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Subject: Calculation of Runway Pavement Bearing Strength using ACR-PCR Methodology

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Seychelles Technical Standards – Aerodromes
ICAO Annex 14, Volume I
ICAO Doc 9137 Part 2
ICAO Doc 9157 Part 3
PANS-Aerodromes Doc 9981

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Note – Aerodrome Safety Publications are published by the SCAA for purposes of promulgating supplementary guidance materials to the Standards and Recommended Practices (SARPs) in the Seychelles Technical Standards. The publications are intended to provide recommendations and guidance to illustrate a means, but not necessarily the only means, of complying with SARPs. Aerodrome Safety Publications may explain certain regulatory requirements by providing interpretive and explanatory materials.

1. Purpose

1.1 The purpose of this Aerodrome Safety Publication (ASP) is to provide supplementary guidance to aerodrome operators applicants in the determination and reporting of the pavement bearing strength of runways using the ACR-PCR method of reporting as per the STS ADR Issue 3.

1.2 This document is provided for information and guidance purposes. It also provides the format in which the strength of the runway pavements is to be reported and submitted to the AIS for publication the AIP.

2. Applicability

2.1 This ASP applies to all aerodrome operators subjected to Regulation 61 of the Civil Aviation (Safety) Regulations, 2017 and the Seychelles Technical Standards - Aerodromes.

2.2 This ASP is applicable to all aerodromes, which accommodated aircraft of apron (ramp) with a mass greater than 5700 Kilograms.

3. Cancellation

3.1 Nil

4. Introduction

4.1 The ACR-PCR method is used only to publish pavement strength data in aeronautical information publications (AIPs). It allows pavement strengths to be reported on a continuous scale that starts at zero and has no upper limit. The same scale is used to measure the load ratings of both aircraft and pavements.

5. Abbreviations and Definitions

5.1 Abbreviations

ACN	Aircraft Classification Number
ACR	Aircraft Classification Rating
AIP	Aeronautical Information Publication
AIS	Aeronautical Information Service
CBR	California Bearing Ratio
CDF	Cumulative Damage Factor
MAGW	Maximum Allowable Gross Weight
MN/m³	Meganewton per cubic metre
MPa	Megapascal
MTOW	Maximum Take-off Weight
PCN	Pavement Classification Number
PCR	Pavement Classification Rating
PCRi	Pavement Classification Rating I
RWY	Runway
TWY	Taxiway

5.2 Definitions

Aircraft Classification Number
Means a number expressing the relative effect of an aircraft on a pavement for a specified standard subgrade category.

Aircraft Classification Rating
Means a number expressing the relative effect of an aircraft on a pavement for a specified Standard subgrade category.

California Bearing Ratio
The resistance of a soil to controlled penetration, usually when soaked, relative to that of a standard Californian limestone.

Coverage
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.

Cumulative Damage Factor
Is the amount of structural fatigue life of a pavement, which has been used up. It is expressed as the ratio of applied load repetitions to allowable load repetition to failure. By convention, a new pavement construction has a CDF equal to zero, while a theoretical end-life pavement has a CDF equal to 1.0.

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 Classification Number
Means a number expressing the bearing strength of a pavement for unrestricted operations.

Pavement Classification Rating
Means a number expressing the bearing strength of a pavement.

Pavement Classification Rating I
The PCR to be reported is the maximum value of all computed PCR (i). where (i) is an index value with an initial value 1.0 (CDF).

6. Overview of the ACR-PCR method of reporting pavement bearing strength.

6.1 The Aircraft Classification Rating - Pavement Classification Rating (ACR-PCR) method of reporting pavement-bearing capacity was developed in a similar way to the ACN-PCN method. This means that the ACR of the aircraft is compared to the PCR of the pavement. If the PCR exceeds the ACR, the aircraft can fly without restriction. However, if the ACR exceeds the PCR, a pavement concession is required. As with the ACN-PCN method, a check of the tyre pressure limit is also required and is almost unchanged.

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

- Standard tyre pressure
- Standard pavement structures
- Subgrade categories
- Calculated indicator of relative damage.

