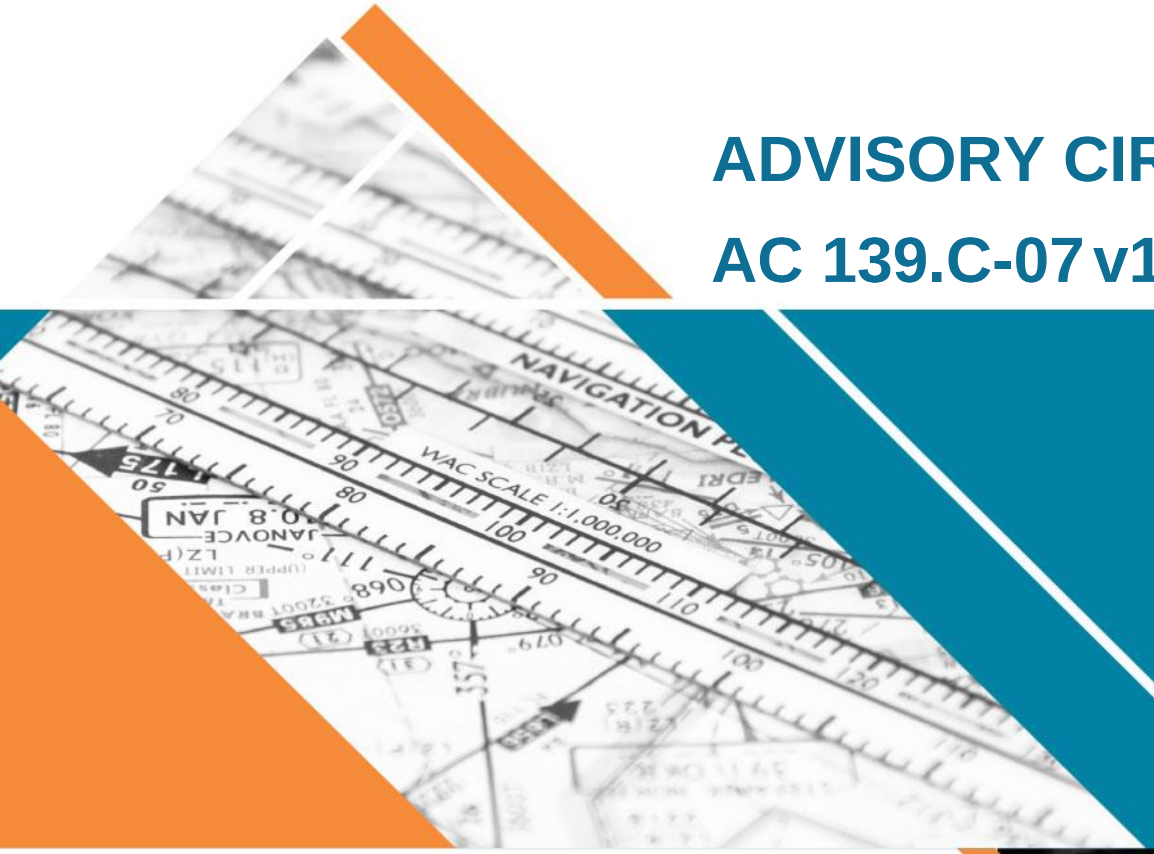
Australian Government
Civil Aviation Safety Authority



ADVISORY CIRCULAR
AC 139.C-07 v1.0

Strength rating of aerodrome pavements

Date February 2021

File ref D19/165507

Advisory Circulars are intended to provide advice and guidance to illustrate a means, but not necessarily the only means, of complying with the Regulations, or to explain certain regulatory requirements by providing informative, interpretative and explanatory material.

Advisory Circulars should always be read in conjunction with the relevant regulations.

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’s Personnel Licensing, Aerodromes and Air Navigation Standards (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 Branch Manager, Flight Standards.

Version	Date	Details
v1.0	February 2021	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)
FWD	Falling Weight Deflectometer
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.
APSDS	A software application developed in Australia and commercially distributed by Pavement Science (formerly Mincad Systems) for aircraft pavement thickness

Term	Definition
	determination.
California Bearing Ratio	The resistance of a soil to controlled penetration, usually when soaked, relative to that of a standard Californian limestone.
COMFAA	A software published by the Federal Aviation Administration (FAA) for calculating the Aircraft Classification Number (ACN) of an aircraft.
coverages	The number of times an aircraft tyre passes over a particular point of a pavement surface, with the most frequently covered point on the pavement surface usually the point of interest.
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 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.
pass-to-coverage ratio (P-C-R)	The ratio between the number of aircraft passes and the number of aircraft coverages, affected by the wheel spacing and degree of aircraft wander across the width of the pavement, usually calculated for the pavement location that is most often covered, which is not the centreline.
passes	The number of times an aircraft moves over a particular cross section of pavement, which is related to the number of passes by the P-C-R.
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	Aerodromes
Part 139 Manual of Standards (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 1995	Airport Pavement Design and Evaluation, Advisory Circular 150/5320-6D. 7 July.
FAA 2014a	COMFAA v3.0 computer program, Federal Aviation Administration, 14 August.
FAA 2014b	Standardized Method of Reporting Aircraft Pavement Strength - PCN, Advisory Circular 150/5335-5C, 14 August.
FAA 2020	Airport Pavement Design and Evaluation, Advisory Circular 150/5320/-6G, DRAFT, 19 June.

