Guidance for the implementation of the new Aircraft Classification Rating (ACR) - Pavement Classification Rating (PCR) method in the EASA Member States

Revision 1

The following is a list of paragraphs affected by Revision 1:

Paragraph 4	text amended
Paragraph 11.4	text amended
Paragraph 11.5	text amended
Paragraph 11.6	text amended

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1 Executive Summary

In 2020, ICAO adopted with Amendment 15 to Annex 14, Volume I Aerodromes — Aerodrome Design and Operations, **a new method for expressing and calculating the bearing strength of a pavement, called the Aircraft Classification Rating (ACR) - Pavement Classification Rating (PCR)**. A transition period of 4 years has been set by ICAO and the new method will become applicable on 28 Nov 2024, replacing the current Aircraft Classification Number (ACN) - Pavement Classification Number (PCN) method. **The applicability of the ACR-PCR method in the EASA Member States has been deferred to a later date to allow a synchronised application for aerodromes and Aeronautical Information Service Providers (AISP).**

The new method is more accurate as it determines the impact that each aircraft produces on a pavement. The expected benefits are optimised use of pavement, reduced maintenance needs and costs, and a reduction of greenhouse gas emissions through a well-managed pavement life cycle.

Just like the current ACN-PCN, the new ACR-PCR method is meant only for the publication of pavement strength data in the AIP. The ACR values were calculated by the aircraft manufacturers and made available either in the dedicated airport planning manuals or through a dedicated software. The PCR values will have to be determined by the aerodrome operators for all pavements intended for aircraft of apron mass greater than 5700 kg, and afterwards reported to the aeronautical information services providers for their publication in the aeronautical information publication (AIP). The reported PCR will indicate that an aircraft with an ACR equal to or less than the reported PCR may operate on the pavement subject to any limitations (e.g. tyre pressure).

Following the questions received from stakeholders, EASA has prepared this guidance to support them in their efforts to implement the new ACR-PCR method in a timely and uniform manner across the EU, and to avoid discrepancies of the published information within individual States and across the EU Member States. The guidance:

- provides information on the steps and planned timeframe for the transposition of the new method in the EU regulatory framework;
- provides recommended actions to the competent authorities, aerodrome operators and aeronautical information services providers to ensure compliance with the new method;
- details the two acceptable methods to determine the PCR values, i.e. either through a technical evaluation which represents a study, or using the aircraft experience which represents a knowledge of the specific type and mass of aircraft satisfactorily being supported under regular use;
- includes examples for the calculation of the ACR and PCR values.

Due to the novelty and technical nature of this new method, EASA recommends that, in addition to this guidance, the competent authorities and aerodrome operators attend dedicated training courses on the subject.

2 Acronyms

ACN	Aircraft classification number
ACR	Aircraft classification rating
AIP	Aeronautical information publication

AISP(s)	Aeronautical information services provider(s)
CBR	California bearing ratio
CDF	Cumulative damage factor
CG	Centre of gravity
E	Modulus of elasticity
K	Modulus of subgrade reaction
MAGW	Maximum allowable gross weight
MPa	Megapascal
v	Poisson's ratio
PCN	Pavement classification number
PCR	Pavement classification rating
WV	Weight variant

3 Definitions

Aircraft classification number	A number expressing the relative effect of an aircraft on a pavement for a specified standard subgrade category.
Aircraft classification rating	A number expressing the relative effect of an aircraft on a pavement for a specified standard subgrade category.
Base course (or base)	The layer or layers of specified or selected material of designed thickness placed on a subbase or subgrade to support a surface course.
Bearing strength	The measure of the ability of a pavement to sustain the applied load, also referred as bearing capacity or pavement strength.
California bearing ratio	The bearing ratio of soil determined by comparing the penetration load of the soil to that of a standard material. The method covers evaluation of the relative quality of subgrade soils but is applicable to sub-base and some base course materials.
Composite pavement	A pavement consisting of both flexible and rigid layers with or without separating granular layers.

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Flexible pavement	A pavement structure that maintains intimate contact with and distributes loads to the subgrade and depends on aggregate interlock, particle friction, and cohesion for stability.
Modulus of elasticity	The modulus of elasticity of a material is a measure of its stiffness. It is equal to the stress applied to it divided by the resulting elastic strain.
Pavement structure (or pavement)	The combination of sub-base, base course, and surface course placed on a subgrade to support the traffic load and distribute it to the subgrade.
Poisson's ratio	The ratio of transverse to longitudinal strains of a loaded specimen.
Pavement classification number	A number expressing the bearing strength of a pavement for unrestricted operations.
Pavement classification rating	A number expressing the bearing strength of a pavement for unrestricted operations.
Rigid pavement	A pavement structure that distributes loads to the subgrade having as its surface course a Portland cement concrete slab of relatively high bending resistance, also referred as concrete pavement.
Sub-base course	The layer or layers of specified selected material of designed thickness placed on a subgrade to support a base course.
Subgrade	The upper part of the soil, natural or constructed, which supports the loads transmitted by the pavement, also referred as the formation foundation.
Surface course	The top course of a pavement structure, also referred as wearing course.

4 A new method to report the bearing strength of pavements

According to point ADR.OPS.A.005 Aerodrome data of Regulation (EU) 139/2014, the aerodrome operator has to determine, document, maintain and provide to the AISP the aeronautical data related to the aerodrome it is operating. AMC1 ADR.OPS.A.005 (Aerodrome data) further details the 'package' of the aeronautical data that needs to be originated by the aerodrome operators. This 'package' includes amongst others the **bearing strength of a pavement**.

Currently, for all pavements intended for aircraft of apron mass greater than 5 700 kg, the bearing strength of the pavement needs to be determined using the ACN-PCN method and then made available to the AISP.

Further guidance on the reporting of the pavement bearing strength is provided in GM1 ADR.OPS.A.005. The PCN data is published by the AISP in Part 3 – Aerodromes of the AIP, in section AD 2.8 for apron and taxiways and in section AD2.12 for runways, including on the aerodrome charts in accordance with Regulation (EU) 2017/373. The EU requirements for the origination and publication of aeronautical data are based on the corresponding SARPs of ICAO Annex 14, Volume I, in particular Chapter 2 and ICAO Annex 15 and ICAO Doc 10066 PANS-AIM.

In 2020, ICAO adopted, with Amendment 15 to Annex 14, Volume I Aerodromes — Aerodrome Design and Operations, a new method for expressing and calculating the bearing strength of a pavement, called the ACR-PCR. A transition period of 4 years has been set by ICAO and the new method will become applicable on 28 Nov 2024, replacing the current ACN-PCN method. However, the applicability of the new ACR-PCR method in the EASA Member States has been deferred to a later date (see point 11).

EASA has already organised a webinar on 06 Oct 2022 with the objective to raise awareness, provide clarifications and support the deployment of the new ACR-PCR method by the EASA Member States. The recording and the presentations on the occasion of the webinar are available on the EASA website. Meanwhile, ICAO and other training providers have launched dedicated training courses for the new ACR-PCR method.

5 The new ACR-PCR method

The new ACR-PCR method shifts the emphasis from the evaluation of pavements to the evaluation of the load rating of aircraft (ACR) and includes a standard procedure for the evaluation of the load rating of aircraft. The strength of a pavement is reported under the method in terms of the load rating of the aircraft, for example, that which the pavement can accept on an unrestricted basis. Reference to unrestricted operations does not mean unlimited operations since the pavement life needs to be accounted for. The term 'unrestricted operations' refers to the relationship between the pavement's PCR and the aircraft's ACR, meaning that it is permissible for an aircraft to operate without weight restrictions (subject to tyre pressure limitations) when the PCR is greater than or equal to the ACR.

The PCR to be reported to the AISP is such that the pavement strength is sufficient for the current and future traffic analysed and should be re-evaluated if traffic changes significantly. A significant change in traffic would be indicated by the introduction of a new aircraft type or an increase in current aircraft traffic levels not accounted for in the original PCR analysis.