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

6.4 The ACR-PCR method uses the elastic modulus of the subgrade (expressed in MPa).

6.5 The measure of relative damage caused by different aircraft will now be based on vertical strain at the top of the subgrade, rather than the maximum deflection at the top of the subgrade. Additionally, layered elastic models will be used to calculate strain magnitudes instead of the simpler models previously employed. This change utilizes the advanced computing power now available, significantly reducing discrepancies between pavement thickness design and pavement strength rating.

6.6 Determination of the numerical PCR value for a particular pavement can be based upon one of two procedures: the **using aircraft method** or the **technical evaluation method**.

6.7 Using Aircraft Method to Determine PCR: The 'Using Aircraft Method' is a procedure where ACR values for all aircraft currently permitted to use the pavement facility are determined and the largest ACR value is reported as the PCR. This method is easy to apply and does not require detailed knowledge of the pavement structure. The subgrade support category is not a critical input when reporting PCR based on the Using Aircraft Method.

a) Assumptions of the Using Aircraft Method.

An underlying assumption with the Using Aircraft Method is that the pavement structure has the structural capacity to accommodate all aircraft in the traffic mix, and that each aircraft is capable of operating on the pavement structure without weight restriction. The methodology used to determine ACR/PCR does not consider the critical design aircraft used to determine airport dimensional requirements.

b) Discrepancies of the Using Aircraft Method.

The accuracy of this method is dependent upon having records of past aircraft traffic. Significant over-estimation of the pavement capacity can result if an excessively damaging aircraft, which uses the pavement on a very infrequent basis, is used to determine the PCR.

Likewise, significant under-estimation of the pavement capacity can lead to uneconomic use of the pavement by preventing acceptable traffic from operating. Although there are no minimum limits on frequency of operation before an aircraft is considered part of the normal traffic, the reporting agency must use a rational

approach to avoid overstating or understating the pavement capacity. Use a consistent method based on a design period minimum frequency of 250 annual departures. Use of the Using Aircraft Method is discouraged on a long-term basis due to the concerns listed above.

6.8 **Using Technical Evaluation Method to Determine PCR**: Pavement technical evaluations may require a combination of on-site inspections, load-bearing tests, and engineering judgement. Pavement strength rating is often conceptualized in terms of ultimate strength or immediate failure criteria.

a) Assumptions of the Technical Evaluation Method.

The technical evaluation method attempts to address site-specific variables that are used to determine reasonable pavement strength. In general terms, for a given pavement structure and given aircraft, the allowable number of operations (traffic) will decrease as the intensity of pavement loading increases (increase in aircraft weight). It is entirely possible that two pavement structures with different cross-sections will report similar strength. However, the permissible aircraft operations will be considerably different. This discrepancy must be acknowledged by the airport operator and may require operational limitations administered outside of the ACR-PCR system.

b) Accuracy of the Technical Evaluation Method.

The accuracy of a technical evaluation is better than that produced with the *Using Aircraft* procedure but requires additional information. Pavement evaluation may require a combination of load-bearing tests, on-site inspections, and engineer's judgment. Pavement strength ratings are often conceptualised in terms of ultimate strength or instant failure criteria.

However, pavements are rarely removed from service due to instantaneous structural failure. A decrease in the serviceability of a pavement is commonly attributed to increases in surface roughness or localized distress, such as rutting or cracking. Determination of the adequacy of a pavement structure must not only consider the magnitude of pavement loads but the impact of the accumulated effect of traffic over the intended life of the pavement. To determine a technical PCR requires information on: **(1)** aircraft traffic composition and frequency, **(2)** thickness, material type and strength of each layer of pavement structure and **(3)** elastic modulus of subgrade.

Understanding and selecting the appropriate damage model and associated parameters for PCR calculation is of paramount importance.

