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ORGANISMO ESPECIALIZADO DE LA ONU

Workshop on the Notification Method and Publication of the New Aircraft Classification Rating Method - Pavement Classification Rating (ACR-PCR)

ADRIANA RODRIGUEZ TORRES
STRINSO

Content

1. Introduction to ACR/PCR
2. Description of the methodology
3. Design traffic
4. Technical evaluation
5. Operation of FAARFIELD software for ACR/PCR calculation.
6. Case studies

INTRODUCTION TO ACR/PCR

ACR/PCR REGULATIONS

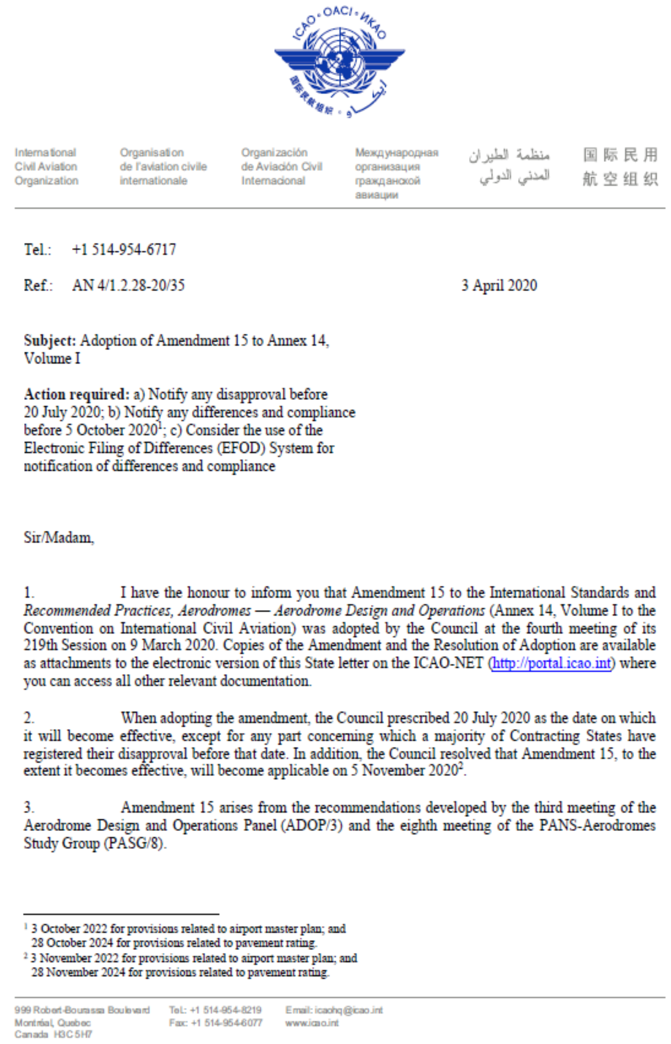
- The ICAO Council approved Amendment 15 to Annex 14 vol. 1 in 2020.
- Established a <u>four-year transition period</u> from ACN/PCN ACR/PCR:

✓Effective July 20, 2020

✓Full applicability November 2024

✓During the transition, both systems remained available.

- FAA published AC 150/5335-5 in April 2022.
- FAARFIELD 2.1.1 calculates PCR
- COMFAA will no longer be updated.



International Civil Aviation Organization | Organisation de l'aviation civile internationale | Organización de Aviación Civil Internacional | Международная организация гражданской авиации | منظمة الطيران المدني الدولي | 国际民用航空组织

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Ref.: AN 4/1.2.28-20/35 3 April 2020

Subject: Adoption of Amendment 15 to Annex 14, Volume I

Action required: a) Notify any disapproval before 20 July 2020; b) Notify any differences and compliance before 5 October 2020[1]; c) Consider the use of the Electronic Filing of Differences (EFOD) System for notification of differences and compliance

Sir/Madam,

1. I have the honour to inform you that Amendment 15 to the International Standards and *Recommended Practices, Aerodromes — Aerodrome Design and Operations* (Annex 14, Volume I to the Convention on International Civil Aviation) was adopted by the Council at the fourth meeting of its 219th Session on 9 March 2020. Copies of the Amendment and the Resolution of Adoption are available as attachments to the electronic version of this State letter on the ICAO-NET (http://portal.icao.int) where you can access all other relevant documentation.

2. When adopting the amendment, the Council prescribed 20 July 2020 as the date on which it will become effective, except for any part concerning which a majority of Contracting States have registered their disapproval before that date. In addition, the Council resolved that Amendment 15, to the extent it becomes effective, will become applicable on 5 November 2020[2].

3. Amendment 15 arises from the recommendations developed by the third meeting of the Aerodrome Design and Operations Panel (ADOP/3) and the eighth meeting of the PANS-Aerodromes Study Group (PASG/8).

[1] 3 October 2022 for provisions related to airport master plan; and 28 October 2024 for provisions related to pavement rating.
[2] 3 November 2022 for provisions related to airport master plan; and 28 November 2024 for provisions related to pavement rating.

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Main Regulations

- FAA Advisory Circular: AC 150/5320-6G - Airport Pavement Design and Evaluation
- FAA Advisory Circular: AC 150/5335-5D - Standardized Method of Reporting Pavement Strength - PCR

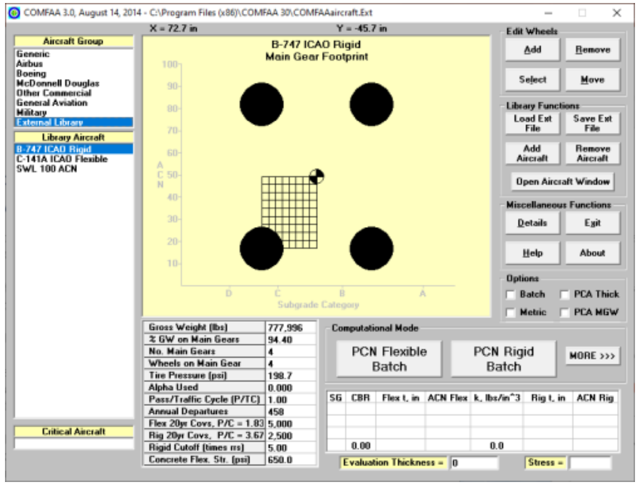
Subject: Standardized Method of Reporting Airport Pavement Strength - PCR	**Date:** 4/29/2022 **Initiated By:** AAS-110	**AC No:** 150/5335-5D **Change:**

Additional documents and regulations

- International Civil Aviation Organization (ICAO) - Aerodrome Design Manual - Annex 14
- ICAO - Aerodrome Design Manual - Part 2 - Taxiways, Aprons and Holding Bays
- ICAO - Aerodrome Design Manual - Part 3 - Pavements
- FAA - Advisory Circular AC 150/5380-6C Guidelines and Procedures for Maintenance of Airport Pavements
- FAA - Advisory Circular AC 150/5370-10H Standards for Specifying Airports Construction
- FAA - Advisory Circular AC 150/5370-11B Use of Nondestructive Testing in the Evaluation of Airport Pavements

BACKGROUND: LEGACY ACN/PCN SYSTEM

- Standardized airport pavement rating system promulgated by ICAO in 1981 for all pavements serving aircraft **MTOW > 5700 kg.**
- It is NOT a pavement design method.
- It is based on the simple comparison of two numbers:
  - The **Aircraft Classification Number (ACN),** a number that expresses the relative effect of an aircraft on a pavement for a specific standard subgrade strength.
  - The **Pavement Classification Number (PCN)** is a number that expresses the bearing strength of a pavement for unrestricted operations.
  - If **ACN ≤ PCN**, the aircraft can operate on pavement without restrictions.
  - If **ACN > PCN**, the aircraft may not operate, or may be allowed to operate subject to weight and/or frequency limitations.