Bibliography

References

1. Ahlvin, R. G. Origin of Developments for Structural Design of Pavement, Technical Report GL91-26, US Army Corps of Engineers, Waterways Experiment Station, Vicksburg, Mississippi, USA, 1991.

2. Hayhoe, G. New Alpha Factor Determination as a Function of Number of Wheels and Number of Coverages, DOT/FAA/AR-08/01, Federal Aviation Administration, Washington, District of Columbia, USA, January 2008.

3. FAA 2017, FAARFIELD, Version 1.42, Federal Aviation Administration, Washington, District of Columbia, USA, 18 September, accessed 17 December 2017, http://www.airporttech.tc.faa.gov/ Download/Airport- Pavement-Software-Programs/Airport-Software-Detail/ArtMID/3708/ArticleID/4/FAARFIELD-142

4. White, G. An Investigation of the Australian Layered Elastic tool for Flexible Aircraft Pavement Thickness Design, A Thesis submitted to the Faculty of Built Environment and Engineering, Queensland University of Technology, for the Award of Master of Engineering, July 2007.

5. Wardle, L. J. & Rodway, B. Advanced design of flexible aircraft pavements, 24th ARRB Conference, Melbourne, Victoria, Australia, 12-15 October 2010, ARRB Transport Research.

6. Airport Practice Note 12L Airfield Pavement Essentials, Australian Airports Association, Canberra,

References

Australian Capital Territory, Australian, May 2017.

7. White, G. Material equivalence for flexible aircraft pavement thickness design, 2006 Airfield and Highway Pavements Specialty Conference, Atlanta, Georgia, USA, 1-3 May 2006.

8. White, G. A sensitivity analysis of APSDS, an Australian mechanistic design tool for flexible aircraft pavement thickness determination, First European Aircraft Pavement Workshop, Amsterdam, Netherlands, 11-12 May 2005.

9. White, G, Sterling, M, Duggan, M & Sterling J. Sensitivity analysis of FAARFIELD rigid airport pavement thickness determination, 12th International Conference on Concrete Pavements, Minneapolis, Minnesota, USA, 29 August to 2 September 2021, article-in-press.

10. ICAO. Aerodrome Design and Operations, Annex 14, Volume 1, to the Conventions on International Civil Aviation, International Civil Aviation Organization, Montreal, Canada, February 2013.

11. Aeronautical Information Package, En-Route Supplement Australia, Airservices Australia, 5 November 2020, accessed 18 September 2020, https://www.airservicesaustralia.com/aip/aip.asp?pg=40&vdate=05NOV2020&ver=2.

12. White, G. Use of Falling Weight Deflectometer for Airport Pavements, 5th GeoChina International Conference, HangZhou, China, 23-25 July 2018.

13. White, G & Barbeler, A, Evaluating falling weight deflectometer back calculation software for aircraft pavement strength rating, GeoMEast Conference, Sustainable Civil Infrastructures: Recent Developments in Pavement Design, Modeling and Performance, Cairo, Egypt, 24-28 November 2018;64-83.

14. White G. Practical implications for the implementation of the new international aircraft pavement strength rating system, 11th International Conference on the Bearing Capacity of Roads, Railways and Airfields, Trondheim, Norway, 28-30 June 2022, article-in-press.

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 (USACE) to develop formalised pavement thickness and strength design systems. (1) The work done by the USACE 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 USACE

2.2.1 The USACE aerodrome pavement design methods were based on the results of full-load trafficking tests conducted on large-scale (i.e. not full-scale) test pavements by the USACE (Figure 1) through the 1950s to the 1970s. These were first considered to be mainly single wheel configurations but were later extended to aircraft with multiple wheels and heavier gear loads, such as the C-5 Galaxy.

2.2.2 The USACE established an empirical relationship between aircraft loads, subgrade CBR and the required pavement thickness to cater for 5,000 'coverages'. The curve generated from the variable data is a line of best-fit that 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 S-77-1 (Figure 2) (1).

