ICAO AERODROME PAVEMENT WORKSHOP

ACR/PCR Concepts

Presented to: ICAO Aerodrome Pavement Workshop
Bangkok, Thailand

By: Harold Muniz
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Date: 9 February 2024

Federal Aviation Administration

ACR/PCR Introduction

- **The ICAO Council approved Amendment 15 to Annex 14, Vol. 1 in 2020.**
- **Amendment 15 covers ACR-PCR.**
- **Established <u>four-year transition period</u> from ACN-PCN to ACR-PCR:**
  - Effective 20 July 2020 (currently effective).
  - Full applicability November 2024.
  - During transition, both systems will remain available.
- **Updated Aerodrome Design Manual (ADM) has been published.**
- **FAA published updated AC 150/5335-5.**
  - FAARFIELD 2.0 calculates PCR.
  - COMFAA will no longer be updated.

<u>ICAO State Letter 3 April 2020</u>

International Civil Aviation Organization | Organisation de l'aviation civile internationale | Organización de Aviación Civil Internacional | Международная организация гражданской авиации | منظمة الطيران المدني الدولي | 国际民用航空组织

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Ref.: AN 4/1.2.28-20/35 — 3 April 2020

Subject: Adoption of Amendment 15 to Annex 14, Volume I

Action required: a) Notify any disapproval before 20 July 2020; b) Notify any differences and compliance before 5 October 2020[1]; c) Consider the use of the Electronic Filing of Differences (EFOD) System for notification of differences and compliance

Sir/Madam,

1. I have the honour to inform you that Amendment 15 to the International Standards and *Recommended Practices, Aerodromes — Aerodrome Design and Operations* (Annex 14, Volume I to the Convention on International Civil Aviation) was adopted by the Council at the fourth meeting of its 219th Session on 9 March 2020. Copies of the Amendment and the Resolution of Adoption are available as attachments to the electronic version of this State letter on the ICAO-NET (http://portal.icao.int) where you can access all other relevant documentation.

2. When adopting the amendment, the Council prescribed 20 July 2020 as the date on which it will become effective, except for any part concerning which a majority of Contracting States have registered their disapproval before that date. In addition, the Council resolved that Amendment 15, to the extent it becomes effective, will become applicable on 5 November 2020[2].

3. Amendment 15 arises from the recommendations developed by the third meeting of the Aerodrome Design and Operations Panel (ADOP/3) and the eighth meeting of the PANS-Aerodromes Study Group (PASG/8).

[1] 3 October 2022 for provisions related to airport master plan; and 28 October 2024 for provisions related to pavement rating.
[2] 3 November 2022 for provisions related to airport master plan; and 28 November 2024 for provisions related to pavement rating.

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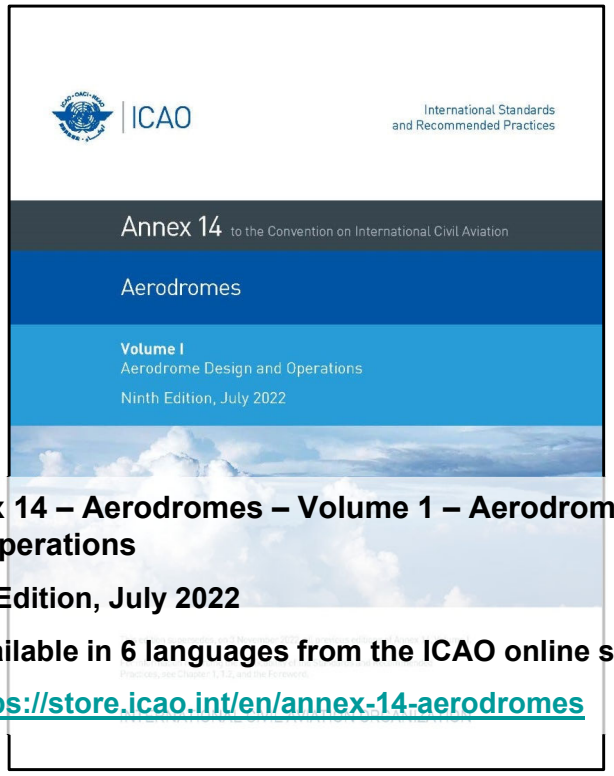
Key ICAO Documents



Annex 14 – Aerodromes – Volume 1 – Aerodrome Design and Operations

- **9th Edition, July 2022**
- **Available in 6 languages from the ICAO online store**
- **https://store.icao.int/en/annex-14-aerodromes**

Aerodrome Design Manual Part 3 – Pavements (Doc 9157 – Part 3)

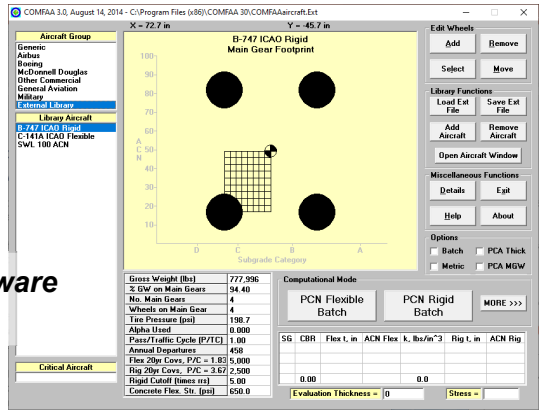
- **3rd Edition, Updated 2022**
- **Available in 6 languages from the ICAO online store**
- **https://store.icao.int/en/aerodrome-design-manual-part-3-pavements-doc-9157-part-3**

