STRENGTH RATING OF AERODROME PAVEMENTS

GENERAL

Ghana Civil Aviation Authority (GCAA) Advisory Circulars from Aerodrome Safety and Standards (ASAS) 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.

PURPOSE

This Advisory Circular provides methods, acceptable to the Authority, for showing compliance with Part 24 of the Ghana Civil Aviation (Aerodrome) Regulations, 2011, LI 2004, as well as explanatory and interpretative material to assist in showing compliance.

REFERENCE

The Advisory Circular relates specifically to the Aerodrome GCARs and Manual of Standards (MOS).

STATUS OF THIS AC

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

FORWARD

The purpose of this Advisory Circular (AC) is to provide aerodrome operators with guidance on how to meet specific requirements in relation to the bearing strength of aerodrome pavements.

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APPROVAL

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GHANA CIVIL AVIATION AUTHORITY
GCAA
DIRECTOR-GENERAL

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1.0 INTRODUCTION

Operators of regulated aerodromes are required to provide pavements on which aeroplanes can operate safely and they are required to rate the strength of the pavements using the ICAO accepted ACN-PCN method and publish the rating in Aeronautical Information Publication (AIP). This AC briefly explains the ACN-PCN method and offers guidelines on what degree of overloading may be considered acceptable for an aerodrome pavement.

This Advisory Circular is aimed at varieties of persons who have an interest in the strength of aerodrome pavements such as:

- operators of aerodromes regulated under Part 24 of the GCARs.
- operators of aerodromes who wish to publish aerodrome information in the AIP
- aircraft operators conducting Regular Public Transport (RPT) and charter operations into these aerodromes;
- persons who specialise in aerodrome pavement design;
- Ghana Civil Aviation Authority (GCAA) approved persons and technical specialists employed by the aerodrome operator to carry out safety inspections and technical inspections at regulated aerodromes; and
- aerodrome reporting officers.

2.0 AERODROME PAVEMENTS

The purpose of an aerodrome pavement is to provide a durable surface on which aircraft can take-off, land and manoeuvre safely on the movement area of an aerodrome.

2.1 What is a Pavement?

A pavement is a load carrying structure constructed on naturally occurring in-situ soil, referred to as the subgrade. The pavement may be composed of a number of horizontal courses termed bound or unbound as described below:

- An unbound course being composed of materials, which are granular, mechanically stabilised or treated with additives to improve their properties other than strength, such as plasticity. Under load the unbound course behaves as if its component parts were not bound together, although significant mechanical interlock may occur.

- A bound course is one in which the particles are bound together by additives such as lime, cement or bitumen, so that under load the course behaves as a continuous system able to develop tensile stresses without material separation.

Pavement courses are also known by their location and function within the pavement structure as described below:

- The surface course provides a wearing surface and provides a seal to prevent entry of water and air into the pavement structure and subgrade preventing weathering and disintegration.
- The base course is the main load-carrying course within the pavement.

- The sub-base course is a course containing lesser quality material used to protect and separate the base course from the subgrade and vice versa. The sub-base course provides the platform upon which the base course is compacted.

As already mentioned, the subgrade is the natural in-situ material on which the pavement is constructed. The use of select fill material may help improve the natural in-situ material and can also be a cost effective way to build up formation level.

2.2 Pavement Types

Pavements are classified as either rigid or flexible depending on their relative stiffness. A rigid pavement is not totally rigid; the terminology is merely an arbitrary attempt to distinguish between pavement types both of which deform elastically to some degree. In particular, it is common to speak of Portland Cement Concrete pavements as rigid and all other pavements (e.g. bound bituminous concrete or unbound natural) as flexible. A relatively stiff rigid pavement produces a uniform distribution of stress on the subgrade, whereas a flexible pavement deforms and concentrates its effect on the subgrade. Therefore, the difference between the two pavement types is one of degree rather than of fundamental mechanism.

A flexible pavement is a structure composed of one or more layers of bound or unbound materials and may either be unsurfaced (unsealed) or surfaced with bituminous concrete or a sprayed bituminous seal. The intensity of stresses within the pavement from aircraft loads diminishes significantly with depth. The quality requirements of the materials used in any of the pavement layers are dependent on its position within the pavement. The material used in the lower layers of a pavement may, for reason of economy and preservation of resources, be of lower quality than the material used in the upper pavement layers.

A rigid pavement is a structure comprising a layer of cement concrete (either steel-reinforced or unreinforced), which may be supported by a sub-base between the cement concrete and the subgrade. Unlike a conventional layered flexible pavement where both the base and sub-base layers contribute significantly to its structural properties, the concrete base layer itself provides the major portion of the structural capacity of a rigid pavement.
This is because the high rigidity of the concrete slab distributes the load over a large area resulting in low stresses being applied to the underlying layers.

It is also possible to have composite pavements comprising a bituminous concrete overlay on a cement concrete pavement or vice versa.

The choice of which pavement type to adopt should be made after consideration of the various matters such as pavement design, loading, tyre pressure, resistance to mechanical and chemical damage, ride quality, antiskid properties, construction, routine maintenance, major maintenance and construction costs.

2.3 Pavement Function

The basic function of a pavement is to support the applied aircraft loading within acceptable limits of riding quality and deterioration over its design life. While subjected to aircraft loading the pavement is to:

- Reduce subgrade stresses such that the subgrade is not overstressed and does not deform extensively.
- Reduce pavement stresses such that the pavement courses are not overstressed and do not shear, crack or deform excessively. This is particularly important for aircraft of more than about 45,000 kgs, because they impose significant stresses on the upper pavement layers.
- Protect the pavement structure and subgrade from the effects of the environment particularly moisture ingress.

The first two requirements are achieved by using the thickness of the pavement layers to disperse the concentrated surface load to stress levels acceptable for the materials encountered in the pavement and the subgrade.

The vertical stress that a material can carry without excessive deformation is referred to as its bearing strength/capacity. Hence the high quality materials should occur at the surface with a steady decrease in quality towards the subgrade.

The flexing of the pavement under load means that horizontal bending stresses are produced in each layer. Excessive horizontal stresses can create cracking in bound layers and horizontal deformation in unbound layers. Excessive vertical compressive strains in the pavement can produce deformations, which lead to rutting of the pavement surface.

2.4 Pavement Design

Designing the pavement structure to support the applied aircraft loading within the limits of riding quality and deterioration over the design life of the pavement is the job of the pavement designer.

The design of heavy-duty aircraft pavements is not the same as that of roads, and road pavement design methods such as Austroads are not applicable to airport pavements. The design methodology for airport pavements is well established in Australia using specialised methods. For both flexible and rigid pavement types, these have evolved from empirical to mechanistic-empirical methods, and finite element analysis methods are being introduced. The most common design methods used in Australia are those of the United States Army Corps of Engineers and the Federal Aviation Administration (FAA) of the United States of America (USA), such as FAA AC 150/5320-6E on Airfield Pavement Design and Evaluation. Boeing produce useful pavement design charts for their aircraft based on these methods.

Pavement design software available from the FAA includes COMFAA, FAARFIELD, LEDFAA, and airport pavement software from Australia includes APSDS. There are also a few pavement engineering text books that specifically include airport pavements, such as *Yoder & Witczak, Principles of Pavement Design, 1975.*

3.0 STRENGTH OF AERODROME PAVEMENTS

The operator of an aerodrome regulated under GCAR Part 24 is required under Regulation to ensure the bearing strength of aerodrome movement area pavements complies with the standards set out in the MOS.

Chapter 6, Sub-section 6.2.10 of the states *'GCAA does not specify a standard for the bearing strength of pavements; however the bearing strength must be such that it will not cause any safety problems to aircraft'*. The reason for not being able to specify a standard is because pavements are normally designed for a defined life. The actual life being a direct function of various factors such as the local environment, design aircraft, frequency of operations, pavement design methodology, type of pavement and quality of pavement materials and subgrade.

It is the responsibility of the aerodrome operator to maintain the load bearing capacity of the pavement for the design or critical aircraft operating over the life of the pavement.

Chapter 6, Sub-section 6.2.10 of the MOS, states *'the pavement strength rating for a runway must be determined using the ACN–PCN pavement rating system'.* For a certified aerodrome the aerodrome operator is required under Part 24 of the GCARs to provide information on runways, including its strength rating, to be reported in the Aerodrome Manual for the aerodrome and for this information to be passed to Aeronautical Information Service (AIS) for notification in AIP.

At a registered aerodrome, information on the pavement strength rating for each runway is to be provided when making an application for the registration of the aerodrome under Part 25 of the GCARs. GCAA will then provide this information to AIS for notification in AIP.

Serviceability inspections and annual technical inspection required to be undertaken at all certified aerodromes (serviceability inspections and annual safety inspections at registered aerodromes) are meant to check for failure mechanisms in the pavement. Any significant deterioration of the surface of the pavement may be caused by weakening of the pavement material and/or subgrade, in which case, a review of the pavement strength rating may be necessary.

The operator of a non–certified or non–registered aerodrome used for RPT or charter operations that wish to publish aerodrome information in AIP may also provide particulars of the aerodrome including the pavement strength rating.

3.1 Defining Strength of Aerodrome Pavements

A pavement strength rating is a set of pavement parameters with a number, which can be translated into an allowable aircraft gross weight. Its purpose is to protect the pavement and ensure a practical and economical life is maintained.

The simplest rating system is one, which defines either the maximum aircraft weight or the largest aircraft type, which can operate unrestricted on the pavement. Some readers will be familiar with the variety of pavement strength reporting systems tried in the past, for instance:

- USA – FAA – single wheel, dual wheel or dual tandem wheel by gross weight taking into consideration average wheel spacing and tyre pressure;

- Max Gross Weight – by wheel gear type; single, dual or dual tandem;

- ICAO - LCN – Load Classification Number together with pavement thickness; Gear Load Limits – for single, dual or dual tandem wheel gear; and

- UK – LCG LCN – Load Classification Group with LCN.

