Civil Aviation Safety Authority
of Papua New Guinea

Advisory Circular

AC139-3.3

Pavement Bearing Strength

Revision 02

10 April 2025

GENERAL

Civil Aviation Authority Advisory Circulars (AC) contain information about standards, practices and procedures that the Director has found to be an Acceptable Means of Compliance (AMC) with the associated rule.

An AMC is not intended to be the only means of compliance with a rule, and consideration will be given to other methods of compliance that may be presented to the Director. When new standards, practices or procedures are found to be acceptable, they will be added to the appropriate Advisory Circular.

PURPOSE

This Advisory Circular provides methods, acceptable to the Director, for showing compliance with the aerodrome certification exposition requirements of Part 139 and explanatory material to assist in showing compliance.

RELATED CAR

This AC relates specifically to Civil Aviation Rule 139.B.6.

CHANGE NOTICE

This AC replaces AC139-3.3 Initial Issue.

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GLOSSARY

DEFINITIONS

Aggregate. General term for the mineral fragments or particles which, through the agency of a suitable binder, can be combined into a solid mass, e.g., to form a pavement.

Aircraft classification number (ACN). A number expressing the relative effect of an aircraft on a pavement for a specified standard subgrade strength.

Aircraft classification rating (ACR). A number expressing the relative effect of an aircraft on a pavement for a specified standard subgrade strength.

All-up mass. Aircraft maximum ramp or taxi mass, also referred as gross weight.

Asphalt. Highly viscous binder occurring as a liquid or semi-solid form of petroleum, also referred as bitumen. May be found in natural deposits or may be a refined product.

Asphalt concrete. A graded mixture of aggregate, and filler with asphalt or bitumen, placed hot or cold, and rolled, also referred as asphaltic concrete or bitumen concrete.

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 (CBR). 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.

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.

Lateral wander. The path of a given aircraft will deviate relative to the path centred on the longitudinal axis of the pavement in question in a statistically predictable pattern. This phenomenon is referred to as lateral wander.

Mean aerodynamic chord (MAC). The MAC is a two-dimensional representation of the whole wing. The pressure distribution over the entire wing can be reduced to a single lift force on and a moment around the aerodynamic centre of the MAC. Centre of gravity position is expressed as percentage of MAC.

Modulus of elasticity (E). 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.

Overlay. An additional surface course placed on existing pavement either with or without intermediate base or sub-base courses, usually to strengthen the pavement or restore the profile of the surface.

Pavement classification number (PCN). A number expressing the bearing strength of a pavement.

Pavement classification rating (PCR). A number expressing the bearing strength of a pavement for unrestricted operations.

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.

Portland cement concrete (PCC). A mixture of graded aggregate with Portland cement and water.

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.

ABBREVIATIONS AND ACRONYMS

2D	Dual tandem
ACN	Aircraft classification number
ACR	Aircraft classification rating
AIP	Aeronautical information publication
ASTM	American Society for Testing and Materials
CBR	California bearing ratio
CDF	Cumulative damage factor
CG	Centre of gravity
cm	Centimetre
D	Dual
DSWL	Derived single wheel load
FAA	Federal Aviation Administration
FOD	Foreign object debris
FWD	Falling weight deflectometers
GPR	Ground penetrating radar

HFWD	Heavy falling weight deflectometer
HWD	Heavy weight deflectometer
kN	Kilonewton
LRFD	Load and resistance factor design
MPa	Megapascal
MRGM	Maximum ramp gross mass
NDT	Non-destructive testing

1 PROCEDURES FOR REPORTING AERODROME PAVEMENT STRENGTH

1.1. The Aircraft Classification Rating – Pavement Classification Rating (ACR-PCR) Method

1.1.1.1. Appendix B.6 of CAR Part 139 specifies that the bearing strength of a pavement intended for aircraft of a mass greater than 5 700 kg should be made available using the aircraft classification rating - *pavement classification rating* (ACR-PCR) method. To facilitate the proper understanding and usage of the ACR-PCR method, the following explanatory material is provided:

a) the concept of the method;

b) how the *aircraft classification ratings* (ACRs) of an aircraft are determined; and

c) how the *pavement classification ratings* (PCRs) of a pavement can be determined using the *cumulative damage factor* (CDF) concept.

1.1.1.2. The key parameters of the determination of the pavement classification rating (PCR) are summarized in Figure 1-1.

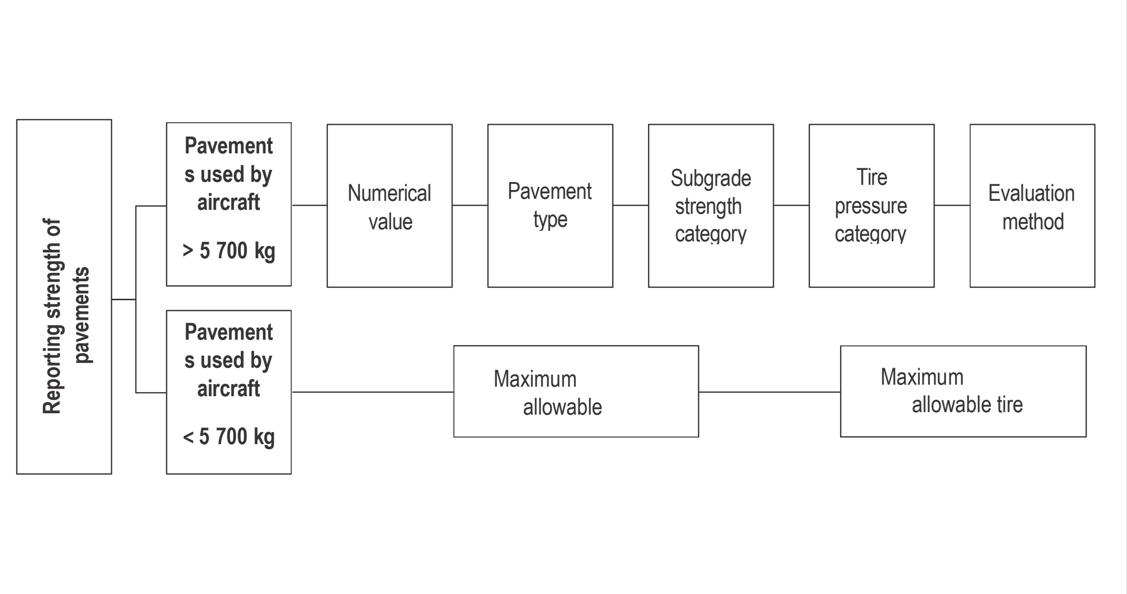


Figure 1-1. Determination of the PCR

1.2. Concept of the ACR-PCR Method

1.2.1.1. The ACR-PCR method is meant only for the publication of pavement strength data in aeronautical information publications (AIPs). It is not intended for the design or evaluation of pavements, nor does it contemplate the use of a specific method by the aerodrome operator for either the design or evaluation of pavements. In fact, the ACR-PCR method does permit States to use any design/evaluation method of their choice. To this end, the 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. When referring to unrestricted operations, it does not mean unlimited operations, but refers to the relationship of the PCR to the aircraft ACR and it is permissible for an aircraft to operate without weight restrictions (subject to tire pressure limitations) when the PCR is greater than or equal to the ACR. The term “unlimited operations” does not take into account pavement life. The PCR to be reported 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. The airport authority can use any method of its choice to determine the load rating of its pavement, provided it uses the CDF concept. The PCR so reported would indicate that an aircraft with an ACR equal to or less than that load rating figure can operate on the pavement, subject to any limitation on the tire pressure.

1.2.1.2. The ACR-PCR method facilitates the reporting of pavement strengths on a continuous scale. The lower end of the scale is zero and there is no upper end. Additionally, the same scale is used to measure the load ratings of both aircraft and pavements.

1.2.1.3. To facilitate the use of the method, aircraft manufacturers will publish, in the documents detailing the characteristics of their aircraft, ACRs computed at two different masses (the maximum apron mass and a representative operating mass empty) both on rigid and flexible pavements, and for the four standard subgrade strength categories. The ICAO-ACR computer programme, which is available to all stakeholders, provides any aircraft ACRs at any mass and centre of gravity (CG) position for both flexible and rigid pavement and for the four standard subgrade strength categories. It is to be noted that the mass used in the ACR calculation is a "static" mass and that no allowance is made for an increase in loading through dynamic effects.

1.2.1.4. The ACR-PCR method also envisages the reporting of the following information in respect of each pavement:

a) pavement type;

b) subgrade category;

c) maximum allowable tire pressure; and

d) pavement evaluation method used.

1.2.1.5. 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. There is, however, no need to report the actual subgrade strength or the maximum allowable tire pressure. Consequently, the subgrade strengths and tire pressures normally encountered have been grouped into categories as indicated in 1.4.6. It is sufficient for the airport authority to identify the categories appropriate to its pavement. The airport authority should, whenever possible, report pavement strength based on a technical evaluation of the pavement. If, due to financial or engineering constraints, a technical evaluation is not feasible, then using the aircraft method must be used for reporting pavement strength. The ACR-PCR method permits States to use the design/evaluation procedure of their choice when determining the PCR for their pavements. However, in many instances, the State may lack expertise in this area or wish to incorporate a standard methodology for performing the technical evaluation of their pavements.

1.2.1.6. In some cases, culverts, bridges, and other surface and subsurface structures can be the critical or limiting element necessitating the reporting of a lower PCR for the pavement. Considerations that permit the use of the ACR- PCR method to limit pavement overloading are not necessarily adequate to protect these structures.

1.3. ACR Determination

1.3.1.1. ACRs of aircraft are computed under the ACR-PCR method as shown in Figure 1-2. Relevant documents and software include the:

(1) Aircraft characteristics for airport planning (published by the aircraft manufacturers).

