURE, PSI</td><td>150</td><td>200</td><td>250</td></tr>
<tr><td>TIRE DIAMETER, INCHES</td><td>56.2</td><td>56.9</td><td>58.4</td></tr>
<tr><td>BOGIE SIZE, INCHES a</td><td>52.2</td><td>52.8</td><td>54.1</td></tr>
<tr><td>b</td><td>120.5</td><td>121.8</td><td>124.9</td></tr>
<tr><td>c</td><td>69.6</td><td>70.3</td><td>72.1</td></tr>
<tr><td></td><td colspan="3">
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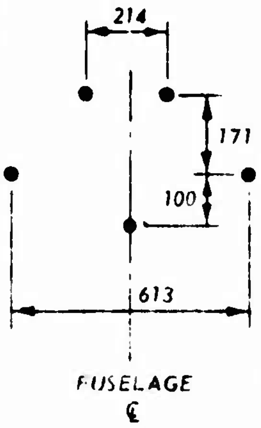
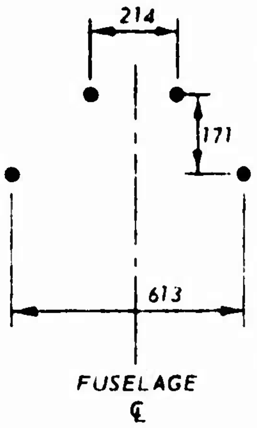
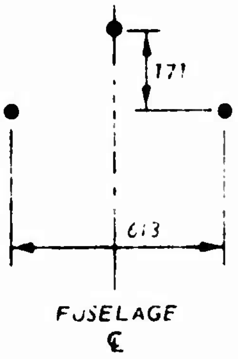
<tr><td>GEAR LOCATIONS, INCHES</td><td>
</td><td>
</td><td>
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4 1985 MAJOR HUB AIRPORTS

For the purpose of this study, a major hub airport was considered to be the same as a large hub airport as defined by the FAA in Reference 7. According to this definition, a major hub airport is one that enplanes more than one percent of the domestic enplaned passengers.

Reference 7 lists the present major hub airports and those planned to be operational by fiscal year 1983. Air carrier operations from these airports are projected for fiscal years 1975, 1978, and 1983. Actual data for fiscal year 1971 are also given. The data from Reference 7 have been extrapolated graphically to obtain calendar year 1985 operations. These are presented in Table 13.

The airports shown in Table 13 do not include all the major hub airports listed in Reference 7. Some of the airports listed will be phased out for scheduled airline traffic by 1985, such as Love and Greater Southwest in Dallas and Kansas City Municipal. Other fields, such as Chicago's Midway and Los Angeles' Hollywood-Burbank, were ruled out as being too small to handle the 1985 projected 1.5-million-lb airplane with which this research effort is concerned: Table 13 lists projected 1985 departures for each of the major hub airports. A compilation of the pavement construction data for the hub airports is given in Appendix A. The last column in Table 13 indicates whether or not the subject airport officials responded to requests as to the validity of the pavement data presented.

Table 13

Projected Departures from Major Hub Airports in 1985

Airport	1985 Calendar Year Number of Departures Thousands	Source of Pavement Data* CALAC	ATI	NASA	FAA	MRD	Airport Response
Chicago (O'Hare)	404				RTA		No
Atlanta	346		RT		RTA		Yes
Los Angeles (International)	242	RTA	RTA	RT	RTA		Yes
Dallas/Ft. Worth Regional	235	RTA	RTA				No
San Francisco	222	RTA	RTA			RTA	Yes
Miami	203		RTA	RT	RTA		Yes
New York (JFK)	198		RTA		RTA		Yes
New York (La Guardia)	177		RTA		RTA		Yes
Newark	175		RTA		RTA		Yes
Denver	161		RTA		RTA		No
Boston	146		RTA		RTA		No
Philadelphia	140				RTA		No
St. Louis	132		RTA		RTA		Yes
Honolulu	121	RTA	RTA	RT	RTA		Yes
Detroit	120		RTA		RTA		Yes
Seattle/Tacoma	110		RTA	RT	RTA		Yes
Pittsburgh	105		RTA		RTA		Yes
Houston	102		RTA		RTA		Yes
Minneapolis/St. Paul	97				RTA		Yes
New Orleans	94		RTA		RTA		Yes
Las Vegas	94				RTA		No
Kansas City (International)	91				RTA		Yes
Baltimore	88	RTA			RTA		Yes
Cleveland	78		RTA		RTA		No
Washington (Dulles)	65	RTA	RTA				Yes
Fort Lauderdale	37				RTA		Yes

Note: R - runway data; T - taxiway data; and A - apron data.

* CALAC - Lockheed data

ATI - Airport data for Air Transportation Planners, Air Transportation Industries Working Group

NASA - Data obtained from recent NASA reports

FAA - Data from FAA surveys

MRD - Data from Materials Research and Development, Inc.

5 AIRCRAFT COSTS

5.1 General Discussion

The airplane costs associated with carrying excess landing gear weight arise from four sources:

a. Acquisition cost.

b. Maintenance cost.

c. Flight operation cost.

d. Lost revenue cost.

The first three of these were discussed in Section 3, Landing Gear Optimization. The total cost penalties for the first three of the above costs were shown in Tables 8 and 11 for the Category I and II airplanes, respectively. These cost penalties were shown for airplane landing gear configurations designed for both current and median pavements, relative to an optimized gear. This section deals with the determination of the lost revenue cost and with the total of the above four costs.

5.2 Lost Revenue Cost Analytical Model

The lost revenue cost due to carrying excess landing gear weight results from the fact that there is a fixed structural limit on the total loaded weight of the airplane; therefore, every excess pound associated with the landing gear design represents the potential loss of 1 lb of revenue payload. The key word in the above statement is "potential"; since not all flights are performed with a full payload, the lost revenue must be determined statistically.

The analysis was performed for the traffic operating out of the 26 U. S. domestic major hub airports for 1985 shown in Table 13. Enplaned passengers and cargo tonnage from each of the hub airports were projected for the year 1985. Assuming 200 lb per passenger (including baggage), the total pounds departing from each hub airport in 1985 were determined in Table 14. The total pounds departing from each hub airport in 1985 were then broken down into departures traveling less than and greater than 1000 statute miles. Based on the current distribution of flight lengths for U. S. domestic traffic, as shown in the Official

Table 14

1985 Departing Pounds by Airport

Airport	Enplaned Passengers Thousands	No. of Departures Thousands	Passengers per Departure	Passenger lb per Departure	Total Passenger lb 10^6	Total Cargo lb 10^6	Total lb 10^6
Chicago (O'Hare)	40,000	404	99	19,800	8,000	2,086	10,086
Atlanta	38,700	346	112	22,400	7,740	290	8,030
Los Angeles (International)	23,700	242	98	19,600	4,740	1,661	6,401
Dallas/Ft. Worth Regional	23,000	235	98	19,600	4,600	267	4,867
San Francisco	20,200	222	91	18,200	4,040	1,298	5,338
Miami	23,000	203	113	22,600	4,600	1,387	5,987
New York (JFK)	22,000	198	111	22,200	4,400	3,000	7,400
New York (La Guardia)	15,500	177	88	17,600	3,100	825	3,925
Newark	15,000	175	86	17,200	3,000	825	3,825
Denver	16,200	161	101	20,200	3,240	159	3,399
Boston	14,200	146	97	19,400	2,840	558	3,398
Philadelphia	10,700	140	77	15,400	2,140	311	2,451
St. Louis	11,300	132	86	17,200	2,260	113	2,373
Honolulu	13,000	121	107	21,400	2,600	1,300	3,900
Detroit	10,900	120	91	18,200	2,180	352	2,532
Seattle/Tacoma	11,400	110	104	20,800	2,280	149	2,429
Pittsburgh	8,100	105	77	15,400	1,640	80	1,720
Houston	8,600	102	84	16,800	1,720	136	1,856
Minneapolis/St. Paul	9,700	97	100	20,000	1,940	159	2,099
New Orleans	7,600	94	81	16,200	1,520	59	1,579
Las Vegas	8,600	94	91	18,200	1,720	6	1,726
Kansas City (International)	5,800	91	64	12,800	1,160	110	1,270
Baltimore	6,700	88	76	15,200	1,340	84	1,424
Cleveland	6,500	78	83	16,600	1,300	210	1,510
Washington (Dulles)	5,500	65	85	17,000	1,100	128	1,228
Fort Lauderdale	2,900	37	78	15,600	580	12	592

Airline Guide, 68.4 percent of the total departing pounds involve flights of less than 1000 miles.

It was assumed that the projected Category II airplanes will not operate over routes of less than 1000 miles and that any short-range usage (less than 1000 miles) of the Category I airplane will not involve a significant revenue loss from lost payload. Accordingly, the lost revenue analysis considered only ranges greater than 1000 statute miles. Table 15 shows the weekly departing pounds from each major hub airport and the departing weights involving ranges over and under 1000 statute miles. The two right-hand columns in Table 15 show the departing pounds that are projected to be carried by the Category I and II airplane, and by other airplanes, such as the B707, DC8, and B727, that may be operating in 1985.

For each hub airport, the departing poundage was distributed over different flight distance blocks, from 1000 to 6500 miles in 500-mile increments. This distribution was based on Lockheed's commercial marketing analyses of current airline route structures, as shown in the Official Airline Guide. Once the departing weight from each major hub airport, Table 15, was distributed to the distance blocks, it was then further distributed to the Category I and the Category II airplanes, in normal- and extended-range versions. The normal-range versions of both airplanes operate up to 2000 miles; the extended-range version of the Category I airplane operates from 2000 to 4500 miles; and the extended-range version of the Category II airplane operates from 2000 to 6500 miles. The departing weight distribution between the two program airplanes (54 percent Category I, 46 percent Category II airplane) reflects the anticipated fleet sizes and relative payload capabilities of Category I and Category II airplanes.

The following inputs are required to calculate expected lost revenue by distance-block:

<u>a</u>. Operating empty weights (OEW) by aircraft type, which reflect the landing gear configurations designed to three pavement strength levels.

<u>b</u>. Maximum allowable TOGW by airplane type by airport. (Function

Table 15

1985 Departing Pounds, Program Airplanes

	Average Weekly Demand 10^3 lb				
				Flights Over 1,000 SM	
Airport	Total Departure	Under 1,000 SM	Over 1,000 SM	In Other Airplanes	In Categories I and II Airplanes
Chicago (O'Hare)	193,962	132,670	61,292	12,258	49,034
Atlanta	154,423	105,625	48,798	9,760	39,038
Los Angeles (International)	123,096	84,198	38,898	7,780	31,118
Dallas/Ft. Worth Regional	93,596	64,019	29,577	5,915	23,662
San Francisco	102,654	70,215	32,439	6,488	25,951
Miami	115,135	78,752	36,383	7,277	29,106
New York (JFK)	142,308	97,339	44,969	8,994	35,975
New York (La Guardia)	74,481	51,629	23,852	4,770	19,082
Newark	73,558	50,314	23,244	4,649	18,595
Denver	65,365	44,710	20,655	4,131	16,524
Boston	65,346	44,697	20,649	4,130	16,519
Philadelphia	47,135	32,240	14,895	2,979	11,916
St. Louis	45,635	31,214	14,421	2,884	11,537
Honolulu	75,000	51,300	23,700	4,740	18,960
Detroit	48,692	33,305	15,387	3,077	12,310
Seattle/Tacoma	46,712	31,951	14,761	2,952	11,809
Pittsburgh	33,077	22,625	10,452	2,090	8,362
Houston	35,692	24,413	11,279	2,256	9,023
Minneapolis/ St. Paul	40,365	27,610	12,755	2,551	10,204
New Orleans	30,365	20,770	9,595	1,919	7,676
Las Vegas	33,192	22,703	10,489	2,098	8,391
Kansas City (International)	24,423	16,705	7,718	1,544	6,174
Baltimore	27,385	18,731	8,654	1,731	6,923
Cleveland	29,038	19,862	9,176	1,835	7,341
Washington (Dulles)	23,615	16,153	7,462	1,492	5,970
Fort Lauderdale	11,385	7,787	3,598	720	2,878
Total	1,756,635	1,201,543	555,098	111,020	444,078

of runway length and elevation and airplane performance.

c. Capacity by airplane type.

d. Average weekly demand of cargo/passenger pounds departing by distance-block.

e. Average combined passenger/cargo yields by distance-block.

f. Load factors.

g. Standard deviation from the mean weekly payload.

The load factors and OEW's are constant in the model, while the other factors vary with airport distance-block and airplane type considered. The model used in calculating expected lost revenue requires the inputs of TOGW at each airport, distance-block average weekly demand, and distance-block yield. To calculate flight frequency for each distance-block, aircraft capacity is taken at 50 percent load factor and divided into average weekly demand. The resultant figure is rounded off to the nearest whole number above or below 0.5. This frequency number is then divided back into the average weekly demand to give the mean $\bar{X}$ of average weekly payload. A normal distribution of expected pounds to arrive on the dock for any one flight is calculated with a standard deviation of 0.6 times the mean $\bar{X}$ of average weekly payload. This relationship between the standard deviation and the mean is based on Lockheed's commercial marketing analysis of airline-furnished data on flight load factor variation over a two-year period, covering 297 city pairs; the normal distribution is considered an adequate assumption for such a large sample. The maximum payload that can be carried per flight X is determined by payload/range curves for the Category I and the Category II airplanes, as well as airplane performance limitations at each hub airport.

The analysis can be readily understood by referring to Figure 25.

The horizontal bar represents airplane weight. The total weight for each flight is made up of the operating weight empty, the fuel weight, and the payload weight. The maximum allowable payload X for a given distance-block and departure hub airport, is determined from the payload/range curve, at the average range for the distance-block being

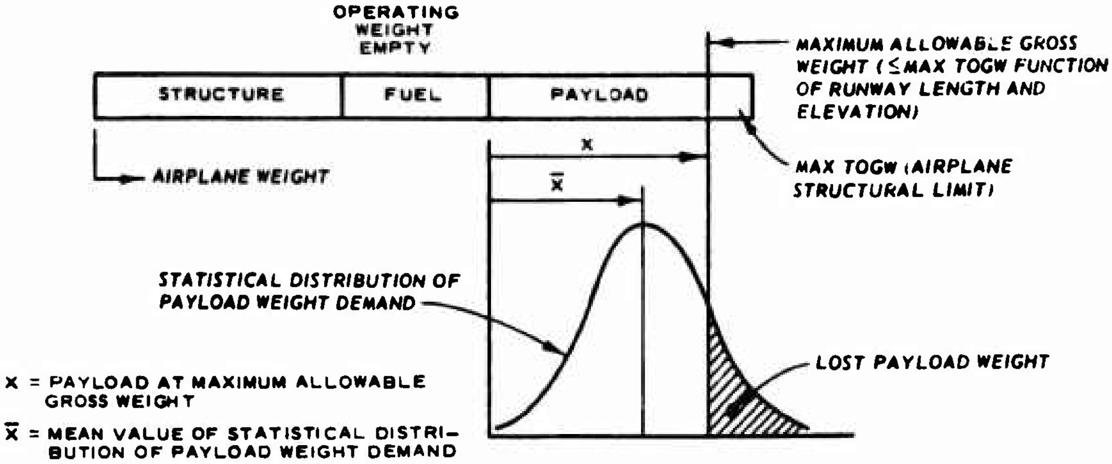

Figure 25. Determination of lost payload

analyzed, as well as airplane performance limitations (if any) due to runway length and altitude at the departure hub airport.

Once the average weekly payload $\bar{X}$ has been determined as previously discussed, the statistical distribution of payload weight can be determined by assuming a normal curve with a standard distribution equal to 0.6 times the mean $\bar{X}$. The crosshatched area under the normal curve shown in the above sketch represents the lost payload for the distance-block analyzed in any one week.

This result is then multiplied by the distance-block yield on cargo/passenger pounds to obtain the expected dollar value of weight loss in any one week. The weighted average yield for combined cargo/passenger pounds is obtained for each distance-block by the following equations:

$$(\text{Total revenue, \$}) = (\text{Passenger miles}) \times (\text{Yield/passenger mile}) + (\text{Cargo ton mile}) \times (\text{Yield/ton mile})$$

$$(\text{Total weight, lb}) = (\text{Passenger miles} \times 200\ \text{lb/passenger}) + (\text{Cargo ton mile} \times 2000\ \text{lb/ton}) \div (\text{Flight distance})$$

$$(\text{Average yield (\$/lb)}) = (\text{Total revenue}) \div (\text{Total weight})$$

The weekly expected revenue loss is then multiplied by 52 to arrive at an annual expected lost revenue by aircraft type by distance-block under varying landing gear/OEW assumptions. This lost revenue is then summed over all the distance-blocks analyzed for the 26 major hub airports to determine the total annual lost revenue from operations out of the major domestic hub airports.

The factors that influence the lost payload are the factors that determine the relative location of $\bar{X}$ and X in Figure 25. The lost payload (crosshatched area in Figure 25) varies inversely with the distance separating $\bar{X}$ and X .

The lost payload is reduced by the following:

a. Lower operating empty weight.
b. Improved fuel economy (lowers fuel weight for given range-payload).
c. Improved takeoff performance (raises X on performance limited airfields).
d. Extended range-payload curve (raises X for given range).

Of the above factors, this study is concerned only with the first. Landing gear configurations designed to different pavement strength criteria result in different operating empty weights, which affect the lost revenue.

5.3 Lost Revenue Cost Results

The lost revenue analytical model was applied to the Category I and the Category II airplanes, operating out of the 26 major hub airports shown in Table 15. Two versions of each airplane were analyzed: normal-range and extended-range versions. The range/payload curves for these airplanes are shown in Figures 26 and 27. Both the normal- and extended-range versions of the Category I airplane weigh 488,000 lb, and both versions of the Category II airplane weigh 1.5 million lb. The landing gear configurations chosen in the previous section for each airplane are the same for both the normal- and extended-range versions. Table 16 summarizes the 1985 number of departures and total departing weight projected for each major hub airport. Also shown is the percentage of these departures accounted for by the normal- and extended-range versions of both the Category I and the Category II airplanes.

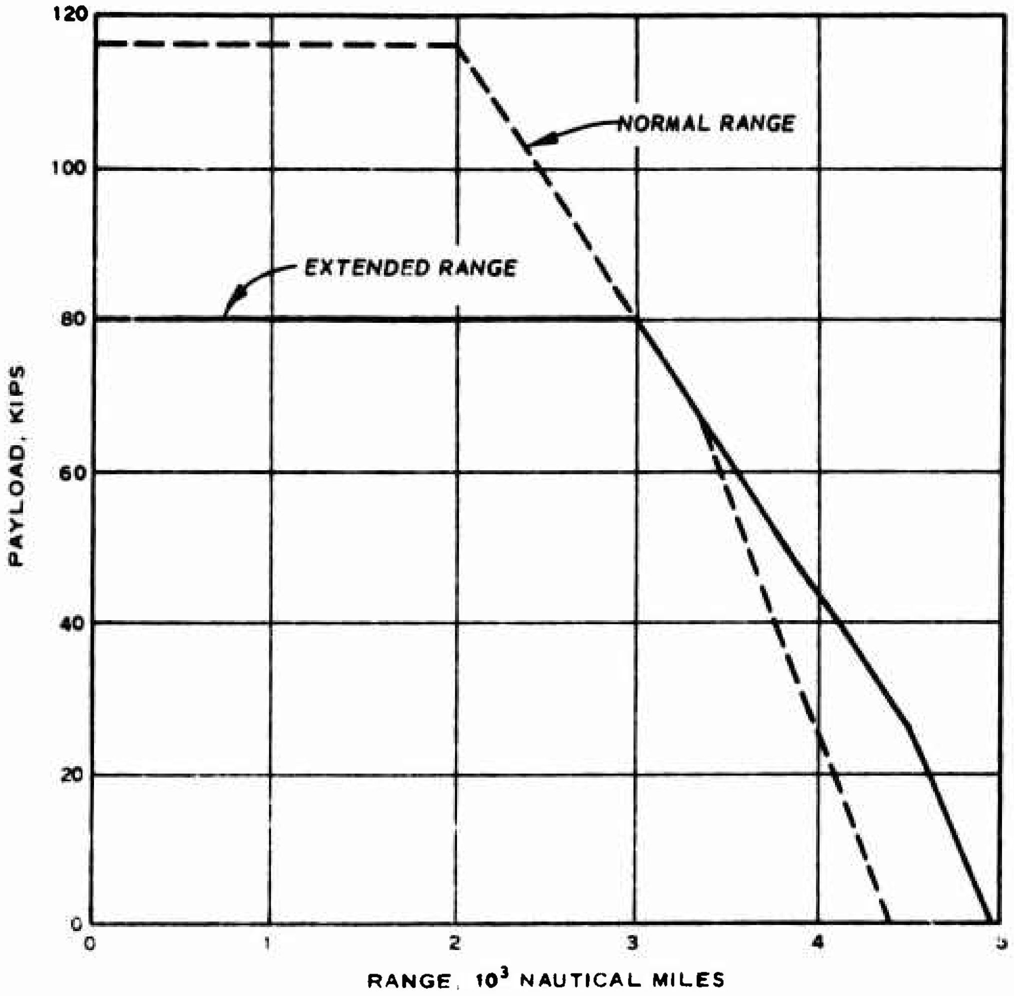

Figure 26. Payload versus range for Category I airplane

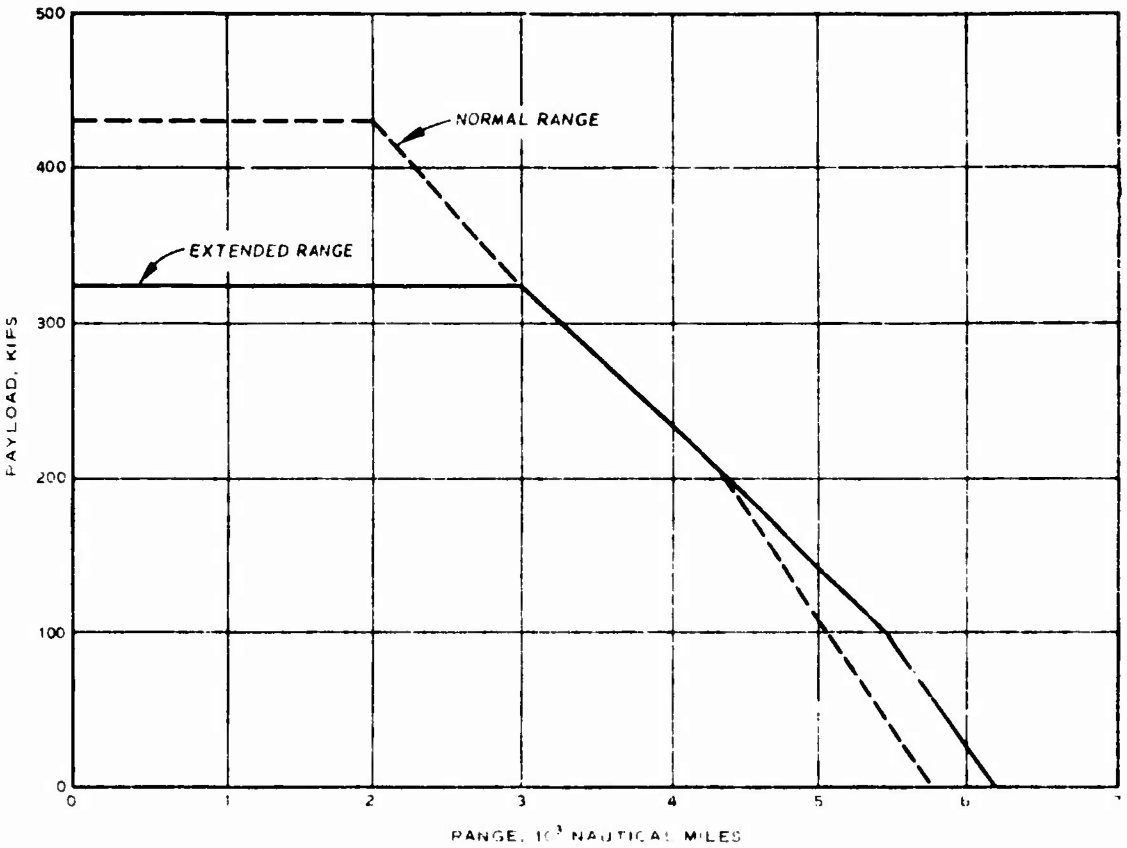

Figure 27. Payload versus range for Category II airplane

Table 16

1985 Major Hub Airport Departures and Departing Weight

Airport	Departing Weight -10^9 lb	Departures -10^3	Percentage of Departures: Category I Airplane, Normal Range	Category I Airplane, Extended Range	Category II Airplane, Normal Range	Category II Airplane, Extended Range
Chicago (O'Hare)	10.086	404	15.83	3.333	0.721	1.017
Atlanta	8.030	346	14.73	3.096	0.676	0.962
Los Angeles (International)	6.401	242	16.76	3.502	0.752	1.117
Dallas/Ft. Worth Regional	4.867	235	13.165	2.744	0.597	0.863
San Francisco	5.338	222	15.225	3.186	0.703	0.984
Miami	5.987	203	18.7	3.919	0.845	1.153
New York (JFK)	7.400	198	23.77	4.990	1.077	1.549
New York (La Guardia)	3.925	177	12.475	2.705	0.578	1.024
Newark	3.825	175	13.965	2.882	0.624	0.981
Denver	3.399	161	13.405	2.842	0.614	1.066
Boston	3.398	146	14.78	3.099	0.677	0.962
Philadelphia	2.451	140	11.145	2.377	0.52	0.780
St. Louis	2.373	132	11.225	2.364	0.512	0.768
Honolulu	3.900	121	0	10.185	0	2.536
Detroit	2.532	120	13.435	2.817	0.607	0.910
Seattle/Tacoma	2.429	110	13.945	2.789	0.615	1.040
Pittsburgh	1.720	105	10.4	2.179	0.495	0.743
Houston	1.856	102	11.47	2.447	0.510	0.816
Minneapolis/St. Paul	2.099	97	13.67	2.895	0.590	1.072
New Orleans	1.579	94	10.51	2.213	0.498	0.774
Las Vegas	1.726	94	11.615	2.434	0.553	0.830
Kansas City (International)	1.270	91	8.57	1.829	0.400	0.743
Baltimore	1.424	88	10.34	2.127	0.473	0.827
Cleveland	1.510	78	12.333	2.600	0.533	0.933
Washington (Dulles)	1.228	65	12.00	2.400	0.560	0.960
Fort Lauderdale	0.592	37	9.84	2.108	0.422	1.265
Total	91.345	3863	14.345	3.329	0.653	1.073

These figures are based on the flight frequencies for the four different airplane models as predicted by the lost revenue analytical model. The flights for the normal range Category I airplane have been increased above the analytical model results to reflect flights of less than 1000 miles. This alteration is required because the departures in Table 16 will be used to determine pavement coverages at each hub airport for each airplane type. While the lost revenue analytical model ignores flights of less than 1000 miles because it is assumed that any revenue loss at this range is negligible, from a pavement-damage viewpoint, the numerous short flights by the Category I airplane, normal-range version, cannot be ignored.

While the percentages of departures in Table 16 appear rather low, totaling about 19.4 percent for the four airplane models, these airplanes have an average payload of around 75,000 lb based on the total annual flights and total annual departing pounds for these planes. The average payload for the total departures shown in Table 16 is 91.345E9/3.863E6 or 23,600 lb. Therefore, the heavy-weight airplanes in this study have an average payload equal to 75,400/23,600 or 3.19 times the total 1985 fleet average payload. Thus, the 19 percent of total departures for these planes represents about 62 percent of total departing weight. Furthermore, since the distribution of airline revenue with flight distance is weighted more heavily toward the longer flights than is the distribution of departing weight (it costs more to fly farther), the 62 percent of total departing weight represents over 90 percent of airline revenue.

The 1985 annual expected lost revenue from each hub airport, for the current pavement and median pavement gear configurations relative to the optimized gear configuration, are shown for the extended-range version of both airplanes, in Tables 17 and 18. The normal-range airplanes, which only operate up to 2000 miles, do not suffer any significant revenue loss from lost payload. The revenue loss for the Category II airplane is far greater than that for the Category I airplane, because the weight penalties are much greater for this airplane, as shown in Tables 8 and 11 (8787 versus 364 lb for the current pavement

Table 17

Annual Lost Revenue from Major Hub Airports

Extended-Range Category I Aircraft

Airport	Current Pavement Dollars/Year	Median Pavement Dollars/Year
Chicago (O'Hare)	139,324	81,471
Atlanta	112,166	65,594
Los Angeles (International)	125,370	73,320
Dallas/Ft. Worth Regional	78,498	45,912
San Francisco	91,570	53,551
Miami	108,458	63,436
New York (JFK)	131,616	76,969
New York (La Guardia)	294,451	172,449
Newark	134,891	78,968
Denver	145,472	85,182
Boston	52,767	30,867
Philadelphia	35,619	20,823
St. Louis	42,896	25,099
Honolulu	67,158	39,282
Detroit	39,066	22,836
Seattle/Tacoma	38,553	22,536
Pittsburgh	27,695	16,202
Houston	31,150	18,230
Minneapolis/St. Paul	36,626	21,419
New Orleans	23,039	13,474
Las Vegas	31,778	18,593
Kansas City (International)	24,247	14,196
Baltimore	21,319	12,463
Cleveland	27,587	16,130
Washington (Dulles)	22,172	12,977
Fort Lauderdale	17,788	10,422
Total	1,901,276	1,112,401

Table 18

Annual Lost Revenue from Major Hub Airports

Extended-Range Category II Aircraft

Airport	Current Pavement Dollars/Year	Median Pavement Dollars/Year
Chicago (O'Hare)	5,955,958	3,115,072
Atlanta	4,719,668	2,466,657
Los Angeles (International)	4,573,753	2,391,495
Dallas/Ft. Worth Regional	2,861,967	1,489,804
San Francisco	3,245,655	1,693,190
Miami	4,384,743	2,290,566
New York (JFK)	4,903,924	2,549,059
New York (La Guardia)	6,410,712	3,278,854
Newark	3,243,256	1,683,129
Denver	2,982,823	1,521,113
Boston	2,024,124	1,055,206
Philadelphia	1,032,096	528,480
St. Louis	1,256,918	648,743
Honolulu	2,162,275	1,121,065
Detroit	1,251,611	643,373
Seattle/Tacoma	1,037,821	531,718
Pittsburgh	885,385	460,163
Houston	842,286	434,445
Minneapolis/St. Paul	1,422,629	734,638
New Orleans	681,251	351,659
Las Vegas	897,852	466,795
Kansas City (International)	337,327	169,746
Baltimore	543,190	277,600
Cleveland	769,850	396,944
Washington (Dulles)	426,013	216,627
Fort Lauderdale	101,943	50,611
Total	58,955,030	30,566,752

gear relative to the optimized gear).

Table 19 presents both the 1985 annual lost revenue costs and the annual acquisition, operating, and maintenance costs for the normal- and extended-range versions of the Category I and the Category II airplanes. The acquisition, operating, and maintenance costs are based on the costs per flight shown in Tables 8 and 11 of Section 3, Landing Gear Optimization. A flight frequency of 1200 flights/year was used for the normal-range airplanes, and 900 flights/year for the extended-range airplanes. These figures were based on historical flight frequency data. The fleet sizes used were as follows:

Category I Airplane	Normal Range	475
	Extended Range	143
Category II Airplane	Normal Range	21
	Extended Range	46

These fleet sizes represent the number of airplanes to satisfy domestic U. S. departures. Worldwide fleet sizes would be approximately twice the above figures.

The bottom line of Table 19 is the total annual cost in 1985 for the two airplanes analyzed, which together in normal- and extended-range versions account for over 90 percent of the total airline domestic U. S. revenue. These are the total airplane costs resulting from designing the landing gears to current and median pavement strength levels; all costs are relative to zero cost for an optimized landing gear system for each airplane. It can be seen from Table 19 that about 80 percent of the total costs are due to lost revenue on the extended-range version of the Category II airplane.

To help place the total cost figures in Table 19 in perspective, the total domestic airline revenue estimated for 1985 by the Air Transport Association of America (ATA) in Reference 8 is $38 billion. Therefore, the $75 million lost revenue at the majob hub airports in Table 19 represents about 0.2 percent of the total domestic airline revenue for 1985. The costs in Table 19 are <u>annual</u> costs in 1985 dollars; over a 25-year time span, the total costs for the current pavement gear relative to the optimized gear would be 1.88 billion dollars, in constant 1985 dollars.

Table 19

Total Annual Airplane Fleet Cost Penalties Relative to Pavement Designed for Optimal Gear Designs

(1985 Dollars)

Airplane		Item	Current Pavement	Median Pavement
Category I Airplane	Normal Range	Acq., Oper., Maint Costs	$ 3,893,100	$ 666,900
		Lost Revenue Costs*	--	--
		Total Costs	3,893,100	666,900
	Extended Range	Acq., Oper., Maint Costs	879,021	150,579
		Lost Revenue Costs	1,901,276	1,112,401
		Total Costs	2,780,297	1,262,980
		Total Costs, Category I Airplane	6,673,397	1,929,880
Category II Airplane	Normal Range	Acq., Oper., Maint Costs	3,716,748	1,738,296
		Lost Revenue Costs*	--	--
		Total Costs	3,716,748	1,738,296
	Extended Range	Acq., Oper., Maint Costs	6,106,086	2,855,772
		Lost Revenue Costs	58,955,030	30,566,752
		Total Costs	65,061,116	33,422,524
		Total Costs, Category II Airplane	68,777,864	35,160,820
		Total Cost, Both Airplanes	$75,451,261	$37,090,700

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* No significant payload loss for normal-range airplanes.

6 PAVEMENT UNIT PRICE ANALYSIS

6.1 Introduction

In developing pavement price, a distinction must be made between cost and price. Pavement cost is defined as the amount of monies that a contractor must spend for labor, materials, equipment, subcontracts, and overhead to construct a pavement structure. Pavement price is the total amount of monies that an agency, or the public, must spend to have a pavement structure constructed. Pavement price includes pavement cost, general contractor overhead, and contractor profit.

In calculating unit prices for a study such as this, which encompasses the country as a whole, an extremely large number of variables are apparent. For each major hub airport, there are spatial and temporal variables. Spatial variables include location of material sources, contractors, and labor contracts. Temporal variables include inflation rates, material availability, labor contract periods, and business climates. Statistical validity, within an acceptable range, can be attached to the spatial variables since it can be assumed that future construction distances will correlate fairly well to previous construction distances. Certain of the temporal variables can be attacked statistically. Inflation rates have been projected; these may or may not be accurate. Material availability and labor contract periods can be assumed to remain as they have in the past. The business climate at a particular award date is extremely difficult to predict. This factor affects greatly the markup that the contractor attaches to his cost. In the author's opinion, this factor is the most sensitive and difficult variable to predict in calculating pavement unit prices.

Prior to presenting the unit prices used in this study, the variability of price due to a change in business climate deserves discussion. The amount that a contractor bids for a particular job includes a markup over his estimated cost. From the contractor's point-of-view, the study of the amount of money that he should mark up his estimated cost in order to maximize his expected ability is commonly referred to as the "Competitive Bidding Problem." In order to establish a strategy for bidding, a contractor must select (either implicitly or explicitly) his utility function. This function is extremely sensitive to his own business situation and has been shown to depend upon the volume of work which he presently has on hand (Reference 9).

A representation of a contractor's volume as a function of time is given by his volume-time function as shown in Figure 28. The ordinate of

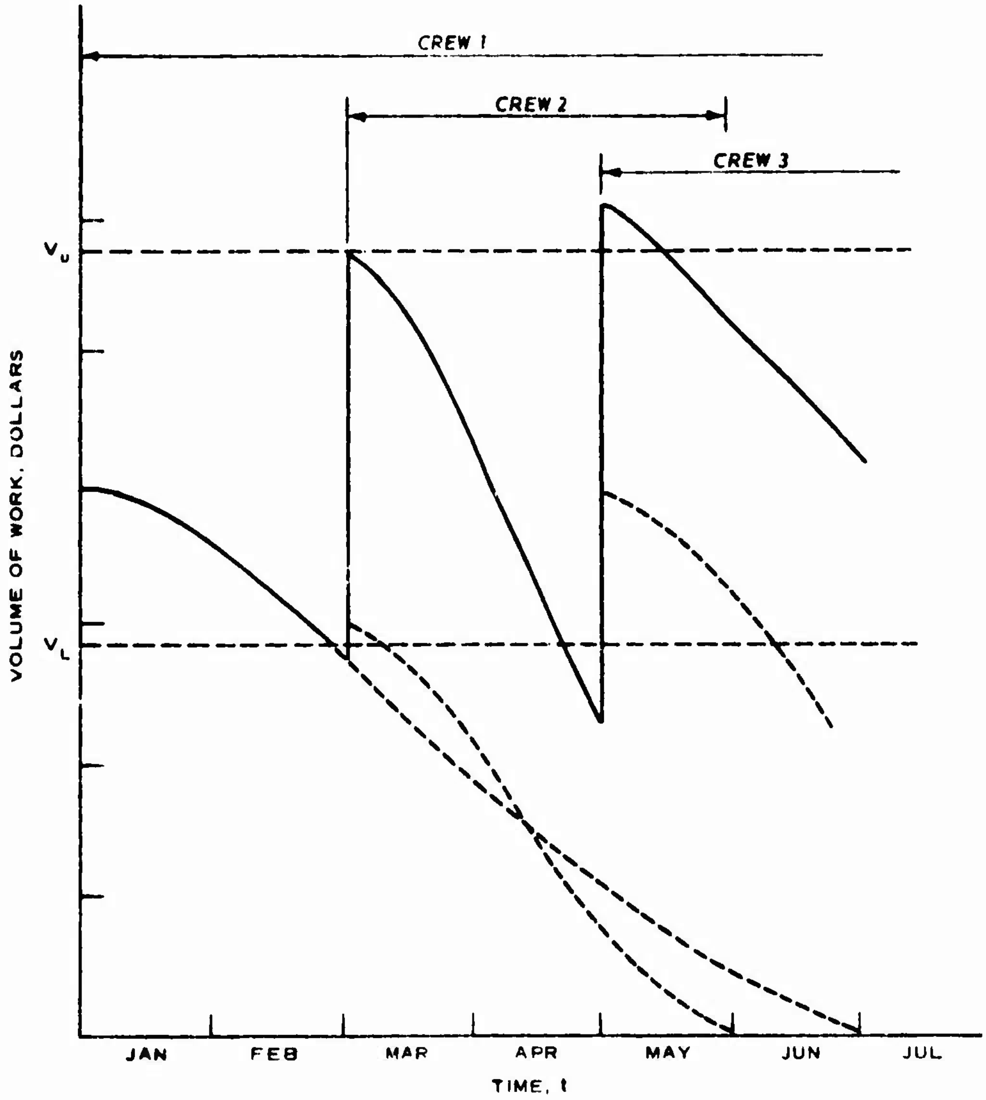

Figure 28. Volume-time function

this function is V , the volume of work that the contractor has on hand in dollars. The abscissa represents time T . There are two usually distinct values of V on each volume-time function. The first V_L is the volume of work below which a contractor does not like to operate. When his volume is below V_L , this implies that a large portion of his cash flow must go to pay his fixed cost thereby making his overhead-volume ratio higher than satisfactory. When a contractor's volume reaches his upper volume V_u (the volume which is generally set explicitly by his bonding capacity, staff or equipment capability, or other constraints), his objective in a particular bidding situation is different than when his volume is at V_L . A contractor operating at or near his maximum volume V_u is in an extremely good business situation. Simply, he does not desire any more work. If he does bid a job while his volume is high, he will mark up his estimated cost to account for the additional risk involved and, quite often, hope to be awarded the job at an extremely high contribution level.

Basically, if the entire local construction industry has a lot of work on hand (i.e., most contractors operating near V_u), the sponsor of a project can expect to pay an extremely high price for construction. If, on the other hand, a large portion of the industry is operating near V_L , the sponsor can expect to pay a lower unit price for construction, since the objective of most contractors will be to bid low in order to be awarded the contract and thereby obtain some contribution to maintain their cash flow.

Ideally, the construction market will be, at the time of each award, in an equilibrium situation. An equilibrium situation implies that most contractors are operating in a volume range between V_u and V_L . This being the case, each contractor's objective, either implicitly or explicitly, is to maximize his expected profit, thus permitting true competition. In this situation, the sponsor gets a reasonable bid for his construction and the contractor gets his fair profit.

The purpose of these introductory paragraphs is to explain to the reader one reason for the high variability in bid prices relative to time in one location. Additionally, there is an extreme variation in bid prices among locations. Thus the approach used in this treatise has been to develop unit prices based on historical data statistically and show the sensitivity of the total pavement cost to these unit prices. Hopefully, an upper and a lower bound have been developed that will permit future rational decisions.

6.2 Relationship of Pavement Cost to Total Cost of Pavements

When one constructs a new pavement or strengthens an old pavement, the actual price of the pavement is only a part of the total price. In an attempt to predict the total cost of upgrading a pavement structure, a total of 14 bid tabulations published during 1971 and 1972 for airport pavements in Engineering News-Record have been analyzed. These bid tabulations have been arbitrarily subdivided into seven categories for analysis. These seven categories are shown as column headings in Table 20.

The elements of the matrix shown in Table 20 are the percentages of the total price of each category. The means $\bar{x}$ and standard deviations σ of each category as a percentage of total cost are:

Category	$\bar{x}$	σ
Excavation	13.10	11.08
Pavement	72.79	9.81
Subsurface Structures	7.13	5.70
Wiring	1.74	2.27
Lighting	2.21	4.47
Painting	0.37	0.65
Miscellaneous	2.66	4.92

Although some rather large variances occur in the categories other than pavement, this is inconsequential. The average price of pavement as a percentage of the total contract price is 72.79 percent with a coefficient of variation of 14 percent. These 14 contracts grouped both flexible and rigid pavements together. An analysis of variance (AOV) was performed to test the significance between the percentage of total contract price of flexible and rigid pavements. There were 7 contracts each for rigid and flexible pavements in the sample of 14 airfield pavement contracts. The percentages of pavement price to total contract

Table 20

Categorical Percentages of Total Contract Price of Seven Pricing Elements in Airfield Pavement Construction

Type of Pavement Surfacing	Percentage of Total Bid and Indicated Category						
	Excavation	Pavement	Subfeature Structures	Wiring	Lighting	Painting	Miscellaneous
Rigid	10.7	75.2	8.1	3.8	0.8	-	1.4
Flexible	34.7	60.2	5.0	-	0.1	-	-
Flexible	9.5	69.0	19.7	-	-	0.5	1.3
Flexible	1.8	58.1	-	6.1	16.6	-	17.4
Rigid	5.7	73.0	10.1	5.3	5.8	0.1	-
Flexible	9.6	80.4	5.3	-	-	1.7	3.0
Rigid	6.1	79.4	9.4	-	3.6	0.1	1.4
Flexible	4.5	80.0	9.7	4.1	1.2	-	0.5
Rigid	26.2	65.4	3.7	0.9	0.4	-	3.4
Rigid	4.4	90.2	3.6	-	-	1.8	-
Flexible	35.0	58.6	3.3	-	-	-	3.1
Rigid	10.4	84.2	5.2	-	-	-	0.2
Flexible	17.9	70.2	-	3.4	2.1	1.1	5.3
Rigid	6.9	75.2	16.7	0.7	0.4	-	0.1

price for each of the two pavement types are:

Pavement Type	$\bar{x}$	σ
Rigid	77.51	8.03
Flexible	68.06	9.60

Based on a standard one-way analysis of variance and a 95 percent level of significance, one can reject the hypothesis that there is no significant difference between the percentage of total contract price of rigid and flexible pavement construction. The AOV is shown in Table 21.

Table 21

One-Way Analysis of Variance*

Source	DF	SS	MS	F**
Total	13	1252.4171	-	-
Treatments	1	313.0314	313.0314	3.9988
Error	12	939.3857	78.2821	-

* Analysis of variance based on the hypothesis that there is no difference between the percentage of pavement cost to total project cost for rigid versus flexible pavement structures.

** Probability of F less than 3.9988 = 0.9313.

Therefore for the purpose of this report, the percentages of pavement price to total contract price will be as shown above.

6.3 Pavement Unit Price Model

Although there are numerous methods that might be used to develop unit prices, this report considers them only statistically. A primary assumption of this section is that pavement price per SY is hyperbolically related to pavement thickness within a reasonable range. This assumption is necessary since the only feasible method for conducting a nationwide price analysis for airport construction is to collect the individual bid tabulations for each project and the associated cross-sectional design from the FAA Form 51001. The bid tabulations list the unit (SY) price, whereas the FAA Form 5100-1 records the depth of each pavement layer. Therefore, for each airport, the price per SYIN for each pavement layer C_u is given by

$$C_u = \frac{C\ SY}{h} \qquad (2)$$

where

$C\ SY$ = price per SY for the pavement layer

h = thickness of the layer in inches

A linear regression analysis was performed on a national basis to test a linearity assumption; the resulting functional relationship is shown in Figure 29. A relatively poor correlation coefficient of -0.60 was found nationwide. Using the homoscedastic assumption inherent in a linear regression analysis, one might assume that a coefficient of variation of 0.36 holds for the derived functional relationship. However, it is reasonable to assume that the variance would shrink when performed on a local level and the calculated correlation coefficient can be considered an upper bound.

An alternate equation using a least-squares fit to a hyperholic function was also performed. The resulting dashed curve in Figure 29 is intuitively more pleasing than the linear functional. However, any statistical description such as the correlation coefficient is meaningless as a goodness-of-fit indicator since most assumptions regarding statistical inference with respect to a regressed function are violated by the nonlinearity of the function considered.

In those cases where asphaltic concrete prices were expressed in cost per ton, the price per SYIN was developed from the equation:

$$C_u = CPT \cdot \frac{1}{2000\ lb/ton} \cdot 150\ lb/cf \cdot 9\ sf/SY \cdot \frac{1}{12\ in./ft} \qquad (3)$$

$$= CPT \cdot 0.05625$$

where CPT is the price per ton.

This explicitly assumed an asphaltic concrete density of 150 lb/cf. In those cases where the price of aggregate and asphalt cement were given

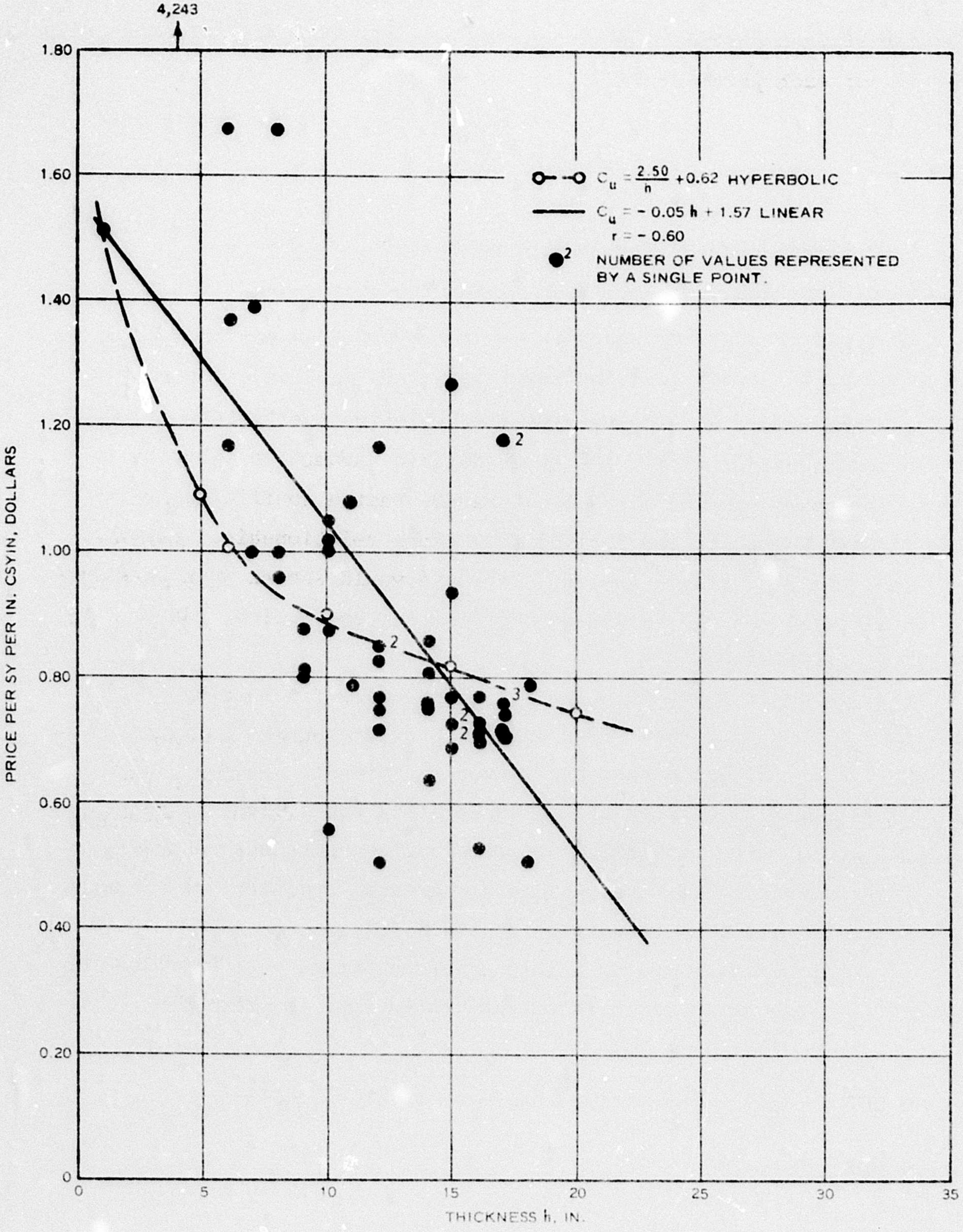

Figure 29. Pavement prices per SYIN as a function of pavement thickness (national statistics for rigid pavement)

separately, an asphalt content of 5 percent was assumed. The rate of application of asphalt prime coats was assumed to be 0.3 gal/SY and tack coats at 0.1 gal/SY. The density of crushed stone was assumed to be 100 and the C_u for crushed stone developed from Equation 2 using the assumed density. A list of national statistics is given in Table 22.

Table 22

Statistical Values Nationwide for Pavement Products

Pavement Product	Cost Units	Number of Observations	Mean Price	Standard Deviation
Portland Cement Concrete (P501)	$/SYIN	46	0.94	0.34
Bituminous Surface Course (P401)	$/SYIN	21	0.54	0.14
Crushed Aggregate Base (P209)	$/SYIN	8	0.19	0.03
Bituminous Base (P201)	$/SYIN	13	0.59	0.22
Prime Coat (P602)	$/SY	9	0.07	0.02
Tack Coat (P603)	$/SY	23	0.03	0.02

The prices per SYIN used for each of the projected 1985 major hub airports were derived in order of priority according to the following sources: (a) project bid data at that particular airport if two or more tabulations were available (this requirement is for some statistical credibility); (b) regional averaged bid data for those regions supplying adequate data; and (c) nationwide averages as given in Table 22. The price per SYIN in 1972 dollars used for each projected major hub airport is given in Table 23.

Table 23

Price per SYIN Used for Each Projected 1985 Major Hub Airport in 1972 Dollars

Airport	Price per SYIN for Indicated Pavement Product				
	Portland Cement Concrete P501	Asphaltic Concrete P401	Bituminous Base Course P201	Crushed Aggregate Base Course P209	Compacted Subbase
Chicago (O'Hare)	0.79	0.76	0.54	0.18	0.13
Atlanta	0.60	0.54	0.66	0.19	--
Los Angeles (International)*	0.94	0.54	0.68	0.19	0.13
Dallas/Ft. Worth Regional	--	--	--	--	--
San Francisco*	0.94	0.54	--	0.19	0.13
Miami*	0.94	0.54	0.66	--	0.13
New York (JFK)	1.37	0.52	0.65	--	0.30
New York (La Guardia)	0.85	0.56	0.65	--	0.30
Newark	0.85	0.54	0.65	--	0.30
Denver	1.27	0.37	0.32	0.19	0.08
Boston	1.37	0.92	0.65	--	0.30
Philadelphia	1.37	0.73	0.65	0.38	--
St. Louis	0.64	0.46	0.44	0.15	0.13
Honolulu	0.94	0.54	0.66	0.19	--
Detroit	0.94	0.76	0.67	0.18	0.13
Seattle/Tacoma	1.38	0.41	0.39	0.27	0.34
Pittsburgh	1.17	0.93	0.74	0.38	0.24
Houston	0.84	0.34	0.71	0.23	0.11
Minneapolis/St. Paul	0.85	0.76	0.67	0.18	0.13
New Orleans	0.79	0.76	0.57	0.23	0.13
Las Vegas	1.27	0.54	0.66	--	0.38
Kansas City (International)	0.85	0.42	0.76	--	0.18
Baltimore	1.37	0.52	0.65	--	0.18
Cleveland	0.85	0.76	0.67	0.18	0.13
Washington (Dulles)	1.37	0.52	0.65	0.38	0.30
Fort Lauderdale*	0.94	0.54	0.66	0.19	0.13

* National averages used.

7 PAVEMENT THICKNESS REQUIREMENTS

7.1 Computational Procedures

Realistic rigid and flexible pavement thicknesses that will be required to support operations of the Category I and the Category II aircraft on the airports listed in Table 13 were determined for input to calculations of pavement costs. It was assumed that all of the airports except Dallas-Fort Worth Regional Airport may need to build new pavements for the 1.5-million-lb Category II aircraft and that overlays would be required on other pavement areas; therefore, thicknesses were calculated both for new construction and for overlay of selected pavement areas.* Dallas-Fort Worth Regional Airport is designed for operation of the Category II aircraft and consequently is omitted from further tables.

The following parameters were used for calculating pavement thicknesses.

CBR. The California Bearing Ratio (CBR) is a measure of soil strength. For each airport, CBR values for the subgrade were determined by correlating the soil group with the subgrade class (F) using Table 2 in FAA Advisory Circular AC-150-5320-6A (Reference 10) and then converting the F-class to CBR using Figure 20 from the same reference. The CBR values are tabulated in Appendix B.

Modulus of subgrade reaction k. The moduli of subgrade reaction used in this report represent the strength of the foundation upon which a rigid pavement will be placed. When a k-value was not a matter of record, the CBR value described above was used with Figure 30 to determine a k-value for the subgrade based upon the average CBR-k correlation curve. When the pavement was to be placed on a base or subbase layer, the subgrade k-value was adjusted by using Figure 31 and then the k-value was determined for the foundation layer. The k-values are shown in Appendix B.

Working stress. The working stress represents the allowable stress

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* The pavement areas selected for overlay calculations were those on which it was assumed that the Categories I and II aircraft might operate. These areas are identified on the airfield layouts in Appendix A.

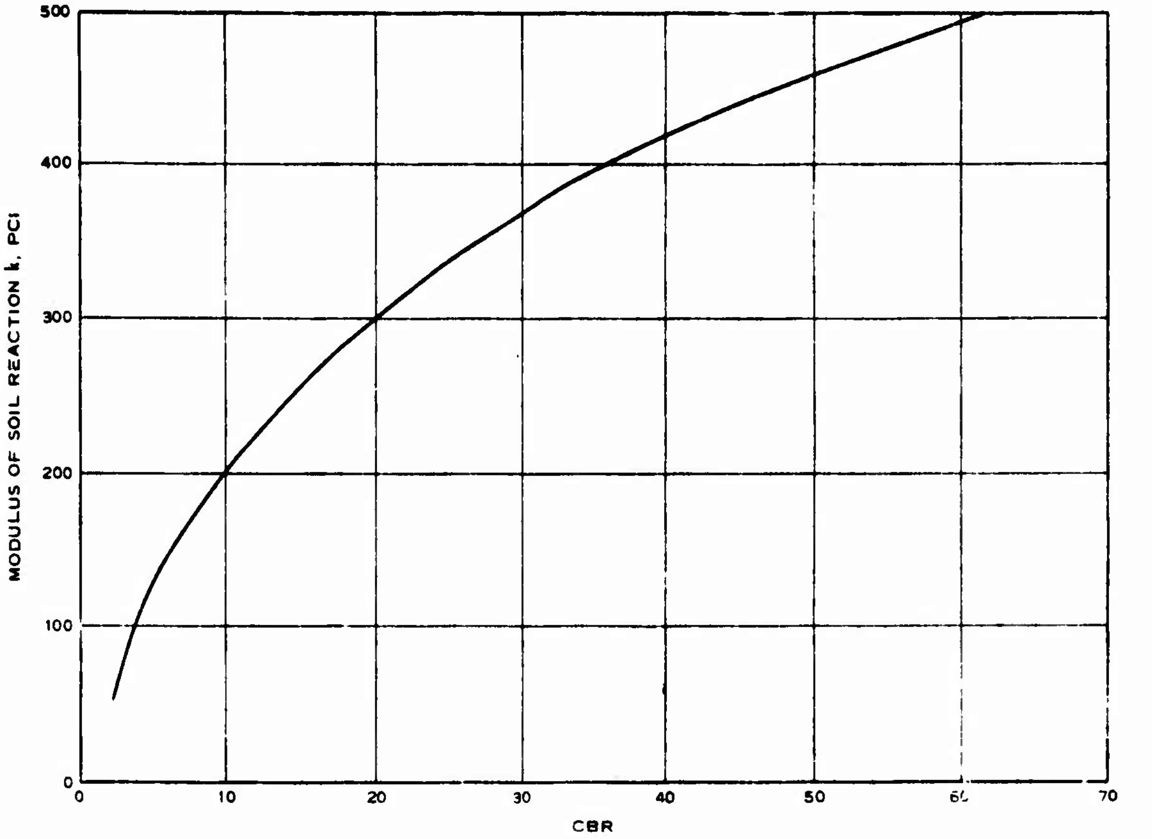

Figure 30. Approximate correlation of CBR and k-value

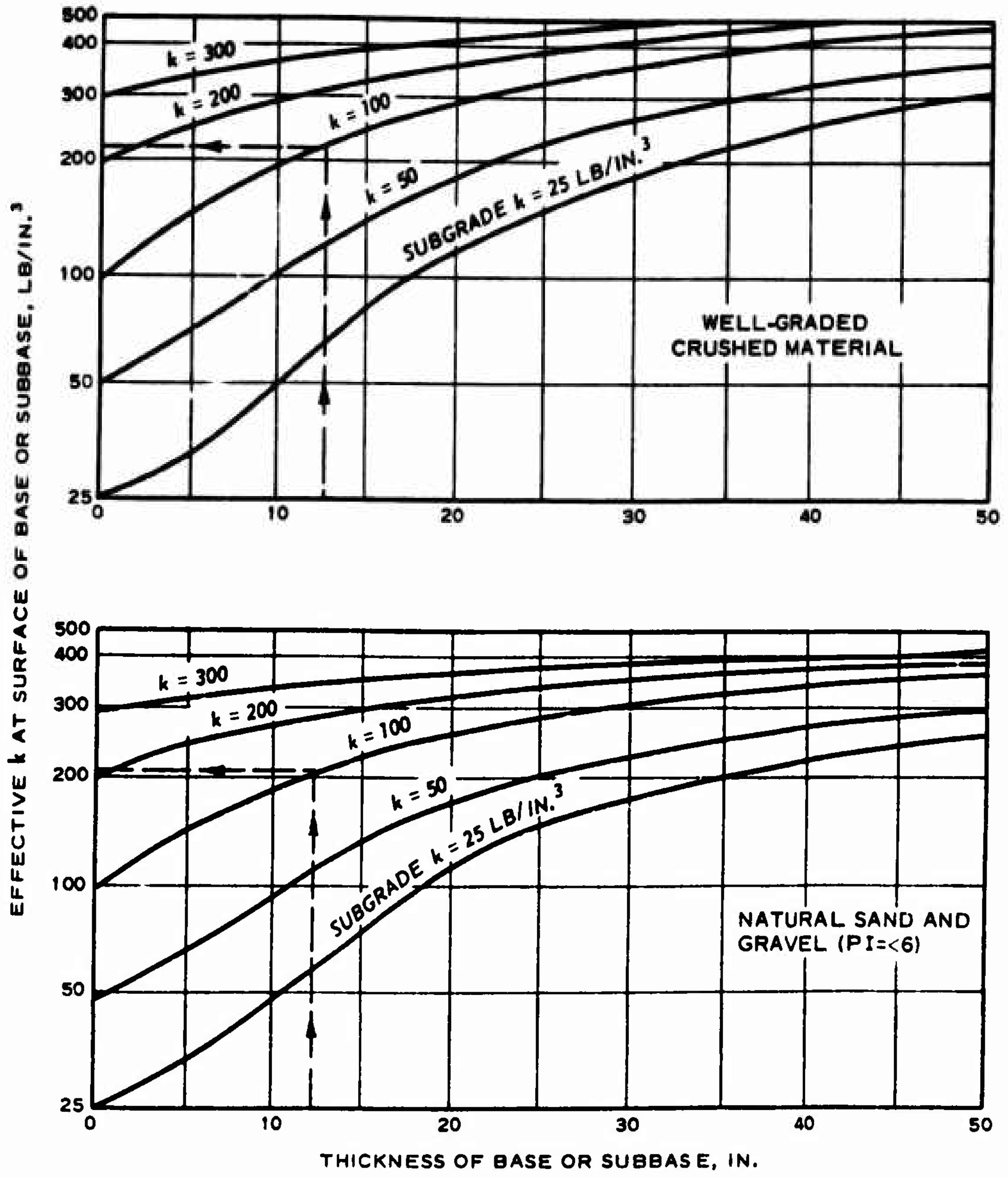

Figure 31. Effect of base or subbase thickness on modulus of soil reaction (from Dept of Army Technical Manual TM 5-88-9 "Airfield Rigid Pavement Evaluation-Air Force, Emergency Construction")

for a rigid pavement slab. This stress is determined by dividing the flexural strength by a safety factor (2.0). For this study, a working stress of 350 psi was assumed for all pavements.

Traffic. A standard level of 100,000 aircraft passes was chosen for the design of all typical pavement sections and overlays.

7.2 Design Criteria

The flexible and rigid pavement design curves used to develop typical sections for the major airports are shown in Figures 32 through 39. These curves were developed basically using the Corps of Engineers procedures for flexible and rigid pavements and were modified to be compatible with current FAA criteria as shown in Reference 10. To make the rigid pavement curves compatible with FAA criteria, rigid pavement curves were developed initially in terms of thickness k , load, and flexural strength, and the flexural strength was then changed to working stress by dividing the flexural strength by a safety factor of 2.0. To make the flexible pavement curves compatible with the FAA flexible pavement criteria, the curves were developed initially in terms of CBR, thickness, and load. The CBR was then converted to the FAA soil class as discussed above. Additional adjustments were made to the flexible pavement curves because the slope of the curves developed using the Corps of Engineers methodology was different from the slope of the current FAA curves. This adjustment was made by multiplying the thickness requirements for the median and optimized aircraft gears by a ratio of the FAA thickness requirement for the dual tandem gear to the Corps of Engineers thickness requirements for a dual tandem gear.

Each design curve was developed for 100,000 passes and covered the ranges of soil strengths, working stresses, and thicknesses necessary to accomplish the study.

7.3 Determination of Thickness Requirements

7.3.1 New construction. The flexible pavement thicknesses were determined by entering the design curves shown in Figures 32 through 35 with the appropriate subgrade CBR value from Appendix B and reading the corresponding thickness. For rigid pavement new construction, the design curves shown in Figures 36 through 39 were entered at a working stress of 350 psi, and the required thickness was determined using the k-value of the foundation under existing pavements and the gross weight of the aircraft. The resulting thicknesses for new construction of flexible and rigid pavements are shown in Appendix C.

7.3.2 Overlays. All overlay thicknesses were determined in accordance with FAA procedures and methods presented in Reference 10. The base pavement for all overlays was assumed to be in good condition. Calculations were made for flexible, bituminous, and rigid overlays* on rigid and flexible pavements. Overlay thicknesses were calculated for each cross section on a pavement item, i.e., runway, taxiway, apron, etc., and the overlay thickness deemed most logical was selected for the entire pavement item. The results of these calculations are shown in Appendix C.

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* Flexible pavement - asphaltic concrete over a granular base course. Bituminous pavement - full-depth asphaltic concrete.

