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STANDARDIZED METHOD OF REPORTING AIRPORT PAVEMENT STRENGTH – PCN

Made this 17th day of July 2023

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1.0 GENERAL

Nigeria Civil Aviation Authority Advisory Circulars from Aerodrome Standards Department contain information about standards, practices and procedures that the Authority has found to be an Acceptable Means of Compliance (AMC) with the associated Regulations.

An AMC is not intended to be the only means of compliance with a regulation, and consideration will be given to other methods of compliance that may be presented to the Authority.

2.0 PURPOSE

This Advisory Circular provides methods, acceptable to the Authority, for showing compliance with the Standardized Method of Reporting Airport Pavement Strength (ACN/PCN) requirements of Nig.CARs Part 12 as well as explanatory and interpretative material to assist in showing compliance.

3.0 REFERENCE

The Advisory Circular relates specifically to Nig.CARs Part 12.1.4.24

4.0 STATUS OF THIS AC

This is the first AC to be issued on this subject.

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CHAPTER 1

Procedure for pavements meant for heavy aircraft (ACN-PCN method)

Introduction. The bearing strength of a pavement intended for aircraft of mass greater than 5700 kg shall be made available using the aircraft classification number - pavement classification number (ACN-PCN) method. To facilitate a proper understanding and usage of the ACN-PCN method the following material explains:

a) The concept of the method; and
b) How the ACNs of an aircraft are determined.

Concept of the ACN-PCN method

Definition:

Aircraft Classification Number (ACN): A number expressing the relative effect of an aircraft on a pavement for specified standard sub grade strength.

Pavement Classification Number (PCN): A number expressing the bearing strength of a pavement for unrestricted operations.

At the outset, it needs to be noted that the ACN-PCN method is meant only for publication of pavement strength data in the Aeronautical Information Publications (AIPs). It is not intended for design or evaluation of pavements, nor does it contemplate the use of a specific method by the airport authority either for the design or evaluation of pavements. In fact, the ACN-PCN method does permit States to use any design/evaluation method of their choice. To this end, the method shifts the emphasis from evaluation of pavement to evaluation of load rating of aircraft (ACN) and includes a standard procedure for evaluation of the load rating of aircraft. The strength of a pavement is reported under the method in terms of the load rating of the aircraft which the pavement can accept on an unrestricted basis. The airport authority can use any method of his choice to determine the load rating of his pavement. If, in the absence of technical evaluation, he chooses to go on the basis of the using aircraft experience, then he would compute the ACN of the most critical aircraft using one of the procedures describe below, convert this figure into an equivalent PCN and publish it in the AIP as the load rating of his pavement. The PCN so reported would indicate that an aircraft with an ACN equal to or less than that figure can operate on the pavement subject to any limitation on the tire pressure.

The ACN-PCN method contemplates the reporting of pavement strengths on a continuous scale. The lower end of the scale is zero and there is no upper end. Additionally, the same scale is used to measure the load ratings of both aircraft and pavements.

To facilitate the use of the method, aircraft manufacturers will publish, in the documents detailing the characteristics of their aircraft, ACNs computed at two different masses; maximum apron mass, and a representative operating mass empty, both on rigid and flexible pavements and for the four standard subgrade strength categories. Nevertheless, for the sake of convenience Annex 14, Attachment B and Appendix 5 hereto include a table showing the ACNs of a number of aircraft. It is to be noted that the mass used in the ACN calculation is a "static" mass and that no allowance is made for an increase in loading through dynamic effects.

ACN-PCN Method -

- for publication of pavement strength data in AIP
- not intended for design or evaluation of pavements
- permit Airport Authorities to use any design/evaluation method of their choice
- emphasizes on evaluation of load rating of aircraft (ACN) not evaluation of pavements.

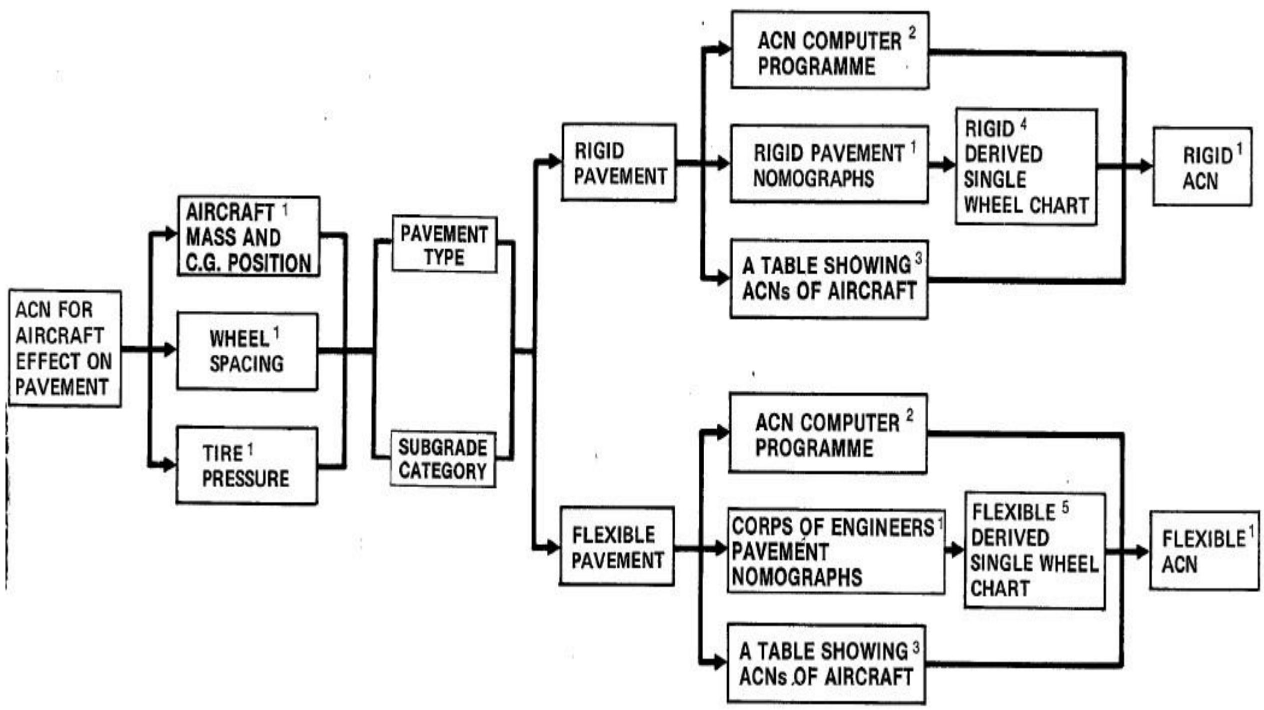
The ACN-PCN method also envisages the reporting of the following information in respect for each pavement;