(2) ICAO-ACR computer programme (current version).

1.3.1.2. The following are standard values used in the method and include descriptions of the various terms:

1.3.2. Subgrade category

1.3.2.1. In the ACR-PCR method, four standard subgrade values (modulus values) are used, rather than a continuous scale of subgrade moduli. The grouping of subgrades with a standard value at the mid-range of each group is considered to be entirely adequate for reporting. Subgrade categories apply to both flexible and rigid pavements.

1.3.2.2. The subgrade categories are identified as high, medium, low and ultra-low and are assigned the following numerical values:

- Code A – High strength; characterized by E = 200 MPa and representing all E values equal to or above 150 MPa, for rigid and flexible pavements.
- Code B – 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.

- Code C – 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.

- Code D – Ultra-low strength; characterized by E = 50 MPa and representing all E values strictly less than 60 MPa, for rigid and flexible pavements.

1.3.3. Concrete working stress for rigid pavements

1.3.3.1. For rigid pavements, a standard stress for reporting purposes is stipulated (σ = 2.75 MPa) only as a means of ensuring uniform reporting. The working stress to be used for the design and/or evaluation of the pavements has no relationship to the standard stress for reporting.

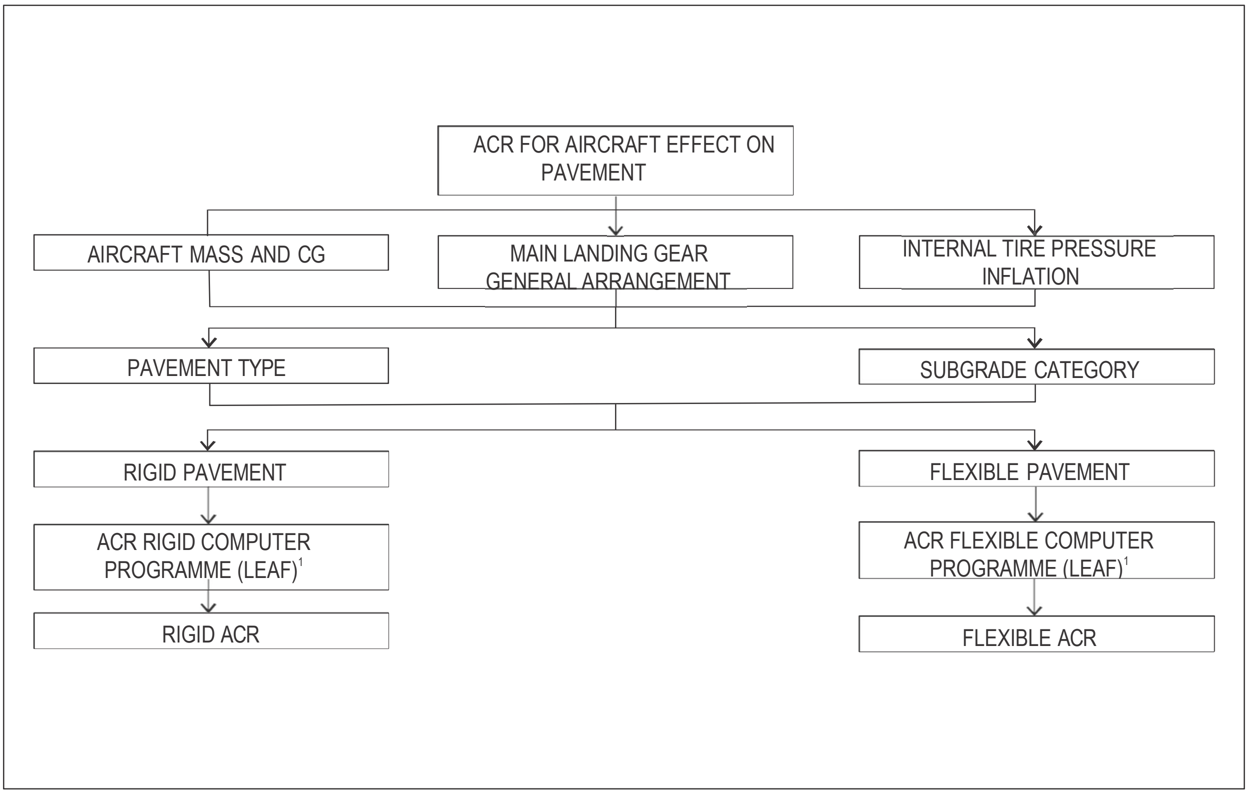


Figure 1-2. ACR Computation

1.3.4. Mathematically derived single wheel load

1.3.4.1. The concept of a mathematically derived single wheel load has been employed in the ACR-PCR method as a means to define the aircraft landing gear-pavement interaction, without specifying pavement thickness as an ACR parameter. This is done by equating the thickness given by the mathematical model for an aircraft landing gear to the thickness for a single wheel at a standard tire pressure of 1.50 MPa. The single wheel load so obtained is then used without further reference to thickness; this is because the essential significance is attached to the fact of having equal thicknesses, implying "same applied stress to the pavement", rather than the magnitude of the thickness. The foregoing is in accordance with the objective of the ACR-PCR method for evaluating the relative loading effect of an aircraft on a pavement.

1.3.5. Aircraft classification rating (ACR)

1.3.5.1. 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. As noted previously, single wheel tire pressure is standardized at 1.50 MPa. Additionally, the derived single wheel load is a function of the subgrade modulus. The aircraft classification rating (ACR) is defined only for the four standard subgrade categories (i.e. high, medium, low and ultra- low). The factor of two in the preceding numerical definition of ACR is used to achieve a suitable ACR versus gross mass scale, so that whole number values of ACR may be used with reasonable accuracy.

1.3.5.2. Because an aircraft operates at various mass and CG conditions, the following conventions have been used in ACR computations:

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

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

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

1.3.6. Mathematical models

1.3.6.1. The sole mathematical model used in the ACR-PCR method is the *layered elastic analysis* (LEA). The LEA model assumes that several homogeneous, elastic, isotropic layers arranged as a stack, whether flexible or rigid, can represent the pavement structure. Each layer in the system is characterized by an *elastic modulus* E_i, *Poisson's ratio* v_i, and *a uniform layer thickness* t_i. Layers are assumed to be of infinite horizontal extent and the bottom or subgrade layer is assumed to extend vertically to infinity (i.e. the subgrade is modelled as an elastic half-space). Due to the linear elastic nature of the model, individual wheel loads can be summed to obtain the combined stress and strain responses for a complex, multiple-wheel aircraft gear load. The use of the LEA model permits the maximum correlation to worldwide pavement design methods.

1.3.7. Computer programmes

1.3.7.1. The computer programme was developed using the above LEA mathematical model by the United States Federal Aviation Administration (FAA), named LEAF. LEAF is an open-source computer programme whose source code is available from the FAA, Airport Technology Research and Development Branch, William J. Hughes Technical Center, United States. In addition, a second LEA programme, Alize-Aeronautique, was developed by the French Institute of Science and Technology for Transport, Development and Networks (IFSTTAR) in partnership with AIRBUS SAS, and has been found to give nearly identical results for equal inputs. The ICAO-ACR computer programme incorporates the LEAF programme and was developed to implement the ACR computational procedures for rigid and flexible pavements. ICAO-ACR is distributed in compiled form as a Visual Basic.NET dynamic-link library (DLL), and may be linked to other programmes that either compute ACR directly or that use the ACR computation to evaluate PCR. By default, the ICAO- ACR programme takes as inputs: the maximum ramp mass for ACR calculations; per cent of maximum ramp mass acting on the main gear (equivalent for this purpose to the aft CG corresponding to maximum ramp mass); the number of wheels; the geometric coordinates of all wheels; and the type of pavement (rigid or flexible). The output is the ACR at each subgrade category and the pavement reference thickness, t, corresponding to ACR at each subgrade category.

1.3.8. Graphical procedures

1.3.8.1. Graphical procedures should not be used for determining the ACR. Instead, use the computer programmes as described above.

1.3.9. Rigid pavements

1.3.9.1. The rigid pavement ACR procedure relates the derived single wheel load at a constant tire pressure of 1.50 MPa to a reference concrete slab thickness, t. It takes into account the four subgrade categories detailed in 1.4.6.1, and a standard concrete stress of 2.75 MPa. Note that, because a standard concrete stress is used, no information concerning either pavement flexural strength or number of coverages is needed for the rigid ACR computation. The steps below are used to determine the rigid ACR of an aircraft.

1.3.10. Reference pavement structure

1.3.10.1. Using the aircraft data published by the manufacturer, obtain the reference thickness, t, for the given aircraft mass, E-value of the subgrade, and standard concrete stress for reporting, i.e. 2.75 MPa. For all four subgrade categories, assume the following cross-section for the LEA model (see Table 1-1):

Table 1-1. Reference pavement structure for rigid ACR

Layer description	*Designation*	*Thickness, mm*	*E, MPa*	*V*
Surface course (PCC)	Layer 1	variable	27 579	0.15
Base course (crushed aggregate)	Layer 2	200	500	0.35
Subgrade	Layer 3	infinite	See 1.1.3.2.2	0..40

1.3.10.2. The minimum allowable thickness of Layer 1 in the LEA model is 50.8 mm. LEA computations further assume that the horizontal interface between Layer 1 and Layer 2 is not bonded (full slip), and that the horizontal interface between Layer 2 and Layer

3 is full bond. Within the LEA model, stress a is the maximum horizontal stress computed on the bottom of Layer 1 (the Portland cement concrete layer).