6 Benefits of the new ACR-PCR method

In contrast to the current ACN-PCN method, the new ACR-PCR method is no longer based on the critical aircraft but considers all aircraft that are intended to serve on a given pavement with their real offset (lateral deviation) from the pavement centre line. By doing so, the reported PCR will address, in a more accurate manner, the amount of damage to the pavement that each aircraft produces within a mix, as a function of its operating weight, full landing gear geometry, individual tyre load and tyre pressure.

The expected benefits are optimised use of the pavement, reduced maintenance needs and costs, and a reduction of greenhouse gas emissions through a well-managed pavement life cycle.

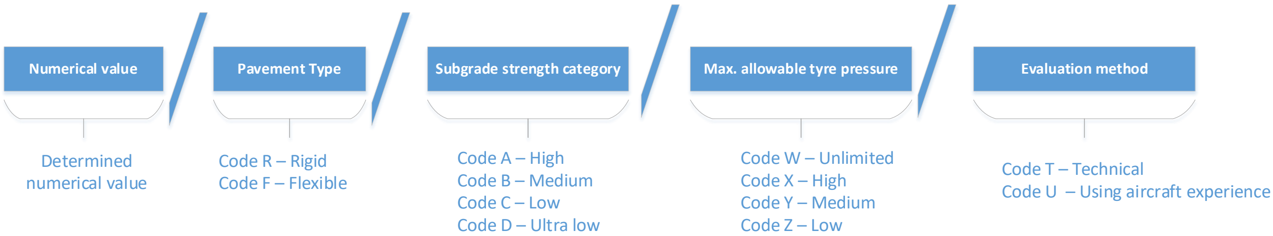
7 Limitations of the new ACR-PCR method

Just like the current ACN-PCN, the new ACR-PCR method is meant only for the publication of pavement strength data in the AIP. It is not intended as a pavement design or pavement evaluation procedure, nor does it restrict the methodology used to design or evaluate a pavement structure.

There is no mathematical correlation between the previous ICAO pavement strength reporting ACN-PCN and the new ICAO ACR-PCR system, i.e. there is no formula to convert the current PCN into the PCR.

8 Reporting format

The pavement bearing strength reported through the new ACR-PCR method uses the same five-part format and codes as for the current ACN-PCN method.



	PCN	PCR
NUMERICAL VALUE	determined numerical value	determined numerical value
PAVEMENT TYPE	**Code R** – Rigid pavement	**Code R** – Rigid pavement
	Code F – Flexible pavement	**Code F** – Flexible pavement
SUBGRADE STRENGTH CATEGORY	**Code A** – High strength *Characterised by K[1] = 150 MN/m³ and representing all K values above 120 MN/m³ for rigid pavements.* *Characterised by CBR[2] = 15 and representing all CBR values above 13 for flexible pavements.*	**Code A** – High strength *Characterised by E[3] = 200 MPa and representing all E values equal to or above 150 MPa, for rigid and flexible pavements.*
	Code B – Medium strength *Characterised by K[1] = 80 MN/m³ and representing a range in K of 60 to 120 MN/m³ for rigid pavements.*	**Code B** – Medium strength *Characterised by E = 120 MPa and representing a range in E values equal to or above 100 MPa and strictly less than 150*

	PCN	PCR
	Characterised by CBR = 10 and representing a range in CBR of 8 to 13 for flexible pavements.	*MPa, for rigid and flexible pavements.*
	Code C – Low strength *Characterised by K¹ = 40 MN/m³ and representing a range in K of 25 to 60 MN/m³ for rigid pavements.* *Characterised by CBR = 6 and representing a range in CBR of 4 to 8 for flexible pavements.*	**Code C** – Low strength *Characterised 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.*
	Code D – Ultra Low strength *Characterised by K¹ = 20 MN/m³ and representing all K values below 25 MN/m³ for rigid pavements.* *Characterised by CBR = 3 and representing all CBR values below 4 for flexible pavements.*	**Code D** – Ultra Low strength *Characterised by E = 50 MPa and representing all E values strictly less than 60 MPa, for rigid and flexible pavements.*
MAXIMUM ALLOWABLE TYRE PRESSURE CATEGORY	**Code W** - Unlimited *no pressure limit*	**Code W** - Unlimited *no pressure limit*
	Code X - High *pressure limited to 1.75 MPa*	**Code X** - High *pressure limited to 1.75 MPa*
	Code Y – Medium *pressure limited to 1.25 MPa*	**Code Y** – Medium *pressure limited to 1.25 MPa*
	Code Z – Low	**Code Z** – Low

	PCN	PCR
	pressure limited to 0.50 MPa	*pressure limited to 0.50 MPa*
EVALUATION METHOD	**Code T** – Technical evaluation *Representing a specific study of the pavement characteristics and application of pavement behaviour technology.*	**Code T** – Technical evaluation *Representing a specific study of the pavement characteristics and the types of aircraft which the pavement is intended to serve.*
	Code U - Using aircraft experience *Representing a knowledge of the specific type and mass of aircraft satisfactorily being supported under regular use.*	**Code U** - Using aircraft experience *Representing a knowledge of the specific type and mass of aircraft satisfactorily being supported under regular use.*

Note:

1. *For existing pavements initially designed with the California bearing radio (CBR) design procedure, subgrade modulus values can be determined in a number of ways. The procedure that will be applicable in most cases is to use available CBR values and substitute the relationship (or others if more relevant):*

   $$E = 1\,500 \times CBR \text{ (E in psi) or } 10 \times CBR \text{ (E in MPa)}$$

   This method provides designs compatible with the earlier flexible design procedure based on subgrade CBR, but other accepted equivalencies can also be used (Shell method, Airport Pavement Design System Knowledge Base (APSDS) method, French conversion etc.). Subgrade modulus values for PCR determination may also be determined from direct soil testing (e.g. heavyweight deflectometer, plate test).

2. *Similarly, for rigid pavement design, the foundation modulus can be expressed as the modulus of subgrade reaction k or as the elastic (Young's) modulus E. However, all structural computations are performed using the elastic modulus E. If the foundation modulus is input as a k value it can be converted to the equivalent E value using the following equations:*

   $$E_{SG}=20.15\times k^{1.284}$$

   where E_{SG} = Elastic (Young's) modulus of the subgrade, pounds per square inch (psi); and K = Modulus of subgrade reaction, pounds per cubic inch (pci).

	PCN	PCR
3. *For new pavement construction, the subgrade modulus value for PCR determination should be the same value used for pavement thickness design.*		

The PCR reported indicates that aircraft with an ACR equal to or less than the reported PCR may operate on the pavement subject to any limitation on the tyre pressure or aircraft all-up mass for specified aircraft type(s).

The data obtained from the characteristics listed above are primarily intended to enable aircraft operators to determine the permissible aircraft types and operating masses, and the aircraft manufacturers to ensure compatibility between airport pavements and aircraft under development.

9 How to determine the ACR values

The ACR of an aircraft is numerically defined as two times the derived single wheel load, where the derived single wheel load is expressed in hundreds of kilograms. ACR values are computed under the ACR-PCR method.

The ACR values have been calculated by the aircraft manufactures and may be determined from the:

1. ACR graphs provided in the manuals of aircraft characteristics for airport planning. The manuals are published by the aircraft manufacturers on their respective websites.
2. ICAO-ACR computer programme. This programme provides aircraft ACR at any mass and centre of gravity (CG) position for both flexible and rigid pavement and for the four standard subgrade strength categories. The mass used in the ACR calculation is a 'static' mass and no allowance is made for an increase in loading through dynamic effects. The official ICAO-ACR computer programme is maintained by the FAA's William J. Hughes Technical Center (WJHTC) and is available at:

   https://www.airporttech.tc.faa.gov/Products/Airport-Safety-Papers-Publications/Airport-Safety-Detail/icao-acr-13

   Note:
   1. *The ICAO-ACR programme provides the possibility to change the input parameters (e.g. gross weight, percent GW, tyre pressure) and calculate the ACR for specific cases, in addition to those provided in its library.*
   2. *Examples on how to determine the ACR values using this software are available in Annex 3.*

10 How to determine the PCR values

The numerical PCR value for a particular pavement can be based upon either of the two acceptable evaluation methods (which are already used for the determination of the PCN): the technical evaluation method (code T) or using the aircraft experience method (code U).