a) pavement type;
b) subgrade category;
c) maximum tire pressure allowable; and
d) pavement evaluation method used.

The above data are primarily intended to enable aircraft operators to determine the permissible aircraft types and operating masses, and the aircraft manufacturers to ensure compatibility between airport pavements and aircraft under development. There is, however, no need to report the actual subgrade strength or the maximum tire pressure allowable. Consequently, the subgrade strength and tire pressures normally encountered have been grouped into categories as indicated in 1.1.2.3 would be sufficient if the airport authority identifies the categories appropriate to his pavement.

How the ACNs of an aircraft are determined

The flow chart, below, briefly explains how the ACNs of aircraft are computed under the ACN-PCN method.



FLOWCHART SHOWING THE COMPUTATION OF THE CAN OF AN AIRCRAFT USING CAN-PCN METHOD

Standard values used in the method and description of the various terms

a) Subgrade category. In the ACN-PCN method eight standard subgrade values (i.e., four rigid pavement k values and four flexible pavement CBR values) are used, rather than a continuous scale of subgrade strengths. The grouping of subgrades with a standard value at the mid- range of each group is considered to be entirely adequate for reporting. The subgrade strength categories are identified as high, medium, low and ultra low and assigned the following numerical values:

Subgrade strength category

High strength; characterized by k* = 150 MN/m^3 and representing all k values above 120 MN/m^3 for rigid pavements, and by CBR 15 and representing all CBR values above 13 for flexible pavements.

Medium strength; characterized by k = 80 MN/m^3 and representing a range in k of 60 to 120 for rigid pavements, and by CBR 10 and representing a range in CBR of 8 to 13 for flexible pavements.

Low strength; characterized by k = 40 MN/m^3 and representing a range in k of 25 to 60 MN/m^3 for rigid pavements, and by CBR 6 and representing a range in CBR of 4 to 8 for flexible pavements.

Ultra low strength; characterized by k = 20 MN/m^3 and representing all k values below 25 MN/m^3 for rigid pavements, and by CBR = 3 and representing all CBR values below 4 for flexible pavements.

Table 01. Standard Subgrade Support Conditions for Rigid Pavement ACN Calculation

Subgrade Strength Category	Subgrade Support k-pci (MN/m^3)	Represents pci (MN/m^3)	Code Designation
High	552.6 (150)	k ≥ 442 (≥120)	A
Medium	294.7 (80)	221<k<442 (60<k<120)	B
Low	147.4 (40)	92<k≤221 (25<k≤60)	C
Ultra Low	73.7 (20)	k≤92 (≤25)	D

Table 02. Standard Subgrade Support Conditions for Flexible Pavement ACN Calculation

Subgrade	Subgrade Support	Represents	Code Designation
High	15	CBR ≥ 13	A
Medium	10	8<CBR<13	B
Low	6	4<CBR≤8	C
Ultra Low	3	CBR≤4	D

b) **Concrete working stress for rigid pavements**. For rigid pavements, a standard stress for reporting purposes is stipulated (0 = 2.75 MPa) only as a means of ensuring uniform reporting. The working stress to be used for the design and/or evaluation of pavements has no relationship to the standard stress for reporting.

c) **Tire pressure.** The results of pavement research and re-evaluation of old test results reaffirm that except for unusual pavement construction (i.e. flexible pavements with a thin asphaltic concrete cover or weak upper layers), tire pressure effects are secondary to load and wheel spacing, and may therefore be categorized in four groups for reporting purposes as: high, medium, low and very low and assigned the following numerical values:

TABLE 03. Tire Pressure Codes for Reporting PCN

Category	Code	Tire Pressure Range
High	W	No pressure limit
Medium	X	Pressure limited to 218 psi (1.5
Low	Y	MPa) Pressure limited to 145 psi
Very Low	Z	(1.00 MPa) Pressure limited to 73
		psi (0.50 MPa)

* Values determined using a 75 cm diameter plate.

d) **Mathematically derived single wheel load**: The concept of a mathematically derived single wheel load has been employed in the ACN-PCN method as a means to define the landing gear/pavement interaction without specifying pavement thickness as an ACN parameter. This is done by equating the thickness given by the mathematical model for an aircraft landing gear to the thickness for a single wheel at a standard tire pressure of 1.25 MPa. The single wheel load so obtained is then used without further reference to thickness; this is so because the essential significance is attached to the fact of having equal thicknesses, implying “same applied stress to the pavement”, rather than the magnitude of the thickness. The foregoing is in accord with the objective of the ACN- PCN method to evaluate the relative loading effect of an aircraft on a pavement.

e) **Aircraft classification number (ACN)**. The ACN of an aircraft is numerically defined as two times the derived signal wheel load, where the derived single wheel load is expressed in thousands of kilograms. As noted previously, the single wheel tire pressure is standardized at 1.25 MPa. Additionally, the derived single wheel load is a function of the subgrade strength. The aircraft classification number (ACN) is defined only for the four subgrade categories (i.e., high, medium low, and ultra low strength). The “two” (2) factor in the numerical definition of the ACN is used to achieve a suitable ACN vs. gross mass scale so that whole number ACNs may be used with reasonable accuracy.