Legacy System – ACN/PCN

- **Standardized airport pavement rating system promulgated by ICAO in 1981 for all pavements serving aircraft with ramp mass >5700 kg.**
- **NOT a pavement design method.**
- **Relies on the simple comparison of two numbers:**
  - The **Aircraft Classification Number (ACN)** – a number expressing the relative effect of an aircraft on a pavement for specified standard subgrade strength
  - The **Pavement Classification Number (PCN)** – a number expressing the bearing strength of a pavement for unrestricted operations.
- **If ACN ≤ PCN, the aircraft can operate on the pavement without restriction.**
- **If ACN > PCN, the aircraft cannot operate, or may be allowed to operate subject to weight and/or frequency limitations.**

ICAO Annex 14 Vol. 1 (method overview and reporting format)

Aerodrome Design Manual, ICAO Doc 9157, Part 3, 2nd edition (implementation details)



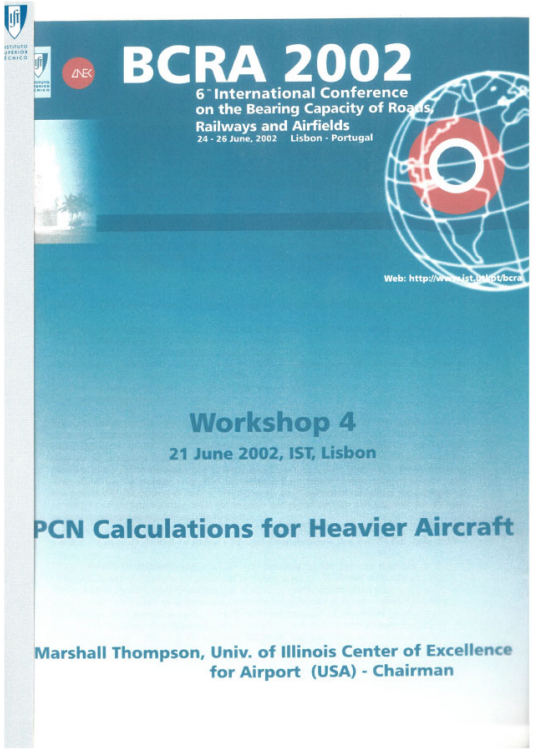
COMFAA 3.0, FAA software for computing PCN

Limitations of ACN/PCN

- **The ACN-PCN method is based on simplified methods originally developed in the late 1930s and 1940s:**
  - Flexible pavements: CBR design procedure based on Boussinesq's theory
  - Rigid pavements: PCA design procedure based on Westergaard's theory
- **These methods have well-known deficiencies:**
  - Unable to consider accurately "complex" landing gear configurations
  - Unable to account for the improved characteristics of new-generation pavement materials
  - Unable to consider the variability of landing gear transverse positions (different overall wheel tracks)
- **Over the years, some changes have been made to the ACN-PCN method to (partially) compensate for some of these deficiencies (alpha factors, layer equivalency factors, etc.)**
- **Over time, the former empirical methods have been replaced by mechanistic-empirical methods for pavement design. Mechanistic models include Layered Elastic Analysis (LEA) and the Finite Element Method (FEM).**
- **Incompatibility between design methods and ACN/PCN leads to illogical results.**

ACR-PCR Background

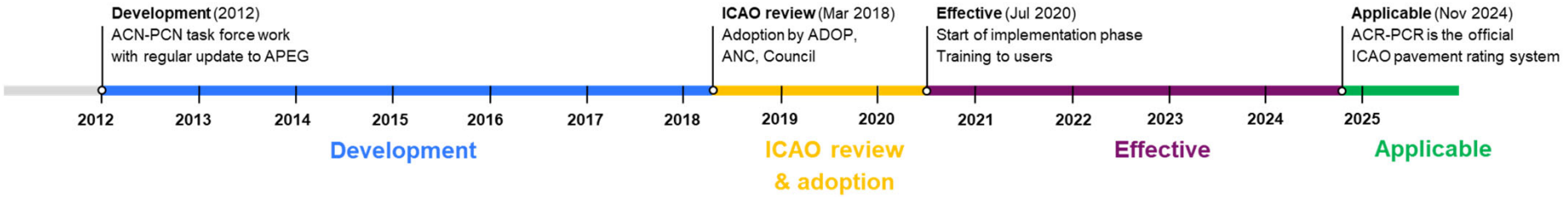
- **The need for an improved "rational" system has been recognized for decades.**
- **PCN workshop was held at BCRA 2002, Lisbon, Portugal.**
- **Participants:**
  - Prof. Marshall Thompson
  - Dr. Al Bush, ERDC
  - Ed Gervais, Boeing
  - J.-M. Balay & Cyril Fabre, Airbus
  - N. Garg & D. Brill, FAA
  - Etc.
- **Ideas discussed at this workshop have been realized 20 years later.**



ACR/PCR Development

- **ICAO Aerodrome Pavement Expert Group (APEG).**
  - Task Force Participants included the major aircraft manufacturers, ACI World, FAA, DGAC STAC (France)
  - Mandated in 2012 to revise the method using new and emerging technology in pavement design
  - Designated ACR-PCR (Aircraft Classification Rating – Pavement Classification Rating) System
- **FAA developed program ICAO-ACR.**
  - Visual Basic class library computes rigid & flexible ACRs.
  - Replacement for legacy ICAO ACN computer programs.
  - Open source library – supports linking to any PCR program.