COMFAA 3.0, FAA software for computing PCN

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ACN/PCN LIMITATIONS

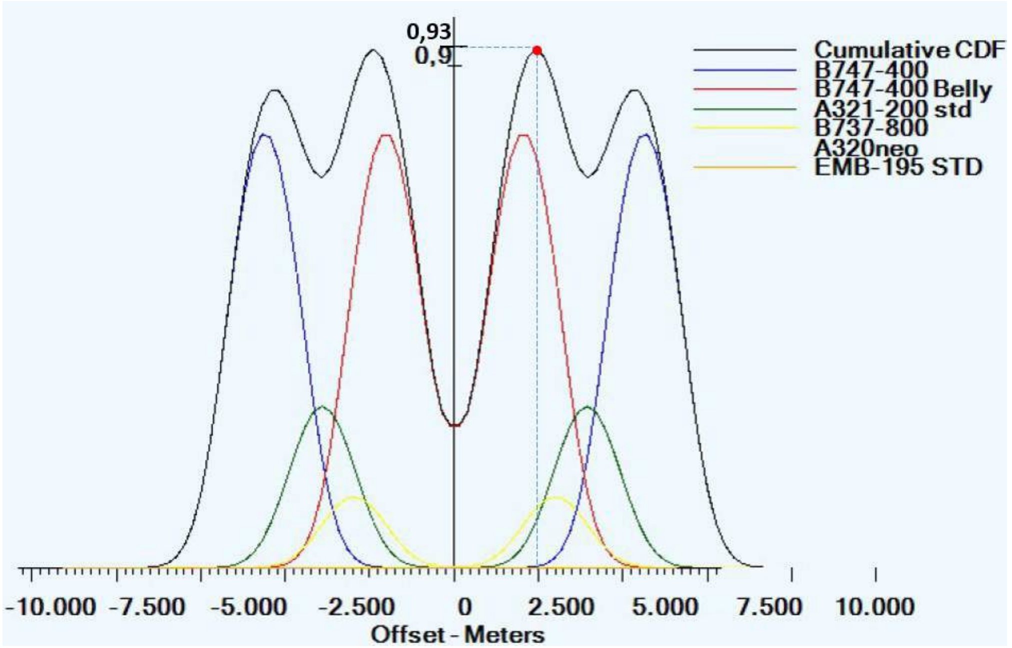
- The ACN PCN method is based on simplified methods originally developed in the late 1930s and 1940s:
  - **Flexible pavements:** CBR design procedure based on Boussinesq theory
  - **Rigid pavements**: PCA design procedure based on Westergaard's theory
- These methods have well-known shortcomings:
  - Unable to accurately consider "complex" undercarriage configurations
  - Cannot account for the improved characteristics of new materials
  - Variability of the transverse positions of the landing gear (different overall wheel tracks) cannot be taken into account
- Over the years, some changes have been made to ACN's PCN method to (partially) compensate for some of these shortcomings.
- Empirical methods have been replaced by empirical mechanistic methods for pavement design. LEA (Layered Elastic Analysis) and FEM.

ACN/PCN vs ACR/PCR COMPARATIVE

KEY CHANGES

- What **does NOT** change is the comparison of ACR and PCR as the central principle of the method:
  - If **ACR ≤ PCR**, the aircraft can operate on pavement without restrictions.
  - If **ACR > PCR**, the operation is not allowed or some restrictions (on operating weight and/or frequency) may apply.

- What **DOES** change are the procedures for determining ACR and PCR:
  - ✓ Based on the calculation of pavement responses (stresses, strains, deflections) of the Layered Elastic Analysis (LEA).
  - ✓ Pavement damage is then quantified from these responses based on a specific damage model.