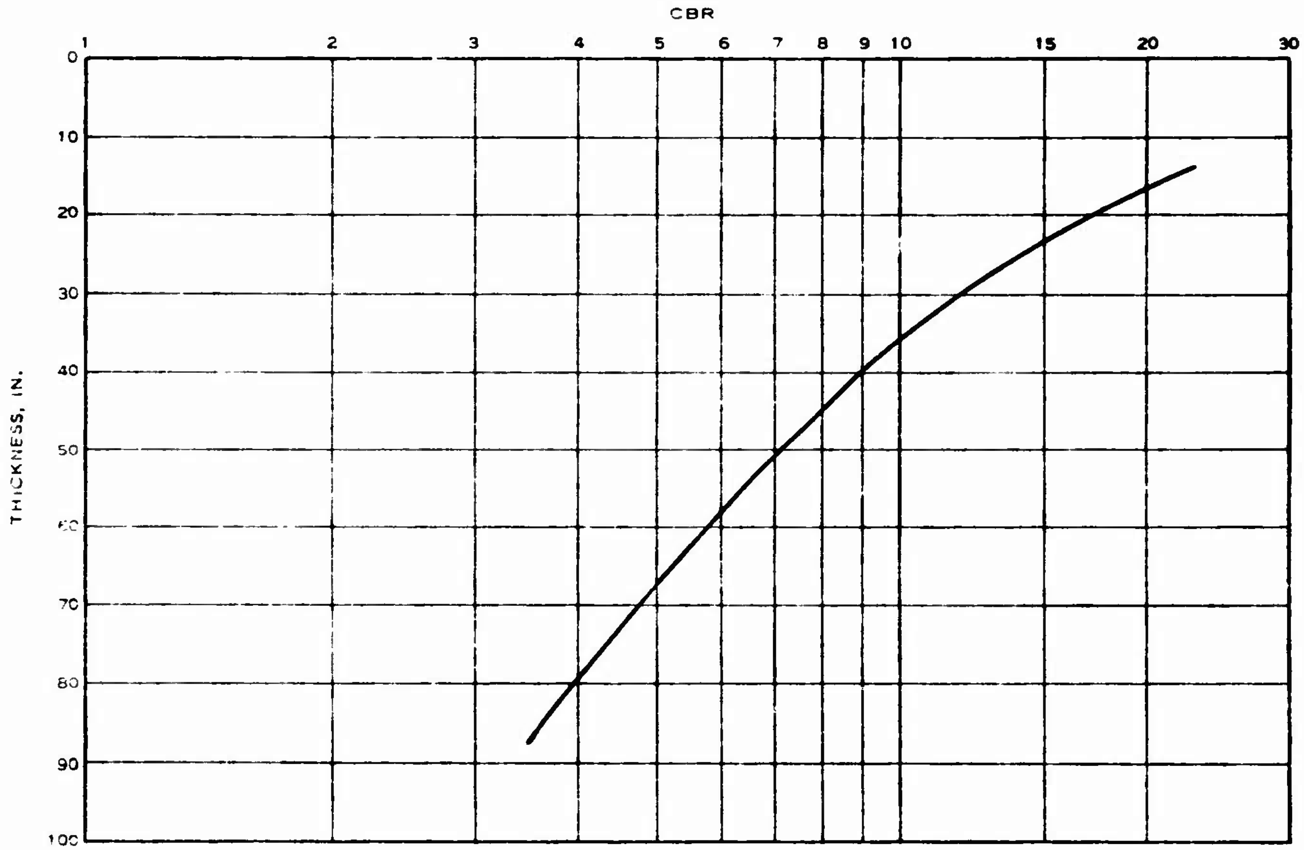


Figure 32. Flexible pavement design curve for Category I airplane with median gear

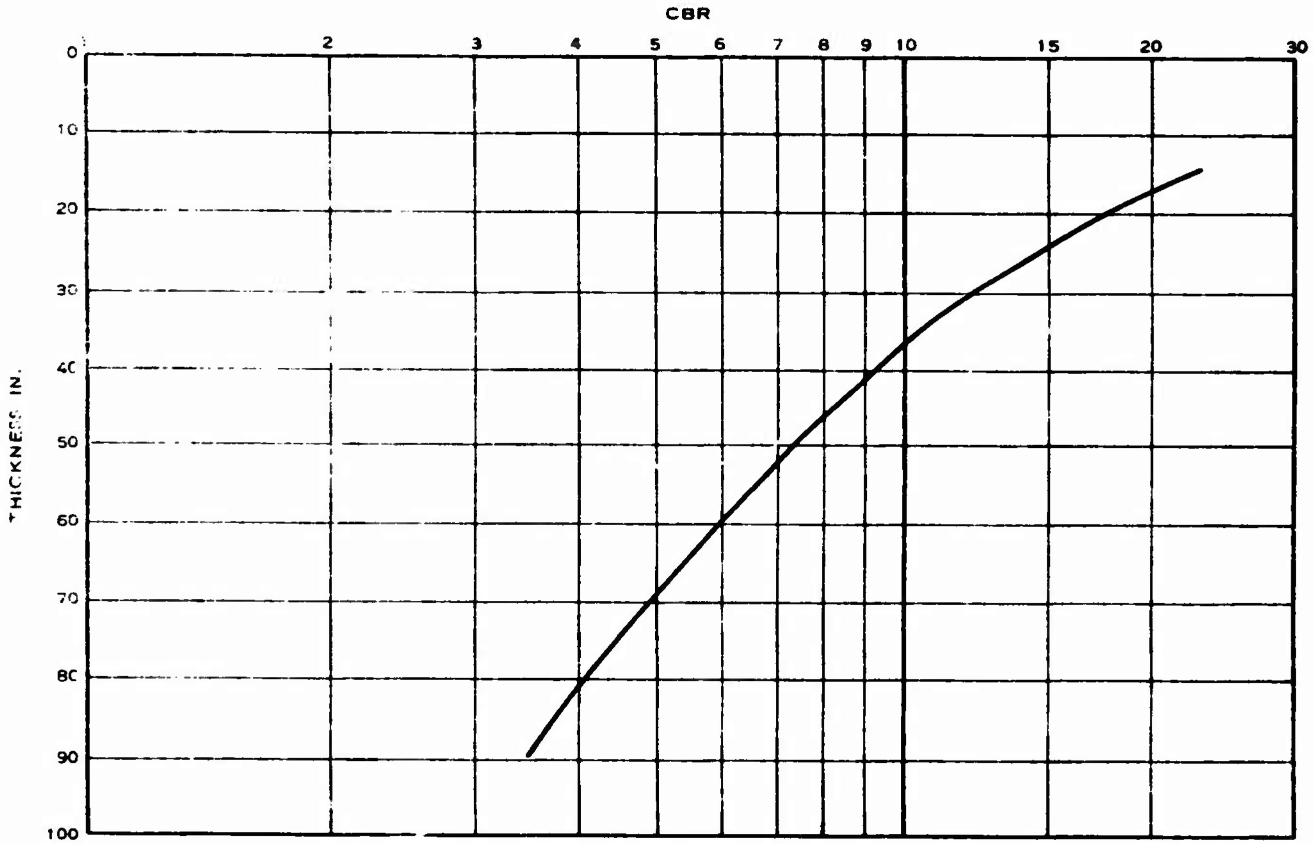


Figure 33. Flexible pavement design curve for Category I airplane with optimized gear

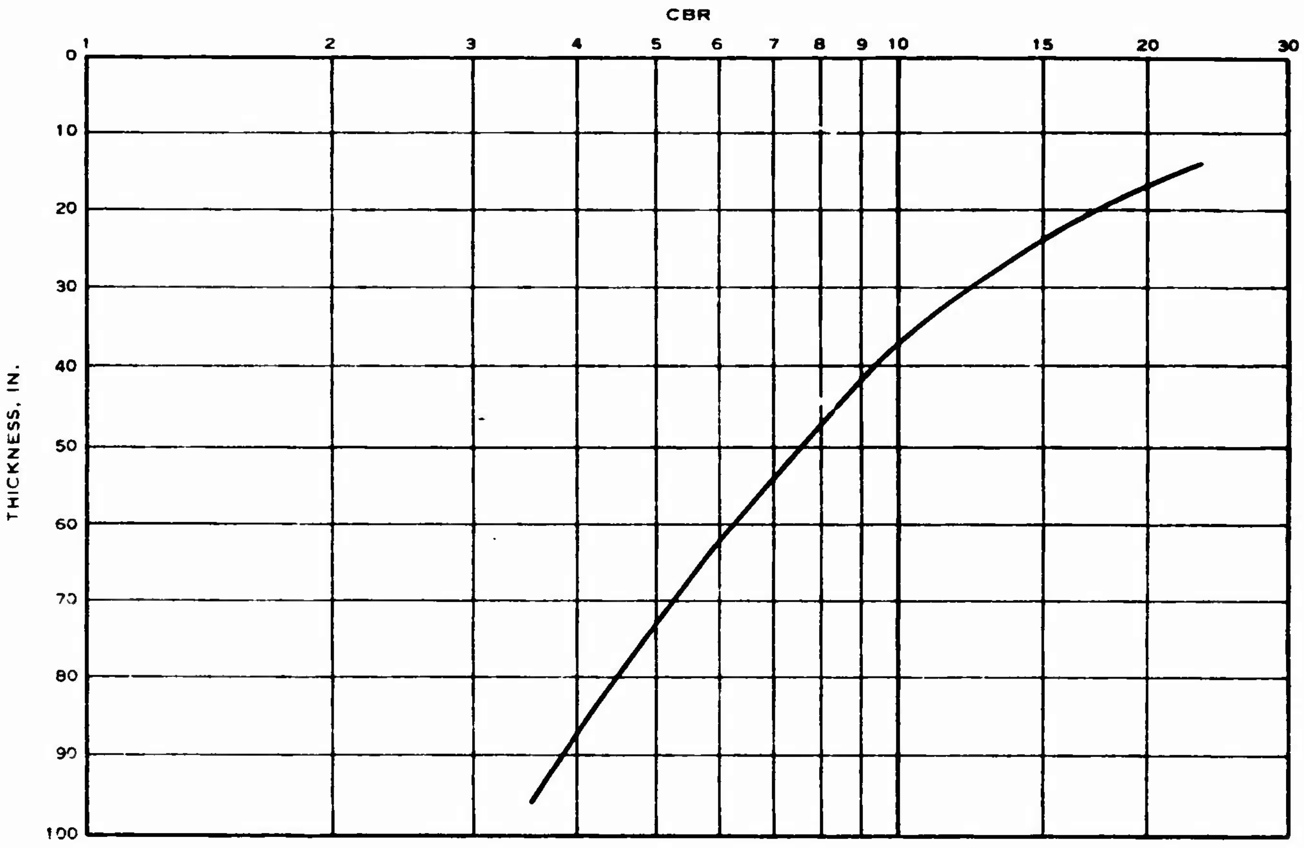


Figure 34. Flexible pavement design curve for Category II airplane with median gear

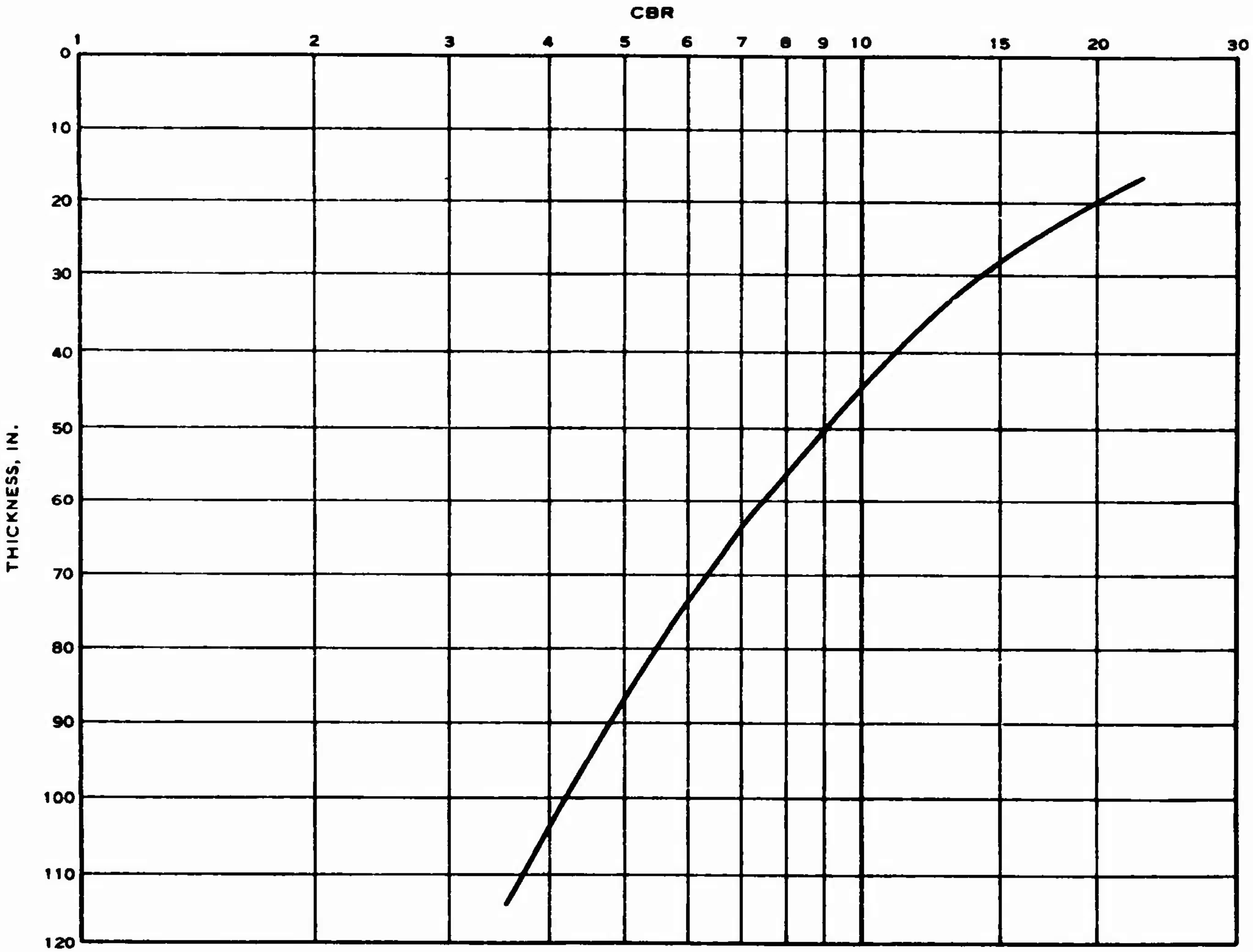


Figure 35. Flexible pavement design curve for Category II airplane with optimized gear

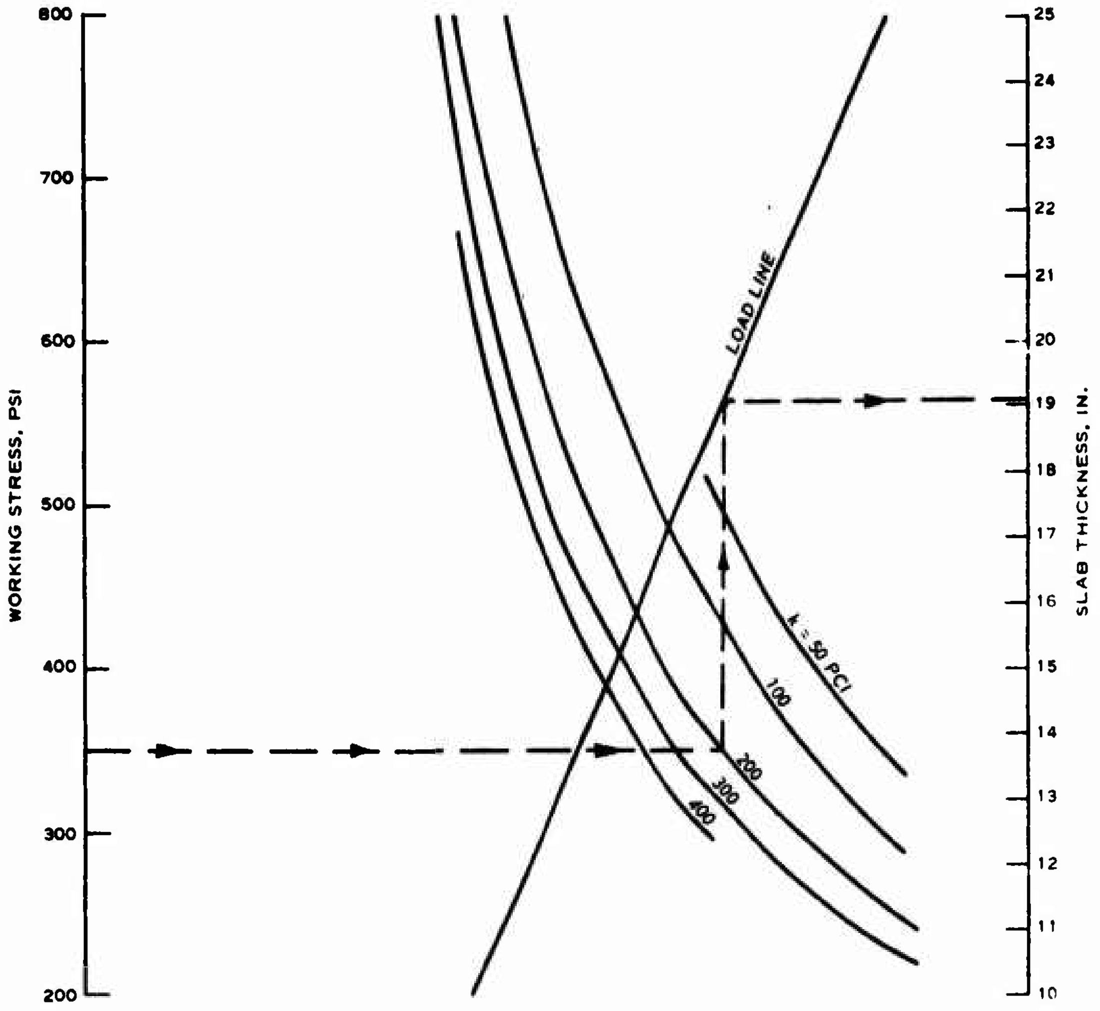


Figure 36. Rigid pavement design curves with example of usage. Category I airplane with median gear

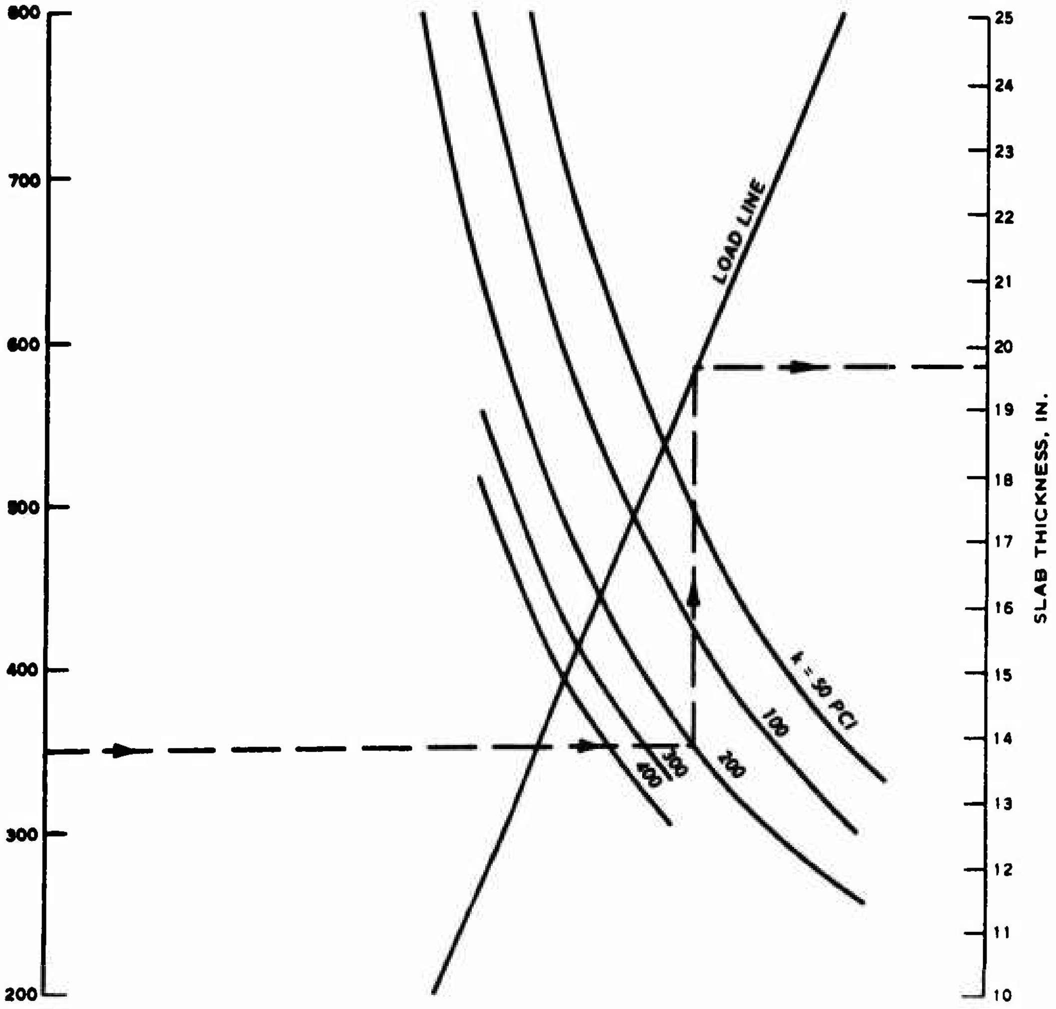


Figure 37. Rigid pavement design curves with example of usage. Category I airplane with optimized gear

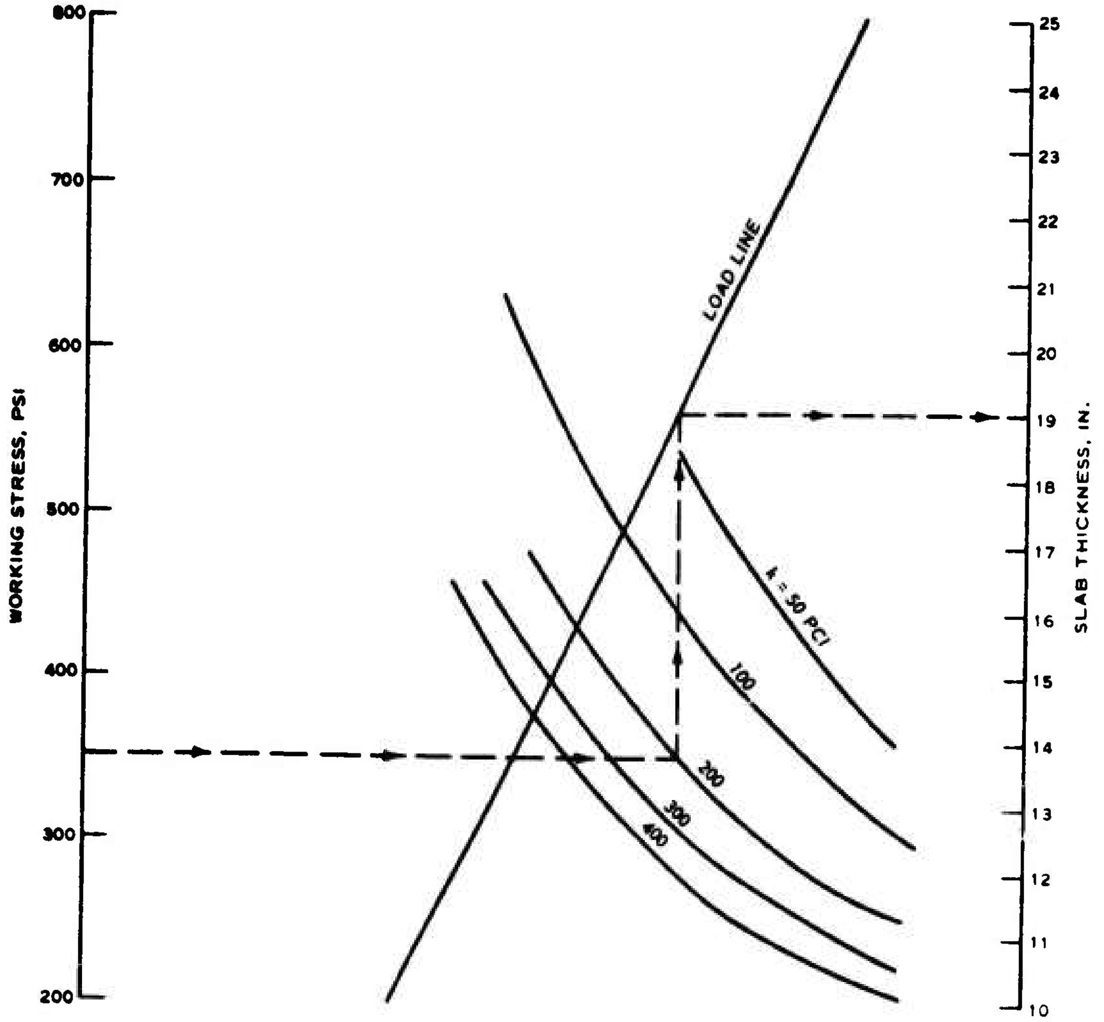


Figure 38. Rigid pavement design curves with example of usage. Category II airplane with median gear

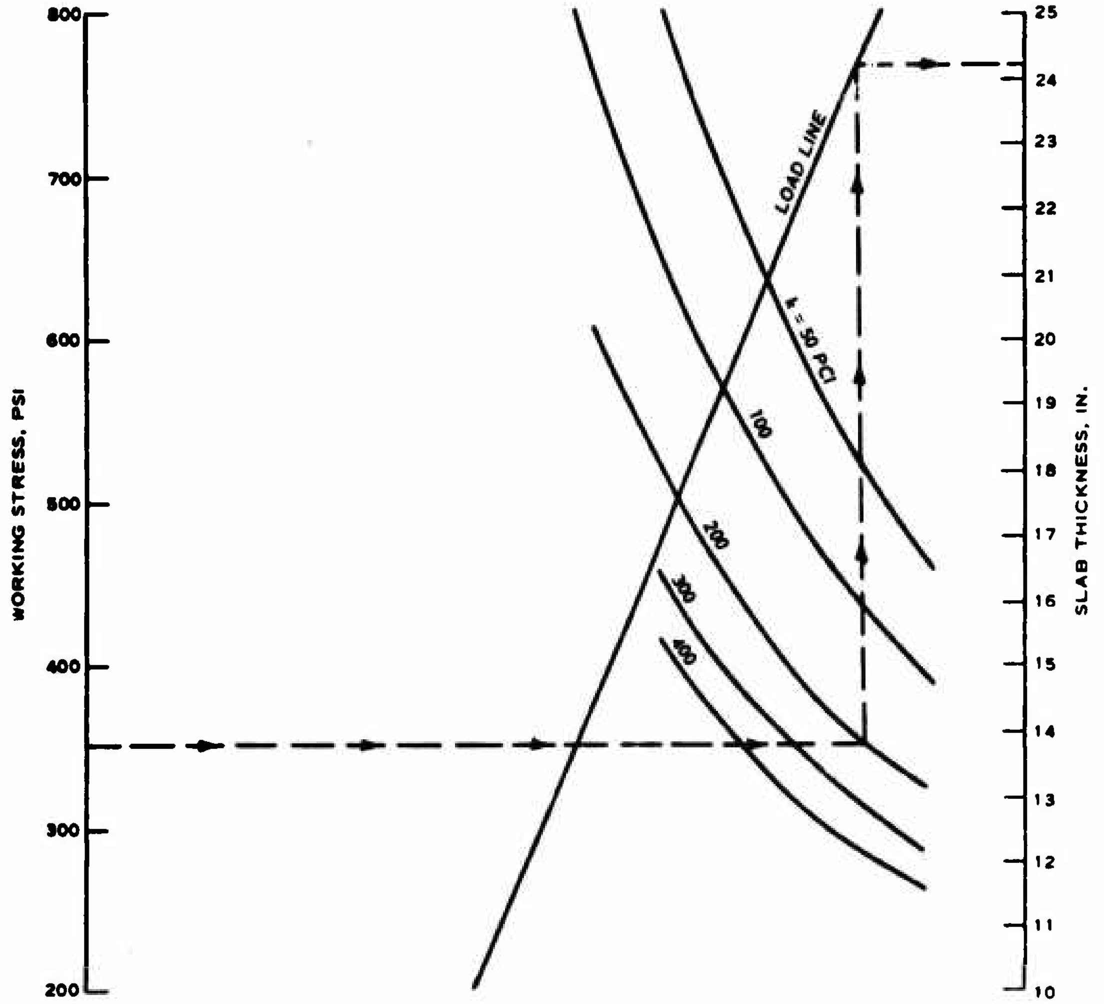


Figure 39. Rigid pavement design curves with example of usage. Category II airplane with optimized gear

8 CALCULATION OF TOTAL PAVEMENT PRICE

8.1 Introduction

Based on information given in the two previous sections, the total price of upgrading the 26 major hub airports can now be calculated. Section 6 developed unit prices in units of dollars per SYIN of thickness in addition to the ratio of pavement price to total price. Section 7 developed the thicknesses required to upgrade the present pavement structure to accommodate the Category I and the Category II aircraft using both the median and optimized gears for each category. The pavement price for the gear type corresponding to present flotation criteria has been considered zero. Thus, this section actually develops the incremental prices.

In order to develop the total price of upgrading the pavements at the major hub airports, one must calculate the pavement area to be upgraded and a pavement structure must then be selected. With these two parameters known, the results of Sections 6 and 7 can be applied and a total price in 1972 dollars can be calculated. In order to be compatible with the aircraft lost revenue costs developed in Section 5, either an equivalent annual cost or a present worth comparison must be made using either 1972 or 1985 dollars. Finally, due to the nationwide scope of this study and the inherent errors associated with the macro estimates performed, a sensitivity analysis of all parameters must be performed to test the consequences of any decisions made based on this analysis.

8.2 Calculations of Pavement Areas

Determining the amount of area to be upgraded for each major hub airport required subjective evaluations by this investigator. In general, pavement areas selected were the two major runways at each major hub airport, the taxiways associated with each of these runways, and the entire commercial apron area. In those cases where available airport master plans indicated a planned new runway, such as Atlanta's Hartsville International Airport, the incremental increases in the structure required for the Category I and the Category II aircraft were included.

For the existing runways, taxiways, and aprons selected, an assumption was made that the existing geometry would be adequate for the design aircraft. It is apparent that the runway length requirements have leveled off for heavy-gross-weight aircraft. This change can be attributed primarily to increased engine thrust and wing lift (Reference 11). The Aerospace Industries Association projections for takeoff field length are shown in Figure 40. This holds true for both landing and takeoff requirements. Although there is a trend implying an increase in wing span as aircraft become larger, it has been assumed that taxiway and runway width will remain the same.

There is a definite trend toward a larger apron area required for the two design types of aircraft as shown in Figure 41. However, to accommodate increases in apron area, more terminal gates will be required and this factor is beyond the scope of this study. Thus, a conservative assumption with respect to pavement price has been made that there will be no increase in present apron area. The sensitivity analysis described later will provide information to the decision maker should this increase be considered in his decisions.

Pavement areas were scaled from the sketch drawings shown on the airfield evaluation forms in Appendix A. Most drawings were adequately scaled for the calculation of areas. For those that were not adequately scaled, suitable assumptions were made with respect to the areas involved. From a macro point of view, this is adequate. Again, however, since the total price varies linearly with area, the sensitivity portion of this study will provide a decision tool with respect to area. Some pertinent statistics associated with area calculations are shown in Table 24.

8.3 Selection of Pavement Structures

It is the airport manager's choice, usually based upon the recommendation of the airport engineer, as to what type of pavement structure he desires for a particular project. Most often, this choice will be based on the least-cost structure, which, among other factors, is based upon availability of materials. For the purpose of this study,

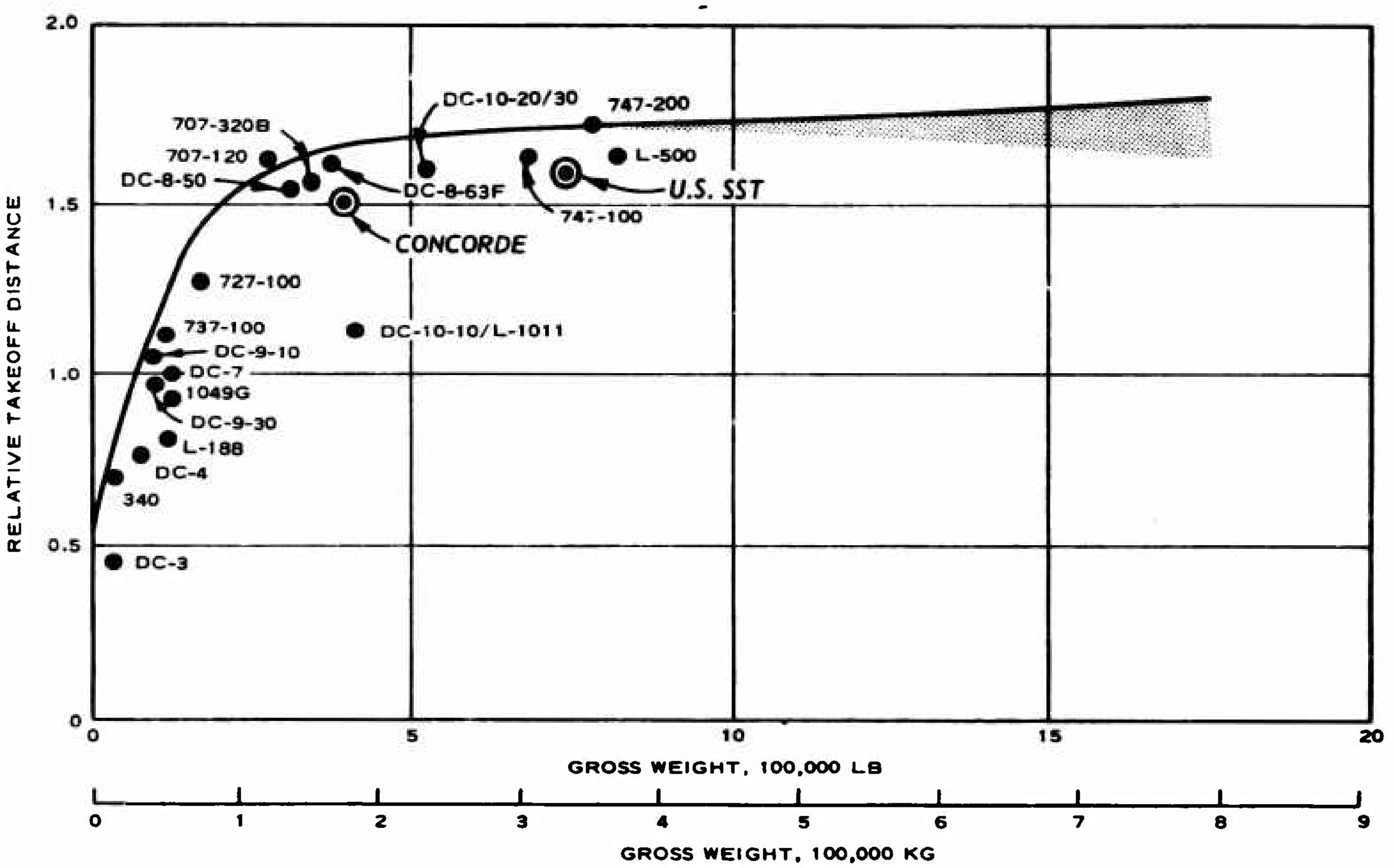


Figure 40. Trend of length of field required for takeoff (from Reference 11)

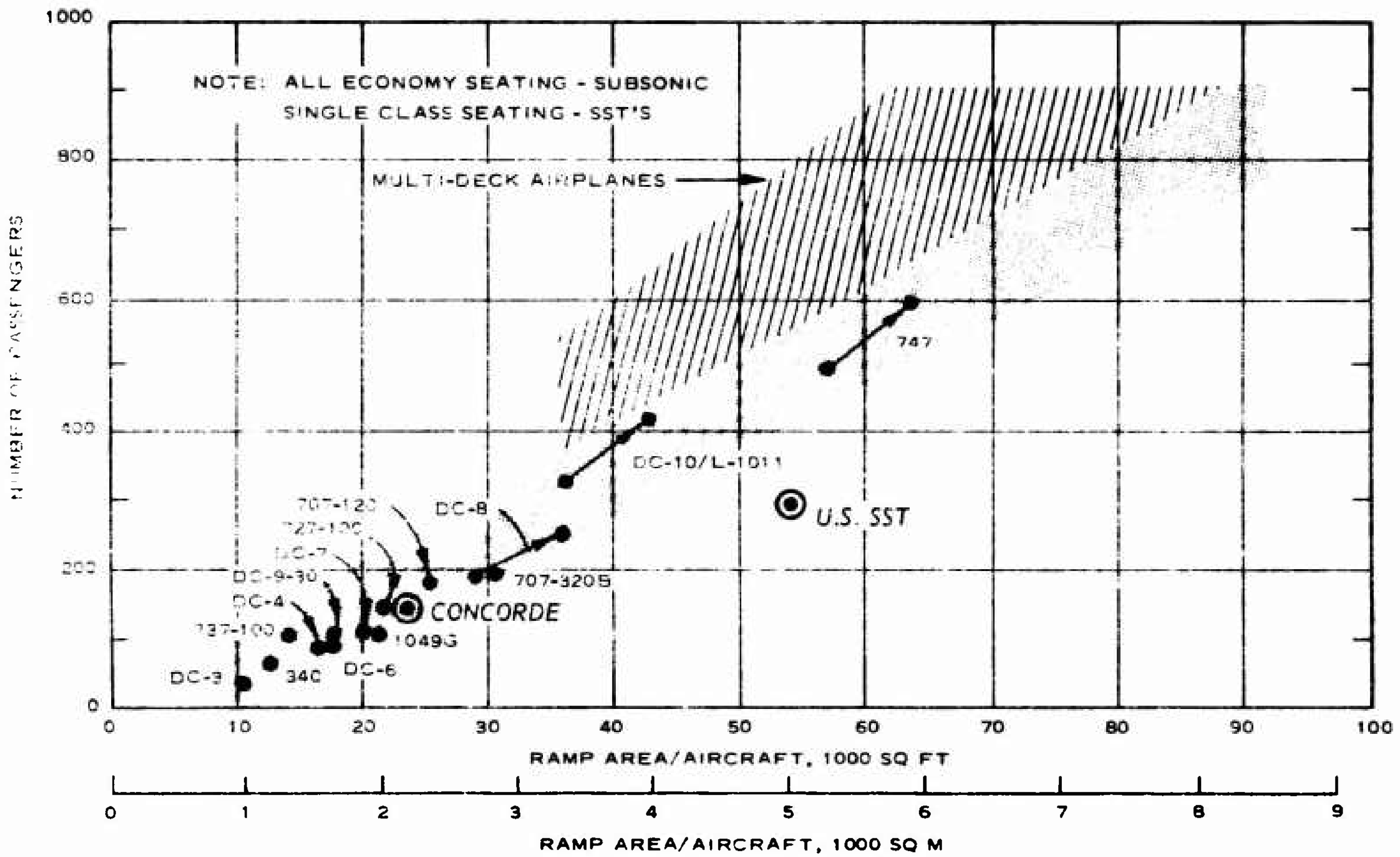


Figure 41. Trend in ramp area requirements (from Reference 11)

Table 24

Area Calculations and Statistics

Airport	Percentage of Area to Total Area			Upgraded Total Area	Ratio of Other Areas to Runway Area	
	Runway	Taxiway	Apron	SY	Taxiway	Apron
Chicago (O'Hare)	24	32	44	2,479,381	1.33	1.83
Atlanta	24	45	31	2,281,975	1.88	1.29
Los Angeles	23	21	56	1,883,831	0.91	2.43
San Francisco	31	15	54	1,688,808	0.48	1.74
Miami	30	27	43	1,315,750	0.90	1.43
New York (JFK)	19	17	64	2,100,400	0.89	3.37
New York (La Guardia)	23	11	66	2,003,641	0.48	2.87
Newark	34	35	31	453,258	1.03	0.91
Denver	23	28	49	914,874	1.22	2.13
Boston	57	31	12	878,955	0.54	0.21
Philadelphia	80	13	7	560,389	0.16	0.09
St. Louis	38	20	42	586,155	0.53	1.11
Honolulu	22	39	39	1,158,949	1.77	1.77
Detroit	29	20	51	1,606,242	0.69	1.76
Seattle/Tacoma	23	16	61	1,350,306	0.70	2.69
Pittsburgh	35	22	43	988,391	0.63	1.23
Houston	14	27	59	1,099,579	1.93	4.21
Minneapolis	53	21	26	1,222,891	0.40	0.49
New Orleans	35	19	46	435,289	0.54	1.31
Las Vegas	31	15	54	1,413,322	0.48	1.74
Kansas City	35	23	42	1,257,233	0.66	1.20
Baltimore	36	26	39	982,425	0.72	1.08
Cleveland	28	15	57	830,095	0.54	2.04
Washington (Dulles)	38	23	39	880,020	0.61	1.03
Fort Lauderdale	21	24	55	667,677	1.14	2.62
$\bar{x}$ =	32.24	23.40	44.40		0.85	1.70
s =	13.97	8.31	14.78		0.47	0.96
v =	0.43	0.36	0.33		0.55	0.56
Total Expected Area				29,939,536 SY		

historical data were considered in selecting the type of pavement structure to be priced. If one airport traditionally used bituminous overlays, this was the type chosen for this study. If, on the other hand, a combination of overlay types were used at a specific airport, a subjective evaluation was made and the most predominant type of overlay was chosen. Only two types of overlays were considered: full-depth bituminous overlays, FAA Item P-401, and portland cement concrete overlays, FAA Item P-501. Flexible overlays that consist of a bituminous surface course with a minimum depth of 4 inches and a base course were not considered due to the possible variations in base course selections and the pricing difficulties involved. Traditional pavement structures were considered for the construction of new areas.

8.4 Total Price Model

The following equation determines the total pavement price for the k^{th} airport,

$$X_k \equiv \left[\sum_{j=1}^{m} \sum_{i=1}^{n} \bar{C}_{ik} h_{ijk} A_{jk} \right] + S \ , \ k = 1,2,\ldots 26 \qquad (4)$$

where

$X_k \equiv$ total pavement price in 1972 dollars at the k^{th} airport

$\bar{C}_{ik} \equiv$ expected unit price for the i^{th} layer at the k^{th} airport in dollars per SYIN

$h_{ijk} \equiv$ thickness in in. of the i^{th} layer in the j^{th} area at the k^{th} airport

$A_{jk} \equiv$ area, in SY, of the j^{th} area at the k^{th} airport

$S \equiv$ ratio of the pavement price to the total airport upgrading price for either rigid or flexible pavement.

X_k must be calculated for median and optimized gear for both the Categories I and II airplanes. Computations for X_k are shown in Appendix D and the results are shown in Tables 25 and 26.

8.5 Development of Common Dollars for Comparisons

The aircraft costs in Section 5 of this treatise are in terms of

Table 25

Total Pavement Upgrading Cost for Each 1985 Major Hub Airport in Terms of 1972 Dollars - Category I Aircraft

Airport	Total Pavement Upgrading Cost Median Gear	 Optimized Gear
Chicago (O'Hare)	$ 14,820,850	$ 15,685,120
Atlanta	12,576,977	12,720,977
Los Angeles	11,596,007	12,377,982
San Francisco	4,017,430	4,017,430
Miami	2,206,712	2,433,004
New York (JFK)	20,630,970	23,239,123
New York (La Guardia)	22,929,004	23,745,126
Newark	504,159	560,176
Denver	12,043,615	12,230,798
Boston	3,929,476	3,800,370
Philadelphia	3,062,560	3,192,564
St. Louis	5,024,018	4,528,715
Honolulu	1,422,342	1,777,928
Detroit	17,348,249	18,200,341
Seattle/Tacoma	6,212,138	6,572,468
Pittsburgh	16,087,501	17,130,735
Houston	9,408,089	9,406,799
Minneapolis	9,668,822	10,777,467
New Orleans	4,398,039	4,716,317
Las Vegas	8,227,866	8,986,433
Kansas City	12,138,043	12,452,762
Baltimore	0	0
Cleveland	7,505,082	7,963,577
Washington (Dulles)	9,338,890	10,889,539
Fort Lauderdale	5,177,427	5,351,784
Total (1972 dollars)	$220,269,266	$232,757,535

Table 26

Total Pavement Upgrading Cost for Each 1985 Major Hub Airport in Terms of 1972 Dollars - Category II Aircraft

Airport	Total Pavement Upgrading Cost	
	Median Gear	Optimized Gear
Chicago (O'Hare)	$ 14,335,571	$ 29,332,323
Atlanta	12,025,466	19,415,827
Los Angeles	11,270,088	18,912,179
San Francisco	4,017,430	6,029,921
Miami	1,754,129	4,469,634
New York (JFK)	18,022,818	34,486,858
New York (La Guardia)	25,649,175	34,630,495
Newark	392,123	1,755,448
Denver	12,182,728	18,413,985
Boston	4,607,590	13,059,612
Philadelphia	3,126,274	4,500,016
St. Louis	5,024,018	8,412,372
Honolulu	1,244,549	3,587,473
Detroit	22,343,112	34,377,628
Seattle/Tacoma	5,655,554	10,799,822
Pittsburgh	16,723,838	26,721,192
Houston	8,279,450	14,666,932
Minneapolis	9,345,637	17,245,238
New Orleans	4,480,185	8,071,317
Las Vegas	9,287,474	12,858,963
Kansas City	11,925,265	19,540,225
Baltimore	0	0
Cleveland	6,964,593	12,883,345
Washington (Dulles)	9,333,890	20,223,427
Fort Lauderdale	5,057,774	9,572,327
Total (1972 Dollars)	$223,048,731	$383,966,559

annual 1985 dollars, whereas the pavement costs have been computed in terms of total 1972 dollars. In order to make valid comparisons, there are several methods available to the analyst. They are equivalent annual cost comparisons, present worth comparisons, and future worth comparisons. The latter can be summarily dismissed as having no advantage over the previous two. In making a present worth comparison, the costs of both airport pavement and aircraft cost must be assumed to have equal lives or at least a combination of equal multiple lifetimes. Therefore, since this type of comparison has no logical basis, the comparison must be an equivalent annual cost basis. Since the aircraft cost has been calculated on an annual basis, the problem now becomes, how does one predict the lifetime of the pavement structure and how does one anticipate the date of the completion of the construction.

If the date of construction for each airport is known, then the amount of 1972 dollars expended at the time of construction can be calculated in terms of the year of construction dollars by the equation

$$X_k^{1972+n} = X_k^{1972}(1 + i)^n \tag{5}$$

where

n ≡ number of years from 1972 until the construction date

i ≡ inflation rate assumed equal to the interest rate

If the lifetime of the pavement structure can be calculated or anticipated, then the equivalent annual cost can be calculated by assuming no future value of the pavement structure and using the following equation:

$$EAC_k = X_k^{1972+n} \left[\frac{i(1 + i)^m}{(1 + i)^m - 1} \right] \tag{6}$$

where EAC_k is the equivalent annual cost at the k^{th} airport and m is the expected lifetime of the pavement structure in years.

One should note at this point that a serious shortcoming in the field of pavement engineering is the fact that no deterioration function has ever been developed for a pavement structure. In fact, there is no real agreement among the pavement "experts" about the failure criteria that should be used in determining the life of a pavement. Although pavement structures are usually designed for a 20-year life span, overlays are required usually within 5 to 7 years (Reference 12).

For the initial calculation of the equivalent annual cost at each major hub airport, the following assumptions have been made.

a. Number of years from 1972 until construction of the pavement structure $n = 13$ years. This converts 1972 dollars into 1985 dollars.

b. Pavement lifetime $m = 20$ years. Implicit in this assumption is the fact that the structures will have no future worth. In actuality, this implies that maintenance cost will be so high as to make new construction a desirable alternative. From another point of view, m can be considered as the period over which the cost of the pavement is amortized.

c. Average inflation factor $i = 5$ percent is assumed to be equal to the average interest rate.

The results of the computations are shown in Tables 27 and 28 for the Category I and the Category II aircraft, respectively.

8.6 Sensitivity Analysis

The computations of pavement prices have been based on variables involving a high degree of uncertainty. The equivalent annual cost for upgrading pavements in this study, x , is explicitly sensitive to the following variables:

a. Unit prices.

b. Calculated areas.

c. Inflation and interest rates.

d. Time to construction.

e. Expected pavement life.

In addition, an implicit variable is the individual decision of upgrading at each major hub airport. This variable cannot be treated by any normal sensitivity analysis; however, the reader should keep this variable in mind when comparing the costs in the succeeding sections.

Table 27

Equivalent Annual Cost for Upgrading Project 1985 Major Hub Airports in 1985 Dollars - Category I Aircraft

	Equivalent Annual Cost	
Airport	Median Gear	Optimized Gear
Chicago (O'Hare)	$ 2,242,533	$ 2,373,306
Atlanta	1,903,814	1,924,803
Los Angeles	1,754,584	1,872,905
San Francisco	607,875	607,875
Miami	333,896	368,136
New York (JFK)	3,121,659	3,516,297
New York (La Guardia)	3,469,373	3,592,860
Newark	76,284	84,760
Denver	1,822,312	1,850,634
Boston	594,567	575,032
Philadelphia	463,394	483,065
St. Louis	760,181	685,237
Honolulu	215,214	269,017
Detroit	2,624,953	2,753,882
Seattle/Tacoma	939,955	994,476
Pittsburgh	2,434,190	2,592,041
Houston	1,423,532	1,423,337
Minneapolis	1,462,983	1,630,732
New Orleans	665,464	713,623
Las Vegas	1,244,953	1,359,731
Kansas City	1,836,600	1,884,220
Baltimore	0	0
Cleveland	1,135,589	1,204,964
Washington (Dulles)	1,412,305	1,647,689
Fort Lauderdale	783,393	809,775
Total Annual Cost	$33,328,803	$35,218,395

Table 28

Equivalent Annual Cost for Upgrading Projected 1985 Major Hub Airports in 1985 Dollars - Category II Aircraft

Airport	Equivalent Annual Cost	
	Median Gear	Optimized Gear
Chicago (O'Hare)	$ 2,169,106	$ 4,438,255
Atlanta	1,819,566	2,937,796
Los Angeles	1,705,270	2,861,590
San Francisco	607,875	912,384
Miami	265,416	676,297
New York (JFK)	2,727,021	5,218,185
New York (La Guardia)	3,880,960	5,239,918
Newark	59,332	265,616
Denver	1,843,361	2,786,208
Boston	697,172	1,976,042
Philadelphia	473,035	680,895
St. Louis	760,181	1,272,871
Honolulu	188,312	542,818
Detroit	3,380,722	5,201,657
Seattle/Tacoma	855,738	1,634,114
Pittsburgh	2,530,473	4,043,167
Houston	1,252,758	2,219,244
Minneapolis	1,414,082	2,609,366
New Orleans	677,894	1,221,266
Las Vegas	1,405,282	1,945,682
Kansas City	1,804,404	2,956,619
Baltimore	0	0
Cleveland	1,053,808	1,949,371
Washington (Dulles)	1,412,305	3,059,994
Fort Lauderdale	765,289	1,448,383
Total Annual Cost	$33,749,362	$58,097,736

The sensitivity model has been developed from the macro point of view and considers only gross total price components. Thus, the sensitivity model is

$$x = \Sigma_k EAC_k = p \times A \times (1 + i)^n \left[\frac{i(1 + i)^m}{(1 + i)^m - 1} \right] \tag{7}$$

where

p ≡ unit price in dollars per SY

A ≡ calculated area in SY

i ≡ inflation rate assumed equal to the interest rate

n ≡ number of years from 1972 until the pavement is upgraded

m ≡ expected pavement life or period of pavement cost amortization

The term m could also be interpreted as the life of the bonds sold to finance the pavement construction. This interpretation would, however, disassociate the costs from the pavement structures and this investigator has chosen to ignore this interpretation.

Equation 7 can be considered as a five-space function of p , A , n , m , and i . To examine its sensitivity with respect to changing any single variable, the following partial derivatives have been completed.

$$\frac{\partial x}{\partial A} = p(1 + i)^n \left[\frac{i(1 + i)^m}{(1 + i)^m - 1} \right] \tag{7a}$$

$$\frac{\partial x}{\partial p} = A(1 + i)^n \left[\frac{i(1 + i)^m}{(1 + i)^m - 1} \right] \tag{7b}$$

$$\frac{\partial x}{\partial n} = pA(1 + i)^n \ell n(1 + i) \left[\frac{i(1 + i)^m}{(1 + i)^m - 1} \right] \tag{7c}$$

$$\frac{\partial x}{\partial m} = pA(1 + i)^n \left\{ \frac{-i(1 + i)^m \ell n(1 + i)}{\left[(1 + i)^m - 1\right]^2} \right\} \tag{7d}$$

$$\frac{\partial x}{\partial i} = pA \left\{ \frac{in(1 + i)^{m+n-1}}{(1 + i)^m - 1} + (1 + i)^n \left[\frac{(1 + i)^{2m} - (1 + i)^m - im(1 + i)^{m-1}}{(1 + i)^{2m} - 2(1 + i)^m + 1} \right] \right\} \qquad (7e)$$

It is obvious that x varies linearly with both the area and the unit price p. A change in either of these two variables will directly change the value of x by a proportional amount. If one assumes a coefficient of variation of 20 percent for each of these variables as shown in Figure 42 and holds n constant at 13 years, m constant at 20 years, and i constant at 5 percent, some feasible bounding costs can be developed. For the purpose of this analysis, the LPC ($n = 13$, $m = 20$, $i = 5$) was defined as the x computed using the expected unit price less two standard deviations and the calculated area less two standard deviations; the MPC ($n = 13$, $m = 20$, $i = 5$) was defined as the x computed using the expected unit cost and the calculated area; and the HPC ($n = 13$, $m = 20$, $i = 5$) was defined as x computed using the expected unit price plus two standard deviations and the calculated area plus two standard deviations. These values were computed using Figure 43 and are shown in Table 29. The bounding values, noting that they inherently involve a compounded coefficient of variation of 20 percent for each parameter, provide the reader with a mechanism by which he can challenge the recommendations in Section 11 by altering either price, area, or both.

Equations 7c through 7e provide some insight of the variations with respect to n, m, and i. The equivalent annual cost increases monotonically with respect to n as one would expect. The cost of construction increases at the annual rate of 5 percent per year and the factor involving n simply considers the time value of money. The slope of the curve is ever increasing, although tempered somewhat by a factor involving a natural logarithm of a relatively small number.

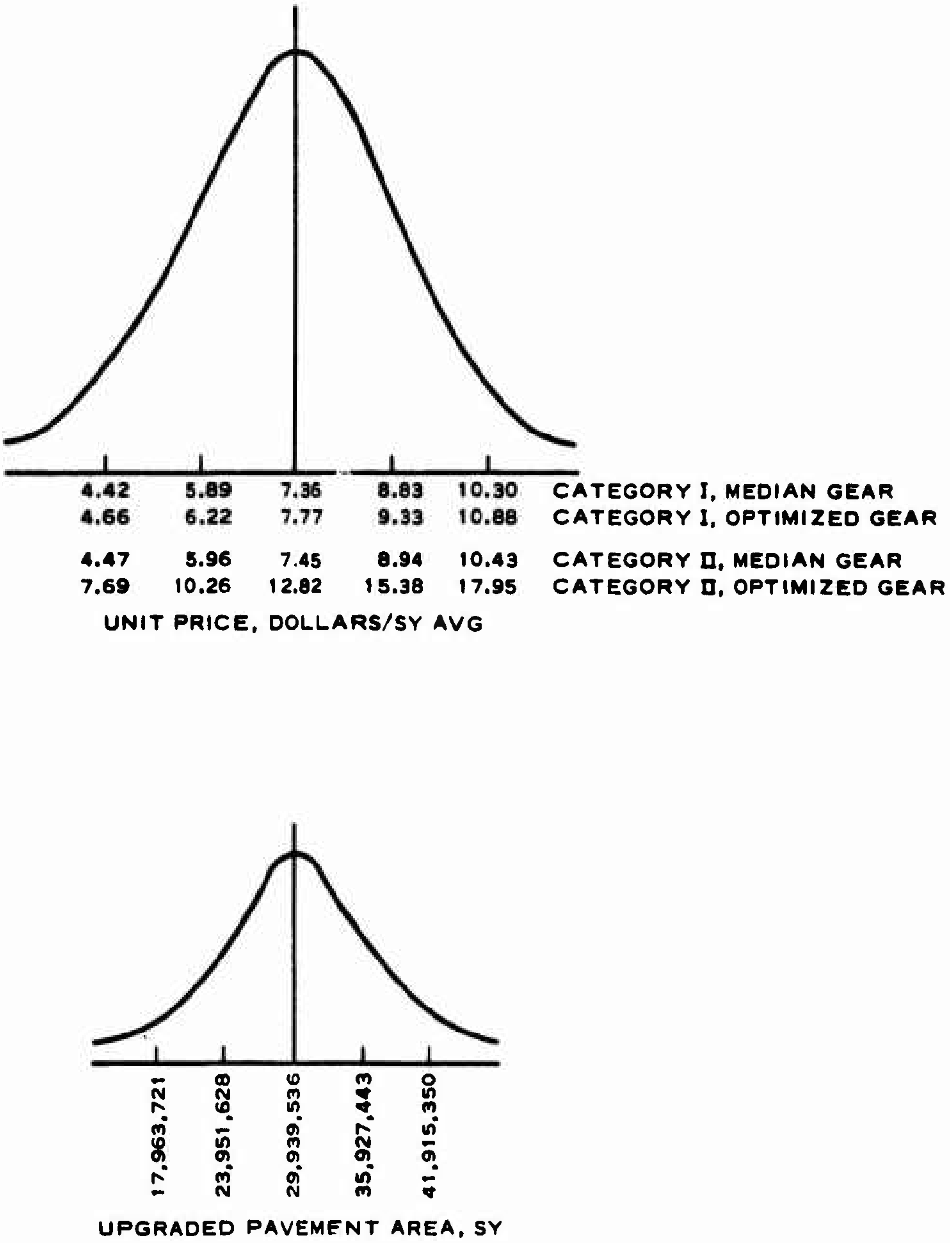


Figure 42. Sensitive parameters (coefficient of variation of 20 percent assumed)

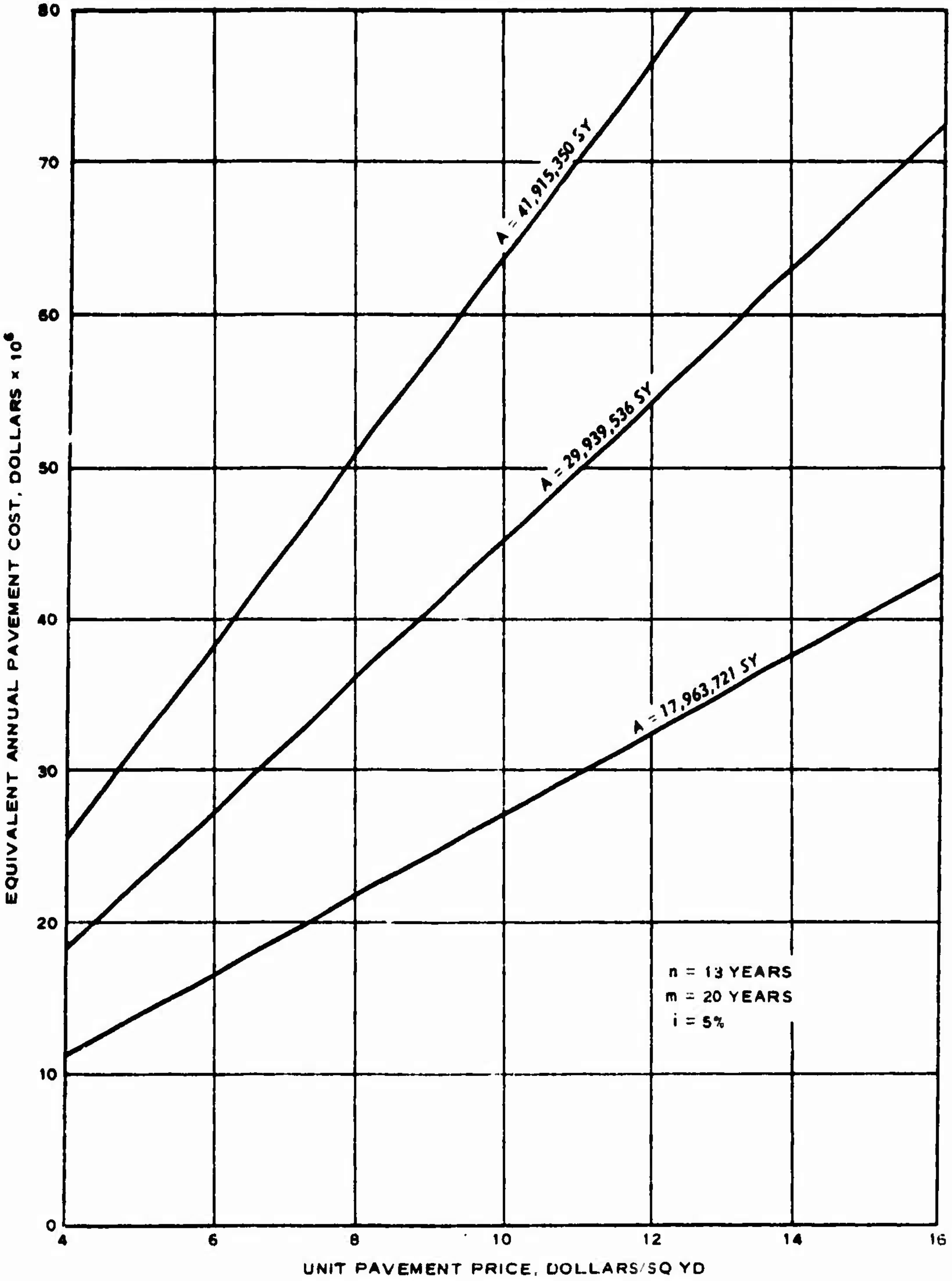


Figure 43. Variation in equivalent annual cost with respect to unit price and pavement area, 1985 dollars

Table 29

Bounding Cost Ranges for Both Categories I and II Airplanes with Constant i at 5 Percent, n at 13 Years, and m at 20 Years

	LPC	MPC	HPC
Category I Airplane:			
Median Gear	$12,013,910	$33,328,803	$ 65,324,506
Optimized Gear	12,666,249	35,218,395	69,002,973
Category II Airplane:			
Median Gear	12,149,814	33,749,362	66,148,990
Optimized Gear	20,902,029	58,097,736	113,842,221

The factor involving m in Equation 7 is the capitalization factor. It assumes that the cost of construction will be capitalized over a period of m years at an interest rate equivalent to the inflation rate. The slope of the curve is a monotonic decreasing function with a limit, as m approaches infinity, of zero. The limit of the factor involving m in Equation 7 is i, the assumed interest rate. Basically, the equivalent annual cost decreases as m increases.

The interest factor i has an extreme effect on the equivalent annual cost. Both x, and the change in x, increase rapidly as i increases. A conservative approach with respect to pavement prices has been taken in this treatise by assuming that interest rates correspond to the annual inflation rate. Thus, the calculated pavement costs should be considerably lower than the actual cost. Figures 44 through 46 show relative in-plane changes in costs with respect to n, m, and i.

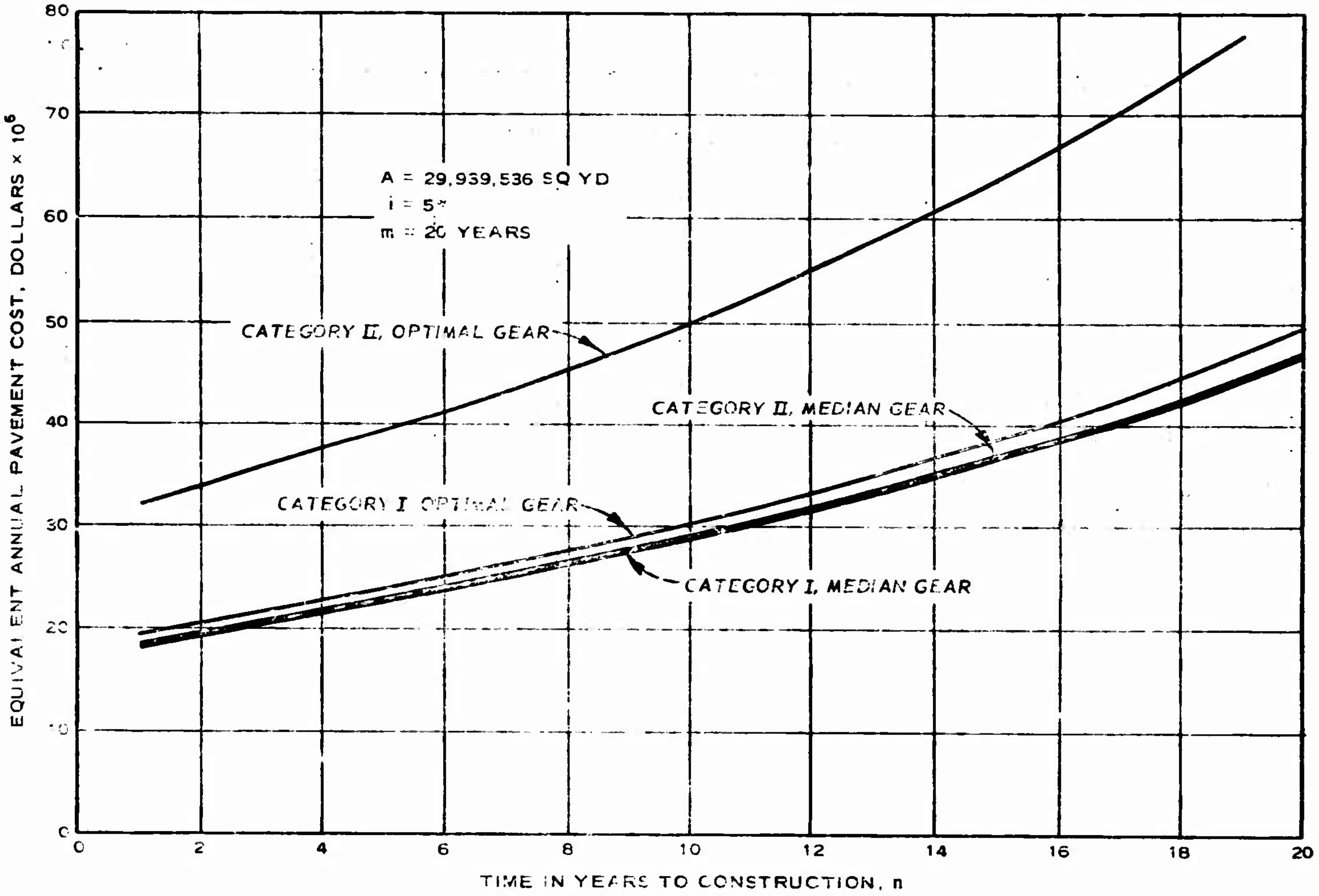


Figure 44. Variation in equivalent annual pavement prices with respect to time to construction n

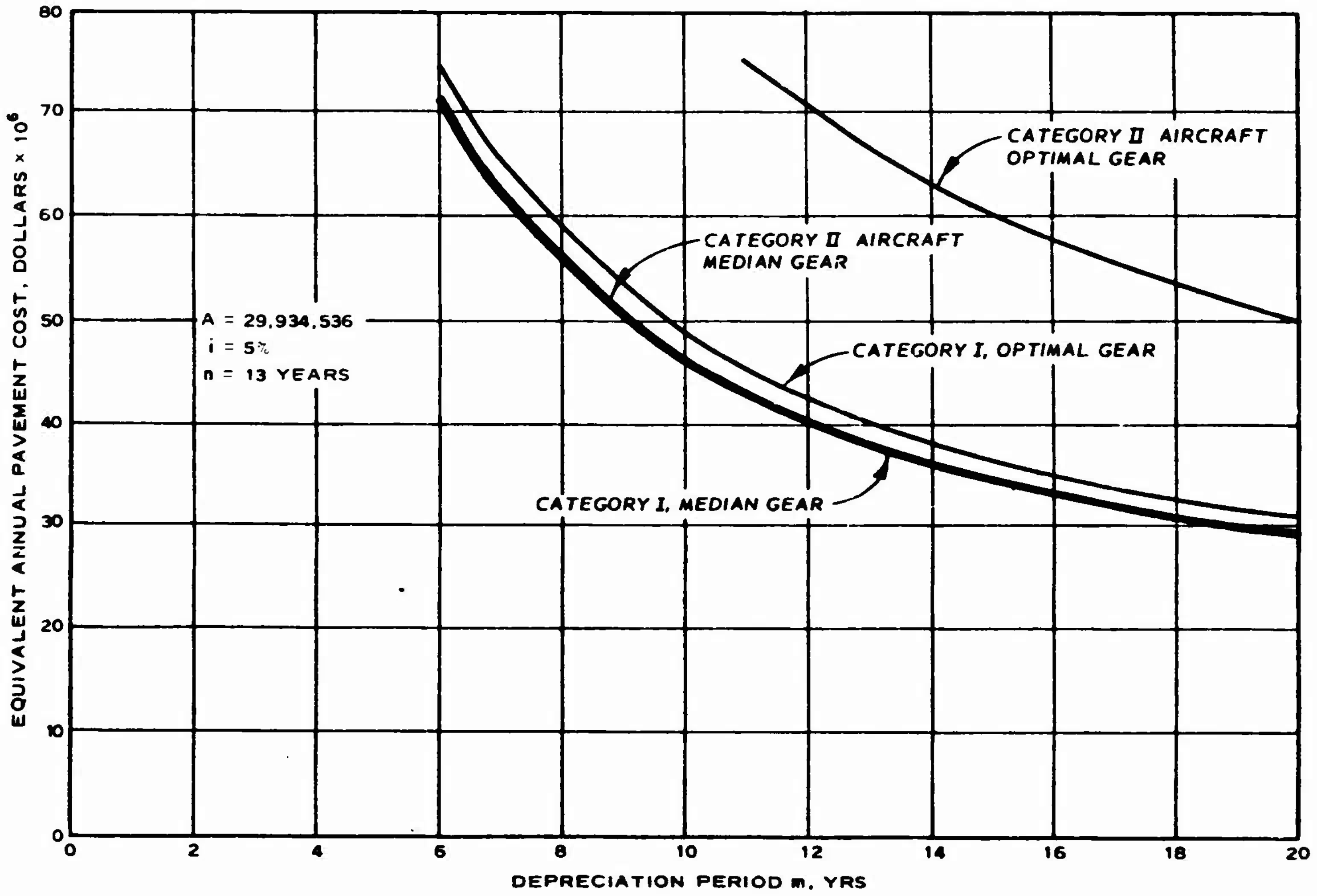


Figure 45. Variation in equivalent annual pavement costs with respect of depreciation period m

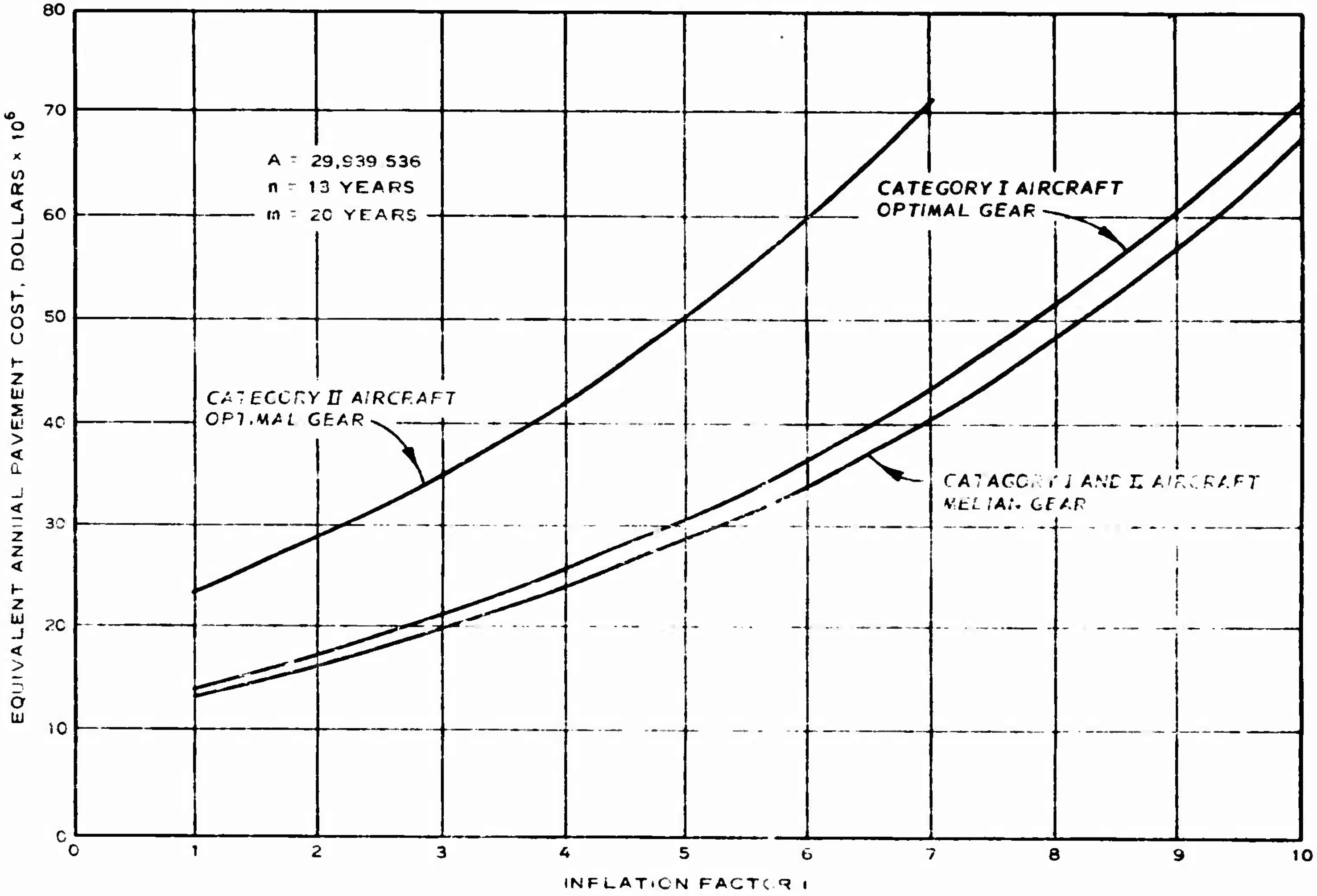


Figure 46. Variation in equivalent annual pavement costs with respect to inflation factor i

9 PRICE ANALYSIS

9.1 Introduction

The purpose of this portion of the aircraft-pavements compatibility study was to determine the most economical of the three alternatives listed below:

a. Require aricraft to meet the flotation requirements imposed by present standards, e.g., impart no greater stress on the pavement structure than a 350,000-lb gross weight aircraft on twin-tandem gears. The implication of this alternative is that aircraft manufacturers are required to put more and more wheels on their aircraft as the gross weight increases. On the other hand, airport pavements will not require upgrading.

b. Permit aircraft to be designed with landing gears optimized with respect to the aircraft without regard for flotation criteria. The implication of this alternative is that the aircraft will not be penalized by being required to haul the extra volume and weight of additional gears and wheels and absorb other associated costs. This alternative required that the pavements at each of the projected 1985 major hub airports be strengthened to the point of accepting such stresses as will be imposed by gears not corresponding to flotation criteria.

c. Compromise between the two previous alternatives. For the purpose of this study, this alternative implies that a median gear could be designed with a lesser flotation restriction and designed more to optimize aircraft performance.

The basis of the conclusions and recommendations is exclusively economic. Other considerations such as those dealing with sociopolitical factors, ecological and environmental restrictions, space constraints, etc., are beyond the scope of this analysis.

