The Aircraft Classification Rating – Pavement Classification Rating ACR-PCR

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The ACN/PCN Task force is composed by members of:

The US, Federal Aviation Administration, FAA
The French Technical Branch of the Civil Aviation Authority, STAC
The ICCAIA, AIRBUS and BOEING rep.

Why a renewed ACN/PCN method?

- Currently, there is an inconsistency between the ACN/PCN system and the recent pavement design methods
- For the above reasons, the current ACN/PCN system is deemed outdated as it fails to take into account accurately:
  - An accurate correlation between the pavement design practice and the rating system
  - The effect of modern and/or complex landing gear configurations (multi-wheel arrangement)
  - The improved mechanical characteristics of new-generation materials
- Hence, the urgent need to **align the ACN/PCN system with the LEA pavement design methods ➔ The ACR-PCR**
- Note: The LEA was already envisaged in the ADM Part 3, in 1983, but the lack of IT technologies solutions postponed its use.

	ACN/PCN system (aircraft admissibility evaluation)	Inconsistencies	Pavement design methods
Type of method	Based on the « CBR design procedure » since the system's entry into service in 1983		Gradually moving to « rational » methods based on the Linear Elastic Analysis (LEA*)
System's rationale	**Empirical method** that does not consider the actual mechanical response of the pavement	⟺	**Mechnanistic-empirical** method that considers the pavement mechanical (stress-strain) response to aircraft loads as well as the pavement performance
Consideration of multi-wheels landing gears	**Equivalencies to single wheels** (ESWL, alpha factors)		**All wheels considered** explicitly for the pavement response computation
Consideration of pavement material characteristics	**Equivalencies to a standard material**		**Pavement material characteristics considered** explicitly for the pavement response computation (E-modulus & Poisson's ratio)

Benefits & Advantages of the renewed ACN/PCN method (ACR-PCR)

- The renewed ACR/PCR method overcomes the identified limitations of the current system and allows a full consideration of the latest evolutions in the field.

- It removes the need of existing equivalency factors or alpha-factors, whose definition might be controversial

- The method will provide several benefits to airport owners:
  - Optimized usage of their pavements
  - Consistency between pavement design and aircraft admissibility parameters
  - Availability of generic PCR computation procedure
  - Improved predictability of pavement life
  - Unified soil characterization method for both flexible and rigid pavements

- This will also benefit the airlines and ultimately the whole air transportation community by allowing optimized operating weights and frequencies, as opposed to the current over-conservative CBR-based system

- The new method could be used by Airport to support pavement management system and subsequent regime of inspection and maintenance

Which Changes?

- By retaining the same appearance and simplicity of the current system, the changes would not be as substantial as they might otherwise appear to those who are unfamiliar with airfield pavement. The plain comparison of two numbers will then continue to be the core principle of the system

- Only the way of determining the two components (ACR calculation method and PCR procedure) will be modified by permanently replacing the CBR design procedure by the LEA as the core of the new ACR/PCR system.

- By adopting the LEA for both Flexible and Rigid pavements, the modulus of subgrade reaction for Rigid pavement (k-value), and the CBR on top of subgrade for flexible pavement will be replaced by a unique soil characterization method (Modulus of elasticity, E), and always declined into four categories (High, medium, low and ultra-low).

- The LEA will permit knowing the contribution of each aircraft composing a mix to the max. damage produced by the total traffic, through the "Cumulative Damage Factor (CDF)" concept. This will ease the pavement overload criteria taking full advantage of how the overload aircraft behaves when it is mixed in an existing traffic mix.

- The Current software ICAO-ACN w1.0 will be replaced by ICAO-ACR 1.0 (already developed) to compute every aircraft ACRs at any weight and center of gravity position.

In a Nutshell…

- The new ACR still relates to a DSWL but its calculation is done through the LEA for both Flexible and Rigid Pavement
- The new PCR procedure consist in determining one or several critical aircraft within a mix and makes this (or those) aircraft equivalent to the mix by:

1. Adjusting their actual number of annual departure so their max CDF equals the critical CDF of the mix at the critical offset (equivalent annual departure)
2. Adjusting critical(s) aircraft operating weight to obtain a CDF of 1.0 for the number of equivalent annual departure
3. Computing the aircraft ACR(s) at that weight. The ACR(s) so obtained is equal to the PCR(s)
4. The PCR is the max of the PCR(s) obtained above

- The PCR of a pavement should reflect the pavement design requirements (the traffic mix for which the pavement was designed).