APEG Meeting, Washington, DC, September 2016



ACR/PCR Development Timeline

- **The ACR-PCR method was finalized by the APEG in 2018, followed by the full ICAO review & adoption process:**
  - Aerodrome Design and Operations Panel (ADOP) adoption in March 2018.
  - Air Navigation Commission (ANC) preliminary adoption in November 2018. Final adoption (after consultation with States) in June 2019.
  - ICAO Council adoption (amendment 15 to Annex 14) in March 2020.
- **The ACR-PCR method has been effective since July 2020:**
  - Aircraft manufacturers start publishing their ACRs.
  - User training (for CAAs, airports, aircraft manufacturers, etc.) is available.
  - CAAs should be implementing the new ICAO standard into the national regulations.
  - Airports can start publishing PCRs.
- **The method will be fully applicable in November 2024:**
  - Airports should have published their PCRs.

Key Changes

- **What DOES NOT change is the comparison of ACR and PCR as the core principle of the method:**
  - If ACR ≤ PCR, the aircraft can operate on the pavement without restriction.
  - If ACR > PCR, operation is disallowed, or some restrictions (on operating weight and/or frequency) may apply.
- **What DOES change are the procedures for determining the ACR and PCR:**
  - Now based on calculation of pavement responses (stresses, strains, deflections) from Layered Elastic Analysis (LEA).
  - Pavement damage is then quantified from these responses based on a specific damage model.

Reporting Requirements

- **Aircraft manufacturers are required to publish properly computed ACR values for all of their aircraft. Must use the ICAO defined procedures.**
- **Airport operators are responsible for determining and publishing PCR values for their pavements.**
  - ICAO does not specify a particular PCR method, giving flexibility to the State CAAs.
  - A model procedure for PCR determination is provided by ICAO in the ADM. The model procedure is general enough to accommodate most national or local practices.
  - The FAA has adopted the PCR procedure in AC 150/5335-5D.

ACR/PCR Versus ACN/PCN

- **ACR numerical values are higher than corresponding ACN values by approximately one order of magnitude.**
  - This was intentional to avoid confusing the two systems during the period of transition.
  - It is not possible to convert PCN to PCR directly.
  - Must use the procedure embedded in FAARFIELD 2.0.
- **In general, ACR/PCR follows the same concepts as current ACN-PCN method, but:**
  - Fully layered elastic-based.
  - Uses uniform standard subgrade categories for flexible and rigid pavements.
  - NO alpha factor, layer equivalency factors, top-of-base k, etc.

Aircraft Planning Manuals

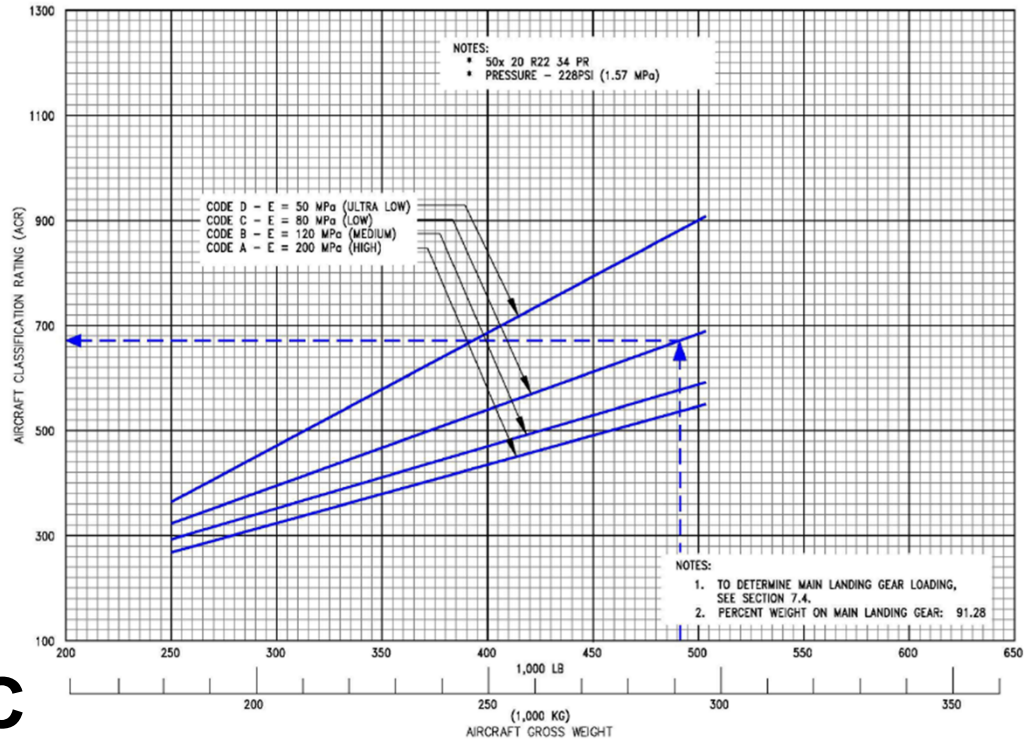
787 Airplane Characteristics for Airport Planning

DOCUMENT NUMBER: **D6-58333** REVISION: **REV O** REVISION DATE: **February 2023**

AIRCRAFT TYPE	MAXIMUM TAXI WEIGHT MINIMUM WEIGHT *[1] LB (KG)	LOAD ON ONE MAIN GEAR LEG (%)	TIRE PRESSURE PSI (MPa)	ACR FOR RIGID PAVEMENT SUBGRADES				ACR FOR FLEXIBLE PAVEMENT SUBGRADES			
				HIGH E = 200 MPa	MEDIUM E = 120 MPa	LOW E = 80 MPa	ULTRA LOW E = 50 MPa	HIGH E = 200 MPa	MEDIUM E = 120 MPa	LOW E = 80 MPa	ULTRA LOW E = 50 MPa
787-8	503,500 (228,383)	45.64	228 (1.57)	670	790	870	970	550	590	690	910
	250,000 (113,398)			270	290	320	360	270	270	280	310
787-9	563,000 (255,373)	46.11	229 (1.58)	740	860	960	1070	620	660	750	970
	250,000 (113,398)			260	280	310	340	270	270	280	290
787-10	561,500 (254,692)	46.63	224 (1.54)	740	870	970	1080	620	660	760	990
	250,000 (113,398)			260	280	310	350	270	270	280	300

*[1] Minimum weight used solely as a baseline for ACR curve generation.