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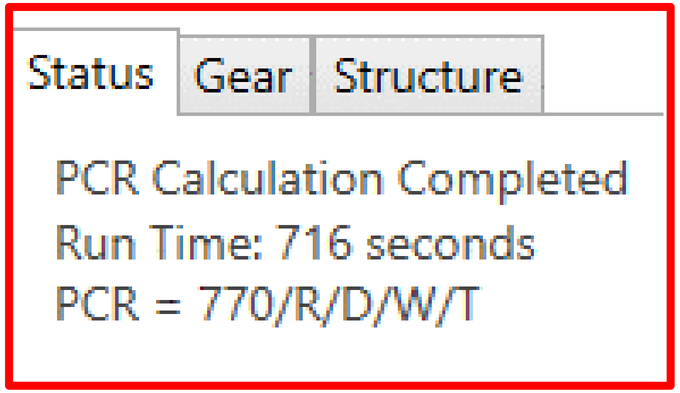
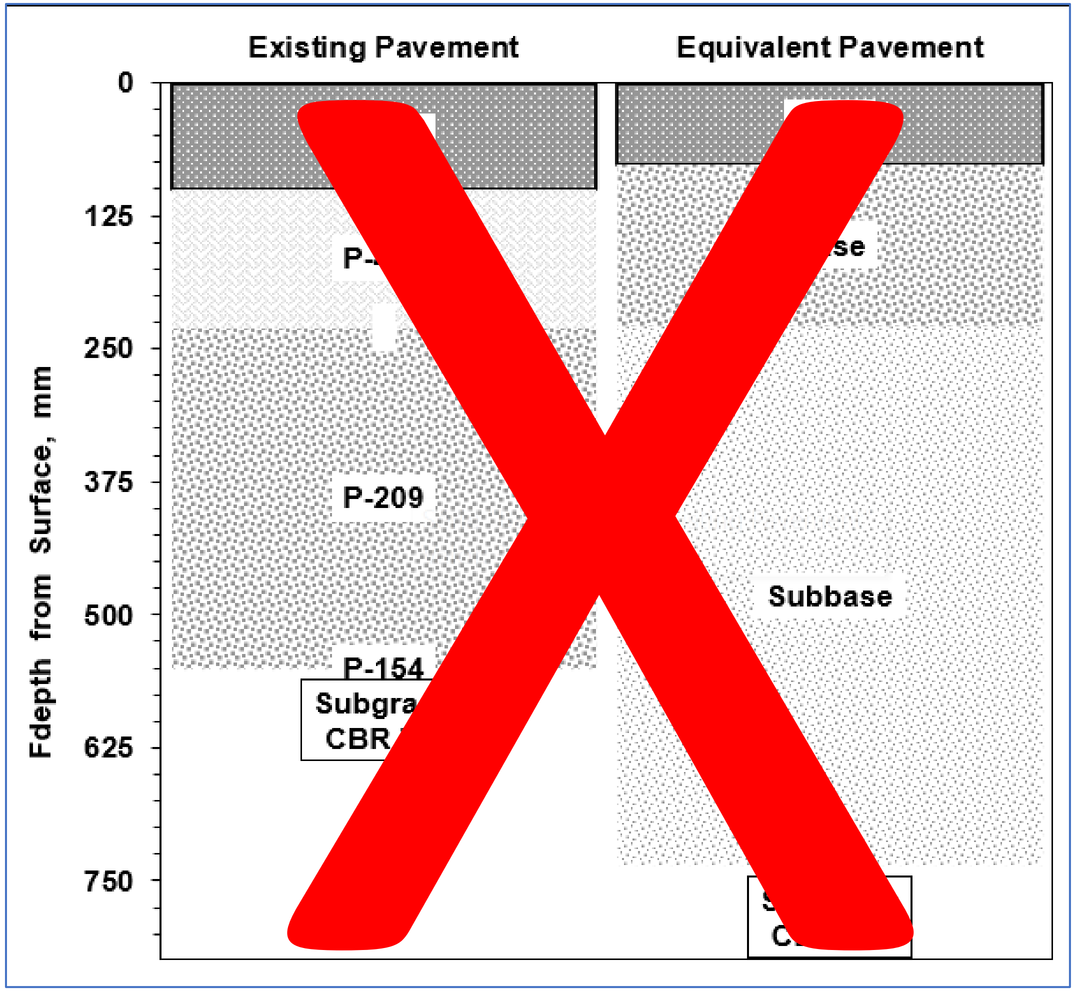
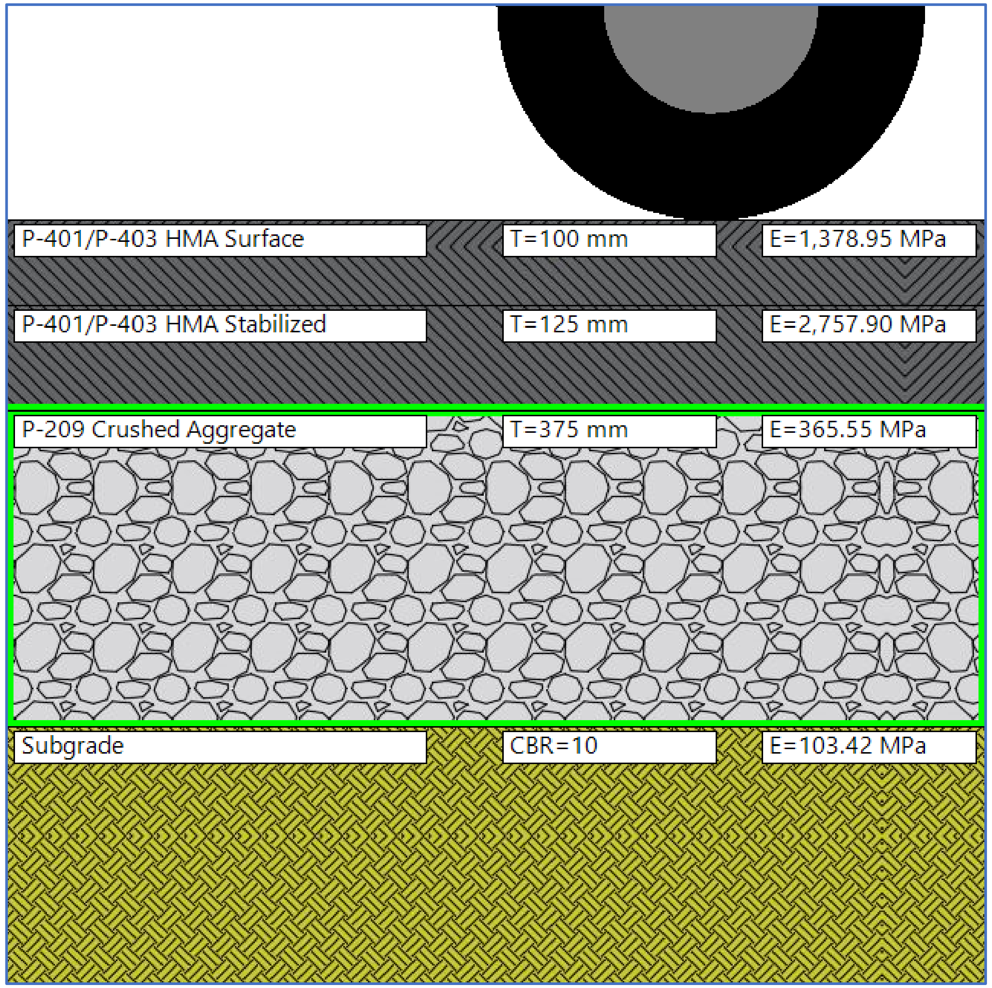
ACR/PCR Versus ACN/PCN

- The numerical ACR values are higher than the corresponding ACN values by about an order of magnitude (x10).
  - This was intentional to avoid confusing the two systems during the transition period.
  - It is not possible to convert PCN to PCR directly.
  - You must use the procedure integrated in FAARFIELD 2.0.
  - Uses uniform standard subgrade categories for flexible and rigid pavements.
  - NO alpha factor, layer equivalence factors, top of base k, etc.



ACR/PCR Vs. ACN/PCN





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Major changes

The reporting format will not change, except for the designation of PCR instead of PCN.

If **ACR ≤ PCR**, the aircraft can operate on pavement without restrictions.

If **ACR > PCR**, the operation is not allowed or some restrictions (on operating weight and/or frequency) may apply.

Based on the calculation of pavement responses (stresses, strains, deflections) of the Layered Elastic Analysis (LEA).

Pavement damage is then quantified from these responses based on a specific damage model.

If continued, the four foundation soil strength categories will continue to be designated by the same letters.

ACR/PCR METHODOLOGY

What is ACR/PCR?

- ***ACR*** is the number that expresses the relative effect of an aircraft of a given weight on a pavement structure at a specified standard subgrade strength.
- ***PCR*** is the number that expresses the pavement's capacity to support traffic loads under unrestricted aircraft operating conditions.

REQUIREMENTS

- ✓ Aircraft manufacturers must publish correctly calculated ACR values for all their aircraft. They must use the procedures defined by ICAO.
- ✓ Airport operators are responsible for determining and publishing PCR values for their pavements.
- ✓ ICAO does not specify a specific PCR method, which gives flexibility to state CAAs.
- ✓ ICAO provides a model procedure for the determination of PCR in the ADM. This model procedure is general enough to be adapted to most national or local practices.
- ✓ The FAA has adopted the PCR procedure in AC 150/5335-5D.

PRINCIPLES OF METHODOLOGY

- LEA (Layered Elastic Analysis)

✓ Homogeneous, elastic and isotropic layers

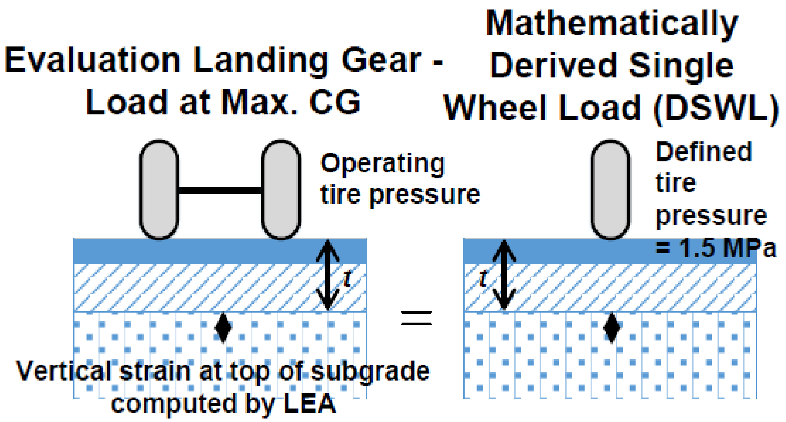
✓ Each layer i is characterized by an elastic modulus Ei, a Poisson's ratio μi and a uniform layer thickness ti.