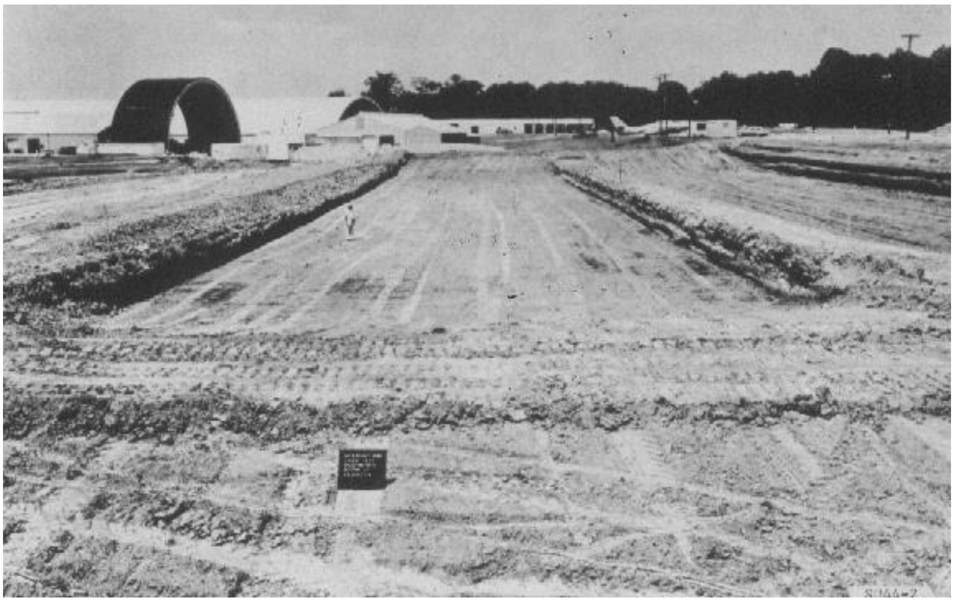


Figure 1. Example of US Army USACE pavement test section

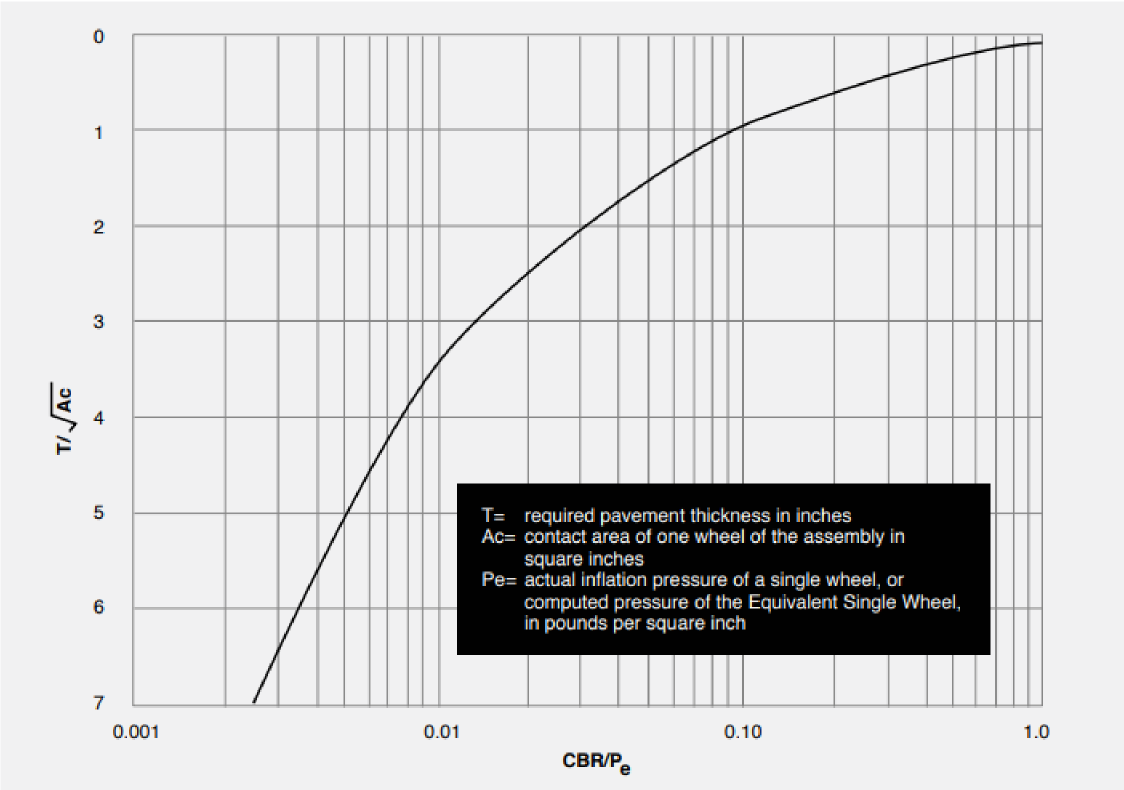


Figure 2. USACE original design curve

2.2.3 Because the S-77-1 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 airports in the USA.

2.2.4 Further testing has also been carried out by the FAA to quantify the pavement damage caused by newer larger aircraft such as the B777 and A380 (2). These tests have resulted in adjustments to the S-77-1 curve and method.

2.2.5 The works undertaken by the USACE, 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. It also remains the basis of most modern aircraft pavement design methods, including those in FAARFIELD (from the USA) (3) and APSDS (commercially developed in Australia) (4).

2.2.6 Similar work has been repeated for rigid aircraft pavements and S-77-1 includes similar relationships between:

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

2.3 S-77-1 design method

2.3.1 The S-77-1 design method, as updated and republished by the FAA, remains the best empirical 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 S-77-1 relationship, despite being far more sophisticated and precise in their calculations (5).

2.3.2 Despite various charts being published over the years, the most practically usable form of S-77-1 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 passes (expressed as annual departures over 20 years) by any aircraft to be entered to determine the required pavement thickness, based on the S-77-1 empirical relationships.