Aircraft Classification Rating- Flexible Pavement: Model 787-8

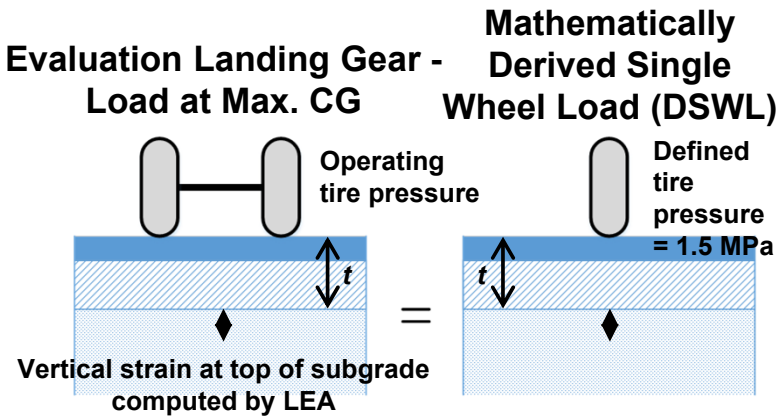


- **787-8 ACR Example= 680/F/C**

ACR Methodology - Principles

Similar to ACN, except:

- **All structures are layered elastic (rigid and flexible).**
- **Retains 4 standard subgrade categories, but defined by modulus (*E*) not CBR or *k*.**
- **Flexible ACR considers <u>all</u> wheels in the main landing gear.**
- **Standard tire pressure 1.5 MPa.**
- **Standard coverages increased to 36,500 for flexible ACR.**
- **DSWL expressed in 100's (not 1000's) of kg. ***<u>ACR numerical values are approximately 10X higher than equivalent ACN</u>*.**



The ACR numerical value is defined as two times the DSWL (expressed in <u>hundreds</u> of kilograms)

Conventions for ACR Computation

a. **The maximum ACR of an aircraft is calculated at the mass and CG that produces the highest main gear loading on the pavement, usually the maximum ramp mass and corresponding aft CG The aircraft tires are considered as inflated to the tire manufacturer's recommendation for the condition;**

b. **Relative aircraft ACR charts and tables show the ACR as a function of aircraft gross mass with the aircraft CG as a constant value corresponding to the maximum ACR value (i.e. usually, the aft CG for maximum ramp mass) and at the maximum ramp mass tire pressure.**

c. **Specific condition ACR values are those ACR values that are adjusted for the effects of tire pressure and/or CG location, at a specified gross mass for the aircraft.**

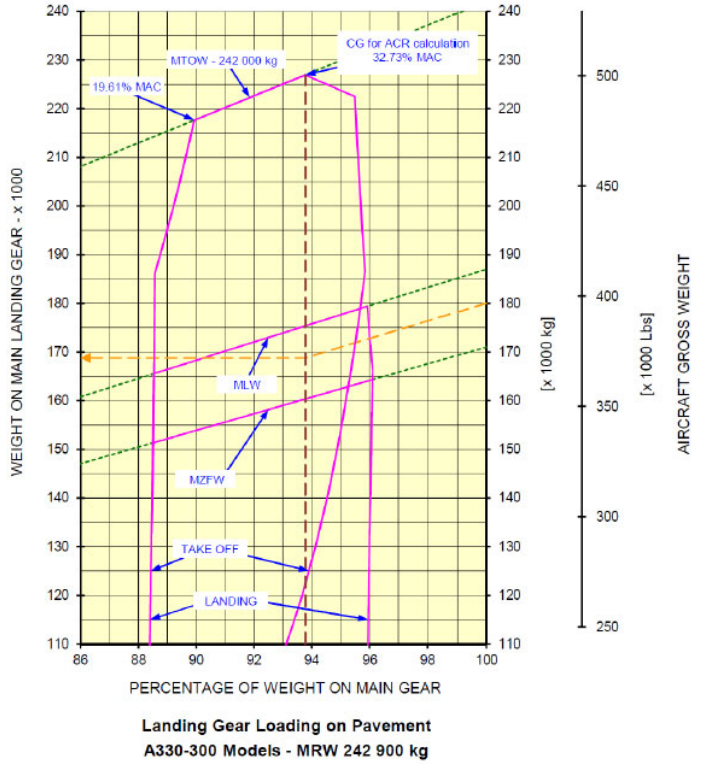


Figure 1-3. Landing gear loading on pavement - Airbus A330-300

ACR-PCR Subgrade Categories

Category	A	B	C	D
Strength	High	Medium	Low	Ultra-Low
E Value, MPa	200	120	80	50
Range, MPa	$E \geq 150$	$150 > E \geq 100$	$100 > E \geq 60$	$60 > E$

- **Categories are defined by *E*, not CBR or *k*.**
- **Same categories for rigid and flexible pavements.**
- **All values are defined at top of subgrade.**

ACR-PCR Tire Pressure Categories

Category	Code	Tire Pressure Range
Unlimited	W	No pressure limit
High	X	Up to 1.75 MPa (254 psi)
Medium	Y	Up to 1.25 MPa (181 psi)
Low	Z	Up to 0.5 MPa (73 psi)