1.3.11. Evaluation gear

1.3.11.1. The ACR value is computed for a single truck in the main landing gear assembly (i.e. for two wheels in a dual, or D assembly, four wheels in a dual-tandem, or 2D assembly, etc.). For more complex landing gear types with more than two trucks (i.e. having a designation in FAA Order 5300.7, "Standard Naming Convention for Aircraft Landing Gear Configurations" consisting of more than two characters), the individual truck in the main gear assembly with the largest rigid ACR determines the rigid ACR for the aircraft. All trucks are evaluated at the mass and CG that produce the highest total main gear loading on the pavement.

1.3.12. Stress evaluation points

1.3.12.1. The number of LEA evaluation points is equal to the number of wheels in the evaluation gear. The evaluation points are located at the bottom of Layer 1, below the centre point of each wheel. The thickness, **t**, of Layer 1 is adjusted until the maximum stress evaluated over all evaluation points is equal to 2.75 MPa. The resulting t is the reference thickness for the ACR.

1.3.13. Derived single wheel load (DSWL) calculation

1.3.13.1. Using the above reference thickness and the same LEA model as in 1.3.10 obtain a derived single wheel load for the selected subgrade. Maintaining the constant tire pressure of 1.50 MPa, the single wheel load magnitude is adjusted until the maximum horizontal stress at the bottom of Layer 1 is equal to 2.75 MPa. For evaluation of stresses under the single wheel load, use one evaluation point located at the bottom of Layer 1, directly below the centre of the wheel.

1.3.14. Modified DSWL calculation for lightweight aircraft

1.3.14.1. For some lightweight aircraft, the required reference thickness, t, is less than the minimum allowable thickness. Use the following modified steps to compute DSWL only when the theoretical thickness of Layer 1 that makes the maximum stress equal to 2.75 MPa is less than 50.8 mm:

a) determine the value of stress (less than 2.75 MPa) corresponding to the minimum allowable concrete thickness (50.8 mm); and

b) calculate DSWL for the selected subgrade using the minimum thickness of the reference structure. Maintaining the constant tire pressure of 1.50 MPa, the single wheel load magnitude is adjusted until the maximum horizontal stress at the bottom of Layer 1 is equal to the value determined in a) above.

1.3.15. ACR calculation

1.3.15.1. The aircraft classification rating, at the selected mass and subgrade category, is two times the derived single wheel load in hundreds of kilograms. The numerical value of ACR may be rounded to the nearest multiple of ten for reporting.

1.3.16. Flexible pavements

1.3.16.1. The flexible pavement ACR procedure relates the derived single wheel load at a constant tire pressure of 1.50 MPa to a reference total thickness, t, computed for 36 500 passes of the aircraft. It takes into account the four subgrade categories detailed in 1.3.7.

1.3.17. Reference pavement structures

1.3.17.1. The ACR-PCR system must cover a wide range of aircraft, weighing from a few to several hundreds of tons. Reference structures have been chosen to produce appropriate thicknesses for the standard subgrade categories for the range of aircraft weights used. Determining the reference structures for the flexible ACR computation consists of defining the materials and constitutive properties of the several layers. All layers are defined by: Elastic modulus E, Poisson's ratio v, and (except for the design layer) the thickness t. LEA computations assume that all horizontal interfaces between layers are fully bonded. Tables 1-2 and 1-3 define the reference structures to be used in calculating flexible ACR.

Table 1-2. Reference structure for flexible ACR (aircraft fitted with two or fewer wheels on all legs of the main landing gear)

Layer description	*Thickness, mm*	*E, MPa*	*V*
Surface course (asphalt)	76	1 379	0.35
Base course (crushed aggregate)	variable	See 1.1.3.10	0.35
Subgrade	infinite	See 1.1.3.2.2	0.35

Table 1-3. Reference structure for flexible ACR (aircraft fitted with more than two wheels on any leg of the main landing gear)

Layer description	*Thickness, mm*	*E, MPa*	*V*
Surface course (asphalt)	127	1 379	0.35
Base course (crushed aggregate)	variable	See 1.1.3.10	0.35
Subgrade	infinite	See 1.1.3.2.2	0.35

1.3.17.2. In the LEA model, the minimum allowable thickness of the variable (base course) layer is 25.4 mm. Because of the intentionally limited number of reference structures, computed layer thicknesses may not be realistic at the extremes of the aircraft weight range. However, this does not invalidate the ACR concept, in which t is a relative indicator rather than the basis for a practical design.

1.3.18. Base layer modulus

1.3.18.1. All flexible reference pavement structures include a variable thickness layer above the subgrade, representing a crushed aggregate base layer. The modulus of the variable thickness layer is not fixed in the ACR procedure, but is a function of the thickness and of the subgrade modulus. Within the LEA model, the base layer is subdivided into smaller sublayers and a modulus value is then assigned to each sublayer using a recursive procedure as explained below. Modulus values are assigned to the sublayers following the procedure in the FAA computer programme FAARFIELD (version 1.42), for item P-209 (crushed aggregate). The steps in the procedure are as follows:

- **Step 1.** Determine the number of sublayers *N*. If the base layer thickness t_B is less than 381 mm, then *N* = 1 and sublayering is not required. If t_B is greater than or equal to 381 mm, the number of sublayers is:

  $$N = int\left(\frac{t_B}{254} + 0.5\right)$$

  where t_B is in mm, and the integer function returns the integer part of the argument (i.e. rounds down to the next whole number).

- **Step 2.** Determine the thickness of each sublayer. If *N* = 1, then the sublayer thickness is equal to the base layer thickness t_B. If *N* > 1, then the thickness of the bottom *N* - 1 sublayer is 254 mm, and the thickness of the top sublayer is $t_B - (N - 1) \times 254$ mm. Note that, in general, the *N* sub-layers do not have equal thickness. For example, if the thickness of the base layer is 660 mm, then from Step 1, the number of sublayers is three. The bottom two sublayers are each 254 mm, while the top sublayer is 660 - 2 x 254 = 152 mm.

- **Step 3.** Assign a modulus value *E* to each sublayer. Modulus values increase from bottom to top, reflecting the effect of increasing confinement of the aggregate material. Modulus values are given by the following equation:

  $$E_n = E_{n-1} \times \{1 + [log10(t_n) - log10(25.4)] \times (c - d[log10(E_{n-1}) + log10(145.037)])\}$$

  where E_n = the modulus of the current sublayer in MPa;

  E_{n-1} = the modulus of the sublayer immediately below the current sublayer; or the modulus of the subgrade layer when the current sublayer is the bottom sublayer;

  t_n = the thickness of the current sublayer in mm;

  c = 10.52 (constant); and

  d = 2.0 (constant).

  The above equation is applied recursively beginning with the bottom sublayer.

- **Step 4.** The modulus assignment procedure in Step 3 must be modified for the top two sublayers whenever t_B is between 127 mm and 254 mm greater than an integer multiple of 254 mm. This modification ensures that the modulus of all sublayers is a continuous function of the layer thickness, with no gaps. If

N > 1 and tB exceeds an integer multiple of 254 mm by more than 127 mm, but less than 254 mm, then:

a) The top sub-layer (sub-layer *N*) is between 127 mm and 254 mm thick, and all sublayers below it (sublayers 1 to *N*-1) are 254 mm thick.

b) Using the equation in Step 3, compute the modulus E254 that would be obtained for sublayer *N* for an assumed top sublayer thickness tn equal to 254 mm.

c) Compute the modulus of sublayer *N*-1 (i.e. the sublayer immediately below the top sub-layer) using the equation in Step 3, but substituting tn = 508 mm - tN, where tN is the actual thickness of the top sublayer in mm.

d) Compute the modulus of sublayer *N* by linear interpolation between EN-1 (the modulus of sublayer *N*-1) and E254:

$$E_N = E_{N-1} + t_N \times \frac{E_{254} - E_{N-1}}{254}$$

1.3.19. Evaluation gear

1.3.19.1. The ACR value is computed using all wheels in the main landing gear (wheels in the nose landing gear are not included). Main landing gears are evaluated at the mass and CG that produces the highest total main gear loading on the pavement.

1.3.20. Strain evaluation points

1.3.20.1. Within the LEA model, strain £ is the maximum vertical strain computed on the top surface of the subgrade (lowest) layer. In the ICAO-ACR computer programme, strains are computed at specific evaluation points based on the geometry of the evaluation gear. Evaluation points are placed directly below the centre point of each wheel, and at the points defined by a regular rectangular grid spaced at 10-cm intervals, and oriented parallel to the principal axes of the gear.

1.3.20.2. For simple main landing gears consisting of two trucks (i.e. for two wheels in a dual, or D assembly, four wheels in a dual-tandem, or 2D assembly, etc.), the grid origin is set at the geometric centre of one truck. The limits of the grid extend 30 cm beyond the maximum wheel coordinates on all sides of the truck (Figure 1-5).

1.3.20.3. For more complex gear types with more than two trucks comprising the main landing gear assembly (i.e. all aircraft whose gear designation consists of more than two characters in FAA Order 5300.7, "Standard Naming Convention for Aircraft Landing Gear Configurations"), the origin of the grid is at the geometric centre of the entire landing gear assembly. The limits of the grid extend 30 cm beyond the maximum wheel coordinates on all sides (see Figure 1-6). For the purpose of computing the geometric centre coordinates, all included wheels should be weighted equally, regardless of different wheel loads or tire pressures.