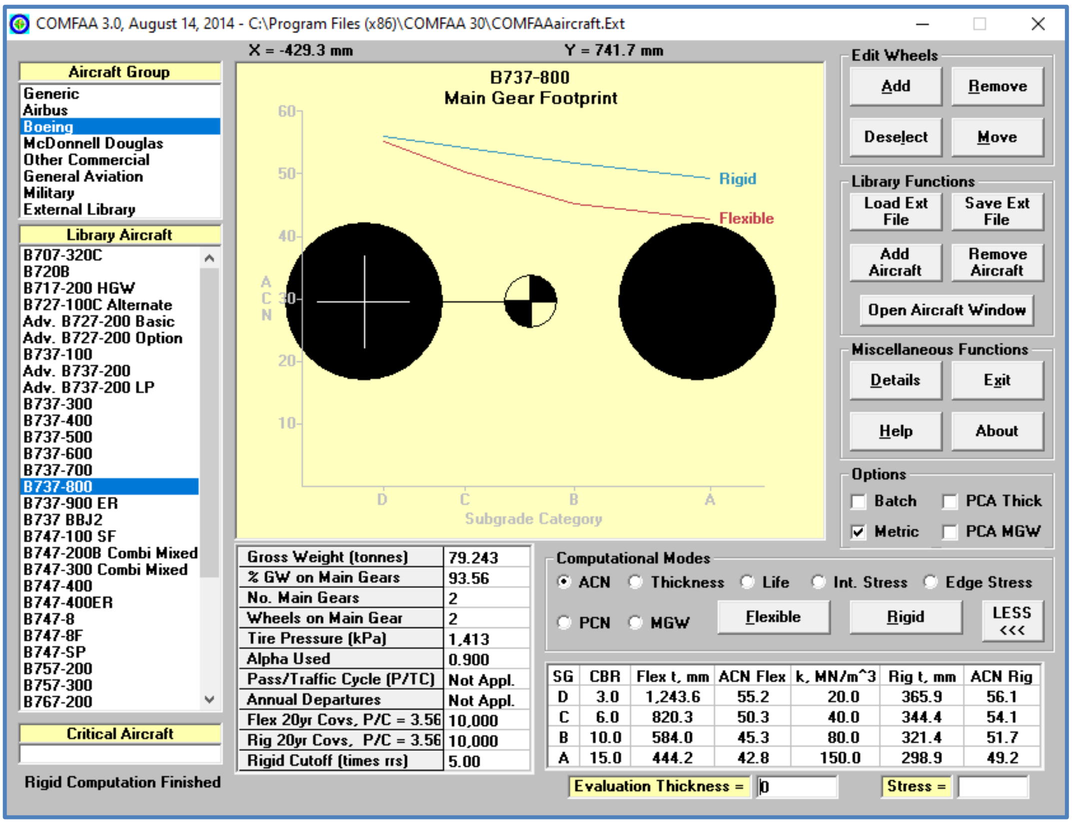


Figure 3. Example of COMFAA calculations for B737-800.

2.3.3 When determining a S-77-1 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 (6).

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 S-77-1 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 thicknesses must be converted to an equivalent thickness based on the S-77-1 structure, using material equivalence factors. 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.

2.3.8 These equivalence factors were originally developed by the FAA based on the results from the full-scale pavement tests to failure. They were previously published in the FAA pavement design requirement Advisory Circular (FAA 1995). However, these were no longer published when the FAA moved away from chart-based design guidance. Since then, statistical analysis of parametric runs of APSDS were used to determine equivalence factors implied by APSDS (7).

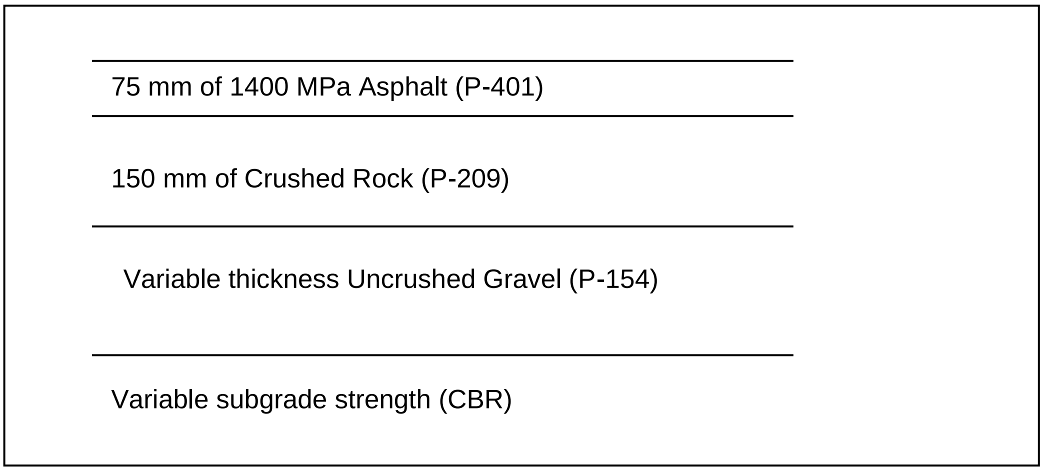


Figure 4. Standard S-77-1 pavement composition.

2.3.9 For example, 100 mm of asphalt is structurally equivalent to 1.3 × 100 mm = 130 mm of crushed rock. Similarly, 200 mm of crushed rock is structurally equivalent to 1.2 × 200 mm = 240 mm of uncrushed gravel.

Table 2. Indicative common materials equivalence factors (7)

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 Development of aircraft pavement rating system

2.4.1 In parallel with the work done by the USACE 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 DC-8-50, first introduced in 1958. At the time, this 159 t aircraft 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, DC-8-50 aircraft. This was achieved by limiting FAA funding of new pavement developments to the cost of a pavement structure required by the DC-8-50 aircraft. The FAA policy was rescinded in 1995 (FAA

1995), 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. However, only runways are formally assigned a PCN, even though some airport owners informally give strength ratings to these other pavement areas.