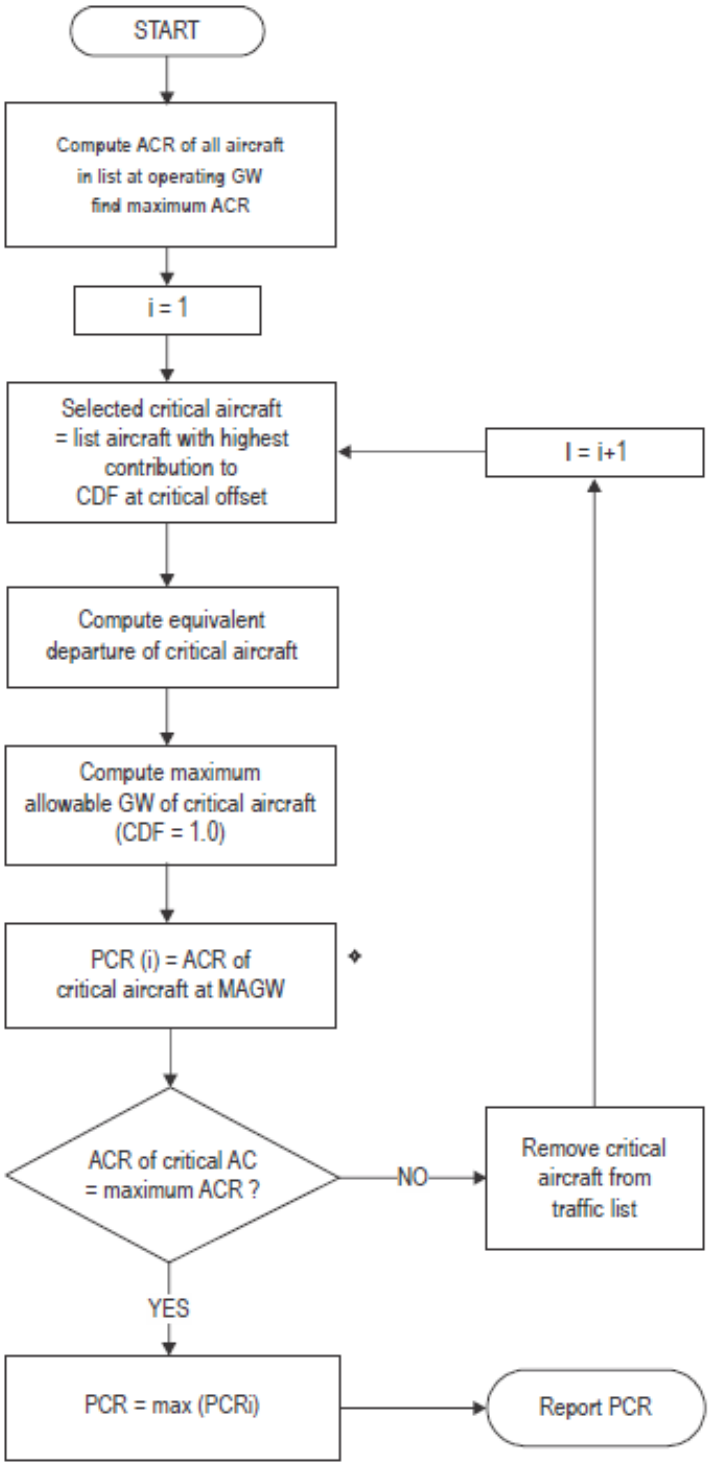
Inconsistencies between the damage models used for pavement design and PCR determination may result in:

I. PCR underestimation – Unoptimized use of pavement and potential denial of aircraft operations results in loss of revenue.

II. PCR overestimation – Accelerated pavement deterioration, reduced pavement life and premature repairs/rehabilitation

6.9. The recommended PCR procedure considers the characteristics of the pavement structure and aircraft traffic forecast over the life period of the pavement infrastructure

selected. The life period should reflect the design life for new pavements and the remaining life for in-service pavements. The PCR should be valid only for this usage period. A new evaluation is required after pavement rehabilitation or when traffic changes as compared to the initial traffic. As a form of good practice, the PCR should be calculated in conjunction with a construction project or as part of the airport's pavement management program. The recommended PCR determination flow chart is as below figure:


START
Compute ACR of all aircraft in list at operating GW find maximum ACR
i = 1
Selected critical aircraft = list aircraft with highest contribution to CDF at critical offset
I = i+1
Compute equivalent departure of critical aircraft
Compute maximum allowable GW of critical aircraft (CDF = 1.0)
PCR (i) = ACR of critical aircraft at MAGW
ACR of critical AC = maximum ACR ?
NO
Remove critical aircraft from traffic list
YES
PCR = max (PCRi)
Report PCR