Steps to Determined ACN of an Aircraft

- use above pavement requirement charts, determine the reference thickness of given aircraft mass, subgrade category and 10,000 coverage’s.

- enter Figure 1-5 with reference thickness determined and CBR corresponding to subgrade category and read the DSWL.

- ACN at the selected mass and subgrade category read from chart or

ACN = 2 x DSWL (in 1000 kg) at tire pressure (1.25 MPa)

f) Because an aircraft operates at various mass and centre of gravity conditions the following conventions have been used in ACN computations (See Figure 1-1).

1) the maximum ACN of an aircraft is calculated at the mass and c.g. that produces the highest main gear loading on the pavement, usually the maximum ramp mass and corresponding aft c.g. The aircraft tires are considered as inflated to the manufacturer's recommendation for the condition;

2) relative aircraft ACN charts and tables show the ACN as a function of aircraft gross mass with the aircraft c.g. at a constant value corresponding to the maximum ACN value (i.e., usually, the aft c.g. for max ramp mass) and at the max ramp mass tire pressure; and

3) specific condition ACN values are those ACN values that are adjusted for the effects of tire pressure and/or c.g. location, at a specified gross mass for the aircraft.

1.1.3.3 <u>Abbreviations</u>

a) Aircraft parameters

MRGM - Maximum ramp gross mass in kilograms

b) Pavement and subgrade parameters

σ - Standard working stress for reporting, 2.75

MPa

t - Pavement thickness in centimeters

Thickness of slab for rigid pavements, or

Total thickness of pavement structural system (surface to subgrade) for flexible pavements (see Figure 1-2)

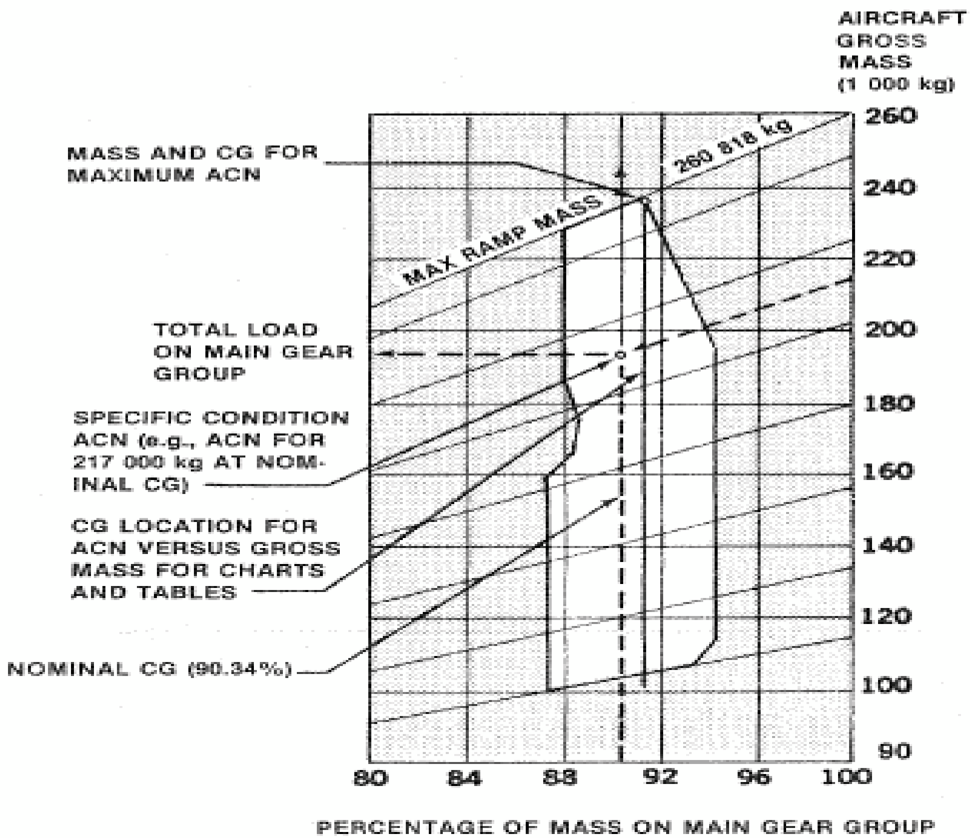


Figure 1-1. Landing gear loading on pavement
Model DC-10 Series 30, 30CF, 40 and 40CF

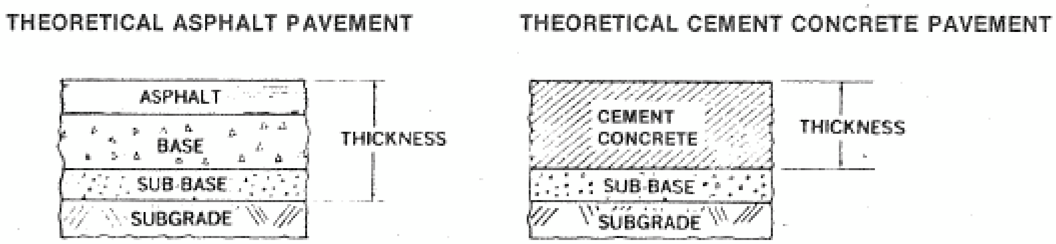


Figure 1-2

k - Westergaard's modulus of subgrade reaction in MN/m^3

l - Westergaard's radius of relative stiffness in centimeters.
This is computed using the following equation (see Figure 1-3)

$$l = \sqrt[4]{\frac{Et^3}{12(1-\mu^2)k}}$$

E is modulus of elasticity
μ is Poisson's ratio (μ = 0.15)