✓ Infinite horizontal and vertical extension (at the level of the elastic half-space subgrade) is assumed.

✓ The individual wheel loads can be summed to obtain the combined stress and strain responses for a complex loading of a multi-wheeled aircraft landing gear.

✓ Standard tire pressure: 1.5 MPa

✓ Standard coverages increased to 36,500 for the flexible ACR



PRINCIPLES OF METHODOLOGY

- The maximum ACR of an aircraft is calculated from the mass and center of gravity (CG) that produces the highest main gear load on the pavement, usually the maximum ramp mass and the corresponding rear CG.
- Aircraft tires are considered inflated to the manufacturer's recommendation for the condition.
- The relative tables and graphs of aircraft ACR show ACR as a function of aircraft gross mass, with aircraft CG as a constant value corresponding to the maximum value of ACR (i.e., generally, rear CG for maximum ramp mass) and tire pressure at maximum ramp mass.
- Specific ACR values for specific conditions are those that adjust for the effects of tire pressure or CG location, at a specific gross mass for the aircraft.

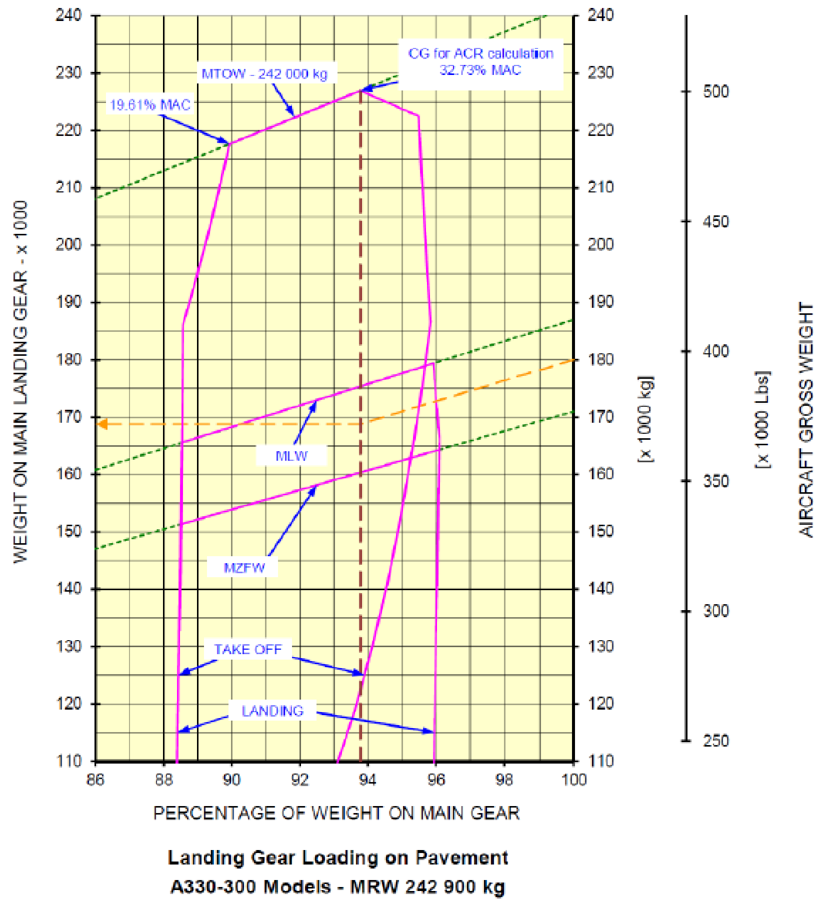
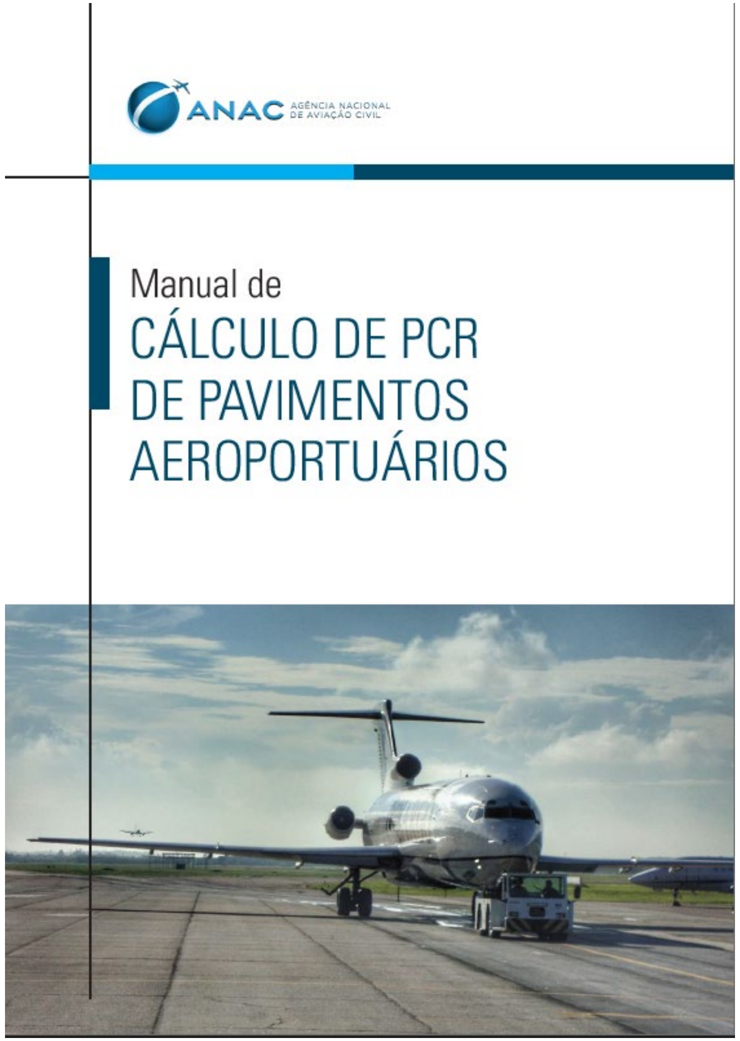
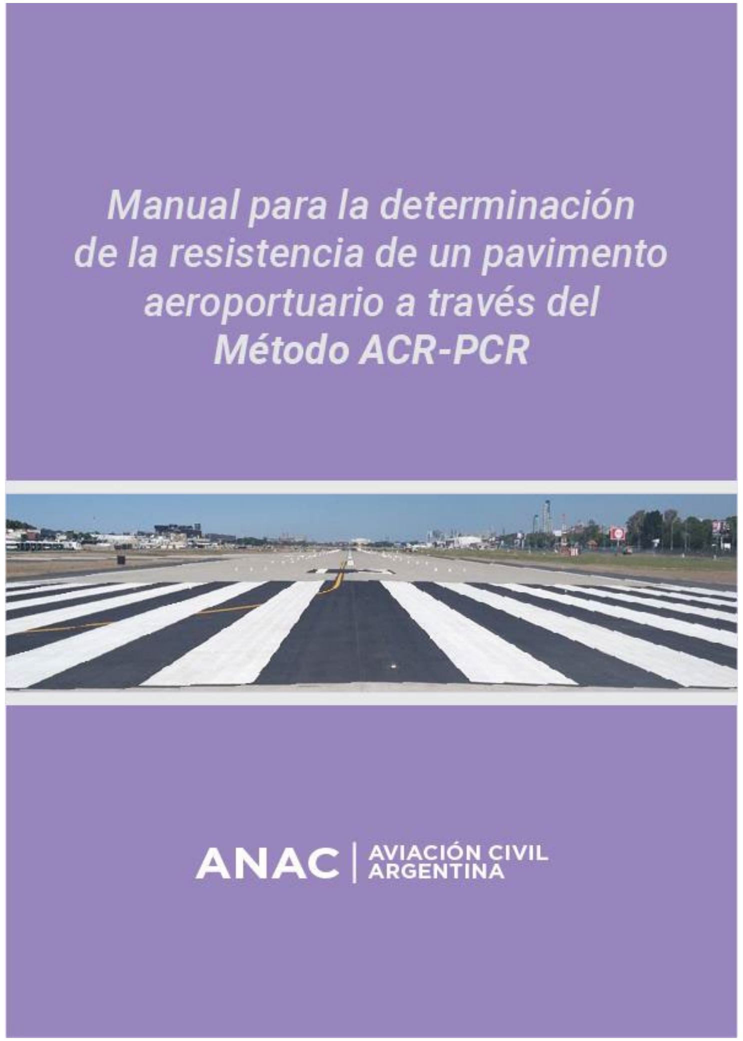


