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7.0 PAVEMENT DATA

7.1 General Information

A brief description of the following pavement charts will facilitate their use for airport planning. Each airplane configuration is shown with a minimum range of four loads imposed on the main landing gear to aid in interpolation between the discrete values shown. All curves are plotted at constant specified tire pressure at the highest certified weight for each model.

Subsection 7.2 presents basic data on the landing gear footprint configuration, tire sizes, and tire pressures.

Subsection 7.3 lists maximum vertical and horizontal pavement loads at the tire ground interfaces for certain critical conditions.

Subsection 7.4 presents a chart showing static loads imposed on the main landing gear struts for the operational limits of the airplane. These main landing gear loads are used for interpreting the pavement design charts. All pavement requirements are based on the wing gear because the center gear is less demanding under normal conditions.

Subsection 7.5 presents a pavement requirement chart for flexible pavements. Flexible pavement design curves are based on the format and procedures set forth in Instruction Report No. S-77-1, Procedures for Development of CBR Design Curves, published in June 1977 by the U.S. Army Engineer Waterways Experiment Station, Soils and Pavements Laboratory, Vicksburg, Mississippi.

The following procedure is used to develop the flexible pavement curves:

1. Having established the scale for pavement depth at the bottom and the scale for CBR at the top, an arbitrary line is drawn representing 6,000 annual departures.
2. Values of the aircraft gross weight are then plotted.
3. Additional annual departure lines are drawn based on the load lines of the aircraft gross weights already established.
4. An additional line is drawn to represent 10,000 “coverages,” statistically the number of maximum stresses the aircraft causes in the pavement. This is used to calculate the flexible pavement Aircraft Classification Number.

Subsection 7.6 provides LCN conversion curves for flexible pavements. These curves have been plotted using procedures and curves in the International Civil Aviation Organization (ICAO) Aerodrome Design Manual, Part 3 — Pavements, Document 9157-AN/901, 1977. The same charts have plots of equivalent single-wheel load versus pavement thickness.

Subsection 7.7 provides rigid pavement design curves prepared with the use of the Westergaard equations in general accord with the relationships outlined in the 1955 edition of Design of Concrete Airport Pavement, published by the Portland Cement Association, 33 W. Grand Ave., Chicago, Illinois, but modified to the new format described in the 1968 Portland Cement Association publication, Computer Program for Airport Pavement Design by Robert G. Packard. The following procedure is used to develop the rigid pavement design curves.

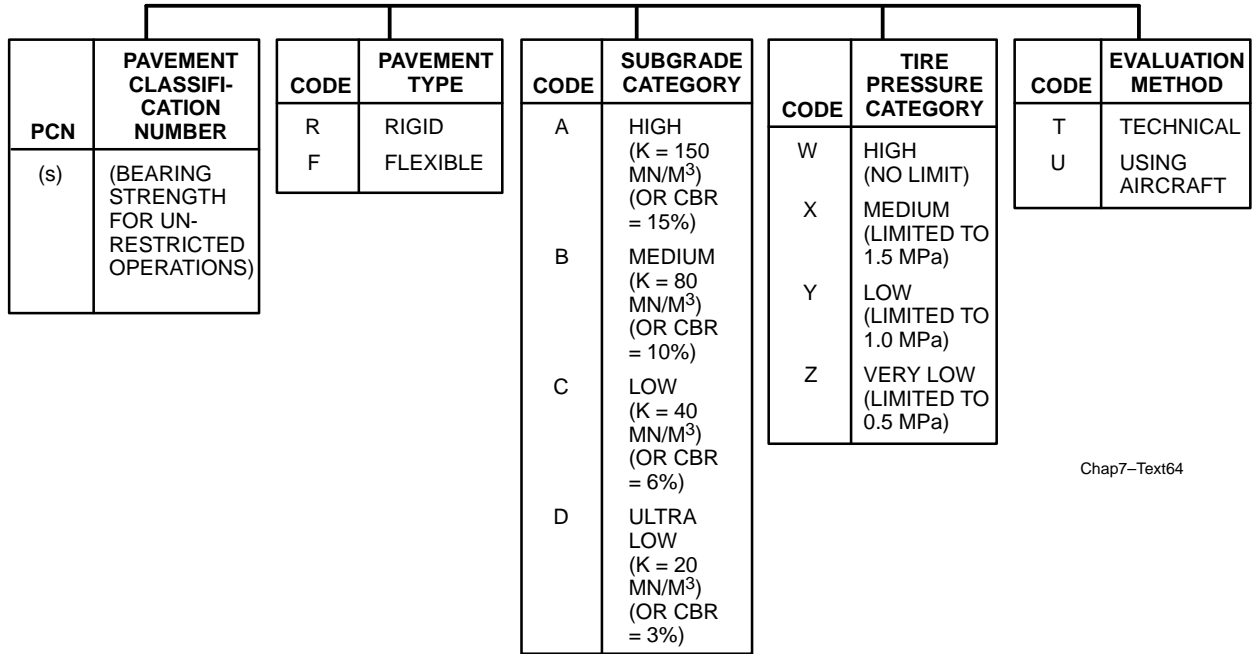
1. Having established the scale for pavement thickness to the left and the scale for allowable working stress to the right, an arbitrary load line is drawn representing the main landing gear maximum weight to be shown.
2. All values of the subgrade modulus (K-values) are then plotted using the maximum load line, as shown.
3. Additional load lines for the incremental value of weight on the main landing gear are then established on the basis of the curve for $K = 300 \text{ lb/in.}^3$ already established.

Subsection 7.8 presents LCN conversion curves for rigid pavements. These curves have been plotted using procedures and curves in the ICAO Aerodrome Design Manual, Part 3 — Pavements, Document 9157-AN/901, 1977. The same charts include plots of equivalent single-wheel load versus radius of relative stiffness. The LCN requirements are based on the condition of center-of-slab loading. Radii of relative stiffness values are obtained from Subsection 7.8.1.

Subsection 7.9 provides ACN data prepared according to the ACN-PCN system described in Aerodromes, Annex 14 to the Convention on International Civil Aviation. ACN is the Aircraft Classification Number and PCN is the corresponding Pavement Classification Number.

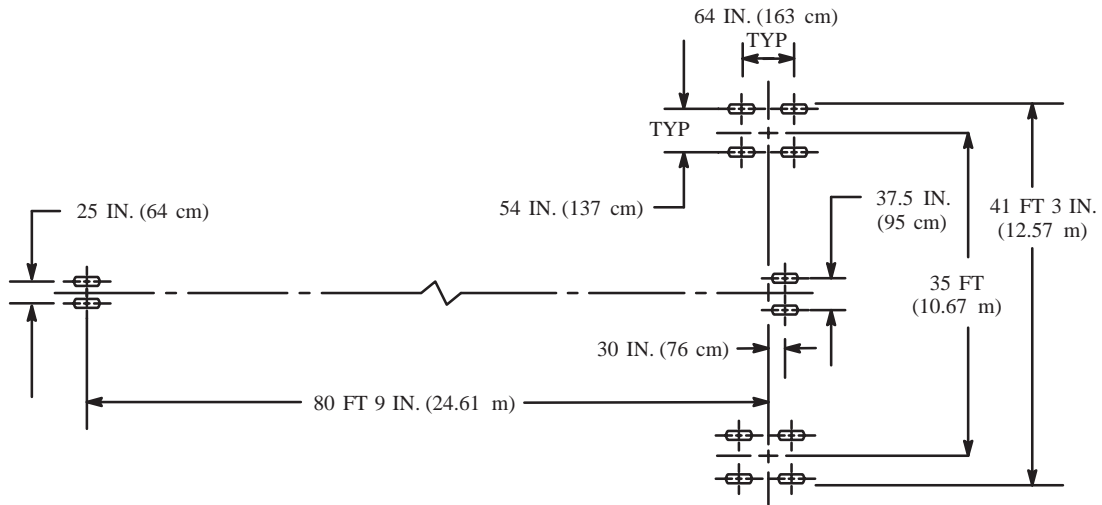
ACN-PCN provides a standardized international airplane/pavement rating system replacing the various S, T, TT, LCN, AUW, ISWL, etc., rating systems used throughout the world. An aircraft having an ACN equal to or less than the PCN can operate without restriction on the pavement. Numerically, the ACN is two times the derived single-wheel load expressed in thousands of kilograms, where the load is on a single tire inflated to 1.25 MPa (181 psi) that would have the same pavement requirements as the aircraft. Computationally, the ACN-PCN system uses PCA program PDILB for rigid pavements and S-77-1 for flexible pavements to calculate ACN values. The method of pavement evaluation is the responsibility of the airport, with the results of its evaluation presented as follows:

REPORT EXAMPLE: PCN 80/R/B/W/T

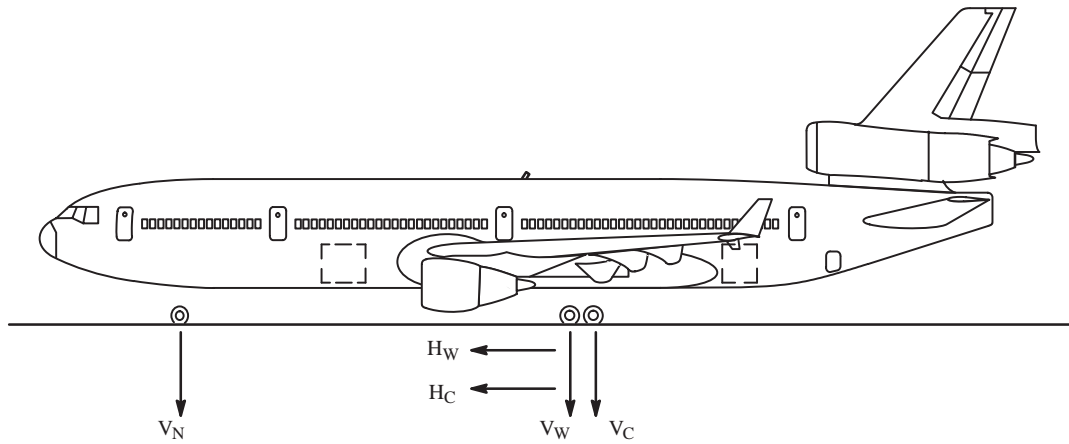


Chap7--Text64

MAXIMUM RAMP WEIGHT	633,000 LB (287,129 kg)
PERCENT OF WEIGHT ON MAIN GEAR	SEE SECTION 7.4
NOSE TIRE SIZE	40 x 15.5 — 16
NOSE TIRE PRESSURE	180 PSI (12.7 kg/cm ²)
WING AND CENTER GEAR TIRE SIZE	H54 x 21.0 — 24
WING GEAR TIRE PRESSURE	206 PSI (14.4 kg/cm ²)
CENTER GEAR TIRE PRESSURE	180 PSI (12.7 kg/cm ²)



**7.2 FOOTPRINT
MODEL MD-11**



PAVEMENT LOADS FOR CRITICAL COMBINATIONS OF WEIGHT AND CG POSITIONS

V_N = VERTICAL NOSE GEAR GROUND LOAD PER STRUT

V_W = VERTICAL WING GEAR GROUND LOAD PER STRUT

V_C = VERTICAL CENTER GEAR GROUND LOAD PER STRUT

H_W = HORIZONTAL WING GEAR GROUND LOAD PER STRUT FROM BRAKING

H_C = HORIZONTAL CENTER GEAR GROUND LOAD PER STRUT FROM BRAKING

MODEL MD-11	RAMP WEIGHT	NOSE GEAR (1) FORWARD CG		WING GEAR (2) AFT CG			CENTER GEAR (1) AFT CG		
		V_N	V_N	V_W	H_W		V_C	H_C	
		STATIC	STEADY BRAKING*	STATIC	STEADY BRAKING*	INST BRAKING**	STATIC	STEADY BRAKING*	INST BRAKING**
LB	633,000	54,900	93,000	245,400	80,800	170,000	106,300	35,000	73,600
kg	287,129	24,903	42,184	111,313	36,651	77,112	48,218	15,876	33,385

* AIRCRAFT DECELERATION = 10 FT/SEC². H_W AND H_C ASSUME DECELERATION FROM BRAKING ONLY
 ** INSTANTANEOUS BRAKING; COEFFICIENT OF FRICTION = 0.8

7.3 MAXIMUM PAVEMENT LOADS MODEL MD-11

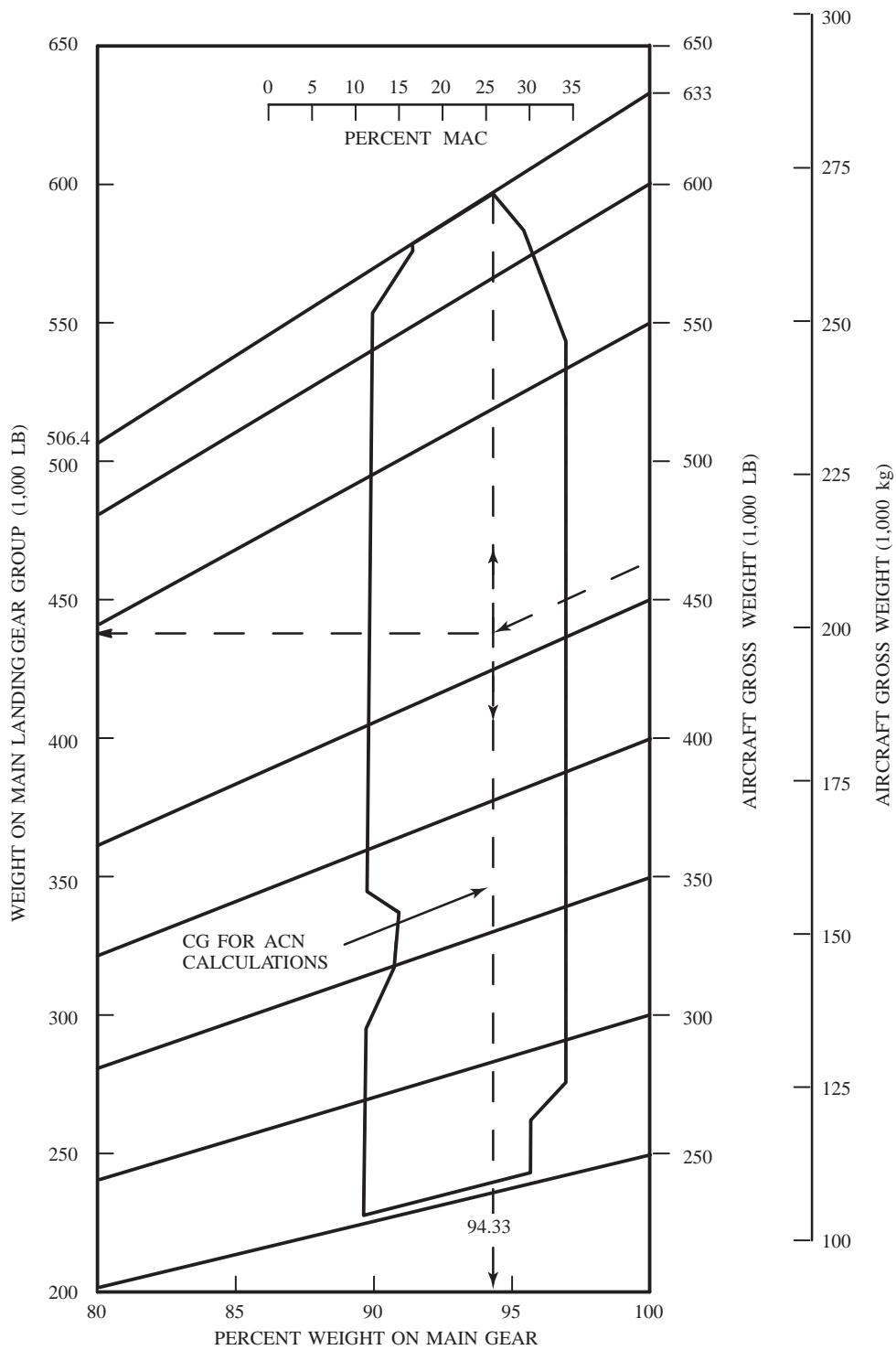
REV E

7.4 Landing Gear Loading on Pavement

7.4.1 Loadson the MainLanding Gear Group

For the MD-11, the main gear group consists of two wing gears plus one center gear.