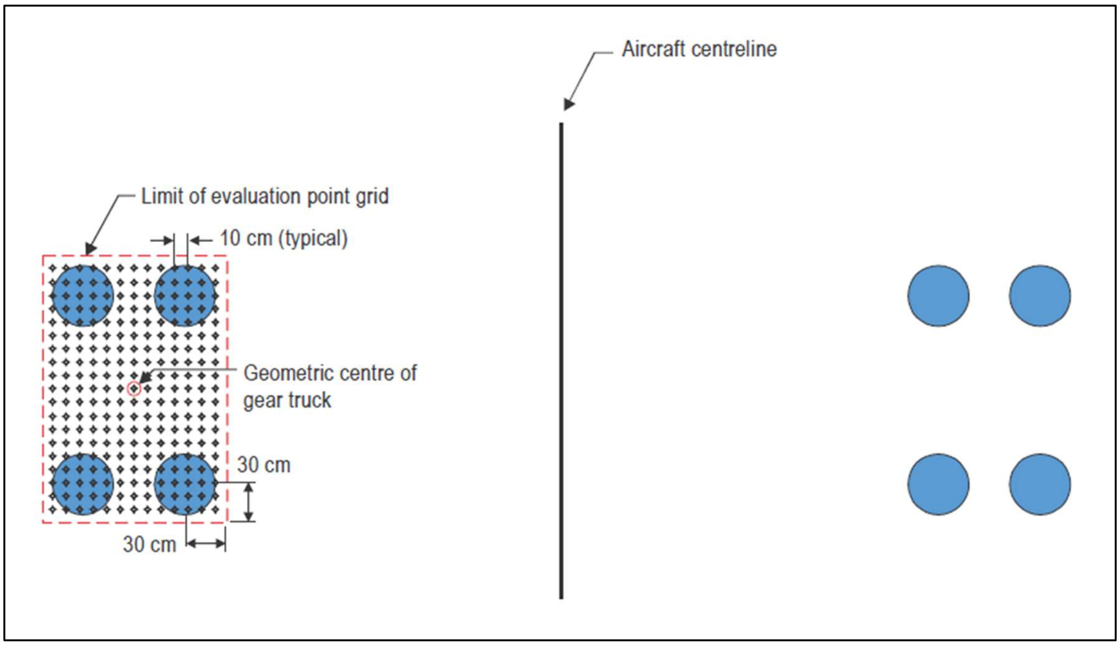


Figure 1-5. Grid definition for simple main landing gear arrangement

1.3.20.4. Strain ε is the maximum of the strains computed for all evaluation points.

Note.- *ICAO-ACR automatically detects symmetries within the evaluation point grid to reduce the number of required computations. In the case of the 8787-9, only one half of the evaluation point grid may actually be computed due to the transverse symmetry.*

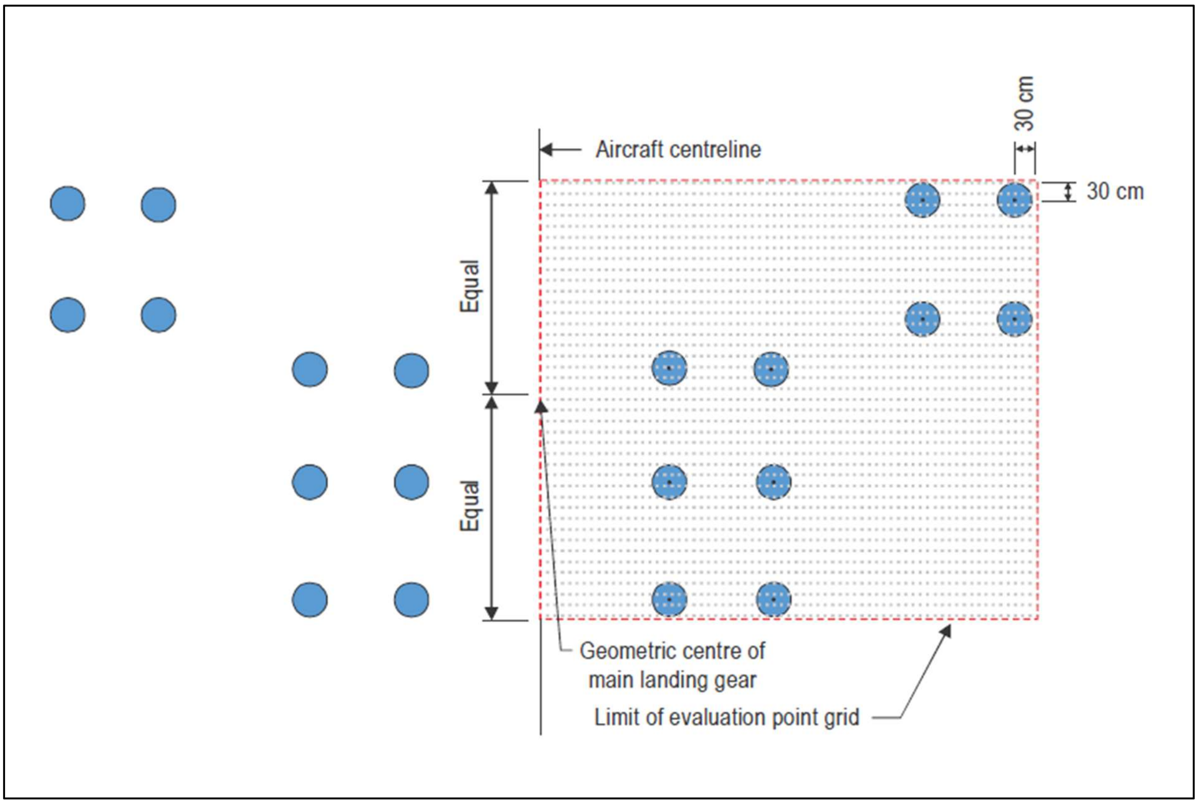


Figure 1-6. Grid definition for complex aircraft main landing gear

1.3.21. Damage model

1.3.21.1. The flexible ACR procedure relies on the subgrade failure criterion associated with the elementary damage law:

$$D_e(\varepsilon) = \frac{1}{C_e(\varepsilon)}$$

1.3.21.2. This elementary damage law is based on the notion of loading cycle (single-peak strain profile with maximum value *E*), which cannot be applied to arrangements with axles in tandem producing complex strain profiles, possibly with multiple strain peaks and no return to zero-strain between peaks. Therefore, the elementary damage law is extended to a continuous integral form:

$$D = \int_{\chi=-\infty}^{\chi=+\infty} \langle \frac{dD_e(x)}{dx} \rangle \, dx$$

where *x* refers to the longitudinal position along the landing gear and <y> to the positive part of y. Details of the integral formulation are described in Appendix 3.

1.3.22. DSWL Calculation

1.3.22.1. Using the pavement requirement data published by the manufacturer, calculate the reference thickness, t, for the given aircraft mass, E-value of the subgrade, and 36 500 passes of the aircraft. Use the appropriate reference pavement structure from 1.3.10 with evaluation points as described in 1.3.20. The thickness of the variable (design) layer is adjusted until the damage as computed from 1.3.21 is equal to 1.0. The resulting thickness, t*,* is the reference thickness for ACR.

1.3.22.2. Using the above reference thickness and the same LEA model as in 1.3.20, obtain a derived single wheel load for the selected subgrade. Maintaining the constant tire pressure of 1.50 MPa, the single wheel load magnitude is adjusted until the damage is equal to 1.0 for 36 500 passes. For evaluation of strains under the single wheel load, use one evaluation point located at the top of the subgrade, directly below the centre of the wheel.

1.3.23. Modified DSWL calculation for lightweight aircraft

1.3.23.1. For some lightweight aircraft, the required reference thickness, t*,* is less than the minimum allowable thickness. Use the following modified steps to compute DSWL only when the theoretical thickness of the variable design layer that makes the damage equal to 1.0 for 36 500 aircraft passes is less than 25.4 mm:

a) determine the value of maximum vertical strain at the top of the subgrade corresponding to the minimum allowable variable design layer thickness (25.4 mm); and

b) calculate DSWL for the selected subgrade using the minimum thickness of the reference structure. Maintaining the constant tire pressure of 1.50 MPa, the single wheel load magnitude is adjusted until the maximum vertical strain at the top of the subgrade is equal to the value determined in a) above.

1.3.24. ACR calculation

1.3.24.1. The aircraft classification rating, at the selected mass and subgrade category is two times the derived single wheel load in hundreds of kilograms. The numerical value of ACR may be rounded to the nearest multiple of ten for reporting.

1.3.25. Tire pressure adjustment to ACR

1.3.25.1. Aircraft normally have their tires inflated to the pressure corresponding to the maximum gross mass without engine thrust, and maintain this pressure regardless of the variation in take-off masses. There are times, however, when operations at reduced masses, modified CG and/or reduced tire pressures are productive and reduced ACRs need to be calculated. To calculate the ACR for these conditions, the adjusted tire inflation pressure should be entered in the ICAO-ACR dedicated input field.

1.4. PCR Determination

1.4.1.1. This section is intended to provide a model procedure for PCR determination and publication, using the CDF concept. States may develop their own methods for PCR determination, consistent with the overall parameters of the ACR-PCR method.

1.4.2. CDF concept

1.4.2.1. 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:

$$CDF = \frac{Applied\ coverages}{Coverages\ of\ failure}$$

Note 1. *– When CDF = 1, the pavement subgrade will have used all of its fatigue life.*

Note 2. *— When CDF < 1, the pavement subgrade will have some remaining life and the value of GDF will give the fraction of the life used.*

Note 3. *— When CDF > 1, all of the fatigue life will have been used and the pavement subgrade will have failed.*

1.4.2.2. 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.

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

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

where CDFi is the CDF for each aircraft in the traffic mix and N is the number of aircrafts in the mix.

1.4.2.4. Since the PCR relates to the structural pavement life, the CDF is based on the subgrade failure mode.

1.4.3. Lateral wander

1.4.3.1. 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 maneuvering area. Another term that is frequently used is the amplitude of lateral wander, which is twice the standard deviation.