- If the critical CDF of a pavement is equal to or lower than 1.0, no aircraft weight restriction should occurred

- If the critical CDF of a pavement is greater than 1.0, weight restrictions should apply to at least one aircraft composing the mix

AIRCRAFT CLASSIFICATION RATING (ACR)

- ACR. A number expressing the relative effect of an aircraft on a pavement for a specified standard subgrade strength.
- Numerically defined as two times the derived single wheel load, where the derived single wheel load is expressed in hundreds of kilograms. The single wheel tire pressure is standardized at 1.50 MPa.
- LEA is used for both Flexible and Rigid Pavement
- Standard Subgrade Strength Categories (Flex. & Rig. Commonality):

CAT. A	CAT. B	CAT. C	CAT. D
200 MPa	120 MPa	80 MPa	50 MPa

AIRCRAFT CLASSIFICATION RATING (ACR) – DSWL (Rigid)

Standard working stress for reporting, 2.75 MPa

DESIGN LAYER

DSWL

Wheel load adjustment at P=1.5 MPa

➔ Working stress = 2.75MPa / t1

E_1 = 27 579 MPa, v_1 = 0.15 / Thickness adjustment ➔ **t1** 2.75 MPa	E_1 = 27 579 MPa, v_1 = 0.15 / **t1**
E_2 = 500 MPa, v_2 = 0.20 / t= 200mm	E_2 = 500 MPa, v_2 = 0.20 / t= 200mm
A, B, C & D / Infinite depth	A, B, C & D / Infinite depth

The aircraft classification rating, at the selected mass and subgrade category, is twice the derived single wheel load in 100 kg.

AIRCRAFT CLASSIFICATION RATING (ACR) – DSWL (Flexible)

<table>
<tr><td rowspan="2">Reference structures</td><th colspan="2">Aircraft MLG with 2 wheels or less</th><th colspan="2">Aircraft MLG with more than 2 wheels</th></tr>
<tr><td colspan="2">P-401 / P-403 HMA E = 1379 MPa ν = 0.35 — 3 in (7.6 cm)
P-209 Crushed Aggregate E = f(t) ν = 0.35 — Design layer
Subgrade E = f(CAT) ν = 0.35</td><td colspan="2">P-401 / P-403 HMA E = 1379 MPa ν = 0.35 — 5 in (12.7 cm)
P-209 Crushed Aggregate E = f(t) ν = 0.35 — Design layer
Subgrade E = f(CAT) ν = 0.35</td></tr>
<tr><td rowspan="2">Subgrade categories & moduli</td><th>CAT A</th><th>CAT B</th><th>CAT C</th><th>CAT D</th></tr>
<tr><td>E = 200 MPa</td><td>E = 120 MPa</td><td>E = 80 MPa</td><td>E = 50 MPa</td></tr>
<tr><td>ACN computation procedure</td><td colspan="4">Step 1: Design the pavement structure for below parameters:
○ 36,500 cumulated aircraft passes
○ No lateral wander ($\sigma = 0$)
○ Design criterion: subgrade failure
○ Failure model: FAARFIELD v 1.41 failure model (Bleasdale + Wöhler)
○ Multi-peak damage integration for multi-axle loading

Step 2: Compute the Derived Single Wheel Load (DSWL) that will produce the same CDF (1.00) on the previously designed pavement structure. The DSWL is computed with a constant tire pressure of 1.5 MPa.

Step 3: The Aircraft Classification Rating at the selected mass and subgrade category is given by twice the DSWL (in hundred of Kgs) computed in step 2.</td></tr>
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PAVEMENT CLASSIFICATION RATING (PCR)

GENERAL PRINCIPLE

For a selected pavement and evaluated aircraft mix:

- Determine the critical CDF (at the critical offset)
  - Critical CDF<=1, No weight limitation
  - Critical CDF>1, Weight limitation for at least one aircraft in the mix
- Determine the critical aircraft
- Make the critical aircraft equivalent to the aircraft mix by adjusting its annual departure until it produces the same CDF as produced by the aircraft mix (equivalent annual departures)
- Adjust the critical aircraft mass so that it produces a CDF of 1.0 for the number of equivalent annual departure. This gives the Maximum Allowable Gross Weight (MAGW)
- Compute the critical aircraft ACR at its MAGW
- The reported PCR is the ACR of the critical aircraft at its MAGW