10.1 Technical evaluation method (Code T)

The technical evaluation **represents a specific study** of the pavement characteristics and its capability of supporting the aircraft mix that is intended to serve, using the CDF concept (see Annex 1) through a mechanistic design/evaluation method calibrated against observed pavement behaviour. If the evaluation represents the results of a technical study, the evaluation method will be coded T in the five-part format.

Whenever possible, reported pavement strength should be based on a technical evaluation. The accuracy of a technical evaluation is better than that produced with the using aircraft experience method (Code U), but requires a technical study, including on-site inspections and tests, etc.

Note:

1. ***In practice, the calculation of the PCR values (just like the calculation of the PCN) through the technical evaluation method may not be performed by the aerodrome operator.*** *Specialised civil engineering companies may be contracted by the aerodrome operator to perform the study and submit the output data together with all supporting documents to the aerodrome operator.*
2. *A summary of the PCR recommended procedure for technical evaluation is presented in Annex 1. This summary represents an extract from the ICAO Doc 9157, Aerodrome Design Manual, Part 3 – Pavements, 3rd edition, 2022.*
3. *An example on how to determine the PCR value through the technical evaluation method is presented in Annex 4.*
4. *Further guidance on the ACR-PCR method can be found in ICAO Doc 9157, Aerodrome Design Manual, Part 3 – Pavements, 3rd edition, 2022.*

10.2 Using aircraft experience method (Code U)

Using aircraft experience **represents a knowledge of the specific type and mass of aircraft satisfactorily being supported under regular use**. If the evaluation is based on using aircraft experience, the evaluation method will be coded U in the five-part format.

When, for economic or other reasons, a technical evaluation is not feasible, the evaluation can be based on experience with 'using aircraft'. A pavement satisfactorily supporting aircraft already using the pavement, can accept other aircraft if they are no more demanding than the using aircraft. This can be the basis for an evaluation. Thus, 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 reasonably straightforward and does not require a technical study nor a detailed knowledge of the pavement structure. The accuracy of this method depends on records of past aircraft traffic and the effect this traffic is having on the pavement. The condition of the pavement in relation to any cracking, distortion or wear, and the experience with needed maintenance are of utmost importance.

Note:

1. *A summary of the PCR recommended procedure for 'using the aircraft experience' method is presented in Annex 2. This summary represents an extract from ICAO Doc 9157, Aerodrome Design Manual, Part 3 – Pavements, 3rd edition, 2022.*
2. *An example on how to determine the PCR value using the aircraft experience method is presented in Annex 4.*
3. *Further guidance on the ACR-PCR method can be found in ICAO Doc 9157, Aerodrome Design Manual, Part 3 – Pavements, 3rd edition, 2022.*

11 Applicability of the ACR-PCR in the EASA Member States

11.1 Transposition

The transposition of the new ACR-PCR method in the EU's aviation regulatory framework has been planned to take place in two phases:

1. 'Setting up the AIP' content, by updating the provisions concerning the content of AD 2.8 and AD 2.12, including the relevant content of the aeronautical data catalogue of Regulation (EU) 2017/373. This is done through the ongoing rulemaking task RMT.0719 (Subtask 4b), as described in the related NPA 2023-08(B).
2. Introducing the new methodology for aeronautical data to be originated by the aerodrome operator, by updating GM1 ADR.OPS.A.005 of Regulation (EU) 139/2014 (including AMC1 ADR.OPS.C.011 and GM1 ADR.OPS.C.011). Please refer to NPA 2020-10 and the Explanatory Note to ED Decision 2024/004/R for further details.

The next milestones in this process are:

- the publication by EASA of the Opinion (**including the proposed amendments to the relevant AMC/GM**) related to the NPA 2023-08 to update Regulation (EU) 2017/373;
- the publication of the amendment to Regulation (EU) 2017/373;
- the publication of the ED Decision by EASA, amending the related AMC/GM of Regulation (EU) 2017/373 and the AMC/GM to Regulation (EU) 139/2014.

The Opinion related to NPA 2023-08(B) is planned to be published by Q4/2024 and the adoption is expected to take place by 2025.

11.2 Transition period

In general, an amendment to either a regulation or an acceptable means of compliance/ guidance material has a transition period which is the period between the publication of the amendment and the time it becomes applicable. This is to provide the competent authorities and the industry with the necessary period to implement the requirements introduced by the respective amendment.

The initially proposed transition period for the publication of the PCR was planned to be **6 months**, but this could be further reduced. In any case, the aerodrome operators would need to originate and provide the relevant data to the AISP at an earlier stage, to ensure the publication of the relevant data in a uniform manner across the EU, to avoid discrepancies of the published information within individual States and across the EU Member States.

11.3 Electronic filling of differences with ICAO

EASA will consider the need for the filling of differences with ICAO and will inform the Member States accordingly.

11.4 Recommended actions by the national competent authorities

1. Training
   - Ensure that the personnel overseeing aerodromes attend a training course on the ACR-PCR to familiarise themselves with the new method.

2. Implementation of new ACR-PCR method
   - Ensure coordination between the aerodrome and ATM/ANS competent authorities with regards to the implementation of the ACR-PCR method.
   - Establish and communicate to the aerodrome operators and the AISP an implementation plan and support the aerodrome operators and the AISP in the implementation of the new ACR-PCR method.
   - Ensure that all aerodrome operators already start originating and providing the AISP with the relevant PCR data without waiting for the final publication of the amendment to the AMC/GM of Regulation (EU) 139/2014 and of the amendment to Regulation (EU) 2017/373 and its related AMC/GM. This is to allow the proper handling of the data by the AISP and the update of the AIP, including aerodrome charts, in a synchronised manner at the State level on the applicable date that will be set through the amendment of Regulation (EU) 2017/373.

11.5 Recommended actions by the aerodrome operators

1. Training
   - Attend a training course on the ACR-PCR to familiarise yourself with the new method.
2. Determine the PCR values
   - The following approach should be applied for the determination of the numerical PCR value:

	TECHNICAL EVALUATION METHOD (CODE T)	AIRCRAFT EXPERIENCE METHOD (CODE U)
IN SERVICE PAVEMENTS	Use this method for cases where the current PCN has also been determined through the technical evaluation (code T). Most of the input data needed for calculations is already available (e.g. pavement type: rigid or flexible, thickness of each layer: surface course, base course, sub-base, subgrade, aircraft mix data: maximum taxi weight, per cent weight on main gear, annual number of departures). Some other parameters will have to be determined (e.g. the E-Modulus and Poisson's ratio for each layer).	Use this method for the following cases: 1. where the current PCN has been determined through the using aircraft experience (code U) and for economic or any other reasons a technical evaluation is not feasible; OR 2. where the current PCN has been determined through the technical evaluation method (code T), but for economic or any other reasons a technical evaluation is not feasible. *Note: Consider upgrading to the technical evaluation method (code T) at the earliest possible opportunity, in particular for case number 2.*

	TECHNICAL EVALUATION METHOD (CODE T)	AIRCRAFT EXPERIENCE METHOD (CODE U)
NEW PAVEMENTS	Use this method only. The input data for calculations is already available since it served for the pavement design.	

3. Provide the PCR values
   - Without waiting for the publication of the amendment to the AMC/GM of Regulation (EU) 139/2014 and of the amendment to Regulation (EU) 2017/373 and its related AMC/GM, send the PCR values in the five-part format and codes (see point 8) to the AISP for publication in AD 2.8 and AD 2.12, including on the aerodrome chart. The current PCN values published in AD 2.8, ~~and~~ AD 2.12 and on the aerodrome chart will be maintained by the AISP until the applicable date that will be set through the amendment of Regulation (EU) 2017/373.