1.4.3.2. 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 ($s \cong 0$) on low-speed sections (e.g. aprons).

1.4.3.3. 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

1.4.3.4. The FAA design procedure assumes s = 0.776 metres (30.54 inches) independently of the type of aircraft or feature.

1.4.3.5. The effect of lateral wander may be considered indirectly by computing a pass-to-coverage (P/C) ratio from the normal aircraft distribution. Alternatively, the distribution function can be discretized (mapped to a calculation grid) and the wandered damage computed numerically. A more closely spaced grid results in higher calculation times but greater accuracy. A grid spacing of 5 cm has been found to give good results. Discretization on a grid with transverse pitch Δy results in the distribution of the paths on nw lines yw of the grid, which are associated with percentages of the traffic Pw.

1.4.3.6. The effect of including lateral wander is to reduce the theoretical damage that would be caused by having all aircraft traverse a single path, i.e. $D_{wander} < D_{zero\ wander}$. Zero wander implies that the number of passes equals the number of coverages (P/C = 1).

1.4.4. Calculation of damage assuming lateral wander

1.4.4.1. When the grid method is used, it is necessary to obtain the total damage (for one aircraft) by summing the individual damage contributions from each of the *nw* profiles. This step consists of adding up the damage profiles $D_{no\ wander}(y, z)$, offset by the value y_w and weighted by probability of occurrence P_w in the lateral wander law:

$$D_{wander}(y,z) = \sum_{w=1}^{nw} P_w \times D_{no\ wander}(y - y_w, z)$$

where nw = total number of damage profiles.

1.4.5. Determination of the cumulative damage for a traffic mix

1.4.5.1. The cumulative damage for all aircraft comprising an aircraft mix is given by the following equation, which treats the additive effect of damage according to Miner's Rule:

$$CDF(y_j, z) = \sum_{i=1}^{m} N_i \times (D_{wander})_i(y_j, z)$$

where *m* = total number of aircraft in the traffic mix; *i* = aircraft within the aircraft mix; and *Ni* = number of aircraft passes.

1.4.5.2. The resulting curve represents the variation of the CDF in the transverse direction (relative to the longitudinal centreline).

1.4.5.3. If the P/C ratio is computed for each aircraft *i*, an equivalent expression giving CDF at lateral offset *j* is:

$$CDF(y_j, z) = \sum_{i=1}^{m} \frac{N_i}{(P/C)_j^i} \times D_i(z)$$

where *Di* is the damage contributed by a pass of aircraft *i*, including any effects of interaction between wheels in tandem.

1.4.5.4. Pavement Strength ReportingPCR shall be reported using the following codes:

a) Rigid pavement = R

b) Flexible pavement = F

Note *– If the actual pavement construction is composite or non-standard, include a note to that effect.*

1.4.6. Subgrade category

1.4.6.1. The subgrade categories are:

a) High strength: Characterized by E = 200 MPa, and representing all E values equal to or above 150 MPa for rigid and flexible pavements = Code A.

b) Medium strength: Characterized by E = 120 MPa and representing a range in E equals to or above 100 and strictly less than 150 MPa, for rigid and flexible pavements = Code B.

c) Low strength: Characterized by E = 80 MPa and representing a range in E equals to or above 60 and strictly less than 100 MPa, for rigid and flexible pavements = Code C.

d) Ultra-low strength: Characterized by E = 50 MPa and representing all E values strictly less than 60 MPa, for rigid and flexible pavements = Code D.

1.4.6.2. 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:

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

1.4.6.3. 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, etc.). Subgrade modulus values for PCR determination may also be determined from direct soil testing (e.g. lightweight deflectometer, plate test).

1.4.6.4. 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:

$$ESG=20.15\times k^{1.284}$$

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

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

1.4.6.6. The maximum allowable tire pressure categories are:

a) Unlimited: no pressure limit = Code W.

b) High: pressure limited to 1.75 MPa = Code X.

c) Medium: pressure limited to 1.25 MPa = Code Y.

d) Low: pressure limited to 0.5 MPa = Code Z.

1.1.4.2.2 There are two types of evaluation methods, mainly:

a) Technical evaluation: representing a specific study of the pavement characteristics and its capability of supporting the aircraft mix that is intended to serve, using the CDF concept through a mechanistic design/evaluation method calibrated against observed pavement behaviour = Code T

b) Using aircraft experience: representing a knowledge of the specific type and mass of aircraft satisfactorily being supported under regular use = Code U

1.4.7. PCR recommended procedure for technical evaluation (T)

1.4.7.1. 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 ACR calculation follows the ACR procedure described in 1.3.

1.4.7.2. 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.

1.4.7.3. 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 manoeuvre area (runway, taxiway, apron, ramp), the traffic can be assigned a lateral wander characterized by a standard deviation as detailed in 1.4.2);

3) compute the ACRs for each aircraft in the aircraft mix at its operating weight and record the maximum ACR aircraft (ACR computations must follow the procedure in 1.3);

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 maximum allowable gross weight (MAGW) for the critical aircraft;

8) compute the ACR of the critical aircraft at its MAGW. The value obtained is designated as PCR(i). (ACR computations must follow the procedure in 1.3);

9) if AC(i) is the maximum ACR aircraft from step 3) above, then skip to step 13);

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).

1.4.7.4. A flowchart of the above procedure is shown in Figure 1-9. 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 (such as the 8737) and a relatively small number of departures of a long-range aircraft (e.g. the 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.

1.4.7.5. The above procedure returns a uniquely determined PCR numerical value based on the identified critical aircraft.

1.4.8. Technical Evaluation Applicability

1.4.8.1. The technical evaluation should be used when pavement characteristics and aircraft mix are consistently known and documented.

1.4.8.2. The PCR procedure does not dictate the use of a preferred subgrade failure/damage model or a method for treating the multi-axle loading. Therefore, States can use their existing pavement design and evaluation methodologies. The use of the initial pavement design parameters will ensure consistency between what the actual pavement is able to withstand and the PCR assignment.

1.4.9. PCR procedure - Using aircraft experience (U)

1.4.9.1. Whenever possible, reported pavement strength should be based on a "technical evaluation". 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.

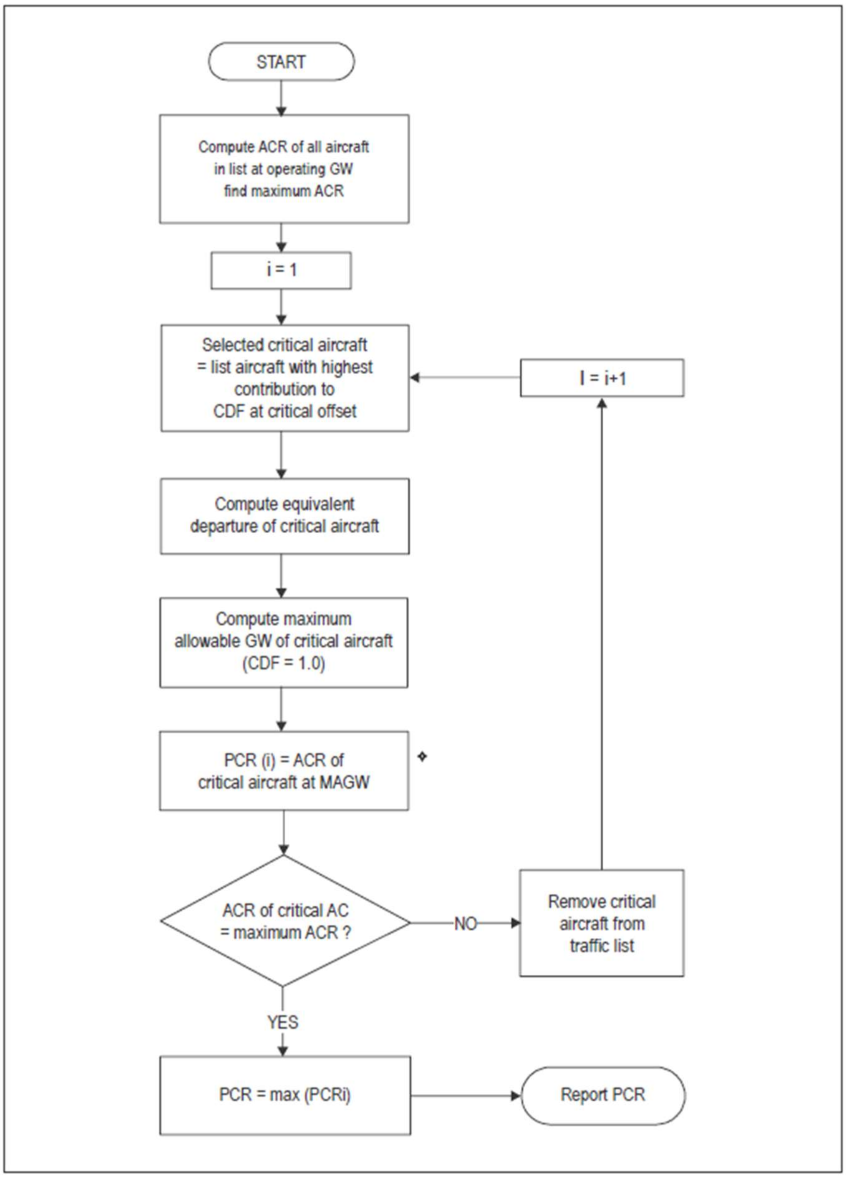


Figure 1-9. Flowchart of recommended PCR computation procedure

2 GUIDANCE FOR OVERLOAD OPERATIONS

2.1.1. CRITERIA SUGGESTED IN ICAO ANNEX 14

2.1.1.1. Overloading of pavements can result either from loads too large or from a substantially increased application rate, or both. Loads larger than the defined (design or evaluation) load shorten the design life while smaller loads extend it. Pavement failures rarely happen due to a single excessive load, but rather due to the repetition of loads exceeding the load rating for which the pavement was designed (cumulative damage principle). The structural behavior of pavement is such that it can sustain a definable load for an expected number of repetitions during its design life. As a result, occasional minor overloading is acceptable, when expedient, with only limited loss in pavement life expectancy and relatively small acceleration of pavement deterioration. For those operations in which magnitude of overload and/or the frequency of use do not justify a detailed analysis, the following criteria are suggested:

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; and

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

2.1.1.2. Such overload movements should not normally be permitted on pavements exhibiting signs of distress or failure. Furthermore, overloading should be avoided during any periods of thaw following frost penetration or when the strength of the pavement or its subgrade could be weakened by water. Where overload operations are conducted, the appropriate authority should review the relevant pavement condition regularly and should also review the criteria for overload operations periodically, since excessive repetition of overloads can cause severe shortening of pavement life or require major rehabilitation of pavement.

