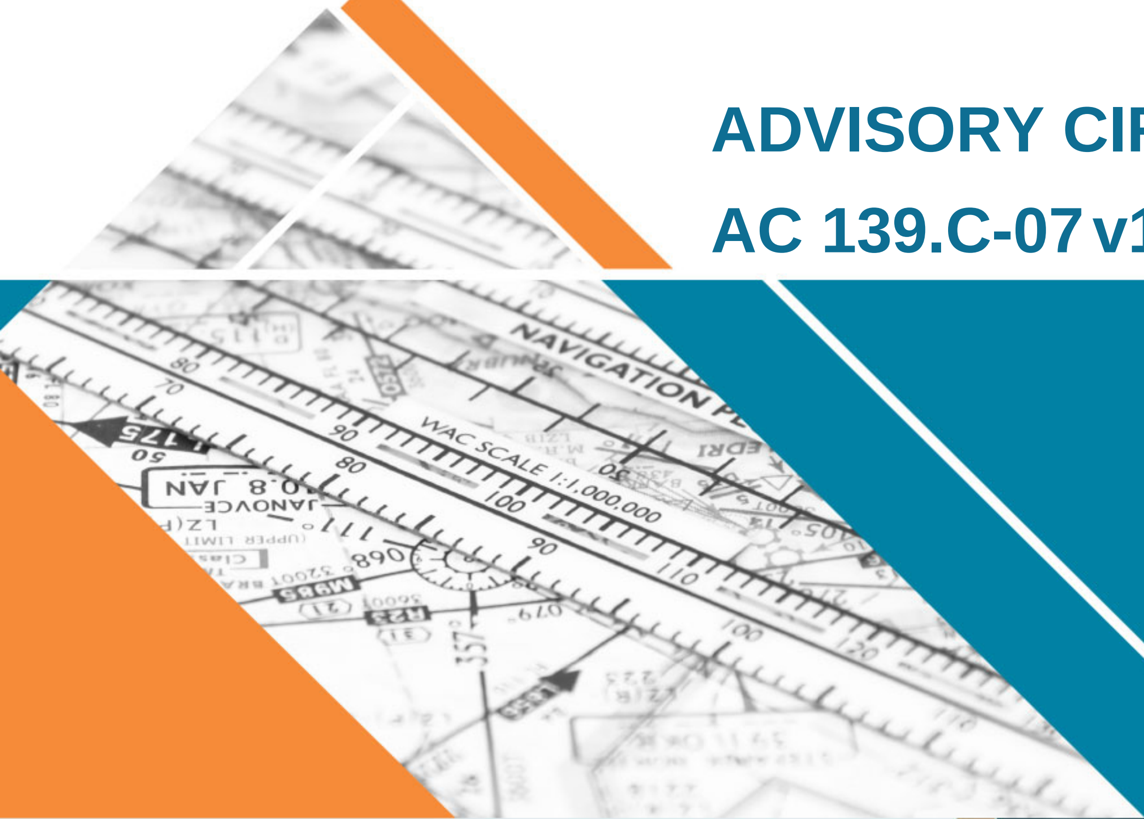
Australian Government
Civil Aviation Safety Authority

ADVISORY CIRCULAR

AC 139.C-07 v1.0



Strength rating of aerodrome pavements

Date August 2020

File ref D19/165507

Audience

This advisory circular (AC) applies to:

- aerodrome owners/operators
- aircraft owners/operators
- persons who specialise in pavement design
- consultants engaged to act on behalf of the aerodrome owner/operator
- the Civil Aviation Safety Authority (CASA).

Purpose

The purpose of this AC is to provide aerodrome operators with guidance on pavement design. Specifically:

- the bearing strength of aerodrome pavements to ensure they are capable of withstanding the traffic of aeroplanes which the aerodrome facility is intended to serve
- rating the strength of pavements using the International Civil Aviation Organization (ICAO) strength rating method (ACN-PCN).

This AC also introduces the new ICAO aerodrome pavement strength rating system that is due to come into effect in 2024.

For further information

For further information, contact CASA (e-mail aerodromes_regs@casa.gov.au or telephone 131 757).

Unless specified otherwise, all subregulations, regulations, divisions, subparts and parts referenced in this AC are references to the *Civil Aviation Safety Regulations 1998 (CASR)*.

Status

This version of the AC is approved by the Manager, Flight Standards Branch.

Note: Changes made in the current version are not annotated. The document should be read in full.

Version	Date	Details
v1.0	August 2020	This AC has been re-written and published to align with the re-write of the Part 139 MOS.
(0)	August 2011	The first Advisory Circular (AC) to be written on the strength rating of aerodrome pavements.

Contents

1 Reference material

1.1 Acronyms

The acronyms and abbreviations used in this AC are listed in the table below.

Acronym	Description
AC	Advisory Circular
ACN	Aircraft Classification Number
ACR	Aircraft Classification Rating
AIP	Aeronautical Information Publication
AIS	Aeronautical Information Service
CASA	Civil Aviation Safety Authority
CASR	*Civil Aviation Safety Regulations 1998*
CBR	California Bearing Ratio
ERSA	En Route Supplement Australia
FAA	Federal Aviation Administration (of the USA)
ICAO	International Civil Aviation Organization
MOS	Part 139 Manual of Standards
MTOW	Maximum Take-off Weight
OWE	Operating Weight Empty
PCA	Portland Cement Association
PCN	Pavement Classification Number
PCR	Pavement Classification Rating
RPT	Regular Public Transport
USA	United States of America

1.2 Definitions

Terms that have specific meaning within this AC are defined in the table below.

Term	Definition
Aircraft Classification Number (ACN)	A number expressing the relative effect of an aircraft on a pavement for a specified standard subgrade category.
California Bearing Ratio	The resistance of a soil to controlled penetration, usually when soaked, relative to that of a standard Californian limestone.

Term	Definition
COMFAA	A software published by the Federal Aviation Administration (FAA) for calculating the Aircraft Classification Number (ACN) of an aircraft.
FAARFIELD	A software published by the FAA.
material equivalence factors	Values that allow the structural contribution of a thickness of one pavement material to be converted to an equivalent amount thickness of another material.
modulus of subgrade reaction (k-value)	The resistance of a subgrade to large scale vertical deformation when subject to a standard loading condition, usually performed in the field.
pavement concession	Permission granted by an aerodrome operator to an aircraft operator to operate to/from a runway with a PCN lower than the aircraft ACN.
Pavement Classification Number (PCN)	A number expressing the bearing strength of a pavement for unrestricted operations by aircraft with aircraft classification number less than or equal to the pavement classification number.
unrestricted operations	Operations that may occur without restraint because the ACN is lower than the PCN.

1.3 References

Regulations

Regulations are available on the Federal Register of Legislation website https://www.legislation.gov.au/

Document	Title
Part 139 MOS	Part 139 (Aerodromes) Manual of Standards

International Civil Aviation Organization documents

International Civil Aviation Organization (ICAO) documents are available for purchase from http://store1.icao.int/

Document	Title
ICAO Doc 9157	Aerodrome Design Manual Part 1 Runways
ICAO Doc 9137	Airport Services Manual Part 2 - Pavement Surface Conditions
ICAO International Standards and Recommended Practices	Annex 14 to the convention on International Civil Aviation - Aerodromes Volume I

Advisory material

CASA's advisory circulars are available at http://www.casa.gov.au/AC

CASA's Civil Aviation Advisory Publications are available at http://www.casa.gov.au/CAAP

Document	Title
FAA 2014	COMFAA v3.0 computer program, Federal Aviation Administration, 14 August.
FAA 2020	Airport Pavement Design and Evaluation, Advisory Circular 150/5320/-6G, DRAFT, 19 June.