Note: Take into consideration the AIRAC effective dates.

11.6 Recommended actions by the AISP

1. Ensure that all relevant AIS personnel are formally updated about the content of the relevant provisions concerning the PCR values to be published in the AIP, including on the aerodrome charts, and update the applicable AISP operating procedures.
2. Ensure that any software tools used for data handling and aeronautical product publication purposes are able to accommodate the new pavement strength method.
3. Receive the PCR values by the aerodrome operators and prepare the relevant information for publication.
4. Report any delay concerning PCR data to be originated by aerodrome operators to the competent authorities.
5. Ensure that PCR information is published for all aerodromes in a single publication, in accordance with the applicability date that will be set through the amendment of Regulation (EU) 2017/373.

12 References

- Regulation (EU) No 139/2014 laying down requirements and administrative procedures related to aerodromes pursuant to Regulation (EC) No 216/2008 of the European Parliament and of the Council;
- Commission Implementing Regulation (EU) 2017/373 of 1 March 2017 laying down common requirements for providers of air traffic management/air navigation services and other air traffic management network functions and their oversight;
- ICAO Annex 14 to the Convention on International Civil Aviation, Aerodromes, Volume I – Aerodrome Design and Operations, 9th edition, July 2022, Amendment 17;
- ICAO Procedures for Air Navigation Services – Aeronautical Information Management (PANS-AIM), 1st edition, Amendment 1.

- ICAO Doc 9157, Aerodrome Design Manual, Part 3 – Pavements, 3rd edition, 2022;
- EASA ED Decision 2024/005/R ‘Regular update of the aerodrome rules’;
- EASA NPA 2023-08 ’Regular update of the air traffic management / air navigation services rules’;
- EASA webinar: New Method to Report Pavement Strength (ACR-PCR), 06 Oct 2022;

Annex 1 - PCR recommended procedure for technical evaluation (T)

The following recommended PCR procedure reduces to the computation of an aircraft ACR. The steps below can be used to convert the mix of using aircraft traffic to an equivalent critical, or reference aircraft at maximum allowable gross weight, which will then produce a CDF of 1.0 on the evaluated pavement.

The CDF is the amount of the structural fatigue life of a pavement that has been used up. It is expressed as the ratio of applied load repetitions to allowable load repetitions to failure, or, for one aircraft and constant annual departures where a 'coverage' is one application of the maximum strain or stress due to load on a given point in the pavement structure:

$$CDF = \frac{\text{Applied coverages}}{\text{Coverages to failure}}$$

Note:

1. *When CDF = 1, the pavement subgrade will have used all of its fatigue life.*
2. *When CDF < 1, the pavement subgrade will have some remaining life and the value of CDF will give the fraction of the life used.*
3. *When CDF > 1, all of the fatigue life will have been used and the pavement subgrade will have failed.*

In these definitions, 'failure' means failure according to the assumptions and definitions on which the design procedures are based. A value of CDF greater than one does not mean that the pavement will no longer support traffic, but that it will have failed according to the definition of failure used in the design procedure. The thickness design is based on the assumption that failure occurs when CDF = 1.

Multiple aircraft types are accounted for using Miner's Rule:

$$CDF = CDF_1 + CDF_2 + \cdots + CDF_N$$

where CDF_i is the CDF for each aircraft in the traffic mix and N is the number of aircraft in the mix. Since the PCR relates to the structural pavement life, the CDF is based on the subgrade failure mode.

The PCR procedure considers the actual pavement characteristics at the time of the evaluation — considering the existing pavement structure, and the aircraft traffic forecast to use the pavement over its design structural life (for new pavement construction) or estimated remaining structural life (for in service pavements). The PCR should be valid only for this usage period. In case of major pavement rehabilitation or significant traffic changes compared to the initial traffic, a new evaluation should be performed.

The PCR procedure involves the following steps:

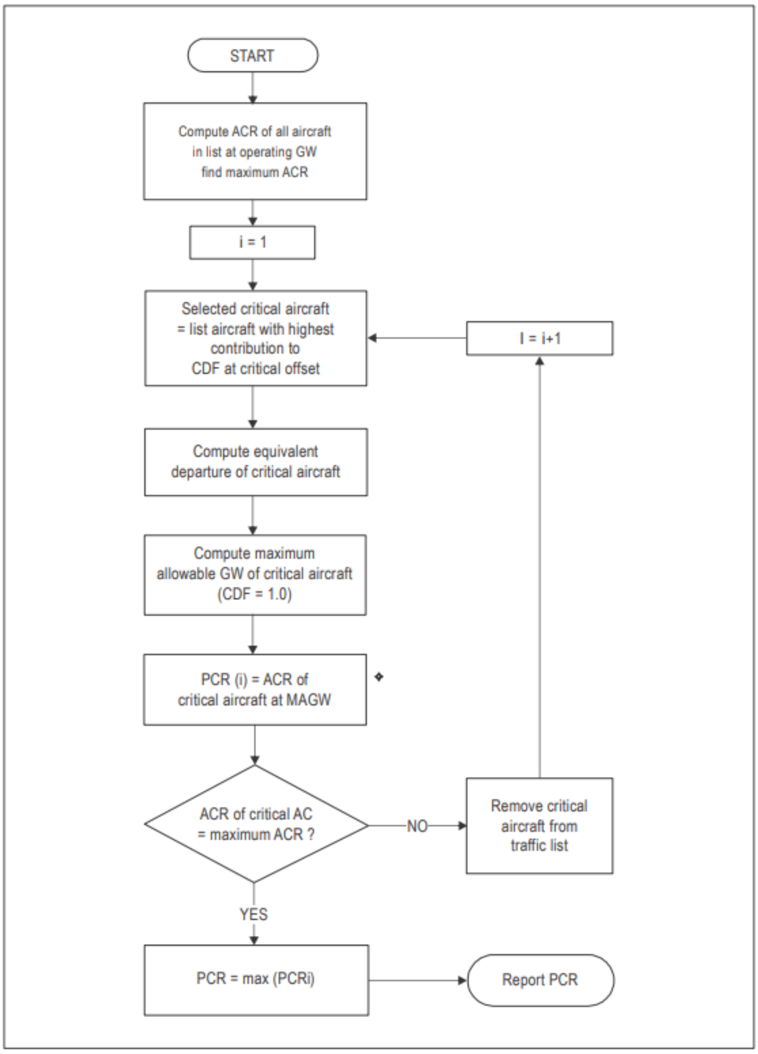
1. collect all relevant pavement data (layer thicknesses, elastic moduli and Poisson's ratio of all layers, using projected aircraft traffic) using the best available sources.
2. define the aircraft mix by aircraft type, number of departures (or operations consistent with pavement design practices), and aircraft weight that the evaluated pavement is expected to experience over its design or estimated remaining structural life. According to the manoeuvring area (runway, taxiway, apron/ramp), the traffic can be assigned a lateral wander characterized by a

standard deviation. The distribution of aircraft passes for a given aircraft type over the life of the pavement is described by a Gaussian (or normal) distribution function, with a standard deviation s that depends on several factors: the type of aircraft, its ground speed, and the manoeuvring area. Another term that is frequently used is the amplitude of lateral wander, which is twice the standard deviation. High-speed sections (e.g. runways) are associated with higher values of s than moderate-speed sections (e.g. taxiways), while wander may be considered negligible (s ≅ 0) on low-speed sections (e.g. aprons). The following values of standard deviation may be used independently of the type of aircraft:

Pavement section	*Standard deviation s (metres)*
High-speed sections (runway, rapid exit taxiway)	0.75
Moderate-speed sections (taxiways)	0.5
Aprons and low-speed sections	0

