GHANA

CIVIL AVIATION AUTHORITY

ADVISORY CIRCULAR
AC 14-042

CALCULATION OF RUNWAY PAVEMENT BEARING STRENGTH USING ACR-PCR METHODOLOGY

1. GENERAL

Ghana Civil Aviation Authority (GCAA) Advisory Circulars from Aerodrome Safety and Standards (ASAS) contain information about standards, practices, and procedures that the Authority has found to be an Acceptable Means of Compliance (AMC) with the associated Directives.

An AMC is not intended to be the only means of compliance with a Directive, and consideration will be given to other methods of compliance that may be presented to the Authority.

1.1. Purpose

The purpose of this document is to assist aerodrome operators in the determination and reporting of the pavement bearing strength of runways using the ACR-PCR method of reporting as per the GCADs Part 14.

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 GCAA for publication in the AIP.

1.2. Reference

It is intended that the following reference materials be used in conjunction with this document:
International Civil Aviation Organization (ICAO) Annex 14 to the *Convention on International Civil Aviation — International Standards and Recommend Practices: Aerodromes – Volume I Aerodrome Design and Operations* (Eighth Edition, July 2018);

i. ICAO Doc 9137 Part 2
ii. ICAO Doc 9157 Part 3
iii. PANS-Aerodromes Doc 9981
iv. GCADs Part 14.

1.3. Related Directives

The following Directives are directly applicable to the guidance contained in this advisory circular—
GCAD Part 14
GCAD Part 27

1.4. Status of this Advisory Circular

This is an original issuance of this AC.

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APPROVAL

Issue No: 01	Approved by: Director-General	Nov. 2024

2. TERMS AND ABBREVIATIONS

2.1. Terms

TERM	DEFINITION
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. Note. The aircraft classification rating is calculated with respect to the centre of gravity (CG) position which yields the critical loading on the critical gear. Normally the aftmost CG position appropriate to the maximum gross apron (ramp) mass is used to calculate the ACR. In exceptional cases the forwardmost CG position may result in the nose gear loading being more critical
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).

2.2. Abbreviations

ABBREVIATION	DESCRIPTION
AC	Advisory Circular
ACN	Aircraft Classification Number
ACR	Aircraft Classification Rating
AIP	Aeronautical Information Publication
AIS	Aeronautical Information Service
CBR	California Bearing Ratio
CDF	Cumulative Damage Factor
ICAO	International Civil Aviation Organization
MAGW	Maximum Allowable Gross Weight
MPa	Megapascal
PANS	Procedures for Air Navigation Services
PCN	Pavement Classification Number
PCR	Pavement Classification Rating
PCRi	Pavement Classification Rating I
RWY	Runway
TWY	Taxiway

3. OVERVIEW OF THE ACR-PCR METHOD OF REPORTING PAVEMENT BEARING STRENGTH

3.1. 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.

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

a) Standard tyre pressure
b) Standard pavement structures
c) Subgrade categories
d) Calculated indicator of relative damage.

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

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

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

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”, as per below:

3.2. Using Aircraft Method to Determine PCR

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) Inaccuracies 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.

3.3. Using Technical Evaluation Method to Determine PCR

Pavement technical evaluations may require a combination of on-site inspections, load-bearing tests, and engineering judgment. It is common to think of pavement strength rating 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 on-site inspections, load-bearing tests, and engineering judgment. It is common to think of pavement strength rating in terms of ultimate strength or immediate 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.