It was found that the use of these different methods created confusion so it was considered more acceptable to adopt a completely new method rather than standardise one existing method, which had only been adopted by some nations.

The result was the ACN–PCN method of rating aerodrome pavements developed by R.C. O'Massey of the then Douglas Aircraft Company. It was developed as a pavement strength rating method not a pavement design method and compares the damaging effect of aircraft with a maximum ramp weight above 5700 kg (ACN) with the supportive capability or bearing strength of the pavements on which they intend to operate (PCN).

Details of the ACN-PCN method are provided in this Advisory Circular. ICAO introduced the method as a standard to identify the bearing strength of aerodrome pavements (ICAO Annex 14 Aerodromes, Volume I – Aerodrome Design and Operations) in 1981. ICAO Aerodrome Design Manual, Part 3 – published a detailed description of the new method *Pavements* in 1983.

Where pavements are to be used only by aircraft whose weight is at or below 5700 kg, the strength rating of the pavement should be reported in terms of the maximum allowable gross weight and the maximum allowable tyre pressure of the critical operating aircraft.

4.0 AIRCRAFT CLASSIFICATION NUMBER (ACN)

The ACN of an aeroplane implies that the aeroplane landing gear configuration, tyre pressure and load result in the critical pavement stress in any pavement overlying the given standard subgrade category as a single wheel load having the same ACN or any other aeroplane with the same ACN.
The first step to calculating the ACN is to translate the aircraft for which the ACN is being derived into an equivalent single wheel load (ESWL), which would have the same pavement thickness requirement as the aircraft:

- ESWL is a mathematical scheme developed to convert a multiple-wheel gear to a single-wheel gear that has similar characteristics; i.e. a single tyre that represents an equivalent damaging effect to the pavement as the multiple-wheel gear.
- ESWL is such that it causes a maximum deflection at the top of the subgrade equal to the maximum deflection caused by the entire gear. For the purpose of ACN calculation, ESWL is defined as the derived single wheel load (DSWL). This is the single load acting through a single wheel with a tyre inflated to 1250 kPa, which results in the same pavement thickness as the aircraft for which the ACN is being calculated.

4.1 Flexible Pavement Operations

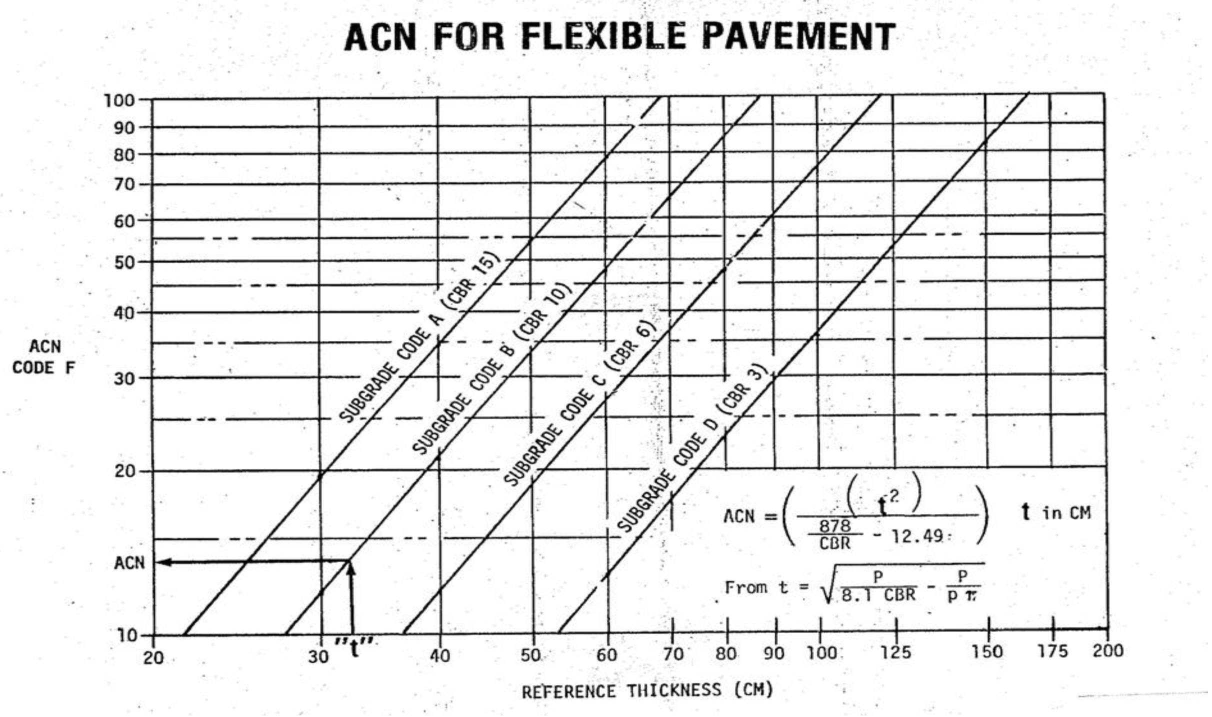
The US Corps of Engineers method, instruction report S-77-1, is used to calculate the pavement thickness required for 10,000 coverage for single wheel loads having 1250 kPa (181 psi) tyre pressure on four standard subgrade strengths.

The four standard subgrades used are based on California Bearing Ratio (CBR):

Subgrade Code A	high strength	CBR 15
Subgrade Code B	medium strength	CBR 10
Subgrade Code C	low strength	CBR 6
Subgrade Code D	ultra low strength	CBR 3

The relationship between ACN, reference pavement thickness't' and subgrade strength for flexible pavements is represented graphically by the ACN for Flexible Pavement Conversion Chart below.

The ACN of the aircraft is numerically two times the DSWL expressed in thousands of kilograms for which the thickness was calculated. The 'two' factor is used to give a more usable range of numbers for the ACN.



4.2 Rigid Pavement Operations

The Portland Cement Association (PCA) calculates the concrete thickness required for the single tyre pressure on four standard subgrade strengths.

The four standard subgrades are referenced to Westergaard's Modules of Subgrade Reaction, K:

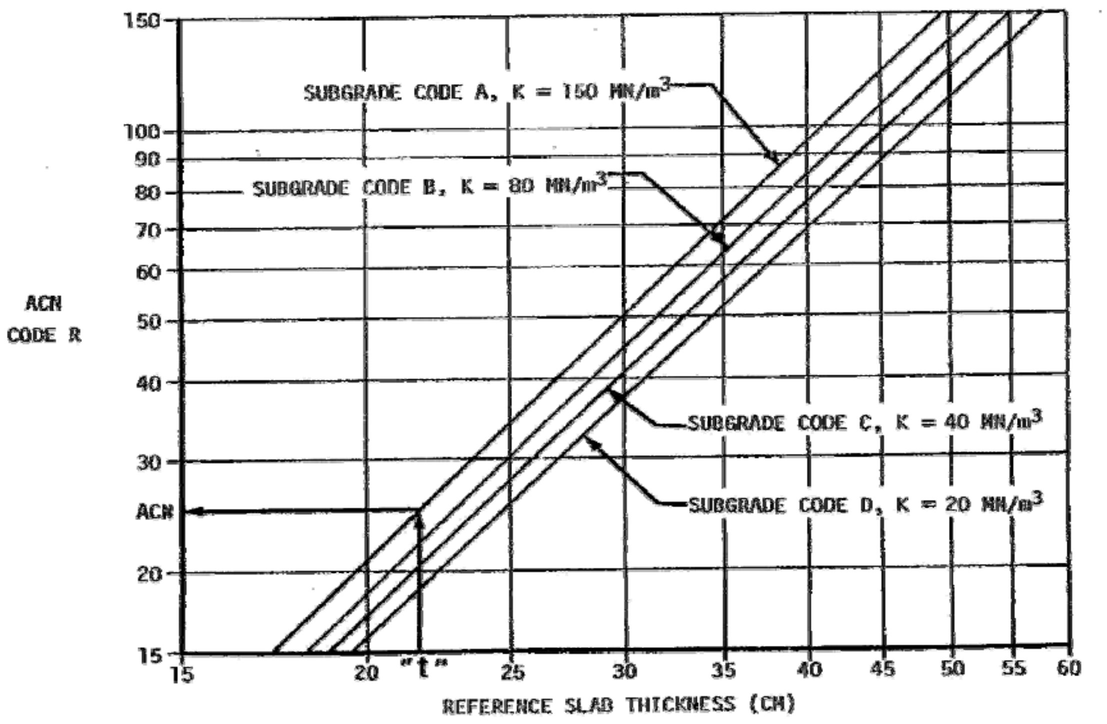
Subgrade Code A	high strength	K = 150 MN/m^3
Subgrade Code B	medium strength	K = 80 MN/m^3
Subgrade Code C	low strength	K = 40 MN/m^3
Subgrade Code D	ultra low strength	K = 20 MN/m^3

Standard concrete working stress – 2.75 MN/m^2

The relationship between ACN, slab thickness and modulus of subgrade reaction for rigid pavements is represented graphically by the ACN for Rigid Pavement Conversion Chart below.

The ACN of the aircraft is numerically two times the DSWL expressed in thousands of kilograms for which the thickness was calculated. The 'two' factor is used to give a more usable range of numbers for the ACN.

ACN FOR RIGID PAVEMENT



$$ACN = 0.0219\, K^{0.6524} * t^{2.059 K^{0.011}}$$

When designing aerodrome pavements in addition to the weight, tyre pressure and undercarriage configuration of the design aircraft a knowledge of the number of aircraft movements for the design life of the pavement is also required.