3. compute the ACRs for each aircraft in the aircraft mix at its operating weight and record the maximum ACR aircraft.
4. compute the maximum CDF of the aircraft mix and record the value (the CDF is computed with any damage/failure model consistent with the procedure used for pavement design).
5. select the aircraft with the highest contribution to the maximum CDF as the critical aircraft. This aircraft is designated AC(i), where i is an index value with an initial value 1. Remove all aircraft other than the current critical aircraft AC(i) from the traffic list.
6. adjust the number of departures of the critical aircraft until the maximum aircraft CDF is equal to the value recorded in step 4. Record the equivalent number of departures of the critical aircraft.
7. adjust the critical aircraft weight to obtain a maximum CDF of 1.0 for the number of departures obtained at step 6. This is the MAGW for the critical aircraft.
8. compute the ACR of the critical aircraft at its MAGW. The value obtained is designated as PCR(i).
9. if AC(i) is the maximum ACR aircraft from step 3 above, then skip to step 13, otherwise
10. remove the current critical aircraft AC(i) from the traffic list and re-introduce the other aircraft not previously considered as critical aircraft. The new aircraft list, which does not contain any of the previous critical aircraft, is referred to as the reduced aircraft list. Increment the index value (i = i+1).
11. compute the maximum CDF of the reduced aircraft list and select the new critical aircraft AC(i).
12. repeat steps 5-9 for AC(i). In step 6, use the same maximum CDF as computed for the initial aircraft mix to compute the equivalent number of departures for the reduced list; and
13. the PCR to be reported is the maximum value of all computed PCR(i). The critical aircraft is the aircraft associated with this maximum value of PCR(i).

The purpose of steps 10 to 13 is to account for certain cases with a large number of departures of a short/medium-range aircraft (e.g. B737) and a relatively small number of departures of a long-range aircraft (e.g. A350). Without these steps, the smaller aircraft would generally be identified as critical, with the result that the PCR would require unreasonable operating weight restrictions on larger aircraft (unreasonable because the design traffic already included the large aircraft). Note that if the initial critical aircraft is also the aircraft in the list with the maximum ACR at operating weight, then the procedure is completed in one iteration, with no subsequent reduction to the traffic list.



The above procedure returns a uniquely determined PCR numerical value based on the identified critical aircraft. The technical evaluation should be used when pavement characteristics and aircraft mix are consistently known and documented.

Annex 2 - PCR recommended procedure for using aircraft experience (U)

Whenever possible, reported pavement strength should be based on the 'technical evaluation'. However, when for economic or other reasons a technical evaluation is not feasible, evaluation can be based on experience with 'using aircraft'. A pavement satisfactorily supporting aircraft using it, can accept other aircraft if they are no more demanding than the using aircraft. This can be the basis for an evaluation.

Heaviest using aircraft

A pavement satisfactorily sustaining its using traffic can be considered capable of supporting the heaviest aircraft regularly using it and any other aircraft that has no greater pavement strength requirements. Thus, to begin an evaluation based on using aircraft, the types and masses of aircraft and number of times each operates in a given period must be examined. Emphasis should be on the heaviest aircraft regularly using the pavement. Support of a particularly heavy load, but only rarely, does not necessarily establish a capability to support equivalent loads on a regular repetitive basis.

Pavement condition and behaviour

There must next be a careful examination of what effect the traffic of using aircraft is having on the pavement. The condition of the pavement in relation to any cracking, distortion or wear, and the experience with needed maintenance are of first importance. Age must be considered since overload effects on a new pavement may not yet be evident, while some accumulated indications of distress may normally be evident in a very old pavement. In general, however, a pavement in good condition can be considered to be satisfactorily carrying the using traffic, while indications of advancing distress show the pavement is being overloaded. The condition examination should take note of relative pavement behaviour in areas of intense versus low usage, such as in and out of wheel paths or most and least used taxiways, zones subject to maximum braking (e.g. taxiway turn-off, etc.). Note should also be taken of behaviour of any known or observable weak or critical areas such as low points of pavement grade, old stream crossings, pipe crossings where initial compaction was poor, structurally weak sections, etc. These will help to predict the rate of deterioration under existing traffic and thereby indicate the degree of overloading or of underloading. The condition examination should also focus on any damage resulting from tyre pressures of using aircraft and the need for tyre pressure limitations.

Reference aircraft

Studying of the types and masses of aircraft will indicate those which must be of concern in establishing a reference aircraft, and the condition survey findings will indicate whether the load of the reference aircraft should be less than that being applied or might be somewhat greater. Since load distribution to the subgrade depends somewhat on pavement type and subgrade strength, the particular reference aircraft and its mass cannot be selected until those elements of the ACR-PCR method, which are reported in addition to the PCR, have been established.

Determination of the pavement type, subgrade strength and tyre pressure categories

The pavement type must be established as rigid or flexible. If the pavement includes a PCC slab as the primary structural element, it should be classified as rigid even though it may have a bituminous overlay resurfacing. If the pavement includes no such load-distributing slab, it should be classified as flexible.

The subgrade category must be determined as high, medium, low, or ultra-low strength. If modulus of elasticity test data are available for the subgrade, these can be used directly to select the subgrade category. Such data, however, must represent in situ subgrade conditions. Similar data from any surrounding structures on the same type of soil and in similar topography can also be used. Soil strength data in almost any other form (such as CBR data) can be used to project an equivalent modulus of elasticity E for use in selecting the subgrade category. Information on subgrade soil strength may be obtainable from local road or highway agencies, or local agricultural agencies. A direct, though somewhat crude or approximate, determination of subgrade strength can be made from classification of the subgrade material and reference to any of many published correlations such as that shown in graph below.

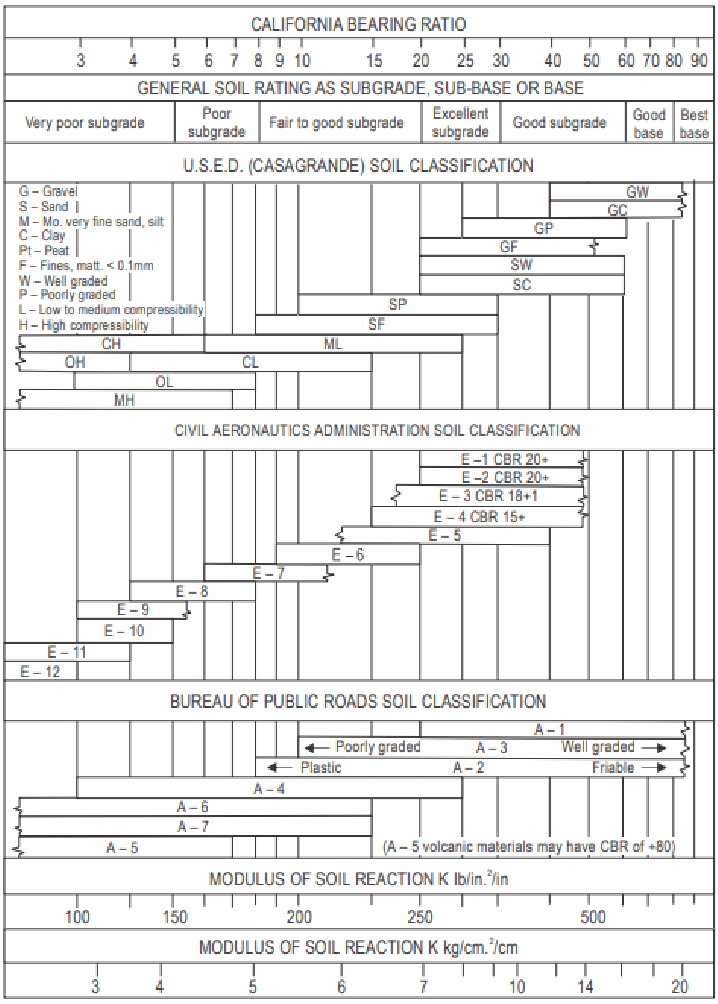


CHART TAKEN FROM "Design of Concrete Airport Pavement" PORTLAND CEMENT ASSOCIATION.
N.B. All interrelationships are very approximate. Actual tests are required to determine CBR, K, etc.