9.2 Category I Aircraft

The total annual airplane costs (TAC) are given in Table 19 for the Category I aircraft in terms of 1985 dollars. It is obvious that, with only a $6,673,397 annual penalty cost for conforming to current pavements that the present gear configuration of the Category I aircraft is close to optimal. The following tabulation shows the total expected annual cost components in 1985 dollars for the Category I comparison.

	Current Gear	Median Gear	Optimized Gear
Aircraft Cost	$6,673,379	$ 1,929,88$	$ 0
MPC Pavement	0	33,328,803	$35,218,395
Total Annual Cost	$6,673,379	$35,258,683	$35,218,395

Figure 47 graphically depicts the relationship between the aircraft annual cost and the MPC, LPC, and the HPC for the Category I aircraft. The obvious inference is that one cannot economically justify upgrading the twenty-six 1985 major hub airports for the Category I aircraft. Figure 47 should be viewed with a jaundiced eye in that the flotation functional relations are highly nonlinear and the figure is simply a graphic representation.

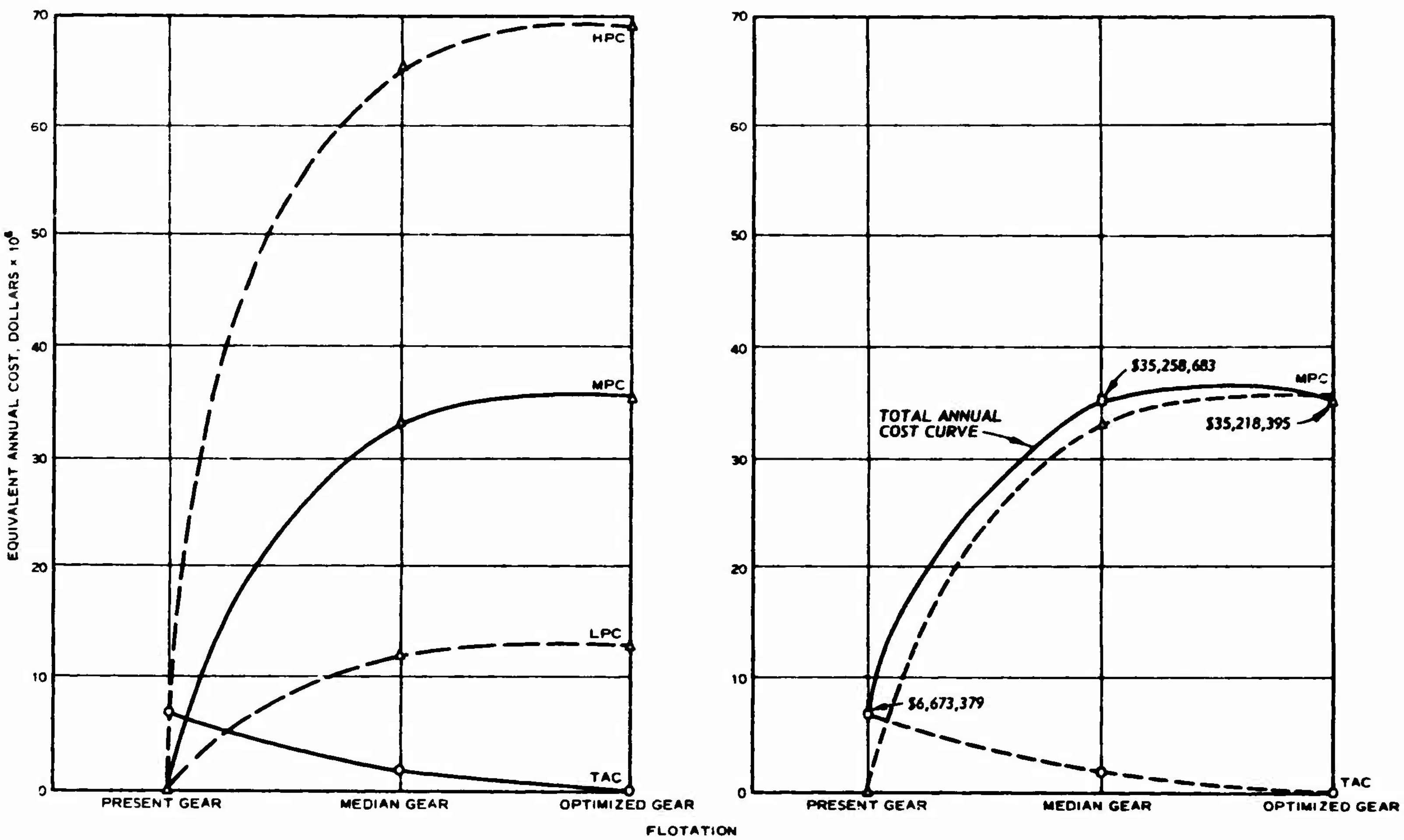
Figure 48 is a graphic illustration of the total cost to the public summing both the pavement upgrading costs and the aircraft costs. Keeping in mind that the HPC and the LPC have been developed assuming the most improbable of pavement price estimates, it is obvious from this figure that the least-cost-to-the-public alternative, assuming only the Category I aircraft is in service, is to maintain the present pavement flotation criteria.

9.3 Category II Aircraft

The TAC's are given in Table 19 for the Category II aircraft in terms of 1985 dollars. Contrary to the small penalty for corresponding to current flotation requirements for the Category I aircraft, the Category II airplane is considerably penalized. The following tabulation shows the total expected annual cost components in 1985 dollars for the Category II airplane.

	Current Gear	Median Gear	Optimized Gear
Aircraft Costs	$68,777,364	$35,160,820	$ 0
MPC Pavements	0	33,749,362	58,097,736
Total Annual Costs	$68,777,864	$68,910,182	$58,097,736

Figure 49 graphically represents the relationship between the



a. COMPARISON OF AIRCRAFT ANNUAL COSTS VERSUS PAVEMENT UPGRADING COSTS

b. TOTAL ANNUAL COST CURVE CONSIDERING ONLY TAC AND MPC ($n = 13$, $m = 20$, $i = 5$)

Figure 47. Category I aircraft costs

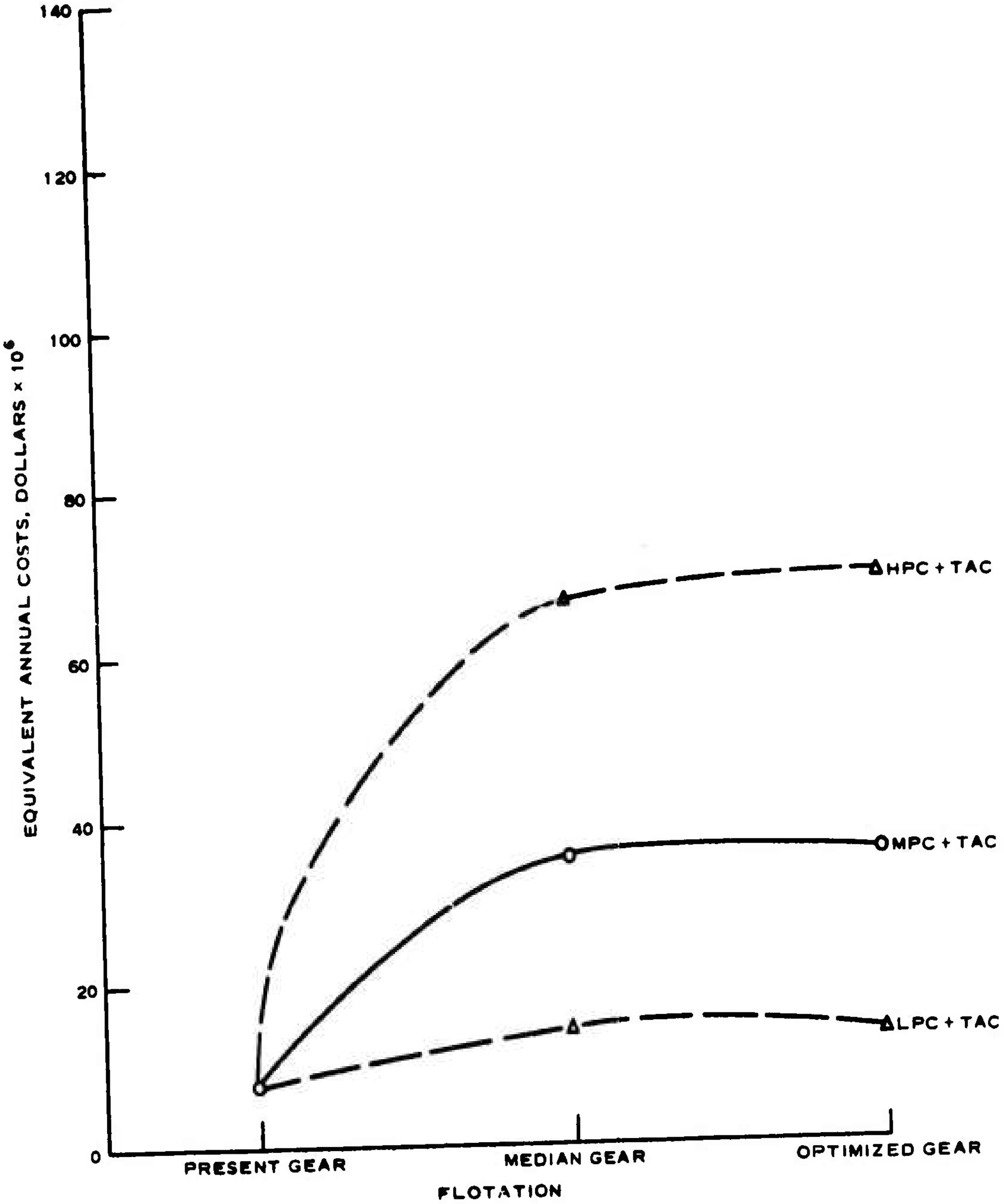
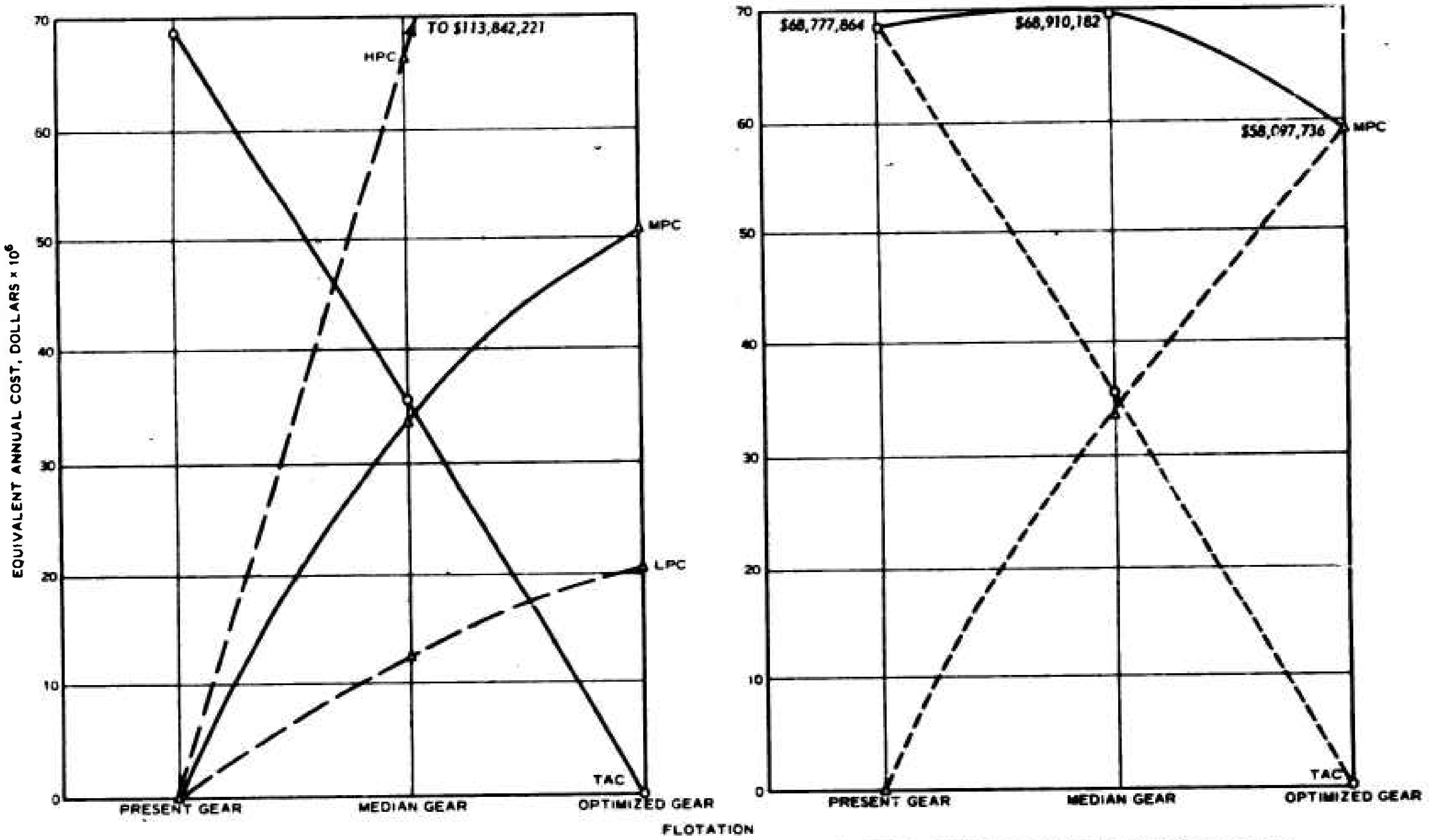


Figure 48. Comparison of total annual cost for aircraft and pavement upgrading for Category I aircraft



a. COMPARISON OF AIRCRAFT ANNUAL COSTS VERSUS PAVEMENT UPGRADING COSTS

b. TOTAL ANNUAL COST CURVE CONSIDERING ONLY TAC AND MPC (n = 13, m = 20, i = 5)

Figure 49. Category II aircraft costs

airplane cost and the LPC, MPC, and HPC for upgrading the pavement structures for the Category II airplane. From a purely economic point of view, it is apparent that the least cost to the public, assuming that a Category II airplane will be using all 26 major hub airports in 1985, will be to upgrade the pavement structures to accommodate the optimized gear for the Category II aircraft. In all probability, the LPC in this analysis should be disregarded since the larger aircraft will require more pavement area to be upgraded than that estimated.

Figure 50 is a graphic illustration of the total cost to the public summing both the pavement upgrading costs and the aircraft cost. Contrary to the results relating Category I aircraft costs to pavement costs, there exists here the possiblity of conflicting alternatives with regard to the Category II aircraft. However, if the Category II aircraft will service all 26 major hub airports in 1985, the Category I aircraft will also. Therefore, the discussion of the conflicting alternatives will be discussed in Section 9.4.

9.4 Policy Derivation

Based on total annual costs given in Sections 9.2 and 9.3 using the MPC and the TAC, one reaches the conclusions that (1) the pavement upgrading criterion should not be changed if only the Category I aircraft is to be in use in 1985, (2) the pavement criteria should be changed so as to permit flotation requirements to correspond to the gear design optimzed with respect to the aircraft if the Category II aircraft is to be in use in 1985, and (3) the following tabulation implies the same alternative selection as (2) above if one considers both the Categories I and II aircraft being in use in 1985.

	Current Gear	Median Gear	Optimized Gear
Category I Aircraft*	$ 6,673,379	$ 1,929,880	$ 0
Category II Aircraft	68,777,864	68,910,182	58,097,736
Total Annual Cost	$75,451,243	$70,840,062	$58,097,736

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* Only aircraft costs necessarily have been considered since pavement upgraded for Category II aircraft will not be significantly changed with the addition of the Category I aircraft.

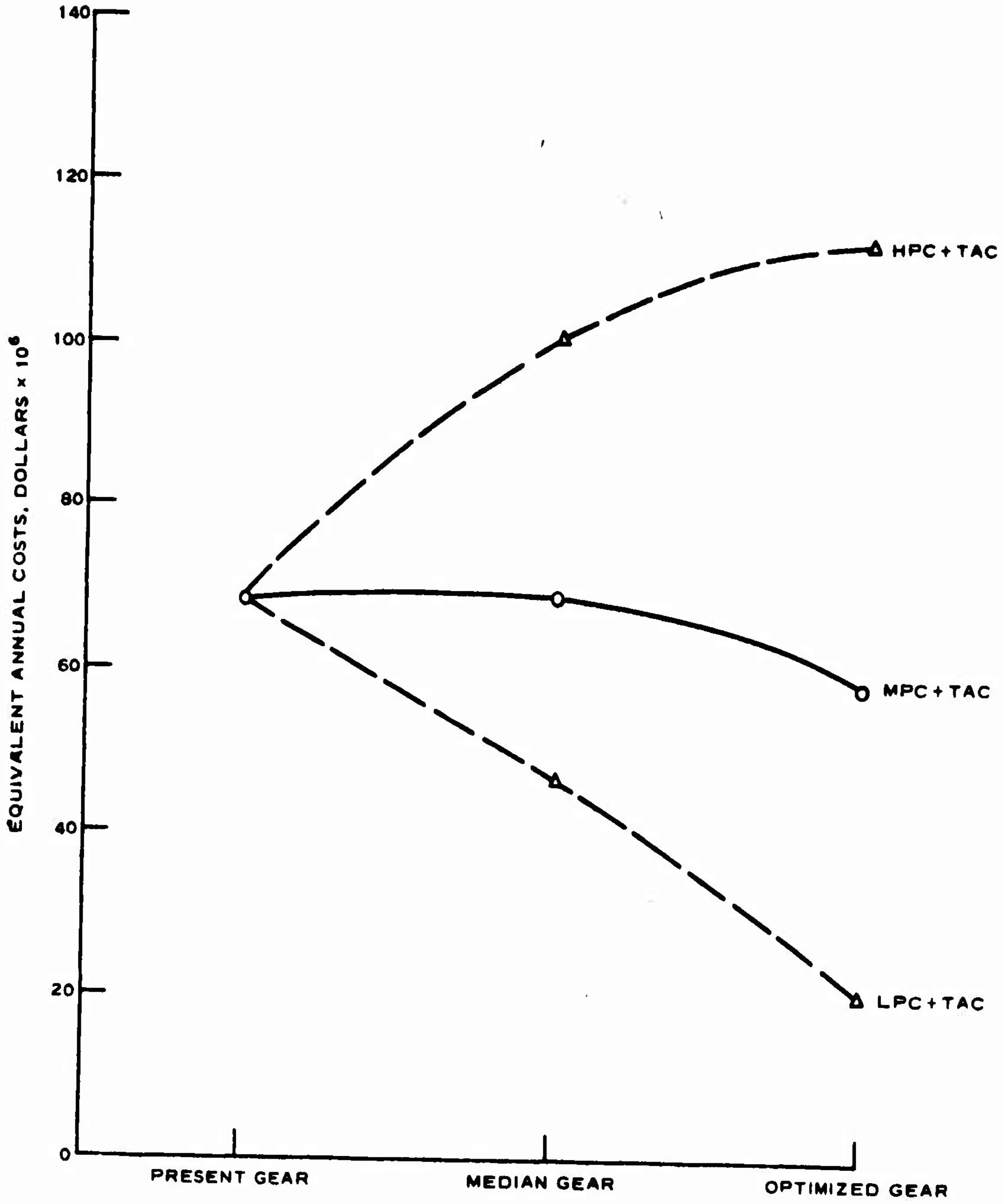


Figure 50. Comparison of total annual cost for aircraft and pavement upgrading for Category II aircraft.

The authors feel that the policy decision should be made only after a careful determination that a Category II aircraft will or will not operate on all the major hub airports in 1985 since the policy decisions are so diametrically opposed.

Figure 51 is a graphic illustration of the total cost assuming both the Categories I and II aircraft are in service in 1985. It is obvious that there are conflicting alternatives. If the MPC assumption is considered valid, the optimal alternative is clearly to change the criteria and permit the gear to be optimized to the aircraft. As mentioned previously, the LPC is probably beyond the realm of feasibility since the area to be paved will, in all probability, be greater than the computed area used to develop the MPC. On the other hand, if the HPC is considered a valid assumption, the optimal alternative is reversed; the present criteria becomes the optimal alternative.

It has been stated throughout this report that, as in any statistical study, there probably exists considerable errors in any of the point estimates. This study lacks sufficient data to attach any great degree of reliability that the point estimates are indeed unbiased estimates. Therefore, it is the intent of this portion of the study, along with Section 7.6, to provide a convenient tool for comparing the aircraft cost with the cost of upgrading the pavement structures should the current data be updated. Section 7.6 provides an insight into the sensitivity of the equivalent annual cost of upgrading the pavement structure to each of the five explict parameters. Equation 7 provides a method of recomputing the equivalent annual pavement upgrading cost as data are updated.

If one equates the annual aircraft cost y_{85} to the equivalent annual pavement upgrading cost, the following equation results:

$$y_{85} = pA(1 + i)^{13} \left[\frac{i(1 + i)^m}{(1 + i)^m - 1} \right] \qquad (8)$$

The parameter n is assumed constant at 13 years in order to have a common time value of money for comparison. Equation 8 provides the break-even point at which the annual aircraft cost equals the equivalent

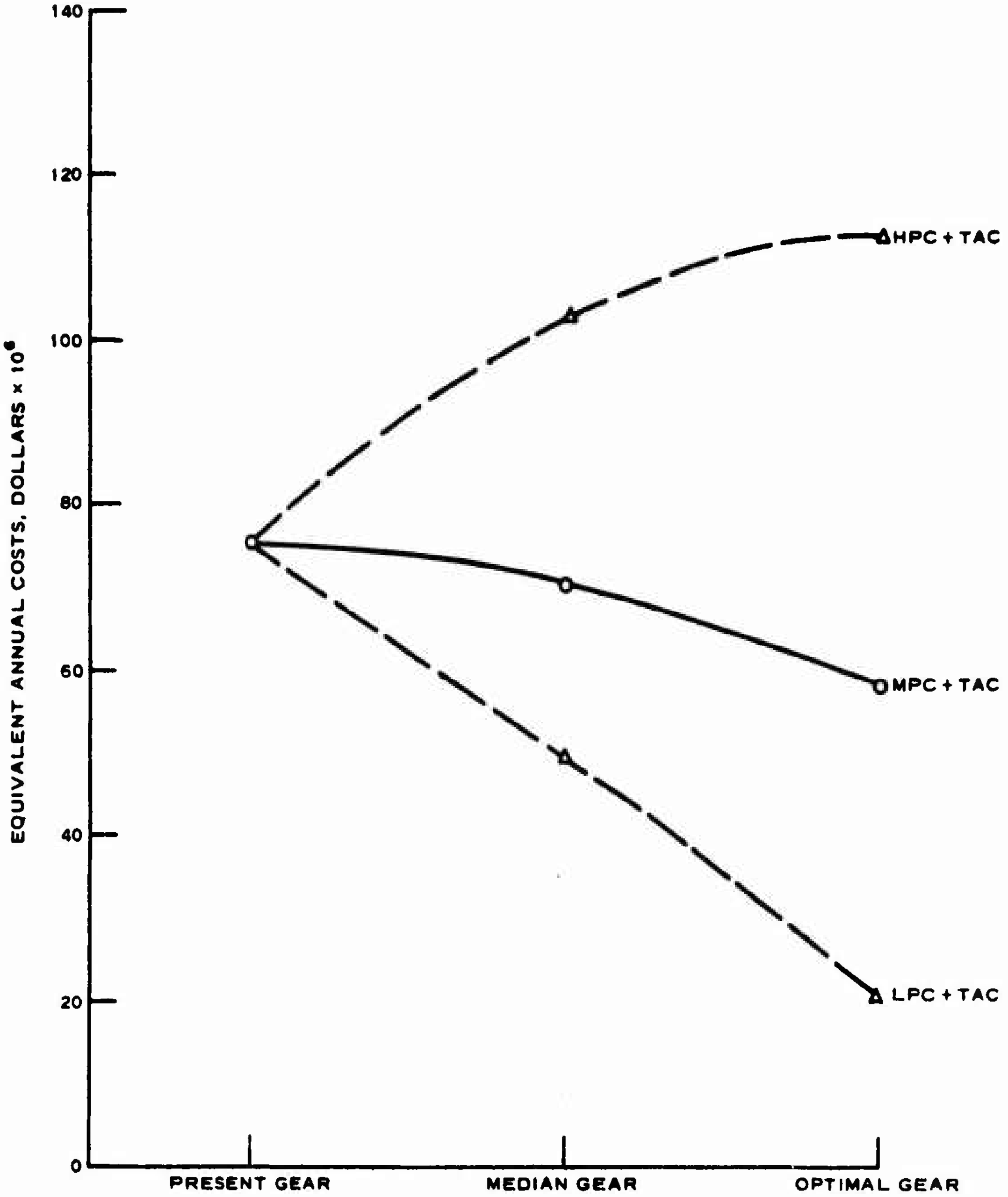


Figure 51. Comparison of total aircraft annual costs versus pavement upgrading costs in 1985 dollars for Categories I and II together

annual pavement upgrading cost. If the left-hand side of Equation 8 is greater, then the most economic policy is to permit gear optimization with respect to the aircraft or the gear type corresponding to the value of y_{85} (optimal or median gear). If the right-hand side (RHS) is greater, then the most economic policy decision is to maintain the present ADAP criterion.

It is a simple matter to relate two of the pavement cost parameters using Equation 8 and holding the other two constant. Considering first i and m as variables and p and A as constants equal to the expected price per SY and computed area, respectively, one can solve for m in terms of i giving

$$m = \frac{1}{\log(1 + i)} \log \left[\frac{1}{1 - \frac{PA}{y_{85}} (1 + i)^{13} i} \right] \qquad (9)$$

For each of the y_{85}'s calculated, Equation 9 divides the i-m plane in two half-spaces. If estimates for i and m provide coordinates to the left of a curve as shown in Figure 52, then the equivalent annual cost of the pavement structure will be less than the annual aircraft cost; conversely, a point to the right gives the aircraft cost the economic advantage. It should be noted that in order for a value for Equation 9 to exist, the denominator of the RHS must be greater than zero. This implies that the aircraft cost conforming to the current pavement flotation requirement can equal the cost of upgrading the pavement corresponding to the optimal gear if $i = 1$ percent and the pavement is amortized for a period of 67 years or $i = 2$ percent and $m \doteq 118$ years. This, of course, is both an unrealistic inflation rate and amortization period. However, for the curve corresponding to the total cost of both the Categories I and II aircraft optimal gears, more reasonable assumptions make the two costs competitive.

A closer examination of the relationship involving p and A is warranted at this point. The variables n , m , and i are quite speculative, whereas the area could conceivably be measured if all airport authorities were to make a decision. Thus, most challenges to the

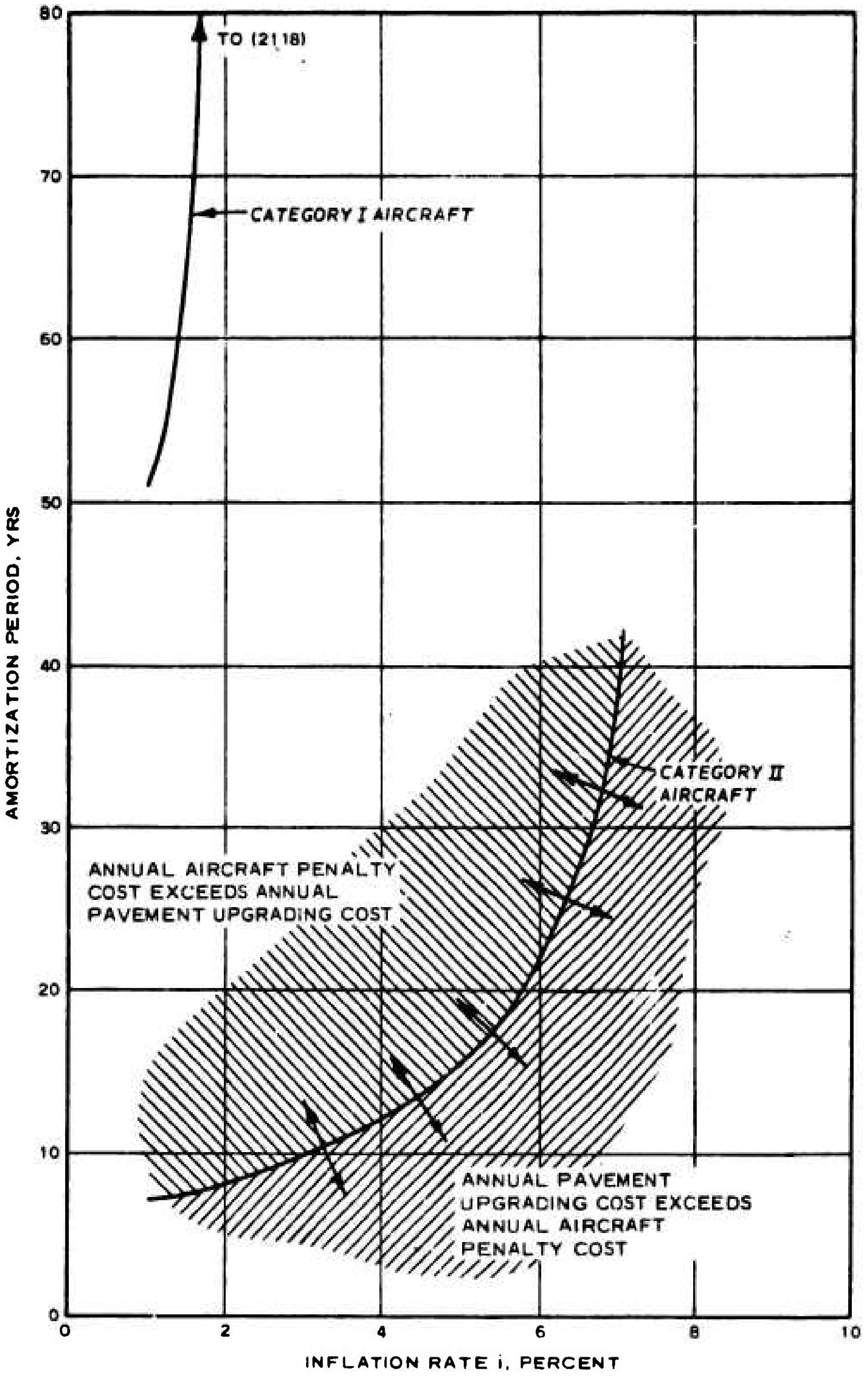


Figure 52. Curves of equal airplane cost corresponding to present flotation requirements and upgrading to optimized gears in terms of i and m

computations in this report should be with regard to p and/or A . If one equates the equivalent annual cost of the aircraft to the equivalent annual cost of the pavement upgrading and solves Equation 7 for A as a function of p and holds the parameters n , m , and i constant, the following result is obtained:

$$A = \frac{y_{85}}{p} (1 + i)^n \left[\frac{(1 + i)^m - 1}{i(1 + i)^m} \right] \tag{10}$$

Assuming n , m , and i as 13 years, 20 years, and 5 percent, respectively, Equation 10 becomes

$$A = 6.605 \frac{y_{85}}{p} \tag{11}$$

With y_{85} fixed, by a single-point estimate, this locus of vertices of an infinite series of constant area rectangles, or more simply, this hyperbola, provides a convenient device for examining the effect of A and p on the policy decision. Examining Figure 53, a series of graphs of Equation 11, it is obvious that is is not economically justifiable to upgrade the pavement structures for the Category I aircraft alone even if estimates of the area and price are made ridiculously low. However, if one considers the Category II aircraft, optimal or median gears, reasonable assumptions can change the selection of the most economical alternative. For instance, if one considers upgrading the largest amount of area probable for the category aircraft, optimal gear (41,915,350 SY), a relatively low unit price of \$11.00 per SY makes the cost of pavement upgrading equal to the aircraft cost. The price of \$11.00 per SY is considerably less than the expected unit price of \$12.82 per SY. The most probable area, 29,939,536 SY, requires a unit price of \$15.40 per SY or roughly one standard deviation of unit price above the expected unit price to make the two costs equal. The Category II, median gear aircraft is also competitive when one changes the price and area. Thus, Figure 53 provides an analytic device for testing updates of areas and price estimates. As in Figure 52, if the intersection of the new

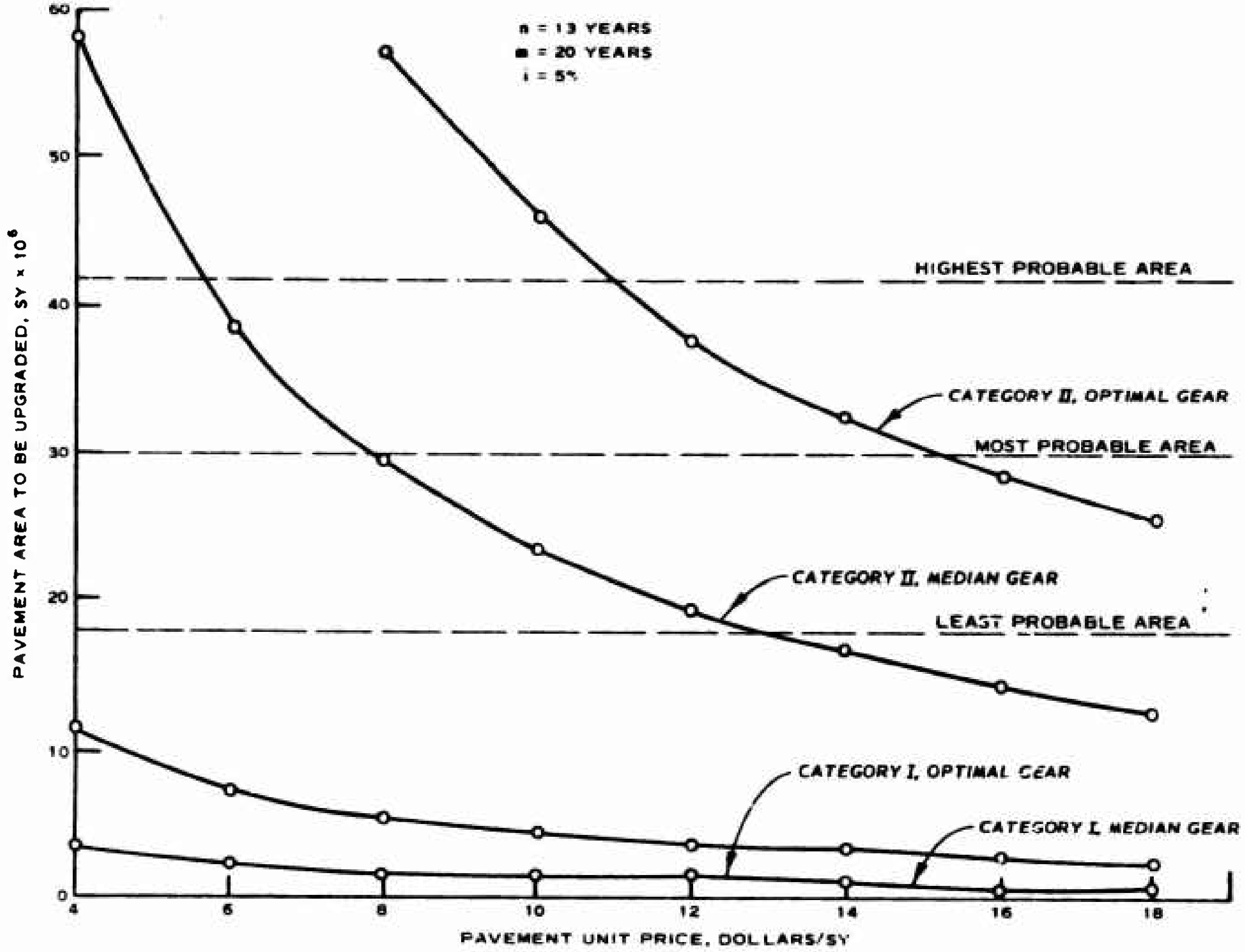


Figure 53. Isocost curves for airplane cost versus pavement upgrading costs as a function of p and A

estimates falls to the left of the curve, pavement upgrading cost is less than the aircraft cost and vice versa.

Finally, by modifying Equation 11 and considering the constant term as a parameter F , the following provides a method of analysis permitting different assumptions to be made for the variables m , i , A , and p . Rewriting Equation 11, one obtains the following description of an infinite series of hyperbolas:

$$A = \frac{F}{p} \times y_{85} \tag{12}$$

Using values of F found in Table 30 for each assumption of i and m and substituting into Equation 11, one can develop a series of curves similar to those in Figure 53. Thus, a new assumption of A and p can be made. If the intersection of the new A and p assumption falls to the left of a particular curve, the aircraft penalty cost for a particular gear configuration is greater than the pavement upgrading cost and the pavement should be upgraded. If the intersection falls to the right of the curve, the pavement should not be upgraded since the cost of upgrading exceeds the aircraft penalty cost.

One note of caution should be provided to the reader prior to concluding this discussion. The point estimate developed for the aircraft penalty cost is an estimate. This estimate also has some inherent variances that have been assumed to be zero in this report. Therefore, prior to making an absolute decision, the variances associated with the aircraft penalty costs should be investigated in those instances where conflicting alternatives are involved.

Table 30

Values of F for Use in Equation 11 for Each i and m Assumption

Amortization Period Years	Values of F for Indicated Inflation Rates									
	1%	2%	3%	4%	5%	6%	7%	8%	9%	10%
1	0.870	0.758	0.661	0.577	[illegible]	0.442	0.388	0.340	0.299	0.263
2	1.731	1.501	1.303	1.133	[illegible]	0.860	0.750	0.656	0.574	0.503
3	2.584	2.229	1.926	1.667	[illegible]	1.253	1.089	0.948	0.826	0.720
4	3.429	2.943	2.531	2.180	1.880	1.625	1.406	1.218	1.057	0.918
5	4.265	3.644	3.119	[illegible]	2.296	1.975	1.701	1.468	1.269	1.098
6	5.092	4.330	3.689	[illegible]	2.692	2.305	1.978	1.700	1.463	1.262
7	5.912	5.003	4.243	[illegible]	3.069	2.617	2.236	1.914	1.642	1.410
8	6.723	5.663	4.780	[illegible]	3.428	2.911	2.478	2.113	1.805	1.545
9	7.527	6.310	5.302	4.465	3.769	3.189	2.704	2.297	1.956	1.668
10	8.322	6.944	5.809	4.871	4.095	3.451	2.915	2.467	2.093	1.780
11	9.110	7.566	6.301	5.261	4.405	3.698	3.112	2.625	2.220	1.881
12	9.889	8.175	6.778	5.636	4.700	3:931	3.296	2.771	2.336	1.974
13	10.661	8.773	7.242	5.997	4.982	4.150	3.468	2.906	2.442	2.058
14	11.426	9.359	7.692	6.344	5.249	4.358	3.629	3.031	2.540	2.134
15	12.183	9.933	8.129	6.677	5.505	4.553	3.779	3.147	2.629	2.203
16	12.932	10.496	8.553	6.998	5.748	4.738	3.920	3.255	2.711	2.266
17	13.674	11.048	8.965	7.306	5.979	4.912	4.051	3.354	2.787	2.324
18	14.409	11.589	9.365	7.603	6.199	5.076	4.174	3.446	2.856	2.376
19	15.136	12.120	9.754	7.868	6.409	5.231	4.289	3.531	2.910	2.423
20	15.856	12.640	10.131	8.162	6.609	5.378	4.396	3.610	2.978	2.466
21	16.569	13.150	10.497	8.426	6.799	5.515	4.496	3.683	3.031	2.505
22	17.275	13.650	10.852	8.679	6.981	5.646	4.590	3.751	3.080	2.541
23	17.974	14.140	11.197	8.923	7.153	5.768	4.678	3.813	3.125	2.573
24	18.666	14.621	11.532	9.157	7.318	5.884	4.759	3.871	3.166	2.603
25	19.351	15.092	11.858	9.382	7.474	5.993	4.836	3.925	3.204	2.629
26	20.029	15.554	12.173	9.599	7.623	6.096	4.907	3.975	3.239	2.654
27	20.701	16.007	12.480	9.807	7.766	6.194	4.974	4.021	3.270	2.676
28	21.366	16.451	[illegible]	10.007	7.901	6.285	5.036	4.063	3.300	2.696
29	22.024	16.886	[illegible]	[illegible]	8.030	6.372	5.095	4.103	3.326	2.714
30	22.676	17.313	13.347	10.365	8.152	6.453	5.149	4.139	3.351	2.731
31	23.322	17.732	13.619	10.563	8.269	6.530	5.200	4.173	3.374	2.746
32	23.961	18.142	13.884	10.734	8.380	6.603	5.248	4.205	3.394	2.759
33	24.593	18.544	14.140	10.899	8.486	6.672	5.292	4.234	3.413	2.772
34	25.220	18.938	14.390	11.057	8.587	6.736	5.334	4.260	3.431	2.783
35	25.840	19.325	14.632	11.209	8.684	6.797	5.373	4.285	3.447	2.794
36	26.454	19.704	14.867	11.356	8.775	6.855	5.409	4.308	3.461	2.803
37	27.062	20.075	15.095	11.497	8.862	6.909	5.443	4.330	3.475	2.811
38	27.664	20.439	15.316	11.632	8.945	6.960	5.475	4.349	3.487	2.819
39	28.260	20.797	15.531	11.762	9.024	7.009	5.504	4.368	3.498	2.826
40	28.851	21.147	15.740	11.887	9.100	7.054	5.532	4.385	3.509	2.833
41	29.435	21.490	15.943	12.007	9 172	7.097	5.558	4.400	3.518	2.838
42	30.013	21.826	16.139	12.123	9.240	7.138	5.582	4.415	3.527	2.844
43	30.586	22.156	16.331	12.234	9.305	7.176	5.605	4.428	3.535	2.849
44	31.153	22.480	16.516	12.341	9.367	7.212	5.626	4.441	3.542	2.853
45	31.715	22.797	16.696	12.444	9.426	7.246	5.646	4.452	3.549	2.857
46	32.271	23.108	16.871	12.543	[illegible]	7.278	5.664	4.463	3.555	2.861
47	32.821	23.413	17.041	12.638	9.536	7.309	5.682	4.473	3.561	2.864
48	33.366	23.711	17.205	12.729	9.587	7.337	5.698	4.482	3.566	2.867
49	33.906	24.004	17.365	12.817	9.635	7.364	5.713	4.490	3.571	2.870
50	34.440	24.291	17.521	12.902	9.682	7.390	5.727	4.498	3.575	2.872

10 FINDINGS AND CONCLUSIONS

10.1 Gear Optimization and Aircraft Cost

The lightest weight gear and gear installation is not necessarily the most optimum from the economic aspect.

The existing six-wheel-bogie landing gear of the Category I airplane is very close in weight and cost to the optimum gear that could be designed without regard to pavement strength.

The total 1985 cost penalty for designing the landing gear to current pavement strength, relative to an optimized gear, is ten times greater for the Category II airplane than for the Category I aircraft ($68.8 million/year versus $6.7 million/year).

The total 1985 cost penalty for both airplanes ($75 million) represents 0.2 percent of total domestic airline revenue projected for 1985 by the ATA ($38 billion).

10.2 Pavement Cost Analysis

Pavement unit prices vary considerably with both location and time. The cost associated with strengthening pavements can only be estimated statistically. Unit prices for portland cement concrete (P501) overlays used in the analysis varied from $0.60 per SYIN in Atlanta to $1.38 per SYIN Seattle with a national average of $0.94 per SYIN with a 34 percent coefficient of variation. Unit prices for asphaltic concrete (P401) overlays varied from $0.34 per SYIN in Houston to $0.93 per SYIN in Pittsburgh with a national average of $0.54 per SYIN with a 26 percent coefficient of variation.

These unit prices were assumed to decrease hyperbolically with increased thicknesses and include direct labor, equipment, and material costs; indirect costs; overhead; and contractor profit in 1972 dollars.

A heuristic approach was used in designing pavements for an optimized gear configuration for the Category II airplane, since no rational procedure was available for extrapolating data to accommodate such stresses.

The area calculations in this study were crude. However, they were made as accurately as possible staying within the macro scope of the research and the Central Limit Theorem lends credence to the possibility of compensating errors. Even with a large error in calculations, the decision with respect to policy would not change.

The total cost of upgrading the pavement structures was calculated on an equivalent annual cost basis in 1985 dollars. The calculations were based on a calculated expected total area of 29,939,536 SY, an interest rate of 5 percent, the time to completion of 13 years (1985), pavement amortization period of 20 years, and expected 1972 SY prices $7.36, $7.77, $7.45, and $12.82 for the Category I median and optimal gears and the Category II median and optimal gears, respectively.

The MPC for strengthening the pavement structure for the Category II aircraft is 165 percent of the MPC for strengthening the pavement structure for the Category I aircraft.

To examine the potential of conflicting alternatives developing by changing the assumptions noted, a 20 percent coefficient of variation was assumed for both unit price and calculated area. By compounding the 20 percent error in both unit price and calculated area, an LPC and an HPC were developed and examined against the aircraft penalty cost. In addition, a procedure was provided by which the decision maker can change the assumptions and arrive at his own pavement upgrading cost.

10.3 Total Cost Analysis

Category I aircraft. Based on the equivalent annual cost analysis using the MPL for pavement, the total equivalent annual cost is:

o Current Gear	$ 6,673,379
o Median Gear	35,258,683
o Optimal Gear	35,218,395

It is obvious from this listing that the optimal alternative is not to modify the present policy if one only considers the Category I aircraft. If one uses the LPC for pavement, the decision remains unchanged as shown below:

o Current Gear	$ 6,673,379
o Median Gear	13,943,790
o Optimal Gear	12,666,249

These results are illustrated in Figure 48.

Categories I and II aircraft. Based on the equivalent annual cost analysis using the MPC for pavement, the total equivalent annual costs are:

o Current Gear	$75,451,243
o Median Gear	70,840,062
o Optimal Gear	58,097,736

Based on this total annual cost listing, the present policy should be changed to permit the optimization of the gear to the Category II aircraft. However, in this instance, if one assumes the HPC for pavement, a conflicting alternative arises as shown below:

o Current Gear	$ 75,451,261
o Median Gear	103,239,590
o Optimal Gear	113,842,221

There is considerable logic behind the assumption that the MPC will be exceeded in the pavement upgrading for the Category II aircraft. In all probability, the paved area will exceed that computed in this report. The unit price differential may or may not increase. Thus, it is extremely critical to the decision maker that a proper determination be made as to whether or not the Category II aircraft will be operational in 1985; whether or not it will operate at all 26 projected major hub airports or perhaps only at 7 to 10 regional airports; and other operational assumptions.

Other variable considerations. Numerous figures and equations are presented in the text to permit the user of this document to change parameters and develop his own policy derivation. Assuming that the MPC calculations are correct and $n = 13$ years, Figure 54 presents a conveient method for changing the assumptions for i and m, two elusive parameters.

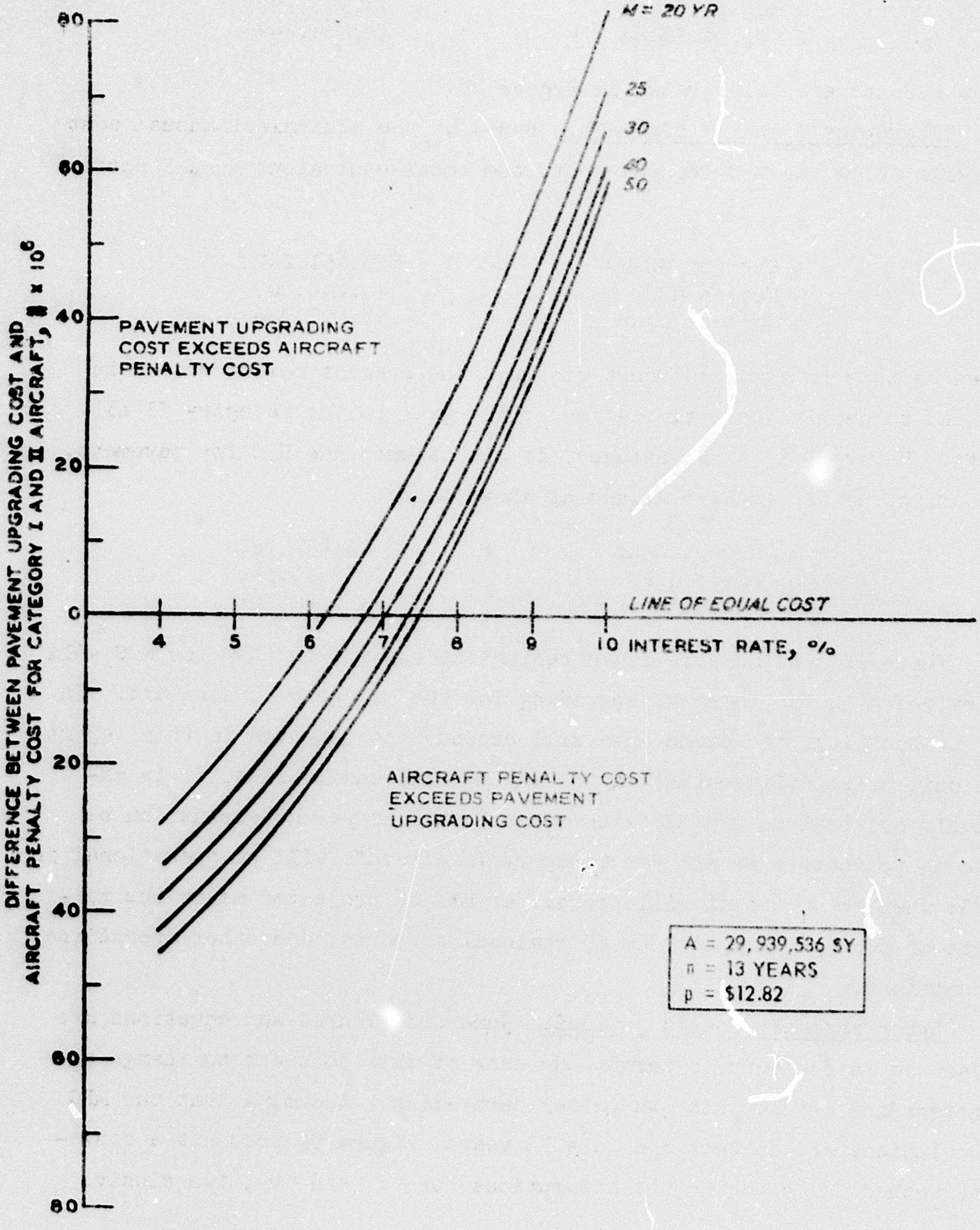


Figure 54. Effects of variations of pavement life m and inflation factor i

11 RECOMMENDATIONS

The following recommendations resulted from this study. They are based on the authors' calculations and assumptions. Devices are presented in this report to permit the decision to change these assumptions and calculations and the possibility exists that the recommendations should change based on further developments.

(1) If only the Category I aircraft will be in operation at each of the 26 projected major hub airports in 1985, the current FAAP criteria should not be changed.

(2) If the Categories I and II (implied also is the Category II aircraft alone) will be in operation at each of the 26 projected major hub airports in 1985, the current FAAP/ADAP criteria should be changed to permit the gear to be optimized to the aircraft. The possibility of operating the Category II aircraft from 7 to 10 regional airports should be investigated.

Further research, to include new gate and terminal construction, socioeconomic factors, and airport geometry requirements should be made to determine if the Category II aircraft will service all 26 projected major hub airports. Criteria should be changed to permit optimized design of gear with respect to aircraft only if the market survey indicates that the Category II aircraft will service the 26 major hub airports.

If further research reveals that only aircraft similar to the Category I aircraft will utilize the 26 projected major hub airports, the existing criteria should not be changed.

Additional research should be performed to study the economic implications of the criteria relative to the medium hub airports projected for 1985.

12 ADDITIONAL VALUE OF THIS REPORT

In addition to providing a useful device exclusive of additional cost for examining various policy decisions, this report provides:

(1) A consolidation of airport layouts and pavement structures as of 1972.

(2) An algorithm for designing aircraft gear types on a minimum cost basis.

(3) Pavement design curves for heavy aircraft.

(4) Methodology for complex cost analyses.

APPENDIX A

PAVEMENT CONSTRUCTION DATA FOR MAJOR HUB AIRPORTS

As a part of the contract study by Lockheed-California Company, a compilation was made of the available pavement construction data for the major hub airports shown in Table 13 of the main text. This effort was necessary because there exists no central agency or location where all of the current pavement data can be found. The data are scattered among FAA Regional and District Offices, airport engineering staffs, and pavement consulting companies. In cases where more than one pavement data source exists, various sources were compared and discrepancies were reconciled by contacting the airport engineer. Table A1 shows the sources for the pavement construction data for the major hub airports. The airport pavement characteristics are shown in Table A2. The last column in Table A1 indicates whether or not the subject airport officials reponded to requests as to the validity of the pavement data presented.

The FAA pavement strength survey data were chosen as the data base for this study. The most current FAA pavement strength survey data were obtained from the FAA Regional and District Offices. These surveys were conducted between 1957 and 1972, with most surveys being as current as 1969. Upon request, the FAA supported these basic data with pavement inspection reports, airport pavement design forms, etc., which describe pavement-related changes to an airport since the strength survey was completed. These data were supplemented by pavement information recorded by the Air Transport Industry (ATI) Working Group. The strength characteristics of the pavement (that is, modulus of subgrade reaction k, design allowable, safety factor, and CBR strength) have been obtained exclusively from the ATI reports.

Additional data were obtained directly from airport engineering staffs of the larger hubs such as Los Angeles International, San Francisco International, and the Port of New York Authority (PONYA) airports. This group of information is classified as "Calac" source data in Table A1. NASA technical notes contained data for four of the major hub airports. Data from Materials Research and Development, Inc., Oakland, Calif., were made available for San Francisco International.

The format of the FAA pavement strength survey varies considerably with each airport. This is particularly true with the identification of pavement segments on airport maps. Thus, a number of the maps have been modified to provide consistent presentations. It should be noted that several airports are currently improving the condition of their pavements, while others have plans to do so in the immediate future.

As a check on the validity of the data presented in Table A2, a letter was sent to all the airport engineers, along with the appropriate data from Table A2, requesting their comments and recommended changes to the data. These changes have been incorporated into the data as presented in Table A2. The airport engineers who replied to the letters are identified by a "Yes" in the column headed "Airport Response" in table A1.

The pavement terminology used in Table A2 is primarily based upon the FAA Advisory Circular, AC 150/5320-6A (Reference 10 in the main text). FAA designations for pavement material have been used frequently. They are defined as follows:

Subbase Course

P-154	Subbase Course
P-206	Dry-Bound Macadam Base Course or Water-Bound Macadam Base Course
P-208	Aggregate Base Course
P-213	Sand-Clay Base Course
P-216	Mixed In-Place Base Course
P-301	Soil Cement Base Course

Base Course

P-201	Bituminous Base Course
P-209	Crushed Aggregate Base Course
P-210	Caliche Base Course
P-211	Lime Rock Base Course
P-212	Shell Base Course
P-214	Penetration Macadam Base Course
P-215	Cold Laid Bituminous Base Course
P-304	Cement Treated Base Course

(Continued)

Flexible Pavement

P-401 Bituminous Concrete or Asphaltic Concrete

Rigid Pavement

Portland Cement Concrete Pavement

In addition, for Newark Airport, a lime-treated subbase is employed. This is denoted in Table A2 by LA, LB, and LC, depending on the composition of hydrated lime, cement, and flyash. See sheet 14 of Table A2 for the definition of these symbols.

Table A1

Sources of Pavement Construction Data for Major Hub Airports

Airport	1985 Calendar Year Number of Departures Thousands	Source of Pavement Data*					Airport Response
		CALAC	ATI	NASA	FAA	MRD	
Chicago (O'Hare)	404				RTA		No
Atlanta	346		RT		RTA		Yes
Los Angeles (International)	242	RTA	RTA	RT	RTA		Yes
Dallas/Ft. Worth Regional	235	RTA	RTA				No
San Francisco	222	RTA	RTA			RTA	Yes
Miami	203		RTA	RT	RTA		Yes
New York (JFK)	198		RTA		RTA		Yes
New York (La Guardia)	177		RTA		RTA		Yes
Newark	175		RTA		RTA		Yes
Denver	161		RTA		RTA		No
Boston	146		RTA		RTA		No
Philadelphia	140				RTA		No
St. Louis	132		RTA		RTA		Yes
Honolulu	121	RTA	RTA	RT	RTA		Yes
Detroit	120		RTA		RTA		Yes
Seattle/Tacoma	110		RTA	RT	RTA		Yes
Pittsburgh	105		RTA		RTA		Yes
Houston	102		RTA		RTA		Yes
Minneapolis/St. Paul	97				RTA		Yes
New Orleans	94		RTA		RTA		Yes
Las Vegas	94				RTA		No
Kansas City (International)	91				RTA		Yes
Baltimore	88	RTA			RTA		Yes
Cleveland	78		RTA		RTA		No
Washington (Dulles)	65	RTA	RTA				Yes
Fort Lauderdale	37				RTA		Yes

Note: R - runway data; T - taxiway data; and A - apron data.

* CALAC - Lockheed data.

ATI - Airport data for Air Transportation Planners, Air Transportation Industries Working Group.

NASA - Data obtained from recent NASA reports.

FAA - Data from FAA surveys.

MRD - Data from Materials Research Development, Inc.

Table A1

Sources of Pavement Construction Data for Major Hub Airports

Airport	1985 Calendar Year Number of Departures Thousands	Source of Pavement Data*					Airport Response
		CALAC	ATI	NASA	FAA	MRD	
Chicago (O'Hare)	404				RTA		No
Atlanta	346		RT		RTA		Yes
Los Angeles (International)	242	RTA	RTA	RT	RTA		Yes
Dallas/Ft. Worth Regional	235	RTA	RTA				No
San Francisco	222	RTA	RTA			RTA	Yes
Miami	203		RTA	RT	RTA		Yes
New York (JFK)	198		RTA		RTA		Yes
New York (La Guardia)	177		RTA		RTA		Yes
Newark	175		RTA		RTA		Yes
Denver	161		RTA		RTA		No
Boston	146		RTA		RTA		No
Philadelphia	140				RTA		No
St. Louis	132		RTA		RTA		Yes
Honolulu	121	RTA	RTA	RT	RTA		Yes
Detroit	120		RTA		RTA		Yes
Seattle/Tacoma	110		RTA	RT	RTA		Yes
Pittsburgh	105		RTA		RTA		Yes
Houston	102		RTA		RTA		Yes
Minneapolis/St. Paul	97				RTA		Yes
New Orleans	94		RTA		RTA		Yes
Las Vegas	94				RTA		No
Kansas City (International)	91				RTA		Yes
Baltimore	88	RTA			RTA		Yes
Cleveland	78		RTA		RTA		No
Washington (Dulles)	65	RTA	RTA				Yes
Fort Lauderdale	37				RTA		Yes

Note: R - runway data; T - taxiway data; and A - apron data.

* CALAC - Lockheed data.

ATI - Airport data for Air Transportation Planners, Air Transportation Industries Working Group.

NASA - Data obtained from recent NASA reports.

FAA - Data from FAA surveys.

MRD - Data from Materials Research Development, Inc.

The following is an index to the airfield pavement property sheets that comprise table A2.

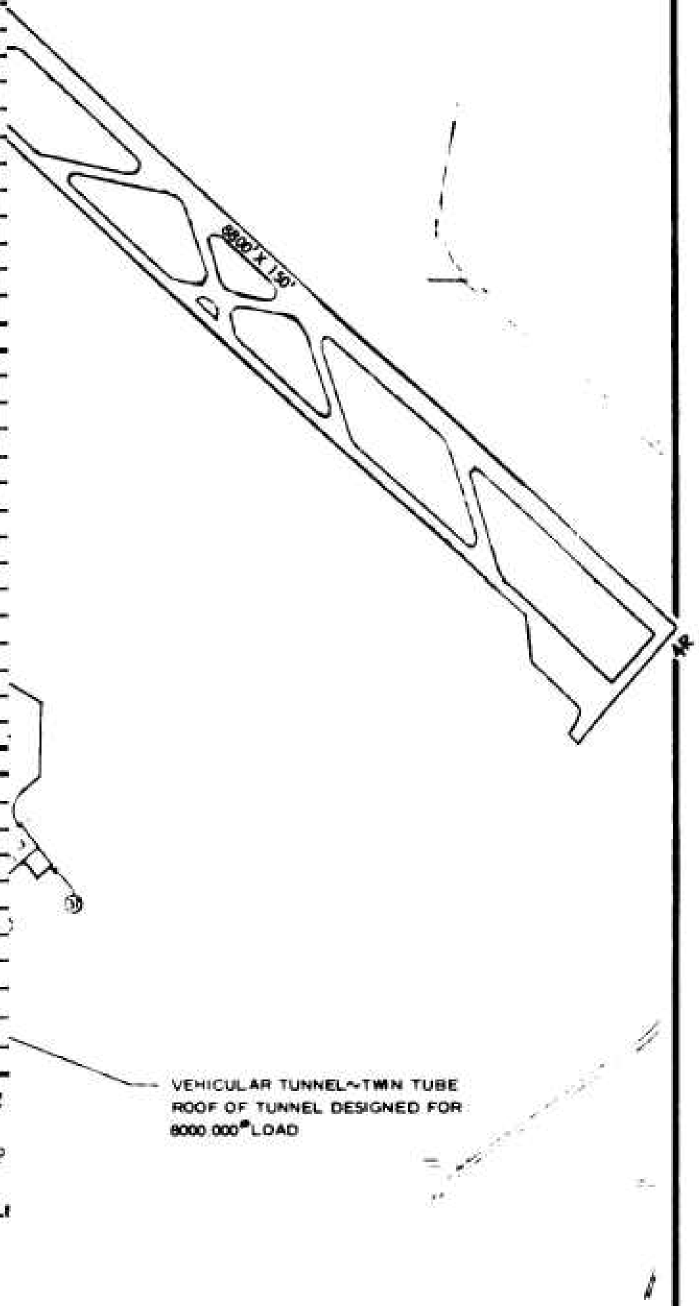
Airport	Sheet No.
Chicago (O'Hare)	1, 2
Atlanta	3
Los Angeles (International)	4, 5, 6
Dallas/Fort Worth Regional	7
San Francisco	8, 9
Miami	10
New York (JFK)	11, 12
New York (La Guardia)	13
Newark	14
Denver	15
Boston	16, 17, 18
Philadelphia	19
St. Louis	20
Honolulu	21, 22, 23
Detroit	24, 25
Seattle/Tacoma	26, 27
Pittsburgh	28, 29
Houston	30
Minneapolis/St. Paul	31, 32, 33
New Orleans	34
Las Vegas	35, 36
Kansas City (International)	37
Baltimore	38
Cleveland	39, 40, 41
Washington (Dulles)	42, 43
Fort Lauderdale	44

Table A2

[A]IRPORT NAME O'Hare International

DATE Jan. '73

I. D. NO.	SOIL CLASS.
1	E-7
2	E-7
3	E-7
4	E-7
5	E-7
6	E-7
18	E-7
19	E-7
20	E-7
24	E-7
29	E-7
30	E-7
35	E-7
7	E-7
8	E-7
9	E-7
10	E-7
11	E-7
13	E-7
14	E-7
15	E-7
16	E-7
17	E-7
25	E-7
26	E-7
12	E-7
23	E-7
28	E-7
33	E-7
51	E-7



REMARKS: PCC
AC
CRCP

* 5" Portl

(Sheet 1 of 44)

AIRPORT PAVEMENT CHARAC

STATE

I. D. NO.	SOIL CLASS.	SUB-GRADE CLASS	SUBBASE COURSE	BASE COURSE	SURFACE COURSE	OVERLAY	MOD. SUBGRADE REAC. K	DESIGN ALLOW.	CONSTRUC. SPEC	YEAR
—— RUNWAYS ——										
1	E-7	Rc	12" P-209	-	10"/7"PCC	4" P-401			C of E	1960
2	E-7	Rc	12" P-209	-	15" PCC				FAA	1958
3	E-7	Rc	16"/18"P-154	-	11" PCC	2" P-401			FAA	1967
4	E-7	Rc	18" P-154	-	12" PCC	2" P-401			FAA	1967
5	E-7	Rc	12" P-154	-	12" PCC	4" P-401			FAA	1960
6	E-7	Rc	-	-	15" PCC	5"+ 2" *			FAA	1967
18	E-7	Rc	12" P-154	6" P-209	12" CRCP				FAA	1966
19	E-7	Rc	12" P-154	6" P-209	10" CRCP				FAA	1966
20	E-7	Rc	12" P-209	-	15" PCC				FAA	1966
24	E-7	Rc	12" P-209	-	10"/7" PCC	9½" AC			C of E	1967
29	E-7	Rc	24" P-154	-	12" CRCP				FAA	1967
30	E-7	Rc	24" P-154	-	10" CRCP				FAA	1967
35	E-7	Rc	15" P-209	-	10"/7" PCC				C of E	1942
—— TAXIWAY ——										
7	E-7	F7	15" P-206	-	3" P-401	4½"/6" P-401			C of E	1957
8	E-7	F7	16" P-206	-	5" P-401	1½"/3" P-401			CAA	1957
9	E-7	F7	16" P-154	8" P-206	3"/4" P-401	1¼"/3" P-401			CAA	1957
10	E-7	F7	16" P-154	8" P-206	3" P-401	4½"/6" P-401			FAA	1969
11	E-7	F7	16" P-154	8" P-206	3" P-401	2" P-401			FAA	1961
13	E-7	Rc	12" P-209	-	10"/7" PCC	2" P-401			FAA	1960
14	E-7	F7	15" P-154	6" P-209	3"/4"P-401				C of E	1961
15	E-7	F7	21" P-154	6" P-209	3"/4" P-401				C of E	1960
16	E-7	Rc	10" P-208	-	10"/7" PCC	4½" P-401			FAA	1961
17	E-7	Rc	10" P-208	-	12" PCC				FAA	1963
25	E-7	Rc	12" P-209	-	15" PCC				FAA	1959
26	E-7	Rc	12" P-154	-	12" PCC				FAA	1961
—— APRONS ——										
12	E-7	Rc	12" P-209	-	15" PCC				FAA	1959
23	E-7	Rc	10" P-154	-	10" PCC				C of E	1942
28	E-7	Rc	10"/12"P-154	-	10" PCC				FAA	1963
33	E-7	Rc	12" P-208	-	10"/7"PCC	2" AC			C of E	1943
51	E-7	Rc	12" P-154	-	12" PCC				UAL	1969

REMARKS:

PCC - Portland Cement Concrete.
AC - Asphaltic Concrete.
CRCP - Continuous Reinforced Concrete Pavement.

* 5" Portland Cement Contrete + 2 Asphaltic Concrete.

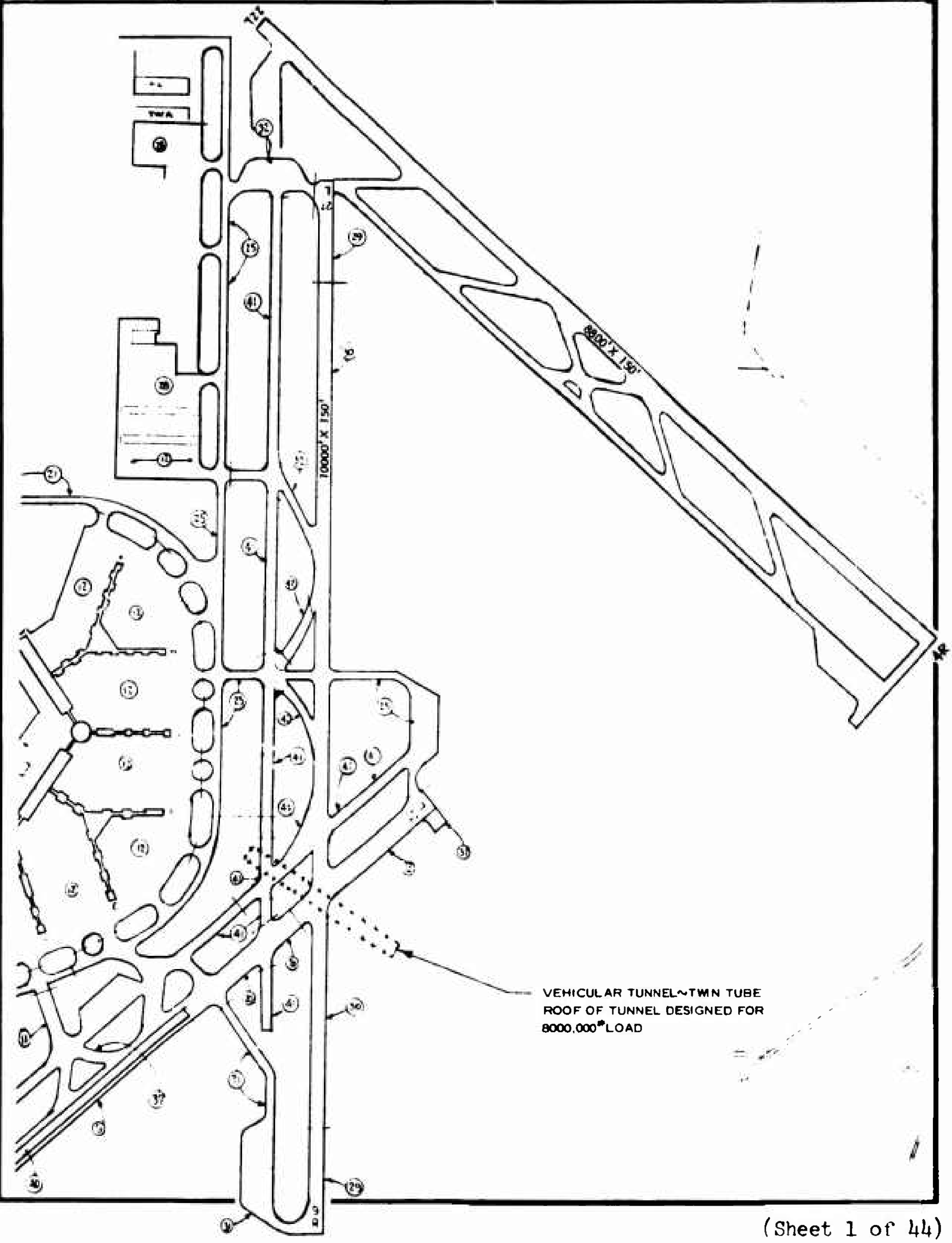
B

Table A2

IRPORT PAVEMENT CHARACTERISTICS

STATE Illinois **CITY** Chicago **AIRPORT NAME** O'Hare International **DATE** Jan. '73

MOD. GRADE EAC. K	DESIGN ALLOW.	CONSTRUC. SPEC	YEAR
		C of E	1960
		FAA	1958
		FAA	1967
		FAA	1967
		FAA	1960
		FAA	1967
		FAA	1966
		FAA	1966
		FAA	1966
		C of E	1967
		FAA	1967
		FAA	1967
		C of E	1942
		C of E	1957
		CAA	1957
1		CAA	1957
		FAA	1969
		FAA	1961
		FAA	1960
		C of E	1961
		C of E	1960
		FAA	1961
		FAA	1963
		FAA	1959
		FAA	1961
		FAA	1959
		C of E	1942
		FAA	1963
		C of E	1943
		UAL	1969



(Sheet 1 of 44)

A

AIRPORT PAVEMENT CHARACT

I. D. NO.	SOIL CLASS.	SUB-GRADE CLASS	SUBBASE COURSE	BASE COURSE	SURFACE COURSE	OVERLAY	MOD. SUBGRADE REAC. K	DESIGN ALLOW.	CONSTRUC. SPEC	YEAR	STATE Ill
—— RUNWAYS ——											
36	E-8	Rd	18" P-154	12" P-209	12" CRCP				FAA	1968	
37	E-8	Rd	24" P-154	-	12" CRCP				FAA	1968	
38	E-8	Rd	18" P-154	12" P-209	12" CRCP				FAA	1968	
39	E-8	Rd	18" P-154	12" P-209	12" CRCP				FAA	1968	
40	E-8	Rd	18" P-154	12" P-209	12" CRCP				FAA	1968	
43	E-7	Rc	12" P-209	-	10"/7" PCC	5½" AC			C of E	1967	
44	E-7	Rc	12" P-209	-	10"/7" PCC	4" P-401			C of E	1967	
50	E-7	Rc	10" P-209	-	12" PCC						
—— TAXIWAY ——											
27	E-7	Rc	15" P-209	-	10"/7"PCC	3" P-401			C of E	1961	
31	E-8	Rd	30" P-154	12" P-209	12" CRCP				FAA	1967	
32	E-7	Rc	24" P-154	12" P-209	12" CRCP				FAA	1967	
34	E-7	Rc	15" P-208	-	12" CRCP	2"/3"P-401			FAA	1967	
41	E-8	Rd	18" P-154	12" P-209	12" CRCP				FAA	1968	
42	E-8	Rd	12" P-154	12" P-209	12" CRCP				FAA	1969	
45	E-8	Rd	14" P-154	20" P-201	4" P-401				FAA	1969	
46	E-8	Rd	12" P-154	14" P-201	4" P-401				FAA	1969	
47	E-8	Rd	12" P-154	12" P-209	12" CRCP				FAA	1969	
48	E-8	Rd	15"/24"P-154	8" P-201	4" P-401				FAA	1969	
49	E-7	Rc	10" P-209	-	12" PCC	2½" P-401			FAA	1961	
21	E-7	Rc	12" P-154	12" P-209	12" CRCP				FAA	1966	
21	at Fillets		12" P-154	12" P-209	15" CRCP				FAA	1968	
—— APRONS ——											

REMARKS:

AC - Asphaltic Concrete.