2.1.2. Overload technical analysis

2.1.2.1. Overloads in excess of 10 per cent may be considered on a case-by-case basis when supported by a more detailed technical analysis. When overload operations exceed allowances described in 2.1.1.1, a pavement analysis is required for granting the proposed additional loads, which was not scheduled in the initial pavement design. In those cases, the pavement analysis should determine how the overload operation contributes to the maximum CDF when it is mixed with the actual aircraft mix. Indeed, the ACR as a relative indicator, even if exceeding the reported PCR, cannot predict how the overload aircraft will affect the pavement structural behaviour and/or its design life, since it will be strongly dependent of its offset to the location of the maximum CDF produced by the aircraft mix (critical offset).

2.1.2.2. The pavement analysis would then mean determining the number of permitted overload operations so that the CDF of the entire aircraft mix, including the overload aircraft, remains in the tolerances agreed by the relevant authority.

3 APPENDIX 1 – AIRCRAFT CHARACTERISTICS AFFECTING PAVEMENT BEARING STRENGTH

1. General

1.1 This appendix describes those characteristics of aircraft which affect pavement strength design, namely: aircraft weight; percentage load on nose wheel; wheel arrangement; main leg load; tire pressure; and contact area of each tire. Table A1-1 (located at the end of this appendix) contains these data for most of the commonly used aircraft.

1.2 Aircraft loads are transmitted to the pavement through the landing gear, which normally consists of two main legs and an auxiliary leg, the latter being either near the nose (now the most frequent arrangement) or near the tail (older system).

1.3 The portion of the load imposed by each leg will depend on the position of the CG with reference to the three supporting points. The static distribution of the load by the different legs of a common tricycle landing gear may be illustrated in Figure A1-1 as follows:

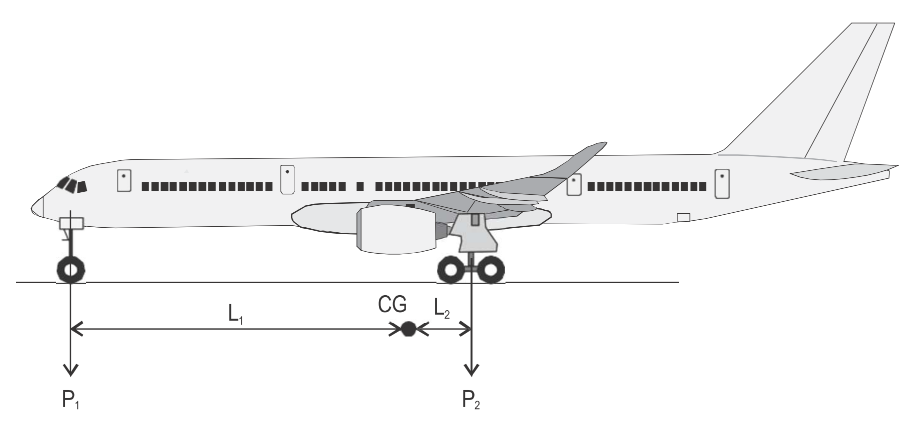


Figure A1-1. Aircraft weight distribution on ground

Where *W* is the aircraft weight; P_1 the load transmitted by the auxiliary leg; P_2 the load transmitted by both main legs; L_1 and L_2 the distance measured along the plane of symmetry from the CG to P_1 and P_2 respectively,

Then:

$W = P_1 + P_2$

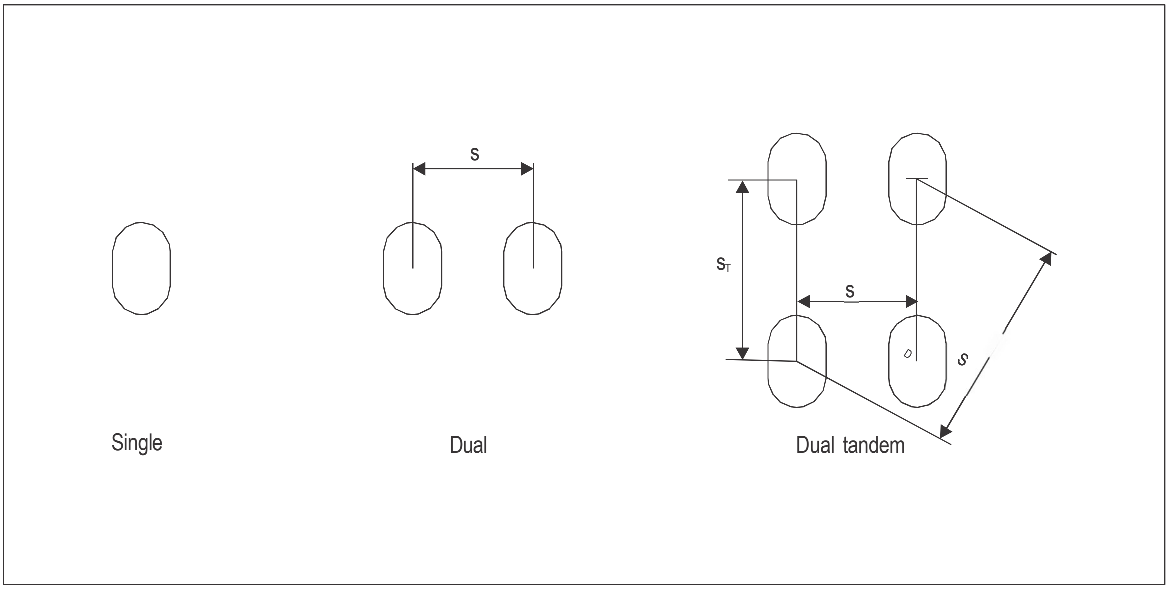
$P_1L_1 = P_2L_2$

3.1.1.1. Therefore:

$$P_2 = P_1\frac{L_1}{L_2}$$

The ratio L1/L2 is usually around 9 (i.e. the auxiliary leg accounts for approximately 10 per cent of the aircraft gross weight). Therefore, each main leg imposes a load equal to about 45 per cent of that weight. Wheel base and track width have not been included, since these dimensions are such that there is no possibility of interaction of the stresses imposed by the different legs of the landing gear.

1.4 From the above considerations, it can be seen that the characteristics of each main leg provide sufficient information for assessing pavement strength requirements. Accordingly, the table confines itself to providing data thereon.



3.1.1.2.

Figure A1-2. Wheel arrangements

1.5 The load supported by each leg is transmitted to the pavement by one or several rubber-tired wheels. The wheel arrangements shown in Figure A1-2 can be found on the main legs landing gear of civil aircraft currently in service.

1.6 For pavement design and evaluation purposes, the following wheel spacings are significant and therefore listed in the table:

S – distance between centres of contact areas of dual wheels

ST – distance between axes of tandem wheels

SD — distance between centres of contact areas of diagonal wheels and is given by the following expression:

$$S_D = \sqrt{(S^2 + S_T^2)}$$

Note.- *Tire pressures given are internal or inflation pressures.*

1.7 It should be noted that throughout the table, figures refer to the aircraft at its maximum take-off weight. For lesser operational weights, figures quoted for "load on each leg" and "contact area" should be decreased proportionally.

2. Aircraft Characteristics for Design and Evaluation of Pavements

2.1 The aircraft listed in Table A1-1 are representative of the aircraft manufacturers' most current commercial aircraft types, typically carrying 70 passengers or greater or having a mass exceeding 40 tons. Aircraft in this weight range are the most demanding in terms of pavement loading. Table A1-1, in most cases, lists the heaviest version of an aircraft model; more detailed information can be found in the aircraft manufacturers' aircraft characteristics for airport planning documents.

2.2 Wheel arrangement nomenclature (used in Table A1-1)

2.2.1 **Basic name for aircraft gear geometry**. Under the naming convention, abbreviated aircraft gear designations may include two variables, the main gear configuration and the body/belly gear configuration, if body/belly gears are present. Figure A1-3 illustrates the two primary variables.