The tyre pressure category must be determined as unlimited, high, medium or low. PCC surfacing and good to excellent quality bituminous surfacing can sustain the tyre pressures commonly encountered and should be classified as unlimited pressure category with no limit on pressure. Bituminous surfacing of inferior quality and aggregate or earth surfacing will require the limitation of lower categories. The applicable pressure category should normally be selected based on experience with using aircraft. The highest tyre pressure being applied, other than rarely, by using aircraft, without producing observable distress should be the basis for determining the tyre pressure category.

The most significant element of the using aircraft evaluation is the determination of the critical aircraft and the equivalent PCR for reporting purposes. Having determined the pavement type and the subgrade category, the next step would be the determination of the ACRs of aircraft using the pavement. For this purpose, needed information can be obtained by analysis using the prescribed ACR-PCR methods (see point 8). Comparison of aircraft regularly using the pavements — at their operating masses — with the above-mentioned programme or the relevant aircraft characteristics documents will permit determination of the most critical aircraft using the pavement. If the using aircraft are satisfactorily being sustained by the pavement and there are no known factors indicating that substantially heavier aircraft could be supported, the ACR of the most critical aircraft should be reported as the PCR of the pavement. Thus, any aircraft having an ACR no higher than this PCR can use the pavement facility at a use rate (as repetitions per month) no greater than that of presently supported aircraft without shortening the use-life of the pavement.

In arriving at the critical aircraft, only aircraft using the pavement on a continuing basis without unacceptable pavement distress should be considered. The occasional use of the pavement by a more demanding aircraft is not sufficient to ensure its continued support even if no pavement distress is apparent.

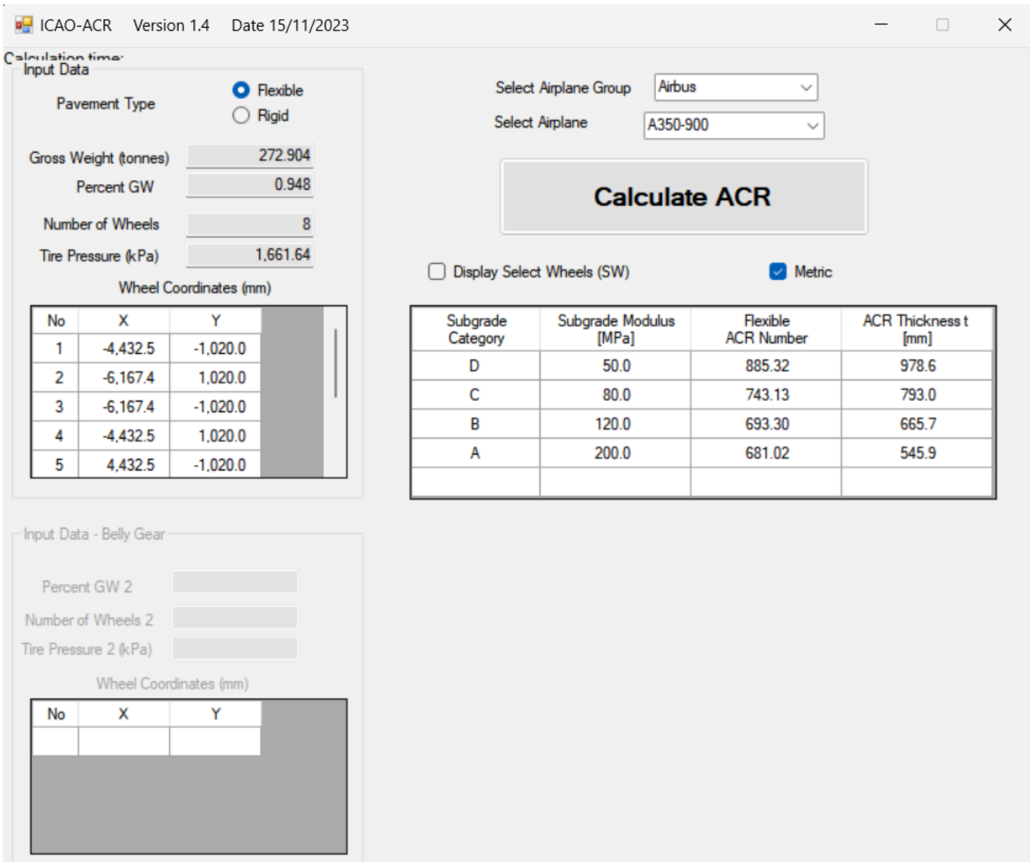
As indicated, a PCR directly selected based on the evaluated critical aircraft loading examines an aircraft use intensity in the future similar to that at the time of evaluation. If a substantial increase in use (wheel load repetitions) is expected, the PCR should be adjusted downward to accommodate the increase. A basis for the adjustment, which relates load magnitude to load repetitions.

Annex 3 – Example of an ACR calculation using the ICAO-ACR programme

A3.1 ACR calculation using the 'standard' library loaded in the ICAO-ACR programme

The following example illustrates the calculation of the ACR values for an A350-900 on a flexible pavement.

1. Go to https://www.airporttech.tc.faa.gov/Products/Airport-Safety-Papers-Publications/Airport-Safety-Detail/icao-acr-13 and install the software on your station.
2. Select the pavement type as 'Flexible'.
3. Select 'Airbus' from the aeroplane group.
4. Select 'A350-900' from the dropdown list.
5. Press 'Calculate ACR'. The software calculates the ACR values for the four subgrade categories.



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A3.2 ACR calculation for a specific WV not loaded in the ICAO-ACR programme

The following example illustrates the calculation of the ACR values for an A350-900 WV000 (CG 33%) on a flexible pavement.

1. Go to https://aircraft.airbus.com/en/customer-care/fleet-wide-care/airport-operations-and-aircraft-characteristics/aircraft-characteristics and open the Airport and Maintenance Planning manual for A350-900/-1000/-1000F. Look up for the following data: maximum ramp weight, percentage of weight on main gear group, and main gear tyre pressure.

WEIGHT VARIANT	MAXIMUM RAMP WEIGHT	PERCENTAGE OF WEIGHT ON MAIN GEAR GROUP	NOSE GEAR TIRE SIZE	NOSE GEAR TIRE PRESSURE	MAIN GEAR TIRE SIZE	MAIN GEAR TIRE PRESSURE
A350-900 WV000 (CG 33%)	268 900 kg (592 825 lb)	93.7%	1 050x395R16 28PR	12.2 bar (177 psi)	1 400x530R23 42PR	16.6 bar (241 psi)
A350-900 WV000 (CG 38.09%)	268 900 kg (592 825 lb)	95.3%	1 050x395R16 28PR	12.2 bar (177 psi)	1 400x530R23 42PR	16.6 bar (241 psi)
A350-900 WV000 (CG 38.1%)	268 900 kg (592 825 lb)	95.3%	1 050x395R16 28PR	12.2 bar (177 psi)	1 400x530R23 42PR	16.6 bar (241 psi)
A350-900 WV001 (CG 33.2%)	275 900 kg (608 250 lb)	93.7%	1 050x395R16 28PR	12.2 bar (177 psi)	1 400x530R23 42PR	16.8 bar (244 psi)
A350-900 WV001 (CG 34.83%)	275 900 kg (608 250 lb)	94.3%	1 050x395R16 28PR	12.2 bar (177 psi)	1 400x530R23 42PR	16.8 bar (244 psi)
A350-900 WV001 (CG 37.07%)	275 900 kg (608 250 lb)	95.0%	1 050x395R16 28PR	12.2 bar (177 psi)	1 400x530R23 42PR	16.8 bar (244 psi)
A350-900 WV002 (CG 36.39%)	272 900 kg (601 650 lb)	94.8%	1 050x395R16 28PR	12.2 bar (177 psi)	1 400x530R23 42PR	16.8 bar (244 psi)