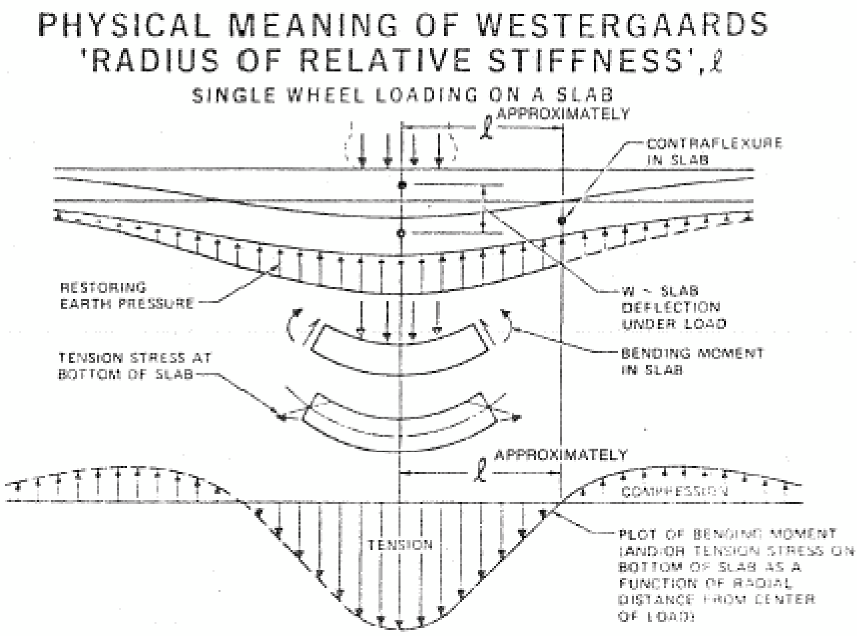


Figure 1-3

CBR - California Bearing Ratio in per cent Tire Pressures

P_S - Tire pressure for derived signal wheel load - 1.25 MPa

P_q - Tire pressure for aircraft at maximum tamp mass condition.

Mathematical models. Two mathematical models are used in the ACN- PCN method: the Westergaard solution for a loaded elastic plate on a Winkler foundation (interior load case) for rigid pavements, and the Boussinesq solution for stresses and displacements in a homogeneous isotropic elastic half-space under surface loading for correlation to world-wide pavement design methodologies, with a minimum need for payment parameter values (i.e., only approximate subgrade k, or CBR values are required).

Computer programmes. The two computer programmes developed using these mathematical models are reproduced in Appendix 2. The programme for evaluation aircraft on rigid pavements is based on the programme developed by Mr. R.G. Packard* of Portland Cement Association, Illinois, USA and that for evaluation aircraft on flexible pavements is based on the US Army Engineering Waterways Experiment Station Instruction Report S-77-1, entitled "Procedures for Development of CBR Design Curves". It may, however, be noted that the aircraft classification tables included in Annex 14, Attachment B and in Appendix 5 of this Manual completely eliminate the need to use these programmes in respect of most of the aircraft currently in use.

Graphical procedures. Aircraft for which pavement thickness requirement charts have been published by the manufacturers can also be evaluated using the graphical procedures described below.

Rigid pavements. This procedure uses the conversion chart shown in Figure 1-4 and the pavement thickness requirement charts published by the aircraft manufacturers. The Portland Cement Association computer programme referred to in 1.1.3.5 as used in developing Figure 1-4. This figure relates the derived signal wheel load at a constant tire pressure of 1.25 MPa to a reference pavement thickness. It takes into accounts the four standard subgrade k values detailed in 1.1.3.2 a) above, and a standard concrete stress of 2.75 MPa. The figure also includes an ACN scale which permits the ACN to be read directly. The following steps are used to determine the ACN of an aircraft.

a) using the pavement requirement chart published by the manufacturer obtain the reference thickness for the given aircraft mass, k value of the subgrade, and the standard concrete stress for reporting, i.e. 2.75 MPa;

b) using the above reference thickness and Figure 1-4, obtain a derivedsignal wheel load of the selected subgrade; and

* Refer to document entitled "Design of Concrete Airport Pavement" by R.G. Packard, Portland Cement Association, Skokie, Illinois, 60076, dated 1973.