Figure 1-3. Landing gear loading on pavement - Airbus A330-300

PCR CALCULATION MANUAL - FAA CIRCULAR





U.S. Department of Transportation
Federal Aviation Administration

Advisory Circular

Subject: Standardized Method of Reporting Airport Pavement Strength - PCR	**Date:** 4/29/2022 **Initiated By:** AAS-110	**AC No:** 150/5335-5D **Change:**

1 **Purpose.**

This advisory circular (AC) provides guidance for the reporting of runway, taxiway and apron pavement strength in accordance with standardized International Civil Aviation Organization (ICAO) methods.

2 **Cancellation.**

This AC cancels AC 150/5335-5C, *Standardized Method of Reporting Airport Pavement Strength – PCN,* dated August 14, 2014.

3 **Applicability.**

This AC does not constitute a regulation, and is not legally binding in its own right. It will not be relied upon as a separate basis by the FAA for affirmative enforcement action or other administrative penalty. Conformity with this AC is voluntary, and nonconformity will not affect rights and obligations under existing statutes and regulations, except for the projects described in subparagraphs 2 and 3 below:

1. The standards and processes contained in this AC are specifications the FAA considers essential for the reporting of pavement strength.
2. Use of these standards and guidelines is mandatory for projects funded under Federal grant assistance programs, including the Airport Improvement Program (AIP). See Grant Assurances #11 and #34.
3. This AC is mandatory, as required by regulation, for projects funded by the Passenger Facility Charge program. See PFC Assurance #9.

Note: This AC provides one, but not the only, acceptable means of meeting the requirements of 14 CFR Part 139, *Certification of Airports*.

4 **Effective Date.**

1. The FAA recommends the guidelines and specifications in this AC for reporting airport pavement strength using the standardized Aircraft Classification Rating-

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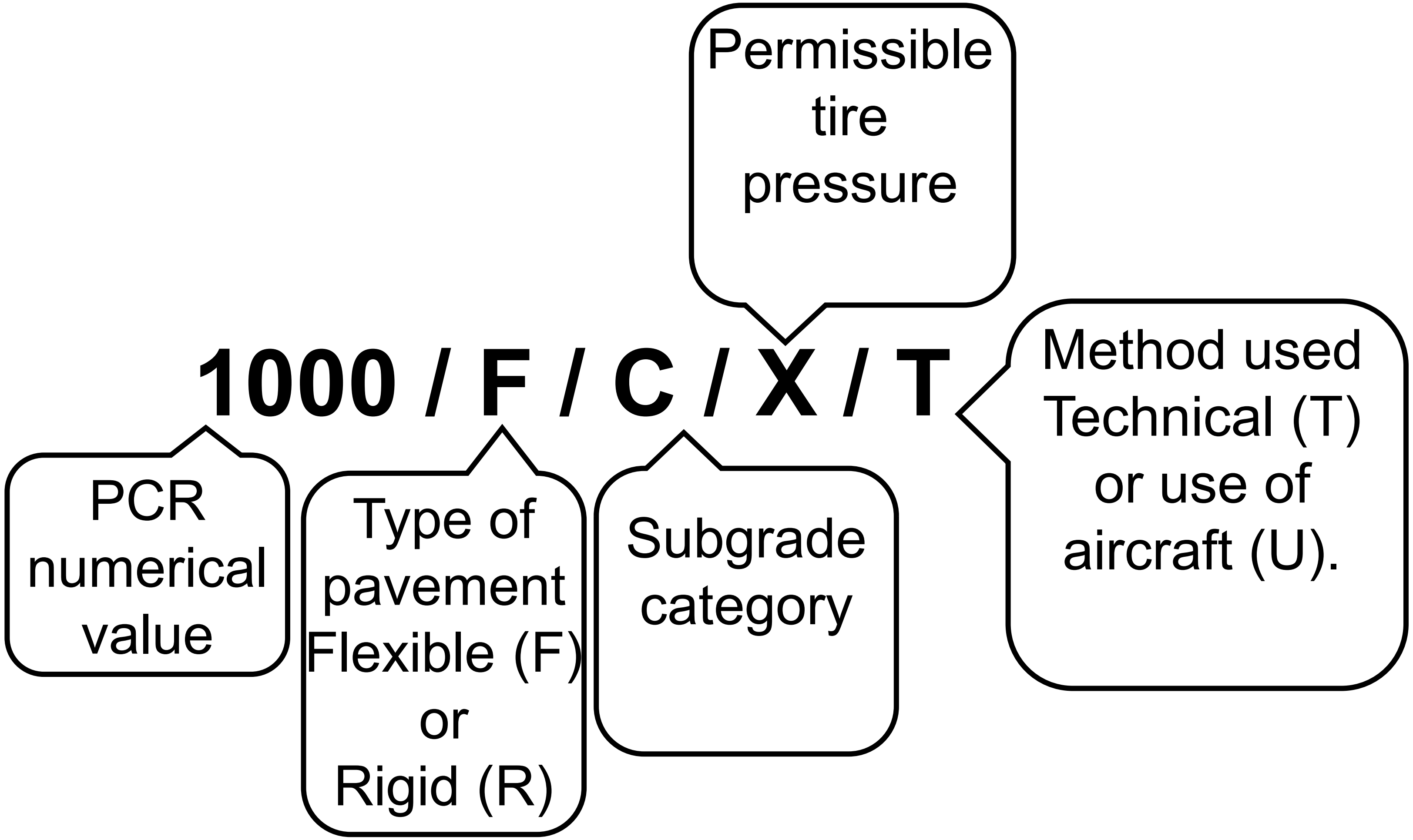
Code for PCR