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 bellow figure 1:

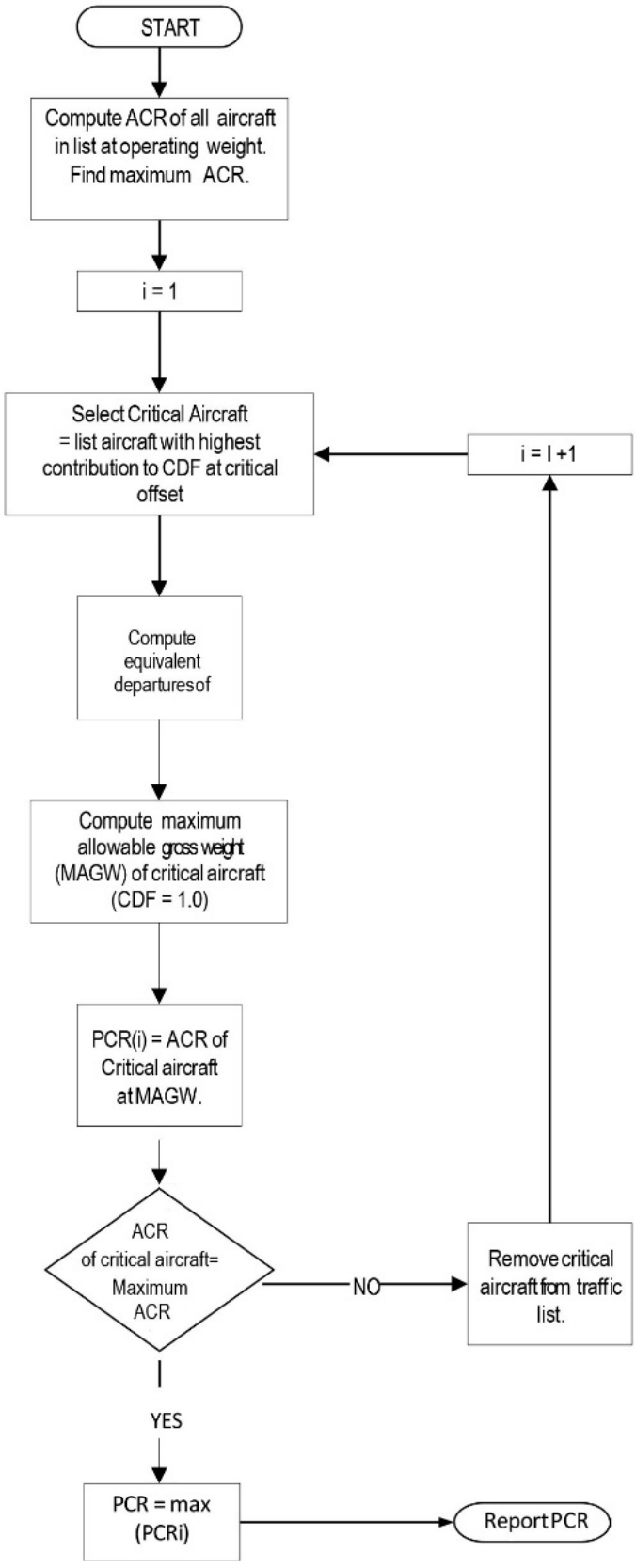

Figure 1: Flowchart of Recommended PCR Procedure

4. THE ACR-PCR METHODOLOGY

1. The bearing strength of a pavement intended for aircraft of an apron ramp mass greater than 5 700 kilograms shall be determined using the aircraft classification rating and pavement classification rating (ACR-PCR) method by reporting all the following information:

   a) The PCR (on the ACR scale).
   b) Pavement type for ACR-PCR determination.
   c) Subgrade strength category.
   d) Maximum allowable tyre pressure category or maximum allowable tyre pressure value; and
   e) Evaluation method.

2. The PCR reported shall indicate that an aircraft with an aircraft classification ACR rating equal to or less than the reported PCR can operate on the pavement subject to any limitation on the tyre pressure, or aircraft all-up mass for specified aircraft types.