In the example for the MD-11, the gross weight is 470,000 pounds, the percent of weight on the main gears is 94.33 percent, and the total weight on the three main gears is 443,351 pounds.



**7.4 LANDING GEAR LOADING ON PAVEMENT
MODEL MD-11**

REV E

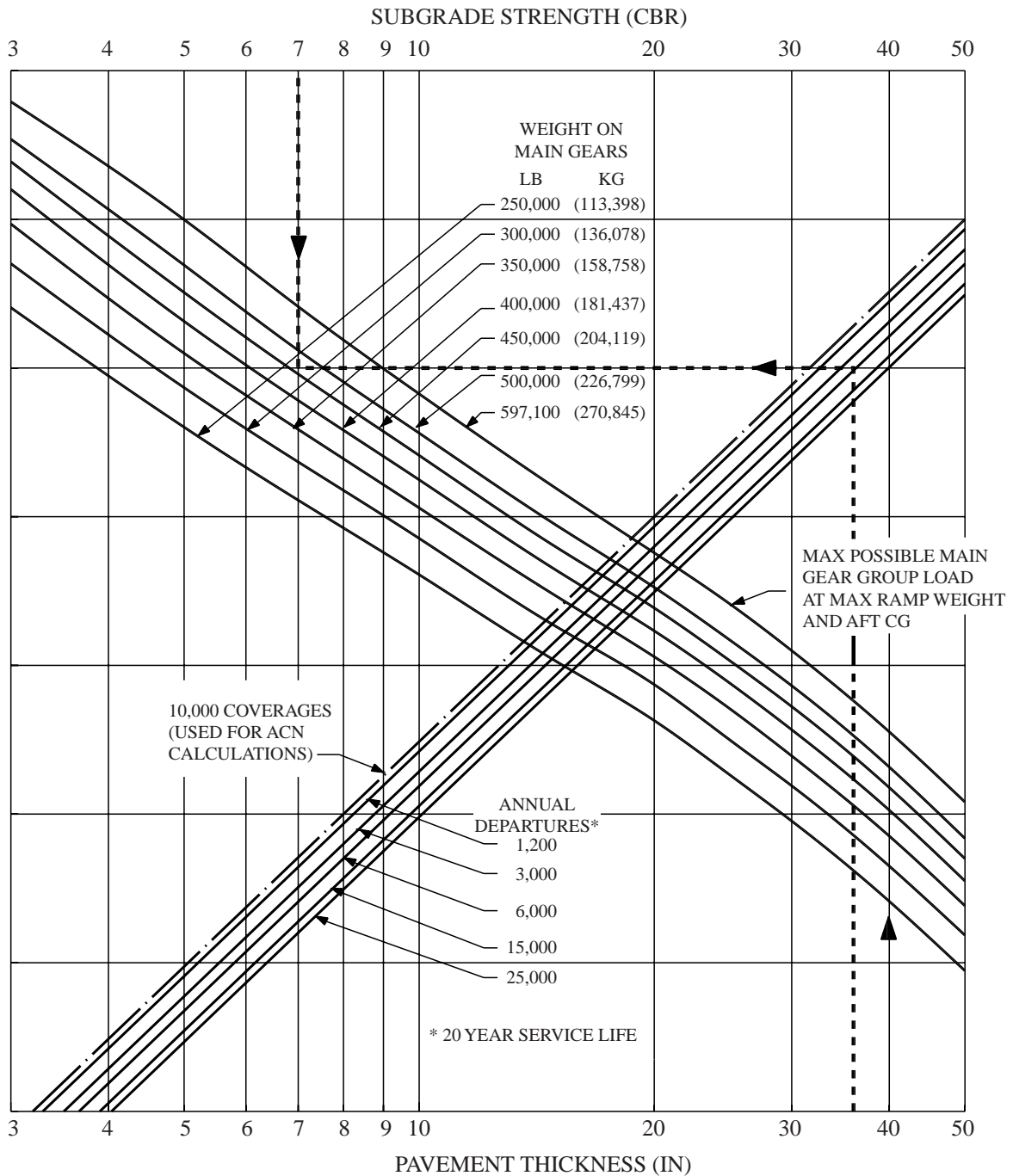
7.5 Flexible Pavement Requirements — U.S. Army Corps of Engineers Method (S-77-1)

To determine the airplane weight that can be accommodated on a particular flexible pavement, the thickness of the pavement, the subgrade CBR, and the annual departure level must be known.

In the example shown for the MD-11, for a CBR of 7.0, an annual departure level of 6,000, and a flexible pavement thickness of 36 inches, the main gear group loading is 450,000 pounds.

The line showing 10,000 coverages is used for ACN calculations, which are shown in another subsection.

NOTE: H54 x 21.0-24 TIRES; TIRE PRESSURE CONSTANT AT 206 PSI (14.5 kg/cm²)



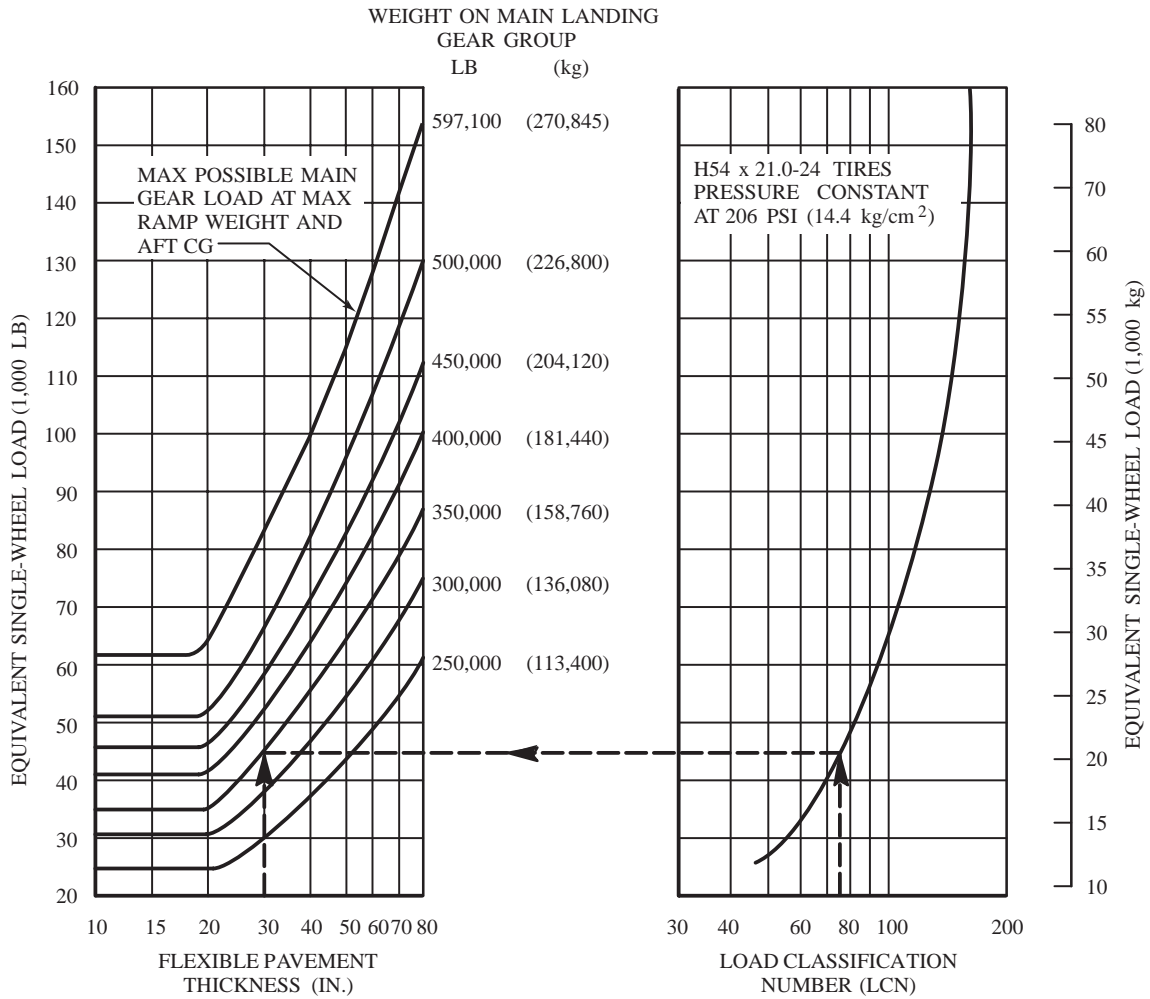
**7.5 FLEXIBLE PAVEMENT REQUIREMENTS
U.S. ARMY CORPS OF ENGINEERS/FAA DESIGN METHOD
MODEL MD-11**