Unchanged from ACN-PCN System

Reference Structure for Flexible ACR

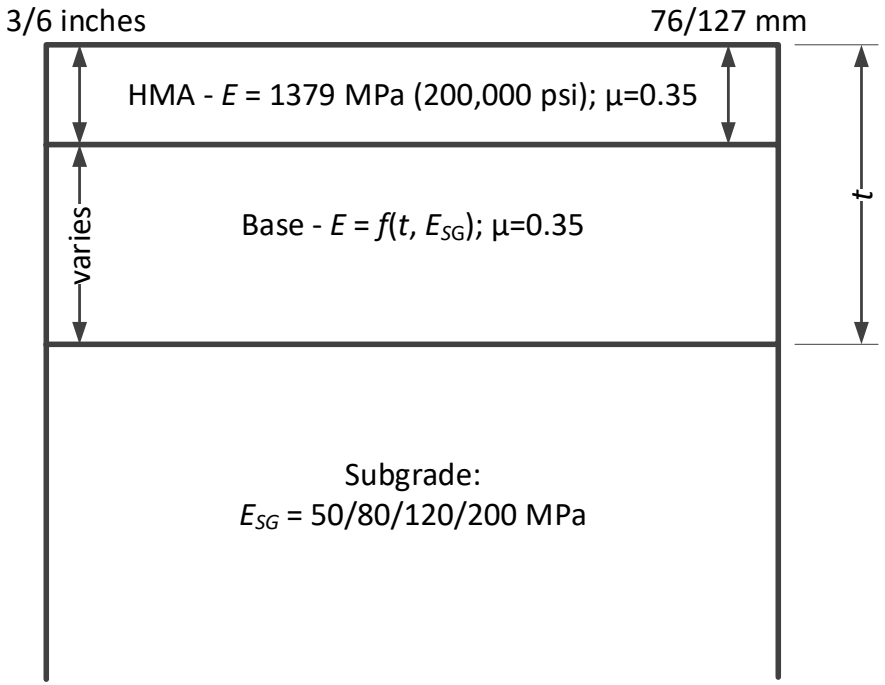
Aircraft with 2 or fewer wheels on all legs of MLG:

Layer	Thickness (mm)	*E*, MPa	*v*
Surface course (asphalt)	76	1379	0.35
Base course (crushed agg.)	varies	formula*	0.35
Subgrade	infinite	based on category	0.35

Aircraft with >2 wheels on any leg of MLG:

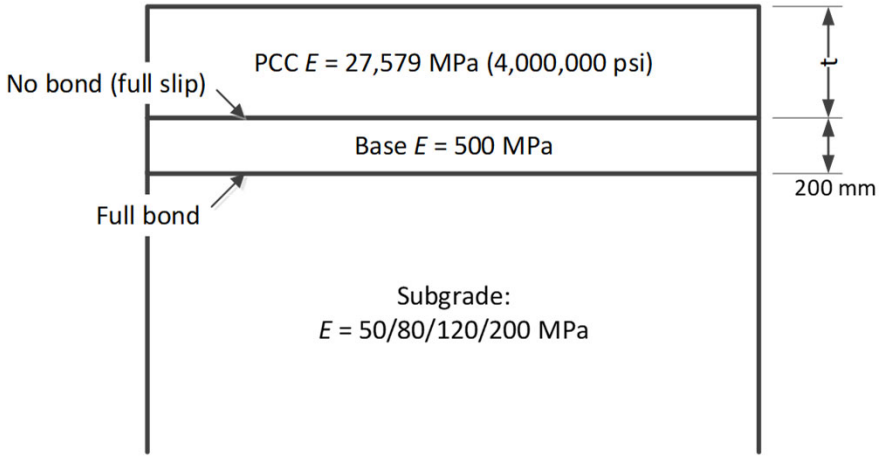
Layer	Thickness (mm)	*E*, MPa	*v*
Surface course (asphalt)	127	1379	0.35
Base course (crushed agg.)	varies	formula*	0.35
Subgrade	infinite	based on category	0.35

*** See AC 150/5335-5D, 3.5.2.2.**



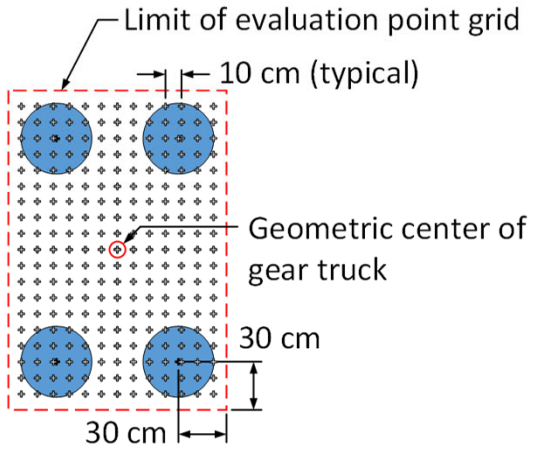
Reference Structure for Rigid ACR

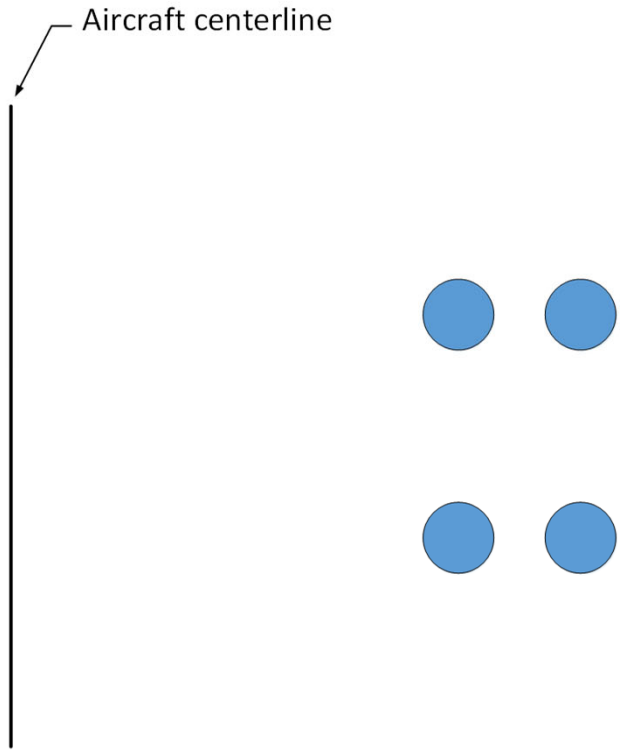
Layer	Thickness (mm)	*E*, MPa	*v*
Surface course (concrete)	varies	27,579	0.15
Base course (crushed agg.)	200	500	0.35
Subgrade	infinite	based on category	0.40