3. An aircraft ACR shall be determined in accordance with the standard procedures associated with the ACR-PCR method.

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

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

4.1. ACR-PCR determination

4.1.1. Pavement type

PAVEMENT TYPE	CODE
Rigid pavement	**R**
Flexible pavement	**F**

4.1.2. Subgrade strength category

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 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 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**

4.1.3. Maximum allowable tyre pressure category

MAX ALLOWABLE TYRE PRESSURE	CODE
Unlimited: no pressure limit	**W**
High: pressure limited to 1.75 MPa	**X**
Medium: pressure limited to 1.25 MPa	**Y**
Low: pressure limited to 0.50 MPa	**Z**

4.1.4. Evaluation method

EVALUATION	CODE
Technical evaluation: representing a specific study of the pavement characteristics and application of pavement behaviour technology	**T**
Using aircraft experience: representing a knowledge of the specific type and mass of aircraft satisfactorily being supported under regular use.	**U**

5. ACR-PCR METHODOLOGY OVERLOADING OPERATIONS

Aircraft loadings that are larger than the defined PCR will shorten the pavement design life, while smaller aircraft loads will use up the life at a reduced rate. With the exception of massive overloading, pavements do not suddenly or catastrophically fail. As a result, occasional minor overloading is acceptable with only limited loss of pavement life expectancy and relatively small acceleration of pavement deterioration.

The following guidelines are recommended when evaluating overloads:

a) For flexible or rigid pavements, occasional traffic by aircraft with an ACR not exceeding 10 percent above the reported PCR should not adversely affect the pavement. For example, a pavement with PCR=600 can support some limited traffic of aircraft with ACR=660.

b) The annual number of overload traffic should not exceed approximately 5 percent of the total annual aircraft traffic. There is no exact guidance for choosing a number of operations that represents 5 percent.

c) Overloads should not normally be permitted on pavements already exhibiting signs of structural distress, during periods of thaw following frost penetration, or when the strength of the pavement or its subgrade could be weakened by water.

d) When overload operations are conducted, the aerodrome operator should regularly inspect the pavement condition. Periodically the aerodrome operator should review the criteria for overload operations. Excessive repetition of overloads can cause a significant reduction in pavement life or accelerate when a pavement will require a major rehabilitation.

5.1. ACR-PCR METHODOLOGY WORKED EXAMPLES

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.

5.1.1. 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:

AIRCRAFT TYPE	OPERATING WEIGHT(TONNES)	ANNUAL DEPARTURES	ACR (AT OPERATING WEIGHT)
A330-300	233.9 t	104	650 F/C
A350-900	268.9 t	52	720 F/C
B777-300ER	352.4 t	6	790 F/C
B787-9	254.7 t	52	750 F/C

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

B. The PCR determination using technical evaluation method relies on the following steps:
i. Identify aircraft with the highest ACR at operating weight (in the traffic mix).
ii. Calculate the maximum pavement damage for the current traffic.
iii. Selection of the aircraft that contributes the most to the maximum pavement damage.
iv. 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.
v. 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.
vi. PCR is equal to ACR of selected aircraft at adjusted weight.
vii. Report the PCR as ACR of the most demanding aircraft (if no diversion encountered)

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

C. A new flexible runway is designed according to the TRH4 Design methods, as bellow:
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:

AIRCRAFT TYPE	OPERATING WEIGHT (TONNES)	PASSES (OVER 10-YEAR PAVEMENT LIFE) NUMBER	ACR (AT OPERATING WEIGHT)
A330-300	233.9	19 396	650 F/C
A319 neo	75.9	32 094	400 F/C
A320 neo	79.4	23 560	380 F/C
A350-900	268.9	8 971	720 F/C
B777-300ER	352.4	37 842	790 F/C
B787-9	254.7	16 044	750 F/C

v. The coverage (Passes) on the pavement surface is considered in analysing the damage on the pavement exerted by each passing aircraft.
vi. Based on the composition of aircraft in the fleet the highest ACR is for B777-300ER.
vii. The PCR should be reported as 790/F/C/W/T (using the B777-300ER ACR).

6. REPORTING OF PAVEMENT BEARING STRENGTH TO THE GCAA

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)

The aerodrome operator is required to report the bearing strength of the RWY, TWY and aprons to GCAA AIS section on an annual basis.

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.

7. SUPPORTING DOCUMENTS

1. Latest ACN-PCN Technical Report
2. Latest ACR-PCR Technical Report
3. Aircraft Annual Traffic Data (Annual departures)
4. Other documentation that may be requested by the authority (i.e. software printouts).