3.2 Flexible pavement strength

3.2.1 Flexible pavement strength is primarily determined by (6):

- 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 stiffnesses, 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 (8). Each factor was normalised by setting the minimum reasonable value to 1 and the maximum reasonable value to 5. For example, subgrade CBR ranges from 3% (normalised to 1) to 15% (normalised to 5). Similarly, aircraft mass ranged from approximately weight operating empty (WOE) (normalised to 1) up to the maximum operating weight (MOM) (normalised to 5). The resulting curves are averages across a range of typical aircraft. Subgrade CBR and aircraft mass are the most influential factors.

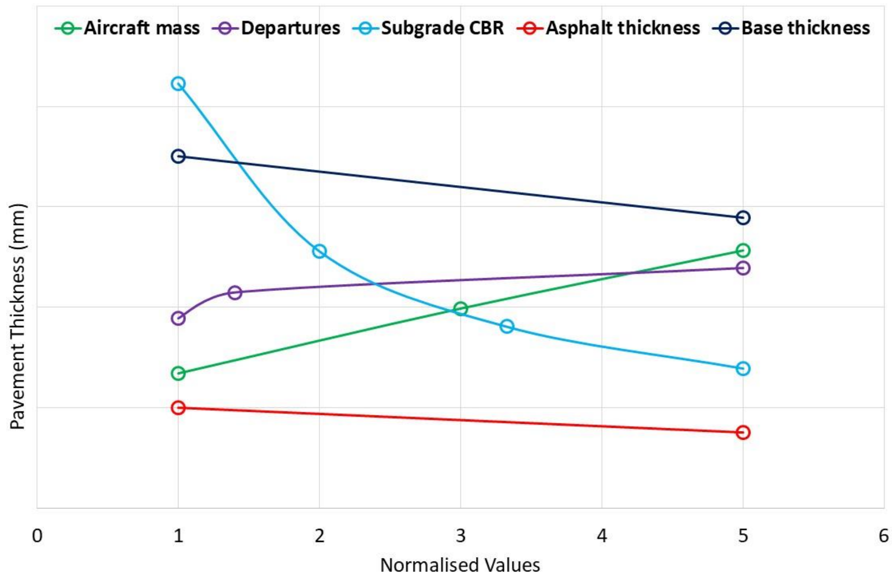


Figure 5. Flexible pavement factor influence on total pavement thickness (8).

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 (4):

- subgrade support (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 (9). 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.

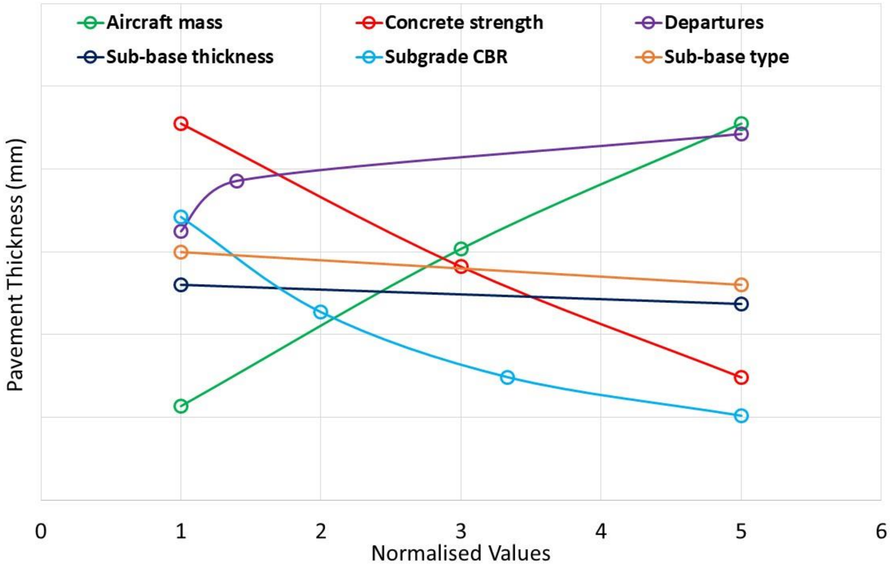


Figure 6. Rigid pavement factor influence on concrete thickness (9).

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 with the same strength:

– 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 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 tailor 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 (FAA 2014a), 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 be unchanged, so they 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.

3.4.9 Since the graded portion of a strip is provided to minimise the hazard to an aircraft running off the runway, the ICAO design manual recommends that the graded strip should be prepared in such a manner as to provide drag to an aircraft, and below the surface it should have sufficient bearing strength to avoid damage to the aircraft. Aircraft manufacturers consider that a depth of 15 cm is the maximum depth to which the nose gear may sink without collapsing. Therefore, it is recommended that the soil at a depth of 15cm below the finished strip surface be prepared to have a bearing strength of CBR value of 15 to 20. The intention of this underlying prepared surface is to prevent the nose gear from sinking more than 15 cm. The top 15 cm may be of lesser strength which would facilitate deceleration of aircraft.

4 Unrated pavements

4.1 General

4.1.1 Where the aerodrome pavements consist 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-ERSA 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 aerodromes where testing for soft wet surfaces is the simplified method of assessing the suitability of the runway pavement.

4.1.2 The following guidelines describe the method of assessing the bearing strength of unrated pavements. At a certified aerodrome, 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.

4.2 Assessing the bearing strength of unrated pavements

4.2.1 The bearing capacity of unrated pavements is depended 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.

4.2.2 Under dry to depth conditions, the bearing capacity of the surface may be considerably greater than under wet conditions and this will allow the nominated aircraft types to operate. This is generally the case in Australia which has a predominantly dry climate.