Evaluation Point Grid (Simple Gear)

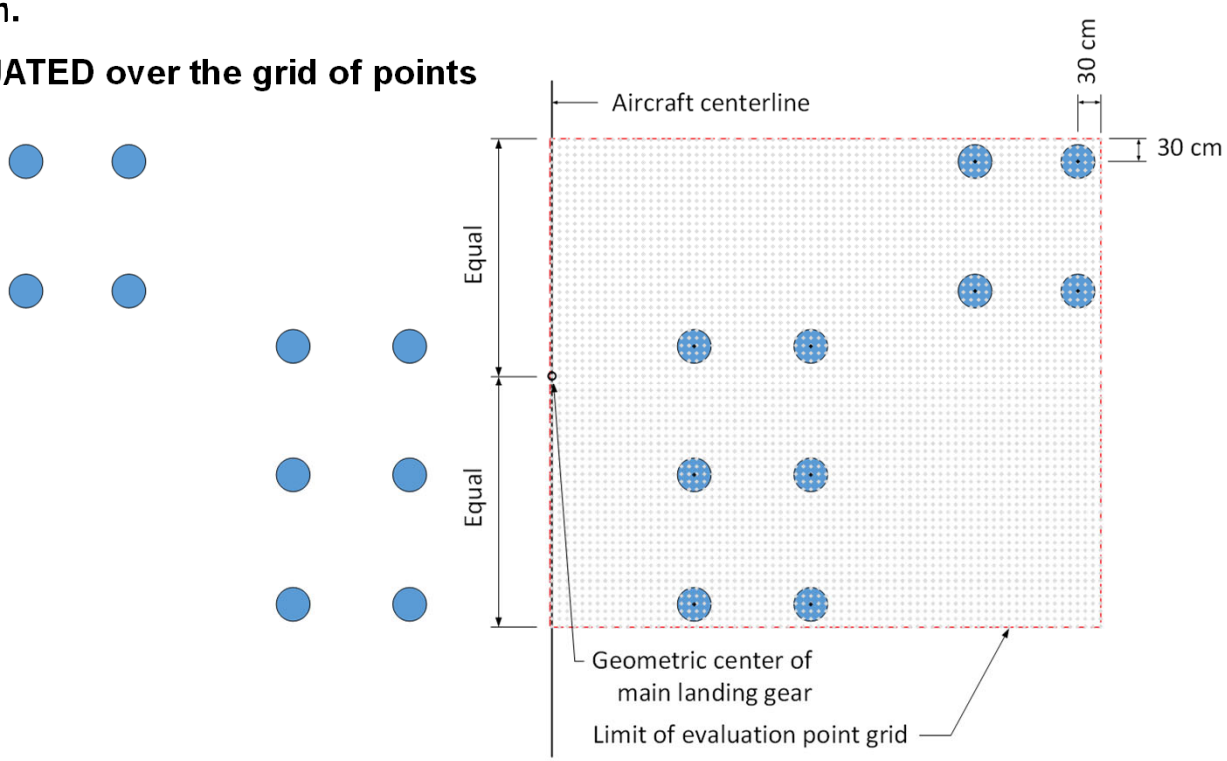
- **ALL main gear wheels contribute to computed strain.**
- **Strain is EVALUATED over the grid of points shown.**





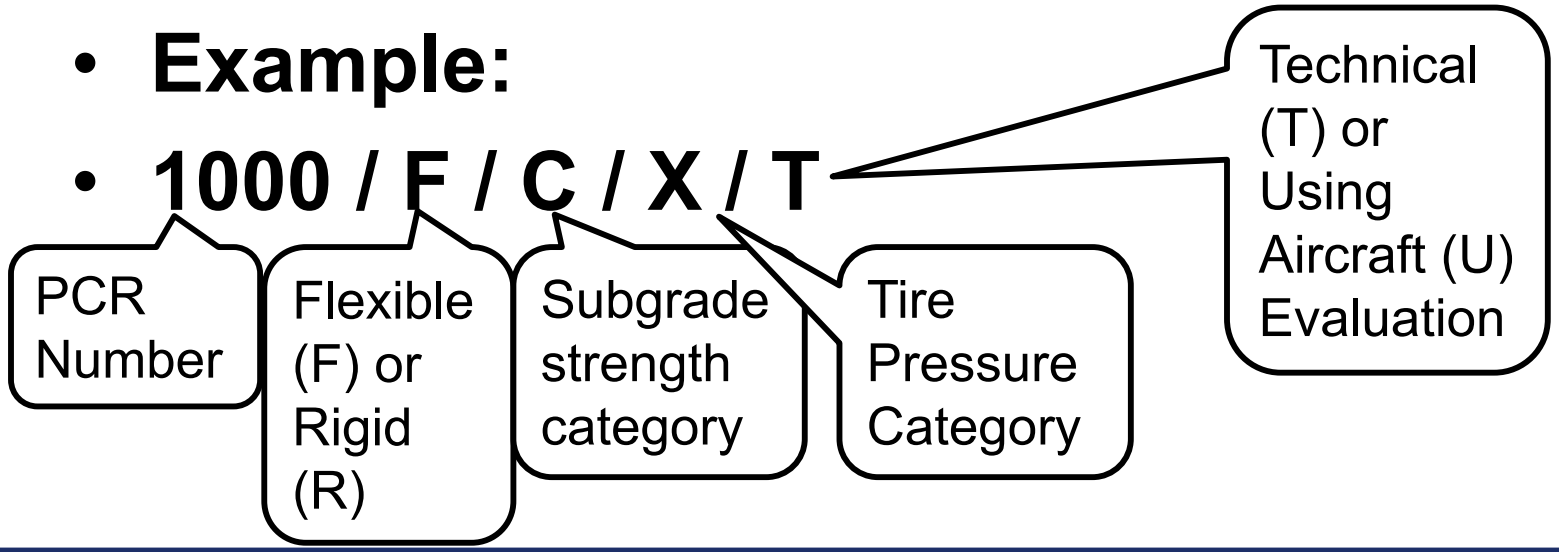
Evaluation Point Grid (Complex Gear)