CRCP - Continuous Reinforced Concrete Pavement.

PCC - Portland Cement Concrete

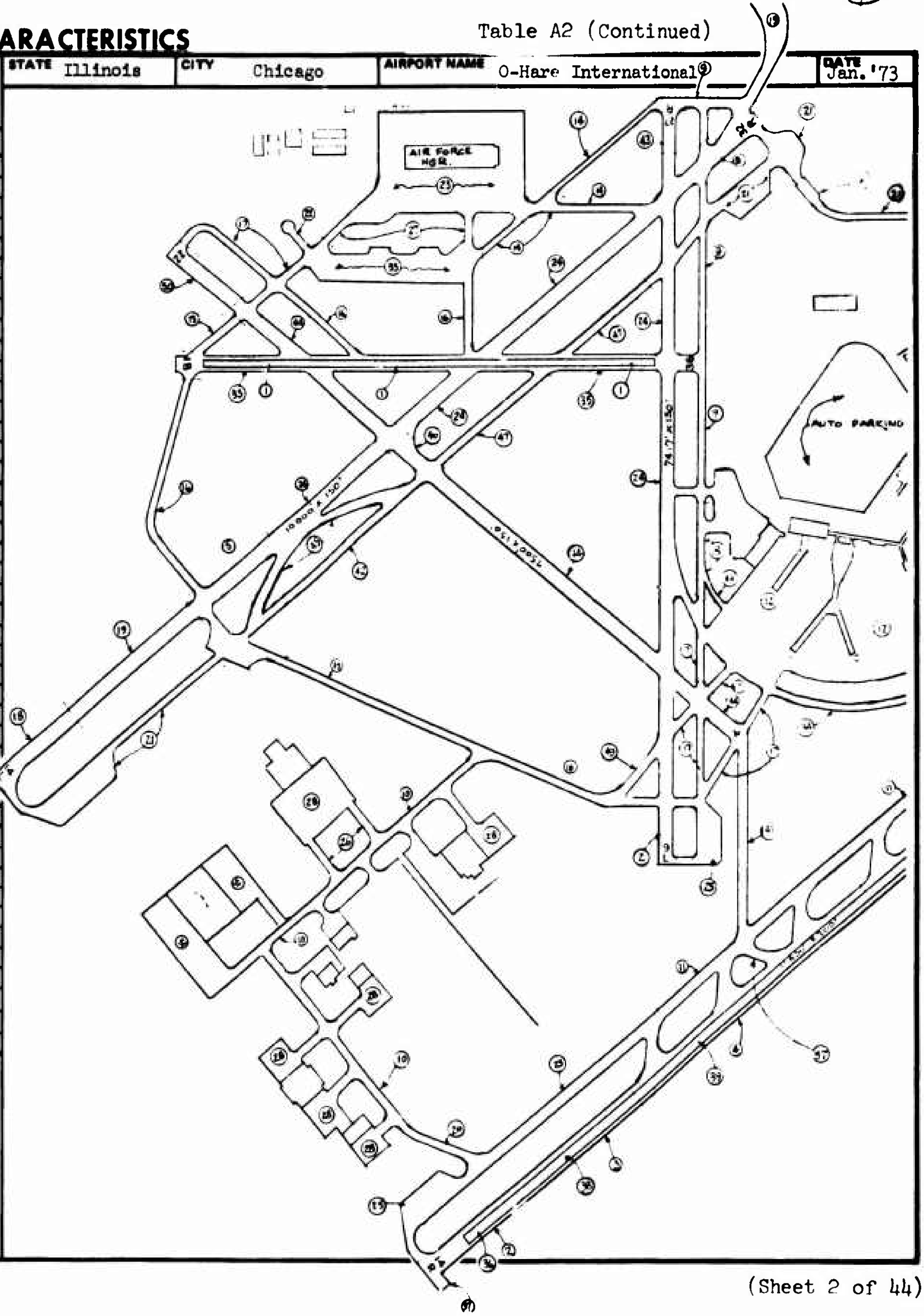
B

AIRPORT PAVEMENT CHARACTERISTICS

Table A2 (Continued)

STATE Illinois **CITY** Chicago **AIRPORT NAME** O-Hare International **DATE** Jan. '73

MOD. UBGRADE REAC. K	DESIGN ALLOW.	CONSTRUC. SPEC	YEAR
		FAA	1968
		FAA	1968
		FAA	1968
		FAA	1968
		FAA	1968
		C of E	1967
		C of E	1967
		C of E	1961
		FAA	1967
		FAA	1967
		FAA	1967
		FAA	1968
		FAA	1969
		FAA	1969
		FAA	1969
		FAA	1969
		FAA	1969
		FAA	1961
		FAA	1966
		FAA	1968



(Sheet 2 of 44)

AIRPORT PAVEMENT CHARACTE

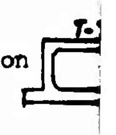
STATE Geo

I. D. NO.	SOIL CLASS	SUB-GRADE CLASS	SUBBASE COURSE	BASE COURSE	SURFACE COURSE	OVERLAY	MOD. SUBGRADE REAC. K	DESIGN ALLOW.	CONSTRUC. SPEC	YEAR
					RUNWAYS					
R-1	E-7	F5	8" Granular	8" WB Macad	3"Bitum.	3½" Bitum.				
R-1 ends	E-7	F5	10" Granul.	10" WB Macad	3" Bitum.	3½" Bitum.				
R-2	E-7	Rc	6" Soil Cem.	6" P-209	16" PCC		150	350 psi*	AAE-REP	1969
R-2 ends	E-7	Rc	6" Soil Cem.	6" P-209	16" PCC		150	350 psi*	AAE-REP	1969
R-3	E-7	Rc	6" P-154	-	10" PCC					
R-3 ends	E-7	Rc	6" P-154	-	12" PCC					
R-4	E-7	F5	10" P-154	10" P-209	3½" Bitum.					
R-5	E-7	Rc	8" P-154	-	10" PCC					
R-5 ends	E-7	Rc	8" P-154	-	12" PCC					
R-6	E-7	Rc	6" P-301	6" P-304	16" PCC		150	350 psi	AAE-REP	1969
+ R-1A	E-7	F5	8-10" P-154	8" P-201	5" P-401					1971
					TAXIWAY					
T-1	E-7	F5	10" Granul.	10" WB Macad	3"Bitum.	3½" Bitum.				
T-2	E-7	Rc	6"Soil-Cem	6" P-209	16" PCC		150	350 psi*	AAE-REP	1969
T-3	E-7	Rc	6" P-154	-	12" PCC					
T-4	E-7	F5	10" P-154	10" P-209	3½" Bitum.					
T-5	E-7	Rc	8" P-154	-	12" PCC					
T-6	E-7	Rc	6" P-301	6" P-304	16" PCC		150	350 psi*	AAE-REP	1969
T-7	E-7	Rc	6" P-301	6" P-304	16" PCC		150	350 psi*	AAE-REP	1969
T-8	E-7	Rc	6" P-301	6" P-304	16" PCC		150	350 psi	AAE-REP	Under Construction
+ T-9	E-7	F5	6" P-301	20" P-304 +11" P-201	5" P-401					1971
					APRONS					
A-1	E-7	Rc	8" Granular	-	11½" PCC					
A-2	E-7	Rc	8" Granular	-	11½" PCC					
A-3	E-7	Rc	10" P-154	-	12" PCC					
A-4	E-7	F5	27" P-154	12" P-209	3" P-401					
A-5	E-7	Rc	6" P-301	6" P-304	16" PCC		150	350psi*	AAE-REP	Under Construction

REMARKS:

* Safety Factor 2

\+ Regarding on 75' center section



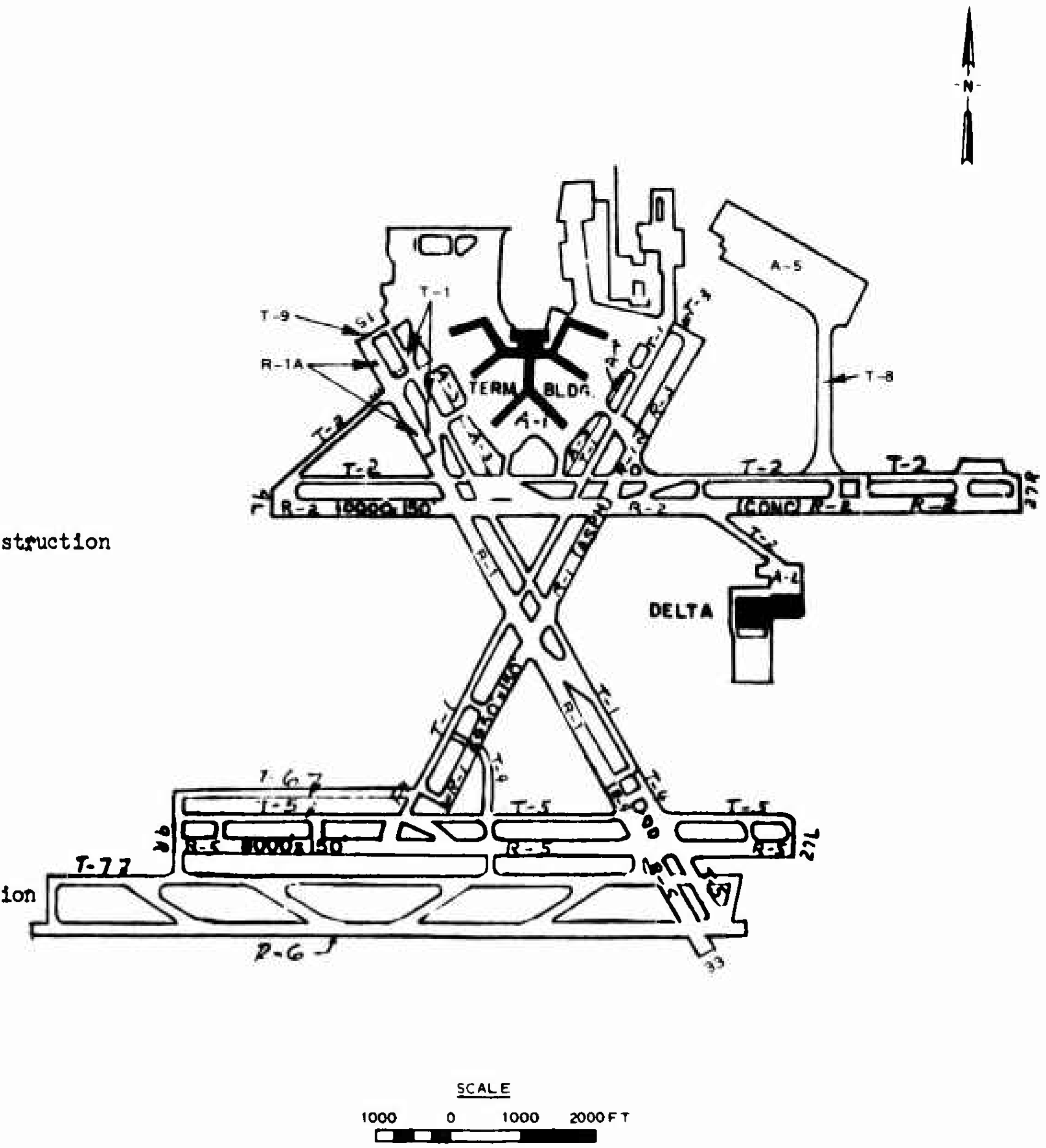
B

IRPORT PAVEMENT CHARACTERISTICS

Table A2 (Continued)

MOD. BGRADE REAC. K	DESIGN ALLOW.	CONSTRUC. SPEC	YEAR
150	350 psi*	AAE-REP	1969
150	350 psi*	AAE-REP	1969
150	350 psi	AAE-REP	1969
			1971
150	350 psi*	AAE-REP	1969
150	350 psi*	AAE-REP	1969
150	350 psi*	AAE-REP	1969
150	350 psi	AAE-REP	Under Construction
			1971
50	350psi*	AAE-REP	Under Construction

STATE Georgia	CITY Atlanta	AIRPORT NAME Atlanta	DATE Jan. '73



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A

AIRPORT PAVEMENT CHARACTER

STATE Cali

I. D. NO.	SOIL CLASS.	SUB-GRADE CLASS	SUBBASE COURSE	BASE COURSE	SURFACE COURSE	OVERLAY	MOD. SUBGRADE REAC. K	DESIGN ALLOW.	CONSTRUC. SPEC	YEAR
— RUNWAYS —										
R-1	E-7/E-2	F5/Ra	8" AC/4"ESB	-	12" PCC				FAAP-19	1960
R-1A	E-7	Rc	SM	-	16" PCC				SE-17	1950
R-1B	E-7	Rc	24" SM	4" CAB	15" PCC				FAAP-19	1960
R-1C	E-2	Ra	4" ESB	8" AC	10½" PCC				FAAP-19	1960
R-1D	E-2	Fa	6" SC-COMP.	10" CAB	3" AC				FAAP-19	1960
R-1E	E-2	Fa	6" SC-COMP.	10" ESB	3" AC				FAAP-08	1951
R-1F	E-7	Fs	4" ESB	4"-15" CAB	3" AC				FAAP-19	1960
R-1G	E-2	Fa	12" SM	8"-10" SC	3" AC				CITY	1958
R-1H	E-2	Fa	12" SM	10" CAB	3" AC				FAAP-20	1960
R-2	E-7	Rc	18" SM	4" CAB	12" PCC				FAAP-18	1958
R-2A	E-7	Rc	18" SM	4" CAB	15" PCC				FAAP-18	1958
R-2B	E-2	Ra	12" SM	6" CAB	3" AC	10" PCC			FAAP-18	1958
R-2C	E-2	Fa	6" SC-COMP.	10" ESB	3" AC				FAAP-08	1951
R-2D	E-2	Ra	12" SC-COMP	6"COMP SOIL	16" PCC				FAAP-08	1951
R-2E	E-2	Fa	12" SM	10" CAB	3" AC				FAAP-19	1959
R-2F	E-2	Fa	28" SM	12" CAB	3" AC				FAAP-26	1965
— TAXIWAY —										
T-1	E-2	Fa	6" SC-COMP	8" ESB	3" AC				CITY	1955
T-1A	E-2	Fa	12" SC-COMP	10" CAB	3" AC				FAAP-16	1957
T-1B	E-2	Fa		10" CAB	3" AC				CITY	1960
T-1C	E-2	Fa	6" SC-COMP	10" CAB	3" AC				FAAP-29	1968
T-2	E-7	Rc	18" SM	-	9" PCC				CITY	1947
T-2A	E-2	Fa	6" SC-COMP	10" CAB	3" AC				FAAP-08	1957
T-2B	E-2	Fa	6" SC-COMP	12" CAB	3" AC				FAAP-08	1951
T-2C	E-7	F5	18" SM	9" CAB	4" AC					1963
T-2D	E-7	F5	28" SM	12" CAB	3" AC				FAAP-18	1958
T-3	E-7	F5	2" SAND	4" ESB	2" AC				WPA	1940
T-4	E-7	F5	34" SM	6" CAB	15" PCC					1963
T-5	E-7	F5	28" SM	12" CAB	3" AC				FAAP-14	1956
T-5A	E-2	Fa	6" SC-COMP	8" ESB	3" AC				FAAP-08	1951
T-5B	E-2	Fa	6" SC-COMP	10" CAB	3" AC				FAAP-08	1951
T-5C	E-2	Fa	6" SC-COMP	10" ESB	3" AC				FAAP-08	1951
— APRONS —										
A-1	E-7	F5	14" SM	6" ESB	2" AC				Unknown	1945
A-2	E-7	Rc	18" SM	-	9" PCC				Unknown	1947
A-3	E-7	F5	18" SM	8" CAB	3" AC				Unknown	1955
A-4	E-7	F5	12" SM	6" CAB	4" AC				Unknown	1948
A-5	E-7	F5	24" SM	8" CAB	3" AC					1953
A-6	E-2	Ra	·		12" PCC					
A-7	E-2	Ra	-	-	12" PCC				FAAP-16	1957
A-8	E-2	Ra	-	-	9" PCC				FAAP-16	1957
A-9	E-7	F5	28" SM	12" CAB	3" AC					1959
A-10	E-7	F5	2" SAND	4" ESB	2" AC					1953
A-11	E-2	Ra	6" SC-COMP	-	12" PCC				FAAP-16	1957

REMARKS:

AC - Asphaltic Concrete
ESB - Emulsion Stabilized Base
PCC - Portland Cement Concrete
SM - Select Material
CAB - Crushed Aggregate Base
SC - Soil Cement (Compacted)

B

IRPORT PAVEMENT CHARACTERISTICS

Table A2 (Continued)

MOD. UBGRADE REAC. K	DESIGN ALLOW.	CONSTRUC. SPEC	YEAR
		FAAP-19	1960
		SE-17	1950
		FAAP-19	1960
		FAAP-19	1960
		FAAP-19	1960
		FAAP-08	1951
		FAAP-19	1960
		CITY	1958
		FAAP-20	1960
		FAAP-18	1958
		FAAP-18	1958
		FAAP-18	1958
		FAAP-08	1951
		FAAP-08	1951
		FAAP-19	1959
		FAAP-26	1965
		CITY	1955
		FAAP-16	1957
		CITY	1960
		FAAP-29	1968
		CITY	1947
		FAAP-08	1957
		FAAP-08	1951
			1963
		FAAP-18	1958
		WPA	1940
			1963
		FAAP-14	1956
		FAAP-08	1951
		FAAP-08	1951
		FAAP-08	1951
		Unknown	1945
		Unknown	1947
		Unknown	1955
		Unknown	1948
			1953
		FAAP-16	1957
		FAAP-16	1957
			1959
			1953
		FAAP-16	1957

STATE California

CITY Los Angeles

AIRPORT NAME Los Angeles International

DATE Jan. '73

SEE SHEET 6

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A

AIRPORT PAVEMENT CHARACTE

STATE Calif

I. D. NO.	SOIL CLASS.	SUB-GRADE CLASS	SUBBASE COURSE	BASE COURSE	SURFACE COURSE	OVERLAY	MOD. SUBGRADE REAC. K	DESIGN ALLOW.	CONSTRUC. SPEC	YEAR
					—— RUNWAYS ——					
R-3	E-2	Fa	12" SC-COMP	8" CAB	2" AC	3" AC *			FAAP-16	1957
R-3A	E-2	Ra	12" SC-COMP	-	12" PCC		300	**	FAAP-16	1957
R-3B	E-2	Fa	12" SC-COMP	10" CAB	3" AC	3" AC *			FAAP-16	1957
R-3C	E-2	Ra	{22" SM} {+9" SC}	6" CAB	15" PCC				FAAP-27	1967
R-4	E-2	Ra	22" SM	6" CAB	15" PCC		400	***	FAAP-29	1970
					—— TAXIWAY ——					
T-5D	E-2	Fa	12" SC-COMP	10" SC	3" AC				CITY	1958
T-5E	E-2	Fa	28" SM	12" CAB	3" AC				FAAP-26	1965
T-6	E-7	F5	2" SAND	4" ESB	2" AC	5" AC			WPA	1951
T-7	E-7	Rc	14" SM	-	8" PCC				-	1947
T-8	E-2	Ra	12" SC-COMP	-	12" PCC				FAAP-16	1957
T-8A	E-2	Ra	12" SC-COMP	12" CAB	3" AC				FAAP-16	1957
T-9	E-7	F5	28" SM	12" CAB	3" AC				CITY	1959
T-10	E-2	Ra	22"P209	6" CAB	15" PCC				FAAP-22	1966
T-11	E-2	Fa	24" SM	12" CAB	3" AC				FAAP-25	1964
T-12	E-7	Rc	34" SM	6" CAB	15" PCC				FAAP-25	1964
T-12A	E-2	Fa	24" SM	12" CAB	3" AC				FAAP-25	1964
T-13	E-2	Fa	-	10" CAB	3" AC				FAAP-22	1960
T-14	E-2	Ra	22" SM	6" CAB	15" PCC				FAAP-29	1970
T-15	E-2	Ra	22" SM	6" CAB	15" PCC				FAAP-27	1967
T-16	E-7	F5	-	-	12" PCC					1965
T-17	E-7	F5	20" SM	11" CAB	—— APRONS ——	4" AC				1968
A-12	E-2	Ra	-	-	11" PCC					
A-13	E-2	Fa	12" SC-COMP	10" CAB	3" AC					1957
A-14	E-2	Ra	-	-	12" PCC				FAAP-21	1960
A-15	E-2	Ra	-	-	8" PCC				FAAP-21	1960
A-16	E-2	Fa	-	10" CAB	3" AC				FAAP-21	1960
A-17	E-2	Fa	-	7" CAB	3" AC				FAAP-21	1960
A-18	E-2	Ra	-	-	12" PCC				FAAP-22	1960
A-19	E-2	Ra	-	-	8" PCC				FAAP-22	1960
A-20	E-2	Fa	-	10" CAB	3" AC				FAAP-22	1960
A-21	E-2	Fa	-	7" CAB	3" AC				FAAP-22	1960
A-22	E-7	F5	6" SM	4" CAB	2" AC					1958
A-23	E-7	F5	6" SC-COMP	12" CAB	12" PCC					1968

AC - Asphaltic Concrete
ESB - Emulsion Stabilized Base
PCC - Portland Cement Concrete
SM - Select Material
CAB - Crushed Aggregate Base
SC - Soil Cement (compacted)

* Overlay 1968
** Working Stress = 400 psi

*** Design Allow = 1,250,000 lbs.
Safety Factor = 1.65

Table A2 (Continued)

RPORT PAVEMENT CHARACTERISTICS

STATE California
CITY Los Angeles
AIRPORT NAME Los Angeles International
DATE Jan. '73

DD. RADE AC. K	DESIGN ALLOW.	CONSTRUC. SPEC	YEAR
		FAAP-16	1957
00	**	FAAP-16	1957
		FAAP-16	1957
		FAAP-27	1967
00	***	FAAP-29	1970
		CITY	1958
		FAAP-26	1965
		WPA	1951
		-	1947
		FAAP-16	1957
		FAAP-16	1957
		CITY	1959
		FAAP-22	1966
		FAAP-25	1964
		FAAP-25	1964
		FAAP-25	1964
		FAAP-22	1960
		FAAP-29	1970
		FAAP-27	1967
			1965
			1968
			1957
		FAAP-21	1960
		FAAP-21	1960
		FAAP-21	1960
		FAAP-21	1960
		FAAP-22	1960
		FAAP-22	1960
		FAAP-22	1960
		FAAP-22	1960
			1958
			1968

00 lbs.

SEE SHEET 6

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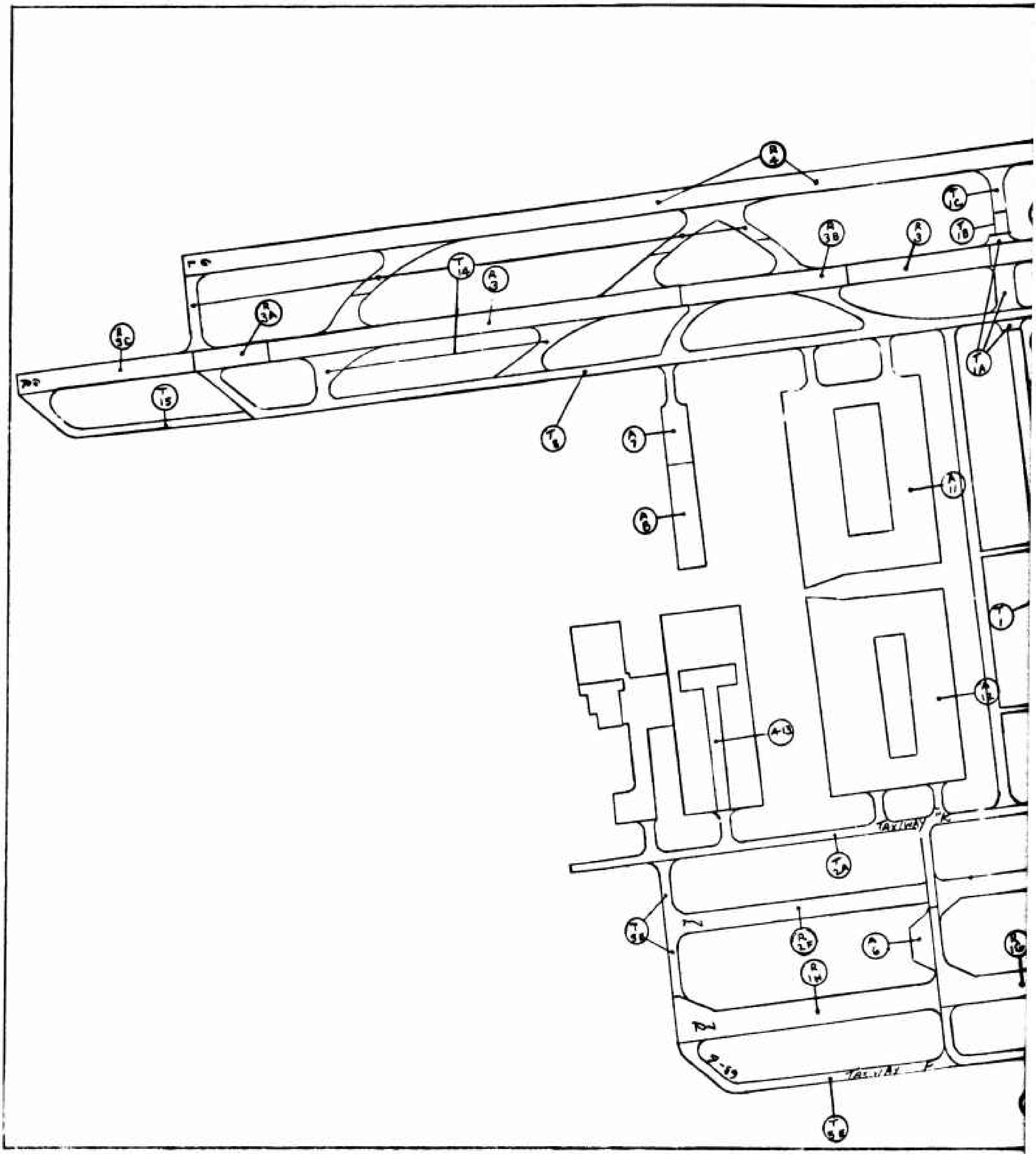
A


R 4
T 1C
T 1B
R 3B
R 3
T 14
A 3
R 3A
R 5C
T 15
T 8
T 1A
A 7
A 8
A 11
T 1
A 12
A-13
TAXIWAY "K"
T 2A
T 5B
R 2F
A 6
R 1H
TAXIWAY F
T 5B

B

STATE: CALIFORNIA

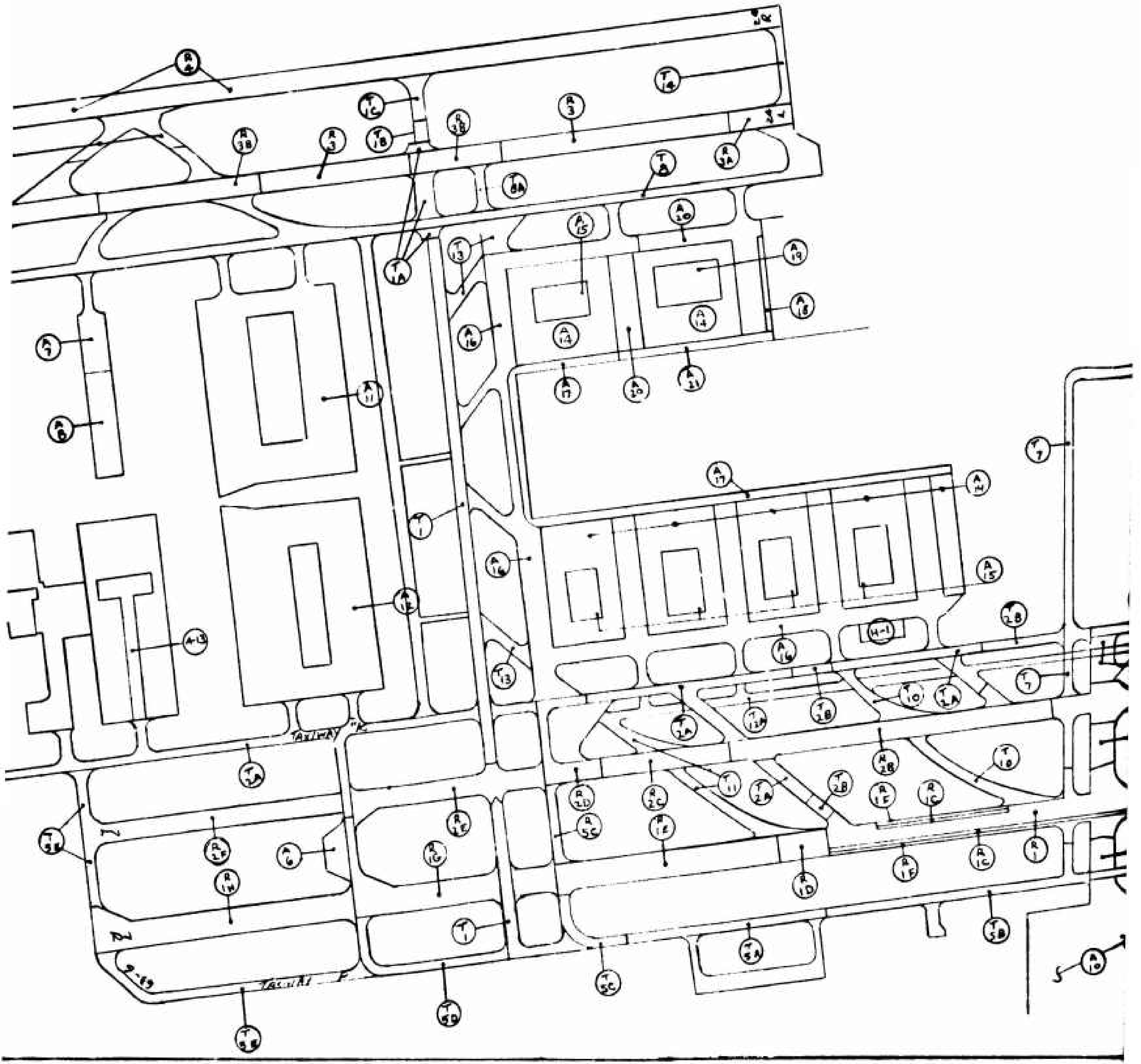


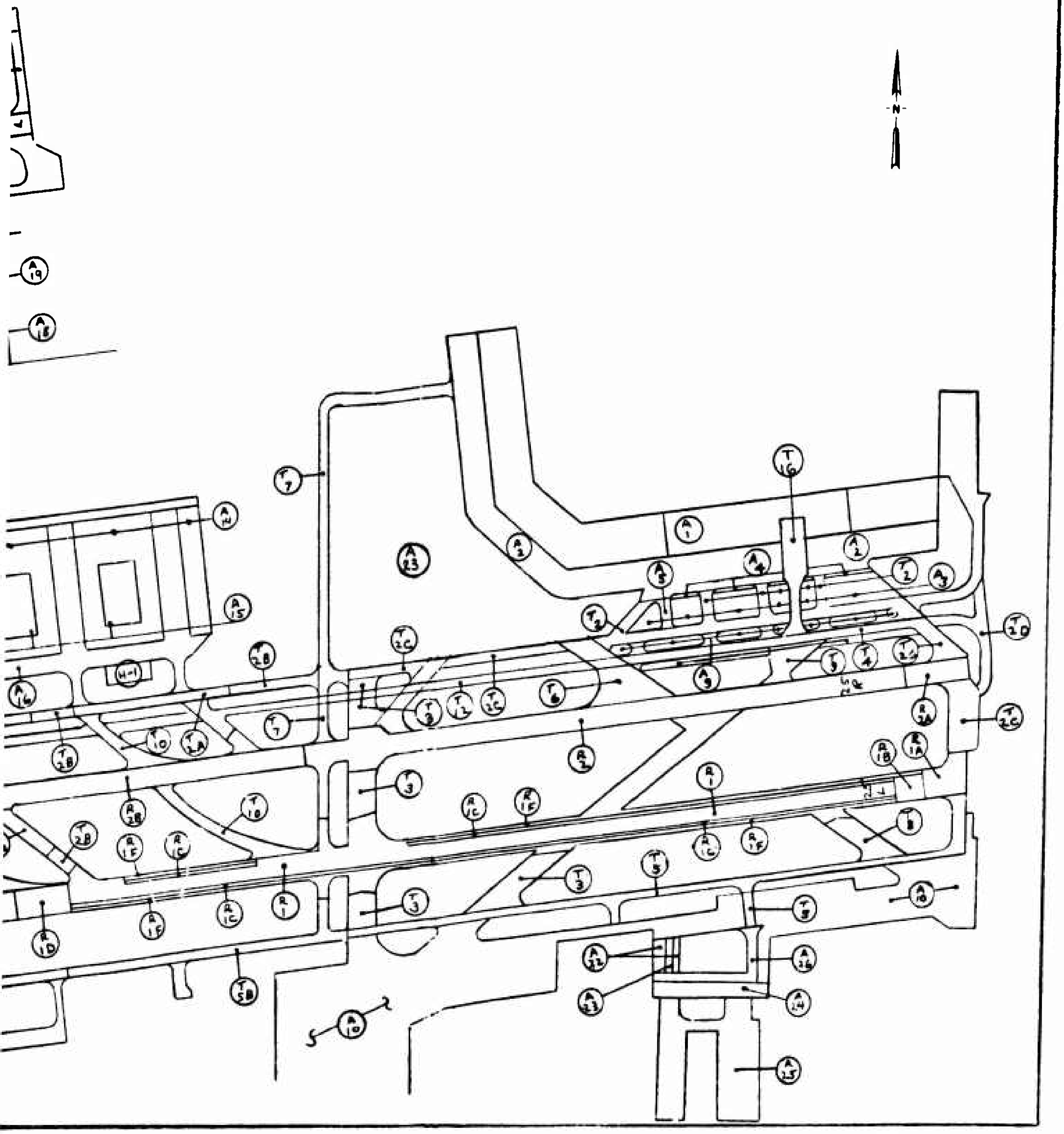
Table A2 (Continued)

STATE: CALIFORNIA

CITY: LOS ANGELES

AIRPORT: LOS ANGELES INTERNATIONAL

DATE: 1/22/73



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AIRPORT PAVEMENT CHARACTER

STATE Tex

I. D. NO.	SOIL CLASS.	SUB-GRADE CLASS	SUBBASE COURSE	BASE COURSE	SURFACE COURSE	OVERLAY	MOD. SUBGRADE REAC. K	DESIGN ALLOW.	CONSTRUC. SPEC	YEAR
— RUNWAYS —										
17R-35L										
R-1			9" LTM	10" CSB	18" JRC				*	
R-2			9" LTM	9" CSB	18" JRC				*	
R-3			9" LTM	9" CSB	17 JRC				*	
R-6			9" LTM	9" CSB	18"/15"JRC				*	
17L-35R										
R-1			9" LTM	10" CSB	18" JRC				*	
R-2			9" LTM	9" CSB	18" JRC				*	
R-3			9" LTM	9" CSB	17" JRC				*	
R-6			9" LTM	9" CSB	18"/15"JRC				*	
13L-31R										
R-3			9" LTM	9" CSB	17" JRC				*	
R-6			9" LTM	9" CSB	17"/14"JRC				*	
— TAXIWAY —										
T-1			9" LTM	10" CSB	18" JRC				*	
T-2			9" LTM	9" CSB	18" JRC				*	
T-3			9" LTM	9" CSB	17" JRC				*	
T-4			9" LTM	9" CSB	16" JRC				*	
T-5			9" LTM	9" CSB	15" JRC				*	
— APRONS —										
A-1			18" LTM	10" CSB	18" JRC				*	

REMARKS:

CSB - Cement Stabilized Base
JRC - Jointed Reinforced Portland Cement Concrete
LTM - Lime Treated Material

* Aircraft pavement design - Mason & Johnston, Sept. 1971.

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PORT PAVEMENT CHARACTERISTICS

Table A2 (Continued)

D. IADE C.	DESIGN ALLOW.	CONSTRUC. SPEC	YEAR
		*	
		*	
		*	
		*	
		*	
		*	
		*	
		*	
		*	
		*	
		*	
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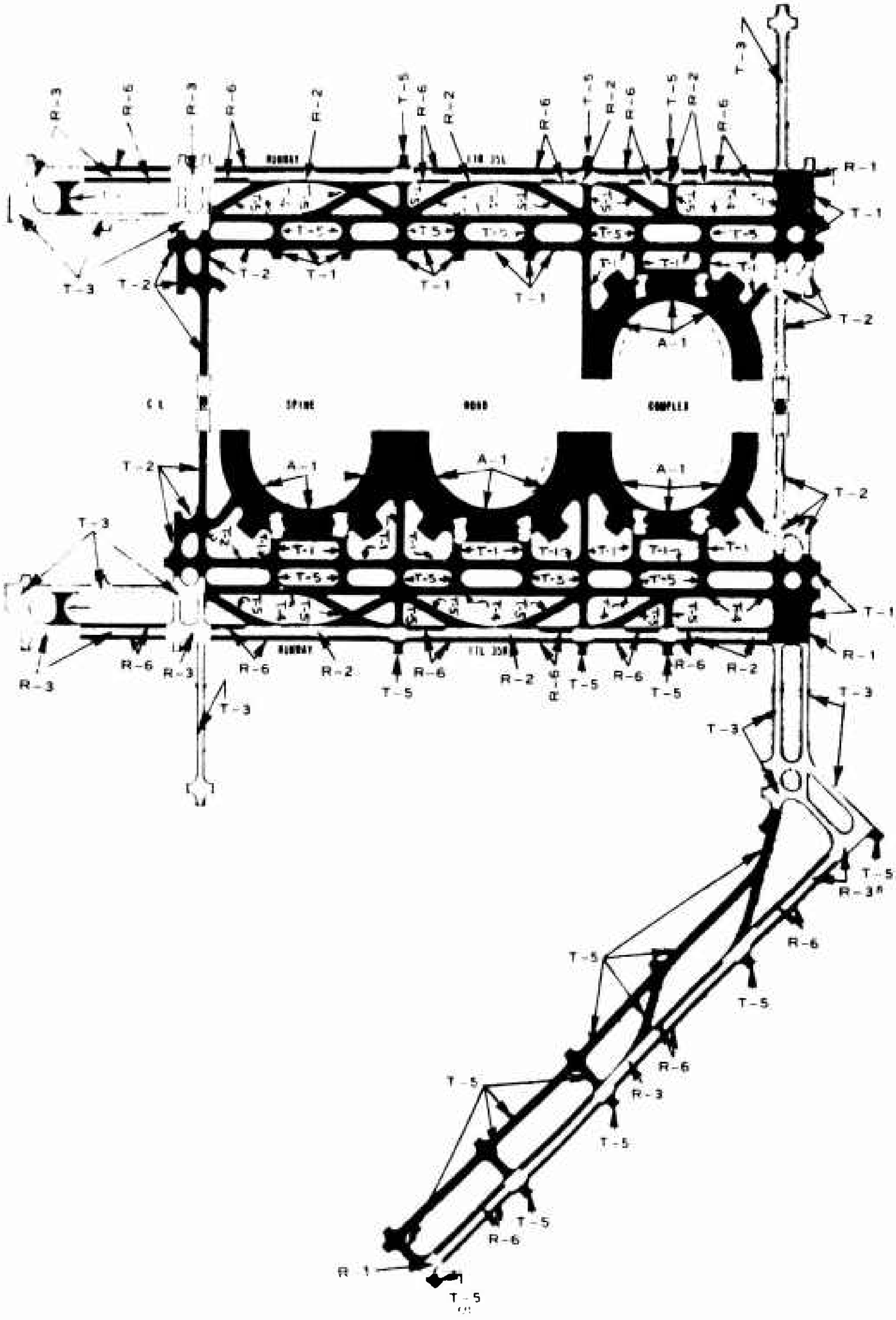
STATE Texas **CITY** Dallas **AIRPORT NAME** Dallas-Fort Worth Regional Airport **DATE** Jan. '73



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AIRPORT PAVEMENT CHARACT

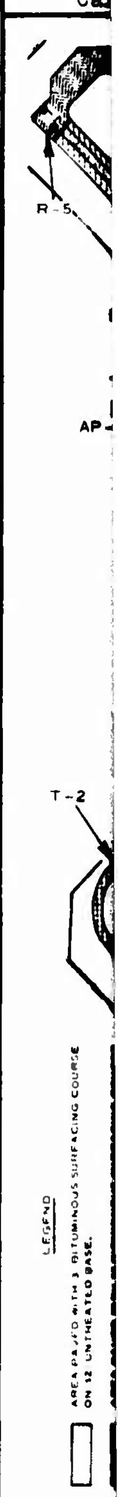
I. D. NO.	SOIL CLASS.	SUB-GRADE CLASS	SUBBASE COURSE	BASE COURSE	SURFACE COURSE	OVERLAY	MOD. SUBGRADE REAC. K	DESIGN ALLOW.	CONSTRUC. SPEC	YEAR
RUNWAYS										
1R-19L										
R-1	E-3	Fl	-	12" U.	3" Bit.				CAA	1951
R-2	E-3	Fl	4" U.	10" C.T.	4" Bit.				FAA	1960
R-3	E-3	Fl	4" U.	10" C.T.	3½" Bit.				CAA	1957
R-4	E-3	Fl	4" U.	14" C.T.	5" Bit.				FAA	1967
R-5	E-3	Rb	-	6" C.T.	13" PCC		400	345psi*	FAA	1962
1L-19R										
R-1	E-3	Fl	-	12" U.	3" Bit.				CAA	1949
R-2	E-3	Fl	4" U.	10" C.T.	4" Bit.				FAA	1960
R-3	E-3	Fl	4" U.	10" C.T.	3½" Bit.				CAA	1957
R-6	E-3	Fl	14" SS	17" C.T.	5" Bit.				FAA	1967
10L-28R										
R-2	E-3	Fl	4" U.	10" C.T.	4" Bit.				FAA	1960
R-3	E-3	Fl	4" U.	10" C.T.	3½" Bit.				CAA	1957
R-5	E-3	Rb	-	6" C.T.	13" PCC		400	345psi*	FAA	1962
TAXIWAY										
T-1	E-3	Fl	-	12" U.	3" Bit.				CAA	1951
T-2	E-3	Fl	4" U.	10" C.T.	4" Bit.				FAA	1960
T-3	E-3	Fl	4" U.	10" C.T.	3½" Bit.				CAA	1957
T-4	E-3	Fl	4" U.	14" C.T.	5" Bit.				FAA	1967
T-5	E-3	Rb	-	6" C.T.	13" PCC				FAA	1962
T-6	E-3	Fl	14" SS	17" C.T.	5" Bit.				FAA	1967
T-9	E-3	Rb	-	6" C.T.**	14" PCC				FAA	1967
T-12	E-3	Fl	-	15" U.	3" Bit.				CAA	1949
APRONS										
AP-1	E-3	Fl	-	12" U.	3" Bit.				CAA	1951
AP-2	E-3	Fl	4" U.	10" C.T.	4" Bit.				FAA	1960
AP-3	E-3	Fl	4" U.	10" C.T.	3½" Bit.				CAA	1957
AP-5	E-3	Rb	-	6" C.T.	13" PCC				FAA	1962
AP-6	E-3	Fl	14" SS	17" C.T.	5" Bit.				FAA	1967
AP-9	E-3	Rb	-	6" C.T.	14" PCC				FAA	1967
AP-10	E-3	Fl	4" U.	12" C.T.	4" Bit.				FAA	1960
AP-11	E-3	Fl	-	8" C.T.	8" Bit.				CAA	1951

REMARKS:

* Safety Factor = 1.74.
** Piers C & E are 14" PCC on 3½" cement treated base.

U - Untreated Base Crushed Aggregate.
CT - Cement Treated Crushed Aggregate.
SS - Stabilized Soil.

STATE Cal



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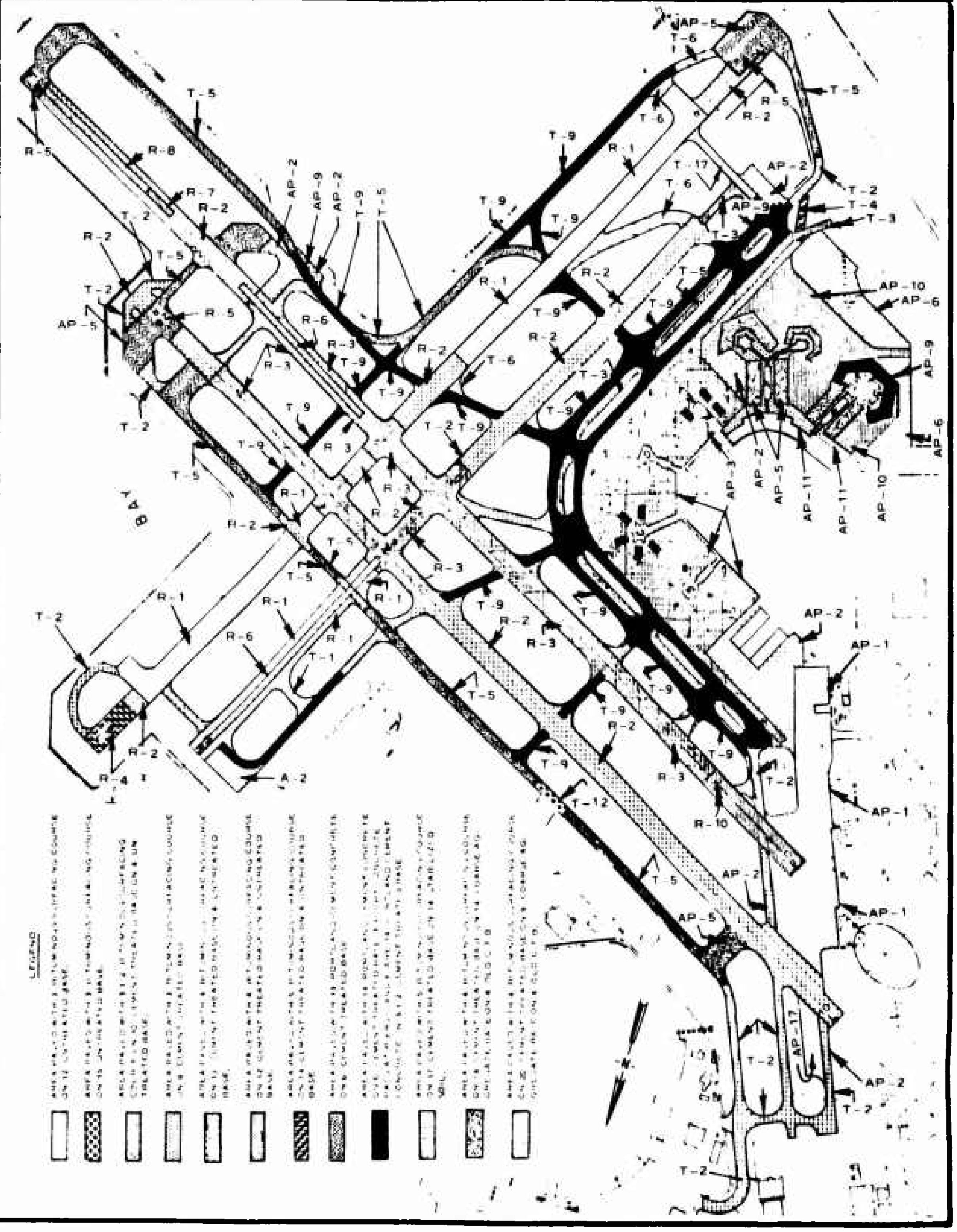
AIRPORT PAVEMENT CHARACTERISTICS

Table A2 (Continued)

MOD. SUBGRADE REAC. K	DESIGN ALLOW.	CONSTRUC. SPEC	YEAR
		CAA	1951
		FAA	1960
		CAA	1957
		FAA	1967
400	345psi*	FAA	1962
		CAA	1949
		FAA	1960
		CAA	1957
		FAA	1967
		FAA	1960
		CAA	1957
400	345psi*	FAA	1962
		CAA	1951
		FAA	1960
		CAA	1957
		FAA	1967
		FAA	1962
		FAA	1967
		FAA	1967
		CAA	1949
		CAA	1951
		FAA	1960
		CAA	1957
		FAA	1962
		FAA	1967
		FAA	1967
		FAA	1960
		CAA	1951

ase.

STATE	CITY	AIRPORT NAME	DATE
California	San Francisco	San Francisco International	Jan. '73



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AIRPORT PAVEMENT CHARACT

STATE Cali

I. D. NO.	SOIL CLASS.	SUB-GRADE CLASS	SUBBASE COURSE	BASE COURSE	SURFACE COURSE	OVERLAY	MOD. SUBGRADE REAC. K	DESIGN ALLOW.	CONSTRUC. SPEC	YEAR
— RUNWAYS —										
10R-28L										
R-2	E-3	Fl	4" U.	10" C.T.	4" Bit.				FAA	1960
R-3	E-3	Fl	4" U.	10" C.T.	3½" Bit.				CAA	1957
R-4	E-3	Fl	4" U.	14" C.T.	5" Bit.				FAA	1967
R-7	E-3	Fl	8" + 4" ①	20" C.T.	4" Bit.				FAA	1960
R-8	E-3	Fl	14"+ 4" ②	14" C.T.	4" Bit.				FAA	1960
R-10	E-3	Fl	4" U.	12" C.T.	4" Bit.				FAA	1960
— TAXIWAY —										
— APRONS —										

REMARKS: ①- 8" Coarse Aggregate Base on 4" old cement treated crushed aggregate base.
②- 14" Coarse Aggregate Base on 4" old cement treated crushed aggregate base.

U - Untreated crushed aggregate
C.T.- Cement treated crushed aggregate

P

Table A2 (Continued)

AIRPORT PAVEMENT CHARACTERISTICS

STATE	CITY	AIRPORT NAME	DATE
California	San Francisco	San Francisco International	Jan. '73

MOD. SUBGRADE REAC. K	DESIGN ALLOW.	CONSTRUC. SPEC	YEAR
		FAA	1960
		CAA	1957
		FAA	1967
		FAA	1960
		FAA	1960
		FAA	1960

l crushed aggregate base.
l crushed aggregate base.

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A

AIRPORT PAVEMENT CHARACTER

STATE Florid

I. D. NO.	SOIL CLASS.	SUB-GRADE CLASS	SUBBASE COURSE	BASE COURSE	SURFACE COURSE	OVERLAY	MOD. SUBGRADE REAC. K	DESIGN ALLOW.	CONSTRUC. SPEC	YEAR
—— RUNWAYS ——										
R-1	E1/E2	Fa	10"LR Stab.	8" LR	3" Bit.					
R-1A	E1/E2	Fa	10"LR Stab.	8" LR	3" Bit.	5" AC				1972
R-2	E1/E2	Fa	10"LR Stab.	10" LR	2" Bit.	6" AC				1972
R-2A	E1/E2	Fa	10"LR Stab.	8" LR	3" Bit.	5" AC				1972
R-3	E1/E2	Fa	-	12" LR	2" Bit.	6" AC				1972
R-4	E-3	F-2	10"LR Stab.	10" LR	2" Bit.	5" AC				1972
R-5	E-2	Ra	-	-	8" PCC	5" AC				1972
R-6	E1/E2	Fa	10"LR Stab.	10" LR	2" Bit.					
R-7	E1/E2	Fa	12" LR Stab.	12" LR	2" Bit.	5" AC *				1972
R-8	E1/E2	Fa	12" LR Stab.	10" LR	2" Bit.	6" AC **				1972
R-9	E1/E2	Fa	-	10" LR	2" Bit.	6" AC				1972
R-10	E1/E2	Fa	-	12" LR	2" Bit.					
R-11	E1/E2	Fa	-	10" LR	2" Bit.					
R-12	E1/E2	Fa	10" LR Stab.	8" LR	3" Bit.					
R-13	E1/E2	Ra	-	-	8" PCC					
R-14	E1/E2	Fa	12" LR Stab.	12" LR	2" Bit.					
—— TAXIWAY ——										
T-1	E1/E2	Fa	10"LR Stab.	8" LR	3" Bit.					
T-1A	E1/E2	Fa	10"LR Stab.	8" LR	3" Bit.					
T-1B	E1/E2	Fa	10"LR Stab.	8" LR	3" Bit.					
T-2	E-1	Fa	10" LR Stab.	10" LR	2" Bit.					
T-3	E1/E2	Fa	-	12" LR	2" Bit.					
T-3A	E1/E2	Fa	-	12" LR	2" Bit.					
T-4	E1/E2	Fa	10"LR Stab.	6" LR	DPST (1")					
T-5	E1/E2	Fa	10"LR Stab.	6" LR	2" Bit.					
T-6	E-1	Fa	-	12" LR	2-3/4" Bit.					
T-7	E-1	Fa	12"LR Stab.	9" LR	2" Bit.					
T-8	E-1	Fa	12" LR Stab.	12" LR	2" Bit.					
T-9	E-1	Fa	-	12" LR	4" Bit.	3" AC				1972
—— APRONS ——										
A-1	E1/E2	Ra	-	-	8" PCC	3" AC				
A-2	E1/E2	Fa	-	12" LR	2-3/4" Bit.					
A-3	E1/E2	Fa	-	12" LR	2" Bit.					
A-4	E-1	Fa	10"LR Stab.	6" LR	DPST (1")					
A-5	E-1	Ra	-	LR Stab.	8" PCC					
A-6	E-1	Fa	12"LR Stab.	9" LR	2" Bit.					
A-7	E1/E2	Ra	-	LR Stab.	6" PCC					
A-8	E-1	Ra	-	LR Stab.	10" PCC	3" AC				
A-9	E1/E2	Fa	8" LR Stab.	12" LR	2" Bit.					
A-10	E1/E2	Fa	12" LR Stab.	12" LR	2" Bit.					
A-11	E1/E2	Fa	12" LR Stab.	12" LR	2" Bit.	6" AC				1972
A-12	E1/E2	Fa	-	12" LR	2" Bit.	6" AC				1972

LR STAB. - Lime Rock Stabilized
AC - Asphaltic Concrete
Bit. - Bituminous Concrete

Note: Runway 12-30 is due to have a 3" asphalt concrete runway early in 1973.

* Overlay on 9L/27R is 6" AC.
** No overlay on 17/35.

B

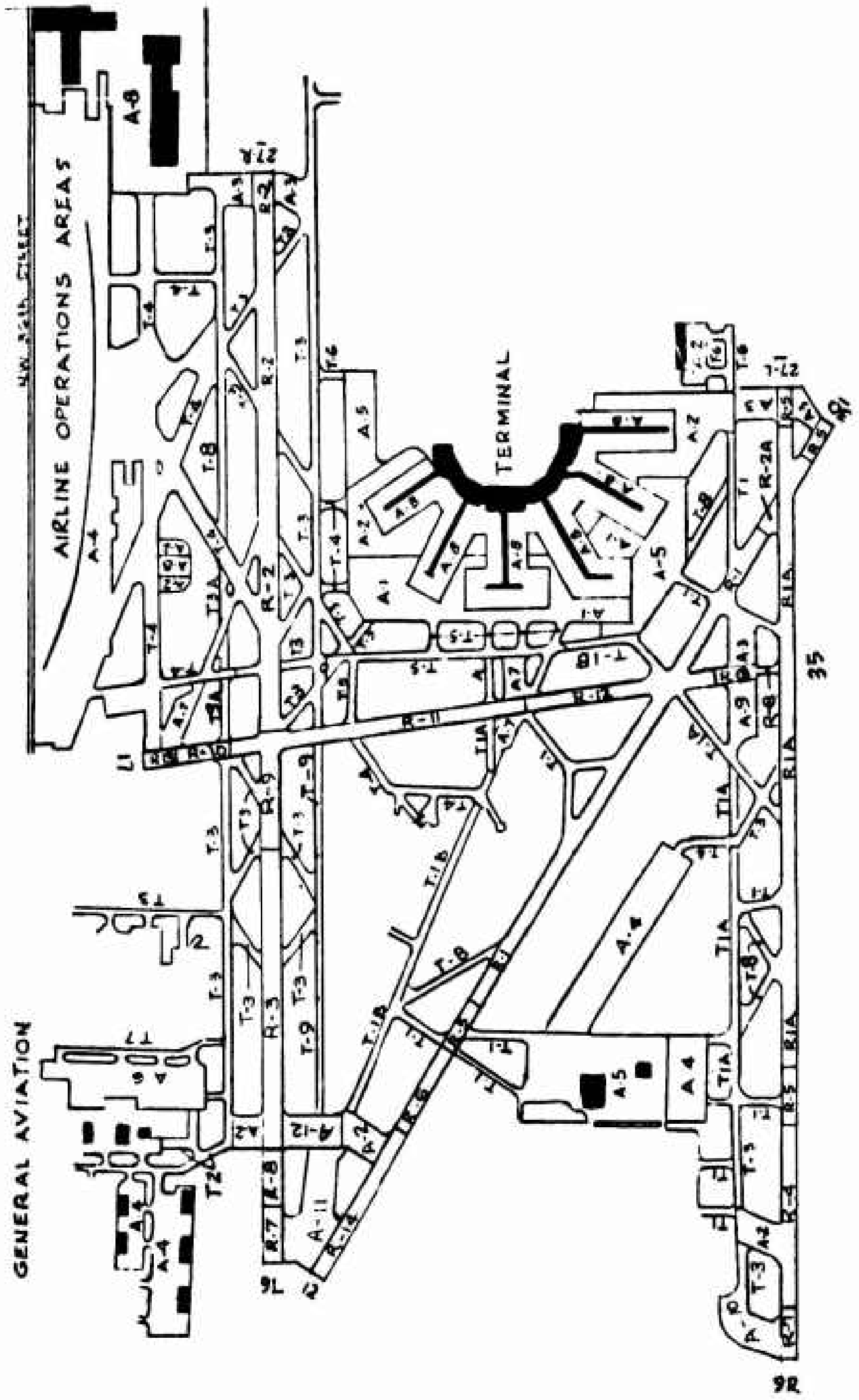
Table A2 (Continued)

RPORT PAVEMENT CHARACTERISTICS

IOD. GRADE EAC. K	DESIGN ALLOW.	CONSTRUC. SPEC	YEAR
			1972
			1972
			1972
			1972
			1972
			1972
			1972
			1972
			1972
			1972
			1972
			1972

/ early in 1973.

STATE	CITY	AIRPORT NAME	DATE
Florida	Miami	Miami International	Jan. '73



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AIRPORT PAVEMENT CHARACTE

STATE New Y

I. D. NO.	SOIL CLASS.	SUB-GRADE CLASS	SUBBASE COURSE	BASE COURSE	SURFACE COURSE	OVERLAY	MOD. SUBGRADE REAC. K	DESIGN ALLOW.	CONSTRUC. SPEC	YEAR
—— RUNWAYS ——										
4R-22L	E-1	Ra	6" SC	-	12" PCC	-	300	430psi	NYC	1959
4L-22R	E-1	Ra	6" SC	-	12" PCC	4"/8"Bit.	300	430psi	NYC	
13R-31L	E-1	Ra	6" SC	-	12" PCC	4"/8" Bit.	300	430psi		
East End	E-1	Ra	6" SC	-	12" PCC	4"/8" Bit.	300	430psi		
						+ 8" PCC				
13L-31R	E-1	Ra	-	-	12" PCC	6"/10"Bit.	300	430psi		
14-32	E-1	Ra	6" SC	8" PM	2" + 2"*	4"/6" Bit.				
4L Ext	E-1	Ra	6" SC	-	1[illegible]" PCC	-	300	430psi	NYC	1964
—— TAXIWAY ——										
I,O,OO										
Critical	E2/E3	F2	30" LS	8" LA	4" AC					
Non-crit.	E2/E3	F[illegible]	15" LS	[illegible]" LA	4" AC					
I',O'	E2	F1	22" LS	8" LA	4" AC					
E			6" SC	8" PM	2"+ 2" *	2/4" AC				
F			6" SC	8" PM	2"+ 2" *	4/6" AC				
G			6" SC	6" PM	3" AC	4/6" AC				
H-1			6" SC	6" PM	3" AC	3" AC				
H-2			6" SC	8" PM	2"+ 2" *	4" AC				
K,KK			6" SC	6" PM	2"+ 2" *					
UU			6" SC	6" PM	2"+ 2" *					
P,PP,PA, PB, PC,PD			6" SC	-	13" PCC					
Q-1			6" SC	8" PM	2"+ 2" *	4/6" AC				
Q-2			6" SC	6" PM	2"+ 2" *	4/6" AC				
R, S			6"SC+6"RS	10" PMM	2"+ 2" AC					
—— APRONS ——										
AP-1			6" SC		13"/14"PCC					
AP-2			6" SC	8" PM	2"+ 2" AC					
AP-3			6" SC	5" PM	2"+1½" AC					
AP-4			6" SC	6" PM	3" AC					
AP-5			6"SC+6"DBS	5"+ 5"PMM	2½"AC+1½"RTC					
AP-6			-	-	12" PCC					
AP-7			26" LS	8" LA	4" AC					
AP-8			6" SC	18" PM	4"+ 4" AC					

REMARKS:

SC - Stone Screening
DBM - Dry Bound Macadam
LS - Lime Cement Flyash Sand
LA - Lime Cement Flyash Aggregate
AC - Asphalt Concrete
PM - Penetrated Macadam
PMM - Plant Mix Macadam
DBS - Dry Broken Stone
RTC - Rubberized Tar Concrete

* 2" Asphalt Binder + 2" Asphalt

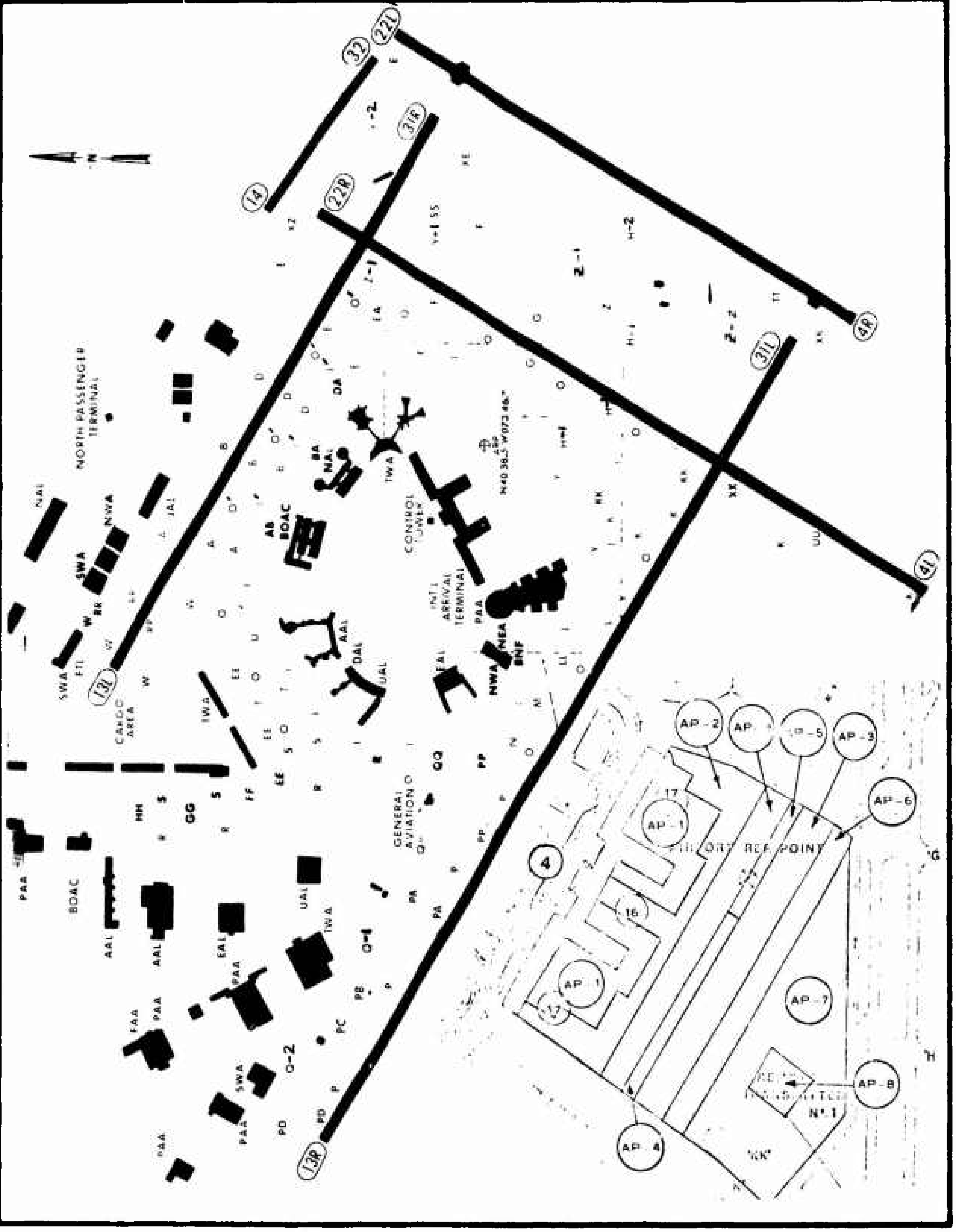
IRPORT PAVEMENT CHARACTERISTICS

Table A2 (Continued)

STATE New York **CITY** New York **AIRPORT NAME** John F. Kennedy International **DATE** Apr. '73

MOD. BGRADE REAC. K	DESIGN ALLOW.	CONSTRUC. SPEC	YEAR
300	430psi	NYC	1959
300	430psi	NYC	
300	430psi		
300	430psi		
300	430psi		
300	430psi	NYC	1964

Binder + 2" Asphalt



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AIRPORT PAVEMENT CHARACTERIS

STATE New York

I. D. NO.	SOIL CLASS.	SUB-GRADE CLASS	SUBBASE COURSE	BASE COURSE	SURFACE COURSE	OVERLAY	MOD. SUBGRADE REAC. K	DESIGN ALLOW.	CONSTRUC. SPEC	YEAR
— RUNWAYS —										
— TAXIWAY —										
TT,XK			6" SC	8" PM	2"+ 2" AC	8/10"AC				
XE			6" SC	-	12" PCC	4" AC				
Y-1			-	-	12" PCC					
Y-2			6" SC	-	12" PCC					
Z-1			-	-	12" PCC	2/4" AC				
Z-2			6" SC	8" PM	2"+ 2" AC	4/6" AC				
— APRONS —										

REMARKS:

SC - Stone Screening
PM - Penetrated Macadam
AC - Asphalt Concrete

B

AIRPORT PAVEMENT CHARACTERISTICS

Table A2 (Continued)

STATE New York | **CITY** New York | **AIRPORT NAME** John F. Kennedy International | **DATE** Apr. '73

MOD. SUBGRADE REAC. K	DESIGN ALLOW.	CONSTRUC. SPEC	YEAR

(Sheet 12 of 44)

A

AIRPORT PAVEMENT CHARACTER

STATE New Yo

I. D. NO.	SOIL CLASS.	SUB-GRADE CLASS	SUBBASE COURSE	BASE COURSE	SURFACE COURSE	OVERLAY	MOD. SUBGRADE REAC. K	DESIGN ALLOW.	CONSTRUC. SPEC	YEAR
					— RUNWAYS —					
13-31	E-3	F1	6" SC	6" PM	2"+ 2" ①	13" AC ②			PONYA	1973
4-22	E-3	F1	4½" SBM	7½" PM	2½" AC	③			PONYA	1972
					— TAXIWAY —					
T-1	E-3	F1	SBM	4½" PM	2½" AC	5" AC			PONYA	1972
T-2	E-3	F1	-	-	7" Concrete	5" AC			PONYA	1972
T-3	E-3	F1	6" SC	6" PM	2"+ 2" ①	5" AC			PONYA	1972
T-4	E-3	F1	SBM	4½" PM	2½" AC	④			PONYA	1973
T-5	-	-	6" SC	6" PM	2"+ 2" ①	4"/8" AC			PONYA	1971
T-6	-	-	6" SC	4" PM	2"+ 2" ①				PONYA	1960
T-7	E-3	F1	6" SC	4" PM	2"+ 2" ①	5" AC			PONYA	1973
T-8	E-3	F1	6" SC	4" PM	2"+ 2" ①	⑤			PONYA	1973
T-9	E-3	F1	6" SC	4" PM	2"+ 2" ①	5" AC			PONYA	1973
T-10	E-3	F1	6" SC	8" PMM	4"+ 3" ①				PONYA	1971
T-11	-	-	6" SC	6" PM	2" + 2" ①				PONYA	1960
T-12	E-3	F1	6" SC	8" PMM	4"+ 3" ①				PONYA	1971
T-13	-	-	6" SC	4" PM	2"+ 2" ①				PONYA	1960
T-14	-	-	6" SC	6" PM	2"+ 2" ①				PONYA	1960
					— APRONS —					
A	-	-	-	-	7"Concrete	AC (Unknown thickness)				1938
B1	E-3	F1	SBM	4½" PM	2½" AC	⑥ + 6"AC			PONYA	1971
B2	E-3	F1	6" SC	6" PM	2"- 2" ①	6" AC			PONYA	1971
B3	E-3	F1	6" SC	4" PM	2"+ 2" ①	6" AC			PONYA	1971
C1	-	-	SBM	4½" PM	2½" AC	⑥			PONYA	1960
C2	-	-	6" SC	6" PM	2"+ 2" ①				PONYA	1960
C3	-	-	6" SC	4" PM	2"+ 2" ①				PONYA	1960
D1	-	-	SBM	4½" PM	2½" AC	⑥			PONYA	1960
D2	-	-	-	-	-	⑥			PONYA	1960
E-1	-	-	SBM	4½" PM	2½" AC	AC (unknown thickness)				1938

REMARKS:

SC - Stone Screening

PM - Penetrated Macadam

PMM - Plant Mix Macadam

AC - Asphaltic Concrete

SBM - Selected Base Material

(1) Asphalt binder + asphalt top course.
(2) 5" AC (1969) + 8" AC (1973).
(3) 8/20" PM + 2" Binder + 2" AC top course (1960) + 5" AC (1972).
(4) 2" PM + 2" AC Binder + 2" AC top course (1960) + 3" AC (1973).
(5) 4" to 8" AC (1971) + 5" AC (1973).
(6) 6" SC + 4" PM + 2" AC Binder + 2" AC top course.