REV E

7.6 Flexible Pavement Requirements, LCN Conversion

To determine the airplane weight that can be accommodated on a particular flexible airport pavement, both the LCN of the pavement and the thickness (h) of the pavement must be known.

In the example for the MD-11, the flexible pavement thickness is 30 inches, the LCN is 76, and the main landing gear group weight is 350,000 pounds.



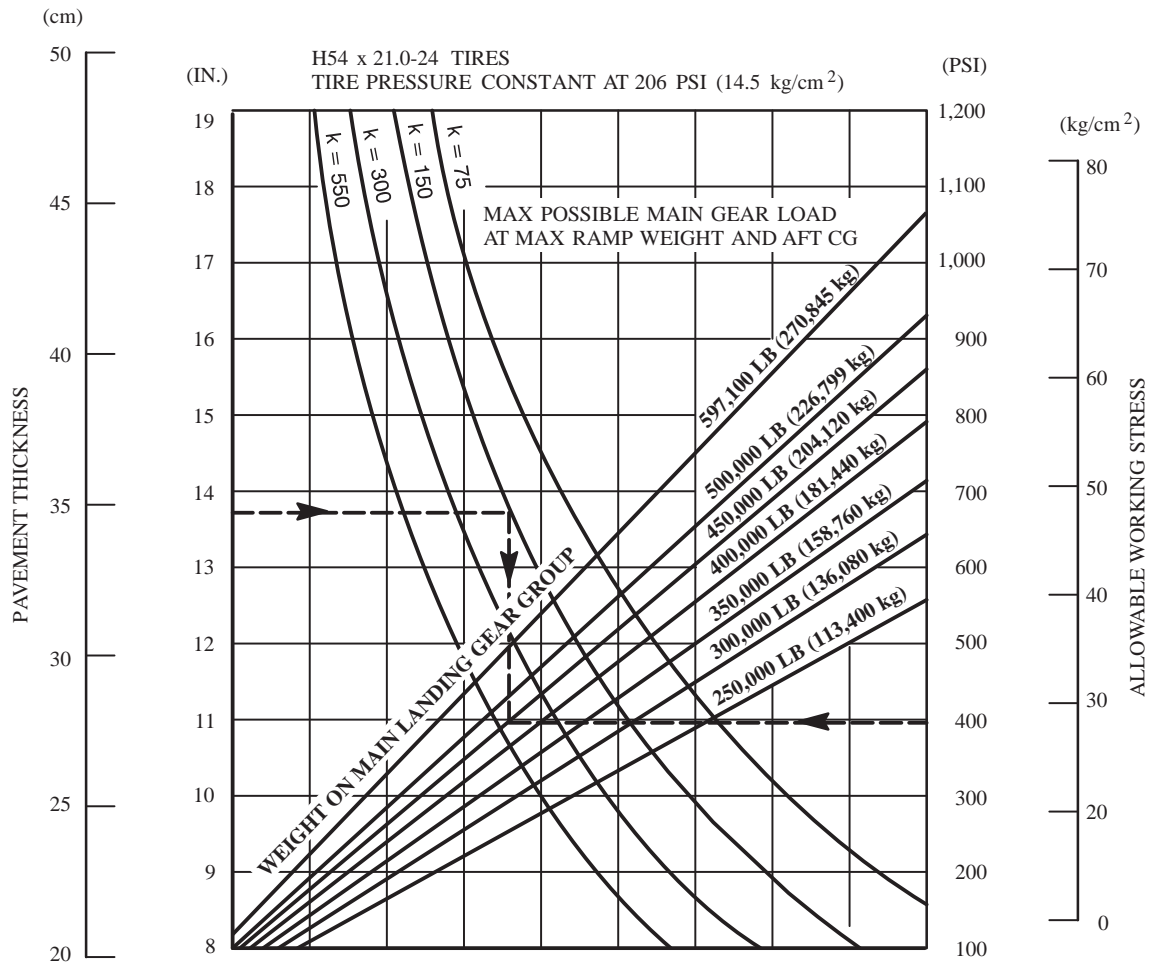
NOTE: EQUIVALENT SINGLE-WHEEL LOADS ARE DERIVED BY METHODS SHOWN IN ICAO AERODROME MANUAL, PART 2, PAR. 4.1.3

7.6 FLEXIBLE PAVEMENT REQUIREMENTS – LCN CONVERSION MODEL MD-11

7.7 Rigid Pavement Requirements, Portland Cement Association Design Method

To determine the airplane weight that can be accommodated on a particular rigid pavement, the thickness of the pavement, the subgrade modulus (k), and the allowable working stress must be known.

In the example for the MD-11, the rigid pavement thickness is 13.7 inches, the subgrade modulus is 150, and the allowable working stress is 400 psi. For these conditions, the weight on the landing gear group is 450,000 pounds.



NOTE: THE VALUES OBTAINED BY USING THE MAX LOAD REFERENCE LINE AND ANY VALUES OF K ARE EXACT. FOR LOADS LESS THAN MAX, THE CURVES ARE EXACT FOR K = 300, BUT DEVIATE SLIGHTLY FOR OTHER VALUES OF K.