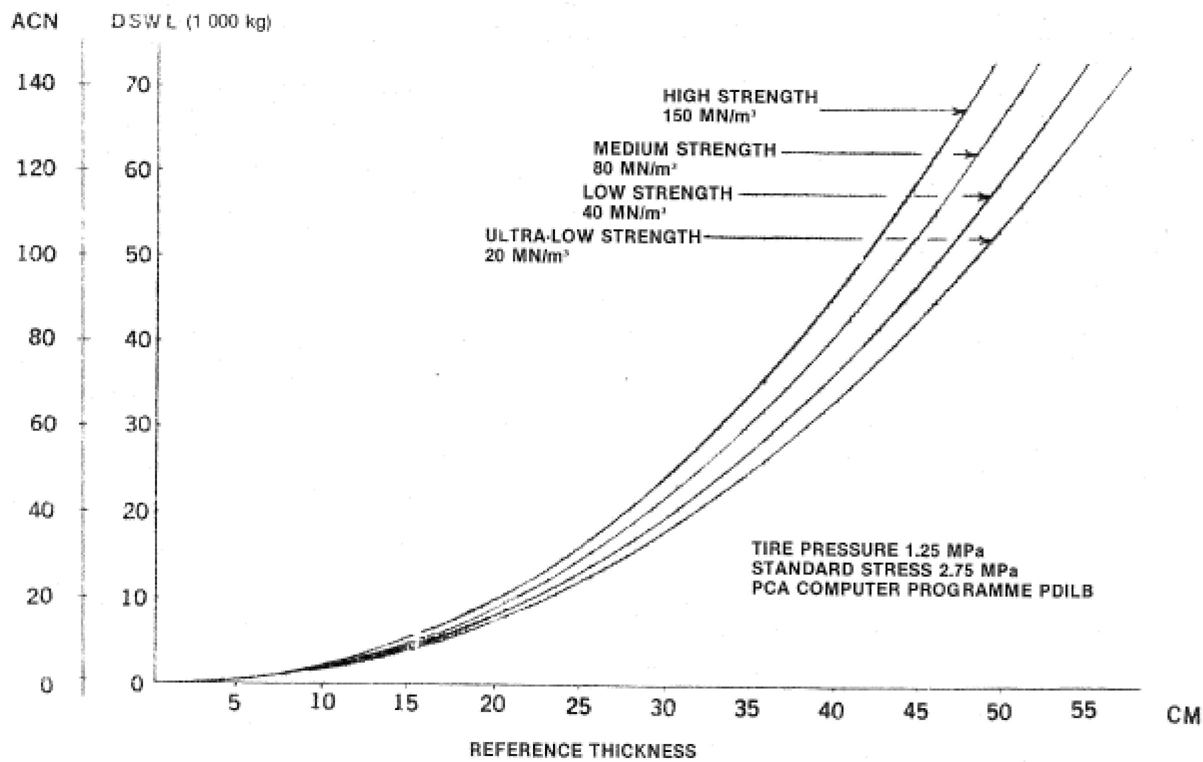


Figure 1-4. ACN Rigid Pavement Conversion Chart

c) the aircraft classification number, at the selected mass and subgrade k value, is two times the derive single wheel load in 1000 kg. Note that the ACN can also be read directly from the chart. Note further that tire pressure corrections are not needed when the above procedure is used.

Flexible pavements. This procedure uses the conversion chart shown in Figure 1-5 and the pavement thickness requirement charts published by the aircraft manufacturers based on the United State Army Engineers CBR procedure. The former chart has been developed using the following expression:

$$t = \sqrt{\frac{DSWL}{C_1 CBR} - \frac{DSWL}{C_2 P_S}}$$

Where t = reference thickness in cm.

DSWL = a single wheel load with 1.25 MPa tire pressure

Ps = 1.25 MPa

CBR = standard subgrade (Note that the chart uses four standard values 3, 6, 10 and 15)

C_1 = 0.5695 C_2 = 32.035

The reason for using the latter charts is to obtain the equivalency between the “group of landing gear wheels effect” to a derived single wheel load by means of Boussinesq Deflection Factors. The following steps are used to determine the ACN o an aircraft:

a) using the pavement requirement chart published by the manufacturer determine the reference thickness for the given aircraft mass, subgrade category, and 10000 coverages;

b) enter Figure 1-5 with the reference thickness determined in step and the CBR corresponding to the subgrade category and read the derived single wheel load; and

c) the ACN at the selected mass and subgrade category is two times the derived single wheel load in 1000 kg. Note that the ACN can also be read directly from the chart. Note further that tire pressure corrections are not needed when the above procedure is used.

Tire pressure adjustment to ACN: Aircraft normally have their tires inflated to the pressure corresponding to the maximum gross mass and maintain this pressure regardless of the variations in take-off masses. There are times, however, when operations at reduced masses and reduced tire pressures are productive and reduced ACNs need to be calculated. To do this for rigid pavements, a chart has been prepared by the use of the PCA computer programme PDILB and is given in Figure 1-6. The example included in the chart itself explains how the chart is used.

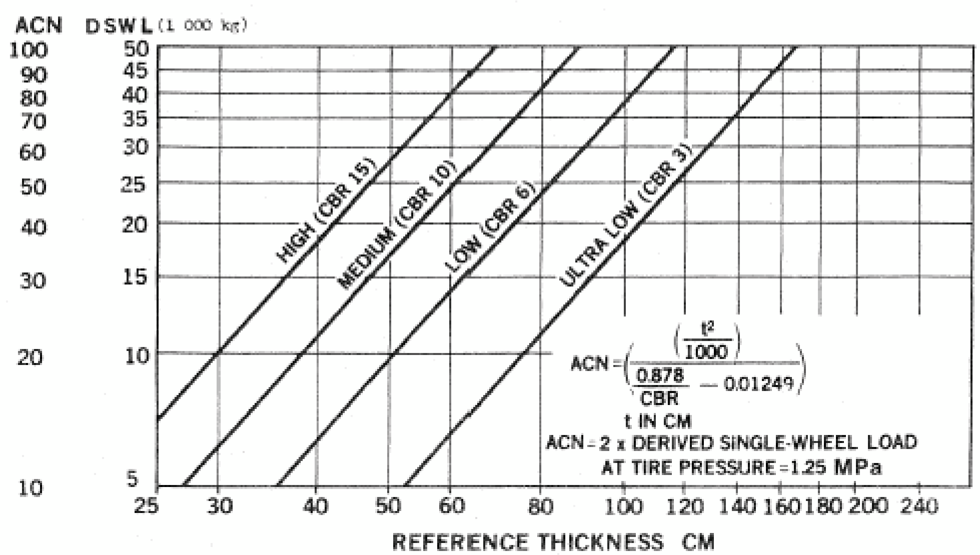


Figure 1-5. ACN Flexible Pavement Conversion Chart

For flexible pavements, the CBR equation t =

$$\sqrt{\frac{DSWL}{C_1 CBR} - \frac{DSWL}{C_2 P_S}}$$

was used to equate thickness and solve for the reduced pressure ACN in terms of the maximum tire pressure ACN at the reduced mass giving the following expression:

$$ACN = ACN \left[\frac{\frac{1}{C_1 CBR} - \frac{1}{C_2 P_{red}}}{\frac{1}{C_1 CBR} - \frac{1}{C_2 P_{max}}} \right]$$

Reduce Pressure Maximum Pressure

(For values of C_1 and C_2 see 1.1.3.8.)

1.1.3.11 Worked Examples

Example-1 : Find the ACN of B727-200 Standard at 78500 kg on a rigid pavement resting on a medium strength subgrade (i.e.,k = 80 MN/m^3). The tire pressure of the main wheels is 1.15 MPa

Solution: The ACN of the aircraft from the table in Appendix -1 48

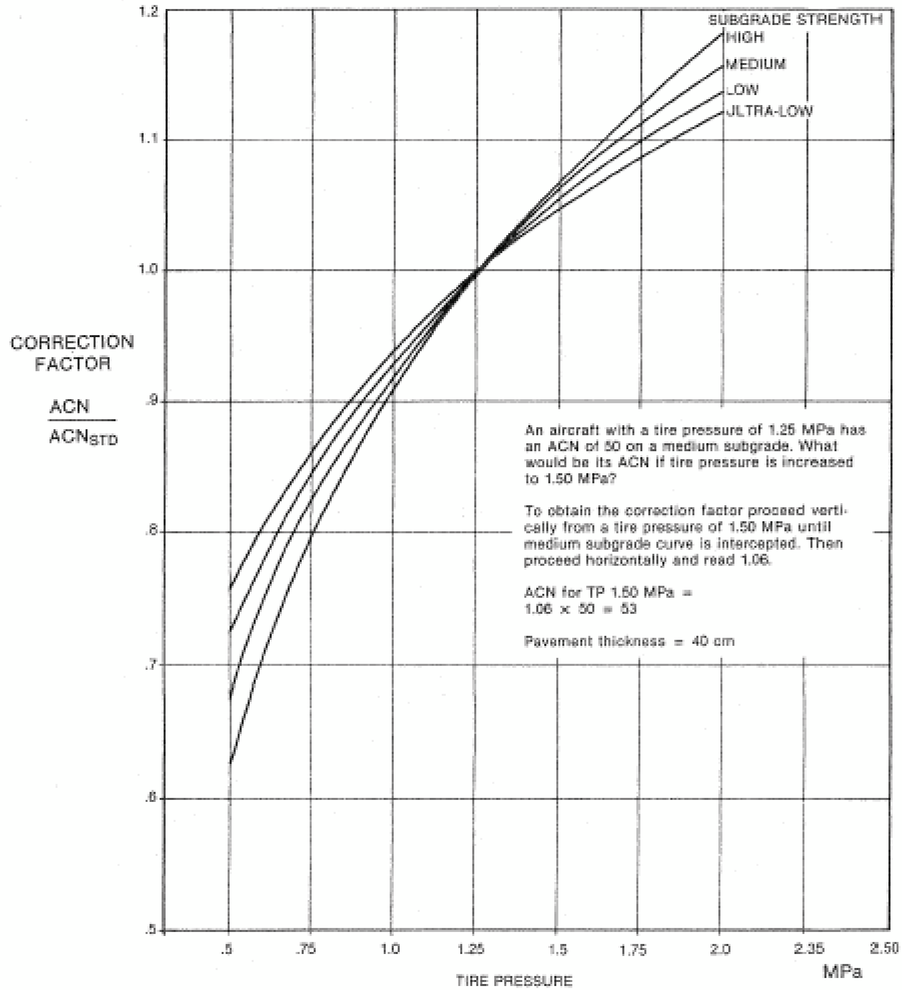


Figure 1-6. ACN tire pressure adjustment - rigid pavements only

Example-2 : An AIP contains the following information related to a runway

pavement: PCN of the pavement = 80
Pavement type = rigid
Subgrade category = medium strength
Tire pressure limitation = none

Determine whether the pavement can accept the following aircraft at the indicated operating masses and tire pressures:

		Mass	Tire
Airbus A 300 Model 82	at	142000 kg	1.23 MPa
B747-100	at	334751 kg	1.55 MPa
Concorde	at	185066 kg	1.26 MPa
DC-10-40	at	253105 kg	1.17 MPa

Solution: ACNs of these aircraft from Appendix 1 are 44, 51, 71 and 53, respectively. Since the pavement in question has a PCN of 80 it can accept all of these aircraft.

Example 3: Find the ACN of DC-10-10 at 157400 kg on a flexible pavement resting on a medium strength subgrade (CBR 10). The tire pressure of the main wheels is 1.28 MPa.