4.2.3 After rain the natural material has a 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 determined if the pavement is dry to depth.

4.3 Assessment of dry to depth conditions

4.3.1 Guidelines for the assessment of dry to depth conditions of a pavement area 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
    - o 3401 to 5700 - a trick 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.
- – 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.

4.4 Assessing the results of the tests

4.4.1 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.

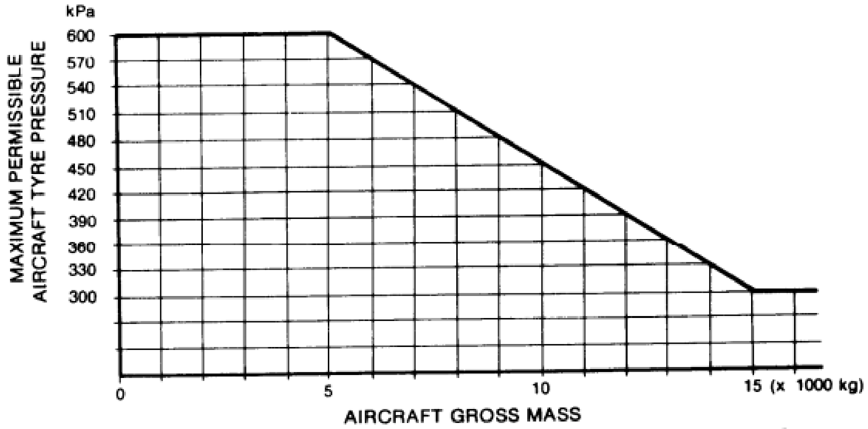
4.4.2 Where personal knowledge may also indicate that a particular pavement surface is not suitable for aircraft when the imprint depth is less than 25 mm, in such cases the lesser depth shall be used.

4.4.3 If the results of any of the tests indicate that the bearing strength of any part of the pavement is inadequate, the affected area is to be declared unserviceable, and a NOTAM issued.

4.4.4 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.

4.5 Aircraft suitability for unrated pavements

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

5 ACN-PCN Pavement Strength Rating System

5.1 General

5.1.1 The ACN-PCN system was introduced by the International Civil Aviation Organization (ICAO) in 1981 (10) 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 aeronautical information service (AIS) provider the strength rating of the runway pavement calculated using the ACN-PCN pavement rating system, for publication in the AIP-ERSA (11).

5.1.2 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.

5.1.3 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. However, this has generally only been an issue when a prescriptive approach is taken to pavement strength rating, such as the system published by the FAA (FAA 2014b) and mandated for airports in the USA. Some airports in Australia have also used this process in recent years.

5.2 Aircraft Classification Number

5.2.1 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.

5.2.2 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.

5.2.3 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.

5.2.4 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 OWE weight to the 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.

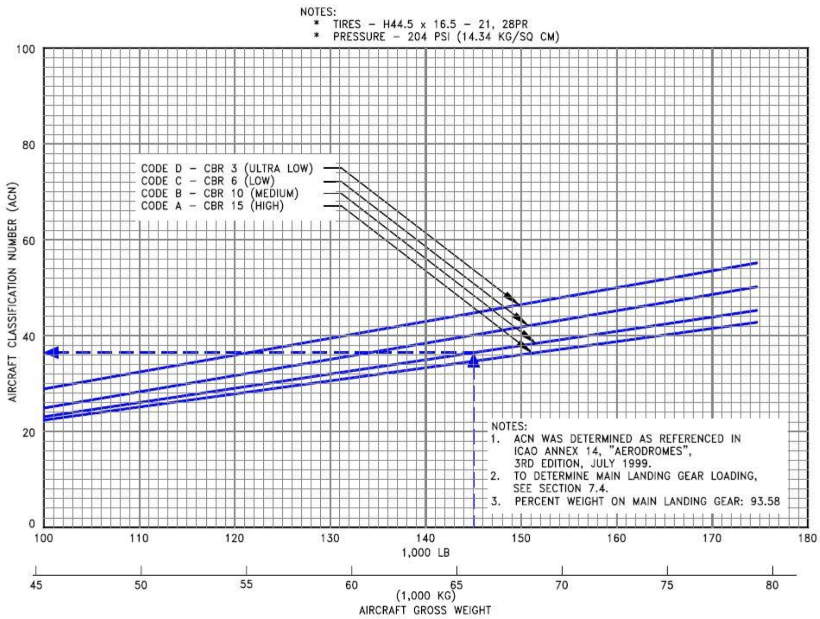


Figure 7. Example of flexible pavement ACN graph for B737-800.

5.2.5 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 2014a) is used to calculate the ACN of any aircraft at any operating mass and any tyre pressure.

5.2.6 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.

5.2.7 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.

5.3 Pavement Classification Number

5.3.1 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 a pavement management tool that allows 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.

5.3.2 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. However, excessive increases in the PCN can lead to gross overloading of the pavement and can result in rapid or even single-load event failures of the pavement that are likely to render it unserviceable.

5.3.3 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.

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

- 108 is the numerical element against which the ACN is compared.
- F indicates 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 indicates a Technical assessment, rather than U for a Usage based assessment.