REF: DESIGN OF CONCRETE AIRPORT PAVEMENT, 1968 PORTLAND CEMENT ASSOCIATION COMPUTER PROGRAM

**7.7 RIGID PAVEMENT REQUIREMENTS,
PORTLAND CEMENT ASSOCIATION DESIGN METHOD
MODEL MD-11**

REV E

7.8 Rigid Pavement Requirements, LCN Conversion

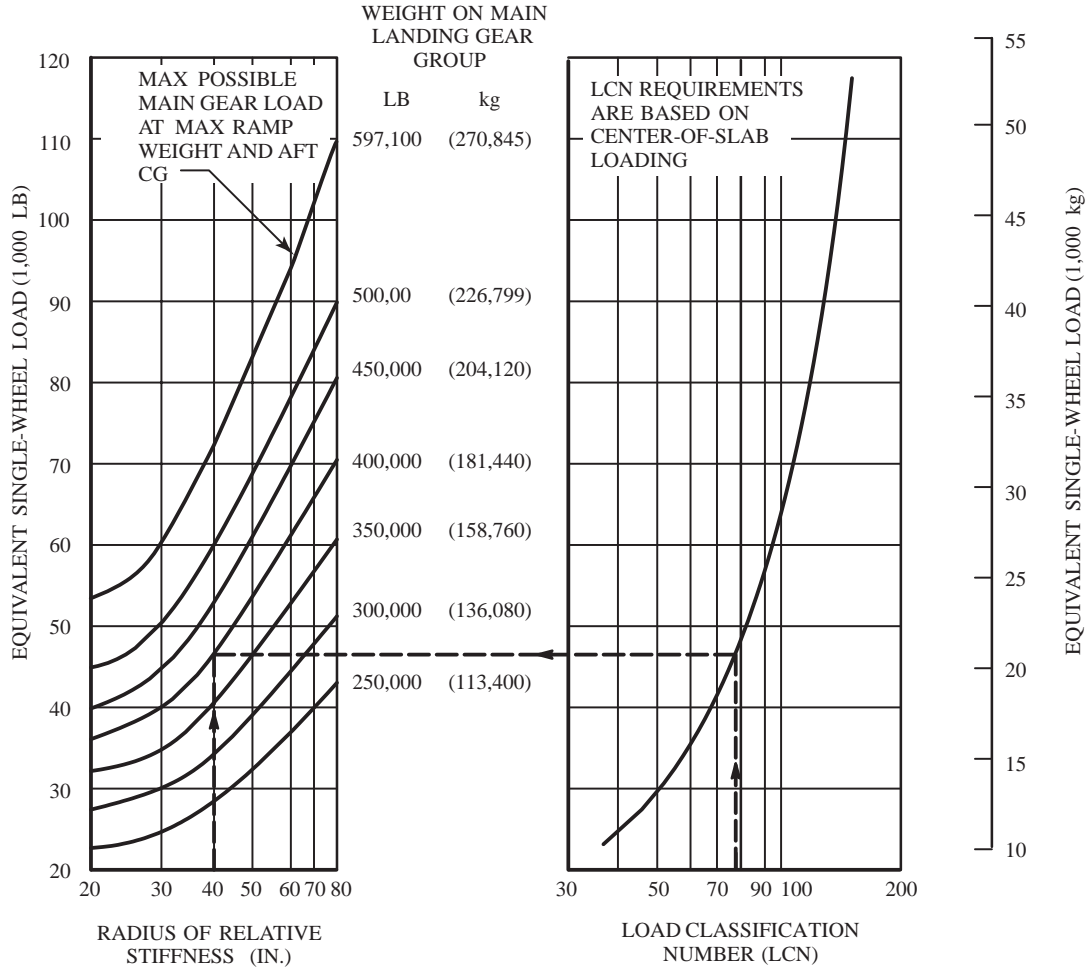
To determine the airplane weight that can be accommodated on a particular rigid airport pavement, both the LCN of the pavement and the radius of relative stiffness must be known.

In the example for the MD-11, the rigid pavement radius of relative stiffness is 40 inches and the LCN is 78. For these conditions, the weight on the main landing gear group is 400,000 pounds.

The LCN charts use ℓ -values based on Young's Modulus (E) of 4 million psi and Poisson's ratio (m) of 0.15. For convenience in finding ℓ -values based on other values of E and m, the curves in chart 7.8.2 are included. For example, to find an ℓ -value based on an E of 3 million psi, the E-factor of 0.931 is multiplied by the ℓ -value found in Chart 7.8.1. The effect of variations in m on the ℓ -value is treated in a similar manner.

Note: If the resulting aircraft LCN is not more than 10 percent above the published pavement LCN, the United Kingdom, which originated the LCN method, considers that the bearing strength of the pavement is sufficient for unlimited use by the airplane. The figure of 10 percent has been chosen as representing the lowest degree of variation in LCN which is significant. (Reference: ICAO Aerodrome Design Manual, Part 3 — Pavements, Document 9157-AN/901, 1977 Edition.)

H54 x 21.0-24 TIRES
 TIRE PRESSURE CONSTANT AT 206 PSI (14.5 kg/cm²)



NOTE: EQUIVALENT SINGLE-WHEEL LOADS ARE DERIVED BY METHODS SHOWN IN ICAO AERODROME MANUAL, PART 2, PAR. 4.1.3

7.8.1 RIGID PAVEMENT REQUIREMENTS, LCN CONVERSION MODEL MD-11

REV E

RADIUS OF RELATIVE STIFFNESS (ℓ)
VALUES IN INCHES

$$\ell = \sqrt[4]{\frac{Ed^3}{12(1-\mu^2)k}} = 24.1652 \sqrt[4]{\frac{d^3}{k}}$$

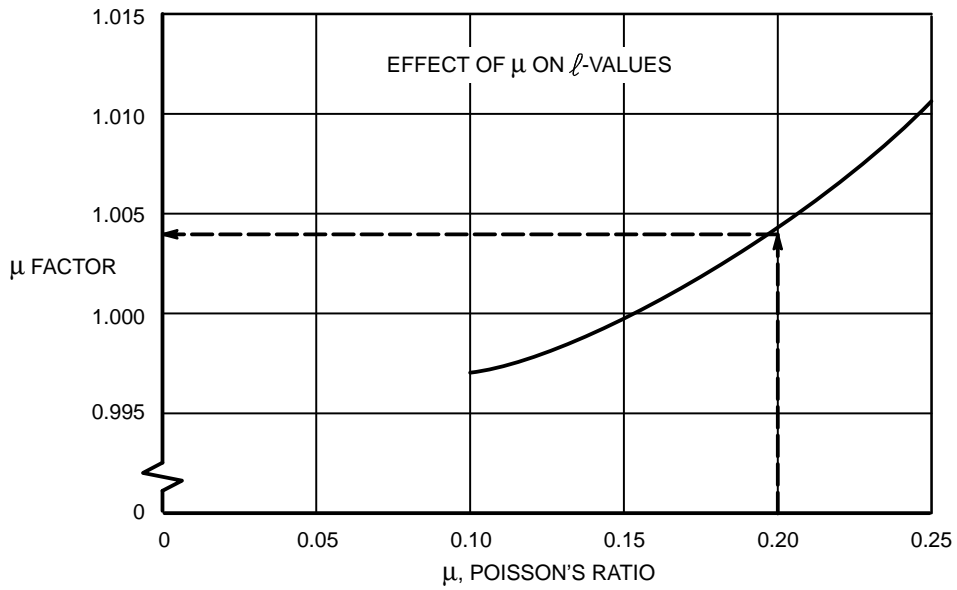
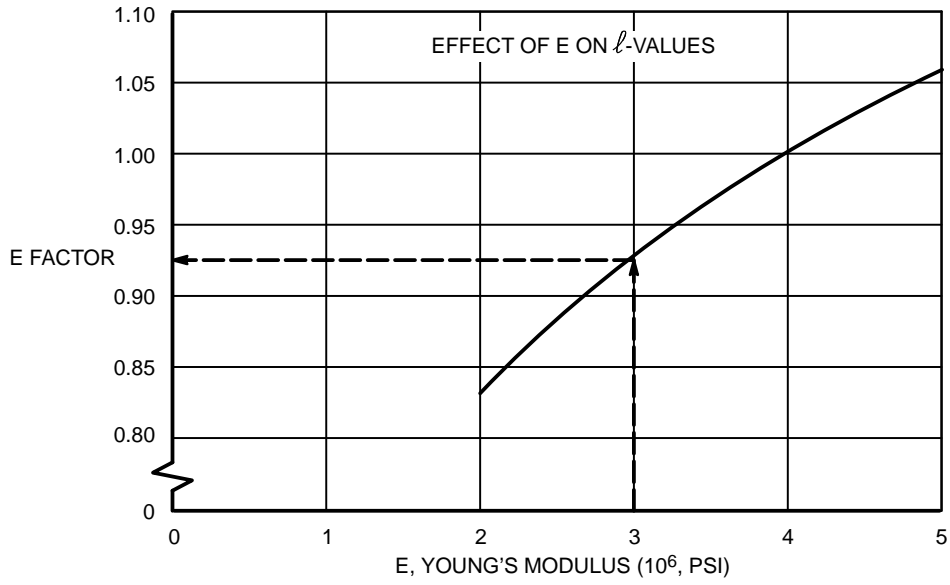
WHERE: E = YOUNG'S MODULUS = 4×10^6 PSI
 k = SUBGRADE MODULUS, LB/IN.³
 d = RIGID-PAVEMENT THICKNESS, IN.
 μ = POISSON'S RATIO = 0.15