2 Background

2.1 Aircraft and pavements

2.1.1 When first developed in the early 1900s, aircraft were light and were commonly operated from grassed paddocks. The DC-3 which was introduced in 1936 was the first aircraft to require a pavement from which to take-off and land. Since that time, aircraft have progressively become larger and heavier, placing more demands on the ground on which they operate from.

2.1.2 Pavement failures in the 1960's prompted the US Army Corps of Engineers[1] to develop formalised pavement thickness and strength design systems. The work done by the Corps between the 1950's and the 1970's remains critical to modern aircraft pavement thickness design and the associated strength rating systems.

2.2 Work by the Corps

2.2.1 The Corps aerodrome pavement design methods were calibrated against the results of full-load trafficking tests conducted on large-scale (i.e. not full-scale) test pavements by the Corps (Figure 1) through the 1950s to the 1970s.

2.2.2 The Corps established an empirical relationship between aircraft loads, subgrade CBR and the required pavement thickness to cater for 5,000 ‘coverages’. The resulting curve represented the outcome of the 37 tests completed up to 1971, which was around the time the Boeing 747 came into service. The resulting empirical design method was known as S77-1 (Figure 2).

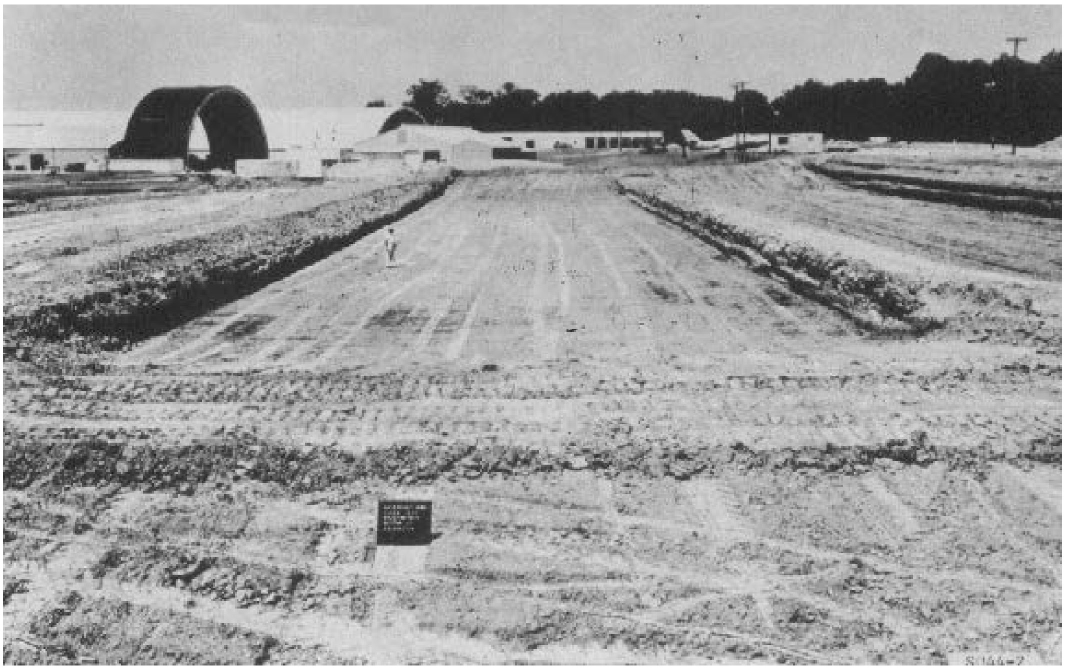


Figure 1. Example of US Army Corps pavement test section

[1] Generally referred to as the Corps.

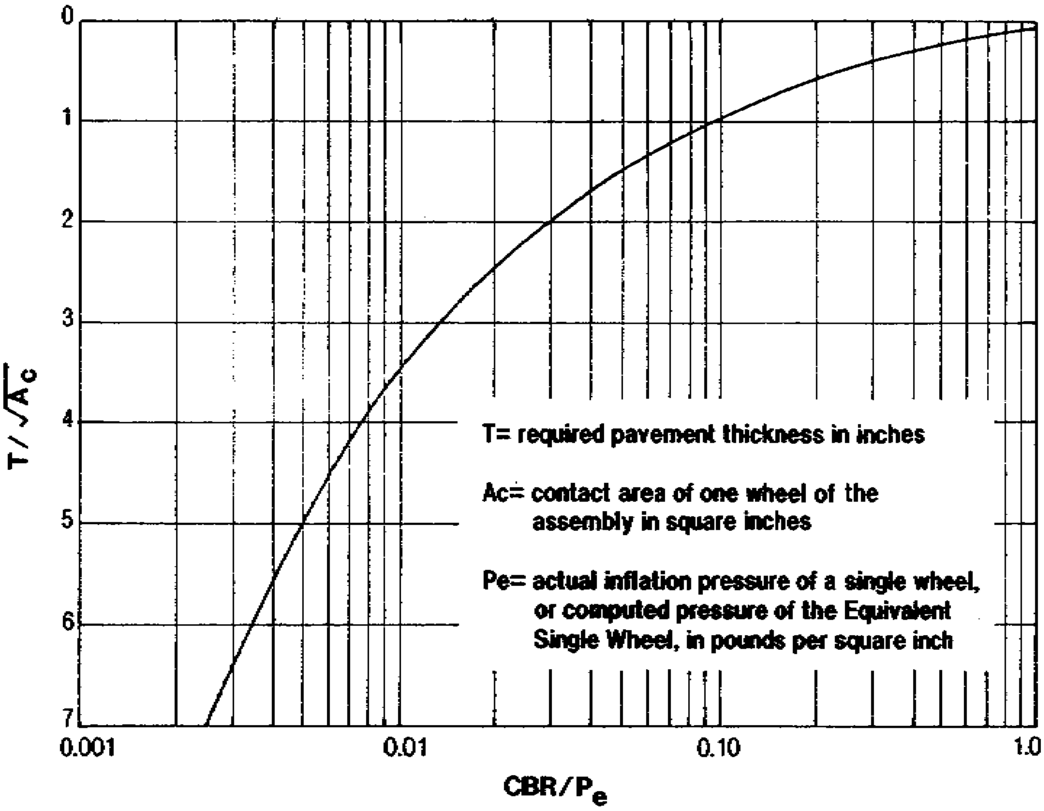


Figure 2. US Corps of Engineers original design curve

2.2.3 Because the S77-1 is an empirical design method, its use to design much thicker pavements, for larger aircraft with greater wheel loads and repetitions, introduced a degree of uncertainty. Consequently, recent FAA design methods attempt to take into account both the test pavement data, as well as the observed performance of full-depth pavements under actual service conditions at US airports.

2.2.4 Further tests have since been carried out by the FAA to quantify the pavement damage caused by newer larger aircraft such as the B777 and A380. These tests have resulted in adjustments to the S77-1 curve and method.

2.2.5 The efforts by the Corps, and later by the FAA, form the basis of the calculations of relative damage caused by different aircraft that is still relied upon for the current aircraft pavement strength rating system.

2.2.6 Similar work has been repeated for rigid aircraft pavements and S77-1 includes similar relationships between:

– aircraft loading
– underlying material support
– concrete strength
– rigid pavement thickness.

2.3 S77-1 design method

2.3.1 The S77-1 design method, as updated and republished by the FAA, remains the purist representation of the relationships between aircraft loading, subgrade bearing capacity (i.e. CBR), aircraft repetitions and pavement thickness. Many modern pavement softwares are calibrated to the S77-1 relationship, despite being far more sophisticated and precise in their calculations.