The terms movement, arrival, departure, pass and coverage are often used interchangeably when determining the effect of traffic operating on a runway. The following is reproduced from Boeing Document D6-8220300 *Precise Methods for Estimating Pavement Classification Number*.

- Coverage or Load Repetition – When an airplane traverses on a runway, it seldom travels in a perfectly straight line or over the exact same wheel path as before. It will wander on the runway with a statistically normal distribution. One coverage or load repetition occurs when a unit area of the runway has been traversed by an aircraft wheel on the main gear. Due to the random wander, this unit area may not be covered by the wheel every time the airplane is on the runway. The number of passes required to statistically cover the unit area one time on the pavement is related to either the pass-to-coverage (P/C) ratio for flexible pavements or the pass-to-load repetition (P/LR) ratio for rigid pavements. A pass is a one-time transaction of the aeroplane over the runway pavement. This is shown in the table below:

4.3 Pass/coverage and pass/load repetition ratio

Pavement	Parameter	Typical Dual gear	Typical Dual tandem gear	Typical tridem gear
Flexible	Pass/coverage	3.6	1.8	1.4
Rigid	Pass/load repetition	3.6	3.6	4.2

4.4 Presenting ACN Values

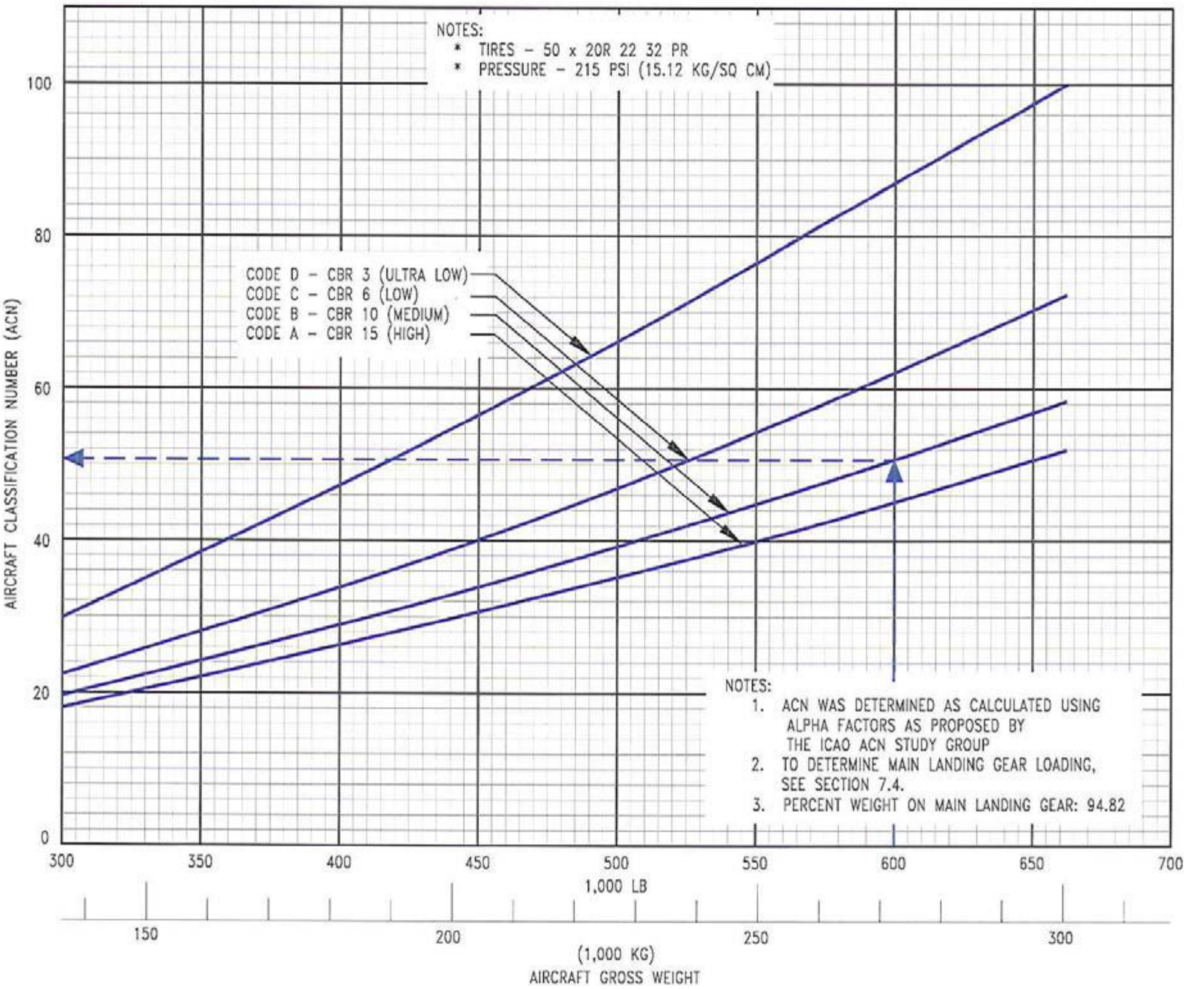
ACN values for both flexible and rigid pavement operations are published by aircraft manufacturers in their Aeroplane Characteristics for Airport Planning Manuals.

The ACN values for an aircraft of known tyre pressure can be presented graphically by plotting ACN (vertical axis) versus the weight (horizontal axis) of the aircraft for the four standard subgrade strengths. Calculating the ACN values at operating weight empty and maximum ramp or take–off weight and drawing a straight line (an approximation) between the two values allows interpolation of ACN values for intermediate aircraft operating weight.

The following diagram depicts ACN values for the Boeing B777-300 operating on a flexible pavement overlying the four standard subgrade strengths and operating with tyres of 215 psi (1482 kPa) tyre pressure.

4.4.1 ACN Flexible Pavement Boeing B777-300

(Source Boeing Airport Planning Manual)



The common form of presenting the ACN values for a known operating tyre pressure is to tabulate the values calculated for each of the four standard subgrade strengths for the aircraft at Maximum Take-off Weight (MTOW) and Operating Weight Empty (OWE).

A list of ACN values for various aircraft found in commercial service throughout the world today has been compiled from various sources and is presented in Appendix A of this Publication.

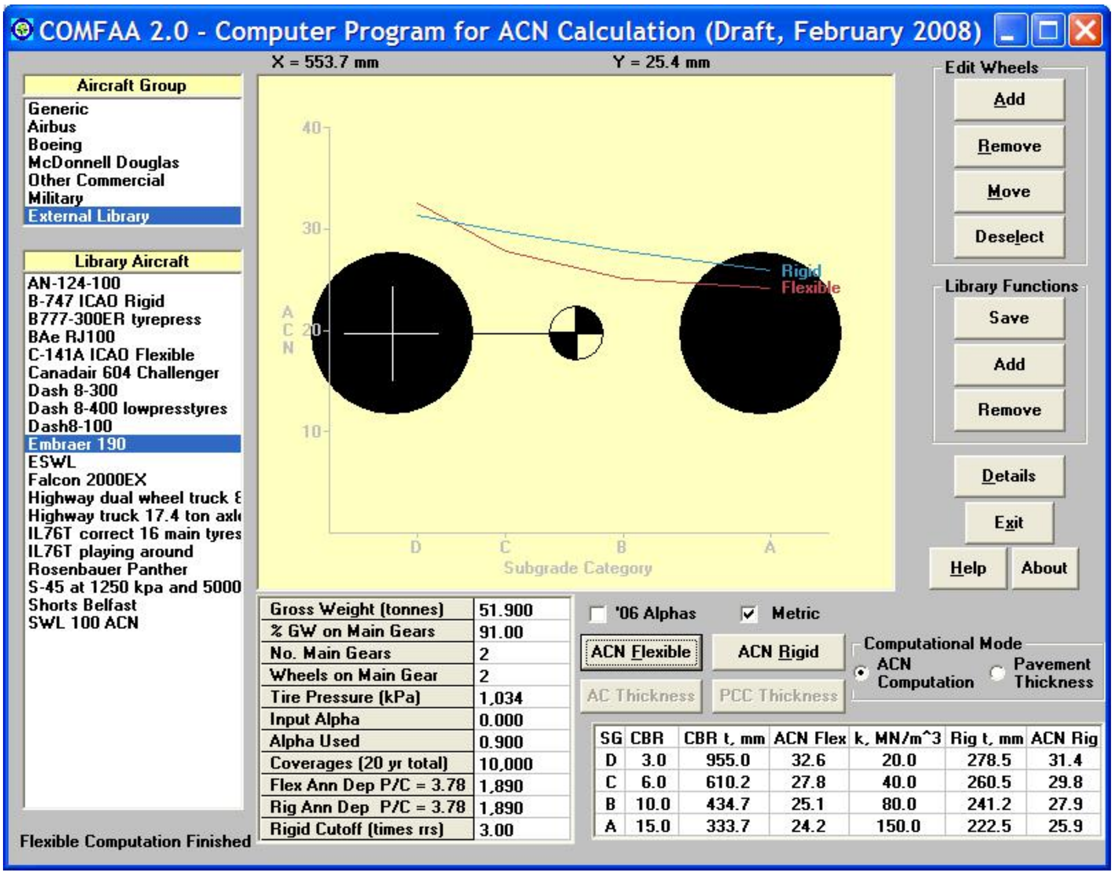
4.5 Calculating ACN Values

The mathematical expressions used for calculating the ACN value have been adapted for use in software applications. The ICAO Aerodrome Design Manual Part 3 – *Pavements,* Appendix 2 describes the computer program developed by the PCA, based on the design of rigid pavements and the program developed by the US Army Engineer’s based on the CBR method for the design of flexible pavements.