d (IN.)	k = 75	k = 100	k = 150	k = 200	k = 250	k = 300	k = 350	k = 400	k = 500	k = 550
6.0	31.48	29.30	26.47	24.63	23.30	22.26	21.42	20.72	19.59	19.13
6.5	33.43	31.11	28.11	26.16	24.74	23.64	22.74	22.00	20.80	20.31
7.0	35.34	32.89	29.72	27.65	26.15	24.99	24.04	23.25	21.99	21.47
7.5	37.22	34.63	31.29	29.12	27.54	26.32	25.32	24.49	23.16	22.61
8.0	39.06	36.35	32.85	30.57	28.91	27.62	26.58	25.70	24.31	23.74
8.5	40.88	38.04	34.37	31.99	30.25	28.91	27.81	26.90	25.44	24.84
9.0	42.67	39.71	35.88	33.39	31.58	30.17	29.03	28.08	26.55	25.93
9.5	44.43	41.35	37.36	34.77	32.89	31.42	30.23	29.24	27.65	27.00
10.0	46.18	42.97	38.83	36.14	34.17	32.65	31.42	30.39	28.74	28.06
10.5	47.90	44.57	40.28	37.48	35.45	33.87	32.59	31.52	29.81	29.11
11.0	49.60	46.16	41.71	38.81	36.71	35.07	33.75	32.64	30.87	30.14
11.5	51.28	47.72	43.12	40.13	37.95	36.26	34.89	33.74	31.91	31.16
12.0	52.94	49.27	44.52	41.43	39.18	37.44	36.02	34.84	32.95	32.17
12.5	54.59	50.80	45.90	42.72	40.40	38.60	37.14	35.92	33.97	33.17
13.0	56.22	52.32	47.27	43.99	41.61	39.75	38.25	36.99	34.99	34.16
13.5	57.83	53.82	48.63	45.26	42.80	40.89	39.35	38.06	35.99	35.14
14.0	59.43	55.31	49.98	46.51	43.98	42.02	40.44	39.11	36.99	36.12
14.5	61.02	56.78	51.31	47.75	45.16	43.15	41.51	40.15	37.97	37.08
15.0	62.59	58.25	52.63	48.98	46.32	44.26	42.58	41.19	38.95	38.03
15.5	64.15	59.70	53.94	50.20	47.47	45.36	43.64	42.21	39.92	38.98
16.0	65.69	61.13	55.24	51.41	48.62	46.45	44.70	43.23	40.88	39.92
16.5	67.23	62.56	56.53	52.61	49.75	47.54	45.74	44.24	41.84	40.85
17.0	68.75	63.98	57.81	53.80	50.88	48.61	46.77	45.24	42.78	41.78
17.5	70.26	65.38	59.48	54.98	52.00	49.68	47.80	46.23	43.72	42.70
18.0	71.76	66.78	60.35	56.16	53.11	50.74	48.82	47.22	44.66	43.61
19.0	74.73	69.54	62.84	58.48	55.31	52.84	50.84	49.17	46.51	45.41
20.0	77.66	72.27	65.30	60.77	57.47	54.92	52.84	51.10	48.33	47.19
21.0	80.55	74.97	67.74	63.04	59.62	56.96	54.81	53.01	50.13	48.95
22.0	83.41	77.63	70.14	65.28	61.73	58.98	56.75	54.89	51.91	50.69
23.0	86.24	80.26	72.52	67.49	63.83	60.98	58.68	56.75	53.67	52.41
24.0	89.04	82.86	74.87	69.68	65.90	62.96	60.58	58.89	55.41	54.11
25.0	91.81	85.44	77.20	71.84	67.95	64.92	62.46	60.41	57.14	55.79

REFERENCE: PORTLAND CEMENT ASSOCIATION

DMC005-71

7.8.2 RADIUS OF RELATIVE STIFFNESS



NOTE: BOTH CURVES ON THIS PAGE ARE USED TO ADJUST THE l -VALUES OF TABLE 7.8.2

7.8.3 EFFECT OF E AND μ ON l -VALUES

DMC005-72

7.9 ACN-PCN Reporting System: Flexible and Rigid Pavements

To determine the ACN of an aircraft on flexible or rigid pavement, both the aircraft gross weight and the subgrade strength category must be known. The examples show that for an aircraft gross weight of 425,000 pounds and low subgrade strength, the ACN for flexible pavement is 50 and the ACN for rigid pavement for the same gross weight is 48.

Note: An aircraft with an ACN equal to or less than the reported PCN can operate on the pavement subject to any limitations on the tire pressure.

7.9.1 Development of ACN Charts

The ACN charts for flexible and rigid pavements were developed by methods referenced in the ICAO Aerodrome Manual, Part 3 — Pavements, Document 9157-AN/901, 1983 Edition. The procedures used in developing these charts are described below.

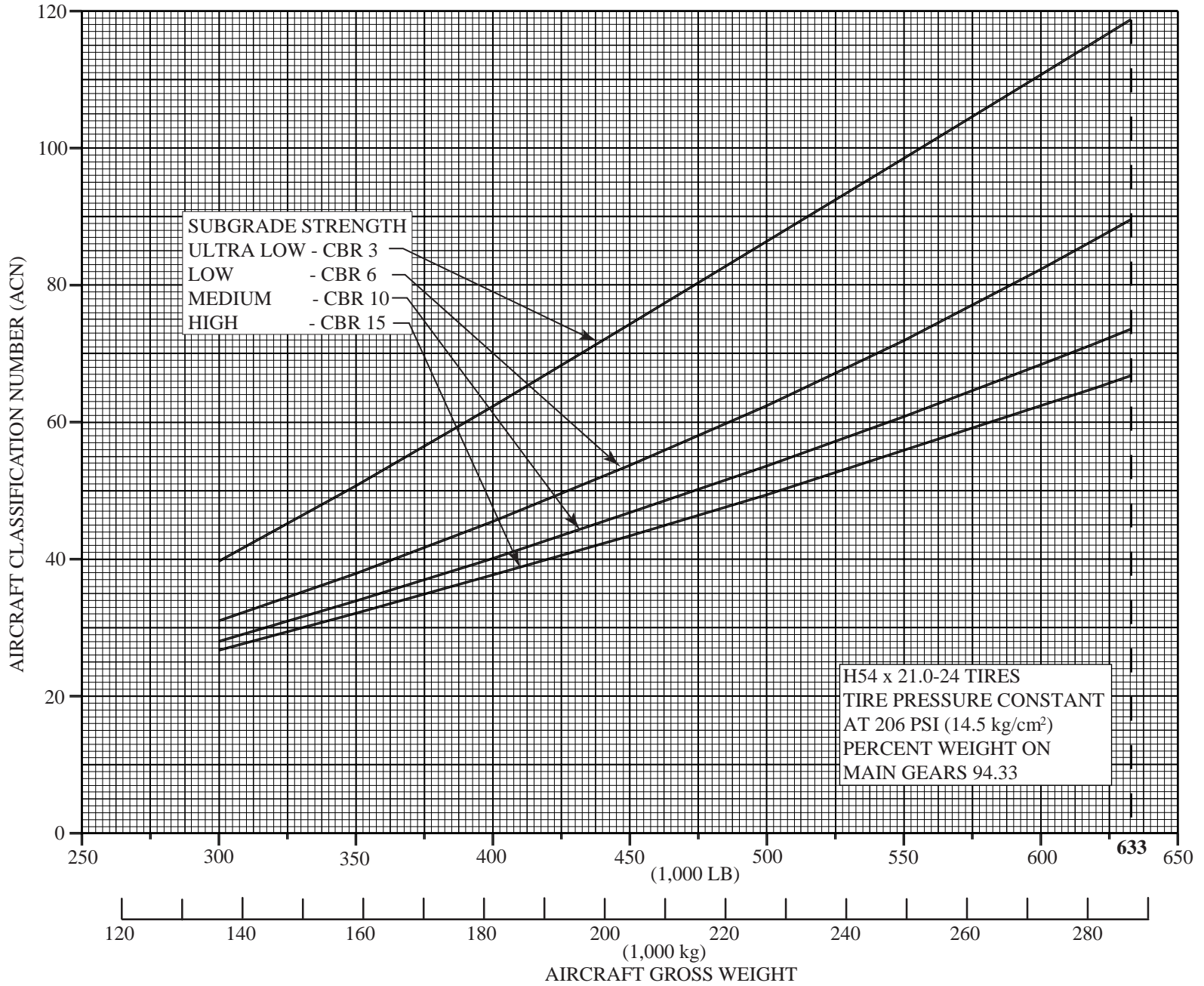
The following procedure was used to develop the flexible-pavement ACN charts already shown in this subsection.