2.3.2 Despite various charts being published over the years, the most practically usable form of S77-1 is the computerised version embedded in the FAA software known as COMFAA (FAA 2014). The main use of COMFAA is to determine the Aircraft Classification Number (ACN) of any aircraft at any operating mass and tyre pressure combination, for use in the aircraft pavement strength rating system, which is described in detail below and as shown for the B737-800 in Figure 3. The software allows any number of coverages by any aircraft to be entered to determine the required pavement thickness, based on the S77-1 empirical relationships.

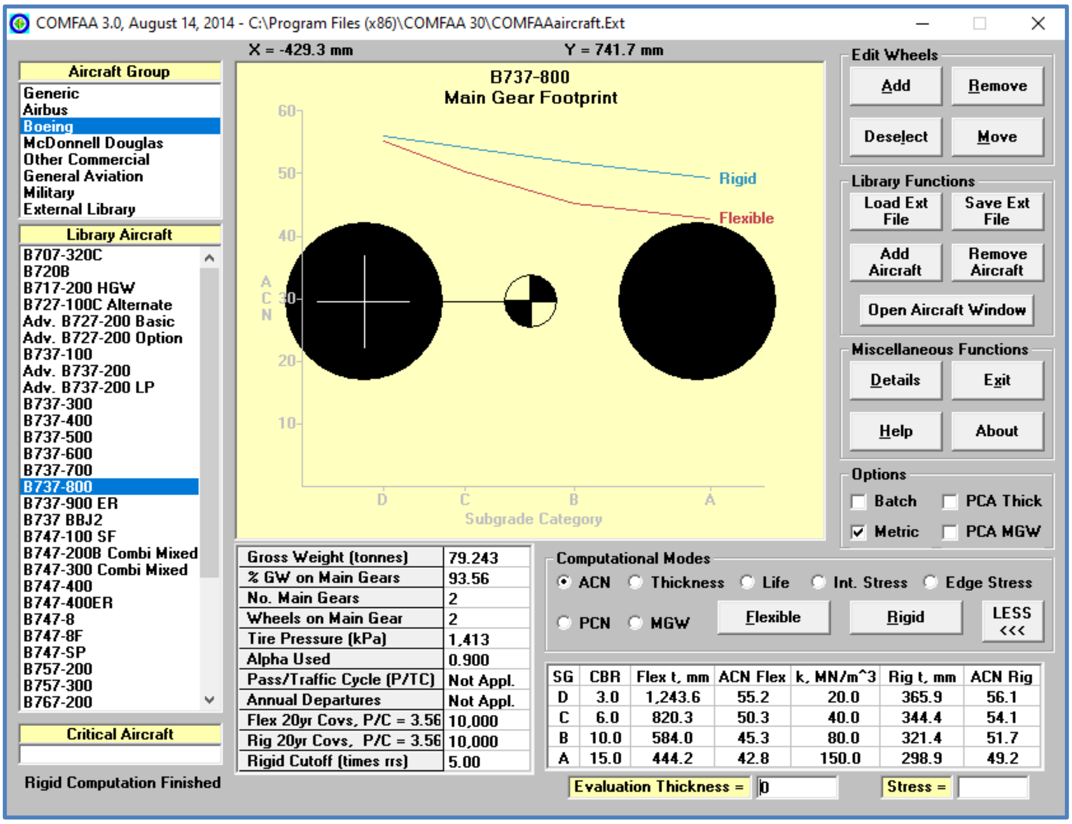


Figure 3. Example of COMFAA calculations for B737-800.

2.3.3 When determining a S77-1 pavement thickness for any given aircraft and subgrade condition, it is important to understand the few limitations. The first relates to rigid pavement subgrade support and the second relates to flexible pavement composition.

2.3.4 Unlike flexible pavements, rigid aircraft pavement subgrade support is expressed by a parameter known as the modulus of subgrade reaction, commonly referred to as the 'k-value'. This is shown in Figure 3 as 'k' in the ACN table in the bottom-right corner. In contrast, the flexible pavement ACN values are based on CBR as the indicator of subgrade support.

2.3.5 In practice, the k-value test is cumbersome and expensive and is rarely performed. Therefore, a conversion between CBR, which is simple and easy to measure in the laboratory, and k-value is required. Different jurisdictions publish different conversions, with indicative values shown in Table 1.

Table 1. Indicative k-values compared to CBR values.

CBR (%)	k-value (kPa/mm or MN/m3)
3	27
4	34
5	40
6	43
8	48
10	54
15	60

2.3.6 Further to that above, there is an additional complication relating to the effect of the sub-base layer, which is commonly located between the concrete slab and the prepared subgrade. The k-value is usually measured at the top of the subgrade. However, COMFAA does not directly account for the benefit associated with the sub-base material or thickness. Rather, the k-value must be selected to account for the combined support offered by the subgrade and the sub-base layer(s).

2.3.7 Regarding flexible pavements, the S77-1 thickness calculated by COMFAA are based on a standard composition of pavement. The standard composition is shown in Figure 4 but is not commonly used for the construction of Australian aerodrome pavements. Where an existing pavement thickness is measured by geotechnical investigation, the thickness must be converted to an equivalent thickness based on the S77-1 structure, using material equivalence factors. Different jurisdictions publish different materials equivalence factors and Table 2 provides indicative factors for common materials. The materials designations (e.g. P-401) are standard FAA materials specification references, although there are comparable materials available in Australia.

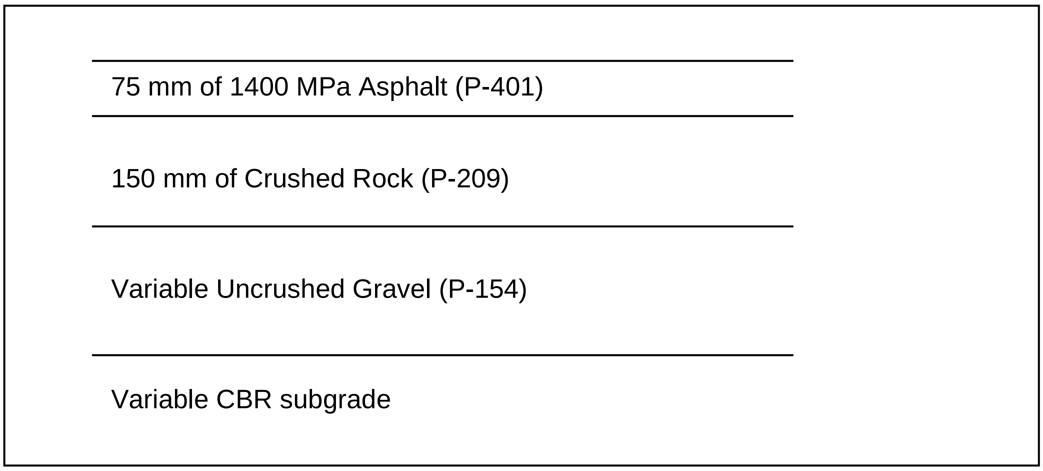


Figure 4. Standard S77-1 pavement composition.

Table 2. Indicative common materials equivalence factors

1 mm of this material	Is equivalent to the following thickness (mm)	Of this material
Asphalt (P-401)	1.3	Crushed rock (P-209)
Crushed rock (P-209)	1.2	Uncrushed gravel (P-154)
Asphalt (P-401)	1.6	Uncrushed gravel (P-154)

2.4 Strength of aerodrome pavements

2.4.1 In parallel with the work done by the Corps to design aerodrome pavement structures in a more reliable manner, aircraft continued to evolve. As aircraft became heavier and their wheel loads increased, pavements needed to be constructed or upgraded to be stronger than they were before.