Solution: The ACN of the aircraft from Appendix 1 of this Manual is

$$57 - \frac{196406 - 157400}{196406 - 108940} \times (57-27)$$

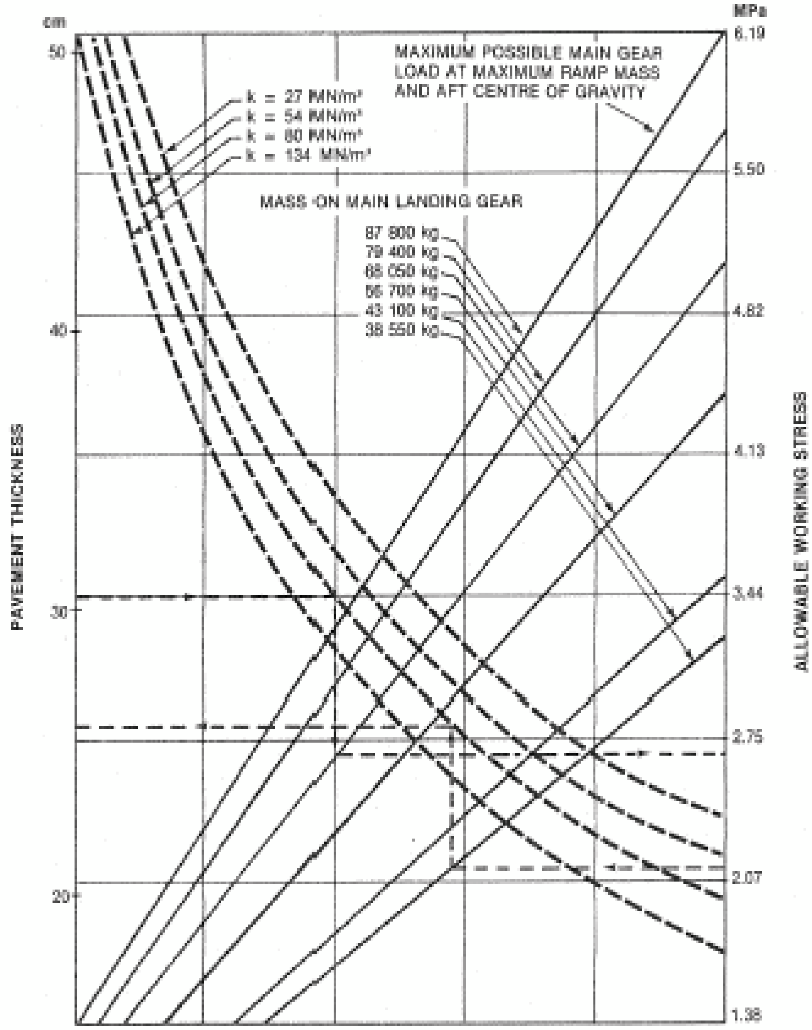
$$= 57 - \frac{39006}{87466} \times 30$$

$$= 57 - 13.4 = 43.6 \text{ or } 44$$

It is also possible to determine the ACN of the aircraft using Figure 1-5 and the pavement requirement chart in Figure 1-8. This method involves the following operations:

a) from Figure 1-8 read the thickness of pavement needed for the aircraft mass of 157400 kg and the subgrade CBR of 10 as 57 cm; and
b) enter Figure 1-5 with this thickness and read the ACN of aircraft for the subgrade CBR of 10 as 44.

124.5 x 43.2 cm TIRES - TIRE PRESSURE CONSTANT AT 11.7 kg/cm²
127 x 53.3 cm TIRES (NEW DESIGN) - TIRE PRESSURE CONSTANT AT 11.7 kg/cm²



NOTE: THE VALUES OBTAINED BY USING THE MAXIMUM LOAD REFERENCE LINE AND ANY VALUE OF k ARE EXACT. FOR LOADS LESS THAN MAXIMUM, THE CURVES ARE EXACT FOR k = 80 BUT DEVIATE SLIGHTLY FOR OTHER VALUES OF k.

REFERENCES:
"DESIGN OF CONCRETE AIRPORT PAVEMENT" AND "COMPUTER PROGRAMME FOR AIRPORT PAVEMENT DESIGN - PROGAMME PDILB."
PORTLAND CEMENT ASSN.

RIGID PAVEMENT REQUIREMENTS—
PORTLAND CEMENT ASSOCIATION DESIGN METHOD
MODELS 727-100, -100C AT 77 200 kg; 727-200 STANDARD AT 78 500 kg,
ADVANCED 727-200 AT 89 800 kg AND 95 300 kg MAXIMUM RAMP MASS.

Figure 1-7

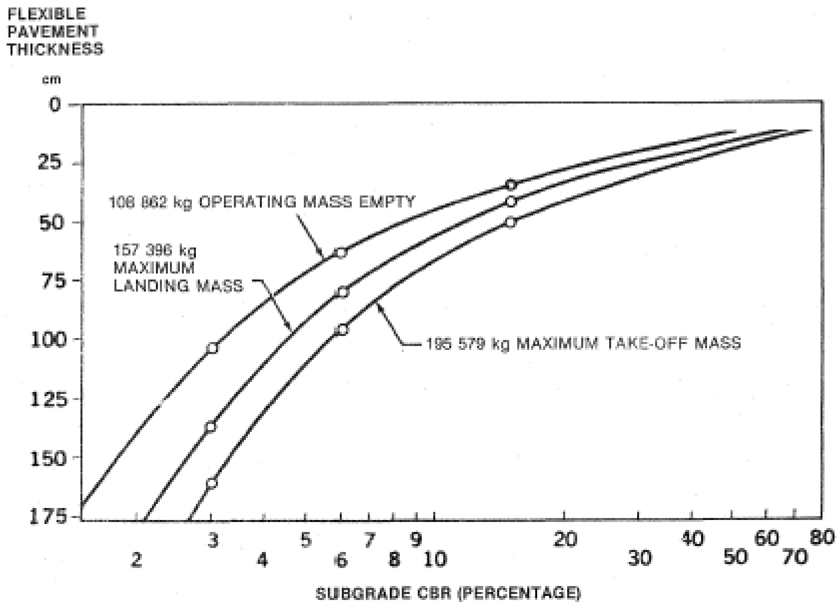


Figure 1-8. DC10-10 Flexible Pavement Requirements
10 000 Coverages aft c.g.