1. Determine the percentage of weight on the main gear to be used below in Steps 2, 3, and 4, below. The maximum aft center-of-gravity position yields the critical loading on the critical gear (see Subsection 7.4). This center-of-gravity position is used to determine main gear loads at all gross weights of the model being considered.
2. Establish a flexible-pavement requirements chart using the S-77-1 design method, such as shown on the right side of Figure 7.9.3. Use standard subgrade strengths of CBR 3, 6, 10, and 15 percent and 10,000 coverages. This chart provides the same thickness values as those of Subsection 7.5, but is presented here in a different format.
3. Determine reference thickness values from the pavement requirements chart of Step 2 for each standard subgrade strength and gear loading.
4. Enter the reference thickness values into the ACN flexible-pavement conversion chart shown on the left side of Figure 7.9.3 to determine ACN. This chart was developed using the S-77-1 design method with a single tire inflated to 1.25 MPa (181 psi) pressure and 10,000 coverages. The ACN is two times the derived single-wheel load expressed in thousands of kilograms. These values of ACN were plotted as functions of aircraft gross weight, as already shown.

The following procedure was used to develop the rigid-pavement ACN charts already shown in this subsection.

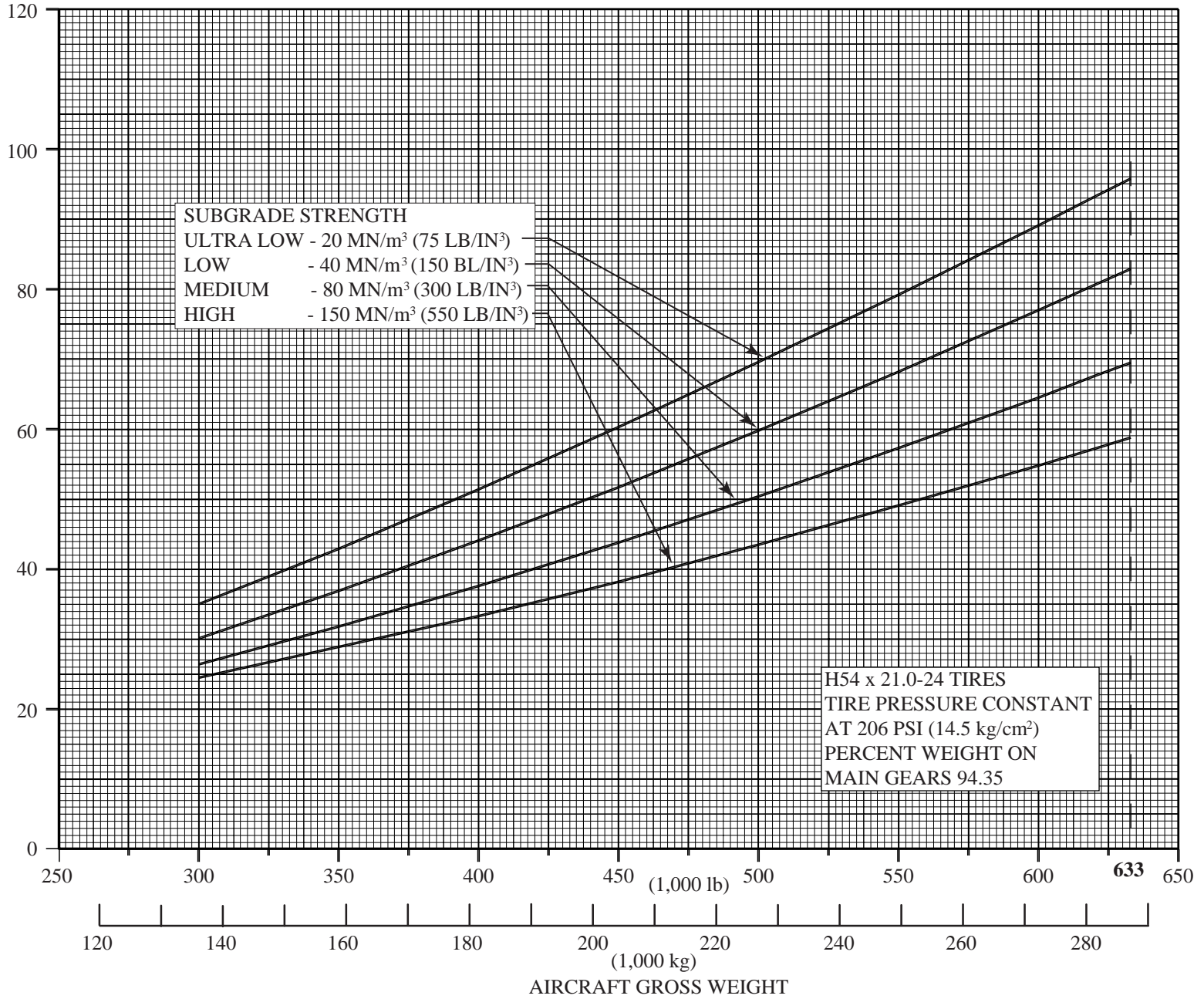
1. Determine the percentage of weight on the main gear to be used in Steps 2, 3, and 4, below. The maximum aft center-of-gravity position yields the critical loading on the critical gear (see Subsection 7.4). This center-of-gravity position is used to determine main gear loads at all gross weights of the model being considered.
2. Establish a rigid-pavement requirements chart using the PCA computer program PDILB, such as shown on the right side of Figure 7.9.4. Use standard subgrade strengths of $k = 75, 150, 300, \text{ and } 550 \text{ lb/in.}^3$ (nominal values for $k = 20, 40, 80, \text{ and } 150 \text{ MN/m}^3$). This chart provides the same thickness values as those of Subsection 7.7.
3. Determine reference thickness values from the pavement requirements chart of Step 2 for each standard subgrade strength and gear loading at 400 psi working stress (nominal value for 2.75 MPa working stress).