2.4.2 One significant step in aircraft growth was the DC8-50, first introduced in 1958. At the time, this was the most damaging commercial aircraft available, with 19 t wheel load on 1.35 MPa tyre pressure and with close wheel spacing. This aircraft had significant impact on airport pavements and triggered considerable pavement strength upgrades.

2.4.3 To prevent aircraft from being developed that increased demand for higher strength pavements, the FAA implemented a policy to restrict the development of new aircraft that stressed pavements more than a 159 t, DC8-50 aircraft. This was achieved by limiting FAA funding of new pavement developments to the cost of a pavement structure required by the DC8-50 aircraft. The FAA policy was rescinded in the 1990s, resulting in a new phase of steadily increasing aircraft weights and tyre pressures over time.

2.4.4 As aircraft got larger, the difference between 'large' and 'small' aircraft became greater. It is clear, that despite the size of the most demanding of the commercial aircraft in operation, many airports only required pavements strong enough to accommodate much smaller aircraft loadings. That necessitated a system for rating and advertising the strength of the aerodrome pavements at any given airport, so that aircraft operators would be able to determine whether the pavements would be able to accommodate the loadings associated with their particular aircraft. Otherwise, many smaller airports would need pavements that were designed for the most demanding aircraft, which would be unlikely to ever operate from that airport.

2.4.5 To allow an internationally consistent system for advising the strength of a particular aircraft pavement, ICAO developed and implemented a system known as Aircraft Classification Number-Pavement Classification Number, or more commonly as ACN-PCN. The ICAO ACN-PCN system was introduced in 1981 and as a member State of ICAO, Australia uses the ACN-PCN pavement strength rating system.

2.4.6 Unrated pavements are generally limited to aircraft of gross weight not exceeding 5,700 kg.

3 Aircraft Pavement Strength

3.1 General

3.1.1 The strength of aircraft pavements is complex and depends on many factors. Some of these factors are theoretical and relate primarily to the designed strength of the pavement. Other factors are related to construction and material variability, and these affect the difference between the designed strength and the actual strength achieved during construction. This is also different to the actual strength of the pavement on any given day, which is affected by the temperature and moisture conditions, as well as the distress or failure in the pavement structure.

3.1.2 Because aircraft pavement strength rating primarily deals with the theoretical or designed strength of the pavement, that is the strength focussed on here. Construction and environmental factors that can affect pavement strength are not considered.

3.1.3 The Part 139 MOS prescribes only that the bearing strength of an aerodrome pavement must be capable of bearing the weights and frequency of the nominated aircraft.

3.1.4 The Part 139 MOS maintenance requirements assess and report the availability of the runway for continued use. The aircraft load limit placed upon the pavement is the PCN and tyre pressure value published in ERSA. The aerodrome operator sets this limit, usually with the assistance of a pavement engineer.

3.1.5 Should an aerodrome operator desire, a more demanding aircraft that the runway was designed for could be permitted to operate. However, the lifespan of the runway is likely to be adversely impacted, particularly when frequent operations occur. Any decision to allow such operations is a cost benefit decision made by the aerodrome operator factoring in increased maintenance and/or rehabilitation earlier than was originally intended.

3.1.6 Runway shoulders, runway strips, stopways, taxiways and taxiway shoulders have other strength requirements that are partly relative to the strength of the associated runway.

3.2 Flexible pavement strength

3.2.1 Flexible pavement strength is primarily determined by:

- subgrade bearing capacity (expressed as the CBR)
- pavement layers and their thickness (the number and thickness of each material layer)
- pavement material types (different materials have different stiffness, which spread the load differently, usually indicated by the elastic modulus of the material).

3.2.2 When designing or rating the strength of the pavement, the traffic loading is also important. Traffic loading is characterised by:

- aircraft type (which determines the number and spacing of wheels)

- weight (including the portion of weight on each wheel, which is affected by the aircraft's centre of gravity)
- tyre pressure (usually standardised but can be adjusted)
- aircraft passes (the number of times the wheels pass a certain section of pavement)
- passes to coverages (the number of times a specific area is covered during a number of passes, which is affected by the number, orientation and spacing of the wheels, as well as the degree of channelisation of the aircraft traffic).

3.2.3 All these factors have different influences on pavement strength. Or conversely, the different factors have different influences on the thickness of pavement that is required for a given design scenario. For example, Figure 5 shows the relative influence of various (normalised to a 1-5 scale) factors on total flexible aerodrome pavement thickness. Subgrade CBR and aircraft mass are the most influential factors.

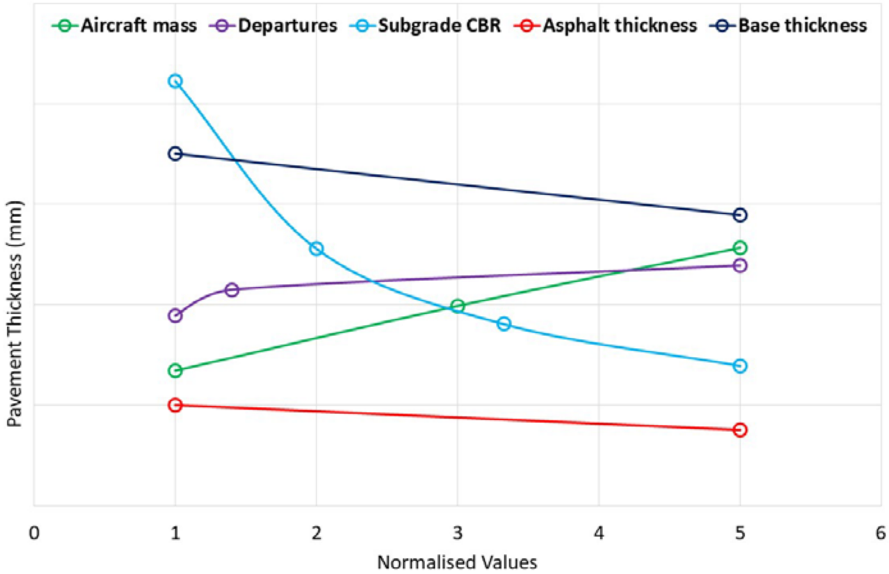


Figure 5. Flexible pavement factor influence on total pavement thickness.

3.3 Rigid pavement strength

3.3.1 Rigid pavement strength (or thickness required) are similarly influenced by similar factors. Although the aircraft factors are the same, the pavement and material related factors differ:

- subgrade bearing capacity (expressed as the k-value)
- sub-base type (usually either granular or bound by cement)
- sub-base thickness (typically 150-250 mm)
- concrete strength (expressed as the flexural strength after 28 days of curing)
- concrete thickness (the primary layer in the pavement structure).

3.3.2 Figure 6 shows the relative influence of various factors on the concrete thickness in a typical rigid aircraft pavement. The aircraft mass and the concrete strength are the most influential parameters. Unlike flexible pavements, the strength of rigid pavements is less influenced by the subgrade support.