The US FAA developed software called COMFAA for calculating ACN values in accordance with the ACN-PCN method. The software may be downloaded from the FAA website: http://www.airporttech.tc.faa.gov/naptf/download/index1.asp#soft.

COMFAA was translated from the ICAO Aerodrome Design Manual and uses the rigid and flexible pavement design programs described therein. The COMFAA program enables computation of ACN values and calculates total flexible pavement thickness and rigid pavement slab thickness.

The following is an example of the COMFAA derived ACN values for the Embraer 190 aeroplane.



5.0 PAVEMENT CLASSIFICATION NUMBER

Determining the PCN is more troublesome than determining the ACN because in the development of the ACN each aircraft characteristic is fixed. Each aerodrome pavement needs to be evaluated individually to determine its rating based on the knowledge of pavement design, construction, type and frequency of traffic and present condition.

In the ACN–PCN method the pavement strength rating may be determined using either a technical evaluation of the pavement or, where little information is available about the pavement but it has performed satisfactorily under regular use by a specific aircraft, the ACN of that aircraft may be adopted as the PCN for the pavement.

The technical evaluation method requires a detailed knowledge of the pavement, traffic type and frequency of movements. The aim is to use the known pavement parameters to calculate the maximum allowable gross weight of the critical aeroplane for the pavement.

The ACN of the aeroplane is determined using the procedure outlined in Section 10 of this AC and the ACN of the critical aeroplane is assigned as the PCN of the pavement. The aircraft usage method may be used when there is limited information on the existing pavement. The PCN assigned in this case is the ACN of the critical aeroplane currently using the pavement which is performing satisfactorily under the current traffic.

Where possible it is recommended the PCN and pavement rating should be based on a technical evaluation.

5.1 PCN based on aircraft usage

There are two basic simple steps involved in this method:

- o determine the aeroplane with the highest ACN value in the traffic mix currently using the pavement; and
- o assign the ACN of this aeroplane as the PCN for the pavement.

The resulting PCN value may be adjusted upwards or downwards by the aerodrome operator to better reflect the actual pavement condition or to restrict certain aeroplane types.

5.2 PCN determined by technical evaluation of the pavement

Pavement design and pavement evaluation is not an exact science and therefore ratings obtained by a technical evaluation are at best a good approximation. For new pavements the design aircraft and the subgrade strength is known or may be checked by field and laboratory testing. The ACN of the design or critical aeroplane is adopted as the PCN for the pavement.

Where the design basis for a pavement is unknown or the adequacy of the pavement for a particular aircraft loading, usually the current aircraft, is unknown a technical evaluation of the pavement and subgrade should be carried out. The aim of a technical evaluation is to measure the pavement thickness and assess the strength of pavement and subgrade material. The following guidelines are provided for the in-situ evaluation of flexible pavements to determine the pavement thickness and subgrade strength:

- Test holes should be located over the whole pavement at intervals of approximately one hole per 300 metres of runway length and concentrated in the more heavily loaded areas of the runway, e.g. the wheel track locations.

- Adopt the subgrade strength type at each test hole should be examined for consistency over the whole pavement. If there are significant variations in subgrade type and strength, the pavement should be divided into appropriate sections and the rating based on the critical subgrade strength.

- The subgrade CBR for each section should be determined as follows:
  - o below the pavement;
  - o discard any values outside the mean plus or minus one standard deviation;
  - o calculate the new mean and standard deviation; and
  - o adopt a subgrade strength category from the evaluation of the subgrade CBR outlined above;

- Engineering judgement should be used in deciding the subgrade CBR to be adopted, based on the history of aircraft loading and pavement performance together with the above calculations. Also check that a deeper layer in the subgrade than that directly below the pavement is not the critical layer for determining subgrade strength.
- Determine the average pavement thickness.
- Assign the standard subgrade strength category based on the subgrade strength evaluation above.
- As a starting point, adopt the current critical aircraft which is operating regular services as the design aircraft. By reverse design, using the average pavement thickness and the adopted subgrade CBR, determine the gross weight of the design aircraft for which the pavement is just adequate for 10,000 coverages. The ACN at that gross weight and for the appropriate subgrade strength category may then be determined using the relationship between ACN, subgrade strength and pavement thickness defined in Section 10 of this Advisory Circular.
- Where there are several critical aircraft operating this process should be repeated for each of the critical aircraft and the ACNs of each of the critical aircraft determined. The ACN which provides the 'best fit' for these design aircraft may be adopted as the PCN. Alternatively determine the critical equivalent aeroplane from the respective mix of aeroplane types using the pavement. For instance, if the critical aeroplane has a dual tandem gear, then all the other aircraft should be converted to the dual tandem gear equivalent.

The procedure for the evaluation of rigid pavements is similar to that for flexible pavements described above except the pavement characteristics which need to be determined here are the subgrade soil modulus K, concrete thickness and elastic modulus.

The aerodrome operator may wish to engage the service of an aerodrome pavement specialist to evaluate the strength characteristics of the aerodrome pavements.

Boeing provides a detailed appraisal of the technical evaluation of the PCN in document D6-8220300 *Precise Methods for Estimating Pavement Classification Number.*

5.3 Reporting PCN

The aerodrome operator may wish to determine the strength characteristics of all the aerodrome pavements; runway, taxiway and apron. The pavement strength rating reported in AIP is normally presented as that for the runway pavement. Where there are significant differences these should be reported or else the pavement strength rating will equally apply to the taxiway and apron pavements.

If a pavement shows signs of distress the PCN and allowable tyre pressure may need to be reduced at the discretion of the aerodrome operator. If the PCN is reduced then some of the aircraft using the pavement may have ACNs that exceed the new PCN the consequences of which are; a weight restriction on those aircraft, acceptance of the resulting overload by the aerodrome operator or consideration of pavement strengthening.

Different PCN values may be reported throughout the year if the strength of the pavement is subject to significant seasonal variation.

6.0 PAVEMENT STRENGTH RATING

The strength rating of an aerodrome pavement intended to be used by aircraft of maximum ramp mass of more than 5700 kg is to be reported using the alpha-numeric notation as shown in the following example of a runway strength rating from AIP:

	(1)	(2)	(3)	(4)	(5)
PCN	**39**	**F**	**A**	**1200 (174)**	**T**

The following paragraphs identify the function of each of the alpha-numeric parameters and how they may be determined:

(1) PCN Value

This is the published PCN. Refer to Section 5 of this Advisory Circular on how to estimate the PCN value.

(2) Pavement Type

A brief description of pavement types is included in paragraph 2.3 of this Advisory Circular. The two types of pavement structures commonly used are termed flexible and rigid pavements and the entry for this category is either **F** - flexible pavement or **R** - rigid pavement.

(3) Subgrade Category

Standard subgrade strengths for flexible and rigid pavements shown here are meant to be representative of the range of subgrade strengths commonly encountered in the field.

	Flexible Pavement		**Rigid Pavement**	
Code	**CBR Range**	**CBR Standard**	**k Range**	**k Standard**
A (high)	>13 %	15 %	>120 MN/m^3	150 MN/m^3
B (medium)	8 to 13	10	60 to 120	80
C (low)	4 to 8	6	25 to 60	40
D (ultra low)	<4	3	<25	20

(4) Tyre Pressure

The maximum allowable tyre pressure which a pavement surface can support is expressed either in terms of the maximum allowable tyre pressure category, defined in the following Table, or by the maximum allowable tyre pressure value in kPa (psi).

Maximum allowable tyre pressure category	**Code**
High: no tyre pressure limit	**W**
Medium: tyre pressure limited to 1500 kPa	**X**
Low: tyre pressure limited to 1000 kPa	**Y**
Very low: tyre pressure limited to 500 kPa	**Z**

6.1 Interaction between tyre and pavement

A tyre exerts a pressure at the surface of a pavement which depends on its tyre inflation pressure. The contact pressure between the pavement and tyre differs from the tyre pressure, the difference depending on the magnitude of the tyre pressure. The walls of high pressure tyres are in tension and the contact pressure is less than the tyre pressure whereas for low pressure tyres the contact pressure is greater than the tyre pressure.

Tyre manufacturers always strive towards using higher inflation pressure because higher tyre pressure is associated with safe tyre loading.

Tyre pressure reduces with the depth of the pavement to an insignificant level. The pavement thickness is required to ensure the stresses in the pavement layers and subgrade do not exceed their capacity.