7. The ACR-PCR methodology

7.1 The bearing strength of a pavement intended for aircraft of apron (ramp) mass greater than 5700kg shall be made available using the aircraft classification rating – pavement classification rating (ACR- PCR) method by reporting all the following information:

a. the pavement classification rating (PCR) and numerical value
b. pavement type of ACR-PCR determination;
c. subgrade strength category;
d. maximum allowable tire pressure category or maximum allowable tire pressure value; and
e. evaluation method

7.2 The pavement classification rating (PCR) reported shall indicate that an aircraft with an aircraft classification rating (ACR) equal to or less than the reported PCR can operate on the pavement subject to any limitation on the tire pressure, or aircraft all-up mass for specified aircraft type(s).

The ACR of an aircraft shall be determined in accordance with the standard procedures associated with the ACR-PCR method.

For the purposes of determining the ACR, the behavior of a pavement shall be classified as equivalent to a rigid or flexible construction.

Information on pavement type for ACR-PCR determination, subgrade strength category, maximum allowable tire pressure category and evaluation method shall be reported using the following codes:

ACR-PCR determination:

Pavement type	**Code**
Rigid pavement	R
Flexible pavement	F

Note – If the actual construction is composite or non-standard, include a note to that effect (See example 2 below).

Subgrade strength category:	**Code**
High strength: characterized by E=200 MPa and representing all E values equal to or above 150 MPa for rigid and flexible pavements.	A
Medium strength: characterized by E=120 MPa and representing a range in E values equal to or above 100 MPa and strictly less than 150 MPa, for rigid and flexible pavements.	B
Low strength: characterized by E=80 MPa and representing a range in E values equal to or above 60 MPa and strictly less than 100 MPa, for rigid and flexible pavements.	C
Ultra-low strength: characterized by E=50 MPa and representing all E values strictly less than 60 MPa, for rigid and flexible pavements.	D

Maximum allowable tire pressure category:	**Code**
High: no pressure limit	W
Medium: pressure limited to 1.50 Mpa	X
Low: pressure limited to 1.00 Mpa	Y
Very low: pressure limited to 0.50 Mpa	Z

Note - See Note 5 to 14.3.1 where the pavement is used by aircraft with tire pressures in the upper categories.

Evaluation method:	**Code**
Technical evaluation: representing a specific study of the pavement characteristics and the types of aircraft which the pavement is intended to serve.	T
Using aircraft experience: representing knowledge of the specific type and mass of aircraft satisfactorily being supported under regular use.	U

Note – The following examples illustrate how pavement strength data are reported under the ACR-PCR method. Further guidance on this topic is contained in the Aerodrome Design Manual (Doc 9157), Part 3 – Pavements.

8. ACR-PCR methodology examples

8.1 The PCR determination using **aircraft experience** relies on the following steps:

1. Identify the aircraft using the pavement, with operating weights and frequency of operation.
2. Determine the corresponding ACR for the identified pavement type and subgrade strength category.
3. Report the PCR as ACR of the most critical aircraft on the fleet.
4. When a significant increase in use of the pavement is expected, the PCR should be adjusted to accommodate the increase.

8.1.1 Worked example using Aircraft Method to Determine PCR:

a. An aerodrome operator wants to assess the PCR of the runway, however due to financial constraints a technical method is deemed infeasible:

i. The runway is a flexible pavement (F).

ii. The subgrade modulus can be estimated from historical CBR of 90 MPa (Subgrade category C).

iii. There is no evidence of pavement distress attributable to high tire pressures. (Tire pressure category W).

iv. The runway has been accommodating the following traffic without any significant damaged recorded:

No.	AIRCRAFT TYPE	OPERATING WEIGHT(TONNES)	ANNUAL DEPARTURES	ACR (AT OPERATING WEIGHT)
1	A330-300	233.9 t	104	650 F/C
2	A350-900	268.9 t	52	720 F/C
3	B777-300ER	352.4 t	6	790 F/C
4	B787-9	254.7 t	52	750 F/C

b. The number of annual departures for the B777-300ER is very low as compared to other aircrafts in the traffic mix; hence, it should be dismissed from the PCR assessment.

i. Based on the composition of aircraft in the fleet the next highest ACR is for B787-9.
ii. The PCR should be reported as **750/F/C/W/U** (using the B787-9 ACR).