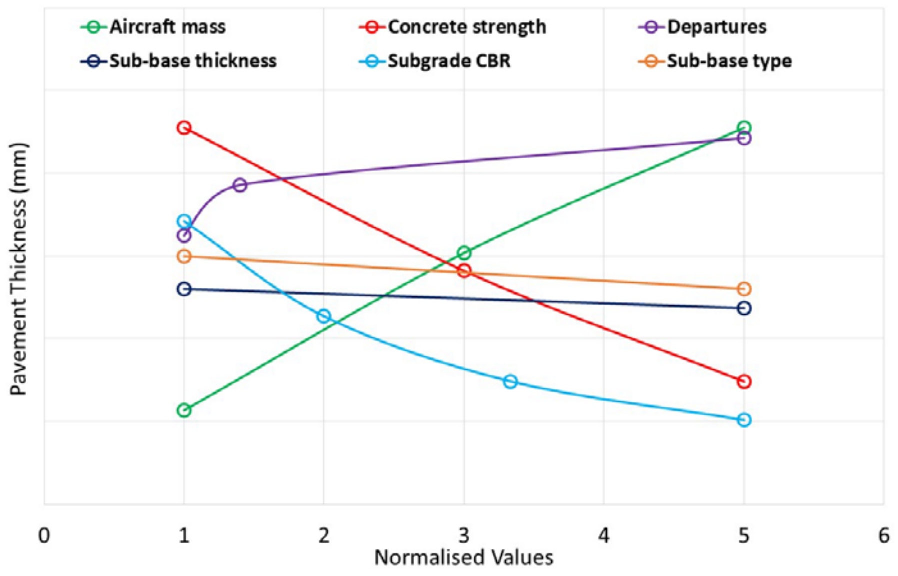


Figure 6. Rigid pavement factor influence on concrete thickness.

3.4 Relative pavement strength

3.4.1 Aircraft pavement strength rating is primarily performed for runways. Each runway is given a strength rating that is published in the AIP. Taxiways, aprons and other areas are not given a strength rating, although airports must understand the relative strength of these other pavements, so that aircraft can safely taxi and park.

3.4.2 In general, the strength of the runway, taxiway(s) and apron(s) are all the same, taking into account minor differences associated with different degrees of aircraft traffic channelisation and doubling of aircraft passes associated with backtracking on runways where required.

3.4.3 The following pavement areas are not regularly trafficked but may be trafficked from time to time and as such they are generally not constructed to the same strength rating:

- Runway shoulders (required to support an aircraft running onto the shoulder without causing structural damage to the aircraft).
- Runway strip (avoid differences in bearing strength that present a hazard to aircraft that run off the runway).
- Stopway (support at least one pass of an aircraft for which the runway is intended to service, without causing structural damage to the aircraft).
- Taxiway (should be at least as strong as the runway that it supports).
- Apron (should support the aircraft traffic that it is intended to support).

3.4.4 Only limited guidance is available regarding the practical requirements for designing these associated pavement areas.

3.4.5 Historically, Australian aerodromes simply designed shoulders and other irregularly trafficked areas to be approximately half the thickness of the pavement they support. It is also logical to sanitise the layer thicknesses and materials to provide a cost effective solution that is also relatively simple to construct at the transition from the full strength pavement to the reduced strength pavement, by avoiding small steps between layers.

3.4.6 As an example, the flexible thickness of a pavement, calculated using COMFAA, for various numbers of passes of a B737-800 and various subgrades, are shown in Table 3. The number of 20 passes was used to approximate 15 passes as recommended in the USA because 1 annual departure (equal to 20 passes over a 20-year design life) is the lowest traffic frequency that can be entered into COMFAA. As a result, pavement thicknesses for 1 pass, required by MOS 139 for the stopway, cannot be determined by this method.

Table 3. Various pavement thickness for the B737-800

Subgrade condition	10,000 passes	20 passes	1 pass
CBR 3	1,138 mm	373 mm	Not computable
CBR 6	743 mm	252 mm	Not computable
CBR 10	531 mm	187 mm	Not computable
CBR 15	406 mm	147 mm	Not computable

3.4.7 The 20 pass pavement thicknesses are around 35% of the 10,000 pass thicknesses, which is generally similar to the half-thickness approach adopted by Australian airports in the past. However, if the runway was heavily trafficked, with say 100,000 passes of the critical aircraft over the life, then the 20 pass thicknesses would reduce, when expressed as a percentage of the greater full pavement strength thickness.

3.4.8 In practice, to simplify construction, the runway shoulder thickness is also appropriate for the stopway, taxiway shoulders and apron shoulders. Furthermore, in practice, the runway strip can only reasonably be constructed from the locally available subgrade material, which will be stronger when dry and weaker when wet. An aerodrome operator's ability to control the runway strip composition is very limited in practice.

4 The Pavement Strength Rating System

4.1 General

4.1.1 The ACN-PCN system was introduced by the International Civil Aviation Organization (ICAO) in 1981 and as a member State of ICAO, Australia follows this system for aerodrome pavement strength rating. The Part 139 MOS requires the operator of a certified aerodrome to provide to the aeronautic information service (AIS) the strength rating of the runway pavement calculated using the ACN-PCN pavement rating system, for publication in the AIP-ERSA.

4.1.2 The ACN-PCN system is fundamentally simple. In principle, every aircraft has a calculatable ACN value. That aircraft is permitted to operate in an unrestricted manner on any runway that has an equal (or greater) PCN value than the aircraft ACN. It is important to note that 'unrestricted' does not mean the pavement is necessarily able to support an infinite number of operations by that aircraft. Rather, it means that no special permission is required prior to each operation. When the aircraft ACN exceeds the runway PCN, the aircraft operator must obtain the aerodrome operator's permission before operating, a process known as obtaining a pavement concession.

4.1.3 Although appearing simple, the system is complicated by the desire for that simplicity. The system was designed to be simple in its operation. That required significant simplifications that lead to anomalies when rating the strength of pavements that are designed with sophisticated modern pavement thickness design tools. These tools use more sophisticated mathematics to calculate the magnitude of the critical indicators of damage that determine the relative effect of different aircraft. As a result, some pavements that have been designed for a particular aircraft to operate, have subsequently been assigned a PCN value that does not allow that same aircraft to be operated in an unrestricted manner.

4.2 Aircraft Classification Number

4.2.1 Every aircraft has an ACN value that represents the relative damage caused to the pavement's subgrade and is dependant only upon the aircraft weight, tyre pressure and the subgrade category of the pavement that it is operating on.

4.2.2 The inclusion of the subgrade category in the ACN seems unusual because the pavement is independent of the aircraft. However, the subgrade category is simply used as an indicator of the degree of interaction between the various wheels in multi-wheel landing gear. A pavement on a strong subgrade will be thin, meaning the degree of wheel interaction is low. In contrast, a weak subgrade requires a thick pavement which means that the wheels interact significantly at the depth of the subgrade. The effect of pavement thickness, indicated by the subgrade category, is important for comparing the relative damage of different aircraft wheel arrangements.

4.2.3 The ACN value is always determined when the aircraft is loaded so that the centre of gravity is in the most adverse location. These calculations are performed by the aircraft manufacturers and are contained in the airport planning manual for each aircraft type and variant.

4.2.4 Conveniently, ACN values increase linearly with the mass of the aircraft and are generally insensitive to tyre pressure. As a result, the ACN of a particular aircraft is readily shown in a graph that ranges from the operating mass empty (OME) weight to the maximum operating mass (MOM) on the horizontal axis and ACN on the vertical axis. This is usually shown for the standard or maximum tyre pressure. Four lines are required for each graph, representing the four subgrade categories that are explained and detailed later, and different graphs are required for flexible and rigid pavements. An example is shown in Figure 7 for the B737-800 on flexible pavements.