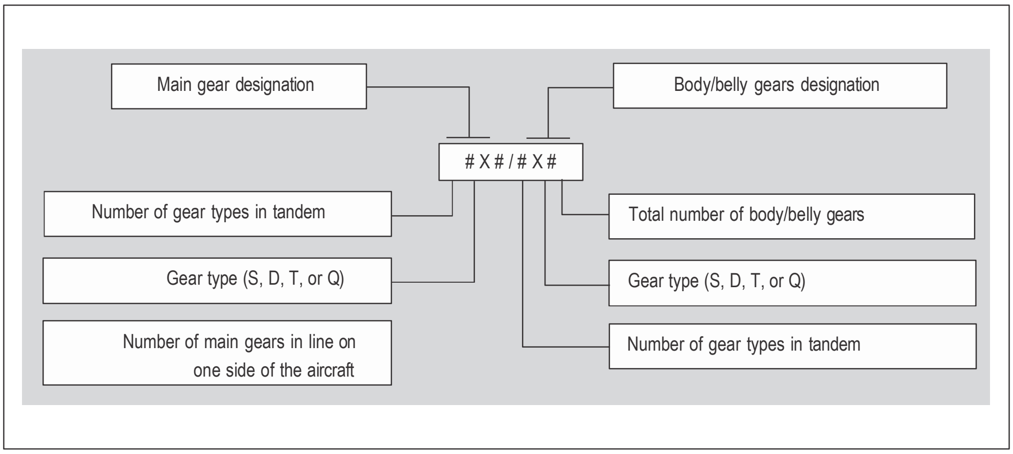


Figure A1-3. Gear naming convention

2.2.2 **Basic gear type**. Gear type for an individual landing strut is determined by the number of wheels across a given axle (or axle line) and whether wheels are repeated in tandem. There may exist, however, instances in which multiple struts are in close proximity and are best treated as a single gear, e.g. Antonov AN-124 (see Figure A1-4). If body/belly gears are not present, the second portion of the name is omitted. For aircraft with multiple gears, such as the 8747 and the A380, the outer gear pair is treated as the main gear.

2.2.3 **Basic gear codes**. This naming convention, as shown in Figure A1-4, uses the following codes for gear designation purposes: single (S); dual (D); triple (T); and quadruple (Q).

3.1.1.3.

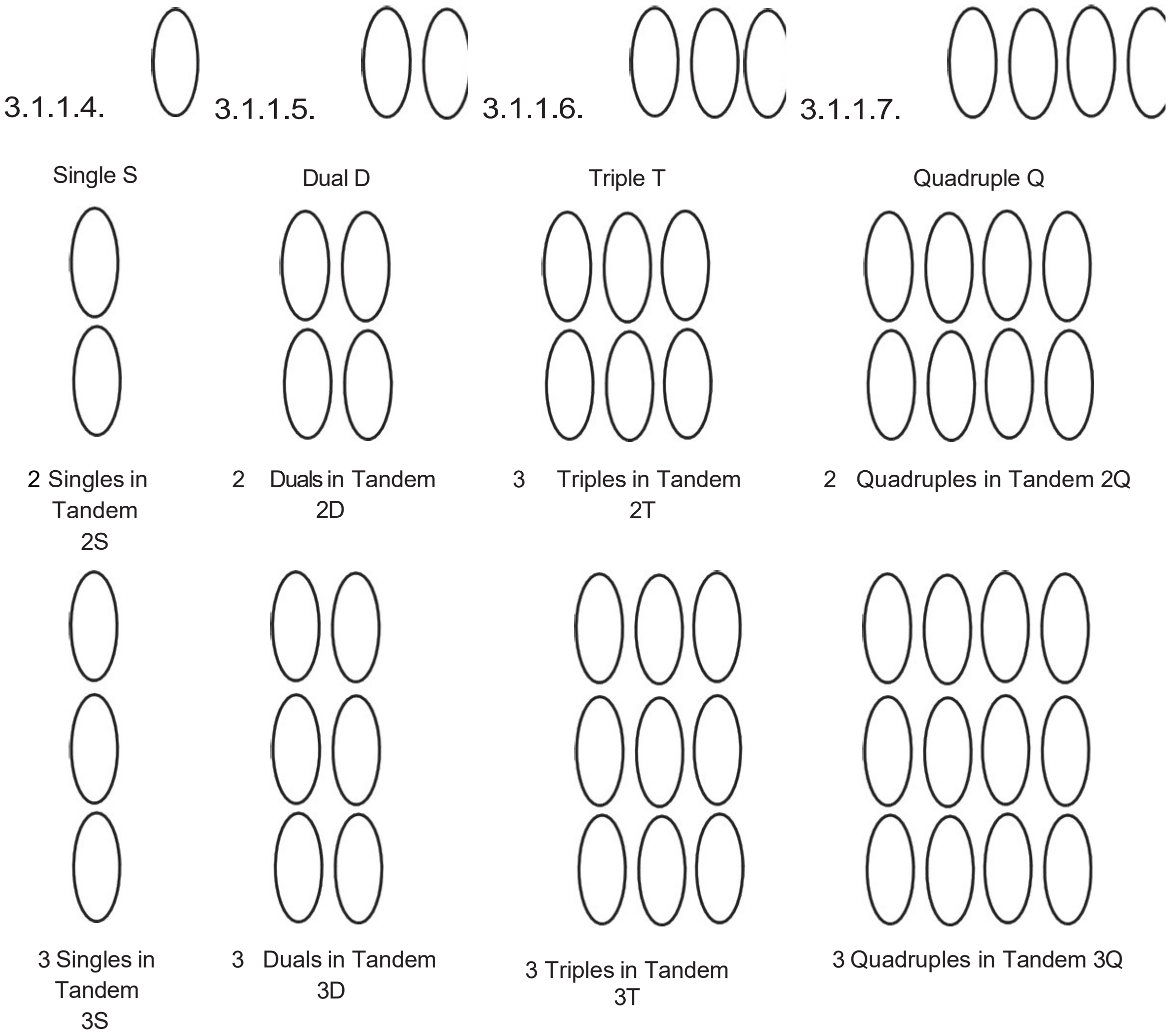


Figure A1-4. **Generic gear configurations (increase numeric value for additional tandem axles)**

2.2.4 **Main gear portion of gear designation**. The first portion of the aircraft gear name comprises the main gear designation. This portion may consist of up to three characters.

(a) **First character** indicates the number of tandem sets or wheels in tandem (e.g. "3D" represents three dual gears in tandem). If a tandem configuration is not present, the leading value of "1" is omitted. Typical codes are: "S" representing single; "2D" representing two dual wheels in tandem; "5D" representing five dual wheels in tandem; and "2T" representing two triple wheels in tandem.

(b) **Second character** of the gear designation indicates the gear code (S, D, T or Q).

(c) **Third character** of the gear designation is a numeric value that indicates multiples of gears. For the main gear, the gear designation assumes that the gear is present on both sides (symmetrical) of the aircraft and that the reported value indicates the number of gears on one side of the aircraft. A value of 1 is used for aircraft with one gear on each side of the aeroplane. For simplicity, a value of 1 is assumed and is omitted from the main gear designation. Aircraft with more than one main gear on each side of the aircraft and where the gears are in line will use a value indicating the number of gears in line.

2.2.5 **Body/belly gear portion of gear designation**. The second portion of the aircraft gear name is used when body/belly gears are present. If body/belly gears are present, the main gear designation is followed by a forward slash (/), followed by the body/belly gear designation. For example, the B-747 aircraft has a two dual wheels in tandem main gear and two dual wheels in tandem body/belly gears. The full gear designation for this aircraft is 2D/2D2. The body/belly gear designation is similar to the main gear designation, except that the trailing numeric value after the gear type (S, D, T or Q) denotes the total number of body/belly gears present (e.g. 2D1 = one dual tandem body/belly gear; 2D2 = two dual tandem body/belly gears). Because body/belly gear arrangements may not be symmetrical, the gear code must identify the total number of gears present and a value of 1 is not omitted if only one gear exists.

2.2.6 **Unique gear configurations**. The Lockheed C-5 Galaxy has a unique gear type and is difficult to name using the proposed method. This aircraft will not be classified using the new naming convention and will continue to be referred to directly as the C5. Gear configurations such as those on the Boeing C-17, Antonov AN-124, and Ilyshin IL-76 might also cause some confusion. In these cases, it is important to observe the number of landing struts and the proximity of the struts. In the case of the AN-124, it is more advantageous to address the multiple landing struts as one gear (i.e. 5D or five duals in tandem) rather than use D5 or dual wheel gears with five sets per side of the aircraft. Due to wheel proximity, the C-17 gear is more appropriately called a 2T, as it appears to have triple wheels in tandem. In contrast, the IL-76 has considerable spacing between the struts and should be designated as a Q2.

2.2.7 **Examples of gear geometry naming convention**. Figure A1-4 provides examples of generic gear types in individual and multiple tandem configurations.

Table A1-1. Aircraft characteristics for design and evaluation of pavements

Note 1.— This table has been prepared in metric units. To convert from kilogram to newton, multiply by 9.80665.

Note 2.— Figures refer to the aircraft at its maximum take-off weight. For lesser operational weights, figures quoted for “load on each leg”, “tire-pressure” and/or “contact area” should be decreased proportionally.