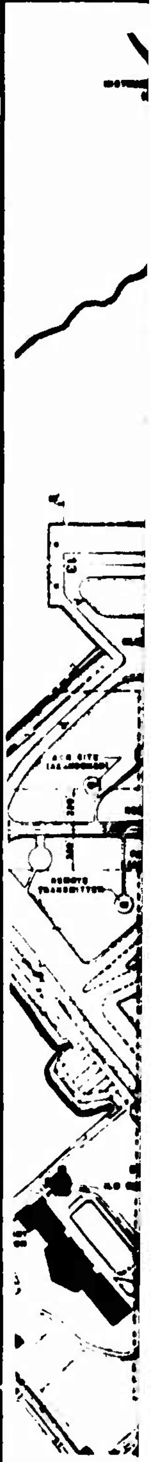

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Table A2 (Continued)

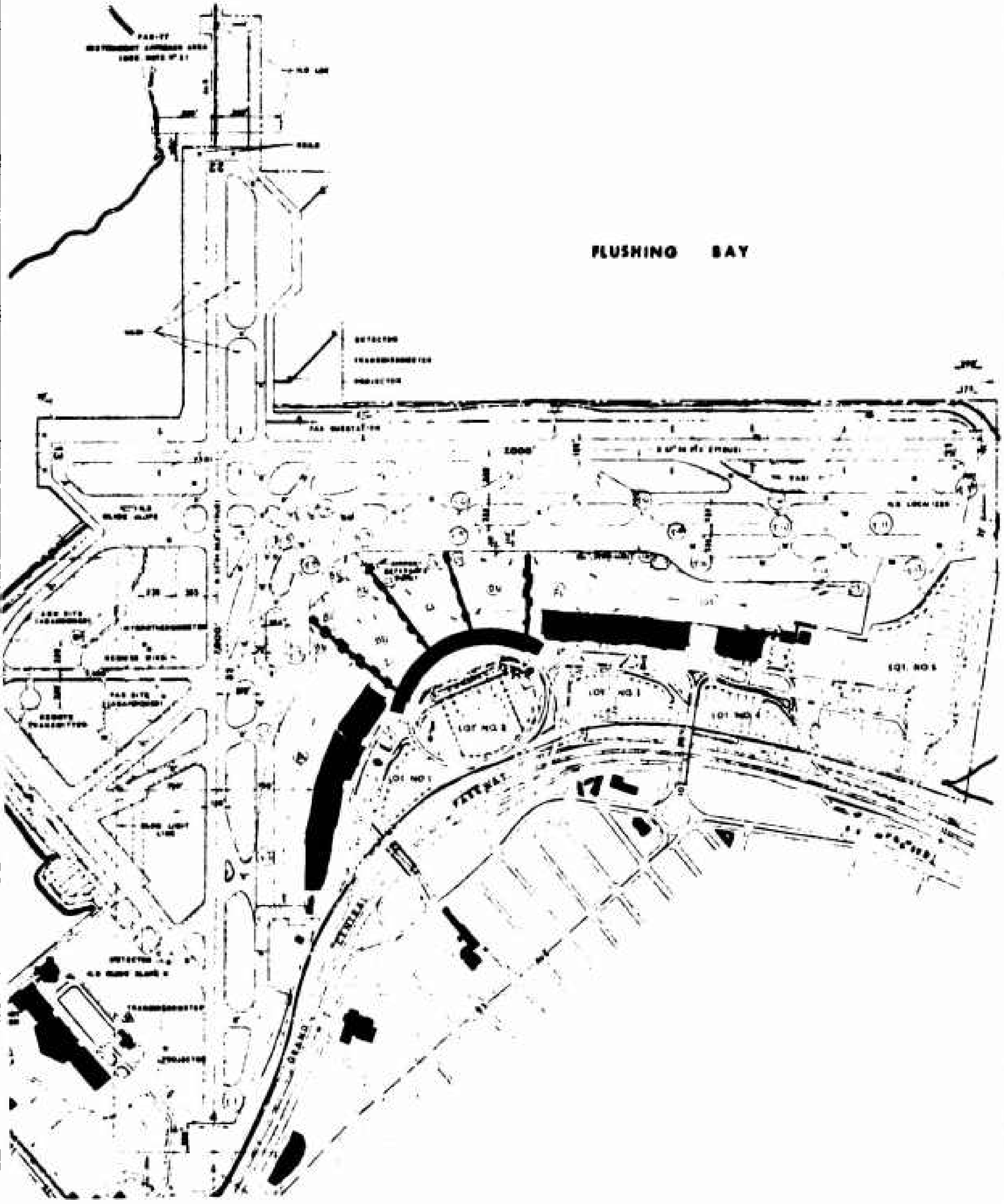
IRPORT PAVEMENT CHARACTERISTICS

MOD. UBGRADE REAC. K	DESIGN ALLOW.	CONSTRUC. SPEC	YEAR
		PONYA	1973
		PONYA	1972
		PONYA	1972
		PONYA	1972
		PONYA	1972
		PONYA	1973
		PONYA	1971
		PONYA	1960
		PONYA	1973
		PONYA	1973
		PONYA	1973
		PONYA	1971
		PONYA	1960
		PONYA	1971
		PONYA	1960
		PONYA	1960
n thickness)			1938
		PONYA	1971
		PONYA	1971
		PONYA	1971
		PONYA	1960
		PONYA	1960
		PONYA	1960
		PONYA	1960
		PONYA	1960
n thickness)			1938

Concrete
Base Material

2).
3).

STATE New York
CITY New York
AIRPORT NAME La Guardia
DATE Apr. '73



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AIRPORT PAVEMENT CHARACTERI

STATE Jers

I. D. NO.	SOIL CLASS.	SUB-GRADE CLASS	SUBBASE COURSE	BASE COURSE	SURFACE COURSE	OVERLAY	MOD. SUBGRADE REAC. K	DESIGN ALLOW.	CONSTRUC. SPEC	YEAR
RUNWAYS										
11/29										
R-1	*	*	*	*	*	6"/18"AC			PONYA	
4R/22L										
R-2	E-2	Fl	8"LC+14"LB	8" LA	4" AC&B				PONYA	1973
R-3	E-1	Fl	6"LC+14" LB	8" LA	4" AC&B				PONYA	1973
R-4	E-2	Fl	14" LB	3" LA	4" AC&B				PONYA	1973
4L/22R										
R-5	E-2	Fa	6"LC+16"LB	8" LA	4" AC&B				PONYA	1973
R-6	E-2	Fa	6"LC+14"LB	8" LA	4" AC&B				PONYA	1973
R-7	E-2	Fa	6"LC+ 8"LB	8" LA	4" AC&B				PONYA	1973
TAXIWAY										
T-1	E-2	Fa	6"LC+14"LB	8" LA	4" AC&B				PONYA	1973
T-2	E-2	Fa	8"LC+14"LB	8" LA	4" AC&B				PONYA	1973
T-3	E-2	Fa	6"LC+8" LB	8" LA	4" AC&B				PONYA	1973
T-4	E-2	Fa	6"LC+16"LB	8" LA	4" AC&B				PONYA	1973
T-5	E-2	Fa	14" LB	8" LA	4" AC&B				PONYA	1973
T-6	E-1	Fa	-	7" PM	3½" AC	6" AC&B			PONYA	1973
T-7	*	*	*	*	*	6" AC&B			PONYA	1973
T-8	*	*	*	*	*	3" AC			PONYA	1962
T-9	E-2	Fa	6" SC	5" PM	3½" AC	3" AC			PONYA	
APRONS										
A-1	E-2	Fa	8"LC+16"LB	8" LA	4" AC&B				PONYA	1973
A-2	E-2	Fa	6"LC+16"LB	8" LA	4" AC&B				PONYA	1973
A-3	E-2	Fa	8"LC+14"LB	8" LA	4" AC&B				PONYA	1973
A-4	*	*	*	*	*	3" AC				
A-5	*	*	*	*	*					
A-6	E-1	Fl	6" SC	6" SC	11" PCC					
A-7	E-1	Fl	6" SC	3" PM	2" AC					
A-8	E-1	Fl	6" SC	5" PM	3½" AC					

REMARKS:
AC&B - Asphalt Concrete and binder or leveling course
PM - Penetrated Macadam
SC - Stone screening
PCC - Portland Cement Concrete.

Composition of lime cement flyash by % of weight:

	Hydrated Lime	Cement	Flyash	Aggregate	Fill Sand
LA	3.6	.9	10	30	55.5
LB	3.2	.8	12	-	84.0
LC	2.8	.7	12	-	84.5

* Sections of original pavement was constructed several years ago and are unknown to present operator.

NOTE: Only critical sections presented.

R

Table A2 (Continued)

RPORT PAVEMENT CHARACTERISTICS

IOD. GRADE EAC. K	DESIGN ALLOW.	CONSTRUC. SPEC	YEAR
		PONYA	
		PONYA	1973
		PONYA	1973
		PONYA	1973
		PONYA	1973
		PONYA	1973
		PONYA	1973
		PONYA	1973
		PONYA	1973
		PONYA	1973
		PONYA	1973
		PONYA	1973
		PONYA	1973
		PONYA	1973
		PONYA	1962
		PONYA	
		PONYA	1973
		PONYA	1973
		PONYA	1973

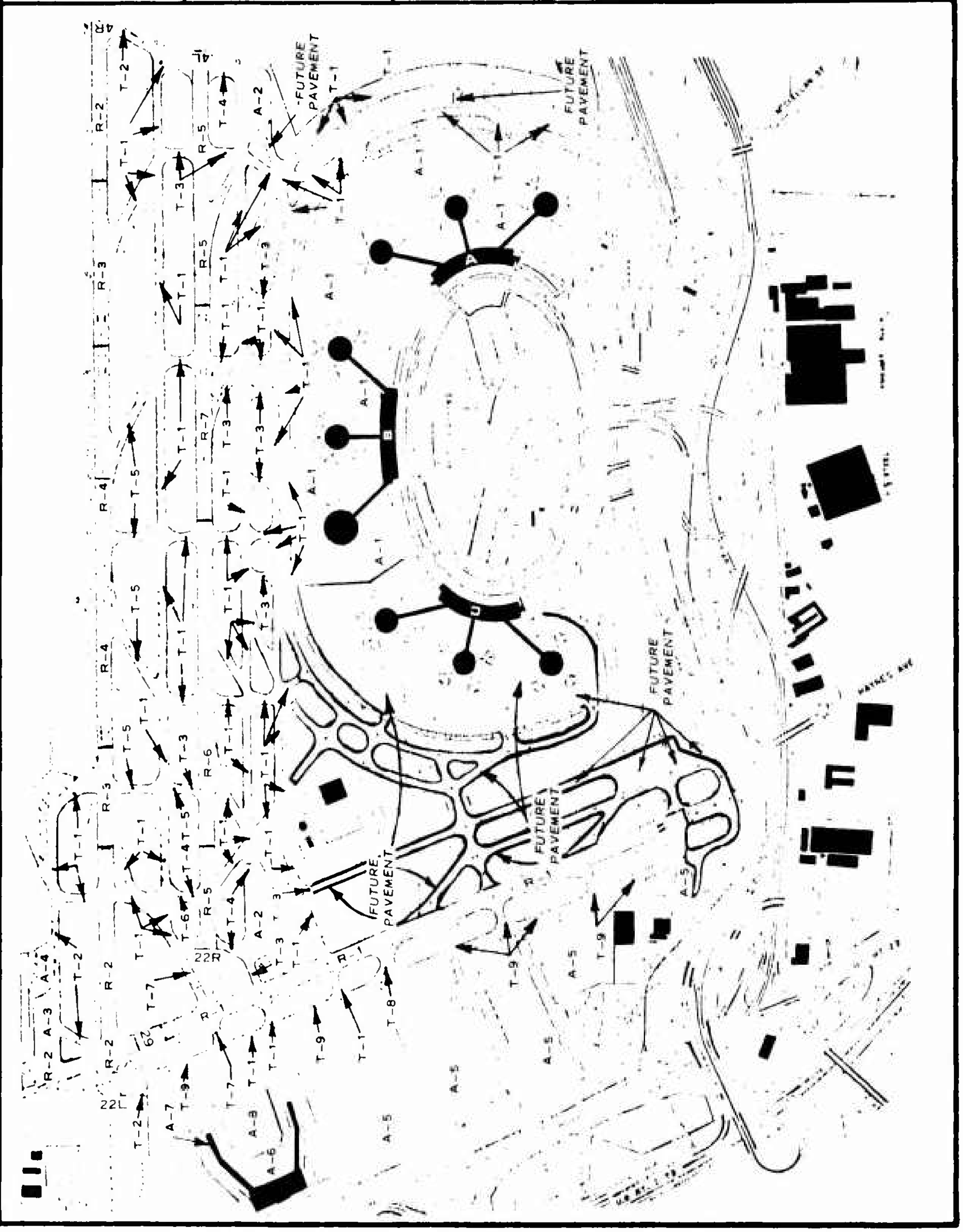
SC - Stone screening

PCC - Portland Cement Concrete.

gate	Fill Sand
	55.5
	84.0
	84.5

and are unknown to

STATE New Jersey **CITY** Newark **AIRPORT NAME** Newark **DATE** Apr.'73



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A

AIRPORT PAVEMENT CHARACT

STATE Col

I. D. NO.	SOIL CLASS.	SUB-GRADE CLASS	SUBBASE COURSE	BASE COURSE	SURFACE COURSE	OVERLAY	MOD. SUBGRADE REAC. K	DESIGN ALLOW.	CONSTRUC. SPEC	YEAR
					— RUNWAYS —					
R-1	E-6	F6	10" SAM	10" CA	3" AC	7" AC			FAAP-32	1969
R-2	E-5	F5	10" SAM	10" CA	3" AC	7" AC			FAAP-32	1969
R-3	E-6	F6	15" SAM	10" CA	3" AC	7" AC			FAAP-32	1969
R-4	E-6	F6	15" SAM	10" CA	3" AC	7" AC			FAAP-32	1969
R-5	E-5	F5	10" SAM	10" CA	3" AC	7" AC			FAAP-32	1969
R-6	E-7	F7	10" SAM	13" AC	4" AC				ADAP-02	1972
R-7	E-2	Ra	-	-	12" PCC		200	600 psi	FAAP-26	1962
R-8	E-2	Ra	-	-	10" PCC		200	600 psi	FAAP-06	1962
R-9	E-7	Rc	24" SAM	6" CA	12" PCC		200	600 psi	CITY	1969
R-10	E-7	Rc	24" SAM	6" CA	12" PCC		200	600 psi	CITY	1969
R-11	E-7	F7	-	25" AC	4" AC				ADAP-02	1972
					— TAXIWAY —					
T-1	E-6	F6	10" SAM	5" CA	2" AC				USED	1944
T-2	E-6	F6	10" SAM	8" CA	2" AC				USED	1944
T-3	E-3	F3	6" SAM	10" CA	3" AC				FAAP-801	1948
T-4	E-6	F6	10" SAM	7" CA	3" AC				USED	1944
T-5	E-7	F7	15" SAM	10" AC	4" AC					1972
T-6	E-6	F6	10" SAM	7" CA	3" AC				USED	1944
T-7	E-6	F6	10" SAM	7" CA	2" AC				USED	1945
T-8	E-7	Rc	3" SAM		12" PCC		200	600 psi	FAAP-22	1963
T-9	E-7	F7	-	16" CA	4" AC				FAAP-22	1963
T-10	E-2	Ra	-		12" PCC		200	600 psi	FAAP-26	1962
T-11	E-7	F7	7" SAM	8" CA	3" AC				FAAP-29	1967
T-12	E-7	F7	-	25" AC	4" AC				ADAP-02	1972
					— APRONS —					
A-1	E-6	Rc	-		12"/8" PCC				USED	1943
A-2	E-6	F6	8" SAM	11" CA	3" AC				FAAP-619	1957
A-3	E-4	F4	-	10" CA	3" AC				FAAP-28	1965
A-4	E-7	F7	8½" SAM	8½" CA	3" AC				FAAP-28	1965
A-5	E-6	Rc	3" SAM		12" PCC		300	200 psi*	FAAP-27	1963
A-6	E-2	Ra	3" SAM		12" PCC		300	200 psi*	CITY	1961
A-7	E-2	Ra	-		13" PCC		300	200 psi*	VAL	1967
A-8	E-6	Rc	6" SAM		12" PCC		300	200 psi	FAAP-29	1966
A-9	E-5	Rb	8" SAM		12" PCC				FAAP-31	1969

REMARKS:

* Safety Factor 1.75

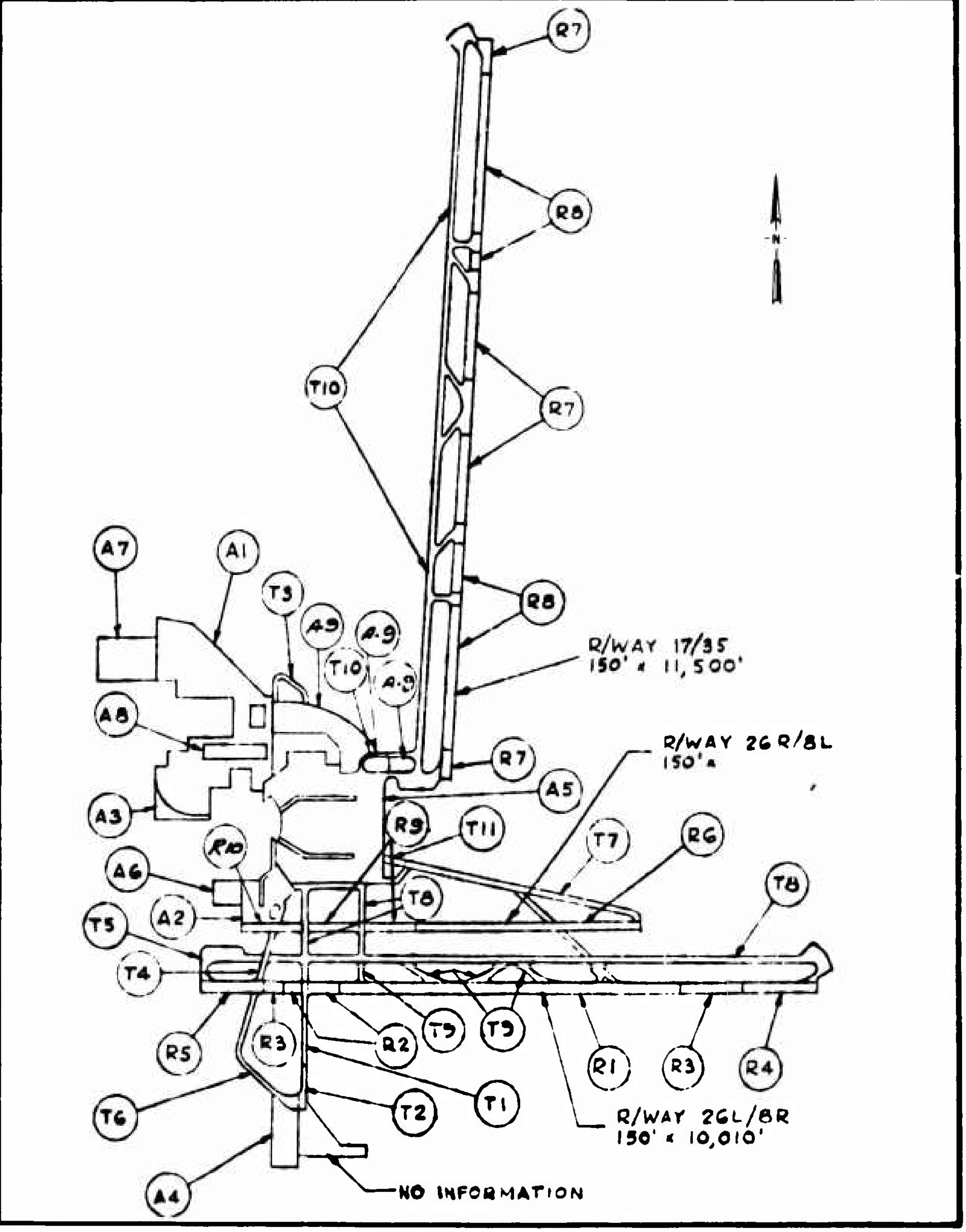
SAM - Selected Aggregate Material
CA - Crushed Aggregate
AC - Asphaltic Concrete

AIRPORT PAVEMENT CHARACTERISTICS

Table A2 (Continued)

STATE Colorado **CITY** Denver **AIRPORT NAME** Stapleton International **DATE** Jan. '73

MOD. SUBGRADE REAC. K	DESIGN ALLOW.	CONSTRUC. SPEC	YEAR
		FAAP-32	1969
		FAAP-32	1969
		FAAP-32	1969
		FAAP-32	1969
		FAAP-32	1969
		ADAP-02	1972
200	600 psi	FAAP-26	1962
200	600 psi	FAAP-06	1962
200	600 psi	CITY	1969
200	600 psi	CITY	1969
		ADAP-02	1972
		USED	1944
		USED	1944
		FAAP-801	1948
		USED	1944
			1972
		USED	1944
		USED	1945
200	600 psi	FAAP-22	1963
		FAAP-22	1963
200	600 psi	FAAP-26	1962
		FAAP-29	1967
		ADAP-02	1972
		USED	1943
		FAAP-619	1957
		FAAP-23	1965
		FAAP-23	1965
300	200 psi*	FAAP-27	1963
300	200 psi*	CITY	1961
300	200 psi*	UAL	1967
300	200 psi	FAAP-29	1966
		FAAP-31	1969



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AIRPORT PAVEMENT CHARACTER

STATE Massach

I. D. NO.	SOIL CLASS.	SUB-GRADE CLASS	SUBBASE COURSE	BASE COURSE	SURFACE COURSE	OVERLAY	MOD. SUBGRADE REAC. K	DESIGN ALLOW.	CONSTRUC. SPEC	YEAR
— RUNWAYS —										
4L-22R										
A	E-7	F7	30" Gravel	4½",6" ②	2½" Bit.C	1¼",VAR ⑧			FAAP & MPA	1969
B	E-7	F7	30" Gravel	4½",6" ②	2½" Bit.C				FAAP	1950
C	E-7	F7	30" Gravel	4½",6" ②	2½" Bit.C	3", 1½", 3" ①			FAAP	1961
D	E-7	F7	30" Gravel	4½",6" ②	2½" Bit.C	3", 3", 5" ①			FAAP	1961
E	E-7	F7	30" Gravel	4½",6" ②	2½" Bit.C	3",1½",3" ①			FAAP	1961
15R-33L										
A	E-7	F7	30" Gravel	4½",6" ②	2½" Bit.C	3",3",6" ③			FAAP	1963
B	E-7	F7	30" Gravel	4½",6" ②	2½"Bit.C	3",3",5" ③			FAAP	
C	E-7	F7	20" P-154	4",11" ④	4" P-401	-			FAAP	1969
D	E-1	Fa	3" P-208	4", 5" ⑤	4" P-401	-			FAAP	1969
E	E-1	Fa	5", 3" ⑦	4", 5" ⑤	4" P-401	-			FAAP	1969
— TAXIWAY —										
South a	E-7	F7	24" Gravel	4", 8" ②	3" P-401	-			FAAP	1963
b	E-7	F7	30" Gravel	4½",6" ⑥	2½" P-401	-			FAAP	1970
S Apron	E-7	F7	24" Gravel	4",8" ②	3" P-401	-			-	-
S a	E-7	F7	30" Gravel	4½",6" ②	2½" P-401	4" P-401			MPA	1969
S b	E-7	F7	30" Gravel	4½",6" ②	2½" P-401	3", 1½", 5" ①			FAAP	1969
C a	E-7	F7	30" Gravel	4½",6" ②	2½" P-401	4" P-401			-	-
C b	E-7	F7	30" Gravel	4½",6" ⑥	2½" P-401	3", 1½", 3" ①			FAAP	1961
C c	E-7	F7	30" Gravel	4½",6" ②	2½" P-401	3", 3",5" ①			FAAP	1960
N	E-7	F7	30" Gravel	4½",6" ②	2½" P-401	4", VAR ⑧			MPA	1970
N Wide	E-7	F7	30" Gravel	4", 8" ⑤	4" P-401	-			MPA	1970
T	E-7	F7	Exist.Gravel	4", 8" ②	3" P-401	-			FAAP	1960
E	E-6	F6	24" Gravel	4", 8" ②	3" P-401	-			FAAP	1966
F	E-6	F6	24" Gravel	4", 8" ②	3" P-401	-			FAAP	1966
G	E-6	F6	24" Gravel	4", 8" ②	3" P-401	-			FAAP	1966
D	E-7	F7	30" Gravel	4½", 6" ②	2½" P-401	4" P-401			-	-
— APRONS —										
A	E-7	F7	22" P-154	4" P-205	3" P-401	-			FAAP	1963
B	E-7	Rc	17" P-154	-	15" PCC	-	300		FAAP	1963
C	E-7	Rc	17" P-154	-	15" PCC	-	300		FAAP	1966
D	E-7	F7	24" P-154	8",8" ②	3" P-401	-			FAAP	1966
E	E-7	F7	24" P-154	8",8" ②	3" P-401	-			FAAP	1971
G	E-7	F7	Gravel	4½",6" ②	2½" P-401	-			FAAP	1957
H	E-7	F7	12" Gravel	-	12" PCC	-	300		FAAP	1957
I	E-7	F7	24" Gravel	-	12" PCC	-	300		FAAP	1960
J	E-7	F7	Gravel	4", 8" ②	3" P-401	-			FAAP	1960
K	E-1	F1	17" Gravel	4", 6" ⑤	3" P-401	-			FAAP	1966
L	E-7	F7	24" Gravel	4", 8" ②	3" P-401	-			FAAP	1966

REMARKS:

Bit.C - Bituminous Concrete
VAR - Variable Thickness
A - Apron

1. P-401; P-201; P-214
2. P-214; P-205
3. Bit.C; P-201, P-214
4. P-214; P-208; P-209
5. P-214; P-209
6. P-214; P-204
7. P-209; P-208
8. P-401; P-201

Runway
Runway
Runway
Runway
Runway

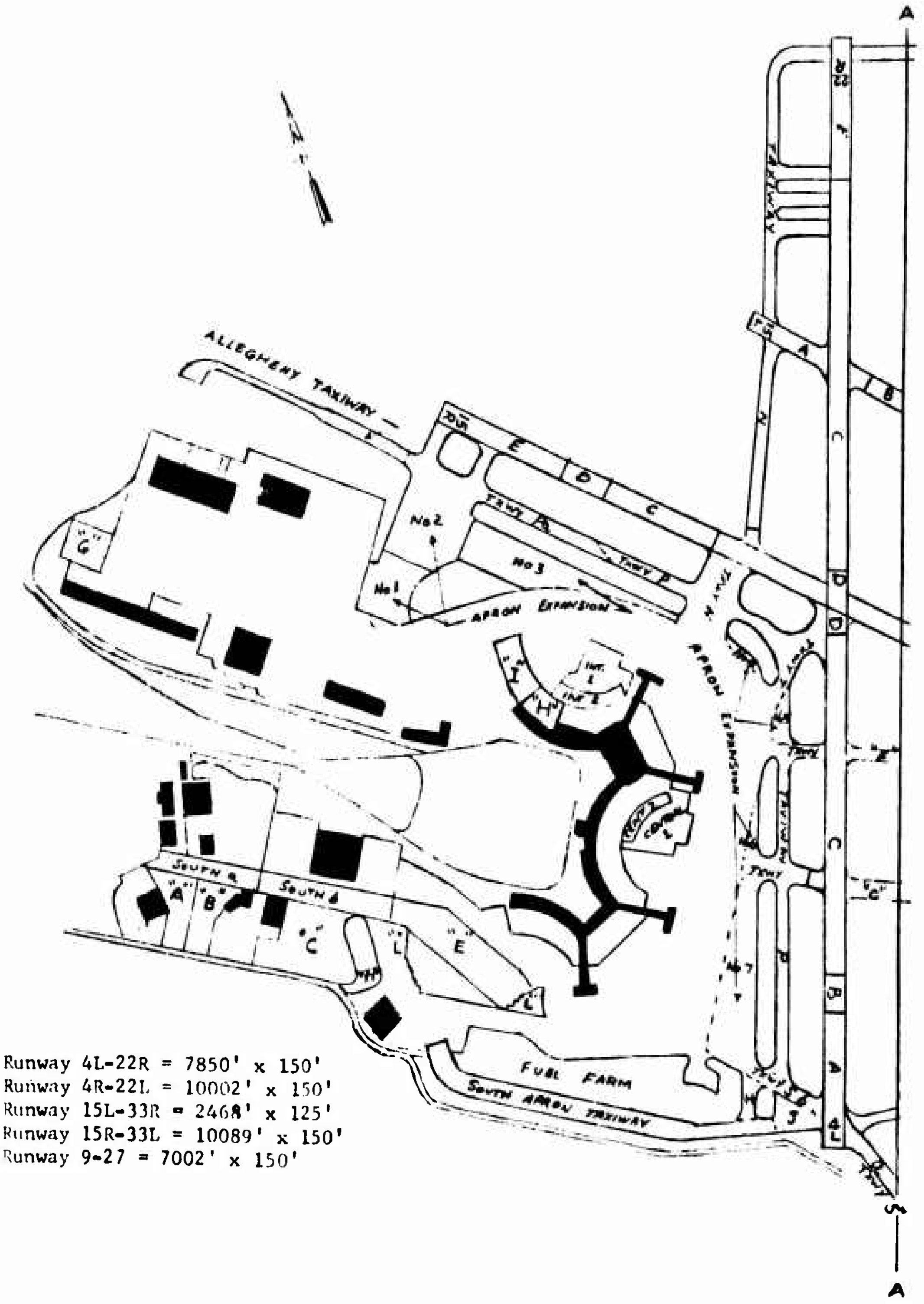
3

Table A2 (Continued)

RPORT PAVEMENT CHARACTERISTICS

STATE Massachusetts | **CITY** Boston | **AIRPORT NAME** Logan International | **DATE** Jan. '73

D. RADE AC.	DESIGN ALLOW.	CONSTRUC. SPEC	YEAR
		FAAP &	1969
		MPA	
		FAAP	1950
		FAAP	1961
		FAAP	1961
		FAAP	1961
		FAAP	1963
		FAAP	
		FAAP	1969
		FAAP	1969
		FAAP	1969
		FAAP	1963
		FAAP	1970
		-	-
		MPA	1969
		FAAP	1969
		-	-
		FAAP	1961
		FAAP	1960
		MPA	1970
		MPA	1970
		FAAP	1960
		FAAP	1966
		FAAP	1966
		FAAP	1966
		-	-
		FAAP	1963
		FAAP	1963
		FAAP	1966
		FAAP	1966
		FAAP	1971
		FAAP	1957
		FAAP	1957
		FAAP	1960
		FAAP	1960
		FAAP	1966
		FAAP	1966



Runway 4L-22R = 7850' x 150'
Runway 4R-22L = 10002' x 150'
Runway 15L-33R = 2468' x 125'
Runway 15R-33L = 10089' x 150'
Runway 9-27 = 7002' x 150'

(Sheet 16 of 44)

AIRPORT PAVEMENT CHARACTE

STATE
Massachu

I. D. NO.	SOIL CLASS.	SUB-GRADE CLASS	SUBBASE COURSE	BASE COURSE	SURFACE COURSE	OVERLAY	MOD. SUBGRADE REAC. K	DESIGN ALLOW.	CONSTRUC. SPEC	YEAR
RUNWAYS										
4R-22L										
A	E-7	F7	30" Gravel	4",6" ①	2½" Bit.C	3", 4" ③			FAAP	1961
B	E-7	F7	30" Gravel	4½",6" ②	2½" Bit.C	3", 4" ③			ADAP	1961
C	E-7	F7	30" Gravel	4½",6" ②	2½" Bit.C	3",1½",3" ④			ADAP	1961
D	E-7	F7	30" Gravel	4½",6" ②	2½" P-401	4" P-401			FAAP	1950
E	E-7	F7	30" Gravel	4½",6" ②	2½" P-401	3",3",5" ④			FAAP	1960
F	E-7	F7	30" Gravel	4½",6" ②	2½" P-401	3",3",5" ④			FAAP	1960
G	E-7	F7	30" Gravel	4½",6" ②	2½" P-401	-			FAAP	1950
H	E-7	F7	30" Gravel	4½",6" ②	2½" P-401	-			FAAP	1950
TAXIWAY										
P	E-7	F7	20" P-154	4",11" ⑤	4" P-401	-			FAAP	1969
Pa	E-1	Fa	5",3" ⑥	4" P-214	4" P-401	-			-	-
H	E-7	F7	26" P-154	4", 8" ⑦	4" P-401	-			MPA	1970
J	E-7	F7	26" P-154	4", 8" ⑦	4" P-401	-			MPA	1970
Alleg.	E-6	F6	24" P-154	4", 8" ⑦	4" P-401	-			MPA	1969
APRONS										
Xpan.1, 3,4,5,6,7	E-7	F7	20" P-154	4",11" ⑤	4" P-401	-			FAAP	1969
Expan. 2	E-1	Fa	3" P-208	4",5" ⑧	4" P-401	-			FAAP	1969
Int.2 & Cent.3	E-7	F7	Compacted	-	14" PCC	-	300		MPA	1969

REMARKS:

1. P-214; P-204
2. P-214; P-205
3. Bit.C; P-401
4. P-401; P-201; P-214
5. P-214; P-208, P-209
6. P-209; P-208
7. P-214; P-208
8. P-214; P-209

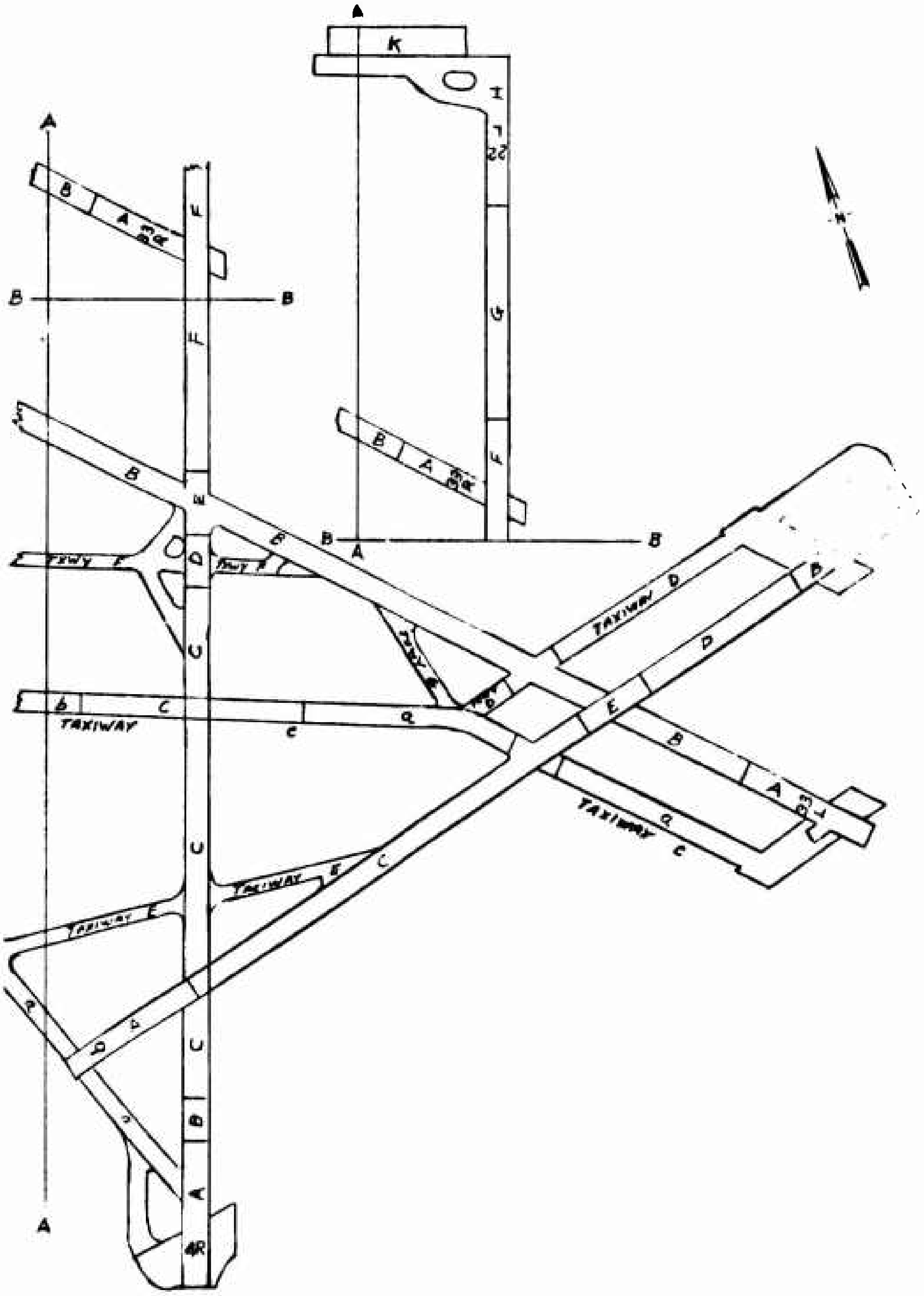
P

Table A2 (Continued)

AIRPORT PAVEMENT CHARACTERISTICS

STATE Massachusetts | CITY Boston | AIRPORT NAME Logan International | DATE Jan. '73

MOD. SUBGRADE REAC. K	DESIGN ALLOW.	CONSTRUC. SPEC	YEAR
		FAAP	1961
		ADAP	1961
④		ADAP	1961
		FAAP	1950
④		FAAP	1960
④		FAAP	1960
		FAAP	1950
		FAAP	1950
		FAAP	1969
		-	-
		MPA	1970
		MPA	1970
		MPA	1969
		FAAP	1969
		FAAP	1969
300		MPA	1969



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AIRPORT PAVEMENT CHARACTE

STATE
Massachus

I. D. NO.	SOIL CLASS.	SUB-GRADE CLASS	SUBBASE COURSE	BASE COURSE	SURFACE COURSE	OVERLAY	MOD. SUBGRADE REAC. K	DESIGN ALLOW.	CONSTRUC. SPEC	YEAR
— RUNWAYS —										
15L-33R										
A	E-7	F7	30" Gravel	4½",6" ①	2½" P-401	-			FAAP	1951
B	E-7	F7	30" Gravel	4½",6" ①	2½" P-401	-			FAAP	1951
9-27										
A	E-7	F7	30" Gravel	4½",6" ①	2½" P-401	3",1½",3" ②			FAAP	1961
B	E-7	F7	30" Gravel	4½",6" ①	2½" P-401	-			FAAP	1951
C	E-7	F7	30" Gravel	4½",6" ①	2½" P-401	3",1½",3" ②			FAAP	1961
D	E-7	F7	30" Gravel	4½",6" ①	2½" P-401	1½",VAR ③			FAAP	1951
E	E-7	F7	30" Gravel	4½",6" ①	2½" P-401	3",1½",5" ②			FAAP	1960
— TAXIWAY —										
— APRONS —										

REMARKS:

VAR - Variable Thickness

1. P-214; P-205
2. P-401; P-201; P-214
3. P-401; P-201

B

Table A2 (Continued)

ORT PAVEMENT CHARACTERISTICS

STATE	CITY	AIRPORT NAME	DATE
Massachusetts	Boston	Logan International	Jan. '73

ADE	DESIGN ALLOW.	CONSTRUC. SPEC	YEAR
		FAAP	1951
		FAAP	1951
		FAAP	1961
		FAAP	1951
		FAAP	1961
		FAAP	1951
		FAAP	1960

(Sheet 18 of 44)

9

AIRPORT PAVEMENT CHARACT

STATE Penn

I. D. NO.	SOIL CLASS.	SUB-GRADE CLASS	SUBBASE COURSE	BASE COURSE	SURFACE COURSE	OVERLAY	MOD. SUBGRADE REAC. K	DESIGN ALLOW.	CONSTRUC. SPEC	YEAR
— RUNWAYS —										
9R-27L	(See note below)									
Critical:										
	E1/E2	F-1	3" SM ①	8" Bit.	②					
Non-Critical:										
	E1/E2	F-1	8" SM ①	3" Bit.	②					
9L-27R	(See note below)									
Critical-					12"-20"Bit C.					
Non-Crit.-					3"-8" Bit C.					
Exten.	E1/E2	F-1	SM	11" WB Mac.	2" Bit.					
— TAXIWAY —										
9R-27L	(See note below)									
Critical:										
	E1/E2	F-1	3" SM 1	8" Bit.	②					
Non-Critical:										
	E1/E2	F-1	7" SM ①	3" Bit.	②					
T-1	E1/E2	F-1	SM	11" WB Mac.	2" Bit.					
T-2			35" SM	8" Bit.	③					
— APRONS —										
Primary	(See note below)									
Apron			Var. Material		12" PCC					

REMARKS: SM - Selected Material Bit. C. - Bituminous Concrete WB Mac.- Water Bound Macadam.

① Pennsylvania Department of Highways standard base course.
② $3\frac{1}{2}$" Binder Bituminous $1\frac{1}{2}$"Surface Bituminous.
③ $2\frac{1}{2}$" Binder Bituminous + $1\frac{1}{2}$" Surface Bituminous.

NOTE: Unable to obtain reliable data on Philadelphia International. Current pavement composition are very complex and the information is not readily available. The above data was obtained by telephone conversation with Harold Taylor, Engineer at Phila. Int'l. 90% of current pavements (excluding the new runway) is planned for major improvement by 1975.

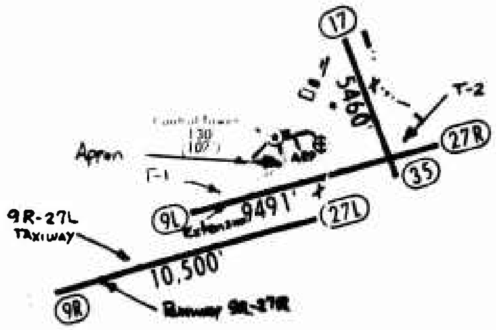
B

Table A2 (Continued)

IRPORT PAVEMENT CHARACTERISTICS

STATE	CITY	AIRPORT NAME	DATE
Pennsylvania	Philadelphia	Philadelphia International	Jan. '73

MOD. BGRADE REAC. K	DESIGN ALLOW.	CONSTRUC. SPEC	YEAR



rete WB Mac.- Water Bound Macadam.

nal. Current pavement com-
ily available. The above data
, Engineer at Phila. Int'l.

anned for major improvement

(Sheet 19 of 44)

A

AIRPORT PAVEMENT CHARA

STATE

I. D. NO.	SOIL CLASS.	SUB-GRADE CLASS	SUBBASE COURSE	BASE COURSE	SURFACE COURSE	OVERLAY	MOD. SUBGRADE REAC. K	DESIGN ALLOW.	CONSTRUC. SPEC	YEAR
					— RUNWAYS —					
3	E-7	Rc	-	-	7" PCC	7"/8" PCC			WPA-City	1941
4	E-7	Rc	-	-	8" PCC	7"/8" PCC			CAA-City	1943
5	E-7	Rc	-	-	12/13" PCC	**			CAA-City	1947
6	E-7	Rc	-	-	14" PCC				CAA-City	1953
7	E-7	Rc	-	-	14" PCC				CAA-City	1959
8	E-7	Rc		-	14" PCC				CAA-City	1958
9	E-7	Rc	-	-	7/8" PCC	7/8" PCC			CAA-City	1959
11	E-7	Rc	-	-	14" PCC				FAA-City	1960
12	E-7	Rc	-	-	14" PCC				FAA-City	1961
6A	E-7	Rc	-	-	14" PCC	**			CAA-City	1947
7A	E-7	Rc	-	-	14" PCC	**			CAA-City	1959
12A	E-7	Rc	-	6" AC	14" PCC				FAA-City	1970
					— TAXIWAY —					
1	E-7	F5	-	8" *	2½" Bit.				City	1940
2	E-7	Rc	5" P-209	-	9" PCC				City	-
4	E-7	Rc	-	-	8" PCC				CAA-City	1943
6	E-7	Rc	-	-	14" PCC				CAA-City	1953
7	E-7	Rc	-	-	14" PCC				CAA-City	1954
11	E-7	Rc	-	-	14" PCC				FAA-City	1960
12	E-7	Rc	-	-	14" PCC				FAA-City	1961
13	E-7	Rc	4½" P-209	-	9" PCC				FAA-City	1963
14	E-7	Rc	4½" P-209	-	12" PCC				FAA-City	1963
15	E-7	Rc	4½" P-209	-	9" PCC				FAA-City	1965
2A	E-7	Rc			9" PCC	2" Asph.				
12A	E-7	Rc	-	6" AC	14" PCC				FAA-City	1969
					— APRONS —					
7	E-7	Rc	-	-	14" PCC				CAA-City	1954
10	E-7	Rc	-	-	14" PCC				FAA-City	1960
11	E-7	Rc	-	-	14" PCC				FAA-City	1960
13	E-7	Rc	4½" P-209	-	9" PCC				FAA-City	1963
12A	E-7	Rc	-	6" AC	14" PCC				FAA-City	1969

REMARKS:

* Water Bound Macadam

** 5" AC overlay at center line tapered to 0" 75' from center line

B

Table A2 (Continued)

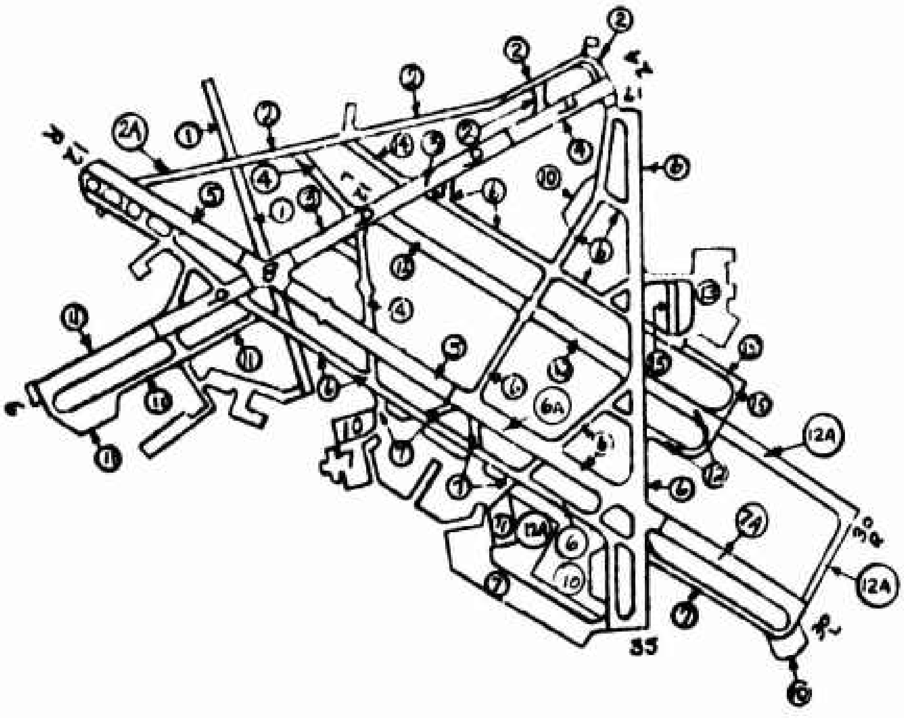
IRPORT PAVEMENT CHARACTERISTICS

STATE Missouri | CITY St. Louis | AIRPORT NAME Lambert International | DATE Jan. '73

MOD. GRADE REAC. K	DESIGN ALLOW.	CONSTRUC. SPEC	YEAR
		WPA-City	1941
		CAA-City	1943
		CAA-City	1947
		CAA-City	1953
		CAA-City	1959
		CAA-City	1958
		CAA-City	1959
		FAA-City	1960
		FAA-City	1961
		CAA-City	1947
		CAA-City	1959
		FAA-City	1970
		City	1940
		City	-
		CAA-City	1943
		CAA-City	1953
		CAA-City	1954
		FAA-City	1960
		FAA-City	1961
		FAA-City	1963
		FAA-City	1963
		FAA-City	1965
		FAA-City	1969
		CAA-City	1954
		FAA-City	1960
		FAA-City	1960
		FAA-City	1963
		FAA-City	1969

er line

Runway	**NE/SW**	**(6 - 24)**	-	**7600'**	x	**200'**
"	**N/S**	**(17 - 35)**	-	**6000'**	x	**150'**
"		**(12R-30L)**	-	**10,018'**	x	**200'**
"		**(12L-30R)**	-	**6,623**	x	**150'**



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A

AIRPORT PAVEMENT CHARAC

I. D. NO.	SOIL CLASS.	SUB-GRADE CLASS	SUBBASE COURSE	BASE COURSE	SURFACE COURSE	OVERLAY	MOD. SUBGRADE REAC. K	DESIGN ALLOW.	CONSTRUC. SPEC	YEAR	STATE
					—— RUNWAYS ——						
8-26											
R-1	E-3	Rb	52" CG	-	15" PCC				USAF	1960	
R-2	E-3	F2	45" CG	12" CG	3" AC	1½" AC	300	600psi	USAF	1965	
R-3	E-3	Rb	45" CG	-	16" PCC		300	600psi	USAF	1967	
R-4	E-3	F2	45" CG	12" CG	5" AC	5" AC			USAF	1965	
R-5	E-3	F2	45" CG	12" CG	5"/6" AC	3"/5" AC			USAF	1967	
R-6	E-3	F2	45" CG	12" CG	5"/6" AC	3/4"-4"AC			C-811	1967	
R-7	E-3	F2	48" CG	-	3" AC	3/4"-4"AC				1963	
R-8	E-3	F2	48" CG	-	3" AC	3/4"-4"AC				1963	
R-9	E-3	F2	48" CG	-	5½" AC	4" AC			C-811	1967	
					—— TAXIWAY ——						
T-1	E-3	F2	36" Agg.	8" CA	4" Bit.					1969	
T-2	E-3	F2	32" CA	26" CA	4" Bit.				USAF	1956	
T-3	E-3	F2	18" CG	40" CG	4" Bit.				USAF	1961	
T-4	E-3	F2	21" CG	9" CA	3" Bit.				6206	1964	
T-5	E-5	F2	21" CG	9" CA	3" Bit.				6004	1961	
T-6	E-3	F2	21" CG	9"/12" CA	3" Bit.				6105	1964	
T-7	E-3	F2	60" CG	-	2½" Bit.				USN	1944	
T-8	E-3	F2	36" CG	12" CA	3" Bit.				6105	1964	
T-9	E-3	F2	60" U. Agg.	12" CA	4" Bit.					1970	
T-10	E-3	F2	21" CG	12" CA	3" Bit.				6105	1964	
T-11	E-3	F2	36" CG	12" CA	3" Bit.					1964	
T-12	E-3	F2	60" CG	-	2½" Bit.				USN	1944	
T-13	E-3	F2	21" CG	4" CA	2" Bit.				6206	1961	
T-14	E-3	F2	60" CG	-	2½" Bit.				USN	1944	
T-15	E-3	F2	60" CG	-	2½" Bit.				USN	1944	
T-16 (See Page 3)					—— APRONS ——						
A-1	E-3	F2	4" CA	-	15" PCC					1969	
A-2	E-3	F2	12"+24" (1)	8" CA	4" Bit.					1969	
A-3	E-3	F2	-	12" CA	3" Bit.					1964	
A-4	E-3	F2	21" CG	9" CA	3" Bit.				6004	1961	
A-5	E-3	F2	9" CG	-	12" PCC				6004	1961	
A-6	E-3	F2	9" CG	-	12" PCC				6105	1964	
A-7	E-3	F2	21" CG	9"/12" CA	3" Bit.				6105	1964	
A-8	E-3	F2	9" CG	12" CA	3" Bit.				C308	1964	
A-9	E-3	F2	21" CG	9" CA	3" Bit.	1½" Bit.			6004	1961	
A-10	E-3	F2	10" Gr. A.	12" CA	4" Bit.					1969	
A-11	E-3	F2	21" CG	9" CA	3" Bit.	1½" Bit.			6084	1961	

REMARKS:

CG - Coral Aggregate
AC - Asphaltic Concrete
U.Agg.- Untreated Aggregated
CR - Crushed Aggregate
Gr.A. - Granular Aggregate
Bit. - Bituminous Asphalt
① 12" Coral Aggregate + 24" Granular Aggregate

B

Table A2 (Continued)

AIRPORT PAVEMENT CHARACTERISTICS

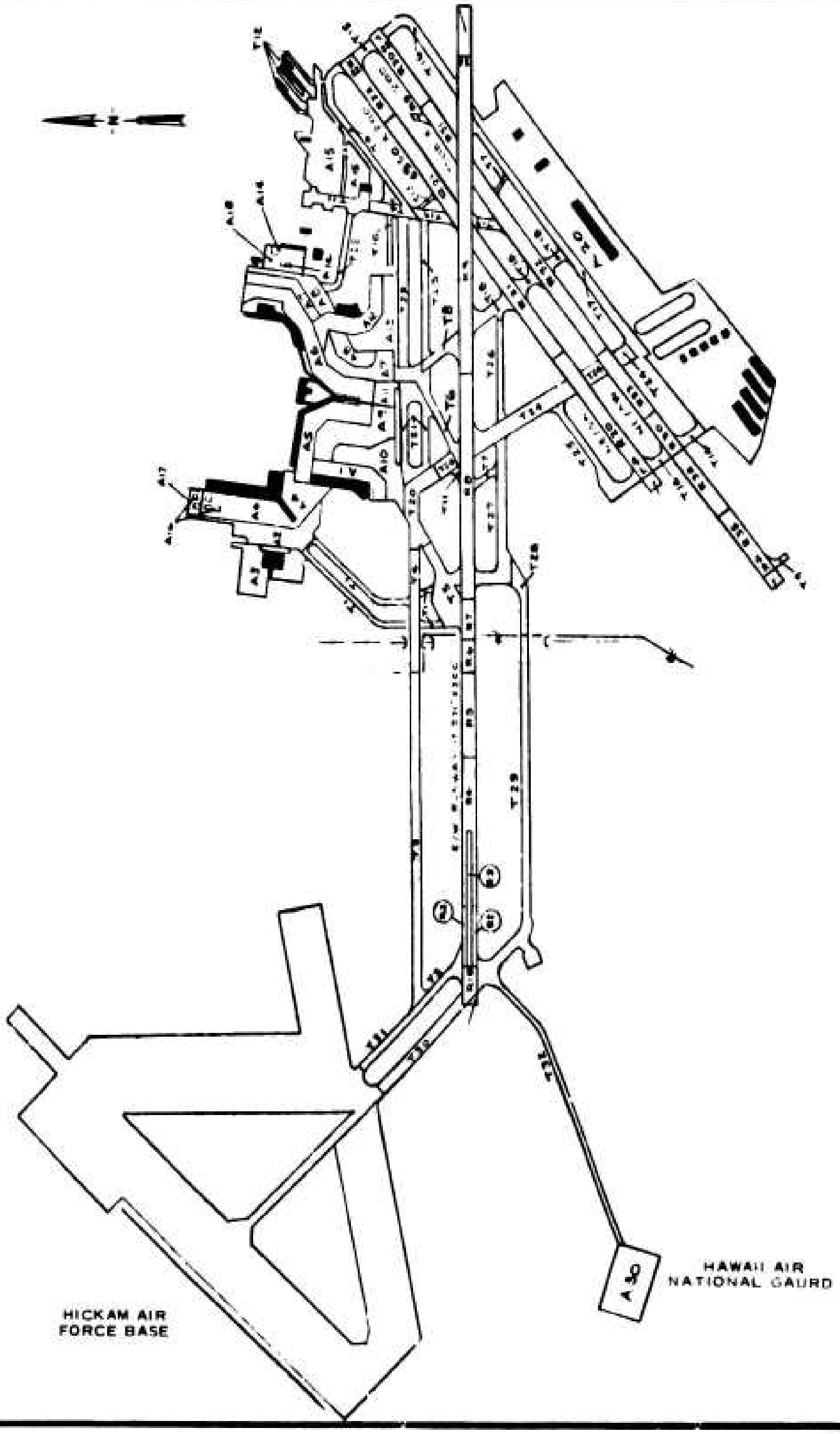
STATE Hawaii

CITY Honolulu

AIRPORT NAME Honolulu International

DATE Jan. '73

MOD. SUBGRADE REAC. K	DESIGN ALLOW.	CONSTRUC. SPEC	YEAR
		USAF	1960
300	600psi	USAF	1965
300	600psi	USAF	1967
		USAF	1965
		USAF	1967
		C-811	1967
			1963
			1963
		C-811	1967
			1969
		USAF	1956
		USAF	1961
		6206	1964
		6004	1961
		6105	1964
		USN	1944
		6105	1964
			1970
		6105	1964
			1964
		USN	1944
		6206	1961
		USN	1944
		USN	1944
			1969
			1969
			1964
		6004	1961
		6004	1961
		6105	1964
		6105	1964
		C308	1964
		6004	1961
			1969
		6084	1961



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AIRPORT PAVEMENT CHARACTER

STATE Hawai

I. D. NO.	SOIL CLASS.	SUB-GRADE CLASS	SUBBASE COURSE	BASE COURSE	SURFACE COURSE	OVERLAY	MOD. SUBGRADE REAC. K	DESIGN ALLOW.	CONSTRUC. SPEC	YEAR
RUNWAYS										
4R-22L										
R-30	E-3	F2	45" CG	18" CG	2½" Bit.	14½" Bit.			C-308	1964
R-31	E-3	F2	45" CG	30" CG	2½" Bit.	14½" Bit.			C-308	1964
R-32	E-3	F2	45" CG	12" CG	2½" Bit.	14½" Bit.			C-308	1964
R-33	E-3	F2	45" CG	12" CG	1½" Bit.	14½" Bit.			C-308	1964
R-34	E-3	F2	62"+24" ①	8" CA	8" Bit.					1970
R-35	E-3	F2	62"+24" ①	8" CA	8" Bit.					1970
4L-22R										
R-20	E-3	F2	45" CG	18" CG	2½" Bit.	4½" Bit.				1963
R-21	E-3	F2	45" CG	18" CG	2½" Bit.	6" Bit.				1963
R-22	E-3	F2	45" CG	18" CG	2½" Bit.	6" Bit.				1963
TAXIWAY										
T-17	E-3	F2	60" CG	-	2½" Bit.	3½" Bit.				1963
T-18	E-3	F2	60" CG	-	2½" Bit.	2½" Bit.			C-308	1964
T-19	E-3	F2	28" CG	10" CA	4" Bit.				0710	1969
T-20	E-3	F2	21" CG	9"/12" CG	3" Bit.	1½" Bit.				1970
T-21	E-3	F2	10" Gr. A.	12" CA	4" Bit.					1970
T-22	E-3	F2	6" Gr. A.	8" CA	4" Bit.					1969
T-23	E-3	F2	10" Gr. A.	12" CA	4" Bit.					1969
T-24	E-3	F2	45" CG	18" CG	2½" Bit.	1" Bit.				1963
T-25	E-3	F2	60" CG	-	2½" Bit.				USN	1944
T-26	E-3	F2	60" CG	-	2½" Bit.	1" Bit.				1963
T-27	E-3	F2	60" CG	-	2½" Bit.	1" Bit.				1963
T-28	E-3	F2	30" CG	30" CG	3" Bit.	1" Bit.				1963
T-29	E-3	F2	30" CG	30" CG	3" Bit.	1" Bit.				1963
T-30	E-3	F2	45" CG	12" CG	2½" Bit.				USAF	1942
T-31	E-3	F2	45" CG	12" CG	6" Bit.				USAF	1942
APRONS										
A-12	E-3	F2	4" CA	-	15" PCC					1969
A-13	E-3	F2	10" Cr. A.	12" CA	4" Bit.					1969
A-14	E-3	F2	21" CG	3" CA	12" PCC				UAL	1962
A-15	E-3	F2	60" CG	-	2½" Bit.				USN	1944
A-16	E-3	F2	6" CA	-	9" PCC					1966
A-17	E-3	F2	-	9" CA	3" Bit.					1966
A-18	E-3	F2	21" CG	12" CG	3" Bit.				UAL	1962

REMARKS:

CG - Coral Aggregate
CA - Crush Aggregate
Gr. A.- Granular Aggregate

① 62" Untreated Aggregate + 24" untreated aggregate

3

Table A2 (Continued)

IRPORT PAVEMENT CHARACTERISTICS

STATE Hawaii

CITY Honolulu

AIRPORT NAME Honolulu International

DATE Jan.'73

MOD. BGRADE REAC. K	DESIGN ALLOW.	CONSTRUC. SPEC	YEAR
		C-308	1964
		C-308	1964
		C-308	1964
		C-308	1964
			1970
			1970
			1963
			1963
			1963
			1963
		C-308	1964
		0710	1969
			1970
			1970
			1969
			1969
			1963
		USN	1944
			1963
			1963
			1963
			1963
		USAF	1942
		USAF	1942
			1969
			1969
		UAL	1962
		USN	1944
			1966
			1966
		UAL	1962

Aggregate + 24'
regate

(Sheet 22 of 44)

A

AIRPORT PAVEMENT CHARACTE

STATE Hawa

I. D. NO.	SOIL CLASS.	SUB-GRADE CLASS	SUBBASE COURSE	BASE COURSE	SURFACE COURSE	OVERLAY	MOD. SUBGRADE REAC. K	DESIGN ALLOW.	CONSTRUC. SPEC	YEAR
—— RUNWAYS ——										
—— TAXIWAY ——										
T-32	E-3	F2	36" CG	14" CA	4" Bit.				USAF	1962
T-16	E-3	F2	60" CG	-	$2\frac{1}{2}$" Bit.				USN	1944
—— APRONS ——										

REMARKS:

CG - Coral Aggregate
CA - Crushed Aggregate
Bit.- Bituminous Asphalt

B

Table A2 (Continued)

IRPORT PAVEMENT CHARACTERISTICS

STATE Hawaii

CITY Honolulu

AIRPORT NAME Honolulu International

DATE Jan. '73

MOD. BGRADE REAC. K	DESIGN ALLOW.	CONSTRUC. SPEC	YEAR
		USAF	1962
		USN	1944

(Sheet 23 of 44)

A

AIRPORT PAVEMENT CHARA

I. D. NO.	SOIL CLASS.	SUB-GRADE CLASS	SUBBASE COURSE	BASE COURSE	SURFACE COURSE	OVERLAY	MOD. SUBGRADE REAC. K	DESIGN ALLOW.	CONSTRUC. SPEC	YEAR
— RUNWAYS —										
1	E-7	Rc	9" P-154	-	13" PCC **	5" P-410			CAA	1969
2	E-7	Rc	9" P-154	-	11" PCC **		200	3750psi*	CAA	1971
3	E-7	Rc	12" P-209	-	11" PCC ++		200	3750psi*	FAA	1967
4	E-7	Rc	12" P-209	-	13" PCC ++				FAA	1967
5	E-7	Rc	9" P-154	-	13" PCC **				CAA	1950
6	E-7	Rc	9" P-154	-	11" PCC **		200	3750psi*	CAA	1950
7	E-7	Rc	9" P-154	-	11" PCC **		200		FAA	1958
8	E-7	Rc	9" P-154	-	13" PCC **				FAA	1958
9	E-7	Rc	9" P-154	-	13" PCC **				FAA	1962
40	E-7	Rc	12" P-209	-	9" PCC **	5" P-410			FAA	1971
41	E-7	Rc	12" P-209	-	13" PCC **	5" P-410			FAA	1971
42	E-7	Rc	12" P-209	-	15" PCC **	5" P-410			FAA	1971
43	E-7	Rc	11" P-154	-	9" PCC **	5" P-410			FAA	1969
44	E-7	Rc	9" P-154	-	11" PCC **	5" P-410			FAA	1969
45	E-7	Rc	16" P-209	9" P-201	17" PCC **			325psi+	FAA	1970
— TAXIWAY —										
10	E-7	Rc	9" P-154	-	12" PCC **				CAA	1953
11	E-7	Rc	9" P-154	-	12" PCC **				FAA	1958
12	E-7	Rc	9" P-154	-	12" PCC **				FAA	1959
13	E-7	Rc	9" P-154	-	12" PCC **				FAA	1960
14	E-7	Rc	9" P-154	-	12" PCC **				FAA	1962
15	E-7	Rc	9" P-154	-	12" PCC **				FAA	1963
16	E-7	Rc	9" P-154	-	12" PCC **				FAA	1963
17	E-7	Rc	12" P-154	-	12" PCC **				FAA	1965
18	E-7	Rc	12" P-154	-	12" PCC **				FAA	1965
19	E-7	Rc	12" P-154	-	12" PCC **				COUNTY	1966
20	E-7	Rc	12" P-154	-	12" PCC **				FAA	1967
21	E-7	Rc	12" P-154	-	12" PCC **				COUNTY	1967
91	E-7	Rc	-	-	8" PCC **	$1\frac{1}{2}$" AC			COUNTY	1966
92	E-7	Rc	-	-	8" PCC **	$1\frac{1}{2}$" AC			COUNTY	1966
50	E-7	Rc	12" P-209	-	15" PCC **				FAA	1967
— APRONS —										
22	E-7	Rc	9" P-154	-	12" PCC **				CAA	1953
23	E-7	Rc	9" P-154	-	12" PCC **				CAA	1955
24	E-7	Rc	9" P-154	-	12" PCC **				COUNTY	1957
25	E-7	Rc	9" P-154	-	12" PCC **				FAA	1958
26	E-7	Rc	9" P-154	-	12" PCC **				FAA	1959
28	E-7	Rc	9" P-154	-	12" PCC **				COUNTY	1962
29	E-7	Rc	12" P-209	-	12" PCC **				FAA	1965
30	E-7	Rc	12" P-702	-	9" PCC **				STATE	1965
33	E-7	Rc	9" P-209	-	12" PCC **				COUNTY	1965
34	E-7	Rc	12" P-209	-	9" PCC	2" PCC			C of E	1962

REMARKS:

* Safety Factor = 1.5

** Mesh Reinforced

\+ Flexural Modulus; Safety Factor = 2

++ Thickened Joint

B

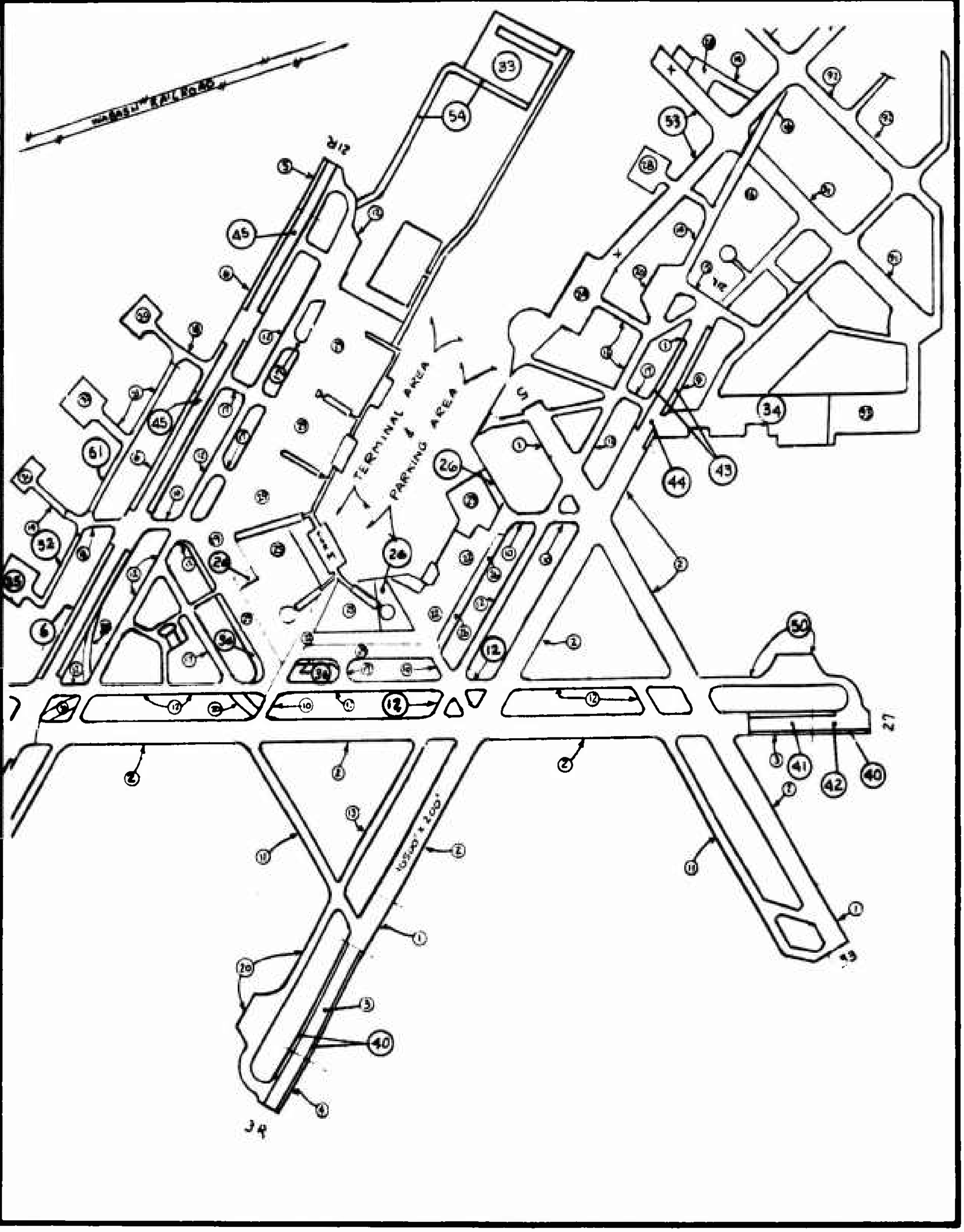
Table A2 (Continued)

RPORT PAVEMENT CHARACTERISTICS

OD. GRADE EAC. K	DESIGN ALLOW.	CONSTRUC. SPEC	YEAR
		CAA	1969
00	3750psi*	CAA	1971
00	3750psi*	FAA	1967
		FAA	1967
		CAA	1950
00	3750psi*	CAA	1950
00		FAA	1958
		FAA	1958
		FAA	1962
		FAA	1971
		FAA	1971
		FAA	1971
		FAA	1969
		FAA	1969
	325psi†	FAA	1970
		CAA	1953
		FAA	1958
		FAA	1959
		FAA	1960
		FAA	1962
		FAA	1963
		FAA	1963
		FAA	1965
		FAA	1965
		COUNTY	1966
		FAA	1967
		COUNTY	1967
		COUNTY	1966
		COUNTY	1966
		FAA	1967
		CAA	1953
		CAA	1955
		COUNTY	1957
		FAA	1958
		FAA	1959
		COUNTY	1962
		FAA	1965
		STATE	1965
		COUNTY	1965
		C of E	1962

lus; Safety Factor = 2
nt

STATE Michigan **CITY** Detroit **AIRPORT NAME** Detroit Metro. **DATE** Jan. '73



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A

AIRPORT PAVEMENT CHARA

I. D. NO.	SOIL CLASS.	SUB-GRADE CLASS	SUBBASE COURSE	BASE COURSE	SURFACE COURSE	OVERLAY	MOD. SUBGRADE REAC. K	DESIGN ALLOW.	CONSTRUC. SPEC	YEAR	STATI
— RUNWAYS —											
— TAXIWAY —											
51	E-7	Rc	-	14" P-201	1½" P-401				COUNTY	1970	
52	E-7	Rc	12" P-209	-	15" PCC*				COUNTY	1969	
53	E-7	Rc	-	-	8" PCC*				COUNTY	'30&'40	
54	E-7	Rc	12" P-154	-	12" PCC *				COUNTY	1966	
55	E-7	Rc	12" P-209	-	15" PCC *				COUNTY	1970	
— APRONS —											
31	E-7	Rc	12" P-209	-	12" PCC *				COUNTY	1966	
32	E-7	Rc	12" P-209	-	12" PCC *				COUNTY	1966	
93	E-7	Rc	15" P-209	-	9" PCC *	2" PCC			C of E	1962	
35	E-7	Rc	12" P-209		15" PCC *				COUNTY	1969	
36	E-7	Rc	16" P-209	9" P-201	17" PCC *			325psi+	FAA	1970	

REMARKS:

* Mesh Reinforced

\+ Flexural Modulus; Safety Factor = 2

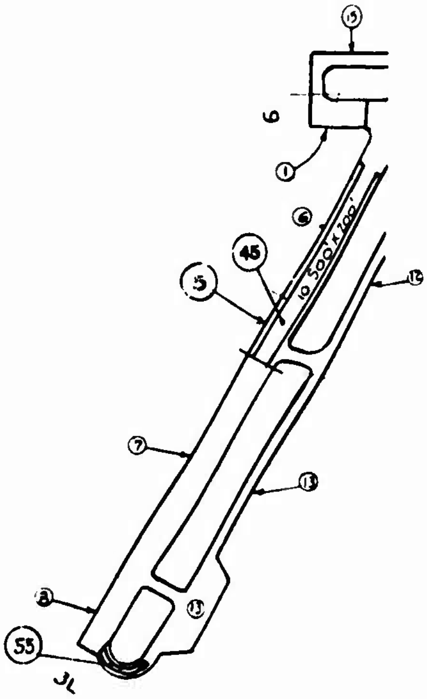
B

Table A2 (Continued)

IRPORT PAVEMENT CHARACTERISTICS

STATE Michigan | CITY Detroit | AIRPORT NAME Detroit Metro. | DATE Jan. '73

MOD. UBGRADE REAC. K	DESIGN ALLOW.	CONSTRUC. SPEC	YEAR
		COUNTY	1970
		COUNTY	1969
		COUNTY	'30&'40
		COUNTY	1966
		COUNTY	1970
		COUNTY	1966
		COUNTY	1966
		C of E	1962
		COUNTY	1969
	325psi+	FAA	1970



(Sheet 25 of 44)

AIRPORT PAVEMENT CHARACTE

STATE Washingto

I. D. NO.	SOIL CLASS.	SUB-GRADE CLASS	SUBBASE COURSE	BASE COURSE	SURFACE COURSE	OVERLAY	MOD. SUBGRADE REAC. K	DESIGN ALLOW.	CONSTRUC. SPEC	YEAR
RUNWAYS										
R-1	E-6	Rc	-	-	12" PCC	8" P-401	300	400 psi*	EDAP	1958
R-2	E-6	Rc	-	-	12" PCC	8" P-401	300	400 psi*	EDAP	1955
R-3	E-6	F4	-	-	8" PCC	5" AC	300	550psi*	EDAP	1963
R-4	E-6	F4	-	-	6" PCC	11" AC	300	550psi*	EDAP	1963
R-5	E-6	Rc	-	8" CA	12" PCC	8" P-401	300	400psi*	EDAP	1961
R-6	E-2	Ra	-	10" CA	14" PCC		300	400psi*	**	1970
TAXIWAY										
T-1	E-6	Rc	-	10" CA	14" PCC		300	400psi*	EDAP	1970
T-2	E-6	Rc	-	10" CA	14" PCC		300	400psi*	EDAP	1970
T-3	E-6	Rc	-	10" CA	14" PCC		300	400psi*	EDAP	1970
T-4	E-6	Rc	-	10" CA	14" PCC		300	400psi*	EDAP	1970
T-5	E-2	Ra	-	10" CA	14" PCC		300	400psi*	EDAP	1970
T-6	E-2	Ra	-	10" CA	14" PCC		300	400psi*	**	1970
T-7	E-6	Rc	-	-	10" PCC		300	*	EDAP	1944
T-8	E-6	Rc	-	-	10" PCC		300	*	EDAP	1944
T-9	E-6	Rc	-	10" CA	14" PCC		300	400psi*	**	1970
T-10	E-6	Rc	-	6" PCC	6" CA	3" AC	300	*	**	1970
T-11	E-6	Rc	-	-	12" PCC		300		EDAP	1955
T-12	E-6	Rc	-	8" CA	12" PCC		300		EDAP	1961
T-13	E-2	Ra	-	10" CA	14" PCC		300	400psi*	**	1970
T-14	E-2	Ra	-	10" CA	14" PCC		300	400psi*	**	1970
T-15	E-2	Ra	-	10" CA	14" PCC		300	400psi*	**	1970
APRONS										
A-1	E-6	Rc	-	-	10" PCC		300	*	EDAP	1944
A-2	E-6	Rc	-	8" CA	12" PCC		300	*	EDAP	1944
A-3	E-2	Ra	-	10" CA	14" PCC		300	400psi*	**	1970
A-5	E-2	Ra	-	10" CA	14" PCC		300	400psi*	**	1970

REMARKS:

* Safety Factor - 1.75

** FAA AC 150/5320-6A

CA - Crushed Aggregate

Current Plans:

Runway 16L-34R - (a) 1974-75; 8" AC overlay of center section, (b) 1979; 8" AC overlay of runway ends, (c) 1982; 8" AC overlay of center section.