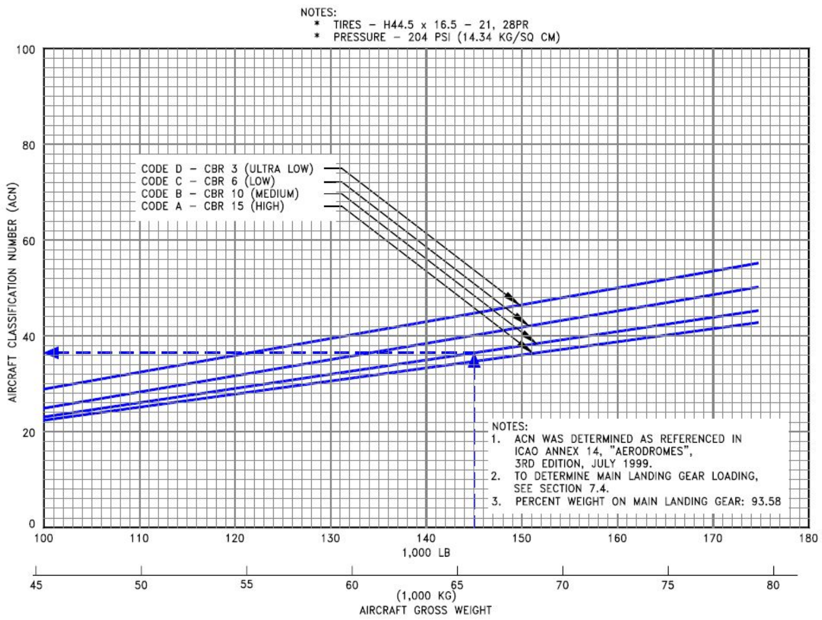


Figure 7. Example of flexible pavement ACN graph for B737-800.

4.2.5 The linear relationships between aircraft weight and ACN allow for interpolation between the minimum and maximum values or equations for the calculations. In practice, software such as COMFAA (FAA 2014) is used to calculate the ACN of any aircraft at any operating mass and any tyre pressure.

4.2.6 The technical definition of the ACN is twice the wheel load (in tonnes) which on a single wheel, inflated to 1.25 MPa, causes vertical pavement deflection (calculated at the top of the subgrade) equal to that caused by the actual multi-wheel aircraft gear, at its actual gear load and its actual tyre pressure. In practice, ACN values for commercial aircraft typically range from 5 to 120.

4.2.7 For a particular aircraft at a specific mass and tyre pressure, there is only one flexible pavement ACN for each subgrade category. There is a second ACN for rigid pavements The ACN value is exact and mathematically determined, meaning it is not open to interpretation or discretion. That is not the case for the PCN value.

4.3 Pavement Classification Number

4.3.1 In contrast to the ACN, the PCN is set by the airport owner with some discretion and is open to interpretation. The PCN is essentially an advertisement to airlines and aircraft operators that are welcome to operate without restriction, that is, without needing to seek specific permission due to pavement strength and overload.

4.3.2 An aerodrome operator might set its PCN conservatively to protect its pavement against damage. Another aerodrome operator might set its PCN aggressively to attract new aircraft operators, accepting the increased damage that these aircraft might cause.

4.3.3 A PCN is reported in a five-part format. Apart from the numerical value, notification is also required of the pavement type (rigid or flexible) and the subgrade support category. Additionally, provision is made for the aerodrome operator to limit the maximum allowable tyre pressure. A final indication is whether the assessment has been made by a technical evaluation or from past experience of aircraft using the pavement.

4.3.4 The full PCN expression is best explained by example. As an example, the PCN for Brisbane Airport is: PCN 108/F/D/X/T.

- 108 is the numerical element against which the ACN is compared.
- F is to indicate a Flexible pavement, rather than R for Rigid.
- D is the category of subgrade bearing strength, detailed in Table 4.
- X is the tyre pressure category, detailed in Table 5.
- T is to indicate a Technical assessment, rather than U for a Usage based assessment.

Table 4. ACN-PCN subgrade categories

Subgrade Category	Nominal CBR	CBR Range
A	15	Greater than 13
B	10	8-13
C	6	4-8
D	3	Less than 4

Table 5. ACN-PCN tyre pressure categories

Tyre pressure category	Tyre pressure limit
W	Unlimited
X	1.75 MPa
Y	1.25 MPa
Z	0.50 MPa

4.3.5 Australia has traditionally published the actual tyre pressure limit, rather than a category of limits as required by ICAO. Consequently, most ERSA entries for Australian aerodromes still include a numeric tyre pressure limit, in kilopascals (kPa). For example, the Brisbane airport runway ERSA includes a tyre pressure limit of 1,750 kPa, which falls into the X category of tyre pressure categories in Table 5.

4.3.6 The Technical (T) or Usage (U) basis of determining the PCN is often confusing. A technical rating is usually associated with reverse engineering of the existing pavement to determine whether a particular aircraft is acceptable or not. In contrast, a usage-based assessment is made when a particular aircraft is known to operate regularly, without causing excessive pavement damage, and the PCN is set equal to the ACN of that aircraft. More detail on setting the PCN for a particular pavement is provided later.

4.3.7 To determine whether an aircraft can operate unrestricted, or whether a pavement concession is required, two checks are made:

- the ACN is no greater than the PCN.
- the tyre pressure (or category) does not exceed the nominated pressure (or category).

4.4 Setting a Pavement Classification Number

4.4.1 The most challenging element of the ACN-PCN system is the setting of an appropriate PCN for the runway in question. It is the primary element that allows discretion and may require some judgment. This reflects the aerodrome owners need to set the PCN at a value that allows reasonable aircraft operations to continue without the administrative burden of unwarranted pavement concessions, but at the same time, not setting the PCN too high, introducing unreasonable risk of excessive pavement damage.

4.4.2 In essence, an aerodrome owner should set the PCN of its runway to a value that allows the aircraft that the aerodrome operator is comfortable to operate on a regular basis, and in an unrestricted manner. For many aerodromes, that is a simple case of:

- determining the appropriate subgrade category based on historical records, the existing published strength rating, design assumptions or some geotechnical assessment of the subgrade
- determining the range of aircraft that regularly use the runway without causing excessive damage
- calculating the ACN of each of the larger regular aircraft, ensuring that the ACN calculated is for the subgrade category that has been determined for the runway
- setting the PCN to the highest of the ACN values
- setting the tyre pressure limit to the highest tyre pressure of the of the regular larger aircraft.

4.4.3 Where a specific design has been prepared for a new or upgraded runway, the design report should include a statement regarding the aircraft traffic adopted for pavement thickness design. In this case, the PCN could be set to the highest ACN of the regular aircraft in operation.

4.4.4 Where a specific design has not been prepared and the basis of the current strength rating is not known, reverse engineering of the existing pavement structure and the existing or future potential aircraft traffic can be used to determine the PCN, using the same principles that are applied to a new design, but adjusting the aircraft traffic to suit the existing pavement structure, rather than determining a structure that is adequate for the predicted aircraft traffic.

4.4.5 The challenge is to determine the basis of 'regular usage'. For many aerodrome operators, identifying regular use is simple because they support flights by just one or two passenger aircraft type. Irregular use of larger military aircraft, firefighting aircraft or one-off freight charters would not normally be considered 'regular'. Another example would be a domestic aerodrome that regularly caters for B737/A321 aircraft, but also supports chartered, or seasonal, limited international flights from a A330/B767 aircraft. The aerodrome operator may be tempted to set the PCN at the ACN of the larger aircraft, but the pavement may only be adequate for limited operations of that aircraft. Therefore, the increased administrative burden associated with pavement concessions for the larger aircraft are likely to be justified by the increased control against excessive pavement damage that may result, in the event that the A330/B767 operations increase in frequency over time.

4.4.6 Once the numerical PCN value is determined, the setting of the tyre pressure limit is generally much simpler. The tyre pressure limit is intended to protect the runway surface against near-surface shear stresses. In reality, well designed and constructed surfaces are unlikely to be damaged by high tyre pressures, with only minor scuffing of the surface caused by dual and triple axles more likely for more fragile surfaces. Furthermore, most runways are provided with airport-quality sprayed seals or airport-quality asphalt mixtures, generally using a modified bituminous binder. This means that tyre pressures limits can generally be set to the tyre pressure of the aircraft whose ACN is selected as the basis of the PCN, or any other regular aircraft that has a lower ACN, but a higher tyre pressure. Table 6 summarises tyre pressures that are generally appropriate for various runway surfaces.