				MAIN LEGS OF LANDING GEAR					
						Wheel spacing (cm)			
Aircraft type	*All-up mass (kg)*	*Load on one main gear leg (%)*	*Wheel arrangement*	*Load on each leg (kg)*	*Tire pressure (MPa)*	*(S)*	*(S_T)*	*(S_D)*	*Additional data for complex wheel arrangement*
A300 B2	142 900	47.0	2D	67 118	1.28	89	140	165.6	
A300 B4	165 900	47.0	2D	77 921	1.46	93	140	167.7	
A300-600 B4	165 900	47.1	2D	78 216	1.28	93	140	167.7	
A300-600R B4	172 600	47.5	2D	81 988	1.34	93	140	167.7	
A300-600R B4F	172 600	47.5	2D	81 988	1.34	93	140	167.7	
A300-600R F4	171 400	47.5	2D	81 418	1.34	93	140	167.7	
A310-200	144 900	46.6	2D	66 243	1.33	93	140	167.7	
A310-200F	142 900	46.6	2D	66 662	1.33	93	140	167.7	
A310-300	164 900	47.2	2D	77 873	1.29	93	140	167.7	
A310-300F	164 900	47.2	2D	77 873	1.29	93	140	167.7	
A318-100	68 400	44.5	D	30 431	1.24	93			
A319-100	75 900	45.8	D	34 746	1.38	93			
A319 CJ	76 900	45.8	D	35 181	1.38	93			
A319neo	75 900	45.8	D	34 746	1.38	93			
A320-100	68 400	47.1	D	32 215	1.28	93			
A320-200	78 400	46.4	D	36 405	1.44	93			
A320neo	79 400	46.3	D	36,757	1.44	93			
A320-200 (2D)	73 900	47.0	2D	34,969	1.22	78	101	127.5	
A321-100	89 400	47.5	D	42,432	1.46	93			
A321-200	93 900	47.6	D	44,717	1.50	93			
A321neo	93 900	47.6	D	44,717	1.50	93			
A330-200	242 900	46.3	2D	112,515	1.47	140	198	242.4	
A330-200F	233 900	47.3	2D	110,674	1.42	140	198	242.4	

				MAIN LEGS OF LANDING GEAR					
						Wheel spacing (cm)			
Aircraft type	*All-up mass (kg)*	*Load on one main gear leg (%)*	*Wheel arrangement*	*Load on each leg (kg)*	*Tire pressure (MPa)*	*(S)*	*(S_T)*	*(S_D)*	*Additional data for complex wheel arrangement*
A330-800neo	242 900	46.3	2D	112,515	1.47	140	198	242.4	
A330-300	242 900	46.9	2D	113 896	1.49	140	198	242.4	
A330-900neo	242 900	46.9	2D	113 896	1.49	140	198	242.4	
A340-200	275 900	39.2	2D/D1	108 219	1.49	140	198	242.4	
A340-300	277 400	39.4	2D/D1	109 190	1.49	140	198	242.4	
A340-500	375 200	31.9	2D/2D1	119 675	1.61	140	198	242.4	
A340-500 HGW	381 200	31.6	2D/2D1	120 592	1.61	140	198	242.4	
A340-600	369 200	32.2	2D/2D1	118 930	1.61	140	198	242.4	
A340-600 HGW	381 200	31.7	2D/2D1	121 016	1.61	140	198	242.4	
A350-900	275 900	46.9	2D	129 326	1.68	173.5	204	267.8	
A350-1000	308 900	47.1	3D	145 427	15.2	140 F 147 C 140 R	140	313.0	
A380-800 (Wing gear)	577 000	18.9	2D	108 847	1.50	135	170	217.1	Full aircraft wheel arrangement 3D/2D2
A380-800 (Body gear)	577 000	28.3	3D	163 271	1.50	153 F 155 C 153 R	170	372.8	Full aircraft wheel arrangement 3D/2D2
A400M	141 400	46.9	3D	66 368	0.95	86	157 F 156 R	325.0	
An-12	64 000	46.3	2D	29 651	0.83	123	49.2	132.5	
An-22	227 500	43.6	3D	99 076	0.49	115	250	275.2	
An-24	21 000	46.6	D	9 786	0.49	50			
An-72-100	35 150	47.2	2S	16 591	0.59		126		
An-74TK-300	37 850	46.5	2S	17 600	0.69		126		
An-124-100M-150	408 000	45.8	5D	186 864	1.18	101	171	198.6	
An-148-100E	43 850	43.8	D	19 184	1.13	58			
An-158	43 850	44.3	D	19 404	1.13	58			
An-225	650 000	46.1	7D	299 650	1.23	101	171	198.6	
B707-320C	152 407	46.7	2D	71 174	1.24	88	142	167.1	
B720B	106 594	46.4	2D	49 460	1.00	81	124	148.1	

				MAIN LEGS OF LANDING GEAR					
						Wheel spacing (cm)			
Aircraft type	*All-up mass (kg)*	*Load on one main gear leg (%)*	*Wheel arrangement*	*Load on each leg (kg)*	*Tire pressure (MPa)*	*(S)*	*(S_T)*	*(S_D)*	*Additional data for complex wheel arrangement*
B727-100	77 110	47.6	D	36 704	1.14	86			
B727-200 (Standard)	78 471	48.5	D	38 058	1.14	86			
B727-200 (Advanced)	95 254	46.5	D	44 293	1.19	86			
B737-100	50 349	45.9	D	23 110	1.08	77			
B737-200/200C	58 332	46.0	D	26 833	1.25	77			
B737-300	63 503	45.4	D	28 830	1.39	77			
B737-400	68 266	46.9	D	32 016	1.28	77			
B737-500	61 915	46.1	D	28 540	1.36	77			
B737-600	66 224	45.3	D	30 000	1.25	86			
B737-700	77 791	45.8	D	35 628	1.35	86			
B737-800	79 333	46.6	D	37 001	1.41	86			
B737-900	79 243	46.7	D	37 006	1.41	86			
B737-900ER	85 366	47.2	D	40 293	1.52	86			
B747-SP	318 875	21.9	2D/2D2	69 834	1.41	110	137	175.7	
B747-100/100B	341 555	23.1	2D/2D2	78 899	1.32	112	147	184.8	
B747-200B/300	379 204	22.7	2D/2D2	86 079	1.31	112	147	184.8	
B747-400/400ER	414 130	23.4	2D/2D2	96 906	1.57	112	147	184.8	
B747-8	449 056	23.7	2D/2D2	106 426	1.52	119	144	186.8	
B757-200	116 120	45.6	2D	52 951	1.26	86	114	142.8	
B757-300	124 058	46.4	2D	57 563	1.38	86	114	142.8	
B767-200/200ER	179 623	45.4	2D	81 549	1.31	114	142	182.1	
B767-300/300ER	187 334	46.2	2D	86 548	1.38	114	142	182.1	
B767-400ER	204 570	47.0	2D	96 148	1.47	116	137	179.5	
B777-200/200ER	298 464	45.9	3D	136 995	1.41	140	145	322.0	
B777-200LR	348 722	45.9	3D	160 063	1.50	140	145.3F 147R	324.0	
B777-300	300 278	47.4	3D	142 332	1.48	140	145	322.0	
B777-300ER	352 442	46.2	3D	162 828	1.52	140	145.3F 147R	324.0	

				MAIN LEGS OF LANDING GEAR					
						Wheel spacing (cm)			
Aircraft type	*All-up mass (kg)*	*Load on one main gear leg (%)*	*Wheel arrangement*	*Load on each leg (kg)*	*Tire pressure (MPa)*	*(S)*	*(S_t)*	*(S_D)*	*Additional data for complex wheel arrangement*
B787-8	228 383	45.6	2D	104 143	1.57	130	146	195.5	
B787-9	254 692	46.2	2D	117 772	1.56	152	151	214	
BAe146 Series 200	40 600	47.1	D	19 123	0.90	71			
CRJ-700	34 132	47.0	D	16 042	0.90	62			
CRJ-900/900 LR	38 555	46.3	D	17 851	1.15	62			
CRJ-1000	41 867	46.4	D	19 426	1.37	69			
Dash 8-400	29 347	47.0	D	13 793	1.57	50			
DC-9-32	49 442	46.2	D	22 842	1.07	64			
DC-9-51	55 338	47.0	D	26 009	1.19	66			
DC-10-10	207 745	46.7	2D	97 017	1.34	137	163	212.9	
DC-10-30	264 444	37.5	2D/D1	99 167	1.22	137	163	212.9	
E170	38 790	45.6	D	17 688	0.94	71			
E175	40 550	46.0	D	18 653	0.97	71			
E190	51 960	46.1	D	23 954	1.08	87			
E195	52 450	46.8	D	24 547	1.06	87			
Fokker 50	20 820	47.8	D	9 952	0.59	52			
Fokker 100	44 680	47.8	D	21 357	0.98	59			
IL-62M	168 000	47	2D	78 960	1.08	80	165	183.4	
IL-76TD-90BD	196 000	46.7	2Q	91 532	0.69	S1=82			
						S2=206			Quadruple wheels in each of two struts per each side. S1/S2 — distances between centres of contact areas of inner/outer wheels accordingly per each strut.
IL-96-400T	271 000	31.7	2D/2D1	85 907	1.23	110	140	178	Two dual wheels in tandem main gear/two dual wheels in tandem

				MAIN LEGS OF LANDING GEAR					
						Wheel spacing (cm)			
Aircraft type	*All-up mass (kg)*	*Load on one main gear leg (%)*	*Wheel arrangement*	*Load on each leg (kg)*	*Tire pressure (MPa)*	*(S)*	(S_t)	(S_D)	*Additional data for complex wheel arrangement*
									body gear.
L-100-30	70 670	48.4	2S	17 102	0.72		154		
L-1011-500	225 889	46.2	2D	104 361	1.27	132	178	221.6	
MD-11ER	287 124	38.8	2D/D1	111 404	1.42	137	163	212.9	
MD-83	73 028	47.4	D	34 615	1.34	71			
MD-87	63 956	47.4	D	30 315	1.17	71			
MD-90-30	76 430	47.0	D	35 922	1.33	71			
Tu-134A	49 000	47.1	2D	23 079	0.88	56	99	113.7	
Tu-154M	100 000	42.4	3D	42 400	0.98	62	F103 R98	210.3	
Tu -204CE	107 500	46.3	2D	49 719	1.37	80	127	150.1	
Tu -204-100C	110 750	46.3	2D	51 277	1.37	80	127	150.1	
Tu -214	110 750	46.3	2D	51 277	1.37	80	127	150.1	
Yak-42	57 500	47.0	2D	27 025	0.88	62.2	98	116	