8.2 The PCR determination using **technical evaluation** method relies on the following steps:

a. Identify aircraft with the highest ACR at operating weight (in the traffic mix).

b. Calculate the maximum pavement damage for the current traffic.

c. Selection of the aircraft that contributes the most to the maximum pavement damage.

d. Keep only the selected aircraft above in the traffic, adjust its number of passes so that the pavement damage is the same as the full traffic.

e. Keep only the selected aircraft in the traffic with its adjusted number of passes, adjust its weight so that the pavement damage (CDF) is equal to 1.0.

f. PCR is equal to ACR of selected aircraft at adjusted weight.

g. Report the PCR as ACR of the most demanding aircraft (if no diversion encountered)

8.2.1. Worked example using Technical Evaluation Method to Determine PCR:

a. A new flexible runway is designed as below:

i. The subgrade modulus can be estimated as CBR of 80 MPa (Subgrade category C).

ii. The surface layer is made of asphalt concrete that can withstand the highest tire pressure (Tire pressure category W)

iii. The damage model for the PCR evaluation is the same as the one used during the design of the pavement.

iv. The forecasted traffic over a 10-year pavement life span, is as follows:

No.	AIRCRAFT TYPE	OPERATING WEIGHT (TONNES)	PASSES (OVER 10-YEAR PAVEMENT LIFE) NUMBER	ACR (AT OPERATING WEIGHT)
1	A330-300	233.9	19 396	650 F/C
2	A319 neo	75.9	32 094	400 F/C
3	A320 neo	79.4	23 560	380 F/C
4	A350-900	268.9	8 971	720 F/C
5	B777-300ER	352.4	37 842	790 F/C
6	B787-9	254.7	16 044	750 F/C

b. The coverage (passes) on the pavement surface is considered in analysing the damage on the pavement exerted by each passing aircraft.

c. Based on the composition of aircraft in the fleet the highest ACR is for B777-300ER.

d. The PCR should be reported as 790/F/C/W/T (using the B777-300ER ACR).

9. ACR-PCR methodology overloading operations

9.1 Overloading of pavements can occur due to excessively large loads, a significantly increased application rate, or a combination of both. Loads exceeding the defined (design or evaluation) load reduce the pavement's design life, whereas smaller loads can extend it. With the exception of extreme overloading, pavements do not have a specific load limit that causes sudden or catastrophic failure. Instead, pavements are designed to sustain a specified load for an expected number of repetitions throughout their design life. Therefore, occasional minor overloading is acceptable when necessary, resulting in only a limited reduction in pavement life expectancy and a relatively small acceleration in pavement deterioration.

9.2 The following guidelines are recommended when evaluating overloads:

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

9.3 Such overload movements should not normally be permitted on pavement exhibiting signs of distress or failure. Furthermore, overloading should be avoided when the strength of the pavement or its subgrade could be weakened by water.

9.4 Where overload operations are conducted, the relevant pavement condition should be reviewed regularly, and the criteria for overload operations should be reviewed periodically since excessive repetition of overloads can cause severe shortening of pavement life or require major rehabilitation of pavement.

10. Reporting the pavement strength to the AIS

10.1 The PCR system uses a coded format to maximize the amount of information contained in a minimum number of characters and to facilitate computerization. The PCR is reported as a five-part code where the following codes are ordered and separated by forward slashes: Numerical PCR value / Pavement type / Subgrade category / Allowable tire pressure / Method used to determine the PCR, (e.g. PCR 680/F/C/X/U)

10.2 The aerodrome operator is required to report the bearing strength of the RWY, TWY and aprons to the Aeronautical Information Service (AIS) on an annual basis.

10.3 The aerodrome operator is required to report the bearing strength of the aerodrome pavements using the prescribed form and supporting technical documentation, as part of the AIP amendment.

11. Queries

Any queries relating to this Aerodrome Safety Publication should be addressed to Aerodrome Safety & Standards Inspectorate on seyaga@scaa.sc

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