Table 6. Reasonable tyre pressure limits for different surface types

Surface type	Tyre pressure limit	Typical aircraft
Reasonable quality sprayed seal without modified binder	750 kPa	General Aviation aircraft and C130 Hercules
Road asphalt without modified binder	1000 kPa	Fokker 100
Good quality sprayed seal with modified binder	1500 kPa	B737-800/A321-200
Reasonable quality airport asphalt	1750 kPa	All known commercial aircraft
Good quality airport asphalt with modified binder	Unlimited	All known commercial and military aircraft

Surface type	Tyre pressure limit	Typical aircraft
Concrete, although this has not been used in Australia for runways	Unlimited	All known commercial and military aircraft. (Note jet fighters often operate with very high tyre pressures)

4.5 Monitoring pavement strength

4.5.1 Pavements subject to overload conditions are likely to deteriorate at an increasing rate. Pavements which have been subjected to overload conditions should be closely monitored for a period of several weeks or until it is clear that deterioration of the pavement is not occurring.

4.5.2 Serviceability inspections are meant to check the integrity of the pavement and should give particular attention to those areas subject to repetitive high loads.

4.5.3 In order to monitor the change in the condition of aerodrome pavements over time, pavements should be subject to inspection by a competent engineer. An aerodrome that has 50 000 or more ai transport passenger movements or 100 000 or more aircraft movements must ensure a pavement inspection is completed annually as part of their aerodrome technical inspection (ATI) program. Aerodromes that have at least 10 000 but less than 50 000 air transport passenger movements, or at least 20 000 but less than 100 000 aircraft movements must ensure a pavement inspection is completed once every two years in accordance with their ATI program.

4.5.4 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.

5 The New Strength Rating System

5.1 General

5.1.1 As explained above, the ACN-PCN system uses simple mathematics to determine the relative damage caused to pavement based on subgrade deflection as the indicator of damage and the pavement analysis systems that were practically available in the late 1970s and early 1980s. Significant advances in pavement thickness design software have occurred since that time and most pavement structures are now designed using more sophisticated layered elastic and even finite element mathematics.

5.1.2 The difference between the sophistication of software used for pavement design, and the software subsequently used for pavement strength rating, has led to anomalies where aircraft that were included in the pavement design are found to require a pavement concession to operate. To resolve these anomalies, ICAO has developed a new aircraft pavement strength rating system which uses the same mathematical models for the determination of relative aircraft damage and the calculation of ACN values, as used for aerodrome pavement thickness design in the USA.

5.2 ACR-PCR

5.2.1 The Aircraft Classification Rating - Pavement Classification Rating (ACR-PCR) system was developed to operate in a similar manner to ACN-PCN. That is the aircraft ACR is compared to the pavement PCR. If the PCR exceeds the ACR, then the aircraft can operate without restriction. However, when the ACR exceeds the PCR, a pavement concession is required. Also similar to the ACN-PCN system, the tyre pressure limit check is also required and this is effectively unchanged.

5.2.2 The main differences between ACN-PCN and ACR-PCR relate to the basis on which the equivalent wheel load is determined, and include:

- standard tyre pressure
- standard pavement structures
- subgrade categories
- calculated indicator of relative damage.

5.2.3 The standard wheel, to which other landing gear are converted, now has a 1.50 MPa tyre pressure to better reflect large modern aircraft.

5.2.4 The flexible standard pavement structure has greater asphalt thickness and now depends on the number of wheels in the landing gear being considered. Table 8 shows the two flexible pavement structures. The rigid pavement structure is not affected by the number of wheels in the landing gear, as shown in Table 8.

Table 7. ACR-PCR standard flexible pavement structures

Layer	ACN-PCN thickness	ACR-PCR thickness for 1-2 wheels	ACR-PCR thickness for 3 or more wheels
Asphalt surface	75 mm	76 mm	127 mm
Crushed rock base	150 mm	As required	As required
Uncrushed gravel sub-base	As required	Not used	Not used
Subgrade	Infinite	Infinite	Infinite

Table 8. ACR-PCR standard rigid pavement structures

Layer	ACN-PCN thickness	ACR-PCR thickness
Concrete base	As required	As required
Crushed rock sub-base	Combined with subgrade	200 mm
Subgrade	Infinite	Infinite

5.2.5 The standard subgrade categories have been adjusted to correspond to subgrades categories used in France for road and highway pavement design. The selection of French roads and highways as the basis is illogical and will result in many aerodromes needing to change from one subgrade category to another, which will complicate the transition from ACN-PCN to ACR-PCR. The current and new subgrade categories are summarised in Table 10.

5.2.6 The ACR-PCR system actually uses the elastic modulus of the subgrade (expressed in MPa) to reflect the input into modern pavement thickness design software, but Table 10 shows equivalent CBR values using a simply linear conversion of 10 times. The use of elastic modulus avoids the need to estimate k-values for rigid pavements, which simplifies the ACR-PCR system for rigid pavements. The category D increase from CBR 3 to CBR 5 reduces the representativeness of the system for many Australian aerodromes that have old and poor natural subgrades with very low CBR values.

Table 9. ACN-PCN and ACR-PCR subgrade categories

Subgrade Category	ACN-PCN system		ACR-PCR system	
	Nominal CBR	CBR Range	Nominal CBR	CBR Range
A	15	13 and above	20	15 and above
B	10	8-12	12	10-14
C	6	4-8	8	6-9
D	3	4 and below	5	5 and below

5.2.7 The indicator of relative damage caused by different aircraft will be vertical strain at the top of the subgrade, instead of maximum deflection at the top of the subgrade. Furthermore, the layered elastic models in FAARFIELD (FAA 2020) are used to calculate the magnitudes of strain, rather than the simpler models used in COMFAA. This change reflects the more sophisticated computer power that is now readily accessible and greatly reduced the anomalies between pavement thickness design and strength rating in the USA.

5.3 Comparing ACR values to ACN values

5.3.1 Figure 8 shows the ACR and ACN values for 17 common commercial and General Aviation (GA) aircraft on each of the four subgrade categories. On average, the ACR values were 9.5 times the ACN values for the same aircraft, with the ratios between ACN and ACR ranging from 7.7 to 12.0. It is these minor deviations away from ACR being 10 times the ACN that will reduce the discrepancies between FAARFIELD designed aerodromes pavement thickness and COMFAA based pavement strength rating and PCN assignment. The approximate 10 times ACR values were selected to avoiding confusion during the transition from ACN-PCN to ACR-PCR.