6.2 Estimating permissible tyre pressure

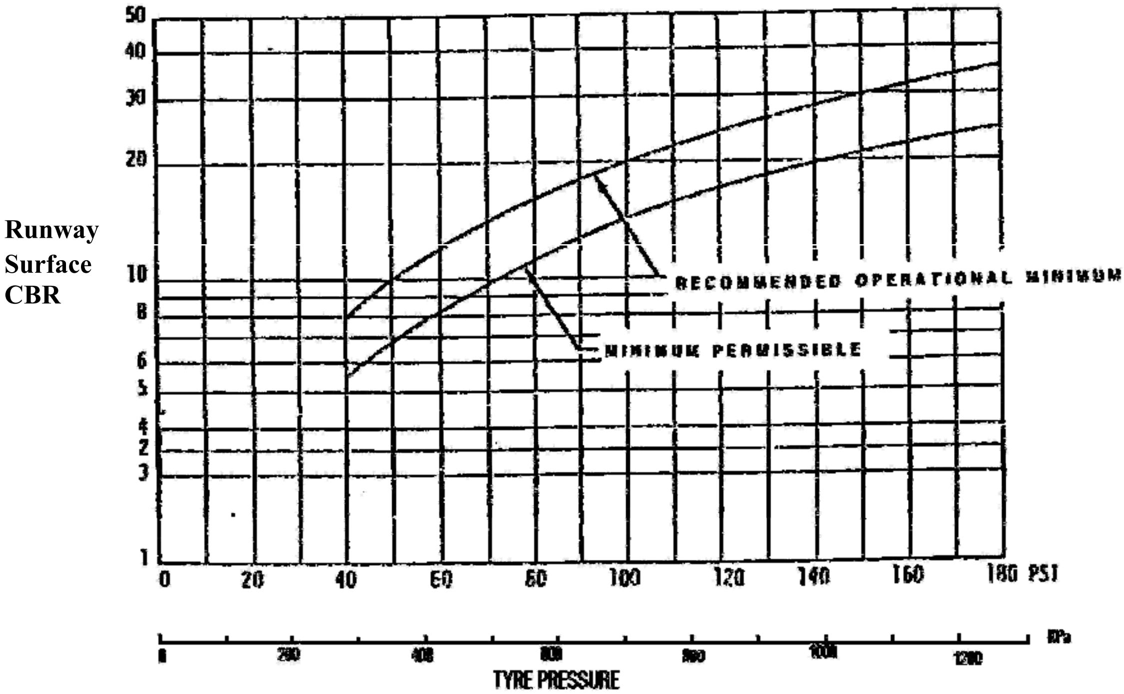
When deciding on the maximum allowable tyre pressure, the type and quality of the surface course and quality and compaction of the pavement material immediately underlying the surface course are important factors to be considered. The following guidelines are provided for different surface courses:

- Portland cement concrete surface course - 2000 kPa;
  Bituminous concrete surface course (asphalt) - 1400 to 175kPa
- Bituminous seal on good quality fine crushed rock or well graded gravel with hard durable stone compacted to 95% modified AASHO - 1000 kPa;
- Bituminous seal on crushed rock or gravel with moderate compaction of 90 to 95% modified AASHO - 550 to 1000 kPa;
- Bituminous seal on crushed rock or gravel with compaction less than 90% modified AASHO and pavements of unknown compaction built before 1950 - 600 kPa; and
- Grass or gravel surfaced pavements - 450 to 550 kPa.

Estimated permissible tyre pressure for unsurfaced pavements and for asphalt surfaced pavements are presented in the following two diagrams, courtesy of Boeing

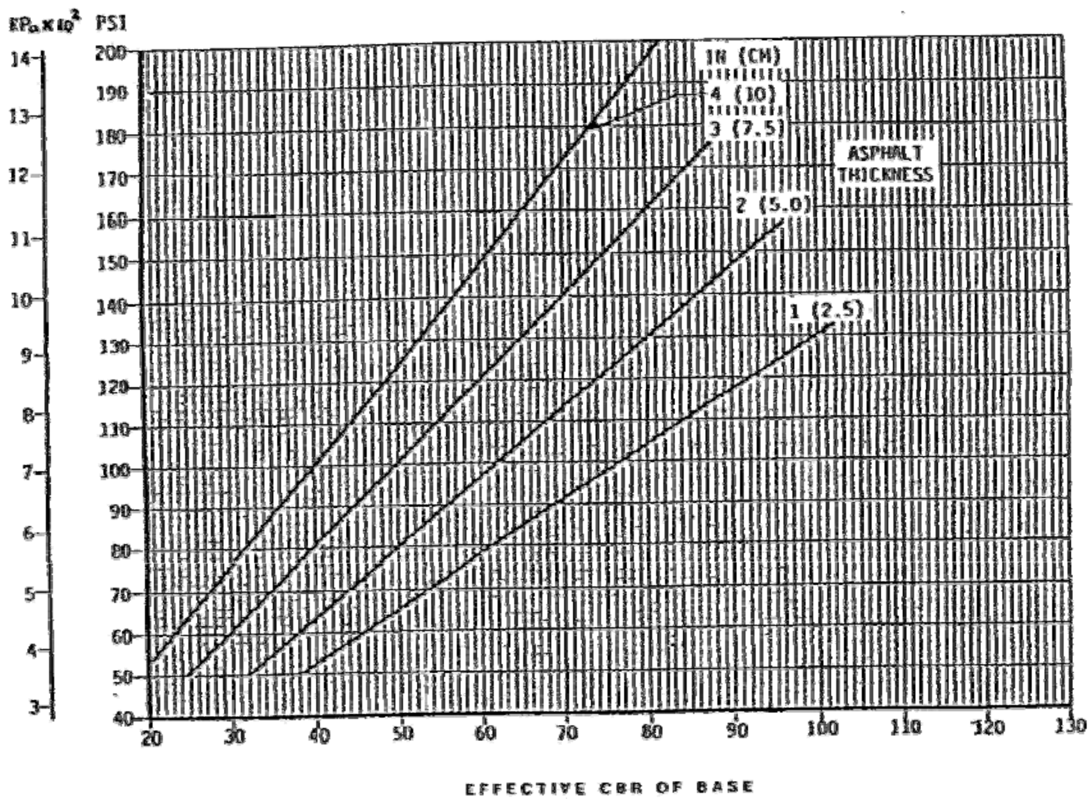
6.3 Unsurfaced Runway Requirements

(Source Boeing)



6.4 Permissible Tyre Pressure Asphalt Surfaced Pavement (Approx.)

(Source Boeing)



6.5 Double-dipping of tyre pressure

A question sometimes asked is why is there a need to report the tyre pressure limitation of a pavement separately when the tyre pressure of the design or critical aircraft is included in the calculation of the ACN which is adopted as the PCN of the pavement:

- The load imposed by an aircraft on a pavement is the mass of the aircraft acting through the main wheels which is applied to the pavement surface through the tyres inflated to a certain tyre pressure. The expression for the thickness of the pavement overlying the subgrade contains both the mass and the inflated tyre pressure but it is the mass of the aircraft which has the greatest influence on the thickness of the pavement.
- The tyre pressure influences the top layers of the pavement but it is the stress generated from the mass of the aircraft which is influential throughout the pavement layers. The ACN, and the derived PCN, reflect the thickness of pavement required to protect the subgrade material. The additional tyre pressure parameter is required in the pavement strength rating to define the stress limitation of the surface layer of the pavement comprising the riding surface and the surface of the sub-base material.

6.6 Method of Evaluating Pavement Strength Rating

As discussed in Section 6 of this Advisory Circular the ACN-PCN method recognises two pavement evaluation methods:

- If the evaluation is determined from a technical study i.e. an assessment of pavement and subgrade parameters necessary to enable the PCN value to be calculated, the evaluation method is coded T for technical evaluation.
- If the strength is assessed as suitable for the aircraft currently using the pavement without causing any distress to the pavement, then the greatest ACN value of the aircraft types is reported as the PCN for the pavement. The evaluation method in this case is coded **U** based on aircraft usage.

Each aerodrome pavement should be evaluated individually to determine its rating based on the knowledge of construction and operations. Where possible, the pavement rating should be based on a technical evaluation.

6.7 Examples of Pavement Strength Rating

For pavements used by aircraft of maximum ramp mass greater than 5700 kg:

PCN 39/F/A/1200 (174)/T

- the bearing strength of a flexible pavement on a high strength subgrade has been assessed by technical evaluation to be PCN 39 and the maximum tyre pressure allowable is 1200 kPa (174 psi).

PCN 11/F/C/Y1/U

- the bearing strength of a flexible pavement on a low strength subgrade has been assessed by using aircraft experience to be PCN 11 and the maximum tyre pressure allowable is limited to 1000 kPa.

For pavements used by aircraft of maximum ramp mass equal to or less than 5700 kg:

3,500 kg/550 kPa

- The bearing strength of a flexible pavement has been assessed as suitable for aircraft of maximum ramp mass not more than 3500 kg and tyre pressure limitation of not more than 550 kPa.

7.0 UNRATED PAVEMENTS

Where the aerodrome pavements consists of a natural surface or a gravel surface of low bearing capacity and a pavement strength rating cannot realistically be assigned to the pavement, the entry in the AIP has traditionally been reported as 'unrated'. The unrated pavement fills the gap where the strength of the pavement has never been determined using either a technical evaluation or from aircraft usage. This is normally applicable to non-certified or non-registered aerodromes where testing for soft wet surfaces is the simplified method of assessing the suitability of the runway pavement.

The following guidelines describe the method of assessing the bearing strength of unrated pavements. At certified and registered aerodromes the results of the assessment should be translated to the pavement strength rating as defined by the ACN-PCN method. Where an assessment suggests the pavement is suitable for aircraft in excess of 5700 kg this should be followed up by a technical evaluation to more accurately define the bearing strength limitations of the pavement.

7.1 Assessing the Bearing Strength of Unrated Pavements

The bearing capacity of unrated pavements is dependent on such factors as the type of material used to construct the pavement, the moisture condition and degree of compaction of the pavement material. Unrated pavements are generally suitable for regular operations under '***dry to depth***' conditions.

- Under dry to depth conditions, the bearing capacity of the surface may be considerably greater than under wet conditions and this would allow the nominated aircraft types to operate.
- After rain when the natural material has high moisture content on the surface and to some depth, the pavement is obviously not dry to depth. After prolonged rainfall the natural material may have high moisture content to considerable depth. After a short dry period a surface crust can form while the underlying material can still be wet and of inadequate strength. In this situation a more detailed investigation is required to determine if the pavement is dry to depth.