Permissible tire pressure
1000 / F / C / X / T
Method used Technical (T) or use of aircraft (U).
PCR numerical value
Type of pavement Flexible (F) or Rigid (R)
Subgrade category

ACR/PCR Development

1. Type of pavement

Type of pavement	Pavement Code
Pav	F
Rigid	R

Table 2-1. Standard Subgrade Conditions for ACR Calculation

Subgrade Strength Category	Subgrade Support E (Elastic Modulus) psi (MPa)	Represents E (Elastic Modulus) psi (MPa)	Code Designation
High	29008 (200)	E ≥ 21,756 (≥150)	A
Medium	17405 (120)	E ≥14,504 <21,756 (≥100 <150)	B
Low	11603 (80)	E≥8,702 <14,504 (≥60 <100)	C
Ultra Low	7252 (50)	E < 8,702 (< 60)	D

2. Subgrade strength category

Strength category of the subgrade	Subgrade support E (Modulus of elasticity) psi (MPa)	E Representation psi (MPa)	Designated code
High	29008 (200)	E ≥ 21,756 (≥ 150)	A
Medium	17405 (120)	21,756 > E ≥ 14,504 (150 > E ≥100)	B
Low	11603 (80)	14,504 > E ≥ 8,702 (100 > E ≥ 60)	C
Very Low	7252 (50)	E < 8,702 (E< 60)	D

- Categories are defined by E, not by CBR or modulus of reaction k.
- Same categories for rigid and flexible pavements.
- All values are defined at the top of the subgrade.

Source: AC 150/5335-5D

ACR/PCR Development

3. Allowed tire pressure

Category	Code	Tire pressure range
Unlimited	W	No pressure limit
High	X	Pressure limited to 254 psi (1.75 MPa)
Medium	Y	Pressure limited to 181 psi (1.25 MPa)
Low	Z	Pressure limited to 73 psi (0.50 MPa)

Table 4-2. Tire Pressure Codes for Reporting PCR

Category	Code	Tire Pressure Range
Unlimited	W	No pressure limit
High	X	Pressure limited to 254 psi (1.75 MPa)
Medium	Y	Pressure limited to 181 psi (1.25 MPa)
Low	Z	Pressure limited to 73 psi (0.50 MPa)

✓ NO CHANGES to ACN/PCN methodology

4. Method used to determine the PCR

The PCR system recognizes two methods of pavement evaluation. If the evaluation represents the results of a technical study, the evaluation method should be coded with the letter "*T*". If the evaluation is based on aircraft operating experience, the evaluation method should be coded as "*U*".

5. Technical Evaluation Method

The technical evaluation method for determining a PCR requires pavement thickness and cross-sectional properties, as well as traffic mix details. FAARFIELD is used, which is a general purpose program that can be used in two ways: ACR calculation mode and thickness calculation mode.

Source: AC 150/5335-5D

PCR TERMINOLOGY

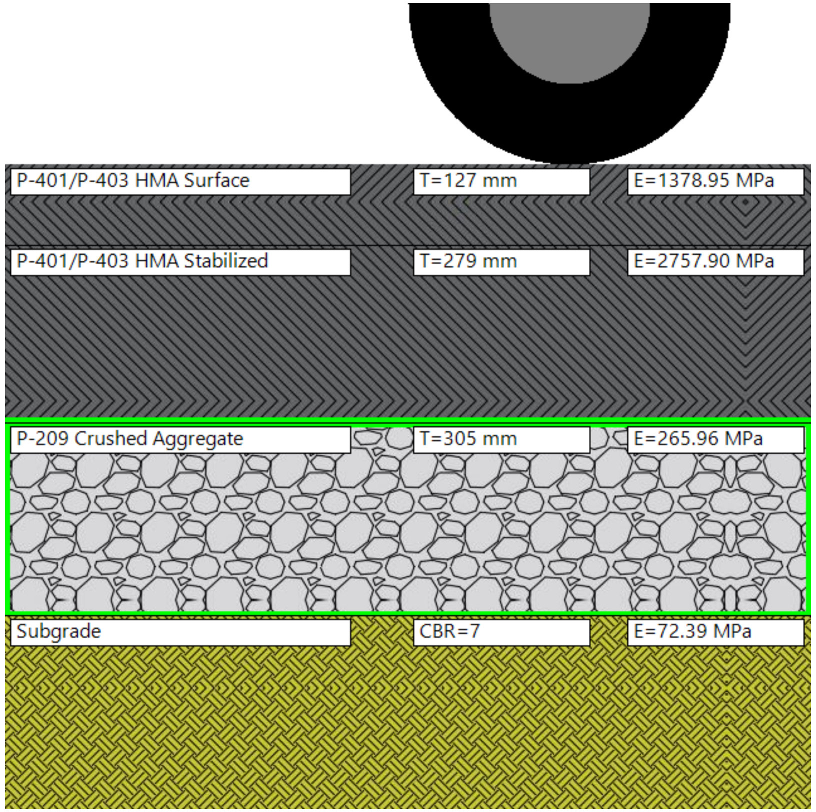
- **Critical aircraft:** Aircraft that are considered representative of the entire traffic mix in the PCR calculation. It is not necessarily the aircraft with the highest ACR.
- **Total critical aircraft equivalent departures** = number of departures of the critical aircraft with the operating weight that results in the same CDF as the entire traffic mix.
- **Maximum allowable gross weight (MAGW)** = gross weight of critical aircraft resulting in CDF = 1 for the evaluation structure (in total equivalent departures).
- **PCR = ACR** of critical aircraft calculated in MAGW

FOR ELEVATED PCR VALUES, THE CIRCULAR RECOMMENDS REPORTING THE VALUE OF THE CRITICAL ACR +25%:

PCR = 1.25 * ACR

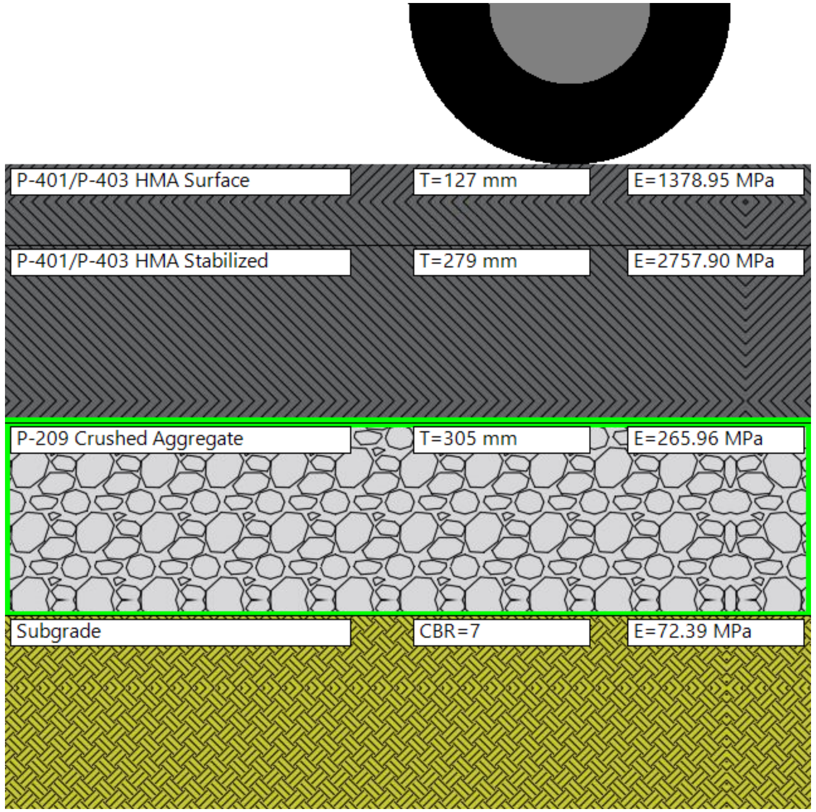
FLEX PAV

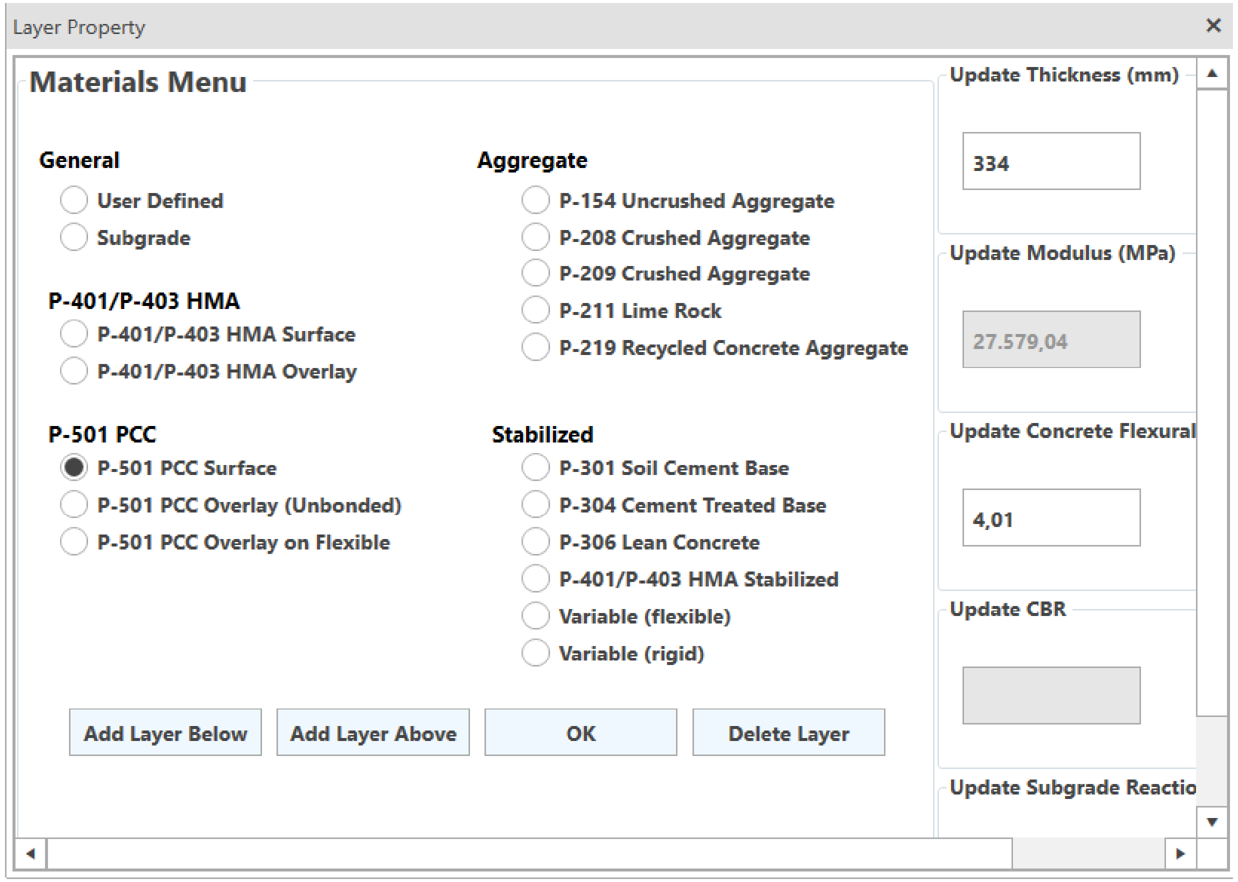
- It is not necessary to calculate the equivalent thickness.
- In PCR mode, FAARFIELD automatically switches to standard conditions and tire pressure for ACR evaluation.
- FAARFIELD automatically determines the subgrade category from the subgrade data.
- FAARFIELD automatically determines critical aircraft from the traffic list.



Airplane Name	Gross Taxi Weight (kg)	Annual Departures	Annual Growth (%)	Total Departures
B767-300	143789	365	0	7300
B757-200	116100	1360	0	27200
B737-900	85366	1360	0	27200
B737-800	79242	4380	0	87600
MD-83	73016	365	0	7300
B737-400	68266	365	0	7300
B737-300	63503	17885	0	357700
B737-500	60781	2920	0	58400
B717-200 HGW	55338	35310	0	706200
CRJ900	38329	6570	0	131400
CRJ700	34019	18615	0	372300
ERJ-145 ER	21999	32405	0	648100
S-10	3969	550	0	11000
S-3	1043	600	0	12000
D-30	13608	6525	0	130500
S-10	4536	15225	0	304500
D-50	22680	40400	0	808000

Definition of existing pavement structure





AC Construction Specification No.: 150/5370-10H

Subject: Standard Specifications for Construction of Airports

Date: 12/21/2018
Initiated By: AAS-100

AC No: 150/5370-10H
Change:

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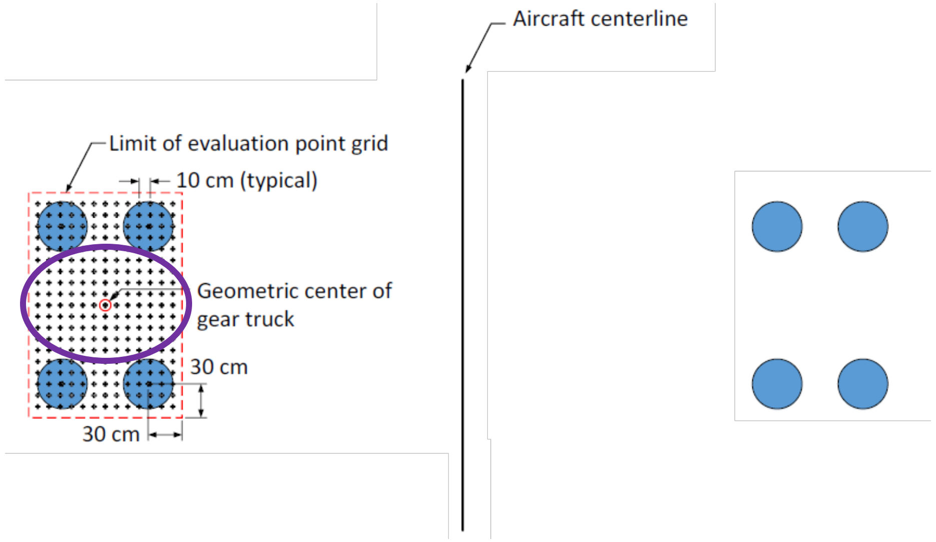
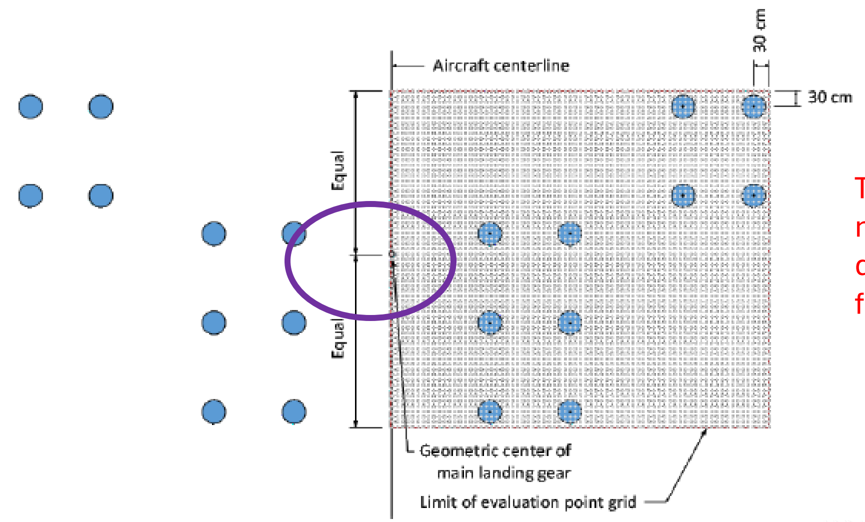
EVALUATION POINTS (GEAR)