Table 4. ACN-PCN subgrade categories

Subgrade Category	Flexible pavement Nominal CBR	Flexible pavement CBR Range	Rigid pavement Nominal k-value	Rigid pavement k-value range
A	15%	Greater than 13%	150 kPa/mm	Greater than 120 kPa/mm
B	10%	8-13%	80 kPa/mm	60-120 kPa/mm
C	6%	4-8%	40 kPa/mm	25-60 kPa/mm
D	3%	Less than 4%	20 kPa/mm	Less than 25 kPa/mm

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

5.3.5 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 entry includes a tyre pressure limit of 1,750 kPa, which falls into the X category of tyre pressure categories in Table 5.

5.3.6 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.

5.3.7 To determine whether an aircraft can operate on an unrestricted basis, 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).

5.4 Setting a Pavement Classification Number

5.4.1 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.

5.4.2 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.

5.4.3 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.

5.4.4 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.

5.4.5 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. This process generally includes:

- Inspection of the pavement by a pavement engineer, for signs of structural distress.
- Projections of historical, current and future aircraft traffic.
- Determination of representative pavement structures and subgrade bearing strength, for areas of uniform strength, which may require one or both of:
  - Non-destructive testing of the pavement response to load
  - Intrusive investigation and sampling material for testing
- Iterative analysis in design software to determine a level of traffic that is predicted to cause failure of the pavement over time.
- Setting the pavement PCN to the ACN of the most demanding aircraft that is 'just acceptable'.

5.4.6 In recent years, the response of pavements to dynamic loading has been increasingly measured using a falling weight deflectometer (FWD) (12). These devices measure the deflection of the pavement at various distances from the point of loading with a variable mass dropped from a variable height to target a pre-determined dynamic load magnitude. This provides a cost-effective method for conducting many tests in a relatively short period and is non-destructive, avoiding the need to intrusively core or auger through the pavement and then reinstate the excavation.

5.4.7 Various software applications are available that estimate the modulus of each pavement layer based on the measured deflections and different distances from the load point. Some softwares go further to provide an estimated PCN at each test point. However, the softwares rely on a nominated or assumed pavement composition, including the type and thickness of each layer, so some intrusive testing is still required. Furthermore, case studies have shown that the estimate PCN values range from unrealistically low to unreasonably high and the recommended PCN value is generally lower than is determined from reverse engineering of the measured pavement thickness and material characteristics from an intrusive investigation (13).

5.4.8 Despite these limitations, FWD surveys provide invaluable information on the consistency of pavement structures to loading and are a valuable element of a comprehensive pavement investigation for strength rating determination.

5.4.9 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 provides indicative tyre pressures that are generally appropriate for various runway surfaces.

Table 6. Indicative tyre pressure limits for different surface types

Surface type	Tyre pressure limit	Typical aircraft
Reasonable quality sprayed seal without sanded lockdown treatment	750 kPa	General Aviation aircraft and C-130 Hercules
Road asphalt without modified binder	1000 kPa	Fokker 100
Good quality sprayed seal with sanded lockdown treatment	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
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)

5.5 Monitoring pavement strength

5.5.1 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.

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

5.5.3 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 air 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.

5.5.4 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 technical review of the pavement strength rating may be necessary.

6 ACR-PCR Pavement Strength Rating System

6.1 General

6.1.1 The ACR-PCR pavement strength rating system is a new classification system that has not yet been implemented by CASA but is planned to be introduced before November 2024. Until the system is adopted the aerodrome operator is still required to publish the PCN in accordance with the Part 139 MOS.

6.1.2 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.

6.1.3 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.

6.2 Proposed ACR-PCR Pavement Strength Rating System

6.2.1 The Aircraft Classification Rating - Pavement Classification Rating (ACR-PCR) system has been developed to operate in a similar manner to ACN-PCN. That is, the ACR of an aircraft is compared to the PCR of a runway. 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.

6.2.2 The main differences between ACN-PCN and ACR-PCR relate to the basis on which the equivalent wheel load is determined, and include (14):

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

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

6.2.4 The flexible standard pavement structure has greater asphalt thickness and now depends on the number of wheels in the landing gear being considered. Table 7 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

6.2.5 The standard subgrade categories have been adjusted to reflect subgrade categories used in France for road and highway pavement design.

6.2.6 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 9 shows equivalent CBR values using a simply linear conversion of CBR being 10% of the corresponding modulus value (in MPa). 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. Flexible pavement 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

Note: The ACR-PCR subgrade CBR values are equivalent to the subgrade modules values and ranges actually used, allowing a comparison of the two systems.

6.2.7 The indicator of relative damage caused by different aircraft is 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.

6.3 Comparing ACR values to ACN values

6.3.1 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 by ICAO to avoid confusion during the transition from ACN-PCN to ACR-PCR.