7.2 Assessment of dry to depth conditions

Guidelines for the assessment of dry to depth conditions of a pavement are set out below:

- Assessment is based on the use of road vehicles to simulate aircraft loading as indicated below, but because aircraft wheel loads and tyre pressures are often higher, as a general rule, than the test vehicle the results of these tests must be assessed in conjunction with a knowledge of the effects of aircraft and road vehicle wheels on the particular pavement surface.
- All up weight of aircraft (kg) – Test vehicle:

- o 2000 and below – utility, four wheel drive, station wagon or equivalent;
- o 2001 to 3400 – a truck with a 1.5 tonne load; and
- o 3401 to 5700 – a truck with a 3 tonne load

- The test vehicle should be driven at a speed not exceeding 16 kph in a zig-zag pattern covering the full length and width of the runway (including runway end safety areas) with particular attention being given to suspect areas and areas which are known to become wet sooner or remain soft longer than other areas. If any doubt exists, the test vehicle should be driven backwards and forwards two or three times over the suspect area; and

- In addition to the vehicular test, the pavement surface should be tested with a crowbar in at least two or three places along the length of the pavement to ensure that a dry looking surface crust does not exist over a wet base. Additional tests can be carried out in other suspect areas particularly where stump holes have been filled or where deep filling has been carried out.

7.3 Assessing the results of the tests

If the tyre imprint of the test vehicle exceeds a depth of 25mm below the normal hard surface of the pavement then the area is not suitable for operations by the aircraft appropriate to the test vehicle. In addition, if the surface deflection resulting from the test vehicle loading is such that there is no rebound in the surface after the test vehicle passes, the area is not considered suitable for the aircraft appropriate to the test vehicle.

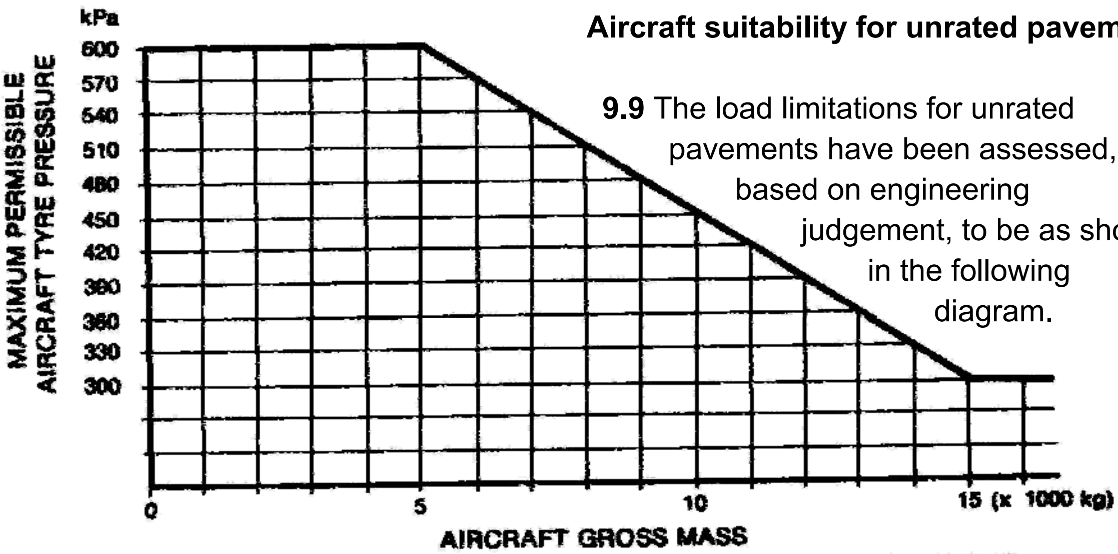
Where personal knowledge may also indicate that a particular pavement surface is not suitable for aircraft when the imprint depth is less than 25mm, in such cases the lesser depth shall be used.

If the results of any of the tests described above indicate that the bearing strength of any part of the pavement is inadequate, the affected area is to be declared unserviceable, closed and a Notice to Airmen issued.

When no suitable test vehicle is available to simulate aircraft wheel loading and when, in the opinion of the person responsible, the serviceability of the runway surface is in doubt, the strip is to be closed to aircraft operations for the duration of the sub-standard conditions.

Aircraft suitability for unrated pavements

9.9 The load limitations for unrated pavements have been assessed, based on engineering judgement, to be as shown in the following diagram.



AIRCRAFT SUITABILITY FOR UNRATED PAVEMENTS

8.0 PAVEMENT OVERLOAD

In theory an aircraft of a known mass and specified operating tyre pressure can operate on a pavement so long as the ACN of the aircraft is less than or equal to the published PCN of the pavement, subject to tyre pressure limitation.

If the ACN of the aircraft intending to operate on the pavement is greater than the PCN of the pavement the aerodrome operator will need to assess whether to allow the operation to take place. Similarly if the tyre pressure of the aircraft intending to operate on a pavement exceeds the maximum allowable tyre pressure for the pavement.

Aerodrome pavements are designed and consequently rated to be able to withstand a specific number of repetitions or loadings by the critical or design aircraft without needing major pavement maintenance. There may be times when aircraft imposing more severe loadings than that which the pavement was designed for will seek approval to operate. These operations will not be permitted without the approval of the aerodrome operator.

Pavements can sustain some overload, that is, pavement ratings are not absolute. There may be good reason why overload operations should be approved. For instance the design traffic is operating at less than design capacity and limited overload may not reduce the life of the pavement or depending on the overload may only marginally reduce the life of the pavement. This reduction in pavement life may be preferred to the alternative of refusing a desirable operation or having to strengthen the pavement for infrequent operations.

8.1 Pavement Life

Pavements are normally designed for a defined life and mix of traffic. The true life expectancy of a pavement is a direct function of:

- Environmental factors; quality of pavement material, traffic distribution
- Number of operations/repetitions of aircraft loading;
- Aircraft characteristics – weight, tyre pressure wheel configuration and overload operations

At some stage in the life cycle of the pavement failure modes will start appearing. The pavement is a structure and like all structures which are exposed to repeated loadings will eventually fail. The pavement distress can be arrested by following planned maintenance practices in accordance with an established pavement management system.

Naturally the consequences of repeated overloads may lead to the following failure conditions:

- excessive roughness caused by general loss of shape after repeated operations by heavy wheel loads;
- cracking of the seal surface where deflections caused are high or compaction of the pavement material is poor;
- surface rutting and cracking of the seal surface and stripping of aggregate due to high tyre pressure; and
- high maintenance costs.
- In respect of aircraft operations:

- reduced braking characteristics by reducing the tyre/pavement interaction; it may lead to an increase in the required operational length of runway; has potential to increase structural fatigue to aircraft;

- increase the likelihood of foreign object damage to aircraft structures from loose stones and material; and
- cause discomfort to passengers.

9.0 OVERLOAD GUIDELINES

9.1 Using ACN vs PCN

The aerodrome operator should decide the pavement overload which is allowable for the aerodrome, and also adopt an appropriate overload policy. This requires consideration of the pavement strength and condition, aircraft frequency and weight, pavement inspection and management procedures, and other commercial and political considerations.

The following are the pavement overload guidelines recommended by ICAO:

- o occasional movements on a flexible pavement by aircraft with an ACN not exceeding 10 per cent of the reported PCN should not adversely affect the pavement;
- o occasional movements on a rigid pavement by aircraft with an ACN not exceeding 5 per cent of the reported PCN should not adversely affect the pavement;
- o where the pavement structure is unknown a limitation of 5 per cent should apply;
- o the annual number of overload movements should not exceed approximately 5 per cent of the total annual aircraft movements;
- o overload movements are not be permitted on pavements exhibiting signs of distress or failure;
- o overloading should be avoided during periods when the strength of the pavement or subgrade could be weakened by water; and
- o the condition of the pavement should be regularly reviewed.

The following overload guidelines are appropriate and provide a balance between commercial demand and risk management for the aerodrome operator:

- The ICAO guidelines are conservative and make them appropriate for the major aerodromes receiving a large number of aircraft movements by heavy aircraft.
  An overload by aircraft with an ACN up to but not exceeding 10 per cent of the reported PCN is generally considered acceptable provided:
  - o the pavement is more than twelve months old;
  - o the pavement is not showing signs of distress; and
  - o overload operations do not exceed 5 per cent of the annual departures and are spread throughout the year.
- An overload by aircraft with an ACN greater than 10 per cent or more than 10 per cent but not exceeding 25 per cent of the reported PCN requires regular inspections of the pavement by a competent person and there should be an immediate curtailment of such overload operations as soon as distress becomes evident.

An overload by aircraft with an ACN greater than 25 per cent but not exceeding 50 per cent of the reported ACN may be undertaken under special circumstances including:

- scrutiny of available pavement construction records and test data by a qualified pavement engineer; and
- a thorough inspection by a pavement engineer before and on completion of the movement to assess any signs of pavement distress.

Overloads by aircraft with an ACN greater than 50 per cent of the reported PCN should only be undertaken in an emergency;

Overloads not exceeding 100 per cent should only be considered in the case of small aeroplanes operating into aerodromes which do not show signs of pavement distress and where the pavement and subgrade material is not subject to moisture ingress.

9.2 Using Pavement Life

An alternative to choosing the amount of overload which would be acceptable on a pavement is the impact on the life of the pavement from overload operations. If the reduction in pavement life is allowable by the pavement management system in place at the aerodrome the decision may be taken to allow the overload operations.