PAVEMENT CLASSIFICATION RATING (PCR)

- HOW TO DETERMINE THE CRITICAL AIRCRAFT
- General case: The most contributing aircraft to the max CDF are the aircraft with the highest ACR at their operating weight

1. Test the most contributing aircraft to the critical CDF (AC1)and Run the procedure ➔ PCR1
2. Remove the aircraft and test the first level reduction list – AC2 (the first critical aircraft is removed and all other reintroduced ➔ PCR2
3. Test the second level reduction list (AC3) ➔ PCR3
4. PCR = Max (PCR1, PCR2, PCR3)

- Specific case: Max aircraft ACRs are weight limited because of their small number of annual departure while their contribution to the critical CDF is minor

1. Run the procedure described above ➔ PCR
2. Run the procedure for the max aircraft ACR ➔ PCR4
3. If PCR4>PCR, then PCR=PCR4 otherwise keep the PCR derived from the initial procedure

Overload Operations

a) For flexible and rigid pavements, occasional movements by aircraft with ACR not exceeding 10 per cent above the reported PCR should not adversely affect the pavement;

b) The annual number of overload movements should not exceed approximately 5 per cent of the total annual movements excluding light aircraft.

c) Overloads in excess of 10% may be considered on a case by case basis when supported by a more detailed technical analysis.

When overload operations exceed allowances described above, a pavement analysis is required for granting the proposed additional loads which was not scheduled in the initial pavement design. In those cases, the pavement analysis should determine how the overload operation contributes to the maximum CDF when it is mixed with the actual traffic mix. Indeed, the ACR as a relative indicator, even if exceeding the reported PCR cannot predict how the overload aircraft will affects the pavement structural behavior and/or its design life, since it will be strongly dependant of its offset to the location of the maximum CDF of the entire fleet (critical offset).

PCR EXAMPLE

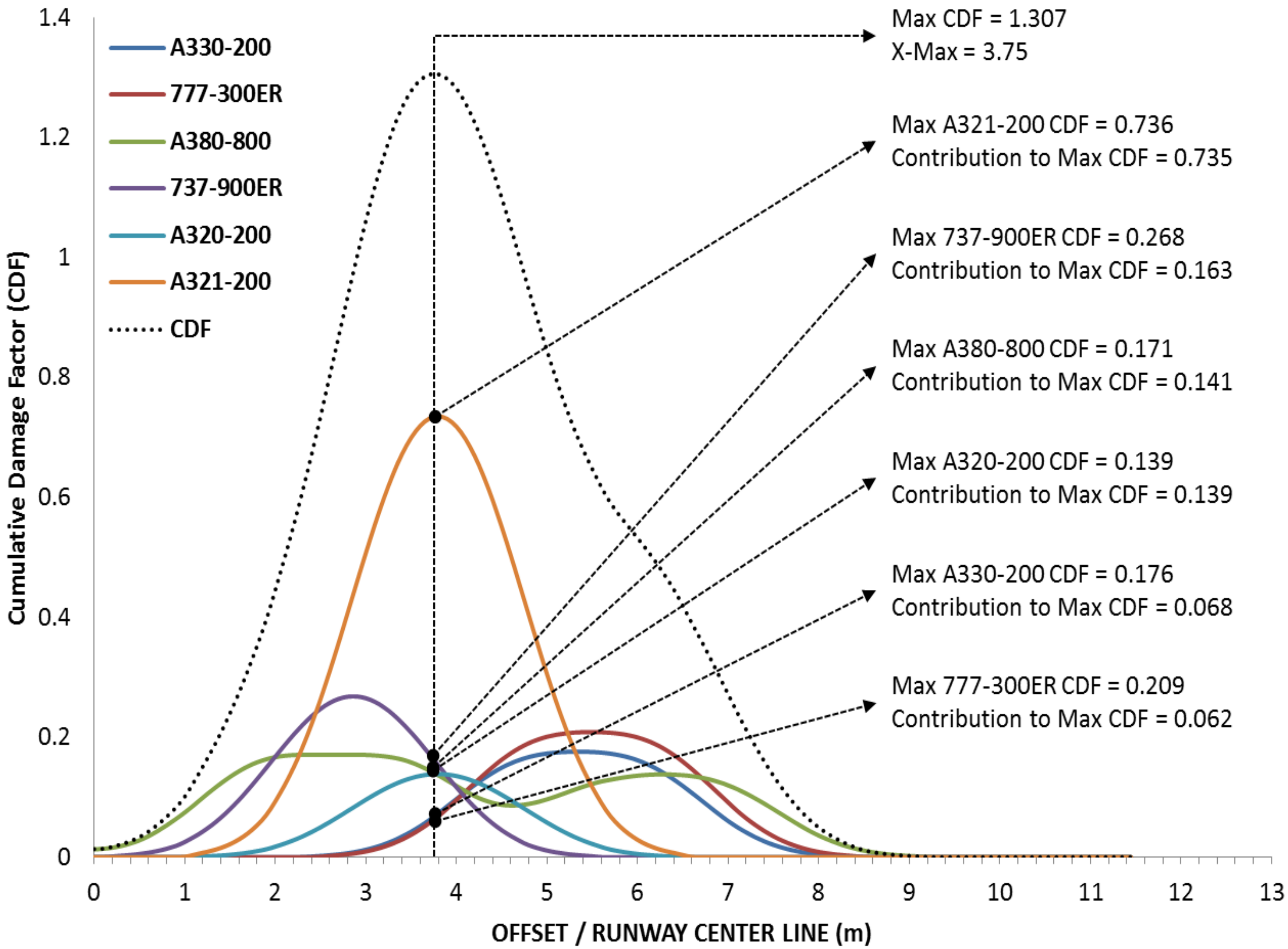
PAVEMENT CHARACTERISTICS				
Layers	Designation	E-Modulus (MPa)	Poisson's ratio	Thickness (cm)
Surface course	P-401/P-403 HMA Surface	1379	0.35	10.2
Base course	P-401/P-403 (flex)	2758	0.35	12.7
Subbase	P209	423	0.35	12.7
Subgrade		200	0.35	∞