1.2 Procedure for pavement meant for light aircraft

The ACN-PCN method described in 1.1 is not intended for reporting strength of pavements meant for light aircraft, i.e., those with mass less than 5700 kg. Annex 14 specifies a simple procedure for such pavements. This procedure envisages the reporting of only two elements: maximum allowable aircraft mass and maximum allowable tire pressure. It is important to note that the tire pressure categories of the ACN-PCN method (1.1.3.2, c) are not used for reporting maximum allowable tire pressure. Instead, actual tire pressure limits are reported as indicated in the following example:

Example: 4000 kg/0.50 MPa

PCN Reporting

PCN is an index rating (1/500th) of the mass which an evaluation shows can be borne by the pavement when applied by a standard (1.25 MPa tire pressure) single-wheel. The PCN rating established for a pavement indicates that the pavement is capable of supporting aircraft having an ACN of equal or lower magnitude.

PCNs are reported using the following typical format/codes:

PCN 35/F/B/W/T

PCN Number
Pavement Type
Subgrade Strength Category
Tire Pressure
Evaluation Method

- PCN Number - highest allowable ACN at the appropriate subgrade category
- Pavement Type - R = rigid and F = flexible
- Subgrade Strength Category - A = high C = low
- Tire Pressure Category - Maximum allowable tyre pressure category of the pavement

  W = high (no pressure limit)
  X = medium (pressure limited to 1.5 MPa) Y = low (pressure limited to 1.0 MPa)
  Z = very low (pressure limited to 0.5 MPa)

Evaluation Method
T = technical
U = experience

EXAMPLE

Consider a flexible pavement on subgrade of CBR 5%. The design Aircraft for the pavement is DC-10-10. Find the design ACN and the PCN for the pavement.

Solution: From ICAO Part 3, Appendix 5,

Aircraft Type	Subgrade Category: Low (CBR 6%)	Subgrade Category: Very Low (CBR 3%)
DC-10-10	ACN 68	ACN 93

i) Design ACN at CBR 5%

$$= 68 + \frac{(93 - 68)}{(6 - 3)}(6 - 5)$$

$$= 77$$

ii) Subgrade Category: Low (Code = C)

Assuming tyre pressure: no pressure limit (high =
w) PCN = 68/F/C/W/T

EXAMPLE

Consider DC-10-10 aircraft, weighing 157,400 kg, on a flexible pavement resting on a medium strength subgrade (CBR = 10). Tire pressure of main wheels = 1.28
MPa. Find ACN.

Method I - Using Charts

a) From Fig 1-8, for aircraft mass 157,400 kg and CBR = 10, thickness of pavement = 57 cm

b) From Fig 1-5, for CBR = 10 and 57 cm reference thickness, ACN of aircraft = 44

Method II - Using ICAO Part 3 (Appendix 5)

For DC-1010,
Maximum apron (ramp) mass = 196,406 kg
Operating mass empty = 108,940 kg
For Medium strength subgrade CBR =10,

ACN are 57 and 27 respectively.

Assuming ACN varies linearly between maximum apron mass and operating mass empty, by interpolation,

ACN of aircraft = 57 - (196,406 - 157,400) x
(57-27) (196,406-108,940)

= 43.6 or 44

CHAPTER 2

GUIDANCE ON OVERLOAD OPERATIONS

Overloading of pavements can result either from loads too large or from a substantially increased application rate or both. Loads larger than the defined (design or evaluation) load shorten the design life whilst smaller loads extend it. With the exception of massive overloading, pavements in their structural behavior are not subject to a particular limiting load above which they suddenly or catastrophically fall. Behavior is such that a pavement can sustain a definable load for an expected number of repetitions during its design life. As a result, occasionally minor overloading is acceptable, when expedient, with only limited loss in pavement life expectancy and relatively small acceleration of pavement deterioration. For those operations in which magnitude of overload and/or the frequency of use do not justify a detailed analysis the following criteria are suggested:

a) for flexible pavements occasional movements by aircraft with ACN not exceeding 10 percent above the reported PCN should not adversely affect the pavement;

b) for rigid or composite pavements, in which a rigid pavement layer provides a primary element of the structure, occasional movements by aircraft with ACN not exceeding 5 percent above the reported PCN should not adversely affect the pavement;

c) if the pavement structure is unknown the 5 percent limitation should apply; and

d) the annual number of overload movements should not exceed approximately 5 percent of the total annual aircraft movements.

Such overload movements should not normally be permitted on pavements exhibiting signs of distress or failure. Furthermore, overloading should be avoided when the strength of the pavement or its subgrade could be weakened by water. Where overload operations are conducted, the aerodrome operator should review the relevant pavement condition regularly and should also review the criteria for overload operations periodically since excessive repetition of overloads can cause severe shortening of pavement life or require major rehabilitation of pavement.

Aerodrome Operator is free to decide on their own criteria for permitting overload operations as long as pavements remain safe for use by aircraft. However, the following guidance is provided:

a) a 10 percent difference in ACN over PCN involves an increase in pavement working stresses which are generally considered acceptable provided the following conditions are satisfied:

1) the pavement is more than twelve months old;
2) the pavement is not already showing signs of loading distress; and
3) overload operations do not exceed 5 percent of the annual departures and are spread throughout the year.