2. In the ICAO-ACR programme, in the Input data section:

   2.1 select the pavement type as ‘Flexible’;

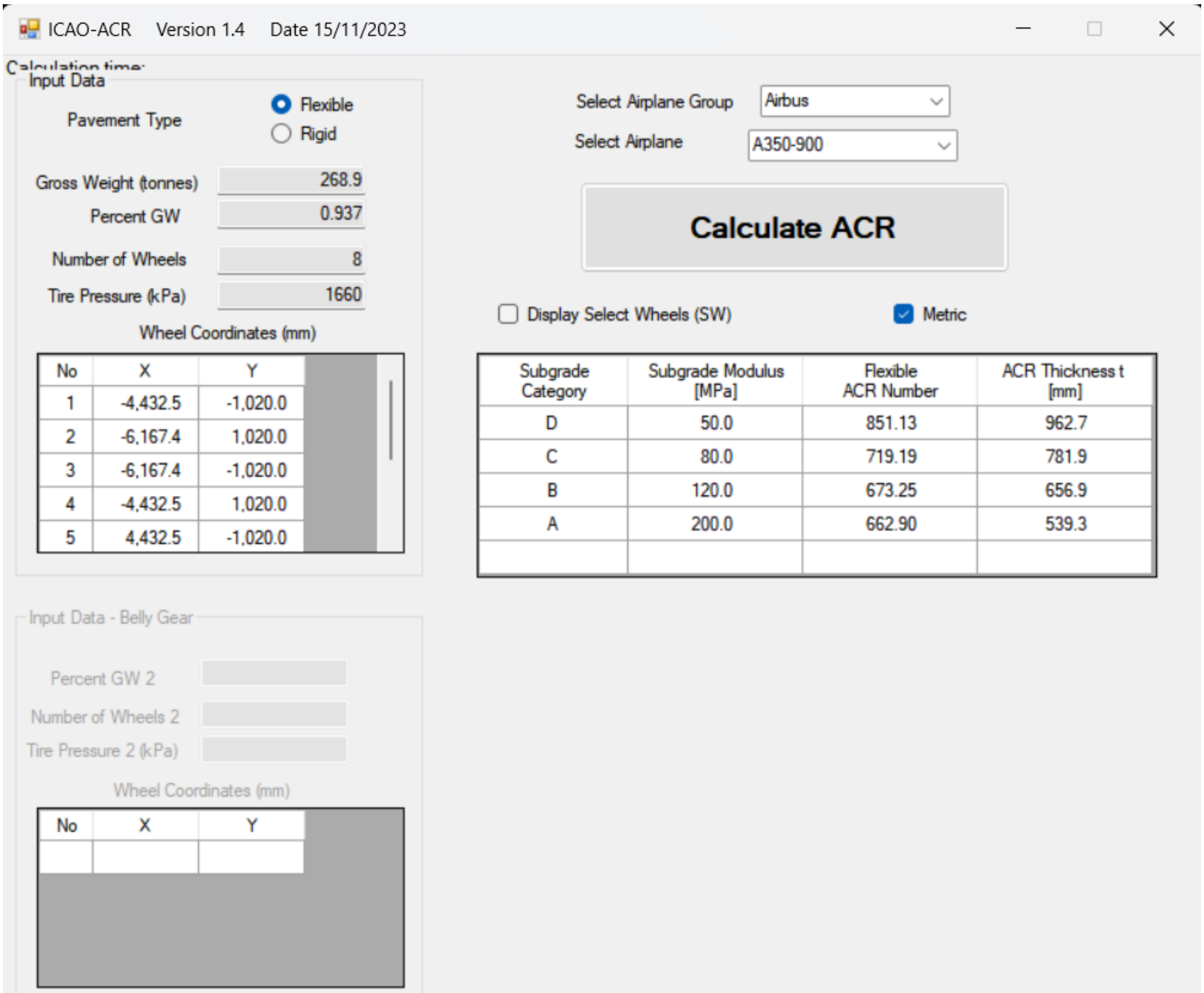
   2.2 select ‘Airbus’ from the aeroplane group;

   2.3 select ‘A350-900’ from the dropdown list;

   2.4 change the ‘standard’ values as follows:

   - gross weight (tonnes) to 268.9 t;
   - percent GM to 0.937;
   - tyre pressure (kPa) to 1660 (*1bar=100kPa*).

   2.5 press ‘Calculate ACR’. The software calculates the ACR values for the four subgrade categories.



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Annex 4 – Example of a PCR calculation

A4.1 PCR calculation involving a technical evaluation (code T)

The following example illustrates the calculation of the PCR value for a **flexible pavement**.

Steps 1 and 2: Data collection

- Pavement characteristics

The pavement description consists of providing for each layer its thickness, modulus of elasticity (E) and Poisson's ratio (ν). For new pavement construction, the data should be those which served for the pavement design.

For in-service pavement, it may be necessary to determine these input values by non-destructive testing (core sampling, heavy-weight deflectometer, etc.). Due to loading or environmental conditions, the pavement material characteristics may change over time. In the following example, the pavement was designed according to the French pavement design procedure, using standard French material specifications found in NF EN 13 108-1, for a period of usage of ten years. For PCR consistency, and to determine precisely the individual contribution of each aircraft in the mix to the maximum CDF, the same parameters that were used for the original pavement design (subgrade failure model, treatment of multi-axle loads, etc.) are also used to determine PCR.

The evaluated pavement is a runway.

PAVEMENT CHARACTERISTICS				
Layers	*Designation*	*E-Modulus (MPa)*	*Poisson's ratio*	*Thickness (cm)*
Surface course	EB-BBSG3	E=f (θ, freq.)	0.35	6
Base course	EB-GB3	E=f (θ, freq.)	0.35	18
Sub-base (1)	GNT1	600	0.35	12
Sub-base (2)	GNT1	240	0.35	25
Subgrade		80	0.35	∞

Subgrade modulus of 80 MPa means a subgrade strength category C.

- Aircraft mix data

For new pavement construction, the aircraft mix for PCR determination is the same aircraft list used for the pavement design.

For in-service pavement, the PCR analysis considers aircraft usage over the remaining pavement (structural) life. If the mixture of aircraft types using the pavement is known to have changed significantly from the design forecast, an updated aircraft list should be used. This example uses the following list of aircraft with maximum operating weights and annual departures:

AIRCRAFT MIX ANALYSED			
No.	*Aircraft model*	*Maximum taxi weight (t)*	*Annual departures*
1	A321-200	93.9	14 600
2	A350-900	268.9	5 475
3	A380-800	571	1 825
4	B737-900	79.2	10 950
5	B787-8	228.4	3 650
6	B777-300ER	352.4	4 380

Note: The evaluated pavement is a runway; each aircraft is assigned a lateral wander of 1.5 m (standard deviation of 0.75 m). Each aircraft is centred on the pavement centreline and modelled with its real main landing gear coordinates.