Pavement Cross Section

TRAFFIC MIX ANALYSED			
#	Aircraft model	Max Taxi Weight (t)	Annual departure
1	A330-300	233.9	52
2	777-300ER	352.4	52
3	A380-800	571	52
4	737-900ER	85.4	10950
5	A320-200	77.4	10950
6	A321-200	93.9	1560

Aircraft Mix

PCR EXAMPLE



1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
1
2
3
4
5
6
7
8
9
10
11
12
13
Cumulative Damage Factor (CDF)
OFFSET / RUNWAY CENTER LINE (m)
A330-200
777-300ER
A380-800
737-900ER
A320-200
A321-200
CDF
Max CDF = 1.307
X-Max = 3.75
Max A321-200 CDF = 0.736
Contribution to Max CDF = 0.735
Max 737-900ER CDF = 0.268
Contribution to Max CDF = 0.163
Max A380-800 CDF = 0.171
Contribution to Max CDF = 0.141
Max A320-200 CDF = 0.139
Contribution to Max CDF = 0.139
Max A330-200 CDF = 0.176
Contribution to Max CDF = 0.068
Max 777-300ER CDF = 0.209
Contribution to Max CDF = 0.062

PCR EXAMPLE

	A321-200 (AC1)	737-900ER(AC2)	777-300ER (Max ACR)	A320-200	A330-200	A380-800
MTW	93.9	85.4	352.4	77.4	233.9	571
MAGW	91.85	84.25	342	NA	NA	NA
Equivalent Annual dep.	2770	53402	325	NA	NA	NA
ACRi@MRW	**465**	**374**	**575**	**364**	**563**	**558**
ACRi@MAGW	455	369	557	NA	NA	NA
PCRi	455	369	557	NA	NA	NA

Retained PCR= Max (PCR1, PCR2, PCR3) = **557 FAXT**

Weight limitations could apply to the 777-300ER, the A330-200 and marginally to the A380, but exceedance remains in the 10% allowance

PROCESS and TIMEFRAME

- New ACR-PCR System proposal submitted and adopted by the ICAO Aerodrome Design and Operation Panel (ADOP) in March 2018
- Next steps are:
  - Air Navigation Commission Review
  - ICAO Council Endorsement
- The ADOP suggested the following time frame:
  - Effectivity date: July 2020, i.e. The ACR-PCR system becomes the new ICAO Pavement rating System; Training for users (CAAs, Airport, AC manufacturers) can be initiated, implementation phase stated
  - Applicability Date: November 2024, i.e AC manufacturer have published their product ACRs in the relevant documentation (Airplane Characteristics for Airport Planning) and Airports have published their new PCRs in their AIPs