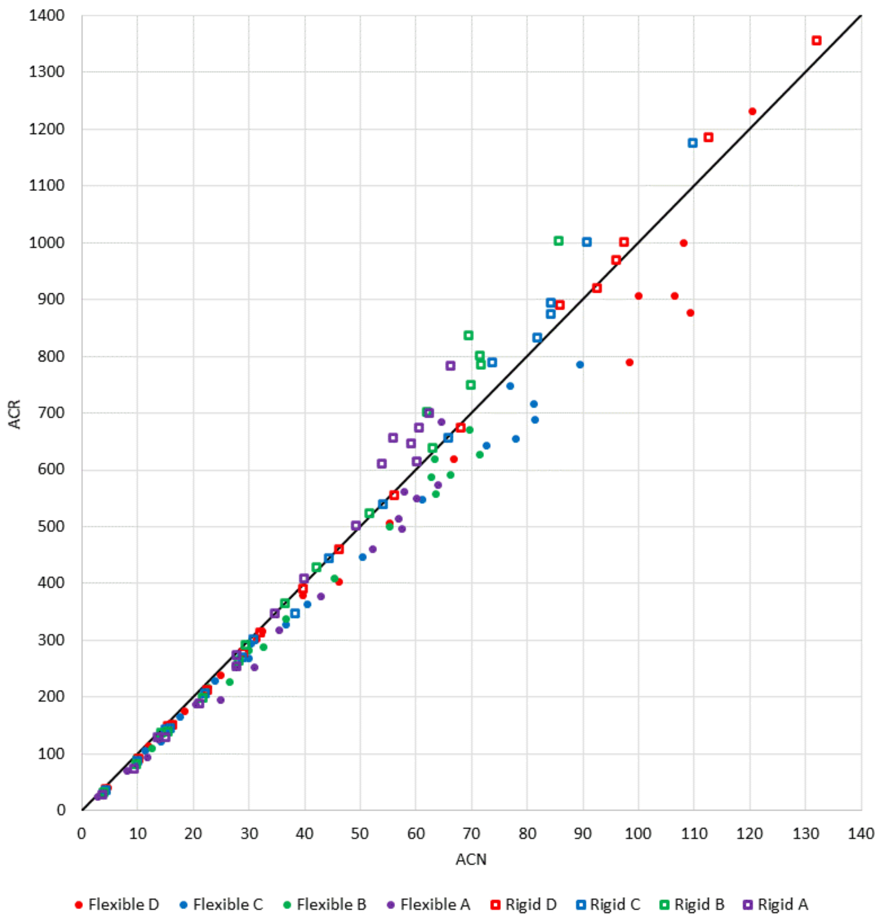


Figure 8. Comparison of ACN and ACR values for various common aircraft.

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

6.4 Transition from ACN-PCN to ACR-PCR

6.4.1 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. CASA will engage further with industry as we look to adopt and implement the new rating system by November 2024.On transition to the new rating system 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 may be a significant challenge.

6.4.2 For 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.

6.4.3 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.

6.4.4 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 operator will need to understand their actual subgrade CBR to determine whether they need to change their subgrade category. This will likely require professional assistance.

7 Pavement Overloads and Concessions

7.1 General

7.1.1 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.

7.1.2 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. For example, the FAA recommends following the ICAO guidance (FAA 2014b). 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.

7.2 Overload guidance

7.2.1 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.

7.2.2 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. However, it is not practically viable to quantify the difference.

7.2.3 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.

7.2.4 When assessing an application for a pavement concession the aerodrome operator should consider the following:

- the safety of the operation:
  - o 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:

  - 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 sings of distress or failure
  - are operations one-off, short term or long term
  - local conditions (for example, recent prolonged rainfall causing loss of subgrade strength).
- the social and economic importance of the operation:
  - are alternative aircraft available
  - the urgency of the operation (for example, urgent medial evacuation, flood, disaster relief)
  - are the operations of significant commercial importance to the community
  - are the operations essential or desirable militarily.
- the consequence of any pavement damage:
  - cost of repairs to any pavement damage
  - resources available to repair any damage
  - disruption to routine operations cause by any damage or repairs.
- other considerations:
  - are the physical characteristics of the aerodrome movement area suitable for the intended operations of the overloading aircraft (for example, parking an manoeuvrability.

7.3 Relationship between overload and damage

7.3.1 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.

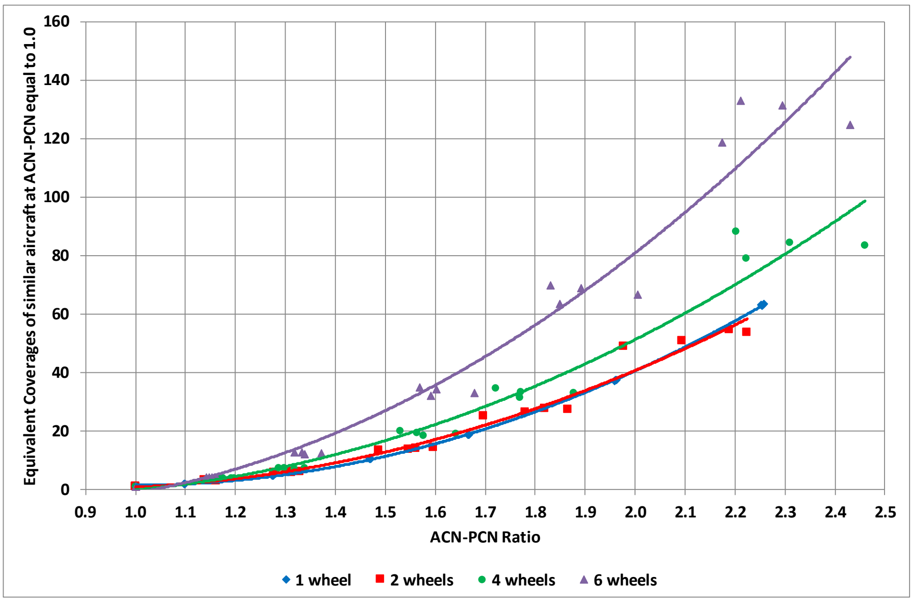


Figure 9. Relationship between overload magnitude and structural pavement damage (4).