Step 3: Aircraft ACR (Flexible C) at operating weight

	B777-300ER	A321-200	A350-900	B787-8	B737-9	A380-800
Operating weight (t)	352.4	93.9	268.9	228.4	79.2	571
ACR	790	550	720	680	450	650

Note:
1. *The maximum taxi weight/ operating weight is calculated by the aircraft manufacturers and made available in the manuals of aircraft characteristics for airport planning. The manuals are published by the aircraft manufacturers on their respective websites.*
2. *See Annex 3 for the calculation of the ACR.*

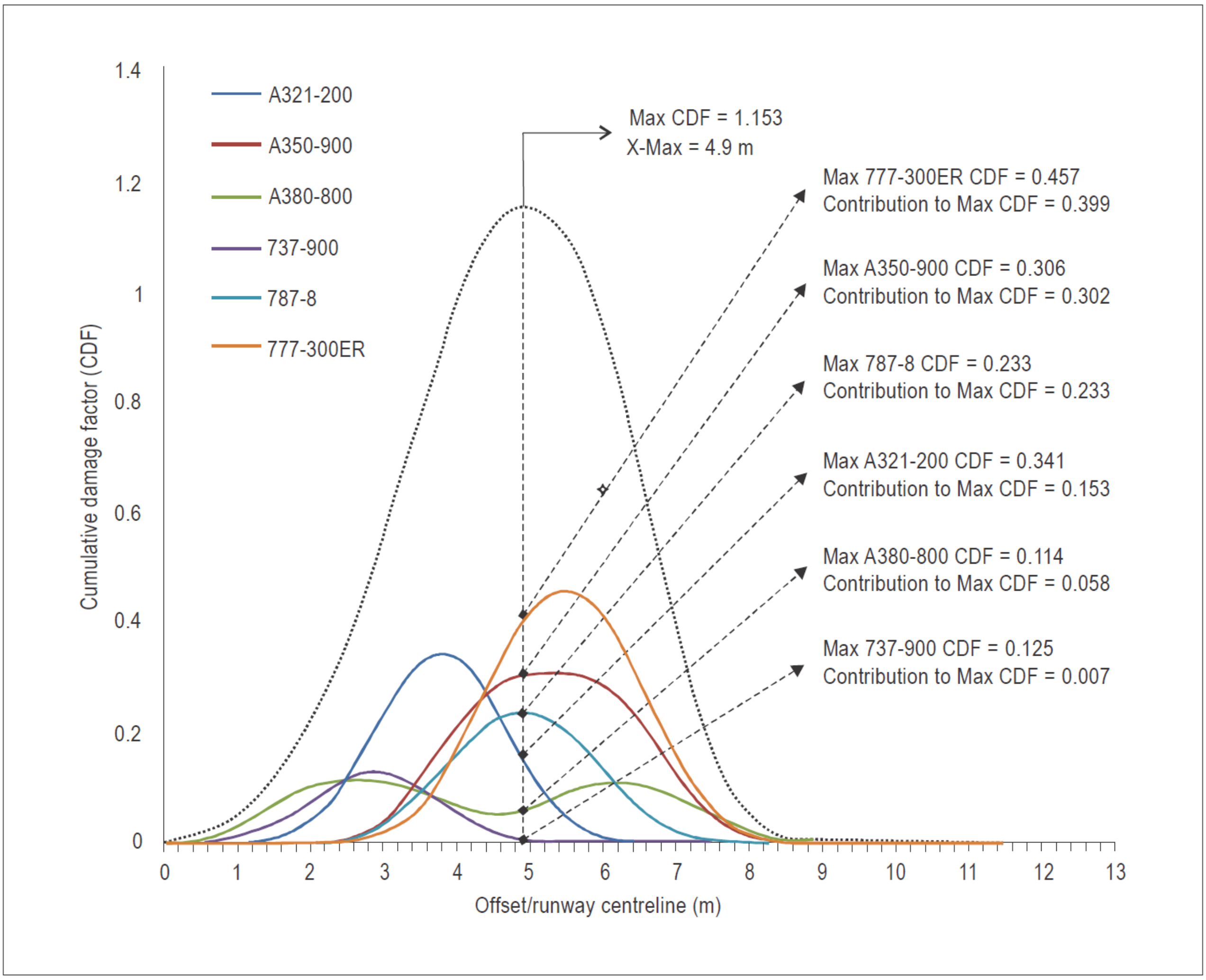
Step 4: CDF of the entire aircraft mix

The CDF is computed for the entire fleet by summing the individual aircraft CDF contributions along a transverse axis perpendicular to the runway centreline. Figure 1-10 shows the individual aircraft contributions to CDF and the resulting total CDF of the mix. The maximum value of CDF is 1.153, located at an offset 4.9 m from the runway centreline.

The maximum CDF is greater than 1.0, indicating that the pavement is under-designed for the traffic analysed.

Note: It is important to distinguish the CDF contributions of each aircraft to the maximum CDF at the critical offset from the maximum damage due to individual aircraft (which may or may not occur at the critical offset). For instance, the A321-200 damage contribution to the maximum CDF at the critical offset is 0.153 while its maximum damage is equal to 0.341. Similarly, the A350-900 produces a maximum damage of 0.306, lower than the A321, but its contribution to the maximum CDF is of 0.302, higher than the A321 contribution. The *difference is due to different track dimensions (distance of the landing gear from the centreline) of the various aircraft.*

The aircraft with the highest CDF contribution (to the maximum CDF) becomes the most demanding aircraft within the mix. In this example, the highest contribution to the maximum CDF (0.399) is produced by the B777-300ER.



Step 5: The B777-300ER is selected as the most contributing aircraft to the maximum CDF. All other aircraft are removed.

Step 6: The contribution of the B777-300ER to the maximum CDF at its initial annual departure level is 0.457. The number of annual departures is adjusted until CDF equals 1.153. This step is performed by simple linear extrapolation, giving 11 050 equivalent annual departures of the B777-300ER (110 500 total departures).

Step 7: The gross weight of the B777-300ER is adjusted to obtain a maximum CDF of 1.0. In other words, the pavement is now correctly designed to accommodate the single equivalent aircraft at its adjusted weight and equivalent annual departure level. The MAGW is 341.3t.

Step 8: The B777-300ER ACR at its MAGW is 740/F/C.

Step 9: Checking against the list in Step 3, the B777-300ER is the maximum ACR aircraft. Therefore, the procedure is stopped. The PCR to be reported is equal to the B777-300ER ACR at its MAGW:

PCR 740 FCWT

For the tyre pressure code, the letter W is selected since the evaluated pavement is new construction, and the surface asphalt mix has been designed to resist the imposed tyre pressures.

A4.2 PCR calculation involving the aircraft experience (code U)

The following example illustrates the calculation of the PCR value for a **flexible pavement**.

The pavement is a runway which is already in service and for which the aerodrome operator has reported the following PCN to the AIS: PCN 85 FCWU.

The following aircraft mix is known based on the recent use of the aerodrome. All of these aeroplanes make regular use of the aerodrome.

AIRCRAFT MIX ANALYSED			
No.	*Aircraft model*	*Maximum taxi weight (t)*	*Annual departures*
1	A321-200	93.9	14 600
2	A350-900	268.9	5 475
3	A380-800	571	1 825
4	B737-900	79.2	10 950
5	B787-8	228.4	3 650
6	B777-300ER	352.4	4 380

The pavement's *estimated* subgrade strength is of CBR 9. Using the conversion equation given in the Notes of the Table in Point 8, the estimated E is calculated: E = 10 × 9 MPa = 90 MPa, which places the subgrade in the subgrade category strength 'C'.

Based on the fact that the pavement is flexible and the estimated subgrade category is 'C', the ACR of the aircraft contained in the aircraft mix can be determined either by manufacturer data or ICAO-ACR tool (see Point 9 and Annex 3).

	B777-300ER	A321-200	A350-900	B787-8	B737-9	A380-800
Operating weight (t)	352.4	93.9	268.9	228.4	79.2	571
ACR	790	550	720	680	450	650

The runway pavement was designed with no tyre limitations (code W). The aerodrome operator is performing regular inspections and maintenance works and the pavement of the runway is in good condition, showing no signs of cracking, distortion or wear.

A pavement satisfactorily sustaining its using traffic can be considered capable of supporting the heaviest aircraft regularly using it and any other aircraft that has no greater pavement strength requirements. From the above table, it can be concluded that the most demanding aeroplane is the B777-300ER

The resulting PCR will be equal to the ACR of the B777-300ER and the reported PCR will be: **790 FCWU.**

Note: For the same traffic mix and same operating weights, the PCR resulting under the technical evaluation method provided in the example of A4.1 is different than the PCR resulting under the using aircraft experience method provided in the example of A4.2 (740 vs.790). This is due to the accuracy of the methods, the technical evaluation method being more accurate (see Point 10).