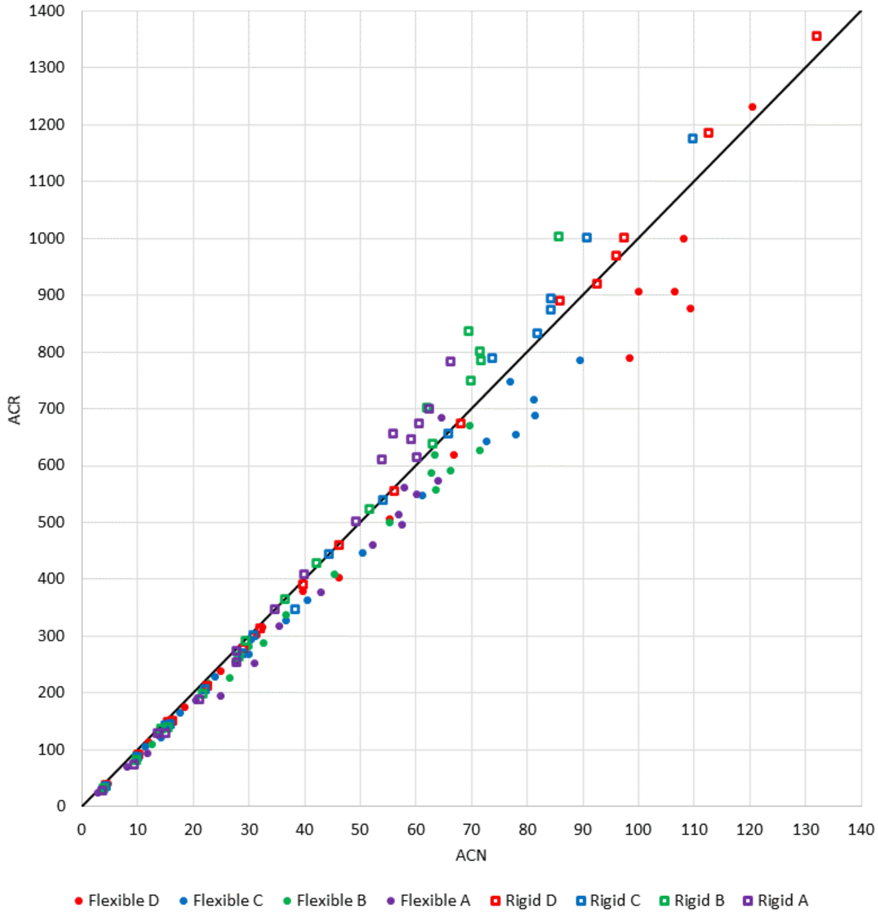


Figure 8. Comparison of ACN and ACR values for various common aircraft.

A, B, C, D indicate the subgrade category of the Flexible or Rigid pavement.

5.4 Transition from ACN-PCN to ACR-PCR

5.4.1 ICAO approved the new aerodrome strength rating system in 2019. Implementation by all member States, including Australia, must occur between July 2020 and November 2024. That is, by a date to be determined by CASA, every aerodrome operator in Australia will be required to update its ERSA entry to replace the PCN with a new PCR. For many aerodromes this will be relatively straight forward; however, for some it will be a significant challenge.

5.4.2 For a major international aerodromes that effectively accept all commercial aircraft in operation, the process will simply require changing from a PCN equal to the highest of all the ACN values, to a PCR that is equal to the highest of all the ACR values. Similarly, for a smaller airport that has one dominant aircraft, the current PCN is likely to be set equal to that dominant aircraft ACN and the PCR will be logically be set to the ACR of that same aircraft.

5.4.3 There will be a number of aerodromes that do not understand and cannot determine the basis of their current PCN. That will complicate the transition to ACR-PCR because the basis for selecting a PCR cannot be replicated from the basis of the current PCN value. In such cases, professional assistance will likely be required to determine an appropriate PCR value.

5.4.4 One significant complication will result from the change in the subgrade categories. Aerodromes that are currently a category D will remain a category D. However, some subgrade category A, B and C runways will move to B, C and D, but others will remain in their current subgrade category. An aerodrome owner will need to understand their actual subgrade CBR to determine whether they need to change their subgrade category. This will likely require professional assistance.

6 Pavement Overloads and Concessions

6.1 General

6.1.1 As described above, when the ACN exceeds the PCN value, a strength-based pavement concession is required prior to the aircraft operating. Similarly, where the tyre pressure exceeds the nominated tyre pressure limit (or category) then a tyre pressure pavement concession is required. The same requirements apply to the ACR-PCR system.

6.1.2 Regardless of whether ACN-PCN or ACR-PCR is the basis for the strength rating, a pavement concession is effectively an overload that has the potential to reduce the structural life of the pavement. Various jurisdictions provide guidance regarding the magnitude and frequency of pavement concession that should be permitted, however, like setting the PCN/PCR value, it is often trade-off between the revenue likely to be generated, the importance of the aircraft operation, and the risk to the pavement.

6.2 Overload guidance

6.2.1 Different jurisdictions provide guidance on the reasonable frequency of aircraft movements under a pavement concession, based on the ratio of the ACN to the PCN, or the ACR to the PCR.

6.2.2 Unlike pavement design and strength rating, pavement concessions can consider the actual or prevailing strength of the pavement at the time of the proposed overload operation. In general, pavements are stronger when the subgrade is drier and the bituminous layers (i.e. asphalt) are colder. Therefore, an overload during cold dry conditions will have less practical impact on the pavement than the same overload will have on a hot day after a period of heavy rain and inundation.

6.2.3 In contrast to pavement strength overloads, tyre pressure related pavement concessions are less likely to be detrimental. For most surfaces in reasonable condition, the pavement strength is a much greater factor than the tyre pressure. Therefore, rejection of tyre pressure related pavement concession requests is rarely justified. In fact, most tyre pressure related pavement concessions result from the under-rating of the surface due to an historical tie to a specific aircraft tyre pressure, which has been exceeded by new aircraft models or variants, but the tyre pressure limit not being updated.

6.3 Relationship between overload and damage

6.3.1 The amount of damage caused to the structure of a pavement is not linearly related to the ACN/ACR value. As shown in Figure 9, the damage increases rapidly as the ACN/ACR value increases. A 50% overload (i.e. ACN 150% of PCN) is equivalent to 13-28 non-overload operations (i.e. ACN = PCN) while a 100% overload (i.e. ACN 200% of PCN) is equivalent to 40-80 non-overload operations. That is why Pavement

Concessions, when the ACN/ACR exceeds the PCN/PCR by more than 50%, should only be considered in emergency situations.

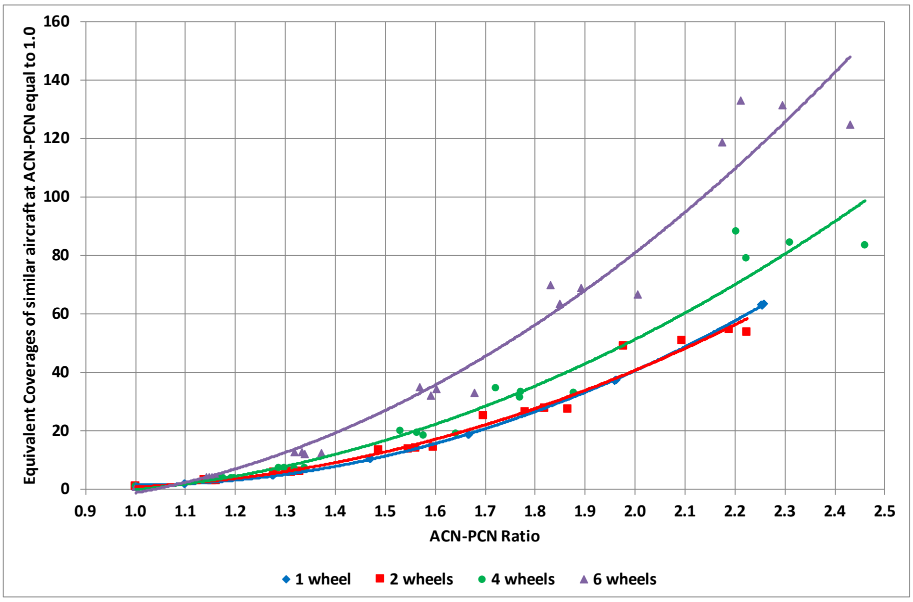


Figure 9. Relationship between overload magnitude and structural pavement damage