Runway 16R-34L - 1985; 8" AC overlay of runway.

Aprons - 1976; Modify "A-1" to 10" CA base and 14" PCC surface course.

B

Table A2 (Continued)

AIRPORT PAVEMENT CHARACTERISTICS

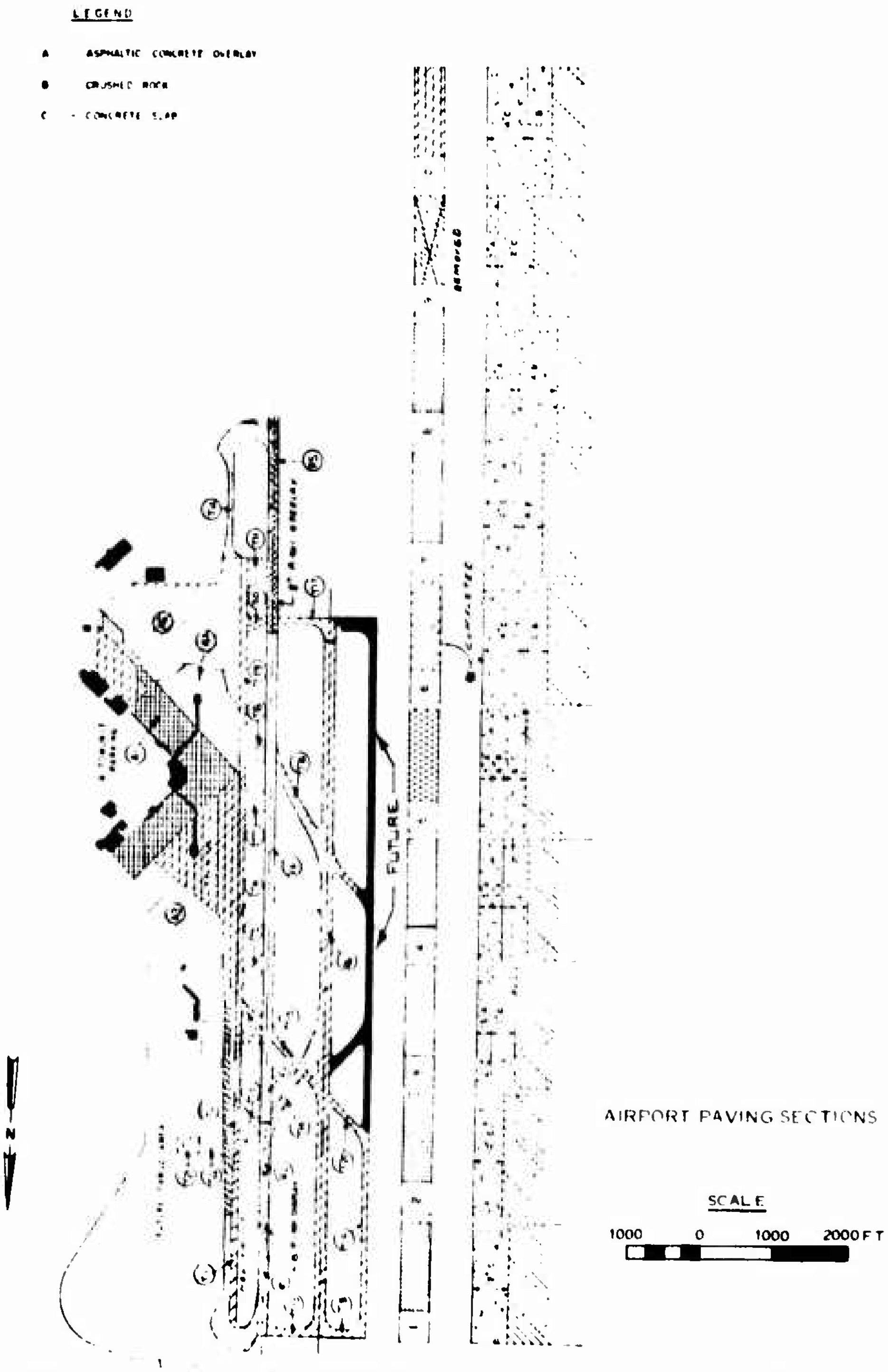
STATE Washington | **CITY** Seattle | **AIRPORT NAME** Seattle-Tacoma International | **DATE** Jan. '73

	MOD. SUBGRADE REAC. K	DESIGN ALLOW.	CONSTRUC. SPEC	YEAR
1	300	400 psi*	EDAP	1958
1	300	400 psi*	EDAP	1955
	300	550psi*	EDAP	1963
	300	550psi*	EDAP	1963
I	300	400psi*	EDAP	1961
	300	400psi*	**	1970
	300	400psi*	EDAP	1970
	300	400psi*	EDAP	1970
	300	400psi*	EDAP	1970
	300	400psi*	EDAP	1970
	300	400psi*	EDAP	1970
	300	400psi	**	1970
	300	*	EDAP	1944
	300	*	EDAP	1944
	300	400psi*	**	1970
	300	*	**	1970
	300		EDAP	1956
	300		EDAP	1961
	300	400psi*	**	1970
	300	400psi*	**	1970
	300	400psi*	**	1970
	300	*	EDAP	1944
	300	*	EDAP	1944
	300	400psi*	**	1970
	300	400psi*	**	1970

rushed Aggregate

section, (b) 1979; 8" AC over-
section.

surface course.



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A

AIRPORT PAVEMENT CHARACTE

STATE Wash

I. D. NO.	SOIL CLASS	SUB-GRADE CLASS	SUBBASE COURSE	BASE COURSE	SURFACE COURSE	OVERLAY	MOD. SUBGRADE REAC. K	DESIGN ALLOW.	CONSTRUC. SPEC	YEAR
— RUNWAYS —										
— TAXIWAY —										
T-16	E-2	Ra	-	10" CA	14" PCC		300	**	*	1970
T-17	E-2	Ra	-	10" CA	14" PCC		300	**	*	1970
T-18	E-2	Ra	-	10" CA	14" PCC		300	**	*	1970
T-19	E-2	Ra	-	10" CA	14" PCC		300	**	*	1970
T-20	E-2	Ra	-	10" CA	14" PCC		300	**	*	1970
T-21			-	10" CA	14" PCC		300	**	*	1969
T-22			-	14" CA	10" AC		300	**	*	1969
— APRONS —										

REMARKS:

* FAA AC 150/5320-6B

** Safety Factor = 1.75.

CA - Crushed Aggregate.

AC - Asphaltic Concrete.

B

IRPORT PAVEMENT CHARACTERISTICS

Table A2 (Continued)

STATE Washington | CITY Seattle | AIRPORT NAME Seattle-Tacoma International | DATE Jan. '73

MOD. UBGRADE REAC. K	DESIGN ALLOW.	CONSTRUC. SPEC	YEAR
300	**	*	1970
300	**	*	1970
300	**	*	1970
300	**	*	1970
300	**	*	1970
300	**	*	1969
300	**	*	1969

(Sheet 27 of 44)

A

AIRPORT PAVEMENT CHARACT

STATE Penn

I. D. NO.	SOIL CLASS.	SUB-GRADE CLASS	SUBBASE COURSE	BASE COURSE	SURFACE COURSE	OVERLAY	MOD. SUBGRADE REAC. K	DESIGN ALLOW.	CONSTRUC. SPEC	YEAR
— RUNWAYS —										
10R-28L	Overlaid in 1972									
R-1	E-7	Rc	4-19" CS	-	18" Bit.C**	7" Bit.C.			FAA	1972
R-2	E-7	Rc	8" CS	-	12" PCC	6" Bit.C.			FAA	1972
R-3	E-7	F7	10" CS	8" WBM	4½" Bit.C.	7" Bit.C.			FAA	1972
R-4	E-7	Rc	8" CS	-	12" PCC	6" Bit.C.			FAA	1972
R-5	E-7	F7	2" CS	12" WBM	3" Bit.C.	10.5"Bit.C.			FAA	1972
10L-28R										
* R-6	E-7	Rc	18-26" CS	-	17" PCC				FAA	1973
* R-7	E-7	Rc	18-26" CS	-	17" PCC				FAA	1973
* R-8	E-7	Rc	18-26" CS	-	17" PCC				FAA	1973
R-9	E-7	Rc	16"/8" CS	-	15"/10"PCC				FAA	1962
14-32										
+ R-10	E-7	Rc	4-19" CS	-	13" PCC				FAA	1973
+ R-11	E-7	Rc	4-19" CS	-	10" PCC	9.5"Bit.C.			FAA	1973
+ R-12	E-7	F7	2" CS	12" DBM	4½" Bit.C.	9.5"Bit.C.			FAA	1973
R-13	E-7	F7	6" CS	8" DBM	3" Bit.C.	2" Bit.C.			FAA	1966
— TAXIWAY —										
T-1	E-7	Rc	-	-	12" PCC					
T-2	E-7	Rc	10" CS	-	12" PCC					
T-3	E-7	F7	2" CS	12" DBM	3" Bit.C.					
T-4	E-7	Rc	8" CS	-	12" PCC	5"Bit.C.			FAA	1972
* T-5	E-7	F7	17" CS	-	6" Bit.C.	4"+ 10.5" Bit.C.			FAA	1973
T-6	E-7	Rc	-	-	12" PCC					
T-7	E-7	Rc	-	-	10" PCC					
T-8	E-7	Rc	9" CS	-	12" PCC				FAA	1962
+ T-9	E-7	Rc	26"CS	-	15" PCC				FAA	1973
T-10	E-7	F7	8" CS	-	12" PCC	4-3/4"Bit.C.			FAA	1962
T-11	E-7	Rc	-	-	12" PCC					
— APRONS —										
A-1	E-7	Rc	-	-	12" PCC					

REMARKS:

CS - Crushed Slag
WBM - Water-bound Macadam
Bit.C.- Bituminous Concrete
DBM - Dry-bound Macadam
PCC - Portland Cement Concrete
CRCP - Cont.Rein.Concrete Pavement

* To be rebuilt in 1973. 100' center section will have 18-26" CS and 17" PCC.

** Only for 50' center section; other is 10" PCC.

\+ To be rebuilt in 1973. R-10 is for 75' center section.

Note: Apron construction data is not readily available.

B

AIRPORT PAVEMENT CHARACTERISTICS

Table A2 (Continued)

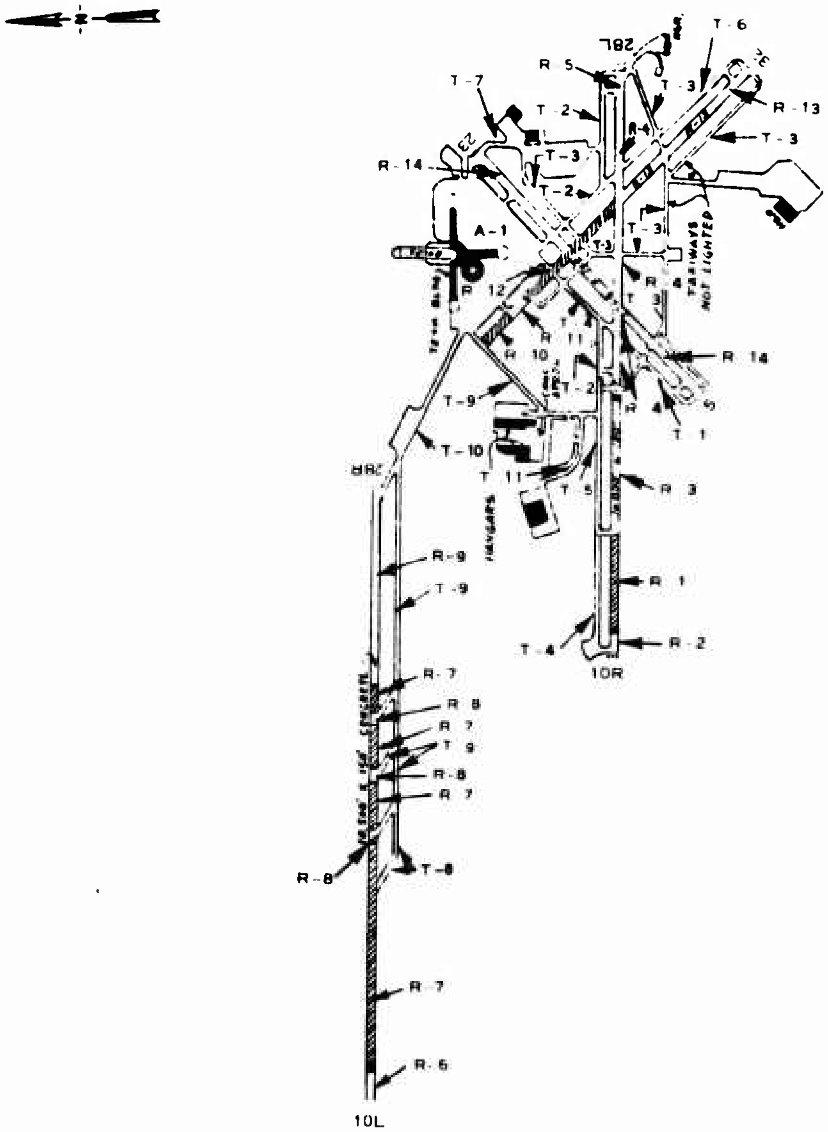
MOD. SUBGRADE REAC. K	DESIGN ALLOW.	CONSTRUC. SPEC	YEAR
		FAA	1972
		FAA	1972
		FAA	1972
		FAA	1972
		FAA	1972
		FAA	1973
		FAA	1973
		FAA	1973
		FAA	1962
		FAA	1973
		FAA	1973
		FAA	1973
		FAA	1966
		FAA	1972
Bit.C.		FAA	1973
		FAA	1962
		FAA	1973
C.		FAA	1962

lt in 1973. 100' center section
8-26" CS and 17" PCC.

)' center section; other is 10"

lt in 1973. R-10 is for 75'
ion.

STATE	CITY	AIRPORT NAME	DATE
Pennsylvania	Pittsburgh	Greater Pittsburgh International	Jan. '73



A

AIRPORT PAVEMENT CHARACT

STATE Per

I. D. NO.	SOIL CLASS.	SUB-GRADE CLASS	SUBBASE COURSE	BASE COURSE	SURFACE COURSE	OVERLAY	MOD. SUBGRADE REAC. K	DESIGN ALLOW.	CONSTRUC. SPEC	YEAR
— RUNWAYS —										
5-23 R-14	E-7	F7	6" CS	8" WBM	3" Bit.C.	2" Bit.C.			FAA	1964
— TAXIWAY —										
— APRONS —										

REMARKS:

CS - Crushed Slag
WBM - Water-Bound Macadam
Bit.C.- Bituminous Concrete

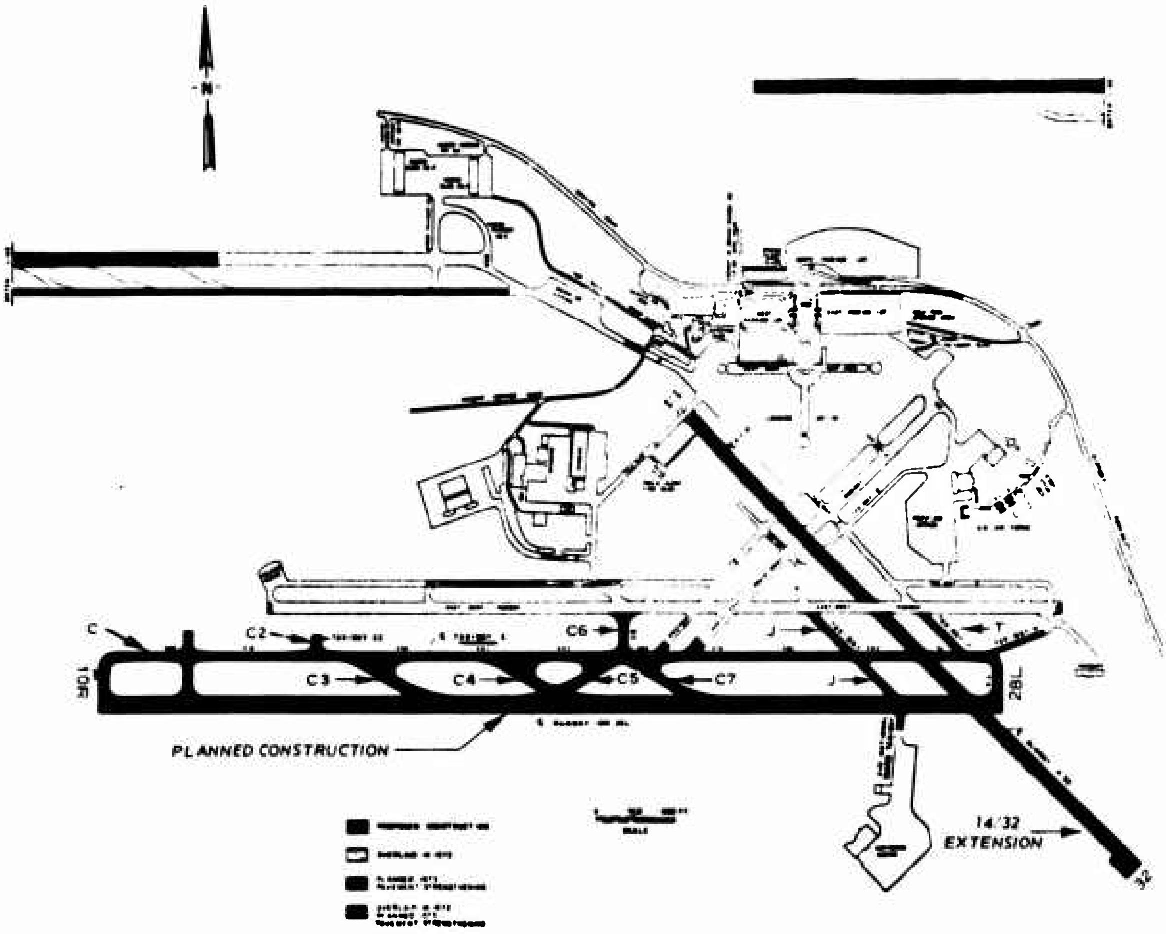
D

IRPORT PAVEMENT CHARACTERISTICS

Table A2 (Continued)

MOD. BGRADE REAC. K	DESIGN ALLOW.	CONSTRUC. SPEC	YEAR
		FAA	1964

STATE Pennsylvania **CITY** Pittsburgh **AIRPORT NAME** Greater Pittsburgh International **DATE** Jan. '73



PAVEMENT PLANS FOR NEW CONSTRUCTION

Item	Critical Section	Stabilized Base*	Subbase*
Runway 10R-28L	16" R.C.C.	8"	20"
Taxiways C, C1, C2 & C6	16" R.C.C.	8"	20"
Taxiways C3, C4 & C5	14" R.C.C.	8"	22"
Taxiway C7	11" R.C.C.	8"	25"
Runway 14-32 . Extension	13" R.C.C.	7"	24"
Taxiway J	13" R.C.C.	7"	24"
Taxiway T	13" R.C.C.	7"	24"

*Material must meet F.A.A. requirements and provide min. K=300.

AIRPORT PAVEMENT CHARAC

STATE

I. D. NO.	SOIL CLASS.	SUB-GRADE CLASS	SUBBASE COURSE	BASE COURSE	SURFACE COURSE	OVERLAY	MOD. SUBGRADE REAC. K	DESIGN ALLOW.	CONSTRUC. SPEC	YEAR
— RUNWAYS —										
R-1	E-6	Rc	6" SM	-	12" P-501			400psi	FAA	1968
R-2	E-6	Rc	6" SM	-	10" P-501				FAA	1968
R-3	E-6	Rc	9" CS	-	14" P-501			400psi*	FAA	1968
R-4	E-6	Rc	9" CS	-	13" P-501			400psi*	FAA	1968
R-5	E-6	Rc	9" CS	-	12" P-501			400psi*	FAA	1968
R-6	E-6	Rc	9" CS	-	11" P-501				FAA	1968
R-7	E-6	Rc	6" SM	-	12" P-501			400psi*	FAA	1968
— TAXIWAY —										
T-1	E-6	Rc	6" SM	-	12" PCC			400psi*	FAA	1968
T-2	E-6	Rc	9" CS	-	14" PCC			400psi*	FAA	1968
T-3	E-6	Rc	9" CS	-	12" PCC			400psi*	FAA	1968
T-4	E-6	Rc	12" CS	-	14" PCC			400psi*	FAA	1968
T-5	E-6	Rc	12" CS	-	12" PCC			400psi*	FAA	1968
T-6	E-6	Rc	6" SM	-	12" PCC			400psi*	FAA	1968
T-7	E-6	Rc	9" CS	-	12" PCC			400psi*	FAA	1968
— APRONS —										
A-1	E-6	Rc	6" SM	-	12" P-501			400psi*	FAA	1968
A-2	E-6	Rc	9" CS	-	12" P-501			400psi*	FAA	1968
A-3	E-6	Rc	12" CS	-	12" P-501			400psi*	FAA	1968
A-4	E-6	Rc	12" CS	-	14" P-501			400psi*	FAA	1968
A-5	E-6	Rc	9" CS	-	14" P-501			400psi*	FAA	1968

REMARKS:

SM - Selected Materials
CS - Cement Stabilized Soil

* Safety Factor = 1.5

Note: Runway 14-32 and its parallel and connecting taxiway will be overlaid. Future pavements and overlays of existing pavements will be designed for 747 and other wide-body jets.

B

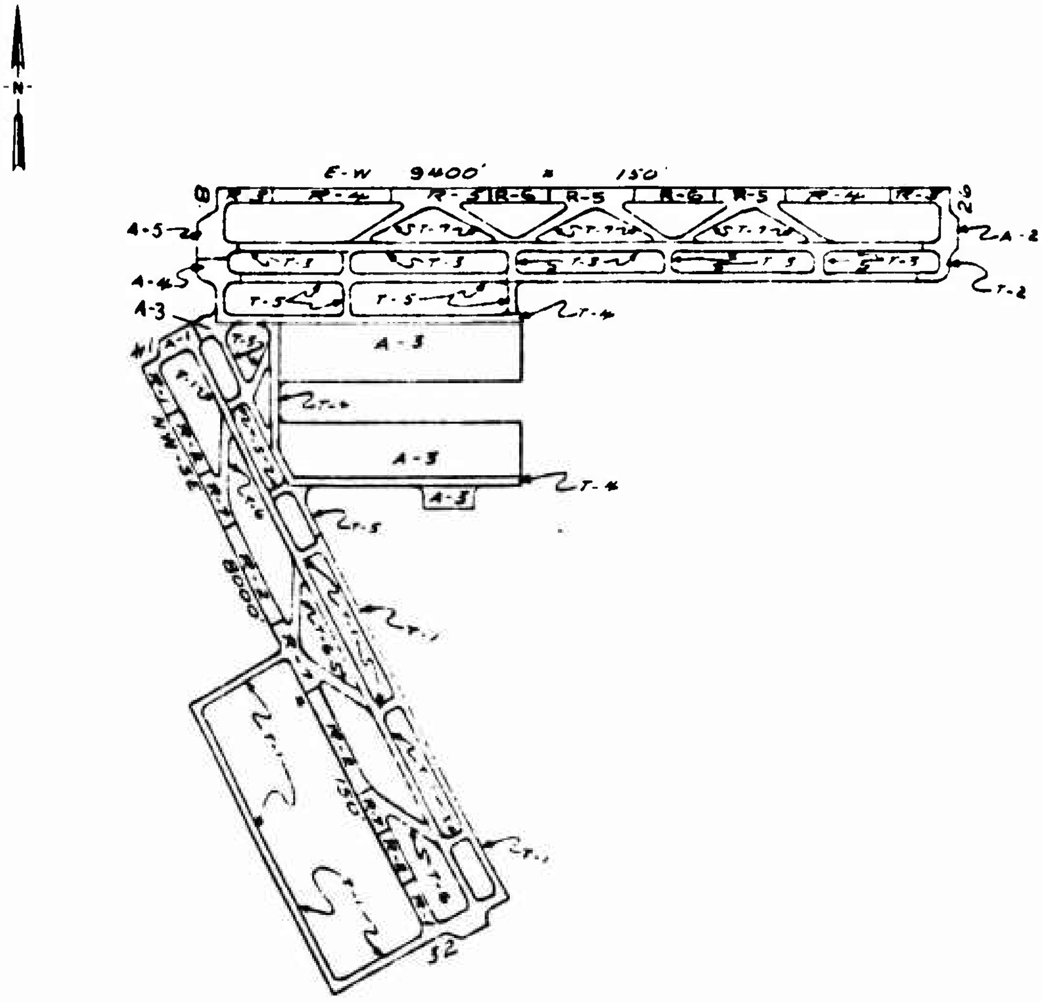
Table A2 (Continued)

IRPORT PAVEMENT CHARACTERISTICS

MOD. BGRADE REAC. K	DESIGN ALLOW.	CONSTRUC. SPEC	YEAR
	400psi	FAA	1968
		FAA	1968
	400psi*	FAA	1968
	400psi*	FAA	1968
	400psi*	FAA	1968
		FAA	1968
	400psi*	FAA	1968
	400psi*	FAA	1968
	400psi*	FAA	1968
	400psi*	FAA	1968
	400psi*	FAA	1968
	400psi*	FAA	1968
	400psi*	FAA	1968
	400psi*	FAA	1968
	400psi*	FAA	1968
	400psi*	FAA	1968
	400psi*	FAA	1968
	400psi*	FAA	1968
	400psi*	FAA	1968

l be overlaid. Future
igned for 747 and other

STATE	CITY	AIRPORT NAME	DATE
Texas	Houston	Houston International	Jan. '73



NOTE
TAXIWAYS ARE 75 WIDE

AIRPORT PAVEMENT CHAR

I. D. NO.	SOIL CLASS.	SUB-GRADE CLASS	SUBBASE COURSE	BASE COURSE	SURFACE COURSE	OVERLAY	MOD. SUBGRADE REAC. K	DESIGN ALLOW.	CONSTRUC. SPEC	YEAR
RUNWAYS										
11R/29L										
R-1	E-4	Rb	-	-	11" PCC				CAA	1952
R-2	E-4	Rb	-	-	9" PCC				CAA	1951
R-3	E-4	Rb	-	-	9" PCC				CAA	1951
R-4	E-6	Rc	-	-	11" PCC				CAA	1951
R-5	E-4	Rb	-	-	9" PCC				CAA	1951
R-6	E-4	Rb	-	-	11" PCC				CAA	1952
R-7	E-4	Rb	8" CA	-	12" PCC				FAA	1962
R-8	E-4	Rb	8" CA	-	10" PCC				FAA	1962
R-9	E-4	Rb	8" CA	-	10" PCC				FAA	1962
R-10	E-4	Rb	8" CA	-	12" PCC				FAA	1962
4/22										
R-11	E-4	Rb	-	-	12" PCC				CAA	1958
R-12	E-4	Rb	-	-	12" PCC				CAA	1958
R-13	E-4	Rb	-	-	11" PCC				CAA	1950
R-14	E-4	Rb	-	-	9" PCC				CAA	1950
TAXIWAY										
T-1	E-4	Rb	-	-	11" PCC				CAA	1951
T-2	E-2	Rb	8" CA	-	12" PCC				CAA	1959
T-3	E-7	Rc	12" CA	-	6" PCC	4" BIT.			FAA	1963
T-4	E-4	Rb	8" CA	-	12" PCC				FAA	1962
T-5	E-4	Rb	-	-	11" PCC	4" BIT.			CAA	1951
T-6	E-4	Rb	12" SAM	-	7" PCC				MAC	1955
T-7	E-4	Rb	-	-	6" PCC	4" BIT.			FAA	1962
T-8	E-2	Rb	6" CA	-	6" PCC	4" BIT.			CAA	1956
T-9	E-2	Rb	12" CA	-	11" PCC				CAA	1952
T-10	E-4	Rb	8" CA	-	12" PCC				FAA	1960
T-11	E-4	Rb	8" CA	-	12" PCC				CAA	1958
T-12	E-2	Rb	8" CA	-	12" PCC				FAA	1959
T-13	E-5	Rb	8" CA	-	12" PCC				MPA	1967
T-14	E-4	Rb	-	-	11" PCC				CAA	1948
T-15	E-3	Rb	8" P-209	-	12" CRCP				FAA	1969
APRONS										
A-1	E-4	Rb	8" CA	-	12" PCC				FAA	1960
A-2	E-4	Rb	-	-	11" PCC				CAA	1952
A-3	E-4	Rb	12" CA	-	11" PCC	4" AC			MAC	1956

REMARKS:

CA - Crushed Aggregate
SAM - Selected Aggregate Mat's.
AC - Asphaltic Concrete
CRCP - Continuous Reinforced Concrete Pavement

B

AIRPORT PAVEMENT CHARACTERISTICS

Table A2 (Continued)

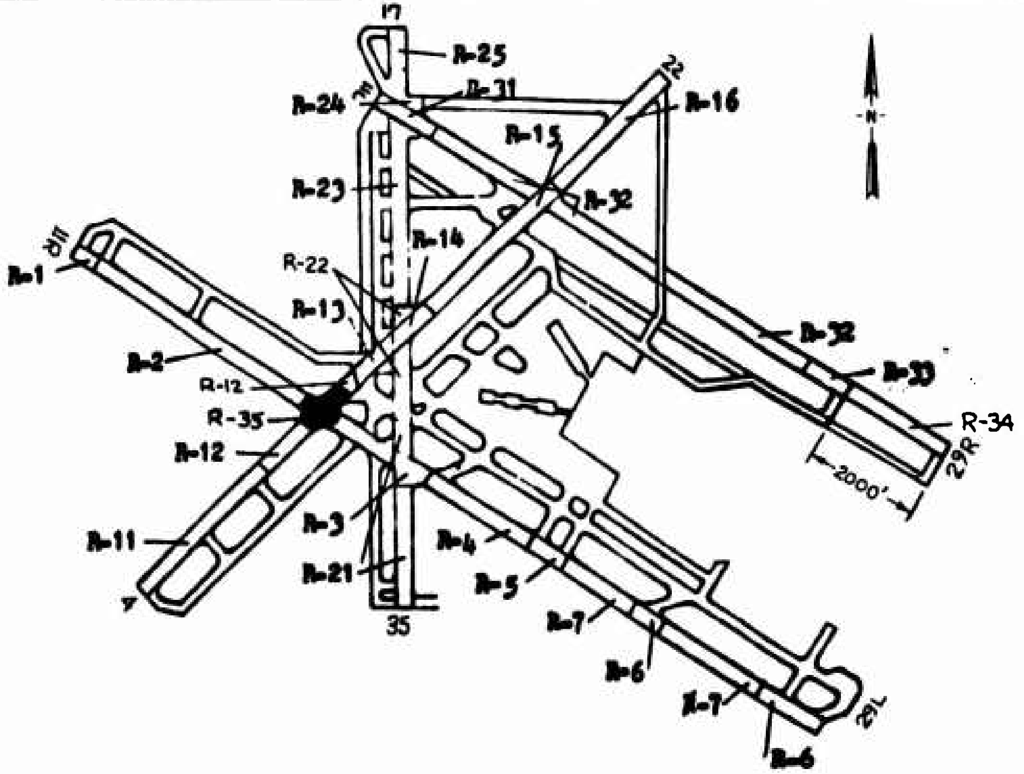
MOD. UBGRADE REAC. K	DESIGN ALLOW.	CONSTRUC. SPEC	YEAR
		CAA	1952
		CAA	1951
		CAA	1951
		CAA	1951
		CAA	1951
		CAA	1952
		FAA	1962
		FAA	1962
		FAA	1962
		FAA	1962
		CAA	1958
		CAA	1958
		CAA	1950
		CAA	1950
		CAA	1951
		CAA	1959
		FAA	1963
		FAA	1962
		CAA	1951
		MAC	1955
		FAA	1962
		CAA	1956
		CAA	1952
		FAA	1960
		CAA	1958
		FAA	1959
		MPA	1967
		CAA	1948
		FAA	1969
		FAA	1960
		CAA	1952
		MAC	1956

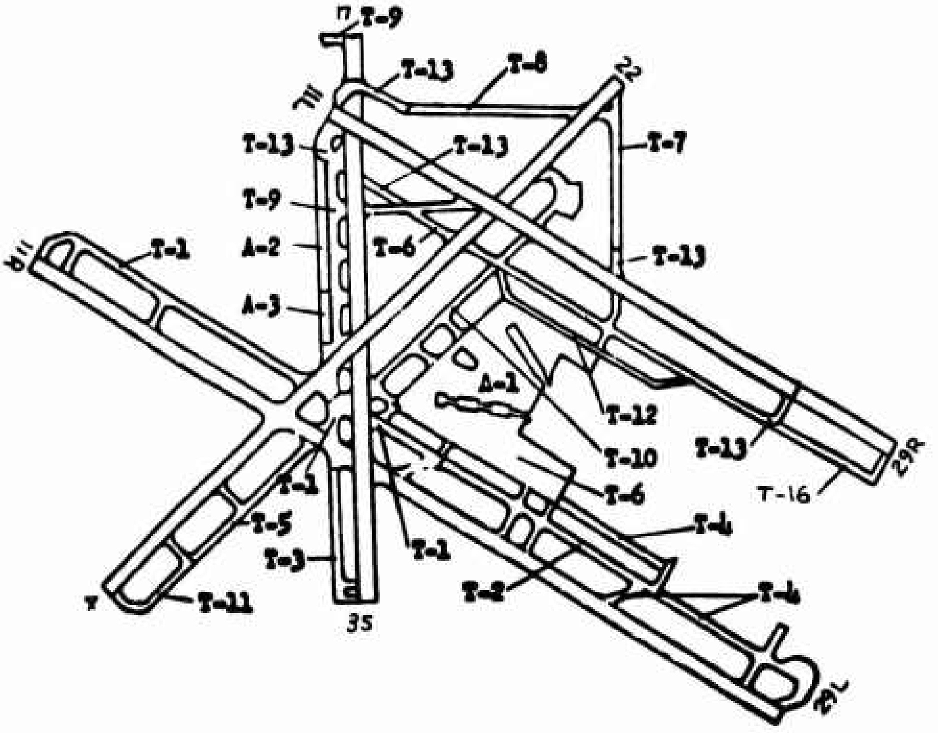
STATE Minnesota

CITY Minneapolis

AIRPORT NAME Minneapolis - St. Paul

DATE Jan. '73





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9

AIRPORT PAVEMENT CHARAC

STATE Mi

I. D. NO.	SOIL CLASS.	SUB-GRADE CLASS	SUBBASE COURSE	BASE COURSE	SURFACE COURSE	OVERLAY	MOD. SUBGRADE REAC. K	DESIGN ALLOW.	CONSTRUC. SPEC	YEAR
					— RUNWAYS —					
4/22										
R-15	E-4	Rb	-	-	9" PCC				CAA	1950
R-16	E-4	Rb	-	-	12" PCC				CAA	1955
R-17	E-4	Rb	-	-	12" PCC				CAA	1955
R-18	E-4	Rb	-	-	11" PCC				CAA	1955
R-19	E-4	Rb	-	-	11" PCC				AF	1955
17/35										
R-21	E-4	Rb	-	-	9" PCC	4" AC			CAA	1953
R-22	E-2	Rb	-	-	9" PCC	4" AC			CAA	1953
R-23	E-6	Rc	12" CA	-	11" PCC				MAC	1951
R-24	E-6	Rc	12" CA	-	12" PCC				MAC	1962
R-25	E-6	Rc	12" CA	-	12" PCC				MAC	1955
R-26	E-7	Rc	8" CA	-	12" PCC				FAA	1968
R-27	E-7	Rc	12" CA	-	6" PCC				CAA	1942
					— TAXIWAY —					
T-16	E-3	Rb	8" CA	-	13 CRCP				FAA	1970
					— APRONS —					

REMARKS:

CA - Crushed Aggregate
AC - Asphaltic Concrete
CRCP - Continuous Reinforced Concrete Pavement

Note: 17/35 is no longer an active runway; used primarily as a taxiway.

B

Table A2 (Continued)

RPORT PAVEMENT CHARACTERISTICS

STATE	CITY	AIRPORT NAME	DATE
Minnesota	Minneapolis	Minneapolis - St. Paul	Jan. '73

IOD. BRADE EAC. K	DESIGN ALLOW.	CONSTRUC. SPEC	YEAR
		CAA	1950
		CAA	1955
		CAA	1955
		CAA	1955
		AF	1955
		CAA	1953
		CAA	1953
		MAC	1951
		MAC	1962
		MAC	1955
		FAA	1968
		CAA	1942
		FAA	1970

ly as a taxiway.

(Sheet 32 of 44)

AIRPORT PAVEMENT CHARAC

STATE M

I. D. NO.	SOIL CLASS.	SUB-GRADE CLASS	SUBBASE COURSE	BASE COURSE	SURFACE COURSE	OVERLAY	MOD. SUBGRADE REAC. K	DESIGN ALLOW.	CONSTRUC. SPEC	YEAR
— RUNWAYS —										
11L/29R										
R-31	E-5	Rb	8" CA	-	12" PCC				FAA	1967
R-32	E-5	Rb	8" CA	-	10" PCC				FAA	1967
R-33	E-3	Rb	8" P-209	-	12" CRCP				FAA	1969
R-34	E-3	Rb	8" CA	-	13" CRCP				FAA	1970
R-35	E-4	Rb	8" CA	-	16" PCC				FAA	1971
— TAXIWAY —										
— APRONS —										

REMARKS:

CA - Crushed Aggregate

CRCP - Continuous Reinforced Concrete Pavement

IRPORT PAVEMENT CHARACTERISTICS

Table A2 (Continued)

STATE Minnesota
CITY Minneapolis
AIRPORT NAME Minneapolis - St. Paul
DATE Jan. '73

MOD. UBGRADE REAC. K	DESIGN ALLOW.	CONSTRUC. SPEC	YEAR
		FAA	1967
		FAA	1967
		FAA	1969
		FAA	1970
		FAA	1971

A

AIRPORT PAVEMENT CHARAC

STATE Lou

I. D. NO.	SOIL CLASS.	SUB-GRADE CLASS	SUBBASE COURSE	BASE COURSE	SURFACE COURSE	OVERLAY	MOD. SUBGRADE REAC. K	DESIGN ALLOW.	CONSTRUC. SPEC	YEAR
					—— RUNWAYS ——					
R-1	E-12	Re	8" SS	-	12" PCC	VAR.P-401	50	400psi①	CAA	1956
R-2	E-12	Re	6" SS ⑩	-	12" PCC	1"P-401②	50	400psi①	FAA	1968
R-3	E-12	Re	-	-	9"/7" PCC	3"HM Bit③			FAA	1968
R-4	E-12	Re	-	-	9"/7" PCC	3"HM Bit④			FAA	1968
R-5	E-12	Re	6" SS ⑩	-	12" PCC	VAR.P-401	50	400psi①	FAA	1968
R-6	E-12	Re	16" RS ⑤	-	12" PCC		50	400psi①	CAA	1943
R-7	E-12	Re	-	-	9"/7" PCC	10" HM Bit⑥			FAA	1965
R-8	E-12	Re	-	-	9"/7" PCC	10" HM Bit⑦			FAA	1965
R-9	E-12	Re	-	-	9"/7" PCC	10" HM.Bit⑧			FAA	1965
R-10	E-12	Re	8" SS ⑩	-	10" PCC		50	400psi①	FAA	1963
R-11	E-12	Re	8" SS ⑩	-	12" PCC		50	400psi①	FAA	1963
R-12	E-12	Re	-	-	9"/7" PCC	12" HM Bit.			FAA	1964
R-13	E-12	Re	-	-	9"/7" PCC	12" HM Bit.			FAA	1964
					—— TAXIWAY ——					
T-1	E-12	Re	8" SS ⑩	-	12" PCC		50	400psi①	FAA	1964
T-2	E-12	Re	6" SS ⑩	-	12" PCC	1" HM.Bit.	50	400psi①	FAA	1965
T-3	E-12	Re	6" SS ⑩	-	12" PCC		50	400psi①	FAA	1964
T-4	E-12	Re	15" RS	-	12" PCC		50	400psi①	FAA	1963
T-5	E-12	Re	-	-	9"/7" PCC	12" PCC			CAA	1956
T-6	E-12	Re	15" SS	-	9"/7" PCC	10" HM.Bit⑨			FAA	1965
T-7	E-12	Re	15" SS	-	12" PCC		50	400psi①	FAA	1964
					—— APRONS ——					
A-1	E-12	Re	15" SS	-	12" PCC		50	400psi①		
A-2	E-12	Re	11" SS	-	8" PCC					
A-3	E-12	Re	6" SS ⑩	-	12" PCC		50	400psi①		
A-4	E-12	Re	-	-	9"/7" PCC	7½" Bit.				
A-5	E-12	Re	15" SS	-	15"/12"PCC		50	400psi①		

REMARKS: SS - Sand Shell

VAR - Variable Thickness

RS -River Sand

HM -Hot Mix

① Safety Factor = 1.75
② 3" P-401 Additional Overlay
③ 10" PCC Additional Overlay
④ 12" PCC Additional Overlay
⑤ 6" Lime Stabilized Subgrade
⑥ 12" PCC Additional Overlay
⑦ 10" PCC Additional Overlay with 12" PCC at T/W intersection.
⑧ Variable Bituminous Overlay
⑨ 12" PCC Additional Overlay
⑩ 24" River Sand as top of subgrade

B

Table A2 (Continued)

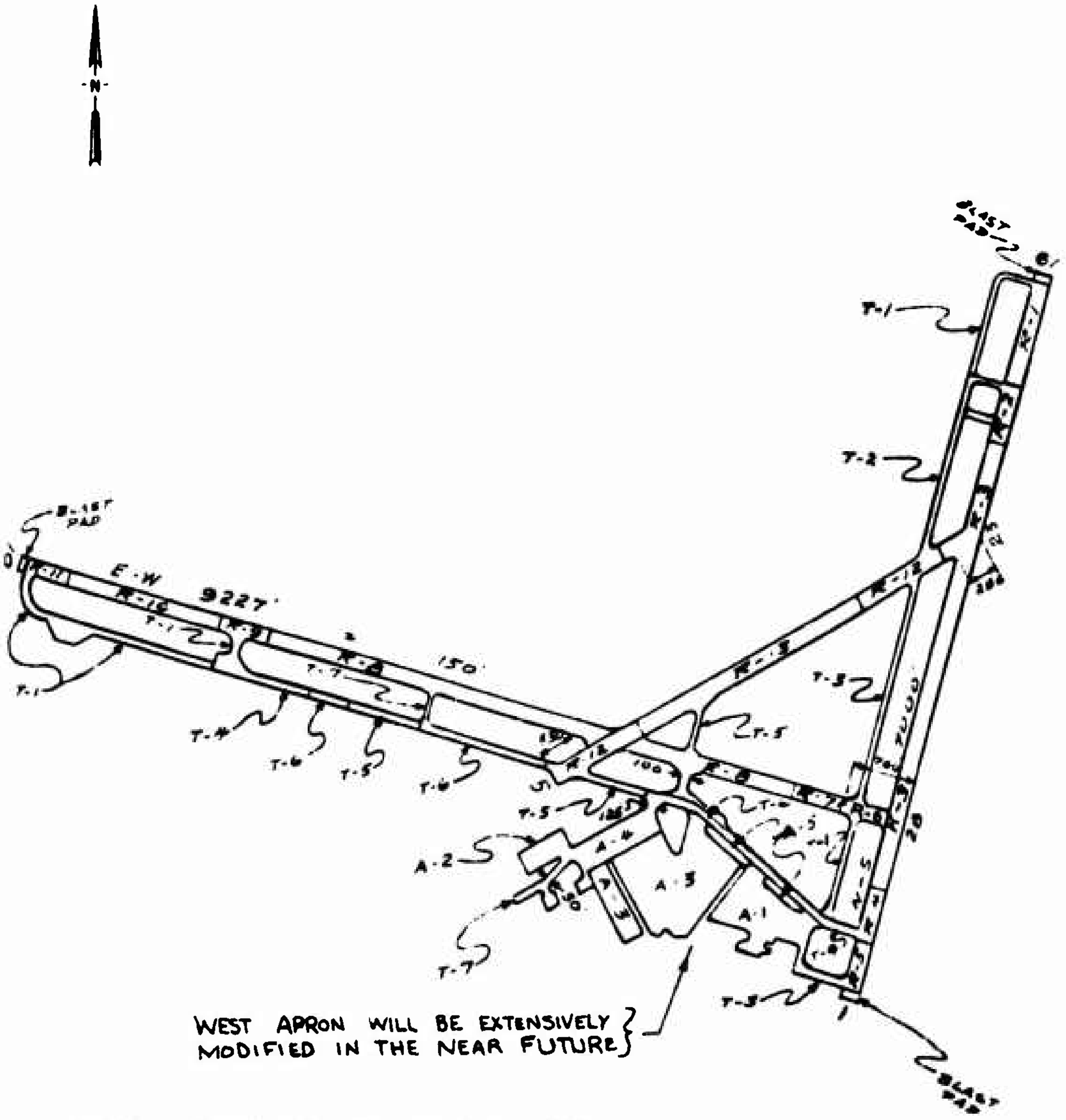
PORT PAVEMENT CHARACTERISTICS

ADE C.	DESIGN ALLOW.	CONSTRUC. SPEC	YEAR
)	400psi②	CAA	1956
)	400psi①	FAA	1968
		FAA	1968
		FAA	1968
)	400psi①	FAA	1968
)	400psi①	CAA	1943
		FAA	1965
		FAA	1965
		FAA	1965
)	400psi①	FAA	1963
)	400psi①	FAA	1963
		FAA	1964
		FAA	1964
)	400psi①	FAA	1964
)	400psi①	FAA	1965
)	400psi①	FAA	1964
)	400psi①	FAA	1963
		CAA	1956
		FAA	1965
0	400psi①	FAA	1964
0	400psi①		
0	400psi①		
0	400psi①		

rerlay
rerlay with 12" PCC at T/W

Overlay
rerlay
p of subgrade

STATE	CITY	AIRPORT NAME	DATE
Louisiana	New Orleans	New Orleans International	Jan. '73



WEST APRON WILL BE EXTENSIVELY MODIFIED IN THE NEAR FUTURE

NOTE TAXIWAYS 75' WIDE UNLESS OTHERWISE NOTED

A

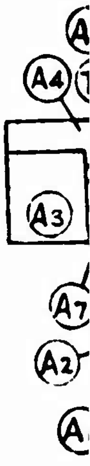
AIRPORT PAVEMENT CHARAC

STATE

I. D. NO.	SOIL CLASS.	SUB-GRADE CLASS	SUBBASE COURSE	BASE COURSE	SURFACE COURSE	OVERLAY	MOD. SUBGRADE REAC. K	DESIGN ALLOW.	CONSTRUC. SPEC	YEAR
—— RUNWAYS ——										
R-1	E-4	F2	-	10" P-208	2" P-401	2" P-401			FAAP	1964
R-2	E-4	F2	-	10" P-208	2" P-401	2" P-401			FAAP	1964
R-3	E-4	F2	-	10" P-208	2" P-401				FAAP	1950
R-4	E-4	F2	-	12" P-208	2½" P-401	2" P-401			FAAP	1964
R-5	E-4	F2	-	12" P-208	2" P-401	2" P-401			FAAP	1964
R-6	E-6	F4	9" P-154	8" P-208	2" P-401	2" P-401			FAAP	1968
R-7	E-6	F4	11" P-154	10" P-208	3" P-401	2" P-401			FAAP	1968
R-8	E-6	F3*	4" P-208	7" P-209	3" P-401				FAAP	1965
R-9	E-6	F3*	5" P-208	10" P-209	3" P-401				FAAP	1965
R-10	E-4	F2	-	12" P-209	2" P-401				FAAP	1950
R-11	E-6	F3*	4" P-208	7" P-209	3" P-401				FAAP	1965
R-12	E-6	F3*	5" P-208	10" P-209	3" P-401				FAAP	1965
R-13	E-4	F2	-	12" P-208	2½" P-401	2" P-401			FAAP	1965
R-14	E-7	F5	4" P-208	6" P-209	3" P-401				FAAP	1970
——TAXIWAY——										
T-1	E-4	F2	-	12" P-208	2" P-401	2" P-401			FAAP	1965
T-2	E-4	F2	-	12" P-208	2½" P-208	2" P-401			FAAP	1965
T-3	E-4	F2	-	12" P-208	2" P-401				FAAP	1950
T-4	E-6	F3*	11" P-154	10" P-208	3" P-401	2" P-401			FAAP	1968
T-5	E-4	F2	2" P-154	9" P-209	3" P-401				FAAP	1959
T-6	E-4	F2	3" P-154	10" P-209	3" P-401				FAAP	1959
T-7	E-6	F3*	5" P-208	10" P-209	3" P-401				FAAP	1965
T-8	E-4	F2	-	12" P-208	2" P-401				FAAP	1948
T-9	E-2	F1	-	11" P-209	3" P-401				FAAP	1966
T-10	E-5	F3	15" P-208	7" P-201	4" P-401				FAAP	1970
T-11	E-7	F5	4" P-208	6" P-209	3" P-401				FAAP	1970
—— APRONS ——										
A-1	E-4	F2	-	14" P-208	3" P-401				FAAP	1948
A-2	E-4	Rb	-	6" P-208	13½"/9" P-501				FAAP	1948
A-3	E-4	F2	-	6" P-208	1" P-609				FAAP	1951
A-4	E-4	F2	-	6" P-208	1" P-609				FAAP	1951
A-5	E-4	F2	-	14" P-208	3" P-401				FAAP	1950
A-6	E-4	F2	-	14" P-208	3" P-401				FAAP	1951
A-7	E-4	F2	-	14" P-208	3" P-401				FAAP	1956
A-8	E-4	F2	2" P-154	9" P-209	3" P-401				FAAP	1959
A-9	E-4	F2	2" P-154	10" P-209	3" P-401				FAAP	1961
A-10	E-4	F2	6" P-154	6" P-209	2" P-401				FAAP	1961
A-11	E-4	Rb	-	-	12" P-501				FAAP	1961

REMARKS:

* Subgrade classified F_3 due to arid conditions



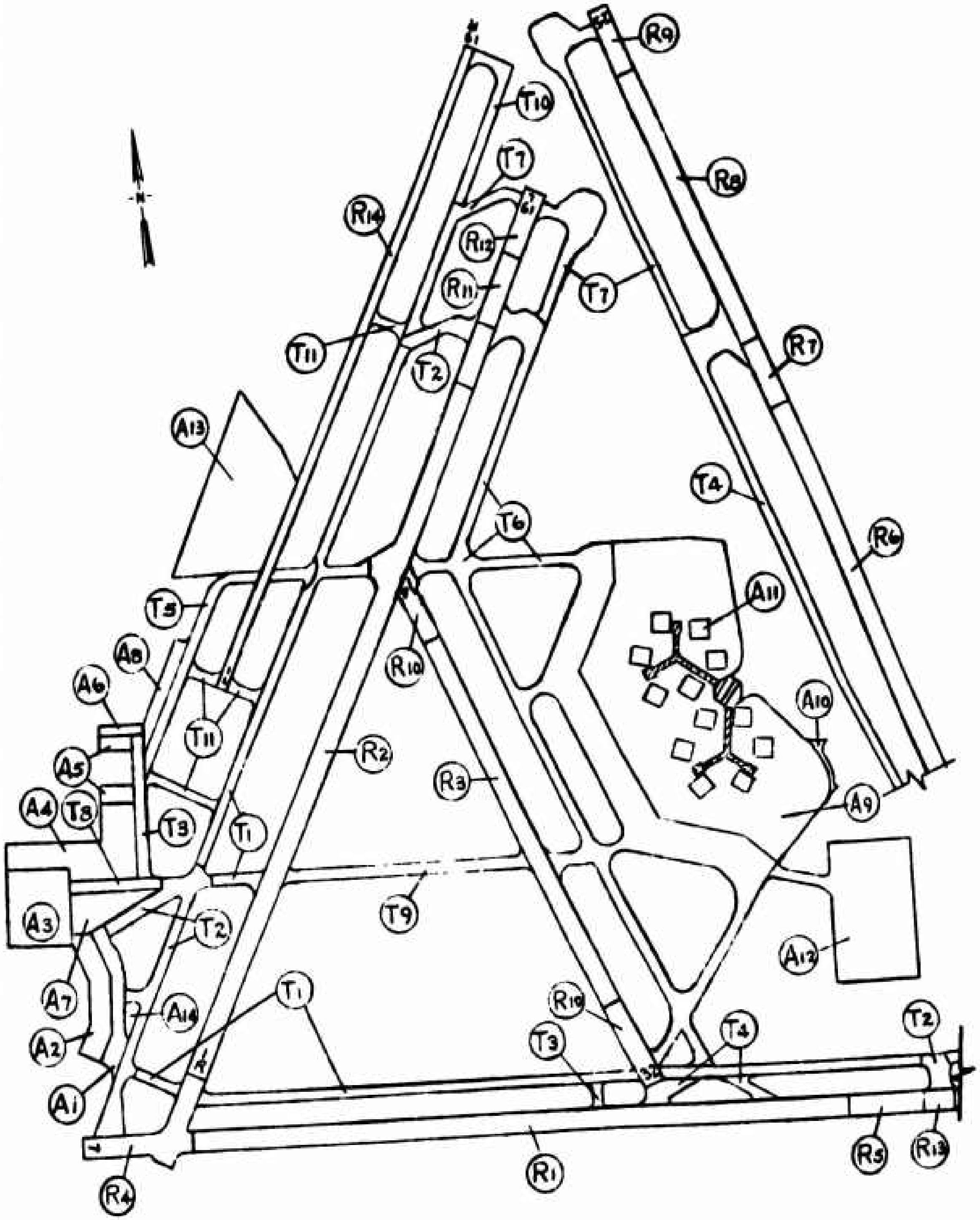
B

Table A2 (Concluded)

RPORT PAVEMENT CHARACTERISTICS

DD. RADE AC. K	DESIGN ALLOW.	CONSTRUC. SPEC	YEAR
		FAAP	1964
		FAAP	1964
		FAAP	1950
		FAAP	1964
		FAAP	1964
		FAAP	1968
		FAAP	1968
		FAAP	1965
		FAAP	1965
		FAAP	1950
		FAAP	1965
		FAAP	1965
		FAAP	1965
		FAAP	1970
		FAAP	1965
		FAAP	1965
		FAAP	1950
		FAAP	1968
		FAAP	1959
		FAAP	1959
		FAAP	1965
		FAAP	1948
		FAAP	1966
		FAAP	1970
		FAAP	1970
		FAAP	1948
		FAAP	1948
		FAAP	1951
		FAAP	1951
		FAAP	1950
		FAAP	1951
		FAAP	1956
		FAAP	1959
		FAAP	1961
		FAAP	1961
		FAAP	1961

STATE	CITY	AIRPORT NAME	DATE
Nevada	Las Vegas	McCarran International	Jan. '73



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AIRPORT PAVEMENT CHARACTE

STATE Nev

I. D. NO.	SOIL CLASS.	SUB-GRADE CLASS	SUBBASE COURSE	BASE COURSE	SURFACE COURSE	OVERLAY	MOD. SUBGRADE REAC. K	DESIGN ALLOW.	CONSTRUC. SPEC	YEAR
— RUNWAYS —										
— TAXIWAY —										
— APRONS —										
A-12	E-6	F3*	5" P-154	10" P-209	3" P-401				FAAP	1965
A-13	E-3	F2	-	7" P-209	2" P-401				FAAP	1966
A-14	E-6	F3*	5" P-154	10" P-209	3" P-401				FAAP	1965

REMARKS:

* Subgrade Classified F_3 due to arid conditions

Table A2 (Continued)

AIRPORT PAVEMENT CHARACTERISTICS

STATE Nevada **CITY** Las Vegas **AIRPORT NAME** McCarran International **DATE** Jan. '73

MOD. SUBGRADE REAC. K	DESIGN ALLOW.	CONSTRUC. SPEC	YEAR
		FAAP	1965
		FAAP	1966
		FAAP	1965

9

AIRPORT PAVEMENT CHARAC

STATE Mi

I. D. NO.	SOIL CLASS.	SUB-GRADE CLASS	SUBBASE COURSE	BASE COURSE	SURFACE COURSE	OVERLAY	MOD. SUBGRADE REAC. K	DESIGN ALLOW.	CONSTRUC. SPEC	YEAR
— RUNWAYS —										
R-1	E-7	Rc	8" P-154	-	12" P-501	6" P-401*			CAA-City	1970
R-2	E-7	Rc	4" P-154	6" P-201	14" P-401				FAA-City	1970
R-6	E-7	Rc	4" P-154	6" P-201	12" P-501				FAA-City	1967
R-7	E-7	Rc	4" P-154	6" P-201	10" P-501				FAA-City	1967
R-8	E-8	F8	-	-	6½" P-201				FAA-City	1972
— TAXIWAY —										
T-1	E-7	Rc	8" P-154		12" P-501				CAA-City	1955
T-2	E-7	Rc	4" P-154	6" P-201	14" P-501				FAA-City	1970
T-3	E-7	Rc	9" P-154		14" P-501				FAA-City	1960
T-6	E-7	Rc	4" P-154	6" P-201	12" P-501				FAA-City	1967
— APRONS —										
A-6	E-7	Rc	4" P-154	6" P-201	12" P-501				FAA-City	1970
A-7	E-7	Rc	6" **	6" P-304	13" P-501				FAA-City	1970

REMARKS:

* The overlay on the original runway 18 - 36 (9000') is 6" on centerline, and constantly sloped to 2" at the runway edges. Subgrade class based on E-7 soil, with severe frost and poor drainage.