4. Enter the reference thickness values into the ACN rigid-pavement conversion chart shown on the left side of Figure 7.9.4 to determine ACN. This chart was developed using the PCA computer program PDILB with a single tire inflated to 1.25 MPa (181 psi) pressure and a working stress of 2.75 MPa (400 psi.) The ACN is two times the derived single-wheel load expressed in thousands of kilograms. These values of ACN were plotted as functions of aircraft gross weight, as already shown in this subsection.



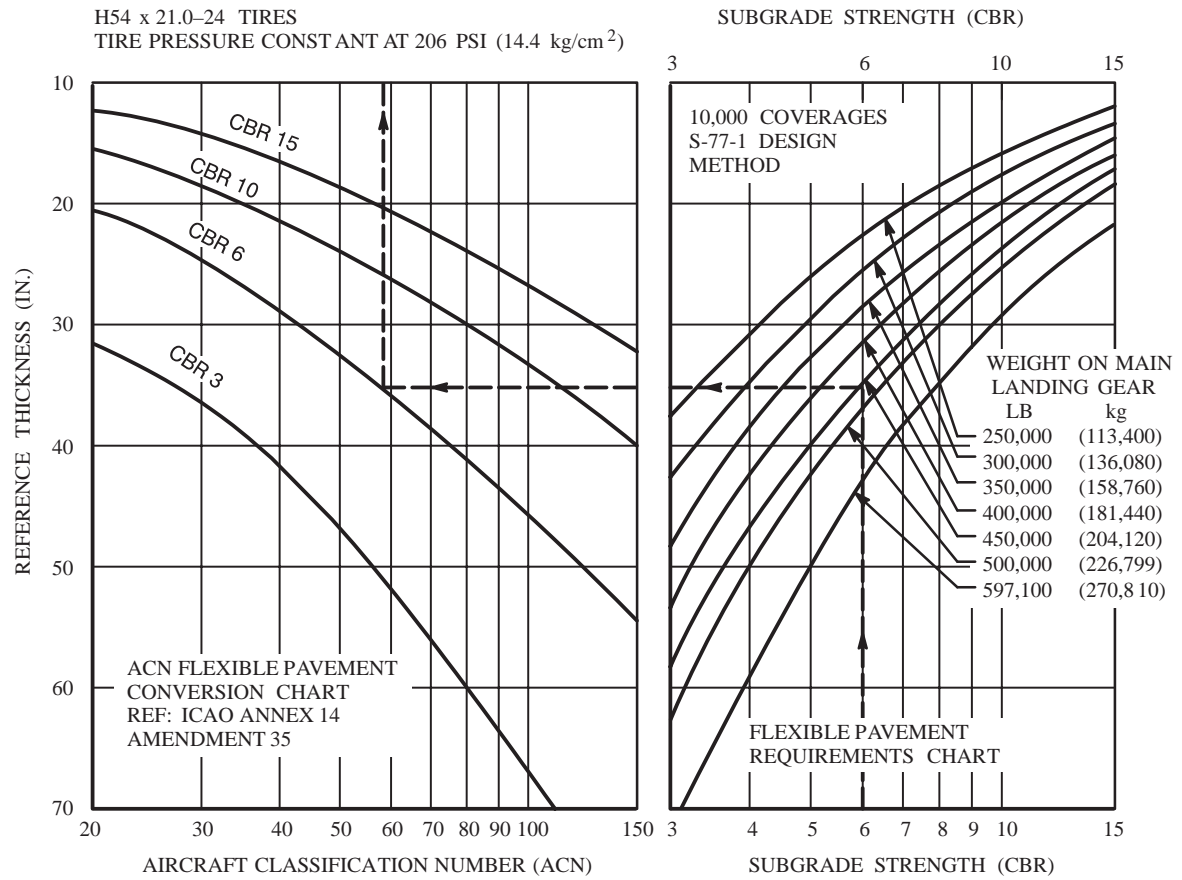
**7.9.1 AIRCRAFT CLASSIFICATION NUMBER – FLEXIBLE PAVEMENT
MODEL MD-11**

7-22



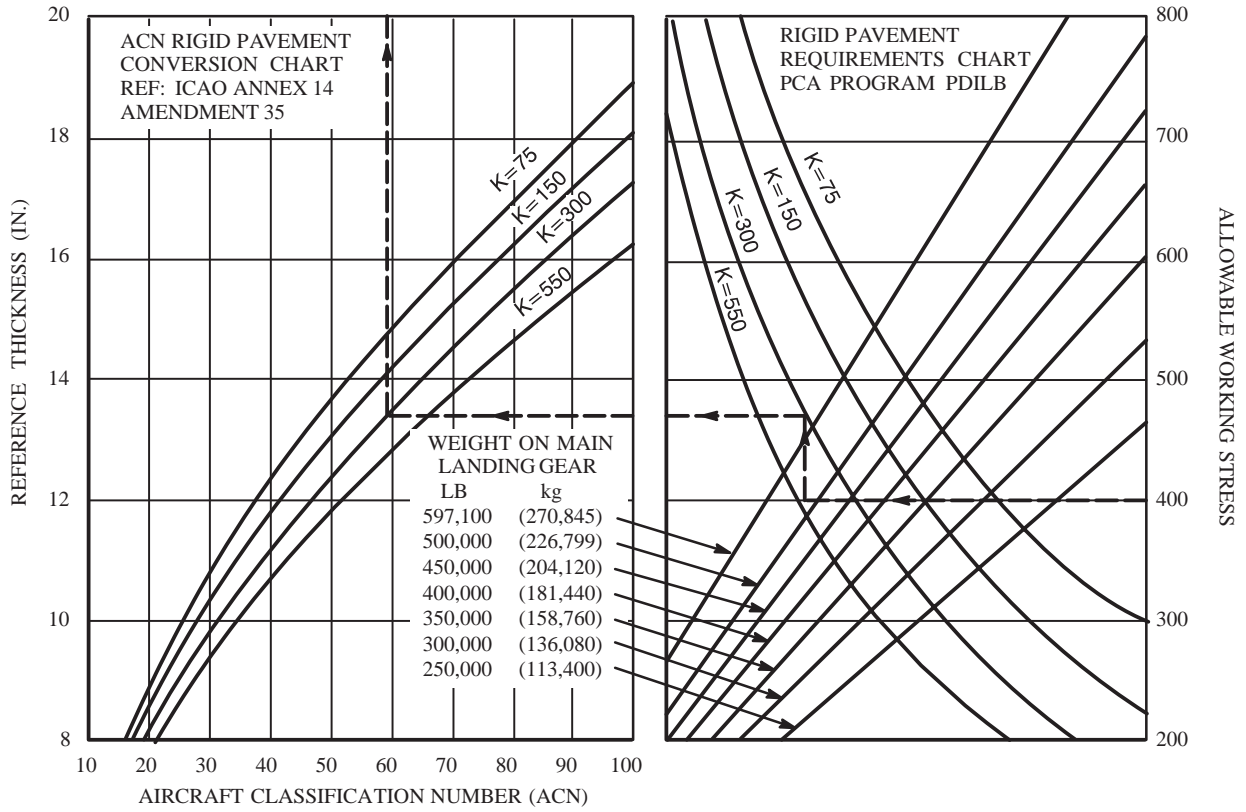
**7.9.2 AIRCRAFT CLASSIFICATION NUMBER – RIGID PAVEMENT
MODEL MD-11**

REV E



7.9.3 DEVELOPMENT OF AIRCRAFT CLASSIFICATION NUMBER (ACN) – FLEXIBLE PAVEMENT MODEL MD-11

H54 x 21.0-24 TIRES
 TIRE PRESSURE CONSTANT AT 206 PSI (14.5 kg/cm²)



7.9.4 DEVELOPMENT OF AIRCRAFT CLASSIFICATION NUMBER (ACN) – RIGID PAVEMENT MODEL MD-11