- **ALL main gear wheels contribute to computed strain.**
- **Strain is EVALUATED over the grid of points shown.**



PCR Reporting

- **Same format as PCN.**
- **Five components, separated by “/”.**
- **Example:**
- **1000 / F / C / X / T**



Method Used to Report PCR

FAA AC 150/5335-5D, Paragraph 4.5.5:

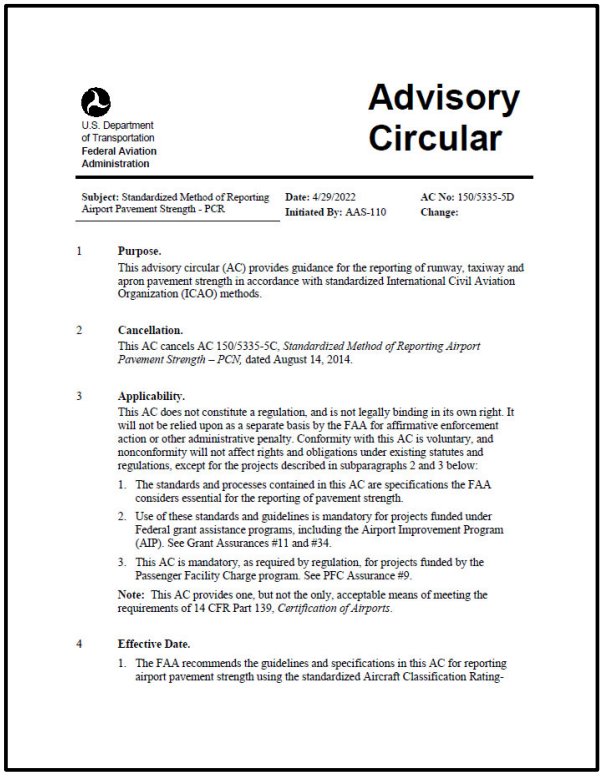
"The PCR system recognizes two pavement evaluation methods. If the evaluation represents the results of a technical study, the evaluation method should be coded T. If the evaluation is based on "Using Aircraft" experience, the evaluation method should be coded U. Technical evaluation implies that some form of technical study and computation were involved in the determination of the PCR. Using Aircraft evaluation means the PCR was determined by selecting the highest ACR among the aircraft currently using the facility and not causing pavement distress."

Generally, PCRs evaluated using FAARFIELD will be reported as "T".

AC 150/5335-5D

Standardized Method of Reporting Airport Pavement Strength - PCR

- **Released April 29, 2022.**
- **Cancels AC 150/5335-5C.**
- **Adopts the ICAO Aircraft Classification Rating -Pavement Classification Rating (ACR-PCR) to replace the current ACN-PCN method.**
- **Covers the process for calculating pavement strength using the new ICAO ACR-PCR method and FAARFIELD 2.0.**
- **All U.S. Part 139 certificated airports are required to report pavement strength on airport master records using PCR no later than <u>September 30, 2024</u>.**



U.S. Department of Transportation
Federal Aviation Administration

Advisory Circular

Subject: Standardized Method of Reporting Airport Pavement Strength - PCR | **Date:** 4/29/2022 | **Initiated By:** AAS-110 | **AC No:** 150/5335-5D | **Change:**

1 **Purpose.**
This advisory circular (AC) provides guidance for the reporting of runway, taxiway and apron pavement strength in accordance with standardized International Civil Aviation Organization (ICAO) methods.

2 **Cancellation.**
This AC cancels AC 150/5335-5C, *Standardized Method of Reporting Airport Pavement Strength – PCN*, dated August 14, 2014.

3 **Applicability.**
This AC does not constitute a regulation, and is not legally binding in its own right. It will not be relied upon as a separate basis by the FAA for affirmative enforcement action or other administrative penalty. Conformity with this AC is voluntary, and nonconformity will not affect rights and obligations under existing statutes and regulations, except for the projects described in subparagraphs 2 and 3 below:

1. The standards and processes contained in this AC are specifications the FAA considers essential for the reporting of pavement strength.
2. Use of these standards and guidelines is mandatory for projects funded under Federal grant assistance programs, including the Airport Improvement Program (AIP). See Grant Assurances #11 and #34.
3. This AC is mandatory, as required by regulation, for projects funded by the Passenger Facility Charge program. See PFC Assurance #9.