** Lime and asphalt stabilized soil

B

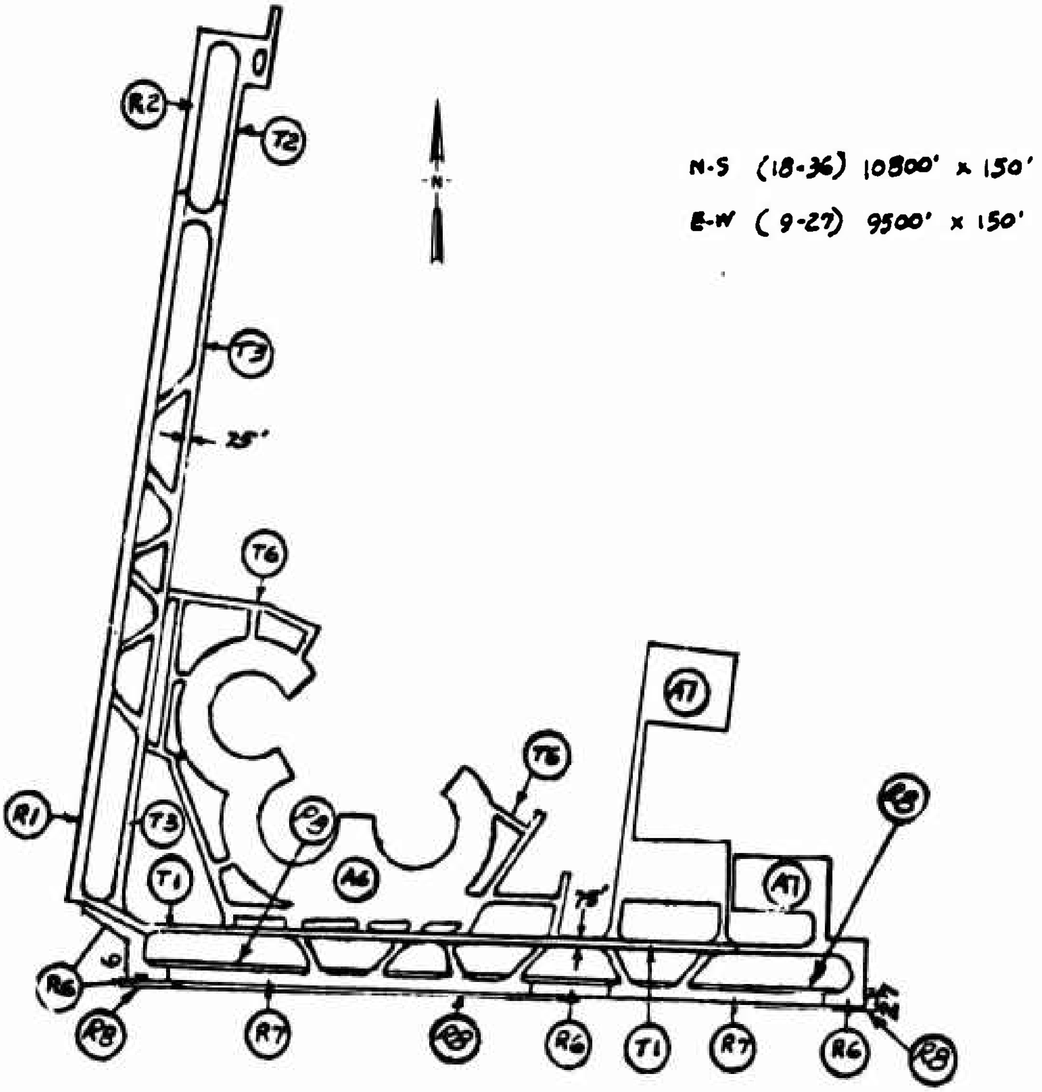
Table A2 (Continued)

ORT PAVEMENT CHARACTERISTICS

DE	DESIGN ALLOW.	CONSTRUC. SPEC	YEAR
		CAA-City	1970
		FAA-City	1970
		FAA-City	1967
		FAA-City	1967
		FAA-City	1972
		CAA-City	1955
		FAA-City	1970
		FAA-City	1960
		FAA-City	1967
		FAA-City	1970
		FAA-City	1970

nterline, and
ased on E-7 soil,

STATE Missouri **CITY** Kansas City **AIRPORT NAME** Kansas City International **DATE** Jan. '73



N-S (18-36) 10800' x 150'

E-W (9-27) 9500' x 150'

A

AIRPORT PAVEMENT CH

I. D. NO.	SOIL CLASS.	SUB-GRADE CLASS	SUBBASE COURSE	BASE COURSE	SURFACE COURSE	OVERLAY	MOD. SUBGRADE REAC. K	DESIGN ALLOW.	CONSTRUC. SPEC	YEAR
RUNWAYS										
10/28										
* R-1	E1/E3	Fa/Fl	13" CA	7" Bit.	3" AC	1½ + 5½"AC				1973
* R-2	E1/E3	Fa/Fl	13" CA	7" Bit.	3" AC	1½ + 4"AC				1973
15/33										
* R-3	E1/E3	Fa/Fl	10" CA	7" Bit.	3" AC	5½" AC				1973
* R-4	E1/E3	Fa/Fl	10" CA	7" Bit.	3" AC	4" AC				1973
* R-5	E1/E3	Fa/Fl	13" CA	7" Bit.	3" AC	1½" + 3½"AC				1973
* R-6	E/E3	Fa/Fl	10" CA	7" Bit.	3" AC	4½" AC				1973
4/22										
R-7	E1/E3	Fa/Fl	13" CA	7" Bit.	3" AC	1½" AC				
TAXIWAY										
* T-1	E1/E3	Fa/Fl	10" CA	7" Bit.	3" AC	5½" AC				1973
* T-2	E1/E3	Fa/Fl	13" CA	7" Bit.	3" AC	4½" AC				1973
* T-2A	E1/E3	Fa/Fl	13" CA	7" Bit.	3" AC	1½"+4½" AC				1973
* T-3	E1/E3	Fa/Fl	13" CA	6" Bit.	4" AC	5½" AC				1973
* T-4	E1/E3	Fa/Fl	13" CA	7" Bit.	3" AC	1½"+5" AC				1973
T-5	E1/E3	Fa/Fl	13" CA	7" Bit.	3" AC					
T-6	E1/E3	Fa/Fl	13" CA	7" Bit.	3" AC	1½" AC				
T-7	E1/E3	Fa/Fl	13" CA	7" Bit.	3" AC					
* T-8	E1/E3	Fa/Fl	13" CA	7" Bit.	3" AC	4½" AC				1973
* T-9	E1/E3	Fa/Fl	13" CA	7" Bit.	3" AC	1½"+4½"AC				1973
* T-9A	E1/E3	Fa/Fl	10" CA	5" Bit.	5" AC	4½" AC				1973
T-10	E1/E3	Fa/Fl	13" CA	7" Bit.	3" AC					
T-11	E1/E3	Fa/Fl	13" CA	7" Bit.	3" AC					
* T-12	E1/E3	Fa/Fl	13" CA	7" Bit.	3" AC	5½" AC				1973
* T-13	E1/E3	Fa/Fl	13" CA	7" Bit.	3" AC	5" AC				1973
APRONS										
Term.	E1/E3	Fa/Fl	13" CA	7" Bit.	3" AC					
Apron										
Exten.	E1/E3	Fa/Fl	10" CA	7" Bit.	3" AC					
Apron										

REMARKS:

CA - Crushed Aggregate
AC - Asphaltic Concrete (Stone)
Bit.- Bituminous Concrete (Sand-Gravel)

* Overlay to be completed in 1973

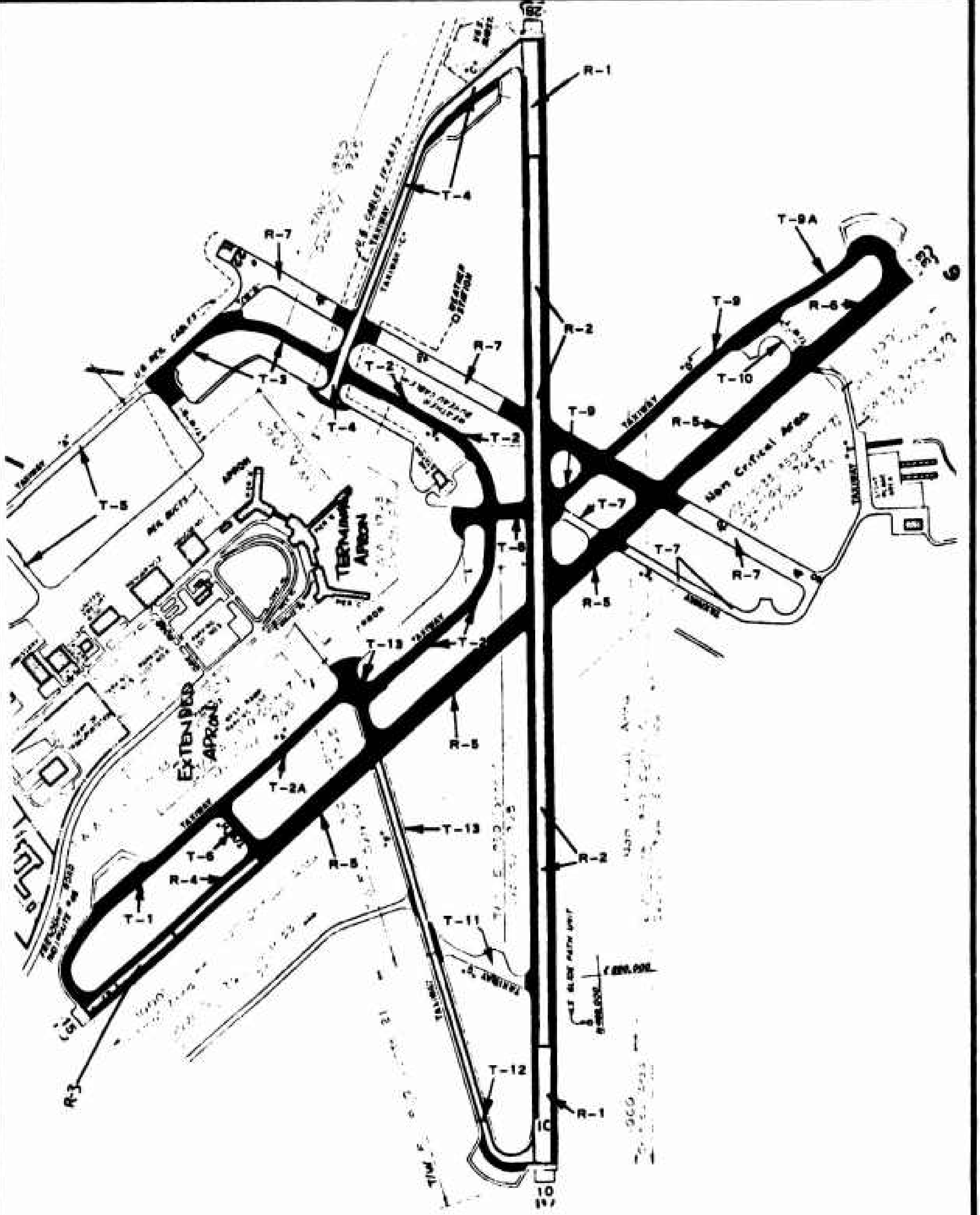
Note: Apron data is unreliable

Table A2 (Continued)

RT PAVEMENT CHARACTERISTICS

DESIGN ALLOW.	CONSTRUC. SPEC	YEAR
		1973
		1973
		1973
		1973
		1973
		1973
		1973
		1973
		1973
		1973
		1973
		1973
		1973
		1973
		1973
		1973

STATE	CITY	AIRPORT NAME	DATE
Maryland	Baltimore	Friendship International	Apr. '73



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A

AIRPORT PAVEMENT CHARAC

STATE

I. D. NO.	SOIL CLASS.	SUB-GRADE CLASS	SUBBASE COURSE	BASE COURSE	SURFACE COURSE	OVERLAY	MOD. SUBGRADE REAC. K	DESIGN ALLOW.	CONSTRUC. SPEC	YEAR
—— RUNWAYS ——										
10L-28R										
A	E-7	Rc	6" WB. MAC.	-	12" PCC				FAAP-01	1950
B	E-7	Rc	6" WB. MAC.	-	11" PCC				FAAP-01	1950
C	E-7	Rc	18" Slag	-	12"/8" PCC	4" Bit.C.			FAAP-16	1966
D	E-7	Rc	8" CA	-	12" PCC				FAAP-09	1957
18R-36L										
A	E-7	Rc	6" WB. MAC.	-	12" PCC				FAAP-01	1950
C	E-7	Rc	18" Slag	-	12"/8" PCC	4" Bit.C.			FAAP-19	1968
E	E-7	Rc	6" WB.MAC.	-	12" PCC	4" Bit.C.			FAAP-19	1968
F	E-7	Rc	18" Slag	-	9" PCC	4" Bit.C.			FAAP-19	1968
18L-36R										
G	E-7	Rc	4" Slag	-	9" PCC				War Dept.	1941
A	E-7	Rc	6" WB. MAC.	-	12" PCC				FAAP-01	1950
H	E-7	F5	2" Slag	*	1½" Bit.C.	14" Bit.C.			FAAP-09	1968
—— TAXIWAY ——										
C	E-7	Rc	18" Slag	-	9" PCC				War Dept.	1942
NASA	E-7	Rc	18" Slag		8" PCC					
J-1	E-6	Rc	8" SAM	-	13" PCC		300	420psi	FAAP-12	1962
J-2	E-6	Rc	8" SAM	-	12" PCC		300	420psi	FAAP-15	1964
J-3	E-7	Rc	8" SAM	-	12" PCC		300	420psi	FAAP-17	1967
K-4	E-6	Rc	8" SAM	-	13" PCC		300	420psi	FAAP-12	1962
K-5	E-6	Rc	10" CA	-	12" PCC		300	420psi	FAAP-18	1967
L-6	E-6	Rc	8" SAM	-	12" PCC		300	420psi	FAAP-14	1962
L-7	E-7	Rc	8" SAM	-	12" PCC		300	420psi	FAAP-17	1967
L-8	E-7	Rc	8" SAM	-	11" PCC				FAAP-16	1966
0-9	E-7	F7	2" Slag	*	1½" Bit. C.	6" Bit.C.				
0-10	E-7	Rc	8" Slag	-	12" PCC		300	420psi		
0-11	E-7	F7	-	8" WB.MAC.	2"Bit.C.	3" Bit.C.				
0-15	E-7	F7	2" Slag	*	1½" Bit.C.					
—— APRONS ——										
Terminal										
1	E-7	Rc	6" WB.MAC.	-	12" PCC				FAAP-01	1950
2	E-7	Rc	8" SAM	-	12" PCC		300	420psi	FAAP-02	1951
3	E-7	Rc	8" SAM	-	12" PCC		300	420psi	FAAP-05	1954
4	E-7	Rc	8" SAM	-	12" PCC		300	420psi	FAAP-08	1956
5	E-7	Rc	8" SAM	-	12" PCC		300	420psi	FAAP-09	1957
6	E-7	Rc	8" SAM	-	12" PCC		300	420psi	FAAP-05	1954
7	E-7	Rc	8" SAM	-	12" PCC		300	420psi	FAAP-10	1960
8	E-7	Rc	8" SAM	-	12" PCC		300	420psi	FAAP-15	1964
9	E-7	Rc	8" CA	-	12" PCC		300	420psi	CITY	1955
10	E-7	Rc	4" CA	-	8" PCC	4" Bit.C.			FAAP-05	1954

REMARKS: * 5" Water Bound Macadam + 2" Penetration Macadam.

SAM - Selected Aggregate Materials.
Bit.C. - Bituminus Concrete.
CA - Crushed Aggregate.

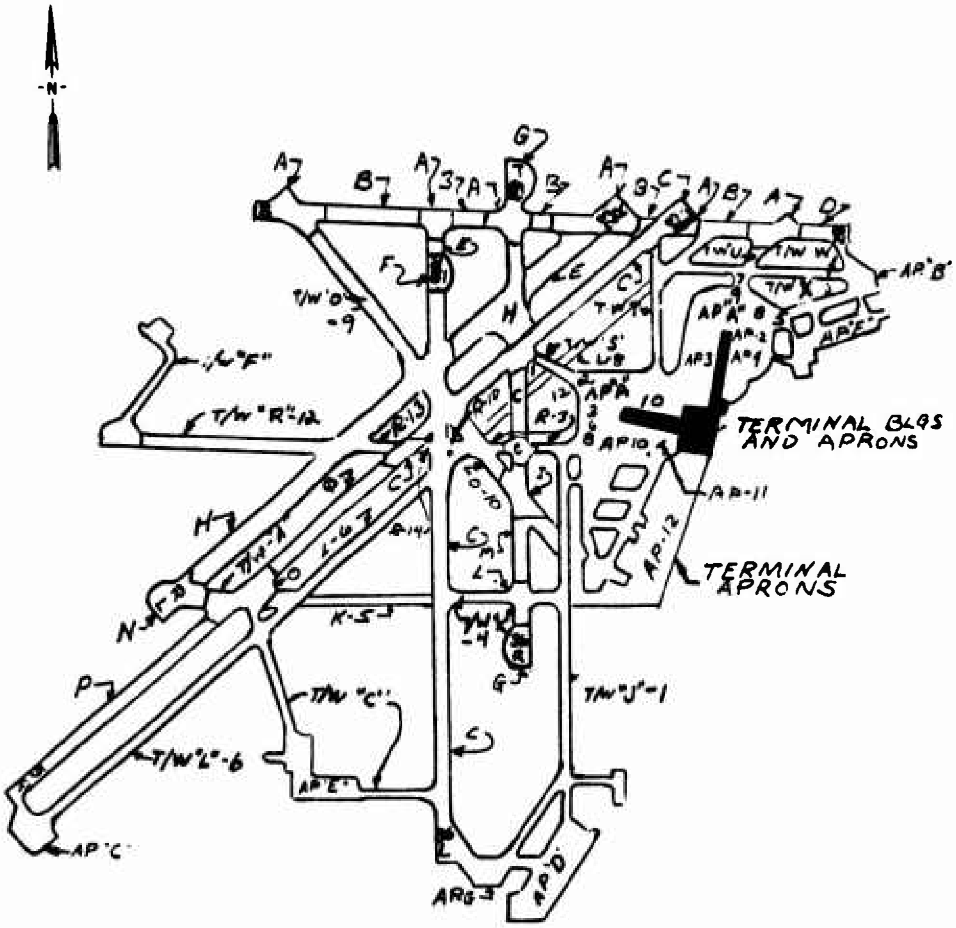
C

PORT PAVEMENT CHARACTERISTICS

Table A2 (Continued)

ADE C.	DESIGN ALLOW.	CONSTRUC. SPEC	YEAR
		FAAP-01	1950
		FAAP-01	1950
		FAAP-16	1966
		FAAP-09	1957
		FAAP-01	1950
		FAAP-19	1968
		FAAP-19	1968
		FAAP-19	1968
		War Dept.	1941
		FAAP-01	1950
		FAAP-09	1968
		War Dept.	1942
	420psi	FAAP-12	1962
	420psi	FAAP-15	1964
	420psi	FAAP-17	1967
	420psi	FAAP-12	1962
	420psi	FAAP-18	1967
	420psi	FAAP-14	1962
	420psi	FAAP-17	1967
		FAAP-16	1966
	420psi		
		FAAP-01	1950
	420psi	FAAP-02	1951
	420psi	FAAP-05	1954
	420psi	FAAP-08	1956
	420psi	FAAP-09	1957
	420psi	FAAP-05	1954
	420psi	FAAP-10	1960
	420psi	FAAP-15	1964
	420psi	CITY	1955
		FAAP-05	1954

STATE	CITY	AIRPORT NAME	DATE
Ohio	Cleveland	Cleveland-Hopkins International	Jan.'73



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A

AIRPORT PAVEMENT CHARA

STATE

I. D. NO.	SOIL CLASS.	SUB-GRADE CLASS	SUBBASE COURSE	BASE COURSE	SURFACE COURSE	OVERLAY	MOD. SUBGRADE REAC. K	DESIGN ALLOW.	CONSTRUC. SPEC	YEAR
—— RUNWAYS ——										
18L-36R										
C	E-7	Rc	18" Slag	-	12"/8" PCC	4" Bit.C.			FAAP-16	1966
I	E-7	Rc	8" CA	-	12" PCC				FAAP-02	1950
J	E-7	F7	-	8" WB.MAC.	2" Bit.C.	3" Bit.C.			FAAP-02	1950
K	E-7	Rc	8" SAM	-	12" PCC				FAAP-17	1967
L	E-6	Rc	8" SAM	-	13" PCC				FAAP-12	1962
M	E-6	F6	2" Slag	*	1½" Bit.C.				WPA	1941
5L-23R										
A	E-7	Rc	6" WB.MAC.	-	12" PCC				FAAP-01	1950
E	E-7	Rc	6" WB.MAC.	-	12" PCC	4" Bit.C.			FAAP-19	1968
H	E-7	F5	2" Slag	*	1½" Bit.C.	14"Bit.C.			FAAP-09	1957
C	E-7	Rc	18" Slag	-	12"/8"PCC	4" Bit.C.			FAAP-01	1968
N	E-7	Rc	4" Slag	-	9" PCC	4" Bit.C.			CITY	1968
——TAXIWAY——										
NASA										
R-12	E-7	F7	2" Slag	*	1½" Bit.C.				CAA	1943
R-13	E-7	Rc	8" SAM	-	12" PCC		300	420 psi	FAAP-14	1962
R-14	E-7	Rc	8" SAM	-	12" PCC		300	420 psi	FAAP-04	1952
R-10	E-7	Rc	8" CA	-	12" PCC		300	420 psi	FAAP-02	1950
R-3	E-7	Rc	8" SAM	-	12" PCC		300	420 psi	FAAP-17	1967
S	E-7	Rc	8" SAM	-	12" PCC		300	420 psi	FAAP-02	1951
T	E-7	Rc	6" WB.MAC.	-	12" PCC				FAAP-01	1950
U	E-7	Rc	8" SAM	-	12" PCC		300	420 psi	FAAP-10	1960
W	E-7	Rc	8" SAM	-	11" PCC		300	420 psi	FAAP-16	1966
X	E-7	Rc	8" SAM	-	12" PCC		300	420 psi	FAAP-09	1957
—— APRONS ——										
Terminal										
11	E-7	Rc	4" CA	-	8" PCC				WPA	1941
12	E-7	Rc	8" SAM	-	12" PCC		300	420 psi	FAAP-17	1967
B	E-6	Rc	8" SAM	-	12" PCC		300	420 psi	FAAP-14	1962
C	E-6	Rc	8" SAM	-	12" PCC		300	420 psi	FAAP-14	1962
D	E-6	Rc	8" SAM	-	12" PCC		300	420 psi	FAAP-15	1964
E	E-7	Rc	18" Slag	-	9" PCC				War Dept	1942
F		UNKNOWN								
G	E-6	Rc	8" SAM	-	12" PCC		300	420 psi	FAAP-12	1962
H		UNKNOWN								
I		UNKNOWN								

REMARKS: * 5" Water Bound Macadam + 3" Penetration Macadam.

SAM - Selected Aggregate Materials
CA - Crushed Aggregate
Bit. C.- Bituminous Concrete

C

Table A2 (Continued)

IRPORT PAVEMENT CHARACTERISTICS

MOD. BGRADE REAC. K	DESIGN ALLOW.	CONSTRUC. SPEC	YEAR
		FAAP-16	1966
		FAAP-02	1950
		FAAP-02	1950
		FAAP-17	1967
		FAAP-12	1962
		WPA	1941
		FAAP-01	1950
		FAAP-19	1968
		FAAP-09	1957
		FAAP-01	1968
		CITY	1968
		CAA	1943
300	420 psi	FAAP-14	1962
300	420 psi	FAAP-04	1952
300	420 psi	FAAP-02	1950
300	420 psi	FAAP-17	1967
300	420 psi	FAAP-02	1951
		FAAP-01	1950
300	420 psi	FAAP-10	1960
300	420 psi	FAAP-16	1966
300	420 psi	FAAP-09	1957
		WPA	1941
300	420 psi	FAAP-17	1967
300	420 psi	FAAP-14	1962
300	420 psi	FAAP-14	1962
300	420 psi	FAAP-15	1964
		War Dept	1942
300	420 psi	FAAP-12	1962

STATE	CITY	AIRPORT NAME	DATE
Ohio	Cleveland	Cleveland-Hopkins International	Jan. '73

(Sheet 40 of 44

4

AIRPORT PAVEMENT CHARA

STATE

I. D. NO.	SOIL CLASS.	SUB-GRADE CLASS	SUBBASE COURSE	BASE COURSE	SURFACE COURSE	OVERLAY	MOD. SUBGRADE REAC. K	DESIGN ALLOW.	CONSTRUC. SPEC	YEAR
— RUNWAYS —										
5R-23L										
O	E-6	Rc	8" SAM	-	13" PCC	4" Bit.C.	300	467	FAAP-10	1968
P	E-6	Rc	8" SAM	-	11" PCC	4" Bit.C.	300	390psi	FAAP- 10	1968
Q	E-7	Rc	18" Slag	-	12"/8"PCC	3" Bit.C.	300	390psi	FAAP-16	1966
C	E-7	Rc	18" Slag	-	12"/8"PCC	4" Bit.C.	300	467	FAAP-16	1966
— TAXIWAY —										
— APRONS —										
J		UNKNOWN								

REMARKS:

SAM - Selected Aggregate Materials

Bit.C.- Bituminous Concrete

13

Table A2 (Continued)

PORT PAVEMENT CHARACTERISTICS

STATE Ohio **CITY** Cleveland **AIRPORT NAME** Cleveland-Hopkins International **DATE** Jan. '73

DESIGN ALLOW.	CONSTRUC. SPEC	YEAR
467	FAAP-10	1968
390psi	FAAP- 10	1968
390psi	FAAP-16	1966
467	FAAP-16	1966

(Sheet 41 of 44)

A

AIRPORT PAVEMENT CHARA

STATE

I. D. NO.	SOIL CLASS	SUB-GRADE CLASS	SUBBASE COURSE	BASE COURSE	SURFACE COURSE	OVERLAY	MOD. SUBGRADE REAC. K	DESIGN ALLOW.	CONSTRUC. SPEC	YEAR
RUNWAYS										
12-30	E-8	Rc	-	9" CA	15" PCC		260	500 psi*	FAA	1960
1L-19R	E-8	Rc	-	9" CA	15" PCC		260	500psi*	FAA	1960
1R-19L	E-8	Rc	-	9" CA	15" PCC		260	500psi*	FAA	1960
TAXIWAY										
N-1	E-8	Rc	-	9" CA	15" PCC		260	500psi	FAA	1960
N-2	E-8	Rc	-	9" CA	15" PCC		260	500psi	FAA	1960
N-3	E-8	Rc	-	9" CA	15" PCC		260	500psi	FAA	1960
N-4	E-8	Rc	-	9" CA	15" PCC		260	500psi	FAA	1960
N-5	E-8	Rc	-	9" CA	15" PCC		260	500psi	FAA	1960
W-1	E-8	Rc	-	9" CA	15" PCC		260	500psi	FAA	1960
W-3	E-8	Rc	-	9" CA	15" PCC		260	500psi	FAA	1960
W-4	E-8	Rc	-	9" CA	15" PCC		260	500psi	FAA	1960
W-5	E-8	Rc	-	9" CA	15" PCC		260	500psi	FAA	1960
W-6	E-8	Rc	-	9" CA	15" PCC		260	500psi	FAA	1960
W-7	E-8	Rc	-	9" CA	15" PCC		260	500psi	FAA	1960
W-8	E-8	Rc	-	9" CA	15" PCC		260	500psi	FAA	1960
APRONS										
JET	E-8	Rc	-	9" CA	15" PCC		260	500psi		1960
										1961
Local	E-8	Rc	-	9" CA	9" PCC		260	500psi		1962
Gen. Aviation	E-8	Rc	-	9" CA	10" PCC		260	500psi		

REMARKS:

* 680 psi non critical areas
Safety Factor = 1.7 Critical Areas and
1.25 Non-critical Areas

CA - Crushed Aggregate

Note: The 15" PCC surface course is only true for a 50' center section and at the intersections with taxiways and high speed turns. The other pavement is tapered to 12" PCC. Jet apron will be widened by 80' on each side in the near future.

β

Table A2 (Continued)

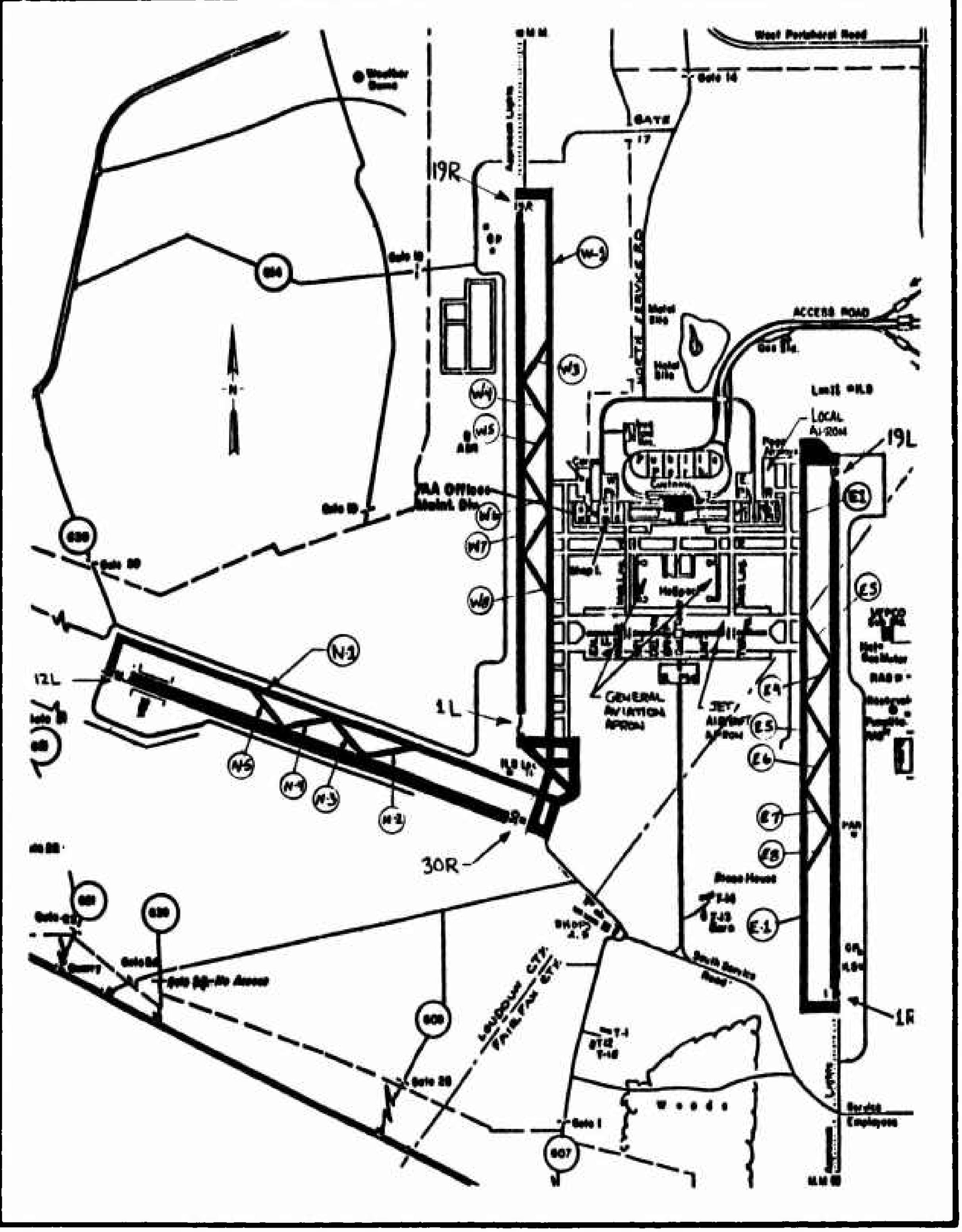
RT PAVEMENT CHARACTERISTICS

DESIGN ALLOW.	CONSTRUC. SPEC	YEAR
500 psi	FAA	1960
500psi*	FAA	1960
500psi*	FAA	1960
500psi	FAA	1960
500psi	FAA	1960
500psi	FAA	1960
500psi	FAA	1960
500psi	FAA	1960
500psi	FAA	1960
500psi	FAA	1960
500psi	FAA	1960
500psi	FAA	1960
500psi	FAA	1960
500psi	FAA	1960
500psi	FAA	1960
500psi		1960
		1961
500psi		1962
500psi		

rushed Aggregate

r section and at the
other pavement is tapered
side in the near future.

STATE D. C.
CITY Washington
AIRPORT NAME Dulles International
DATE Jan. '73



A

AIRPORT PAVEMENT CHARAC

STATE I

I. D. NO.	SOIL CLASS.	SUB-GRADE CLASS	SUBBASE COURSE	BASE COURSE	SURFACE COURSE	OVERLAY	MOD. SUBGRADE REAC. K	DESIGN ALLOW.	CONSTRUC. SPEC	YEAR
— RUNWAYS —										
— TAXIWAY —										
E-1	E-8	Rc	-	9" CA	15" PCC		260	500psi	FAA	1960
E-3	E-8	Rc	-	9" CA	15" PCC		260	500psi	FAA	1960
E-4	E-8	Rc	-	9" CA	15" PCC		260	500psi	FAA	1960
E-5	E-8	Rc	-	9" CA	15" PCC		260	500psi	FAA	1960
E-6	E-8	Rc	-	9" CA	15" PCC		260	500psi	FAA	1960
E-7	E-8	Rc	-	9" CA	15" PCC		260	500psi	FAA	1960
E-8	E-8	Rc	-	9" CA	15" PCC		260	500psi	FAA	1960
— APRONS —										

REMARKS:

CA - Crushed Aggregate

B

Table A2 (Continued)

RPORT PAVEMENT CHARACTERISTICS

STATE D. C. **CITY** Washington **AIRPORT NAME** Dulles International **DATE** Jan. '73

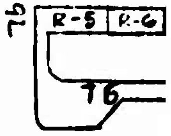
O. RADE AC. K	DESIGN ALLOW.	CONSTRUC. SPEC	YEAR
0	500psi	FAA	1960
0	500psi	FAA	1960
0	500psi	FAA	1960
0	500psi	FAA	1960
0	500psi	FAA	1960
0	500psi	FAA	1960
0	500psi	FAA	1960

(Sheet 43 of 44)

A

AIRPORT PAVEMENT CHA

I. D. NO.	SOIL CLASS.	SUB-GRADE CLASS	SUBBASE COURSE	BASE COURSE	SURFACE COURSE	OVERLAY	MOD. SUBGRADE REAC. K	DESIGN ALLOW.	CONSTRUC. SPEC	YEAR
					— RUNWAYS —					
R-1	E-1	F1	4" LR Stab.	8" P-211	2" Bit.	1½" P-401*			FAAP	1964
R-1(N	E-1	F1	4" LR Stab.	6½" P-211	2" Bit.	2" P-401*			FAAP	1964
R-2(N	E-1	F1	4" LR Stab.	8" P-211	2" P-401	*			FAAP	1961
R-3	E-1	F1	6" LR Stab.	6½" P-211	2" Bit.	2" P-401			FAAP	1965
R-3A	E-1	F1	6" LR Stab.	6½" P-211	1½" Bit.				NAVY	1940
R-4	E-1	F1	4" LR Stab.	8" P-211	2" Bit.				COUNTY	1965
R-5	E-1	F1	4" LR Stab.	9" P-211	3" P-401	*			FAAP	1964
R-6	E-1	F1	4" LR Stab.	8" P-211	2" P-401	*			FAAP	1964
R-7A	E-1	F1	6" LR Stab.	6½" P-211	1½" Bit.				NAVY	1940
R-8	E-1	F1	4" LR Stab.	6" P-211	1½" P-401				FAAP	1966
R-9	E-1	F1	4" LR Stab.	8" P-211	2" P-401				FAAP	1961
					— TAXIWAY —					
T-1	E-3	F1	-	12" P-211	2" P-401				FAAP-03	1959
T-2	E-1	F1	4" LP Stab.	12" P-211	2" P-401	*			FAAP-04	1961
T-3	E-2	F1	-	12" P-211	2" P-401	*			FAAP-03	1961
T-4	E-1	F1	-	9" P-211	3" P-401				FAAP-05	1963
T-5	E-1	F1	-	6½" P-211	1½" Bit.				COUNTY	1964
T-6	E-1	F1	4" LR Stab.	9" P-211	3" P-401	*			FAAP-06	1964
T-7	E-1	F1	4" LR Stab.	6" P-211	1½" P-401				FAAP-08	1966
T-8	E-3	F1	4" LP Stab.	6" P-211	1½" P-401				FAAP-12	1970
T-9	E-2	F1	4" LP Stab.	6" P-211	1½" P-401				FAAP-11	1968
T-10	E-3	F1	4" LP Stab.	9" P-211	3" P-401				FAAP-11	1968
T-11	E-2	F1	4" LP Stab.	**	**	*			ADAP-01	1971
T-12	E-2	F1	4" LP Stab.	12" P-211	2" P-401	2½" P-401*			FAAP-09	1970
T-13	E-3	F1	4" LP Stab.	9" P-211	3" P-401				FAAP-11	1968
					— APRONS —					
A-1	E-3	F1	-	-	10" P-501				FAAP-02	1959
A-2		Ra	-	-	6" P-501				NAVY	WW II
A-3	E-1	F1	-	8" P-211	2" Bit.				COUNTY	1964
A-4	E-2	Ra	-	-	6" P-501				NAVY	WW II
A-5	E-1	F1	-	9" P-211	3" P-401				FAAP-05	1963
A-6	E-1	F1	8" LR Stab.	6" P-211	1" Bit.					
A-7	E-1	F1	8" LR Stab.	8" P-211	1" Bit.					
A-8	E1/E3	F1	4" LR Stab.	6" P-211	1½" P-401				FAAP-10	1967
A-9	E1/E3	F1	4" LR Stab.	9" P-211	3" P-401				ADAP-01	1971
A-10	E-3	F1	4" LR Stab.	9" P-211	3" P-401				FAAP-11	1968



REMARKS:

LR - Lime Rock

* An additional 3" asphalt concrete overlay is programmed for 1973 on runway 9L-27R and parallel taxiway. The pavement at this location is old and is showing signs of distress (rutting, oxidation, cracking, etc.), and the overlay is necessary to bring the pavement up to a strength of 350,000 lbs. dual tandem gear gross load.

** Old Navy Base with a 4½" surface.

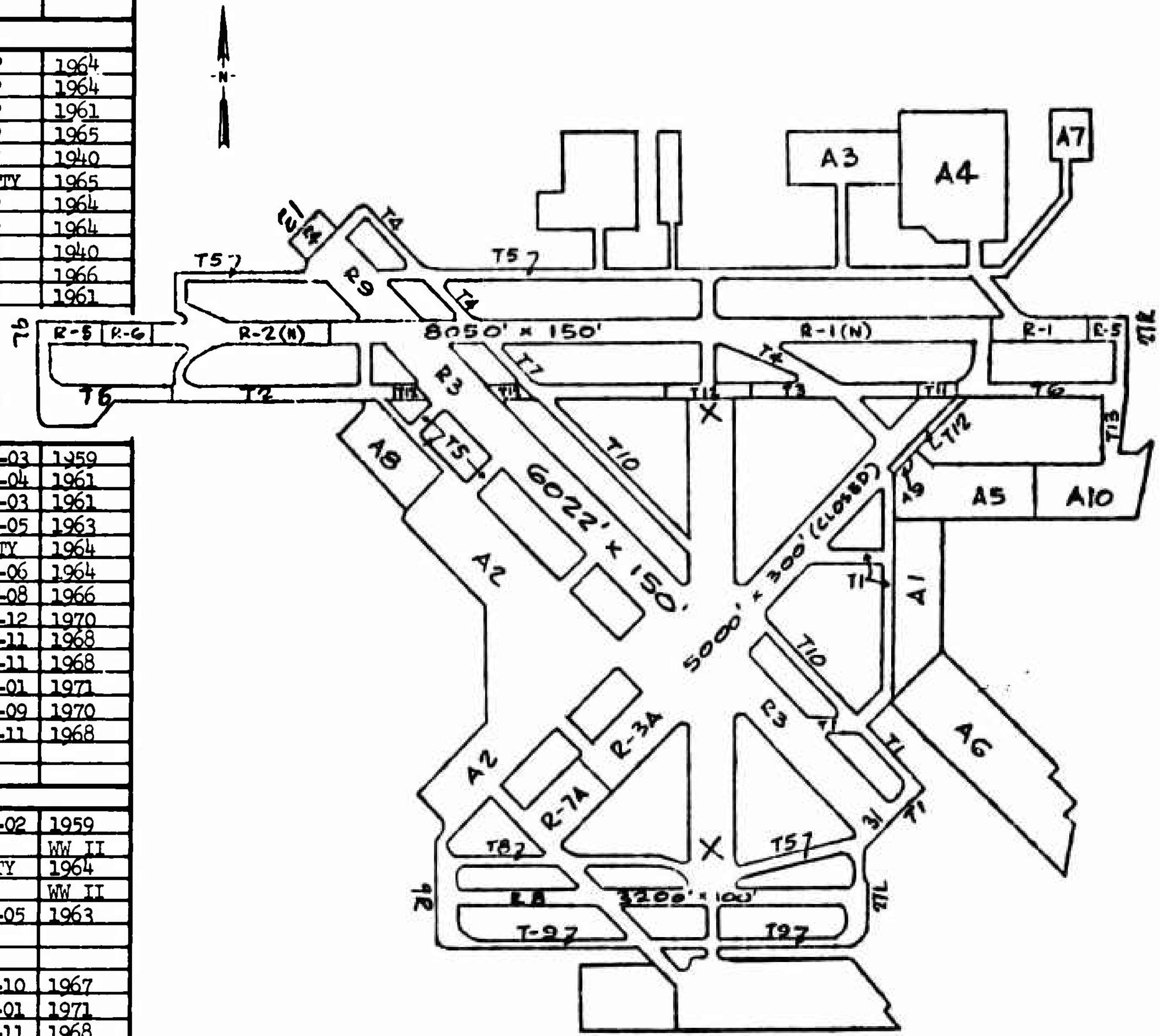
B

Table A2 (Continued)

RT PAVEMENT CHARACTERISTICS

DESIGN ALLOW.	CONSTRUC. SPEC	YEAR
	FAAP	1964
	FAAP	1964
	FAAP	1961
	FAAP	1965
	NAVY	1940
	COUNTY	1965
	FAAP	1964
	FAAP	1964
	NAVY	1940
	FAAP	1966
	FAAP	1961
	FAAP-03	1959
	FAAP-04	1961
	FAAP-03	1961
	FAAP-05	1963
	COUNTY	1964
	FAAP-06	1964
	FAAP-08	1966
	FAAP-12	1970
	FAAP-11	1968
	FAAP-11	1968
	ADAP-01	1971
	FAAP-09	1970
	FAAP-11	1968
	FAAP-02	1959
	NAVY	WW II
	COUNTY	1964
	NAVY	WW II
	FAAP-05	1963
	FAAP-10	1967
	ADAP-01	1971
	FAAP-11	1968

STATE	CITY	AIRPORT NAME	DATE
Florida	Ft. Lauderdale	Hollywood International	Jan. '73



'73 on runway 9L-27R
id is showing signs
lay is necessary to
m gear gross load.

(Sheet 44 of 44)

APPENDIX B

CONTROLLING PAVEMENT CHARACTERISTICS USED TO DETERMINE PAVEMENT THICKNESS REQUIREMENTS

The CBR's of subgrade soil and the moduli of subgrade reaction k are input parameters essential to the determination of required thickness. These values, determined as described in the main text for the pavement section that controlled the evaluation of each pavement item, are listed in the following tabulation.

Airfield	Pavement Item*	Controlling ID No.*	Subgrade CBR	Foundation k**
Chicago (O'Hare)	Runway 1	30	6.5	360
	Runway 2	38	5.5	390
	Runway 3	24	6.5	270
	Taxiway 1 & 6	41	5.5	380
	Taxiway 2	25	6.5	260
	Taxiway 3	11	6.5	360
	Taxiway 4	42	5.5	340
	Taxiway 5	10	6.5	300
	Taxiway 7	9	6.5	360
	Apron 1	12	6.5	260
Atlanta	Runway 1	R-6	8.5	280
	Runway 2	R-2	8.5	280
	Taxiway 1	T-7	8.5	280
	Taxiway 2	T-6	8.5	280
	Taxiway 3	T-1	8.5	390
	Taxiway 4	T-2	8.5	280
	Apron 1	A-1	8.5	260
Los Angeles (International)	Runway 1	R-1	8.5	260
	Runway 2	R-3	22	460
	Taxiway 1	T-2A	22	290
	Taxiway 2	T-8	22	290
	Taxiway 4	T-7	8.5	305
	Taxiway 5	T-5E	8.5	490
	Taxiway 6	R-5C & T-2B	8.5	340
	Taxiway 7	T-11	8.5	460
	Taxiway 8	T-10	22	380
	Apron 1	A-11	22	360

---

* Identification of pavement items and controlling ID numbers are shown in Table A2.

** Where flexible pavement is base pavement, k shown represents k on top of flexible pavement. Where rigid pavement is base pavement, the k shown represents k of foundation layer directly under existing pavement slab.

Airfield	Pavement Item	Controlling ID No.	Subgrade CBR	Foundation k
	Apron 2	A-12	22	315
	Apron 3	A-15	22	315
	Apron 4	A-1	8.5	350
	Apron 5	A-20	22	400
San Francisco	Runway 1	R-1	18	400
	Runway 2	R-3	18	400
	Taxiway 1	T-2	18	400
	Taxiway 2	T-9	18	400
	Taxiway 3	T-5	18	400
	Apron 1	A-3	18	400
Miami	Runway 1	R-1A	23	450
	Runway 2	R-2	23	490
	Taxiway 1	T-1	23	450
	Taxiway 2	T-3	23	410
	Taxiway 3	T-3	23	410
	Taxiway 4	T-5	23	430
	Taxiway 5	T-1B	23	450
	Apron 1	A-8	23	370
New York (JFK)	Runway 1	13R-31L	23	370
	Runway 2	4L-22R	23	370
	Taxiway 1	P	23	370
	Taxiway 2	O	23	430
	Taxiway 3	I	23	430
	Taxiway 4	K	23	430
	Apron 1	Terminal	23	370
New York (La Guardia)	Runway 1	13-3i	23	400
	Runway 2	4-22	7.5	330
	Taxiway 1	13-31	23	390
	Taxiway 2	4-22	7.5	330
	Apron 1	Terminal and Hanger	7.5	340
Newark	Runway 1	4-22	23	410
	Taxiway 1	T-2	23	410
	Taxiway 2	Taxi-B	23	410
	Apron 1, 2, 3	B	23	400
Denver	Runway 1	R-8	23	200
	Runway 2	R-1	7.5	390
	Taxiway 1	T-10	23	200
	Taxiway 2	T-8	6.5	220
	Taxiway 3	T-7	7.5	325
	Taxiway 4	T-8	6.5	220
	Aprons	A-1	7.5	165
Boston	Runway 1	C	6.5	500
	Runway 2	B	6.5	500

(Continued)

Airfield	Pavement Item	Controlling ID No.	Subgrade CBR	Foundation k
	Taxiway 1	P	6.5	450
	Taxiway 2	D	6.5	450
	Taxiway 3	N	6.5	410
	Taxiway 4	S Apron	6.5	410
	Taxiway 5	Cb	6.5	500
	Apron 1	Expons 1	6.5	450
	Apron 2	Expons 2	22	410
Phildelphia	Runway 1	Critical	18	390
	Runway 2	Noncritical	18	360
	Taxiway 1	T-1	18	390
	Taxiway 2	T-2	18	500
	Taxiway 3	Critical	18	390
	Apron 1	A-1	18	280
St. Louis	Runway 1	5	8.5	180
	Taxiway 1	6	8.5	180
	Apron 1	7 & 11	8.5	180
Honolulu	Runway 1	R-8	14.5	500
	Taxiway 1	T-29	14.5	500
	Taxiways 3, 4, 8, & 10	T-8, T-15, T-27, T-24	14.5	500
	Taxiways 5, 6, 7, 11, & 13	T-5, T-20, T-4, T-6	14.5	500
	Taxiway 12	T-23	14.5	500
	All Aprons	A-5	14.5	500
Detroit	Runway 1	2	6.5	200
	Runway 2	6	6.5	200
	Taxiway 1	13, 12, 10	6.5	200
	Taxiway 2	12, 13	6.5	200
	Taxiway 3	11	6.5	200
	Taxiway 4	12	6.5	200
	Apron	29	6.5	200
Seattle/ Tacoma	Runway 1	R-3, R-4	10	200
	Runway 2	R-6	18	340
	Taxiway 1	T1, T2, T6, T9	10	300
	Taxiway 2	T-19	18	340
	Taxiway 3	T-12	10	200
	Taxiway 4	T15, T16, T20	18	340
	Aprons	A-1	10	200
Pittsburgh	Runway 1	R-7	6.5	220
	Runway 2	R-4	6.5	220
	Taxiway 1	T-9	6.5	220
	Taxiway 2	T-10	6.5	220
	Taxiway 3	T-5	6.5	375
	Taxiway 4	T-9	6.5	220

(Continued)

Airfield	Pavement Item	Controlling ID No.	Subgrade CBR	Foundation k
	Taxiway 5	T-2	6.5	250
	Apron 1	A-1	6.5	150
Houston	Runway 1	R-5	10	400
	Taxiway 1	T-3	10	400
	Taxiway 2	T-7	10	400
	Taxiway 3	T-3	10	400
	Taxiway 4	T-4	10	400
	Apron 1	A-3	10	400
Minneapolis/ St. Paul	Runway 1	R-2, R-3, R-5	10	200
	Runway 2	R-13	10	200
	Taxiway 1	T-2	10	275
	Taxiway 2	T-10	10	275
	Apron 1	A-1	10	275
New Orleans	Runway 1	R-6	3.5	160
	Taxiway 1	T-4	3.5	145
	Taxiway 2	T-1	3.5	270
	Apron 1	A-1	3.5	145
	Apron 2	A-3	3.5	270
	Apron 3	A-4	3.5	50
Las Vegas	Runway 1	R-6	10	370
	Runway 2	R-2	14.5	250
	Taxiway 1	T-4	12.5	370
	Taxiway 2	T-6	14.5	370
	Apron 1	A-9	14.5	360
Kansas City (International)	Runway 1	R-7	6.5	250
	Runway 2	R-1	6.5	220
	Taxiway 1	T-1	6.5	220
	Taxiway 2	T-2, T-3	6.5	230
	Taxiway 3	T-6	6.5	250
	Apron	A-6	6.5	200
Baltimore	Runway 1	10-78	18	430
	Runway 2	15-33	18	410
	All Taxiways	B,C,D,E,F,G	18	430
	Apron 1	--	18	430
Cleveland	Runway 1	Q	6.5	300
	Taxiway 1	L-6	6.5	300
	Taxiway 2	T	6.5	300
	Apron 1	AP-12	6.5	300
	Apron 2	AP-3, AP-4, AP-2	6.5	300
	Apron 3	AP-10	6.5	300
Washington (Dulles)	All Pavements	--	7.5	260
Hollywood	Runway 1	R-1, R1(N)	18	380

(Continued)

Airfield	Pavement Item	Controlling ID No.	Subgrade CBR	Foundation k
	Taxiway 1	T-5	18	335
	Taxiway 2	T-12	18	410
	Apron 1	A-2	18	280

APPENDIX C

PAVEMENT THICKNESS REQUIREMENTS FOR OPERATION OF CATEGORY I AND II AIRCRAFT

The flexible pavement thicknesses for new construction were determined by entering the design curves shown in Figures 32 through 35 of the main text with the appropriate subgrade CBR value from Appendix B and reading the corresponding thickness. For rigid pavement new construction, the design curves shown in Figures 36 through 39 of the main text were entered at a working stress of 350 psi, and the required thickness was determined using the k-value of the foundation under existing pavements and the gross weight of the aircraft.

All overlay thicknesses were determined in accordance with FAA procedures and methods presented in Reference 10. The base pavement for all overlays was assumed to be in good condition. Calculations were made for flexible, bituminous, and rigid overlays on rigid and flexible pavements. Overlay thicknesses were calculated for each cross section on a pavement item (i.e., runway, taxiway, apron, etc.) and the overlay thickness deemed most logical was selected for the entire pavement item.

The results of these calculations are shown in this appendix.

Appendix C

Pavement Thickness Requirements for Operation of Category I and II Aircraft

					Thickness Requirements, in.**				
					New Construction		Overlays†		
Airport*	Pavement Item	Base Pavement Type	Aircraft Category	Gear	Rigid	Flexible	Flexible	Bituminous	Rigid
Chicago (O'Hare)	Runway 1	PCC	I	Median	17	--	--	11.0	11
				Optimized	17	--	--	11.5	11
			II	Median	16	--	--	9.5	10
				Optimized	21	--	--	17.0	15
	Runway 2	PCC	I	Median	17	--	--	6.0	8
				Optimized	17	--	--	6.5	9
			II	Median	16	--	--	4.5	7
				Optimized	20	--	--	11.5	13
	Runway 3	PCC	I	Median	18	--	--	3.0	12
				Optimized	19	--	--	4.0	13
			II	Median	18	--	--	3.0	11
				Optimized	23	--	--	10.5	17
	Taxiway 1 and 6	PCC	I	Median	17	--	--	3.0	8
				Optimized	17	--	--	4.0	9
			II	Median	16	--	--	3.0	7
				Optimized	24	--	--	13.0	17
	Taxiway 2	PCC	I	Median	18	--	--	3.0	6
				Optimized	19	--	--	3.0	7
			II	Median	18	--	--	3.0	6
				Optimized	23	--	--	6.5	13
	Taxiway 3	AC	I	Median	--	55, 4, 14	--	17.5	17
				Optimized	--	56, 4, 14	--	18.0	17
			II	Median	--	58.5, 4, 14	--	19.0	16
				Optimized	--	64.5, 4, 15	--	26.5	21
	Taxiway 4	PCC	I	Median	17	--	--	4.0	9
				Optimized	18	--	--	4.5	9
			II	Median	16	--	--	3.0	8
				Optimized	21	--	4 + 8	9.5	14
	Taxiway 5	AC	I	Median	--	55, 4, 14	4 + 14	13.5	17
				Optimized	--	56, 4, 14	4 + 14	13.5	17
			II	Median	--	58.5, 4, 14	4 + 17	15.5	16
				Optimized	--	69.5, 4, 15	4 + 28	22.5	21
	Taxiway 7	AC	I	Median	--	55, 4, 14	4 + 18	16.0	17
				Optimized	--	56, 4, 14	4 + 18	16.0	17
			II	Median	--	58.5, 4, 14	4 + 20	17.5	16
				Optimized	--	69.5, 4, 15	4 + 31	24.5	21
	Apron 1	PCC	I	Median	18	--	--	3.0	6
				Optimized	19	--	--	3.0	7
			II	Median	18	--	--	3.0	6
				Optimized	23	--	4 + 4	6.5	13
Atlanta	Runway 1	PCC	I	Median	18	--	--	3.0	6
				Optimized	18	--	--	3.0	6
			II	Median	17	--	--	3.0	6
				Optimized	22	--	--	4.5	11
	Runway 2	PCC	I	Median	18	--	--	3.0	6
				Optimized	18	--	--	3.0	6
			II	Median	17	--	--	3.0	6
				Optimized	22	--	--	4.5	11
	Taxiway 1, 2, and 4	PCC	I	Median	18	--	--	3.0	6
				Optimized	18	--	--	3.0	6
			II	Median	17	--	--	3.0	6
				Optimized	22	--	--	4.5	11
	Taxiway 3	AC	I	Median	--	42.5, 4, 14	4 + 8.5	9.5	16
				Optimized	--	43.5, 4, 14	4 + 9.5	10.5	17

(Continued)

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* Dallas-Fort Worth Regional Airport was not included because it is designed for operation of the Category II aircraft.

** Multiple entries such as 55, 4, 14 indicate total thickness, thickness of wearing course, and thickness of base course.

† Flexible pavement is defined as asphaltic concrete wearing course plus granular foundation courses; bituminous pavement is defined as full-depth asphaltic concrete.

(Sheet 1 of 11)

Appendix C (Continued)

Airport	Pavement Item	Base Pavement Type	Aircraft Category	Gear	Thickness Requirements, in.				
					New Construction		Overlays		
					Rigid	Flexible	Flexible	Bituminous	Rigid
Atlanta (Continued)	Taxiway 3	AC	II	Median	--	44, 4, 14	4 + 10.5	11.0	16
				Optimized	--	54, 4, 15	4 + 20	17.5	20
	Apron 1	PCC	I	Median	18	--	--	6.0	11
				Optimized	19	--	4 + 4.5	7.0	11
			II	Median	18	--	--	6.0	10
				Optimized	23	--	4 + 13	12.5	16
Los Angeles (International)	Runway 1	PCC	I	Median	16	--	4 + 5	7.5	10
				Optimized	19	--	4 + 6	8.0	11
			II	Median	18	--	4 + 4.5	7.0	10
				Optimized	23	--	4 + 15.5	14.5	16
	Runway 2	AC	I	Median	--	15, 4, 11	0	0	0
				Optimized	--	15.5, 4, 11.5	0	0	0
			II	Median	--	15.5, 4, 11.5	0	0	0
				Optimized	--	18, 4, 14	0	0	0
	Taxiway 1	AC	I	Median	--	15, 4, 11	0	0	0
				Optimized	--	15.5, 4, 11.5	0	0	0
			II	Median	--	15.5, 4, 11.5	0	0	0
				Optimized	--	18, 4, 14	0	0	0
	Taxiway 2	PCC	I	Median	18	--	--	5.0	10
				Optimized	18	--	--	5.5	10
			II	Median	17	--	--	4.0	9
				Optimized	22	--	4 + 10	11.0	15
	Taxiway 4	PCC	I	Median	18	--	4 + 10.5	11.0	13
				Optimized	18	--	4 + 12	12.0	14
			II	Median	17	--	4 + 9.5	10.5	13
				Optimized	22	--	4 + 19.5	17.0	18
	Taxiway 5	AC	I	Median	--	42.5, 4, 14	0	0	0
				Optimized	--	43.5, 4, 14	--	3.0	16
			II	Median	--	44.1, 4, 14	--	3.0	15
				Optimized	--	53.7, 4, 15	4 + 4	6.5	19
	Taxiway 6	AC	I	Median	--	42.5, 4, 14	4 + 18	16.0	17
				Optimized	--	43.5, 4, 14	4 + 19	16.5	18
			II	Median	--	44, 4, 14	4 + 18.5	16.5	16
				Optimized	--	54, 4, 15	4 + 29	23.5	21
	Taxiway 7	AC	I	Median	--	42.5, 4, 14	--	3.0	16
				Optimized	--	43.5, 4, 14	--	3.0	16
			II	Median	--	44, 4, 14	--	3.0	15
				Optimized	--	54, 4, 15	4 + 9	10.0	19
	Taxiway 8	PCC	I	Median	17	--	--	3.0	8
				Optimized	17	--	--	4.0	9
			II	Median	16	--	--	3.0	7
				Optimized	24	--	4 + 13.5	13.0	17
	Apron 1	PCC	I	Median	17	--	--	3.5	8
				Optimized	17	--	--	4.0	9
			II	Median	16	--	--	3.0	8
				Optimized	21	--	4 + 7.5	9.0	13
	Apron 2	PCC	I	Median	17	--	--	6.0	10
				Optimized	18	--	--	6.5	11
			II	Median	17	--	--	5.0	9
				Optimized	22	--	4 + 11.5	11.5	15
	Apron 3	PCC	I	Median	17	--	4 + 10.5	11.0	13
				Optimized	18	--	4 + 11.5	11.5	14
			II	Median	17	--	4 + 9	10.0	12
				Optimized	22	--	4 + 19	17.0	18
	Taxiway 6	AC	I	Median	--	42.5, 4, 14	4 + 18	16.0	17
				Optimized	--	43.5, 4, 14	4 + 19	16.5	18
			II	Median	--	44, 4, 14	4 + 18.5	16.5	16
				Optimized	--	54, 4, 15	4 + 29	23.5	21

(Continued)

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Appendix C (Continued)

Airport	Pavement Item	Base Pavement Type	Aircraft Category	Gear	Thickness Requirements, in.				
					New Construction		Overlays		
					Rigid	Flexible	Flexible	Bituminous	Rigid
Los Angeles (International) (Cont'd)	Taxiway 7	AC	I	Median	--	42.5, 4, 14	--	3.0	16
				Optimized	--	43.5, 4, 14	--	3.0	16
			II	Median	--	44, 4, 14	--	3.0	15
				Optimized	--	54, 4, 15	4 + 9	10.0	19
	Taxiway 8	PCC	I	Median	17	--	--	3.0	8
				Optimized	17	--	--	4.0	9
			II	Median	16	--	--	3.0	7
				Optimized	24	--	4 + 13.5	13.0	17
	Apron 1	PCC	I	Median	17	--	--	3.5	8
				Optimized	17	--	--	4.0	9
			II	Median	16	--	--	3.0	8
				Optimized	21	--	4 + 7.5	9.0	13
	Apron 2	PCC	I	Median	17	--	--	6.0	10
				Optimized	18	--	--	6.5	11
			II	Median	17	--	--	5.0	9
				Optimized	22	--	4 + 11.5	11.5	15
	Apron 3	PCC	I	Median	17	--	4 + 10.5	11.0	[illegible]
				Optimized	18	--	4 + 11.5	11.5	14
			II	Median	17	--	4 + 9	10.0	12
				Optimized	22	--	4 + 19	17.0	18
	Apron 4	AC	I	Median	--	42.5, 4, 14	4 + 15.5	14.5	17
				Optimized	--	43.5, 4, 14	4 + 16.5	15.0	17
			II	Median	--	44, 4, 14	4 + 17	15.5	16
				Optimized	--	54, 4, 15	4 + 26.5	21.5	21
	Apron 5	AC	I	Median	--	15, 4, 11	--	3.0	16
				Optimized	--	15.5, 4, 11.5	--	3.0	17
			II	Median	--	15.5, 4, 11.5	--	3.0	16
				Optimized	--	17.5, 4, 13.5	--	3.0	20
San Francisco	Runway 1	AC	I	Median	--	19, 4, 12	--	3.0	16
				Optimized	--	19.5, 4, 12	--	3.0	17
			II	Median	--	19.5, 4, 12	--	3.0	16
				Optimized	--	23, 4, 13	--	5.5	20
	Runway 2	AC	I	Median	--	19, 4, 12	--	3.0	16
				Optimized	--	19.5, 4, 12	--	3.0	17
			II	Median	--	19.5, 4. 12	--	3.0	16
				Optimized	--	23, 4, 13	--	4.0	20
	Taxiway 1	AC	I	Median	--	19, 4, 12	--	3.0	16
				Optimized	--	19.5, 4, 12	--	3.0	17
			II	Median	--	19.5, 4, 12	--	3.0	16
				Optimized	--	23, 4, 13	--	3.0	20
	Taxiway 2	PCC	I	Median	16	--	--	3.0	6
				Optimized	17	--	--	3.0	6
			II	Median	16	--	--	3.0	6
				Optimized	20	--	--	5.5	10
	Taxiway 3	PCC	I	Median	16	--	--	3.0	6
				Optimized	17	--	--	3.0	7
			II	Median	16	--	--	3.0	5
				Optimized	20	--	4 + 4.5	7.0	12
	Apron 1	AC	I	Median	--	19,4,12	--	3.0	16
				Optimized	--	19.5, 4, 12	--	3.0	17
			II	Median	--	19.5, 4, 12	--	3.0	16
				Optimized	--	23, 4, 13	--	4.0	20
Miami	Runway 1	AC	I	Median	--	14, 4, 10	0	0	0
				Optimized	--	14.5, 4, 10.5	0	0	0
			II	Median	--	14.5, 4, 10.5	0	0	0
				Optimized	--	16.5, 4, 12.5	0	0	0
	Runway 2	AC	I	Median	--	14, 4, 10	0	0	0
				Optimized	--	14.5, 4, 10.5	0	0	0
			II	Median	--	14.5, 4, 10.5	0	0	0

(Continued)

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Appendix C (Continued)

		Base			Thickness Requirements, in.				
					New Construction		Overlays		
Airport	Pavement Item	Pavement Type	Aircraft Category	Gear	Rigid	Flexible	Flexible	Bituminous	Rigid
Miami (Continued)	Runway 2	AC	II	Optimized	--	16.5, 4, 12.5	0	0	0
	Taxiway 1	AC	I	Median	--	14, 4, 10	0	0	0
				Optimized	--	14.5, 4, 10.5	0	0	0
			II	Median	--	14.5, 4, 10.5	0	0	0
				Optimized	--	16.5, 4, 12.5	0	0	0
	Taxiway 2	AC	I	Median	--	14, 4, 10	--	3.0	16
				Optimized	--	14.5, 4, 10.5	--	3.0	17
			II	Median	--	14.5, 4, 10.5	--	3.0	15
				Optimized	--	16.5, 4, 12.5	--	3.0	20
	Taxiway 3	AC	I	Median	--	14, 4, 10	--	3.0	16
				Optimized	--	14.5, 4, 10.5	--	3.0	17
			II	Median	--	14.5, 4, 10.5	--	3.0	15
				Optimized	--	16.5, 4, 12.5	--	3.0	20
	Taxiway 4	AC	I	Median	--	14, 4, 10	0	0	0
				Optimized	--	14.5, 4, 10.5	0	0	0
			II	Median	--	14.5, 4, 10.5	0	0	0
				Optimized	--	16.5, 4, 12.5	0	0	0
	Taxiway 5	AC	I	Median	--	14, 4, 10	0	0	0
				Optimized	--	14.5, 4, 10.5	0	0	0
			II	Median	--	14.5, 4, 10.5	0	0	0
				Optimized	--	16.5, 4, 12.5	0	0	0
	Apron 1	PCC	I	Median	17	--	--	4.0	10
				Optimized	17	--	--	4.5	11
			II	Median	16	--	--	3.0	9
				Optimized	21	--	4 + 9	9.0	15
New York (JFK)	Runway 1	PCC	I	Median	17	--	--	3.5	8
				Optimized	17	--	--	4.0	9
			II	Median	16	--	--	3.0	7
				Optimized	21	--	4 + 7	8.5	13
	Runway 2	PCC	I	Median	17	--	0	0	0
				Optimized	17	--	0	0	0
			II	Median	16	--	0	0	0
				Optimized	21	--	--	3.0	13
	Taxiway 1	PCC	I	Median	17	--	--	3.0	7
				Optimized	17	--	--	3.0	8
			II	Median	16	--	--	3.0	6
				Optimized	21	--	4 + 4.5	7.0	12
	Taxiway 2	AC	I	Median	--	14, 4, 10	0	0	0
				Optimized	--	14.5, 4, 10.5	0	0	0
			II	Median	--	14.5, 4, 10.5	0	0	0
				Optimized	--	16.5, 4, 12.5	0	0	0
	Taxiways 3 and 4	AC	I	Median	--	14, 4, 10	0	0	0
				Optimized	--	14.5, 4, 10.5	0	0	0
			II	Median	--	14.5, 4, 10.5	0	0	0
				Optimized	--	16.5, 4, 12.5	0	0	0
	Apron	PCC	I	Median	17	--	--	3.5	8
				Optimized	17	--	--	4.0	9
			II	Median	16	--	--	3.0	7
				Optimized	21	--	4 + 7	8.5	13
New York (La Guardia)	Runway 1	AC	I	Median	--	14, 4, 10	--	3.0	16
				Optimized	--	14.5, 4, 10.5	--	3.0	17
			II	Median	--	14.5, 4, 10.5	--	3.0	16
				Optimized	--	16.5, 4, 12.5	--	3.0	20
	Runway 2	AC	I	Median	--	48, 4, 14	4 + 19	16.5	17
				Optimized	--	49, 4, 14	4 + 20	17.5	18
			II	Median	--	51, 4, 14	4 + 22	18.5	17
				Optimized	--	61, 4, 15	4 + 32	25.0	21
	Taxiway 1	AC	I	Median	--	14, 4, 10	--	3.0	17
				Optimized	--	14.5, 4, 10.5	--	3.0	17

(Continued)

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Appendix C (Continued)

Airport	Pavement Item	Base Pavement Type	Aircraft Category	Gear	Thickness Requirements, in.				
					New Construction		Overlays		
					Rigid	Flexible	Flexible	Bituminous	Rigid
New York (La Guardia) (Continued)	Taxiway 1	AC	II	Median	--	14.5, 4, 10.5	--	3.0	16
				Optimized	--	16.5, 4, 12.5	--	4.5	20
	Taxiway 2	AC	I	Median	--	48, 4, 14	4 + 22	18.5	17
				Optimized	--	49, 4, 14	4 + 23	19.5	18
			II	Median	--	51, 4, 14	4 + 25	20.5	17
				Optimized	--	61, 4, 15	4 + 35	27.0	21
	Apron 1	AC	I	Median	--	48, 4, 14	4 + 18	16.0	17
				Optimized	--	49, 4, 14	4 + 19	16.5	18
			II	Median	--	51, 4, 14	4 + 21	18.0	16
				Optimized	--	61, 4, 15	4 + 31	24.5	21
Newark	Runway 1	AC	I	Median	--	14, 4, 10	0	0	0
				Optimized	--	14.5, 4, 10.5	0	0	0
			II	Median	--	14.5, 4, 10.5	0	0	0
				Optimized	--	16.5, 4, 12.5	--	3.0	16
	Taxiways 1 and 2	AC	I	Median	--	14, 4, 10	0	0	0
				Optimized	--	14.5, 4, 10.5	0	0	0
			II	Median	--	14.5, 4, 10.5	0	0	0
				Optimized	--	16.5, 4, 12.5	--	3.0	20
	Taxiway 3	--	I	Median	--	--	--	--	--
				Optimized	--	--	--	--	--
			II	Median	--	--	--	--	--
				Optimized	--	--	--	--	--
	Aprons 1, 2, and 3	PCC	I	Median	16	--	--	4.5	9
				Optimized	17	--	--	5.0	9
			II	Median	16	--	--	3.5	8
				Optimized	20	--	4 + 8.5	9.5	14
Denver	Runway 1	PCC	I	Median	19	--	4 + 9.5	10.0	13
				Optimized	20	--	4 + 10.5	11.0	14
			II	Median	19	--	4 + 9.5	10.0	13
				Optimized	25	--	4 + 20	17.5	20
	Runway 2	AC	I	Median	--	48, 4, 14	4 + 9	10.0	17
				Optimized	--	49, 4, 14	4 + 10	10.5	17
			II	Median	--	51, 4, 14	4 + 12	12.0	16
				Optimized	--	61, 4, 15	4 + 22	18.5	20
	Taxiway 1	PCC	I	Median	19	--	4 + 4.5	7.0	12
				Optimized	20	--	4 + 5.5	7.5	12
			II	Median	19	--	4 + 4.5	7.0	12
				Optimized	25	--	4 + 15	14.0	18
	Taxiways 2 and 4	PCC	I	Median	19	--	4 + 7	8.5	11
				Optimized	19	--	4 + 8	9.5	12
			II	Median	19	--	4 + 6.5	8.5	11
				Optimized	24	--	4 + 18	16.0	17
	Taxiway 3	AC	I	Median	--	48, 4, 14	4 + 24	20.0	17
				Optimized	--	49, 4, 14	4 + 25	20.5	18
			II	Median	--	51, 4, 14	4 + 27	22.0	17
				Optimized	--	61, 4, 15	4 + 37	28.5	22
	Apron 1	PCC	I	Median	20	--	4 + 11	11.5	13
				Optimized	21	--	4 + 12.5	12.0	13
			II	Median	20	--	4 + 11.5	12.0	13
				Optimized	26	--	4 + 24.5	20.0	19
Boston	Runway 1	AC	I	Median	--	55, 4, 14	--	3.0	15
				Optimized	--	56, 4, 14	--	3.0	16
			II	Median	--	58.5, 4, 14	--	3.0	14
				Optimized	--	69.5, 4, 15	4 + 10	10.5	19
	Runway 2	AC	I	Median	--	55, 4, 14	0	0	0
				Optimized	--	56, 4, 14	0	0	0
			II	Median	--	58.5, 4, 14	0	0	0
				Optimized	--	69.5, 4, 15	4 + 5	7.5	19

(Continued)

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Appendix C (Continued)