9.3 Use of COMFAA to assess impact on pavement life from overload operations:

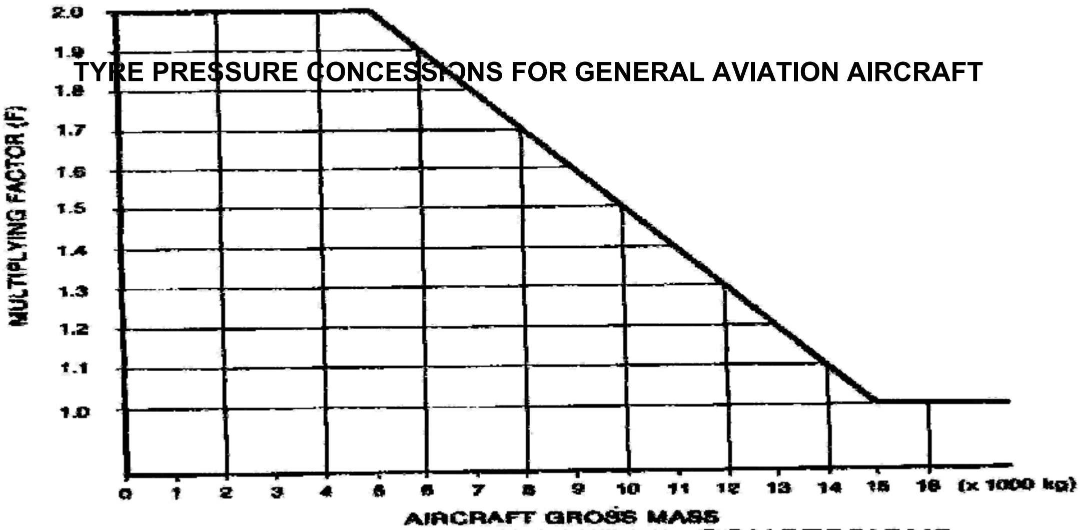
- The advent of modern computing techniques has meant that the impact on pavement life from aircraft overloads can now be readily estimated without resorting to the production of elaborate overload curves or pavement life charts.

- The FAA developed COMFAA computer program, mentioned in Para 5.18 of this Advisory Circular, enables computation of ACN values and calculates total flexible pavement thickness and rigid pavement slab thickness. The program may readily be used to assess the impact on the pavement life from an overloading aircraft. First the pavement thickness required for the overloading aircraft is determined. The resulting thickness is compared to that of the existing pavement and the additional pavement thickness required could be translated into the additional equivalent coverages of the design aircraft which the pavement would be subjected to if the overload operations were allowed to proceed. The reduction in pavement life caused by the overloading aircraft operations can then be estimated.

9.4 Tyre Pressure Overload

Experience has shown that the problem of tyre pressure overload is greatest with low gross weight high tyre pressure aircraft such as executive jets. Based on engineering judgement, the allowable tyre pressure for these aircraft can be increased by the factors shown in the graph below, without adversely affecting pavement life.

TYRE PRESSURE CONCESSIONS FOR GENERAL AVIATION AIRCRAFT



PERMANENT TYRE PRESSURE CONCESSIONS

10.0 AIRCRAFT GROSS WEIGHT

The permissible tyre pressure may be increased using the factor obtained in the graph up to a limit of 1400 kPa, provided that no more than four movements within a seven day period are proposed for these general aviation aircraft

Derivation of theoretical guidelines for tyre pressure overloads is more difficult than that for weight overload in that there is no well accepted relationship between allowable tyre pressure, measurable properties of pavement materials and number of allowable operations

As a general rule, tyre pressure overloads greater than 50 per cent should only be allowed under special circumstances. When significant tyre pressure overloads are allowed, an inspection of the pavement should be carried out before and after the operation to determine whether there has been significant damage done to the pavement.

It is important to remember that the final decision to allow a pavement to be overloaded should be based on full recognition of the actual pavement condition and pavement life history.

11.0 PAVEMENT CONCESSIONS

Normally an aeroplane with an ACN value greater than the PCN of the aerodrome pavements or operating with a tyre pressure greater than that which the pavement is rated for, will not be permitted to operate at the aerodrome unless a pavement concession has been approved by the aerodrome operator for the period of operations. A pavement concession given to the aircraft operator formalises the acceptance of the heavier aircraft and sets conditions under which the operation will be accepted.

In combination with the overload guidelines described earlier the aerodrome operator should also consider the following when assessing an application for a pavement concession:

- The safety of the operation:

  - where overloading of the pavement is so severe that damage to aircraft is likely and the safety of the occupants is in doubt a pavement concession is not to be approved;

- The probability of pavement damage:
  - majority of one-off operations requiring a concession are not likely to cause pavement damage or may cause only minor damage in localised areas;
  - basis of pavement design;
  - report on pavement evaluation and condition;
  - data on aircraft usage;
  - reports on damage caused by previous operations;
  - overload operations should not normally be permitted on pavements exhibiting signs of distress of failure;
  - are operations one-off, short term or long term; and
  - local conditions e.g. recent prolonged rainfall causing loss of subgrade strength; The social and economic importance of the operation:
  - are alternative aircraft available;
  - are the operations for humanitarian or compassionate reasons e.g. urgent medical evacuation, flood or disaster relief. These are rarely refused unless there is doubt about the safety of the operation;
  - are the operations politically desirable e.g. Head of State visits, Ministerial flights etc.;
  - are the operations of significant commercial importance to the community;
  - are the operations essential or desirable militarily; and

- The consequence of any pavement damage:
  - the cost of repairs to any pavement damage;
  - the resources available to repair any damage;
  - the disruption to routine operations caused by any damage or repairs; and
  - where the licensee considers that the damage resulting from aircraft operations under pavement concessions has been caused by the aircraft operator’s carelessness or non compliance with the conditions of the pavement concession, the licensee should consider seeking compensation directly from the aircraft operator for part or all of the repair costs involved;

- Other considerations:
  - are the physical characteristics of the aerodrome movement area suitable for the intended operations of the overloading aircraft, for example, parking and manoeuvrability.

APPENDIX A

Tabulation of ACN Values

To assist with general use, ACN values for various aircraft types operating on flexible and rigid pavements are provided in the table below:

The ACN values have been determined for operations on flexible and rigid pavements overlying the four standards subgrade strengths by aircraft operating at MTOW, OWE and a given operating tyre pressure (TP).

Units of weight (mass) are kilograms and units of tyre pressure are kilopascals.

Specific ACN values for a particular aircraft should be obtained from the aircraft manufacturer.

The reader is reminded that for aircraft not included in this list the ACN values can be obtained from the aeroplane manufacturer or, where ACN values are sought for a specific weight or tyre pressure, use of computer programs such as COMFAA may be used.

AIRCRAFT CLASSIFICATION NUMBER

Aircraft Type	MTOW (kg) OWE (kg) TP (kPa)	Flexible Pavement Subgrade CBR%				Rigid Pavement Subgrade K in MN/m3			
		A 15	B 10	C 6	D 3	A K150	B K80	C K40	D K20
A319-100	75865 38952 1380	39 18	40 18	44 20	50 22	44 20	46 21	48 22	50 23
A320-100	68013 39768 1210	35 19	36 19	40 21	46 24	38 20	41 22	43 23	45 24
A320-200	77395 44968 1440	41 22	42 22	47 24	53 28	46 24	49 26	51 27	53 28
A321-100	78414 47000 1280	42 23	44 24	49 25	55 30	47 25	50 27	52 29	54 30
A330–300	212000 121870 580	55 29	60 30	69 33	94 41	47 28	54 27	64 31	75 36
A340–300	271000 129300 1380	59 24	64 25	74 28	100 34	50 25	58 24	69 26	80 30
A340-500,600	366072 178448 1420	70 29	76 31	90 34	121 42	60 29	70 28	83 32	97 37
A380-800	562262 281233 1470	56 23	62 25	75 28	106 36	55 26	67 27	88 31	110 38
Antonov AN-124-100	391972 203940 1030	51 20	60 23	77 27	107 40	35 17	48 18	73 23	100 32
Antonov AN-225	600000 458865 1130	63 41	75 48	95 62	132 88	45 30	61 39	89 55	125 75
ATR 42 -200	18559 11217 720	9 5	10 5	11 6	13 7	10 6	11 6	12 7	12 7
ATR 72	21516 12746 790	11 6	12 6	14 7	15 8	13 7	14 7	14 8	15 8
B707-320C	152407 67495 1240	44 16	50 17	60 19	76 25	41 15	49 16	58 19	66 22
B717-100,200,300	54885 32110 1048	31 16	33 17	37 19	40 22	35 18	37 19	38 20	40 21
B737-BBJ	77826 42942 1470	43 21	45 22	50 24	55 28	50 24	52 26	54 27	56 28

Aircraft Type	MTOW (kg) OWE (kg) TP (kPa)	Flexible Pavement Subgrade CBR %				Rigid Pavement Subgrade K in MN/m3 Subgrade			
		A 15	B 10	C 6	D 3	A K150	B K80	C K40	D K20
B727-200	78517 45887 1150	42 23	44 23	50 25	55 30	47 24	50 26	52 28	54 29
B737-300	63527 33140 1400	35 16	37 17	41 18	45 21	40 19	42 20	44 21	46 22
B737-400	68320 35689 1280	38 18	40 18	45 20	49 23	43 20	45 21	47 22	49 23
B737-500	60774 32630 1340	33 16	35 16	39 18	43 21	38 18	40 19	42 20	43 21
B737-600	65770 36400 1300	35 18	36 18	40 19	45 22	39 19	41 21	44 22	45 23
B737–700	70359 37728 1390	38 18	40 19	44 20	49 23	43 21	46 22	48 23	50 24
B737–800	79230 41400 1470	44 21	46 21	51 23	56 26	51 23	53 25	55 26	57 27
B737-900	79230 42827 1470	44 21	46 22	51 24	56 28	51 24	53 25	55 27	57 28
B747-200B	364200 173320 1400	51 20	57 22	69 24	91 31	47 19	56 21	66 24	76 28
B747-300	379100 174820 1296	53 20	60 22	74 24	95 31	48 18	57 20	68 24	79 28
B747-400	398192 183546 1380	59 23	66 24	82 27	105 35	54 20	65 23	77 27	88 31
B757-200	115634 58123 1240	34 14	38 15	47 17	60 23	32 13	38 15	45 18	52 20
B767-200	141520 80890 1172	37 18.7	40 19	48 22	66 28	32 16	38 18	45 21	53 25
B767-200 ER	157400 80890 1260	42 19	46 20	55 22	75 28	37 17	44 19	53 22	61 25
B767-300	159685 87694 1380	44 21	49 22	59 25	79 33	40 19	48 22	57 25	65 29
B767-300 ER	172820 88000 1260	48 21	53 22	65 25	86 32	41 18	50 20	60 24	70 28