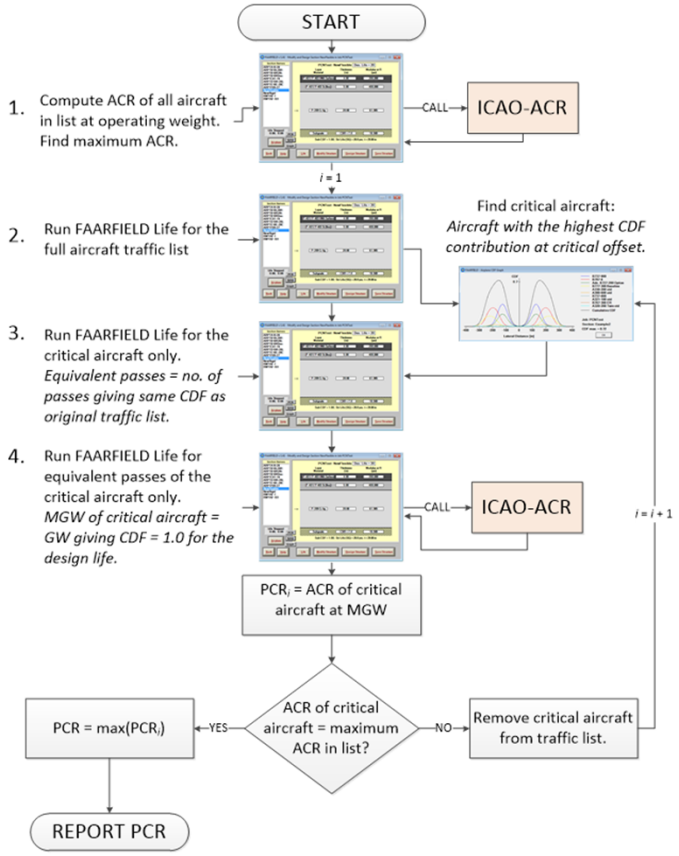
Note: This AC provides one, but not the only, acceptable means of meeting the requirements of 14 CFR Part 139, *Certification of Airports*.

4 **Effective Date.**

1. The FAA recommends the guidelines and specifications in this AC for reporting airport pavement strength using the standardized Aircraft Classification Rating-

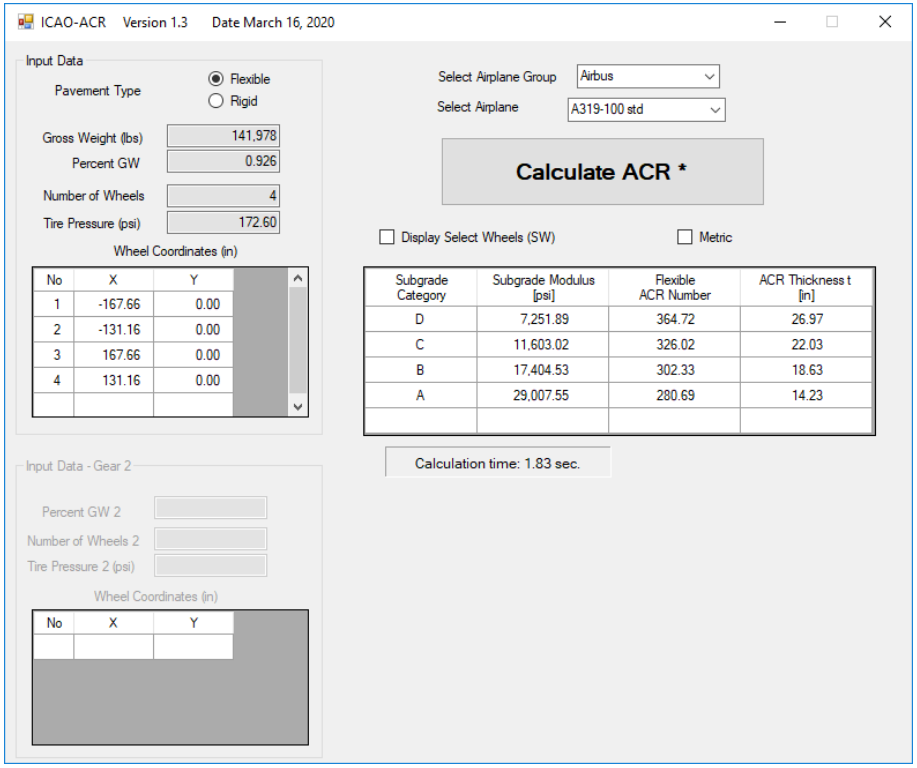
FAARFIELD 2.0 Provides PCR

- **Directly uses FAARFIELD structure and traffic list.**
- **Replacement for COMFAA 3.0 & support spreadsheets.**
- **Method yields uniquely defined PCR – *no more looping through all aircraft in the list*.**
- **Implemented in FAARFIELD 2.0**
  - Solves problem of computing PCR for mixed traffic (narrow bodies and LR aircraft) without unnecessary operating weight restrictions.
  - Seamlessly handles HMA overlays on rigid pavements.



ICAO-ACR Version 1.3

- **FAA developed program.**
- **Standalone version of ACR library implemented in FAARFIELD 2.0.**
- **Calculates standard ACR numbers for aircraft operating on flexible and rigid airport pavements.**
- **Core library can be linked directly to other programs to either compute ACR directly or use as part of a technical PCR evaluation.**
- **Get technical information on how to link the library to a calling program from the ICAO-ACR download page:**



http://www.airporttech.tc.faa.gov/Products/Airport-Pavement-Software-Programs/Airport-Software-Detail/ArtMID/3708/ArticleID/2838/ICAO-ACR-13

Questions?

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APEG:
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Prisca Nkolo (ACI); Dr. Michael Broutin, Lucy Travailleur (DGAC-France);
John Cook (MOD-UK); Dr. Greg White

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