					Thickness Requirements, in.				
					New Construction		Overlays		
Airport	Pavement Item	Base Pavement Type	Aircraft Category	Gear	Rigid	Flexible	Flexible	Bituminous	Rigid
Boston (Continued)	Taxiways 1 and 2	AC	I	Median	--	55, 4, 14	4 + 10	10.5	16
				Optimized	--	56, 4, 14	4 + 5	7.5	16
			II	Median	--	58.5, 4, 14	4 + 13.5	13.0	15
				Optimized	--	69.5, 4, 15	4 + 24.5	20.5	20
	Taxiway 3	AC	I	Median	--	55, 4, 14	--	4.5	16
				Optimized	--	56, 4, 14	--	5.0	17
			II	Median	--	58.5, 4, 14	4 + 4	7.0	15
				Optimized	--	69.5, 4, 15	4 + 15	14.0	20
	Taxiway 4	AC	I	Median	--	55, 4, 14	4 + 12.5	12.5	16
				Optimized	--	56, 4, 14	4 + 13.5	13.0	17
			II	Median	--	58.5, 4, 14	4 + 16	14.5	15
				Optimized	--	69.5, 4, 15	4 + 27	22.0	20
	Taxiway 5	AC	I	Median	--	55, 4, 14	--	3.0	15
				Optimized	--	56, 4, 14	--	3.0	16
			II	Median	--	58.5, 4, 14	--	3.0	14
				Optimized	--	69.5, 4, 15	4 + 10	10.5	19
	Apron 1	AC	I	Median	--	55, 4, 14	4 + 10.5	11.0	16
				Optimized	--	56, 4, 14	4 + 11	11.5	16
			II	Median	--	58.5, 4, 14	4 + 13.5	13.0	15
				Optimized	--	69.5, 4, 15	4 + 24.5	20.5	20
	Apron 2	AC	I	Median	--	15, 4, 11	0	0	0
				Optimized	--	15.5, 4, 11.5	0	0	0
			II	Median	--	15.5, 4, 11.5	0	0	0
				Optimized	--	17.5, 4, 13.5	--	3.0	20
Philadelphia	Runway 1	AC	I	Median	--	19, 4, 12	--	3.0	17
				Optimized	--	19.5, 4, 12	--	3.0	17
			II	Median	--	19.5, 4, 12	--	3.0	16
				Optimized	--	23, 4, 13	--	4.5	20
	Runway 2	AC	I	Median	--	19, 4, 12	--	6.0	17
				Optimized	--	19.5, 4, 12	--	6.5	17
			II	Median	--	19.5, 4, 12	--	6.5	16
				Optimized	--	23, 4, 13	4 + 7	8.5	21
	Taxiway 1	AC	I	Median	--	19, 4, 12	--	4.5	17
				Optimized	--	19.5, 4, 12	--	5.0	17
			II	Median	--	19.5, 4, 12	--	5.0	16
				Optimized	--	23, 4, 13	4 + 5	7.5	20
	Taxiway 2	AC	I	Median	--	19, 4, 12	0	0	0
				Optimized	--	19.5, 4, 12	0	0	0
			II	Median	--	19.5, 4, 12	0	0	0
				Optimized	--	23, 4, 13	0	0	0
	Taxiway 3	AC	I	Median	--	19, 4, 12	--	3.0	17
				Optimized	--	19.5, 4, 12	--	3.0	17
			II	Median	--	19.5, 4, 12	--	3.0	16
				Optimized	--	23, 4, 13	--	4.5	20
	Apron 1	PCC	I	Median	18	--	--	5.0	10
				Optimized	18	--	--	5.5	10
			II	Median	17	--	--	4.5	9
				Optimized	22	--	4 + 10.5	11.0	15
St. Louis	Runway 1	PCC	I	Median	20	--	4 + 9.5	10.5	11
				Optimized	20	--	4 + 11	11.5	12
			II	Median	20	--	4 + 10	10.5	11
				Optimized	26	--	4 + 23	19.5	18
	Taxiway 1	PCC	I	Median	20	--	4 + 7	9.0	10
				Optimized	20	--	4 + 8.5	9.5	11
			II	Median	20	--	4 + 7.5	9.0	10
				Optimized	26	--	4 + 20.5	18.0	17
	Apron 1	PCC	I	Median	20	--	4 + 7	9.0	10
				Optimized	20	--	4 + 8.5	9.5	11
			II	Median	20	--	4 + 7.5	9.0	10

(Continued)

(Sheet 6 of 11)

Appendix C (Continued)

					Thickness Requirements, in.				
					New Construction		Overlays		
Airport	Pavement Item	Base Pavement Type	Aircraft Category	Gear	Rigid	Flexible	Flexible	Bituminous	Rigid
St. Louis (Continued)	Apron 1	PCC	II	Optimized	26	--	4 + 20.5	18.0	17
Honolulu	Runway 1	AC	I	Median	--	24, 4, 12	0	0	0
				Optimized	--	25, 4, 12	0	0	0
			II	Median	--	25, 4, 12	0	0	0
				Optimized	--	29, 4, 13	0	0	0
	Taxiways 3, 4, 8, and 10	AC	I	Median	--	24, 4, 12	0	0	0
				Optimized	--	25, 4, 12	0	0	0
			II	Median	--	25, 4, 12	0	0	0
				Optimized	--	29, 4, 13	0	0	0
	Taxiways 5, 6, 7, 11, and 13	AC	I	Median	--	24, 4, 12	0	0	0
				Optimized	--	25, 4, 12	0	0	0
			II	Median	--	25, 4, 12	0	0	0
				Optimized	--	29, 4, 13	0	0	0
	Taxiway 12	AC	I	Median	--	24, 4, 12	0	0	0
				Optimized	--	25, 4, 12	0	0	0
			II	Median	--	25, 4, 12	0	0	0
				Optimized	--	29, 4, 13	--	3.0	20
	Aprons	PCC	I	Median	17	--	--	4.0	9
				Optimized	18	--	--	5.0	10
			II	Median	17	--	--	3.5	8
				Optimized	22	--	4 + 9	10.0	14
	Taxiway 1	AC	I	Median	--	24, 4, 12	0	0	0
				Optimized	--	25, 4, 12	0	0	0
			II	Median	--	25, 4, 12	0	0	0
				Optimized	--	29, 4, 13	0	0	0
Detroit	Runways 1 and 2	PCC	I	Median	19	--	4 + 7	8.5	13
				Optimized	20	--	4 + 8	9.5	13
			II	Median	19	--	4 + 7	8.5	13
				Optimized	25	--	4 + 18	16.0	19
	Taxiways 1, 2, 3, and 4	PCC	I	Median	19	--	4 + 7	8.5	13
				Optimized	20	--	4 + 8	9.5	13
			II	Median	19	--	4 + 7	8.5	13
				Optimized	25	--	4 + 18	16.0	19
	Apron 1	PCC	I	Median	19	--	4 + 4.5	7.0	12
				Optimized	20	--	4 + 5	7.5	12
			II	Median	19	--	4 + 4.5	7.0	12
				Optimized	25	--	4 + 15	14.0	18
Seattle/Tacoma	Runway 1	PCC	I	Median	18	--	4 + 9	15.0	13
				Optimized	18	--	4 + 10	16.0	14
			II	Median	17	--	4 + 8	14.5	13
				Optimized	22	--	4 + 19	22.0	18
	Runway 2	PCC	I	Median	18	--	--	3.0	7
				Optimized	18	--	--	3.0	8
			II	Median	17	--	--	3.0	6
				Optimized	22	--	4 + 4.5	7.0	13
	Taxiways 1, 2, and 4	PCC	I	Median	18	--	--	3.0	7
				Optimized	18	--	--	3.0	8
			II	Median	17	--	--	3.0	6
				Optimized	22	--	4 + 4.5	7.0	13
	Taxiway 3	PCC	I	Median	18	--	--	4.5	9
				Optimized	18	--	--	5.0	10
			II	Median	17	--	--	4.0	9
				Optimized	22	--	4 + 9.5	10.5	15
	Aprons 1, 2, 3, and 4	PCC	I	Median	18	--	4 + 6	8.0	11
				Optimized	18	--	4 + 7	8.5	12

(Continued)

Appendix C (Continued)

		Base			Thickness Requirements, in.				
					New Construction		Overlays		
Airport	Pavement Item	Pavement Type	Aircraft Category	Gear	Rigid	Flexible	Flexible	Bituminous	Rigid
Seattle/Tacoma (Cont'd)	Aprons 1,2, 3, and 4	PCC	II	Median	17	--	4 + 5	7.0	11
				Optimized	22	--	4 + 14.5	14.0	17
Pittsburgh	Runway 1	PCC	I	Median	19	--	4 + 8.5	9.5	13
				Optimized	19	--	4 + 9.5	10.5	14
			II	Median	19	--	4 + 8	9.5	13
				Optimized	24	--	4 + 19	16.5	19
	Runway 2	PCC	I	Median	19	--	4 + 10.5	11.0	11
				Optimized	19	--	4 + 12	12.0	12
			II	Median	19	--	4 + 11.5	11.5	11
				Optimized	24	--	4 + 24	20.0	17
	Taxiways 1 and 4	PCC	I	Median	19	--	4 + 7	8.5	11
				Optimized	19	--	4 + 8	9.5	12
			II	Median	19	--	4 + 6.5	8.5	11
				Optimized	24	--	4 + 18	16.0	17
	Taxiway 2	PCC	I	Median	19	--	--	3.5	11
				Optimized	19	--	--	4.5	12
			II	Median	19	--	--	3.5	11
				Optimized	24	--	4 + 11	11.5	17
	Taxiway 3	AC	I	Median	--	55, 4, 14	4 + 19	16.5	17
				Optimized	--	56, 4, 14	4 + 20	17.0	17
			II	Median	--	59, 4, 14	4 + 23	19.0	16
				Optimized	--	70, 4, 15	4 + 33	26.0	21
	Taxiway 5	PCC	I	Median	19	--	--	5.5	10
				Optimized	19	--	--	6.5	11
			II	Median	19	--	--	5.0	10
				Optimized	24	--	4 + 12	12.0	16
	Apron 1	PCC	I	Median	21	--	4 + 14	13.5	13
				Optimized	21	--	4 + 15.5	14.5	13.5
			II	Median	21	--	--	6.5	13.5
				Optimized	27	--	4 + 28.5	23.0	20
Houston	Runway 1	PCC	I	Median	16	--	--	3.0	8
				Optimized	17	--	--	3.5	8
			II	Median	16	--	--	3.0	7
				Optimized	20	--	4 + 6	8.0	13
	Taxiways 1, 2, and 3	PCC	I	Median	16	--	--	3.0	8
				Optimized	17	--	--	3.5	8
			II	Median	16	--	--	3.0	7
				Optimized	20	--	4 + 6	8.0	13
	Taxiway 4	PCC	I	Median	16	--	--	3.0	6
				Optimized	17	--	--	3.0	6
			II	Median	16	--	--	3.0	6
				Optimized	20	--	--	4.5	11
	Apron 1	PCC	I	Median	16	--	--	3.0	8
				Optimized	17	--	--	3.5	8
			II	Median	16	--	--	3.0	7
				Optimized	20	--	4 + 6	8.0	12
Minneapolis/St. Paul	Runway 1	PCC	I	Median	19	--	4 + 16.5	15.0	14
				Optimized	20	--	4 + 18	16.0	15
			II	Median	19	--	4 + 16.5	15.0	14
				Optimized	25	--	4 + 29	23.0	20
	Runway 2	PCC	I	Median	19	--	4 + 11.5	4 + 8	13
				Optimized	20	--	4 + 13	4 + 9	13
			II	Median	19	--	4 + 11.5	4 + 8	13
				Optimized	25	--	4 + 24	4 + 16	19
	Taxiways 1 and 2	PCC	I	Median	18	--	--	5.0	10
				Optimized	19	--	--	6.0	10
			II	Median	18	--	--	4.5	9
				Optimized	23	--	4 + 11	11.0	15
	Apron 1	PCC	I	Median	18	--	--	5.0	10

(Continued)

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Appendix C (Continued)

					Thickness Requirements, in.				
					New Construction		Overlays		
Airport	Pavement Item	Base Pavement Type	Aircraft Category	Gear	Rigid	Flexible	Flexible	Bituminous	Rigid
Minneapolis/St. Paul (Continued)	Apron 1	PCC	I	Optimized	19	--	--	6.0	10
			II	Median	18	--	--	4.5	9
				Optimized	23	--	4 + 11	11.0	15
New Orleans	Runway 1	PCC	I	Median	20	--	4 + 6.5	8.0	11.5
				Optimized	21	--	4 + 7.5	9.0	12
			II	Median	21	--	4 + 7	8.5	10
				Optimized	26	--	4 + 18.5	16.5	15.7
	Taxiway 1	PCC	I	Median	21	--	4 + 7	9.0	13
				Optimized	21	--	4 + 8.5	9.5	14
			II	Median	21	--	4 + 8	9.5	14
				Optimized	27	--	4 + 20	17.0	21
	Taxiway 2	PCC	I	Median	18	--	--	5.0	10
				Optimized	19	--	--	6.0	11
			II	Median	18	--	--	4.5	9
				Optimized	23	--	4 + 11	11.5	16
	Apron 1	PCC	I	Median	21	--	4 + 7	9.0	13
				Optimized	21	--	4 + 8.5	9.5	14
			II	Median	21	--	4 + 8	9.5	14
				Optimized	27	--	4 + 20	17.0	21
	Apron 2	PCC	I	Median	18	--	--	5.0	10
				Optimized	19	--	--	6.0	11
			II	Median	18	--	--	4.5	9
				Optimized	23	--	4 + 11	11.5	16
	Apron 3	PCC	I	Median	25	--	4 + 24.5	20.0	20
				Optimized	26	--	4 + 26	21.0	21
			II	Median	27	--	4 + 29	23.0	22
				Optimized	32	--	4 + 42	31.5	28
Las Vegas	Runway 1	AC	I	Median	--	35.5, 4, 13	4 + 8.5	9.5	17
				Optimized	--	37, 4, 13	4 + 10	10.5	17
			II	Median	--	37, 4, 13	4 + 10	10.5	16
				Optimized	--	45, 4, 14	4 + 18	16.5	21
	Runway 2	AC	I	Median	--	24, 4, 12	4 + 4	6.5	18
				Optimized	--	25, 4, 12	4 + 5	7.5	19
			II	Median	--	25, 4, 12	4 + 5	7.5	18
				Optimized	--	29, 4, 13	4 + 9	10.0	23
	Taxiway 1	AC	I	Median	--	28, 4, 12	--	3.0	17
				Optimized	--	29, 4, 12	--	3.0	17
			II	Median	--	29, 4, 12	--	3.0	16
				Optimized	--	35, 4, 14	4 + 5	7.5	21
	Taxiway 2	AC	I	Median	--	24, 4, 12	4 + 4	6.5	17
				Optimized	--	25, 4, 12	4 + 5	7.5	17
			II	Median	--	25, 4, 12	4 + 5	7.5	16
				Optimized	--	29, 4, 13	4 + 9	10.0	21
	Apron 1	AC	I	Median	--	24, 4, 12	4 + 5	7.5	17
				Optimized	--	25, 4, 12	4 + 6	8.0	17
			II	Median	--	25, 4, 12	4 + 7	8.5	16
				Optimized	--	29, 4, 13	4 + 10	11.0	21
Kansas City (International)	Runway 1	PCC	I	Median	18	--	4 + 7.5	9.0	12
				Optimized	19	--	4 + 8.5	9.5	13
			II	Median	18	--	4 + 7	8.5	12
				Optimized	23	--	4 + 17	15.5	18
	Runway 2	PCC	I	Median	19	--	--	5.5	11
				Optimized	19	--	--	6.0	12
			II	Median	19	--	--	5.5	11
				Optimized	24	--	4 + 15	14.0	17
	Taxiway 1	PCC	I	Median	19	--	4 + 10.5	11.5	11
				Optimized	19	--	4 + 12	12.0	12
			II	Median	19	--	4 + 11.5	11.5	11

(Continued)

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Appendix C (Continued)

					Thickness Requirements, in.				
					New Construction		Overlays		
Airport	Pavement Item	Base Pavement Type	Aircraft Category	Gear	Rigid	Flexible	Flexible	Bituminous	Rigid
Kansas City (International) (Continued)	Taxiway 1	FPC	II	Optimized	24	--	4 + 24	20.0	17
	Taxiway 2	PCC	I	Median	19	--	--	4.0	9
				Optimized	19	--	--	5.0	9
			II	Median	19	--	--	4.0	8
				Optimized	24	--	4 + 10.5	11.0	15
	Taxiway 3	PCC	I	Median	18	--	--	5.5	10
				Optimized	19	--	--	6.5	11
			II	Median	18	--	--	5.0	10
				Optimized	23	--	4 + 12	12.0	16
	Apron 1	PCC	I	Median	19	--	4 + 5.5	7.5	12
				Optimized	20	--	4 + 6.5	8.5	12
			II	Median	19	--	4 + 5.5	7.5	12
				Optimized	25	--	4 + 16.5	15.0	18
Baltimore	Runways 1 and 2	AC	I	Median	--	19, 4, 12	0	0	0
				Optimized	--	19.5, 4, 12	0	0	0
			II	Median	--	19.5, 4, 12	0	0	0
				Optimized	--	23, 4, 13	0	0	0
	All Taxiways	AC	I	Median	--	19, 4, 12	0	0	0
				Optimized	--	19.5, 4, 12	0	0	0
			II	Median	--	19.5, 4, 12	0	0	0
				Optimized	--	23, 4, 13	0	0	0
	Apron 1	AC	I	Median	--	19, 4, 12	0	0	0
				Optimized	--	19.5, 4, 12	0	0	0
			II	Median	--	19.5, 4, 12	0	0	0
				Optimized	--	23, 4, 13	0	0	0
Cleveland	Runway 1	PCC	I	Median	18	--	--	3.0	9
				Optimized	18	--	--	3.0	10
			II	Median	17	--	--	3.0	9
				Optimized	22	--	4 + 5	7.0	15
	Taxiway 1	PCC	I	Median	18	--	4 + 4	7.0	9
				Optimized	18	--	4 + 5	7.5	10
			II	Median	17	--	--	6.0	9
				Optimized	22	--	4 + 13.5	13.0	15
	Taxiway 2	PCC	I	Median	18	--	4 + 5.5	8.0	9
				Optimized	18	--	4 + 7	8.5	10
			II	Median	17	--	4 + 4.5	7.0	9
				Optimized	22	--	4 + 15.5	14.5	15
	Apron 1	PCC	I	Median	18	--	4 + 5.5	8.0	9
				Optimized	18	--	4 + 7	8.5	10
			II	Median	17	--	4 + 4.5	7.0	9
				Optimized	22	--	4 + 15.5	14.5	15
	Apron 2	PCC	I	Median	18	--	4 + 4	7.0	9
				Optimized	18	--	4 + 5	7.5	10
			II	Median	17	--	--	6.0	9
				Optimized	22	--	4 + 13.5	13.0	15
	Apron 3	PCC	I	Median	18	--	4 + 16	14.5	13
				Optimized	18	--	4 + 17	15.5	13.5
			II	Median	17	--	4 + 15	14.0	12.5
				Optimized	22	--	4 + 26	21.5	18
Washington (Dulles)	All pavements	PCC	I	Median	18	--	--	3.0	6
				Optimized	19	--	--	3.0	7
			II	Median	18	--	--	3.0	6
				Optimized	23	--	4 + 7	8.5	13
Hollywood International	Runway 1	AC	I	Median	--	19, 4, 12	--	3.0	17
				Optimized	--	19.5, 4, 12	--	3.0	17
			II	Median	--	19.5, 4, 12	--	3.0	16
				Optimized	--	23, 4. 13	--	3.0	24
	Taxiway 1	AC	I	Median	--	19, 4 12	4 + 6	8.0	17

(Continued)

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Appendix C (Continued)

					Thickness Requirements, in.				
					New Construction		Overlays		
Airport	Pavement Item	Base Pavement Type	Aircraft Category	Gear	Rigid	Flexible	Flexible	Bituminous	Rigid
Hollywood International (Continued)	Taxiway I	AC	I	Optimized	--	19.5, 4, 12	4 + 7	8.5	17
			II	Median	--	19.5, 4, 12	4 + 7	8.5	17
				Optimized	--	23, 4, 13	4 + 10	10.5	21
	Taxiway 2	AC	I	Median	--	19, 4, 12	0	0	0
				Optimized	--	19.5, 4, 12	0	0	0
			II	Median	--	19.5, 4, 12	0	0	0
				Optimized	--	23, 4, 13	--	4.0	20
	Apron 1	PCC	I	Median	18	--	4 + 16.5	15.0	15
				Optimized	18	--	4 + 17.5	15.5	16
			II	Median	17	--	4 + 15.5	14.5	15
				Optimized	22	--	4 + 37	28.5	20

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APPENDIX D

COMPUTATION OF TOTAL PAVEMENT PRICE FOR MAJOR HUB AIRPORTS (1972 DOLLARS)

The total pavement prices for the major hub airports were computed using Equation 3 from the main text. Computations made for the median and the optimized gear for Category I and Category II aircraft are shown on following tabulation.

Airport	Category Aircraft	Pavement Item*	Area Sq Yd	Pavement Type	Thickness, in.		Unit Price	Pavement Cost		S	Sub-Total Cost	
					Median	Optimized		Median	Optimized		Median	Optimized
Chicago (O'Hare)	I	RW-1	166,667	P401 O/L	11.0	11.5	0.76	$1,393,336	$1,456,669	0.681	$2,046,015	$2,139,015
		RW-2	257,778	P401 O/L	6.0	6.5	0.76	1,175,467	1,175,467	0.681	1,726,090	1,869,931
		RW-3	166,667	P401 O/L	3.0	4.0	0.76	380,000	506,667	0.681	558,003	744,006
			All = 591,112	(24%); Used	(24%)							
		TW-1 & 6	175,922	P401 O/L	3.0	4.0	0.76	401,102	534,802	0.681	588,990	785,319
		TW-2	131,075	P401 O/L	3.0	3.0	0.76	298,851	298,851	0.681	438,841	438,841
		TW-3	256,428	P401 O/L	17.5	18.0	0.76	3,410,492	3,507,935	0.681	5,008,065	5,151,153
		TW-4	182,814	P401 O/L	4.0	4.5	0.76	555,754	625,223	0.681	816,085	918,095
		TW-7**	55,189									
			All = 801,428	(32%); Used	= 746,239	(31%)						
		AP-1	1,086,841	P401 O/L	3.0	3.0	0.76	2,477,997	2,477,997	0.681	3,638,762	3,638,762
			All (44%)									
			Used (45%)									
	Total	Used:	2,424,192					10,893,002	10,681,511		14,820,850	15,685,120
		All:	2,479,381									
Atlanta	I	RW-1	213,867	PCC O/L	6.0	6.0	0,60	769,921	769,921	0.775	993,446	993,446
		RW-2	166,667	PCC O/L	6.0	6.0	0.60	600,001	600,001	0.775	774,195	774,195
			A = 380,534									
		TW-1										
		TW-2	525,000	PCC O/L	6.0	6.0	0.60	1,890,000	1,890,000	0.775	2,438,710	2,438,710
		TW-4										
		TW-3	186,000	PCC O/L	16.0	17.0	0.60	1,785,600	1,897,200	0.775	2,304,000	2,448,000
		AP-1	712,369	PCC O/L	11.0	11.0	0.60	4,701,635	4,701,635	0.775	6,066,626	6,066,626
		RW-3	166,667	PCC								
		TW-5	311,405	PCC								
			A = RW = 547,201 (24%)/used = 380,534 (22%)									
			A = TW = 1,022,405 (45%)/used = 711,000 (39%)									
			A = AP = 712,369 (31%) (39%)									
	Total	Used:	1,803,903					9,747,158	9,858,758		12,576,977	12,720,977
		All:	2,281,975									

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* See Table A2 for locations of pavement items.

** Not included.

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Airport	Category Aircraft	Pavement Item	Area Sq Yd	Pavement Type	Thickness, in.		Unit Price	Pavement Cost		β	Sub-Total Cost	
					Median	Optimized		Median	Optimized		Median	Optimized
Los Angeles	I	RW-1	257,778	PCC O/L	10.0	11.0	0.94	$2,423,113	$2,665,425	0.775	$3,126,597	$3,439,258
		RW-2	166,667	P401 O/L	0.0	0.0	0.54					
			All = 424,441 (23%)									
			Used = 257,778 (17%)	(17%)								
		TW-1	169,724	P401 O/L	0.0	0.0	0.54					
		TW-2	122,516	P401 O/L	5.0	5.5	0.54	330,793	363,873	0.681	485,746	534,322
		TW-4	32,034	P401 O/L	11.0	12.0	0.54	190,282	207,580	0.681	279,416	304,816
		TW-5	10,116	P401 O/L	0.0.	3.0	0.54	-	16,388	0.681	-	24,065
		TW-6	22,480	P401 O/L	16.0	16.5	0.54	194,227	200,297	0.681	285,209	294,122
		TW-7	21,256	P401 O/L	3.0	3.0	0.54	34,435	34,435	0.681	50,565	50,565
		TW-8	14,612	P401 O/L	3.0	4.0	0.54	23,671	31,562	0.681	34,759	46,347
			All = 392,738 (21%)	All = 392,738 (21%)								
			Used = 212,898 (14%)	Used = 223,014 (14%)								
		AP-1	151,605	P401 O/L	3.5	4.0	0.54	286,537	327,467	0.681	420,793	480,862
		AP-2	151,605	P401 O/L	6.0	6.5	0.54	491,200	532,134	0.681	721,292	781,401
		AP-3	334,091	P401 O/L	11.0	11.5	0.54	1,984,501	2,074,705	0.681	2,914,098	3,046,557
		AP-4	247,421	P401 O/L	14.5	15.0	0.54	1,937,306	2,004,110	0.681	2,844,796	2,942,893
		AP-5	181,926	P401 O/L	3.0	3.0	0.54	294,720	294,720	0.681	432,775	432,775
			All = 1,066,648 (56%)									
			Used - (69%)	(69%)								
	Total All:		1,883,831					8,190,782	8,752,694		11,596,007	12,377,982
San Francisco	I	RW-1	222,224	P401 O/L	3.0	3.0	0.54	360,003	360,003	0.681	528,639	538,639
		RW-2	298,596	P401 O/L	3.0	3.0	0.54	483,726	483,726	0.681	710,317	710,317
			All = 520,820 (31%)									
		TW-1	39,167	P401 O/L	3.0	3.0	0.54	63,451	63,451	0.681	93,173	93,173
		TW-2	70,000	P401 O/L	3.0	3.0	0.54	113,400	113,400	0.681	166,520	166,520
		TW-3	150,000	P401 O/L	3.0	3.0	0.54	243,000	243,000	0.681	356,828	356,828
			All = 259,167 (15%)									
		AP-1	908,821	P401 O/L	3.0	3.0	0.54	1,472,290	1,472,290	0.681	2,161,953	2,161,953.
			All = 908,821 (54%)									
	Total		1,688,808					2,735,869	2,735,869		4,017,438	4,017,430

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Airport	Category Aircraft	Pavement Item	Area Sq Yd	Pavement Type	Thickness, In. Median	Thickness, In. Optimized	Unit Price	Pavement Cost Median	Pavement Cost Optimized	S	Sub-Total Cost Median	Sub-Total Cost Optimized
Miami	I	RW-1	155,833	P401 O/L	0.0	0.0	0.54					
		RW-2	233,333	P401 O/L	0.0	0.0	0.54					
			All = 389,166 (30%)									
			Used = (0%)									
		TW-1	129,000	P401 O/L	0.0	0.0	0.54					
		TW-2	37,625	P401 O/L	3.0	3.0	0.54†	$ 60,952	$ 60,952	0.681	$ 89,504	$ 89,504
		TW-3	129,000	P401 O/L	3.0	3.0	0.54†	208,980	208,980	0.681	306,872	306,872
		TW-4	17,200	P401 O/L	0.0	0.0	0.54					
		TW-5	43,000	P401 O/L	0.0	0.0	0.54					
			All = 355,825 (27%)									
			Used = 166,625 (22%)									
		AP-1	570,759	P401 O/L	4.0	4.5	0.54†	1,232,839	1,386,944	0.681	1,810,336	2,036,628
			All = 570,759 (43%)									
			Used = - (77%)									
		Total Used:	737,334					1,502,772	1,656,877		2,206,712	2,433,004
		All:	1,315,750									
New York (JFK)	I	RW-1	220,000	P401 O/L	3.5	4.0	0.52†	400,400	457,600	0.681	587,959	671,953
		RW-2	172,500	P401 O/L	0.0	0.0	0.52	-	-			
			All = 392,500 (19%)									
			Used = 220,000 (13%)									
		TW-1	85,000	PCC O/L	7.0	8.0	1.37†	815,150	931,600	0.775	1,051,806	1,202,065
		TW-2	125,000	PCC O/L	0.0	0.0	1.37					
		TW-3 & 4	155,000	P401 O/L	0.0	0.0	0.52					
			All = 365,000 (17%)									
			Used = 850,000 (05%)									
		AP-1	1,342,900	PCC O/L	8.0	9.0	1.37†	14,718,184	16,557,957	0.775	18,991,205	21,365,106
			All = 1,342,900 (64%)									
			Used = (82%)									
		Total Used:	1,647,900					15,933,734	17,947,157		20.630,970	23,239,123
		All:	2,100,400									

† These used I's.

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Airport	Category Aircraft	Pavement Item	Area Sq Yd	Pavement Type	Thickness, in. Median	Thickness, in. Optimized	Unit Price	Pavement Cost Median	Pavement Cost Optimized	$	Sub-Total Cost Median	Sub-Total Cost Optimized
New York (La Guardia)	I	RW-1	235,556	P401 O/L	3.0	3.0	0.56	$ 395,734	$ 395,734	0.681	$ 581,107	$ 581,107
		RW-2	228,250	P401 O/L	16.5	17.5	0.56	2,109,030	2,236,850	0.681	3,096,960	3,284,655
			All = 463,806 (23%)									
		TW-1	114,125	P401 O/L	3.0	3.0	0.56	191,730	191,730	0.681	281,542	281,542
		TW-2	102,712	P401 O/L	18.5	19.5	0.56	1,064,096	1,121,615	0.681	1,562,549	1,647,012
			All = 216,837 (11%)									
		AP-1	1,322,998	P401 O/L	16.0	16.5	0.56	11,854,062	12,224,502	0.681	17,406,846	17,950,811
			All = 1,322,998 (66%)									
	Total	2,003,641						15,614,652	16,170,431		22,929,004	23,745,126
Newark	I	RW-1	155,557	P401 O/L	0.0	0.0	0.54					
			All = 155,557 (34%)									
			Used = -									
		TW-1 & 2	134,966	P401 O/L	0.0	0.0	0.54					
		TW-3	21,446	P401 O/L	-	-	0.54					
			All = 156,412 (35%)									
			Used = -									
		AP-1, 2 & 3	141,289	P401 O/L	4.5	5.0	0.54†	343,332	381,480	0.681	504,159	560,176
			All = 141,289 (31%)									
			Used = (100%)									
	Total Used:	141,289						343,332	381,480		504,159	560,176
	All:	453,258										
Denver	I	RW-1	111,111	P401 O/L	10.0	11.0	0.37	411,111	452,222	0.681	603,687	664,006
		RW-2	96,620	P401 O/L	10.0	10.5	0.37	357,494	375,369	0.681	524,954	551,203
			All = 207,731 (23%)									
		TW-1	108,698	P401 O/L	7.0	7.5	0.37	281,500	301,637	0.681	413,404	442,932
		TW-2 & 4	115,044	P401 O/L	8.5	9.5	0.37	361,813	404,380	0.681	531,297	593,803
		TW-3	31,401	P401 O/L	20.0	20.5	0.37	232,367	238,177	0.681	341,214	349,746
			All = 255,143 (28%)									
		AP-1	452,000	PCC O/L	13.0	13.0	1.27	7,462,520	7,462,520	0.775	9,629,058	9,629,058
			All = 452,000 (49%)									
	Total Used:	914,874						9,106,833	9,234,304		12,043,615	12,230,798
	All:	914,874										

† These used I's.

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Airport	Category Aircraft	Pavement Item	Area Sq Yd	Pavement Type	Thickness, in. Median	Thickness, in. Optimized	Unit Price	Pavement Cost Median	Pavement Cost Optimized	$	Sub-Total Cost Median	Sub-Total Cost Optimized
Boston	I	RW-1	222,222	P401 O/L	3.0	3.0	0.92†	$ 613,333	$ 613,333	0.681	$ 900,636	$ 900,636
		RW-2	283,046	P401 O/L	0.0	0.0	0.92					
		All = 505,268 (57%)										
		Used = 222,222 (42%)										
		TW-1 & 2	58,480	P401 O/L	10.5	7.5	0.92†	564,917	403,512	0.681	829,540	592,529
		TW-3	72,516	P401 O/L	4.5	5.0	0.92†	300,216	333,574	0.681	440,846	489,830
		TW-4	50,293	P401 O/L	12.5	13.0	0.92†	578,369	601,504	0.681	849,294	883,266
		TW-5	88,890	P401 O/L	3.0	3.0	0.92†	245,336	245,336	0.681	360,258	360,258
		All = 270,179 (31%)										
		Used = (51%)										
		AP-1	36,937	P401 O/L	11.0	11.5	0.92†	373,802	390,793	0.681	548,902	573,852
		AP-2	66,571	P401 O/L	0.0	0.0	0.92					
		All = 103,508 (12%)										
		Used = 36,937 (07%)										
	Total Used:		529,338					2,675,974	2,588,052		3,929,476	3,800,370
	All:		878,955									
Philadelphia	I	RW-1	233,333	P401 O/L	3.0	3.0	0.73†	510,999	510,999	0.681	750,366	750,366
		RW-2	215,556	P401 O/L	6.0	6.5	0.73†	944,135	1,022,813	0.681	1,386,395	1,501,928
		All = 448,889 (80%)										
		Used = (81%)										
		TW-1	27,000	P401 O/L	4.5	5.0	0.73†	88,695	98,550	0.681	130,242	144,714
		TW-2	5,750	P401 O/L	0.0	0.0	0.73					
		TW-3	41,250	P401 O/L	3.0	3.0	0.73†	90,337	90,337	0.681	132,653	132,653
		All = 74,000 (13%)										
		Used = 68,250 (12%)										
		AP-1	37,500	PCC O/L	10.0	10.0	1.37†	513,750	513,750	0.775	662,903	662,903
		All = 37,500 (07%)										
		Used = (07%)										
	Total Used:		554,639					2,147,917	2,236,450		3,062,560	3,192,564
	All:		560,389									

† These used Σ's.

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Airport	Category Aircraft	Pavement Item	Area Sq Yd	Pavement Type	Thickness, in. Median	Thickness, in. Optimized	Unit Price	Pavement Cost Median	Pavement Cost Optimized	S	Sub-Total Cost Median	Sub-Total Cost Optimized
St. Louis	I	RW-1	222,222	PCC O/L	11.0	12.0	0.64	$1,564,443	$1,706,665	0.775	$2,018,636	$2,202,148
			All = 222,222 (38%)									
		TW-1	119,792	PCC O/L	10.0	11.0	0.64	766,669	84,336	0.775	989,250	108,821
			All = 119,792 (20%)									
		AP-1	244,141	PCC O/L	10.0	11.0	0.64	1,562,502	1,718,753	0.775	2,016,132	2,217,746
			All = 244,141 (42%)									
	Total	586,155						3,893,614	4,268,753		5,024,018	4,528,715
Honolulu	I	RW-1	257,778	P401 O/L	0.0	0.0	0.54					
			All = 257,778 (22%) Used = - (0%)									
	I	TW-3,4,8&10	347,614	P401 O/L	0.0	0.0	0.54					
	I	TW-5,6,7,11& 13	51,958	P401 O/L	0.0	0.0	0.54					
	I	TW-12	13,291	P401 O/L	0.0	0.0	0.54					
	I	AP-1-12	448,433	P401 O/L	4.0	5.0	0.54†	968,615	1,210,764	0.681	1,422,342	1,777,928
	I	TW-1	39,875	P401 O/L	0.0	0.0	0.54					
			TW = All = 452,738 (39%) Used = -- (0%) ** data used. Apron = All = 448,433 (39%) Used = (100%) Total 448,433 All 1,158,949					968,615	1,210,764		1,422,342	1,777,928
Detroit	I	RW-1&2	466,667	PCC O/L	13	13	0.94	5,702,671	5,702,671	0.775	1,358,285	7,358,285
			All = 466,667 (29%)									
	I	TW-1,2,3,4	315,954	P401 O/L	8.5	9.5	0.76	2,041,063	2,281,188	0.681	2,997,156	3,349,762
			All = 315,954									
	I	AP-1	823,621	PCC O/L	7.0	7.5	0.94	5,419,426	5,806,528	0.775	6,992,808	7,492,294
			All = 823,621 (51%)									
			1,606,242					13,163,160	13,790,387		17,348,249	18,200,341

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Airport	Category Aircraft	Pavement Item	Area Sq Yd	Pavement Type	Thickness, in.		Unit Price	Pavement Cost		S	Sub-Total Cost	
					Median	Optimized		Median	Optimized		Median	Optimized
Seattle-Tacoma	I	RW-1	175,200	P401 O/L	15.0	16.0	0.41	$1,077,480	$1,149,312	0.681	$1,582,203	$1,687,683
	I	RW-2	136,267	P401 O/L	3.0	3.0	0.41	167,608	167,608	0.681	246,120	246,120
			All = 311,467 (23%)									
	I	TW-1,2,&4	192,234	P401 O/L	3.0	3.0	0.41	236,448	236,448	0.681	347,207	347,207
	I	TW-3	19,467	P401 O/L	4.5	5.0	0.41	35,917	39,907	0.681	52,742	58,601
			All = 211,701 (16%)									
	I	AP-1-4	827,138	P401 O/L	8.0	8.5	0.41	2,713,013	2,882,576	0.681	3,983,866	4,232,858
			All = 827,138 (61%)									
			1,350,306					4,230,475	4,475,852		6,212,138	6,572,468
Pittsburg	I	RW-1	175,000	P401 O/L	9.5	10.5	0.93	1,546,125	1,708,875	0.681	8,414,133	8,737,754
	I	RW-2	166,667	P401 O/L	11.0	12.0	0.93	1,705,003	1,860,004	0.681	2,503,675	2,731,283
			All = 341,667 (35%)									
	I	TW-1&4	86,812	P401 O/L	8.5	9.5	0.93	686,249	766,984	0.681	1,007,708	1,126,261
	I	TW-2	28,938	P401 O/L	3.5	4.5	0.93	94,193	121,106	0.681	138,316	177,836
	I	TW-3	65,592	P401 O/L	16.5	17.0	0.93	1,006,509	1,037,010	0.681	1,477,987	1,522,775
	I	TW-5	36,654	P401 O/L	5.5	6.5	0.93	187,485	221,573	0.681	275,308	325,364
			All = 217,996 (22%)									
	I	AP-1	428,728	PCC O/L	13	13.5	1.17	6,520,953	6,771,759	0.775	8,414,133	8,737,754
			988,391					11,746,518	12,487,310		16,087,501	17,130,735
	I	RW-1	156,667	PCC O/L	8.0	8.0	0.84	1,052,802	1,052,802	0.775	1,358,454	1,358,454
			All = 156,667 (14%)									
	I	TW-1-3	238,650	PCC O/L	8.0	8.0	0.84	1,603,728	1,603,728	0.775	2,069,326	2,069,326
	I	TW-4	58,275	PCC O/L	6.0	6.0	0.84	293,706	293,706	0.775	378,975	377,685
			All = 296,925 (27%)									
	I	AP-1	645,987	PCC O/L	8.0	8.0	0.84	4,341,033	4,341,033	0.775	5,601,333	5,601,333
			All = 645,987 (59%)									
			1,099,579					7,291,269	7,291,269		9,408,089	9,406,799

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Airport	Category Aircraft	Pavement Item	Area Sq Yd	Pavement Type	Thickness, in. Median	Thickness, in. Optimized	Unit Price	Pavement Cost Median	Pavement Cost Optimized	$	Sub-Total Cost Median	Sub-Total Cost Optimized
Minneapolis	I	RW-1	233,333	P401 O/L	15.0	16.0	0.76	$2,659,996	$2,837,329	0.681	$3,906,015	$4,166,416
	I	RW-2	205,189	P401 O/L	4	4	0.76	623,775	623,775	0.681	915,969	915,969
			205,189	P201 O/L	8	9	0.67	1,099,813	1,237,290	0.681	1,614,997	1,816,872
		All = 643,711 (53%)										
	I	TW-1&2	255,617	P401 O/L	5.0	6.0	^.76	971,345	1,165,614	0.681	1,426,351	1,711,621
		All = 255,617 (21%)										
	I	AP-1	323,563	P401 O/L	5.0	6.0	0.76	1,229,539	1,475,447	0.681	1,805,490	2,166,589
		All = 323,563 (26%)										
			1,222,891					6,584,468	7,339,454		9,668,822	10,777,467
New Orleans	I	RW-1	153,783	P401 O/L	8.0	9.0	0.76	935,001	1,051,876	0.681	1,372,982	1,544,605
		All = 153,783 (35%)										
	I	TW-1	75,833	PCC O/L	13.0	14.0	0.79	778,805	838,713	0.775	1,004,910	1,082,210
	I	TW-2	8,667	PCC O/L	10.0	11.0	0.79	68,469	75,316	0.775	88,347	97,182
		All = 84,500 (19%)										
	I	AP-1	52,577	P401 O/L	9.0	9.5	0.76	359,627	379,606	0.681	528,087	557,424
	I	AP-2	116,497	P401 O/L	5.0	6.0	0.76	531,226	531,226	0.681	780,068	780,068
	I	AP-3	27,941	P401 O/L	20.0	21.0	0.76	424,703	445,938	0.681	623,646	654,828
		All = 197,015 (46%)										
			435,298					3,097,831	3,322,676		4,398,039	4,716,317
Las Vegas	I	RW-1	233,333	P401 O/L	9.5	10.5	0.54	1,196,998	1,322,998	0.681	1,757,706	1,942,728
	I	RW-2	202,898	P401 O/L	6.5	7.5	0.54	712,172	821,737	0.681	1,045,774	1,206,662
		All = 436,231 (31%)										
	I	TW-1	77,038	P401 O/L	3.0	3.0	0.54	124,802	124,802	0.681	183,263	183,263
	I	TW-2	140,760	P401 O/L	6.5	7.5	0.54	494,068	570,078	0.681	725,504	837,119
		All = 217,798 (15%)										
	I	AP-1	759,293	P401 O/L	7.5	8.0	0.54	3,075,137	3,280,146	0.681	4,515,620	4,816,661
		All = 759,293 (54%)										
			1,413,322					5,603,176	6,119,760		8,227,866	8,986,433

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Airport	Category Aircraft	Pavement Item	Area Sq Yd	Pavement Type	Thickness, in. Median	Thickness, in. Optimized	Unit Price	Pavement Cost Median	Pavement Cost Optimized	S	Sub-Total Cost Median	Sub-Total Cost Optimized
Kansas City	I	RW-1	233,333	P401 O/L	9.0	9.5	0.42	$ 881,999	$ 930,999	0.681	$1,295,153	$1,367,106
	I	RW-2	203,333	P401 O/L	5.5	6.0	0.42	469,699	512,399	0.681	689,720	752,421
		All = 436,666 (35%)										
	I	TW-1	124,050	PCC O/L	11.0	12.0	0.85	1,759,867	1,265,310	0.775	1,496,603	1,632,658
	I	TW-2	128,400	PCC O/L	9.0	9.0	0.85	982,260	982,260	0.775	1,267,432	1,267,432
	I	TW-3	40,125	PCC O/L	10.0	11.0	0.85	341,062	375,169	0.775	440,080	484,089
		All = 292,575 (23%)										
	I	AP-1	527,992	PCC O/L	12.0	12.0	0.85	5,385,518	5,385,518	0.775	6,949,055	6,949,055
		All = 527,992 (42%)										
			1,257,233					9,220,406	9,451,655		12,138,043	12,452,762
Baltimore	I	RW-1&2	350,000	P401 O/L	0.0	0.0	0.52					
		All = 350,000 (36%)										
		Used = _ (0%)										
	I	TW-Total	253,750	P401 O/L	0.0	0.0	0.52					
		All = 253,750 (26%)										
		Used = _ (0%)										
	I	AP-1	378,675	P401 O/L	0.0	0.0	0.52					
		All = 378,675 (38%)										
		Used = _ (0%)										
		Total	982,425									
Cleveland	I	RW-1	233,333	P401 O/L	3.0	3.0	0.76	531,999	531,999	0.681	781,203	781,203
		All = 233,333 (28%)										
	I	TW-1	90,125	P401 O/L	7.0	7.5	0.76	479,465	513,712	0.681	704,060	754,349
	I	TW-2	33,475	P401 O/L	8.0	8.5	0.76	203,528	216,248	0.681	298,866	317,545
		All = 123,600 (15%)										
	I	AP-1	127,308	P401 O/L	8.0	8.5	0.76	774,033	822,410	0.681	1,136,612	1,207,651
	I	AP-2	120,943	P401 O/L	7.0	7.5	0.76	643,417	689,375	0.681	944,812	1,012,298
	I	AP-3	224,911	P401 O/L	14.5	15.5	0.76	2,478,519	2,649,452	0.681	3,639,529	3,890,532
		All = 473,162										
			830,095					5,110,961	5,423,197		7,505,082	7,963,577

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Airport	Category Aircraft	Pavement Item	Area Sq Yd	Pavement Type	Thickness, in.		Unit Price	Pavement Cost		S	Sub-Total Cost	
					Median	Optimized		Median	Optimized		Median	Optimized
Washington	I	RW-1	166,667	PCC O/L	6.0	7.0	1.37	$1,370,003	$1,598,337	0.775	$1,767,746	$2,062,370
	I	RW-2	166,667	PCC O/L	6.0	7.0	1.37	1,370,003	1,598,337	0.775	1,767,746	2,062,370
		All = 333,334 (38%)										
	I	TW-1	100,000	PCC O/L	6.0	7.0	1.37	822,000	959,000	0.775	1,060,645	1,237,419
	I	TW-2	100,000	PCC O/L	6.0	7.0	1.37	822,000	959,000	0.775	1,060,645	1,237,419
		All = 200,000 (23%)										
	I	AP-1	346,686	PCC O/L	6.0	7.0	1.37	2,849,759	3,324,719	0.775	3,677,108	4,289,960
		All = 346,686 (39%)										
			880,020					7,233,764	8,439,392		9,333,890	10,889,539
Ft. Lauderdale	I	RW-1	137,167	P401 O/L	3.0	3.0	0.54	222,211	222,211	0.681	326,301	326,301
	I	TW-1	69,167	P401 O/L	8.0	8.5	0.54	298,801	317,477	0.681	438,768	466,192
	I	TW-2	90,378	P401 O/L	0.0	0.0	0.54					
		All = 296,712 (44%)										
		Used = 206,334 (36%)										
	I	AP	370,965	P401 O/L	15.0	15.5	0.54	3,004,816	3,104,977	0.681	4,412,358	4,559,291
		Total colored										
		All = 370,965 (56%)										
		Used = 370,965 (64%)										
		Total	577,299					3,525,828	3,644,664		5,177,427	5,351,784
		All	667,677									

Airport	Category Aircraft	Pavement Item	Area Sq yds	Pavement Type	Thickness, in.		Unit Price	Pavement Cost		S	Sub-Total Cost	
					Median	Optimized		Median	Otpimized		Median	Optimized
Chicago O'Hare	II	RW-1	166,657	P401 O/L	9.5	17.0	0.76	$1,203,336	$2,153,338	0.681	$1,767,013	$3,162,023
	II	RW-2	257,778	P401 O/L	4.5	11.5	0.76	881,601	2,252,980	0.681	1,294,568	3,308,341
	II	RW-3	166,667	P401 O/L	3.0	10.5	0.76	380,001	1,330,003	0.681	558,004	1,953,015
		All =	591,112									
	II	TW-1 &6	175,922	P401 O/L	3.0	13.0	0.76	401,102	1,738,109	0.681	588,990	2,552,289
	II	TW-2	131,075	P401 O/L	3.0	6.5	0.76	298,851	647,570	0.681	438,841	950,822
	II	TW-3	256,428	P401 O/L	18.0	26.5	0.76	3,702,820	5,164,460	0.681	5,437,327	7,583,642
	II	TW-4	182,814	P401 O/L	3.0	9.5	0.76	416,816	1,319,917	0.681	612,065	1,938,204
	II	TW-7	55,189									
		All =	801,428									
		Used =	746,239									
	II	AP-1	1,086,841	P401 O/L	3.0	6.5	0.76	2,477,997	5,368,995	0.681	3,638,762	7,883,987
		All =	1,086,841									
		Used =	2,424,192									
		All =	2,479,381					9,762,524	19,975,311		14,335,571	29,332,323
Atlanta	II	RW-1	213,867	PCC O/L	6.0	11.0	0.60	769,921	141,522	0.775	993,446	1,821,319
	II	RW-2	166,667	PCC O/L	6.0	11.0	0.60	600,001	1,100,002	0.775	774,195	1,419,357
	II	TW-1										
	II	TW-2	525,000	PCC O/L	6.0	11.0	0.60	1,890,000	3,465,000	0.775	2,438,710	4,470,968
	II	TW-4										
	II	TW-3	186,000	PCC O/L	16.0	20.0	0.60	1,785,600	2,232,000	0.775	2,304,000	2,880,000
	II	AP-1	712,369	PCC O/L	10.0	16.0	0.60	4,274,214	6,838,742	0.775	5,515,115	8,824,183
	II	RW-3	166,667	PCC O/L								
	II	TW-5	311,405	PCC O/L								
		R/W										
		T/W										
		Total	1,803,903					9,319,736	15,047,267		12,025,466	19,415,827

Airport	Category Aircraft	Pavement Item	Area Sq yds	Pavement Type	Thickness, in.		Unit Price	Pavement Cost		S	Sub-Total Cost	
					Median	Optimized		Median	Otpimized		Median	Optimized
Los Angeles	II	RW-1	257,778	PCC O/L	10.0	16.0	0.94	$2,423,113	$3,876,981	0.775	$3,126,597 -	$5,002,556
	II	RW-2	166,667	P401 O/L	0.0	0.0	0.54	--	--	0.775		
	II	TW-1	169,724	P401 O/L	0.0	0.0	0.54	--	--	--		
	II	TW-2	122,516	P401 O/L	4.0	11.0	0.54	264,635	727,745	0.681	388,598	1,068,642
	II	TW-4	32,034	P401 O/L	10.5	17.0	0.54	181,633	294,072	0.681	266,715	431,824
	II	TW-5	10,116	P401 O/L	3.0	6.5	0.54	16,388	35,507	0.681	24,065	52,140
	II	TW-6	22,480	P401 O/L	16.5	23.5	0.54	200,297	285,271	0.681	294,122	418,900
	II	TW-7	21,256	P401 O/L	3.0	10.0	0.54	34,435	114,782	0.681	50,565	168,549
	II	TW-8	14,612	P401 O/L	3.0	13.0	0.54	23,671	102,576	0.681	34,759	150,626
	II	AP-1	151,605	P401 O/L	3.0	9.0	0.54	245,600	736,800	0.681	360,646	1,081,938
	II	AP-2	151,605	P401 O/L	5.0	11.5	0.54	409,333	941,477	0.681	601,076	1,382,477
	II	AP-3	334,091	P401 O/L	10.0	17.0	0.54	1,804,091	3,066,955	0.681	2,649,174	4,503,605
	II	AP-4	247,421	P401 O/L	15.5	21.5	0.54	2,070,914	2,872,558	0.681	3,040,990	4,218,147
	II	AP-5	181,926	P401 O/L	3.0	3.0	0.54	294,720	294,720	0.681	432,775	432,775
	Total 1,547,440							7,968,830	13,349,436		11,270,088	18,912,179
San Francisco	II	RW-1	222,224	P401 O/L	3.0	5.5	0.54	360,003	660,005	0.681	528,639	969,170
	II	RW-2	298,596	P401 O/L	3.0	4.0	0.54	483,726	644,967	0.681	710.317	947,088
	II	TW-1	39,167	P401 O/L	3.0	3.0	0.54	63,451	63,451	0.681	93,173	93,173
	II	TW-2	70,000	P401 O/L	3.0	5.5	0.54	113,400	207,900	0.681	166,520	305,286
	II	TW-3	150,000	P401 O/L	3.0	7.0	0.54	243,000	567,000	0.681	356,828	832,599
	II	AP-1	908,821	P401 O/L	3.0	4.0	0.54	1,472,290	1,963,053	0.681	2,161,953	2,882,604
	Total 1,686,808							2,735,869	4,106,377		4,017,430	6,029,921
Miami	II	RW-1	155,833	P401 O/L	0.0	0.0	0.54					
	II	RW-2	233,333	P401 O/L	0.0	0.0	0.54					
	II	TW-1	129,000	P401 O/L	0.0	0.0	0.54					
	II	TW-2	37,625	P401 O/L	3.0	3.0	0.54	60,952	60,952	0.681	89,504	89,504
	II	TW-3	129,000	P401 O/L	3.0	3.0	0.54	208,980	208,980	0.681	306,872	306,872
	II	TW-4	17,200	P401 O/L	0.0	0.0	0.54					
	II	TW-5	43,000	P401 O/L	0.0	0.0	0.54					
	II	AP-1	570,759	P401 O/L	3.0	9.0	0.54	924,630	2,773,889	0.681	1,357,753	4,073,258
	Total 737,384							1,194,562	3,043,821		1,754,129	4,469,634

Airport	Category Aircraft	Pavement Item	Area Sq yds	Pavement Type	Thickness, in. Median	Thickness, in. Optimized	Unit Price	Pavement Cost Median	Pavement Cost Otpimized	S	Sub-Total Cost Median	Sub-Total Cost Optimized
New York (JFK)	II	RW-1	220,000	P401 O/L	3.0	8.5	0.52	$ 343,200	$ 972,400	0.681	$ 503,965	$1,427,900
	II	RW-2	172,500	P401 O/L	0.0	3.0	0.52	-	269,100	0.681	-	395,154
	II	TW-1	85,000	PCC O/L	6.0	12.0	1.37	698,700	1,397,400	0.775		
	II	TW-2	125,000	PCC O/L	no data	no data	1.37	-	-	0.775		
	II	TW-3	155,000	P401 O/L	no data	no data	0.52	-	-	0.681		
	II	TW-4	155,000	P401 O/L	no data	no data	0.52	-	-	0.681		
	II	AP-1	1,342,900	PCC O/L	7.0	13.0	1.37	12,878,411	23,917,049	0.775	16,617,305	30,860,708
	Total 1,820,400						-	13,920,311	26,555,949		18,022,818	34,486,858
New York (La Guardia)	II	RW-1	235,556	P401 O/L	3.0	3.0	0.56	395,734	395,734	0.681	581,107	581,107
	II	RW-2	228,250	P401 O/L	18.5	25.0	0.56	2,364,670	3,195,500	0.681	3,472,349	4,692,364
	II	TW-1	114,125	P401 O/L	3.0	4.5	0.56	191,730	287,595	0.681	281,542	422,313
	II	TW-2	102,712	P401 O/L	20.5	27.0	0.56	1,179,134	1,553,005	0.681	1,731,474	2,280,477
	II	AP-1	1,322,998	P401 O/L	18.0	24.5	0.56	13,335,820	18,151,533	0.681	19,582,702	26,654,233
	Total 2,003,641							17,467,088	23,583,367		25,649,175	34,630,495
Newark	II	RW-1	155,557	P401 O/L	0.0	3.0	0.54	-	252,002	0.681	-	370,047
	II	TW-1	134,966	P401 O/L	0.0	3.0	0.54	-	218,645	0.681	-	321,065
	II	TW-2	134,966	P401 O/L	0.0	3.0	0.54	-	218,645	0.681	-	321,065
	II	TW-3	21,446	P401 O/L	-	-	0.54					
	II	AP-1	141,289	P401 O/L	3.5	9.5	0.54	267,036	724,813	0.681	392,123	1,064,336
	II	AP-2	141,289	P401 O/L	3.5	9.5	0.54	267,036	724,813	0.681	392,123	1,064,336
	II	AP-3	141, 289	P401 O/L	3.5	9.5	0.54	267,036	724,813	0.681	392,123	1,064,336
	Total 431,812							267,036	1,195,460		392,123	1,755,448
Denver	II	RW-1	111,111	P401 O/L	10.0	17.5	0.37	411,111	719,444	0.681	603,687	1,056,452
	II	RW-2	96,620	P401 O/L	12.0	18.5	0.37	428,993	661,364	0.681	629,946	971,166
	II	TW-1	108,698	P401 O/L	7.0	14.0	0.37	281,528	563,056	0.681	413,404	826,808
	II	TW-2	115,044	P401 O/L	8.5	16.0	0.37	361,813	681,060	0.681	531,297	1,000,088
	II	TW-4	115,044	P401 O/L	8.5	16.0	0.37	361,813	681,060	0.681	531,297	1,000,088
	II	TW-3	31,401	P401 O/L	22.0	28.5	0.37	255,604	331,124	0.681	375,336	486,232
	II	AP-1	452,000	PCC O/L	13.0	19.0	1.27	7,462,520	10,906,760	0.775	9,629,058	14,073,239
	Total 914,874							9,201,579	13,862,807		12,182,728	18,413,985

Airport	Category Aircraft	Pavement Item	Area Sq yds	Pavement Type	Thickness, in. Median	Thickness, in. Optimized	Unit Price	Pavement Cost Median	Pavement Cost Otpimized	S	Sub-Totel Cost Median	Sub-Totel Cost Optimized
Boston	II	RW-1	222,222	P401 O/L	3.0	10.5	0.92	$ 613,333	$2,146,665	0.681	$ 900,636	$3,152,225
	II	RW-2	283,046	P401 O/L	0.0	7.5	0.92	-	1,953,017	0.681	-	2,867,866
	II	TW-1	58,480	P401 O/L	13.0	20.5	0.92	699,421	1,102,933	0.681	1,027,050	1,619,579
	II	TW-2	58,480	P401 O/L	13.0	20.5	0.92	699,421	1,102,933	0.681	1,027,050	1,619,579
	II	TW-3	72,516	P401 O/L	7.0	14.0	0.92	467,003	934,006	0.681	685,761	1,371,521
	II	TW-4	50,293	P401 O/L	14.5	22.0	0.92	670,909	1,017,930	0.681	985,182	1,494,758
	II	TW-5	88,890	P401 O/L	3.0	10.5	0.92	245,336	858,677	0.681	360,258	1,260,906
	II	AP-1	36,937	P401 O/L	13.0	20.5	0.92	441,767	696,632	0.681	648,703	1,022,954
	II	AP-2	66,571	P401 O/L	0.0	3.0	0.92	-	183,736	0.681	-	269,803
	Total 878,955							3,137,768	8,893,596		4,607,590	13,059,612
Philadelphia	II	RW-1	233,333	P401 O/L	3.0	4.5	0.73	510,999	766,499	0.681	750,366	1,125,545
	II	RW-2	215,556	P401 O/L	6.5	8.5	0.73	1,022,813	1,337,525	0.681	1,501,928	1,964,060
	II	TW-1	27,000	P401 O/L	5.0	7.5	0.73	98,550	147,825	0.681	144,714	217,070
	II	TW-2	5,750	P401 O/L	0.0	0.0	0.73	-	-	0.681	-	-
	II	TW-3	41,250	P401 O/L	3.0	4.5	0.73	90,337	135,506	0.681	132,652	198,981
	II	AP-1	37,500	PCC O/L	9.0	15.0	1.37	462,375	770,625	0.775	596,613	994,355
	Total 519,139							2,185,075	3,157,980		3,126,274	4,500,016
St. Louis	II	RW-1	222,222	PCC O/L	11.0	18.0	0.64	1,564,443	2,559,997	0.775	2,018,636	3,303,222
	II	TW-1	119,792	PCC O/L	10.0	17.0	0.64	766,669	130,337	0.775	989,250	1,681,725
	II	AP-1	244,141	PCC O/L	10.0	17.0	0.64	1,562,502	2,656,254	0.775	2,016,132	3,427,425
	Total 586,155							3,893,614	6,519,588		5,024,018	8,412,372
Honolulu	II	RW-1	257,778	P401 O/L	0.0	0.0	0.54					
	II	TW-3	347,614	P401 O/L	0.0	0.0	0.54					
	II	TW-4	347,614	P401 O/L	0.0	0.0	0.54					
	II	TW-8	347,614	P401 O/L	0.0	0.0	0.54					
	II	TW-10	347,614	P401 O/L	0.0	0.0	0.54					
	II	TW-5	51,958	P401 O/L	0.0	0.0	0.54					
	II	TW-6	51,958	P401 O/L	0.0	0.0	0.54					
	II	TW-7	51,958	P401 O/L	0.0	0.0	0.54					
	II	TW-11	51,958	P401 O/L	0.0	0.0	0.54					
	II	TW-13	51,958	P401 C/L	0.0	0.0	0.54					

Airport	Category Aircraft	Pavement Item	Area Sq yds	Pavement Type	Thickness, in. Median	Thickness, in. Optimized	Unit Price	Pavement Cost Median	Pavement Cost Otpimized	E	Sub-Total Cost Median	Sub-Total Cost Optimized
Honolulu (Continued)	II	TW-12	13,291	P401 O/L	0.0	3.0	0.54	$ -	$ 21,531	0.681	$ -	$ 31,617
	II	AP-1-12	448,433	P401 O/L	3.5	10.0	0.54	847,538	2,421,538	0.681	1,244,549	3,555,856
	II	TW-1	39,875	P401 O/L	0.0	0.0	0.54					
	Total 461,724							847,538	2,443,070		1,244,549	3,587,473
Detroit	II	RW-1&2	466,667	PCC O/L	13.0	19.0	0.94	5,702,671	8,334,673	0.775	7,358,285	10,754,417
	II	TW-1-4	315,954	P401 O/L	8.5	16.0	0.76	2,041,063	3,842,001	0.681	2,997,156	5,641,755
	II	AP-1	823,621	PCC O/L	12.0	18.0	0.94	9,290,445	13,935,667	0.775	11,987,671	17,981,506
	Total 1,606,242							17,034,179	26,112,341		22,343,112	34,377,638
Seattle-Tacoma	II	RW-1	175,200	P401 O/L	14.5	22.0	0.41	1,041,564	1,580,304	0.681	1,529,463	2,320,564
	II	RW-2	136,267	P401 O/L	3.0	7.0	0.41	167,608	391,086	0.681	246,120	574,282
	II	TW-1,2&4	192,234	P401 O/L	3.0	7.0	0.41	236,448	551,712	0.681	347,207	810,150
	II	TW-3	19,467	P401 O/L	4.0	10.5	0.41	31,926	83,805	0.681	46,881	12,062
	II	HP-1-4	827,138	P401 O/L	7.0	14.0	0.41	2,373,886	4,747,772	0.681	3,485,883	6,971,769
	Total 1,350,306							3,851,432	7,354,679		5,655,554	10,799,822
Pittsburgh	II	RW-1	175,000	P401 O/L	9.5	16.5	0.93	1,546,125	2,685,375	0.681	2,270,374	3,943,282
	II	RW-2	166,667	P401 O/L	11.5	20.0	0.93	1,782,504	3,100,006	0.681	2,617,480	4,552,138
	II	TW-1&4	86,812	P401 O/L	8.5	16.0	0.93	686,249	1,291,763	0.681	1,007,708	1,896,862
	II	TW-2	28,938	P401 O/L	3.5	11.5	0.93	94,193	309,492	0.681	138,316	454,467
	II	TW-3	65,592	P401 O/L	19.0	26.0	0.93	1,159,011	1,586,015	0.681	1,701,925	2,328,950
	II	TW-5	36,654	P401 O/L	5.0	12.0	0.93	170,441	409,059	0.681	250,280	600,674
	II	AP-1	428,728	PCC O/L	13.5	20.0	1.17	6,771,759	10,032,235	0.775	8,737,754	12,944,819
	Total 988,391							12,210,281	19,413,944		16,723,838	26,721,192
Houston	II	RW-1	156,667	PCC O/L	7.0	13.0	0.84	921,202	1,710,804	0.775	1,188,648	2,207,489
	II	TW-1-3	238,650	PCC O/L	7.0	13.0	0.84	1,403,262	2,606,058	0.775	1,810,661	3,362,655
	II	TW-4	58,275	PCC O/L	6.0	11.0	0.84	293,706	538,461	0.775	378,975	694,788
	II	AP-1	645,987	PCC O/L	7.0	12.0	C.84	379,804	6,511,549	0.775	4,901,166	8,401,999
	Total 1,099,579							6,416,574	11,366,872		8,279,450	14,666,932

Airport	Category	Pavement	Area	Pavement	Thickness, in.		Unit	Pavement Cost			Sub-Total Cost	
	Aircraft	Item	Sq yds	Type	Median	Optimized	Price	Median	Otpimized	S	Median	Optimized
Minneapolis	II	RW-1	233,333	P401 O/L	15.0	23.0	0.76	$2,659,996	$4,078,661	0.681	$3,906,015	$5,989,223
	II	RW-2	205,189	P401 O/L	4	4	0.76	623,775	623,775	0.681	915,969	915,969
			205,189	P201 O/L	8	16	0.67	1,099,813	2,199,626	0.681	1,614,997	3,229,994
	II	TW-1&2	255,617	P401 O/L	4.5	11.0	0.76	874,210	2,136,958	0.681	1,283,715	3,137,971
	II	AP-1	323,563	P401 O/L	4.5	11.0	0.76	1,106,585	2,704,987	0.681	1,624,941	3,972,081
	Total 1,222,891							6,364,379	11,744,006		9,345,637	17,245,238
New Orleans	II	RW-1	153,783	P401 O/L	8.5	16.5	0.76	993,438	1,928,439	0.681	1,458,793	2,831,775
	II	TW-1	75,833	PCC O/L	14.0	21.0	0.79	838,713	1,258,069	0.775	1,082,210	1,623,315
	II	TW-2	8,667	PCC O/L	9.0	16.0	0.79	61,622	109,551	0.775	79,512	141,356
	II	AP-1	52,577	P401 O/L	9.5	17.0	0.76	379,606	679,255	0.681	557,424	997,496
	II	AP-2	116,497	P401 O/L	4.5	11.5	0.76	398,420	1,018,184	0.681	585,051	1,495,131
	II	AP-3	27,941	P401 O/L	23.0	31.5	0.76	488,409	668,908	0.681	717,194	982,244
	Total 435,298							3,160,208	5,662,445		4,480,185	8,071,317
Las Vegas	II	RW-1	233,333	P401 O/L	10.5	16.5	0.54	1,322,998	2,078,997	0.681	1,942,728	3,052,859
	II	RW-2	202,898	P401 O/L	7.5	10.0	0.54	821,737	1,095,649	0.681	1,206,662	1,608,893
	II	TW-1	77,038	P401 O/L	3.0	7.5	0.54	124,802	312,004	0.681	183,263	458,156
	II	TW-2	140,760	P401 O/L	7.5	10.0	0.54	570,078	760,104	0.681	837,119	1,116,159
	II	AP-1	759,293	P401 O/L	8.5	11.0	0.54	3,485,155	4,510,200	0.681	5,117,702	6,622,907
	Total 1,413,322							6,324,769	8,756,955		9,287,474	12,858,963
Kansas City	II	RW-1	233,333	P401 O/L	8.5	15.5	0.42	832,999	1,518,998	0.681	1,223,200	2,230,540
	II	RW-2	203,333	P401 O/L	5.5	14.0	0.42	469,699	1,195,598	0.681	689,720	1,755,651
	II	TW-1	124,050	PCC O/L	11.0	17.0	0.85	1,159,868	1,792,523	0.775	1,496,604	2,312,933
	II	TW-2	128,400	PCC O/L	8.0	15.0	0.85	873,120	1,637,100	0.775	1,126,606	2,112,387
	II	TW-3	40,125	PCC O/L	10.0	16.0	0.85	341,063	545,700	0.775	440,081	704,129
	II	AP-1	527,992	PCC O/L	12.0	18.0	0.85	5,385,518	8,078,278	0.775	6,949,055	10,423,585
	Total 1,257,233							9,062,267	14,768,197		11,925,265	19,540,225

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Airport	Category Aircraft	Pavement Item	Area Sq yds	Pavement Type	Thickness, in.		Unit Price	Pavement Cost		S	Sub-Total Cost	
					Median	Optimized		Median	Otpimized		Median	Optimized
Baltimore	II	RW-1&2	350,000	P401 O/L	0.0	0.0	0.52	$	$	0.681	$	$
	II	TW-Total	253,750	P401 O/L	0.0	0.0	0.52					
	II	AP-1	378,675	P401 O/L	0.0	0.0	0.52					
Cleveland	II	RW-1	233,333	P401 O/L	3.0	7.0	0.76	531,939	1,241,332	0.681	781,203	1,822,608
	II	TW-1	90,125	P401 O/L	6.0	13.0	0.76	410,970	890,435	0.681	603,480	1,307,540
	II	TW-2	33,475	P401 O/L	7.0	14.5	0.76	178,087	368,894	0.681	261,508	541,695
	II	AP-1	127,308	P401 O/L	7.0	14.5	0.76	677,279	1,402,934	0.681	994,536	2,060,109
	II	AP-2	120,943	P401 O/L	6.0	13.0	0.76	551,500	1,194,917	0.681	809,838	1,754,651
	II	AP-3	224,911	P401 O/L	14.0	21.5	0.76	2,393,053	3,675,046	0.681	3,514,028	5,396,543
	Total 830,095							4,742,888	8,773,558		6,964,593	12,883,345
Washington	II	RW-1	166,667	PCC O/L	6	13	1.37	1,370,003	2,968,339	0.775	1,767,746	3,830,115
	II	RW-2	166,667	PCC O/L	6	13	1.37	1,370,003	2,968,339	0.775	1,767,746	3,830,115
	II	TW-1	100,000	PCC O/L	6	13	1.37	822,000	1,781,000	0.775	1,060,645	2,298,065
	II	TW-2	100,000	PCC O/L	6	13	1.37	822,000	1,781,000	0.775	1,060,645	2,298,065
	II	AP-1	346,686	PCC O/L	6	13	1.37	2,849,759	6,174,478	0.775	3,677,108	7,967,068
	Total 880,020							7,233,764	15,673,156		9,333,890	20,223,427
Ft. Lauderdale	II	RW-1	137,167	P401 O/L	3.0	3.0	0.54	222,211	222,211	0.681	326,301	326,301
	II	TW-1	69,167	P401 O/L	8.5	10.5	0.54	317,477	392,177	0.681	466,192	575,884
	II	TW-2	90,378	P401 O/L	0.0	4.0	0.54	-	195,216	0.681	-	286,661
	II	AP Total	370,965	P401 O/L	14.5	28.5	0.54	2,904,656	5,709,151	0.681	4,265,280	8,383,482
	Total 667,677							3,444,343	6,518,755		5,057,774	9,572,327

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