Aircraft Type	MTOW (kg) OWE (kg) TP (kPa)	Flexible Pavement Subgrade CBR %				Rigid Pavement Subgrade K in MN/m3			
		A 15	B 10	C 6	D 3	A K150	B K80	C K40	D K20
B777–200ER	287861 136945 1480	49 19	54 20	67 23	93 30	50 22	63 22	82 26	100 33
B777-300	300300 159277 1480	53 23	59 25	73 28	101 38	54 20	69 27	89 33	108 42
B777-300ER	352441 167830 1550	64 24	71 25	89 29	120 40	66 27	86 28	110 35	132 43
B787-9	245847 115350 1470	67 27	73 28	87 31	119 38	60 26	70 27	82 30	95 35
BAe 125 -800	12483 6858 1007	6.6 3.2	7.0 3.4	8 3.8	8.7 4.4	7.9 3.9	8.2 4.1	8.6 4.3	8.8 4.5
BAe 146-200	42419 23962 970	22 11	23 12	26 13	29 15	24 12	26 13	27 14	29 15
Beech 1900	7750 5710 670	3 2	4 3	4 3	5 4	4 3	4 3	5 3	5 4
Beech King Air 300	6832 5710 730	3 2	3 3	4 3	4 4	4 3	4 3	4 3	4 3
Bombardier Challenger 800	24166 15397 1120	13 8	14 8	16 9	17 10	16 9	16 10	17 10	18 11
Bombardier CRJ 900	38442 21617 1060	21 10	21 11	24 12	27 14	23 12	24 12	26 13	27 14
Bombardier Dash 8-300	19578 11828 670	8 4	9 5	11 6	13 7	10 5	11 6	11 6	12 7
Bombardier Dash 8-400	29265 17130 670	14 7	16 8	18 9	20 11	16 8	17 9	18 10	19 10
Canadair CL-600	19590 10000 1316	10.6 4.8	11.4 4.9	12.5 5.4	13 6.3	12.8 5.8	13.3 6.1	13.7 6.3	14.1 6.6
Cessna 525B Citation Jet 3	6396 5700 910	6	7	7	7	7	7	7	7
Cessna 550S2	6940 4146 830	5.3 3.2	5.8 3.4	5.8 3.5	6.1 3.6	5.5 3.3	5.6 3.3	5.6 3.4	5.7 3.4
Cessna 560 Citation V	7650 5712 1000	7 4	7 5	7 5	7 5	7 4	7 5	7 5	7 5

Aircraft Type	MTOW (kg) OWE (kg) TP (kPa)	Flexible Pavement Subgrade CBR %				Rigid Pavement Subgrade K in MN/m3			
		A 15	B 10	C 6	D 3	A K150	B K80	C K40	D K20
Cessna 560 XL	9180 5916 1500	9 6	9 6	9 6	9 6	9 6	9 6	9 6	9 6
Cessna 650 III/VI	10098 5712 1160	6 3	7 3	7 3	8 4	7 3	8 4	8 4	8 4
Cessna 650 VII	10608 6324 1160	7 3	7 3	8 4	8 4	8 4	8 4	8 4	8 5
Cessna 750 X	16320 9792 1310	10 5	11 6	12 6	12 7	12 6	12 7	13 7	13 7
Cessna Citation 3	9525 5670 1013	5.5 2.8	5.9 3.0	6.3 3.4	6.6 3.8	6.5 3.5	6.7 3.6	6.9 3.8	7 3.9
C141B Starlifter	158359 61182 1310	52 15	60 16	73 18	88 24	51 14	61 16	70 19	78 22
C 5 Galaxy	379634 169780 770	31 11	33 12	40 14	51 17	28 12	31 13	37 13	45 15
Dassault Falcon 10	8565 5710 930	5 3	5 3	6 4	6 4	6 4	6 4	6 4	6 4
Dassault Falcon 2000	16728 9486 1360	9	10	11	12	11	12	12	13
Dassault Falcon 50	17600 9600 1400	9.6 4.6	9.9 4.8	11 5.1	12 6	11.4 5.6	11.8 5.8	12.2 6.1	12.5 6.3
Dassault Falcon 900	20598 10503 1300	11 5	12 5	14 6	15 7	14 6	14 7	15 7	15 7
Fairchild Metro 227	7545 5710 730	3 2	4 3	4 3	5 4	4 3	5 3	5 3	5 4
Brasilia Embraer 120	11600 7150 830	5.4 3.1	5.9 3.5	6.7 3.8	7.8 4.6	7.2 4.1	7.5 4.5	7.8 4.7	8.1 4.9
Embraer 170	37525 21210 1040	20 10	21 11	24 12	26 14	22 11	24 12	25 13	26 14
Embraer 190	49048 26104 1100	28 14	30 14	33 16	35 18	31 15	33 16	35 17	36 18
Embraer ERJ 145	24167 12542 900	14 6	15 6	16 7	17 8	16 7	16 8	17 8	18 8

Aircraft Type	MTOW (kg) OWE (kg) TP (kPa)	Flexible Pavement Subgrade CBR %				Rigid Pavement Subgrade K in MN/m3			
		A **15**	**B** **10**	**C** **6**	**D** **3**	**A** **K150**	**B** **K80**	**C** **K40**	**D** **K20**
F/A- 18 S	23542 10523 1723	22.5 10	21.6 9.7	21.5 9.6	21 9.5	23.4 10.4	23.2 10.3	23 10.2	22.8 10.2
Fokker 100	46090 24779 940	25 12	27 13	31 14	33 16	28 13	30 14	31 15	33 16
Fokker 50	20904 12746 590	9 5	11 6	13 7	14 8	11 6	12 7	13 7	13 8
Fokker F27- 500	20904 12236 570	9 5	11 5	13 6	14 8	11 6	12 6	13 7	13 7
Fokker F28- 1000	33140 17845 530	14 6	17 8	20 9	23 11	16 8	18 9	20 9	21 10
GG II	28100 16000 930	15.4 7.7	16.6 8	18.3 9.3	19 10.5	17.6 9.0	18.4 9.5	19 10	19.7 10.4
GG III	31824 17340 1210	19 9	20 9	22 10	23 12	22 11	23 11	23 12	24 12
GG IV	34068 19278 1210	20 10	22 11	24 12	25 13	24 12	25 13	25 13	26 14
GG V	41310 21930 1370	26 12	28 13	30 14	31 15	31 14	32 15	32 16	33 16
Hercules C130	79333 36709 670	29 12	34 14	37 15	43 17	33 14	36 15	39 16	42 18
HS-748	20183 11786 550	7.7 4	9.5 4.8	11.1 5.6	13 7	9.6 5	10.5 5.5	11.3 6	12 6.4
HS/BAe 125	11420 6220 830	6 3	6 3	7 3	8 4	7 3	7 4	8 4	8 4
Ilyushin IL- 76T	171000 83819 640	24 9	27 10	34 12	45 16	29 11	33 13	30 14	34 14
Jetstream 31,32	7036 5710 390	3 3	4 3	5 4	6 5	4 4	5 4	5 4	5 4
Jetstream 41	10910 6424 830	5 3	5 3	6 3	7 4	6 3	6 3	7 4	7 4
Learjet 24F	6322 5710 790	3 3	3 3	4 3	4 4	4 3	4 4	4 4	4 4

Aircraft Type	MTOW (kg) OWE (kg) TP (kPa)	Flexible Pavement Subgrade CBR %				Rigid Pavement Subgrade K in MN/m3			
		A **15**	**B** **10**	**C** **6**	**D** **3**	**A** **K150**	**B** **K80**	**C** **K40**	**D** **K20**
Lear 35A	7824 4132 1080	3.9 1.9	4 1.9	4.6 2.1	5.1 2.4	4.7 2.2	4.9 2.3	5.1 2.5	5.3 2.6
Learjet 40, 45	9996 6222 790	5 3	6 3	7 4	7 4	6 4	7 4	7 4	7 4
Learjet 55B,C	9891 5914 1240	6 3	6 3	7 3	7 4	7 4	7 4	7 4	7 4
Learjet 60	10812 6426 1480	6 3	7 4	7 4	8 4	8 4	8 4	8 5	8 5
Lockheed C130-H	70300 35000 550	23 10	28 13	32 15	37 16	26 13	29 14	32 15	35 16
Lockheed C130-JH	70300 35000 725	27 12	30 14	33 15	38 17	30 14	33 15	35 16	38 17
MD-81	64037 35690 1140	36 18	38 19	43 21	46 24	41 20	43 21	45 23	46 24
MD-90-30	71277 39972 1140	41 20	43 21	48 24	52 27	46 23	48 24	50 26	52 27
Orion P3A	61235 27000 1310	35 13	38 14	42 15	44 17	41 15	43 16	44 17	46 18
SAAB 340 A,B	13358 8259 820	6 4	6 4	8 4	9 5	7 4	8 4	8 5	9 5
Shorts 330	10400 6730 550	6 4	8 5	9 6	9 6	7 5	8 5	8 5	8 5
Shorts 360	12338 7851 540	7 5	9 6	10 7	11 7	9 6	9 6	9 6	9 6
Westwind I	10660 6066 1050	9 5.1	9.3 5.3	9.2 5.3	9.4 5.4	9.1 5.2	9.1 5.2	9.2 5.2	9.2 5.3