- ALL main gear wheels contribute to calculated deformation.
- Tension is EVALUATED on the point grid.
- The evaluation points are located directly below the center point of each wheel and at points defined by a regular rectangular grid, spaced at 10 cm intervals and oriented parallel to the main axes of the gear.



The origin of the grid is established at the geometric center of an axis.

Figure 3-2. Grid Definition for Complex Aircraft Main Landing Gear



The origin of the grid is located at the geometric center of the entire landing gear assembly.

The deformation ε is the maximum of the deformations calculated for all evaluation points.

Key points: rigid pavement

- ✓ The minimum allowable thickness of the P501 PCC in the model is 127 mm.
- ✓ LEA calculations also assume that the horizontal interface between Layer 1 and Layer 2 is not bonded (total slip) and that the horizontal interface between Layer 2 and Layer 3 is bonded.
- ✓ The thickness t of Layer 1 is adjusted until the maximum evaluated stress at all evaluation points equals 399 psi (2.75 MPa). The resulting t is the reference thickness for the ACR.
- ✓ Maintaining a constant tire pressure of 218 psi (1.50 MPa), adjust the magnitude of the load per wheel until the maximum horizontal stress at the bottom of Ply 1 equals 399 psi (2.75 MPa).
- ✓ The numerical value of ACR may be rounded to the nearest multiple of ten for reporting purposes.
- ✓ Aircraft tire pressure will have little effect on pavements with concrete surfaces.

Table 3-2a. Reference Structure for Flexible ACR (Aircraft fitted with 2 or fewer wheels on all legs of the main landing gear)

Layer Description	Thickness, in (mm)	*E*, psi (MPa)	*ν*
Surface course (asphalt)	3 (76)	200,000 (1379)	0.35
Base course (crushed aggregate)	Variable	Paragraph 3.5.2.2	0.35
Subgrade	infinite	Paragraph 2.2 Table 2.1	0.35

Table 3-2b. Reference Structure for Flexible ACR (Aircraft fitted with more than 2 wheels on any leg of the main landing gear)

Layer Description	Thickness, in(mm)	*E*, psi (MPa)	*ν*
Surface course (asphalt)	5 (127)	200,000(1379)	0.35
Base course (crushed aggregate)	variable	Paragraph 3.5.2.2	0.35
Subgrade	infinite	Paragraph 2.2 Table 2.1	0.35

Key points: flexible pavement

- ✓ The ACR procedure for flexible pavement relates the load derived from a single wheel, at a constant pressure of 218 psi (1.50 MPa), to a total reference thickness t, calculated for 36,500 aircraft passes. Consider the four categories of subgrade.
- ✓ Definition of the materials and constitutive properties of the different layers: elastic modulus E, Poisson's coefficient v and thickness (except for the design layer).
- ✓ LEA calculations assume that all horizontal interfaces between layers are fully bonded.
- ✓ The modulus of the variable thickness layer is not fixed in the ACR procedure, but is a function of the thickness and modulus of the subgrade.

- ✓ The flexible ACR procedure is based on the subgrade failure criterion.

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

- ✓ Tire pressure may be restricted in asphalt concrete (asphalt), depending on the quality of the asphalt mix and weather conditions.
- ✓ A properly prepared and placed mixture meeting FAA specification P-401 can withstand substantial tire pressure in excess of 218 psi (1.5 MPa).

Technical evaluation method to determine PCR.

The following information is required to determine the PCR:

(1) the composition and frequency of air traffic,
(2) the thickness, type of material, and strength of each layer of the pavement structure; and
(3) the elastic modulus of the subgrade.

- Determine the type of aircraft and the number of annual departures of each aircraft type that the pavement will experience over its service life.
- Determine the elastic modulus of the subgrade. The modulus can be determined from test data or converted from the CBR value using $E = 1500 \times CBR$ (for E in psi).
- Determine the characteristics of the pavement layer.
- Determine the P/TC ratio
- Enter all information in FAARFIELD and run the PCR evaluation.

ICAO Guide for the evaluation of pavement overloads.

- ✓ On flexible or rigid pavements, occasional aircraft traffic with an ACR not more than 10% greater than the reported PCR should not adversely affect the pavement. For example, a pavement with a PCR of 600 can withstand limited traffic. limited traffic aircraft with an ACR of 660.
- ✓ The annual number of overload traffic should not exceed approximately 5% of the total annual air traffic.
- ✓ When overburden operations are performed, airport personnel should periodically inspect the condition of the pavement.
- ✓ Let the PCR remain as derived from the technical evaluation method, but retain local knowledge that there are some aircraft in the traffic mix that may be allowed to operate with ACRs that exceed the published PCR or at a reduced weight so as not to exceed the PCR.
- ✓ Provide for an increased PCR by adding an overlay or by reconstruction to accommodate aircraft with higher ACRs.
- ✓ Adjust the PCR upward, to that of the aircraft with the highest ACR, but take into account the need to provide for possible rigorous maintenance. This will result in higher and anticipated costs for reconstruction or resurfacing projects.

Technical concepts / Design traffic

FAARFIELD TECHNICAL CONCEPTS

- FAARFIELD is based on the concept of cumulative damage factor (CDF) in which the contribution of each aircraft type in a given traffic mix is summed to obtain the total cumulative damage of all aircraft operations in the traffic mix.

- The CDF is the amount of structural fatigue life of a pavement that has been used. It is expressed as the ratio between the applied load repetitions and the allowable load repetitions to failure. FAARFIELD analyzes the pavement damage for each aircraft and determines a final thickness for the total cumulative damage for all aircraft in the assessment for each 10-inch wide strip over a total width of 820 inches. The CDF for the design is the maximum over the 82 strips.

- FAARFIELD calculates the damaging effects of each aircraft on the traffic mix as a function of landing gear spacing, loading, and landing gear location relative to the pavement centerline.

- When the CDF adds up to a value of 1.0 in any of the 82 bands, the structural design conditions are met. A CDF value greater than one does not necessarily 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 procedures and within the constraints of the material property assumptions.

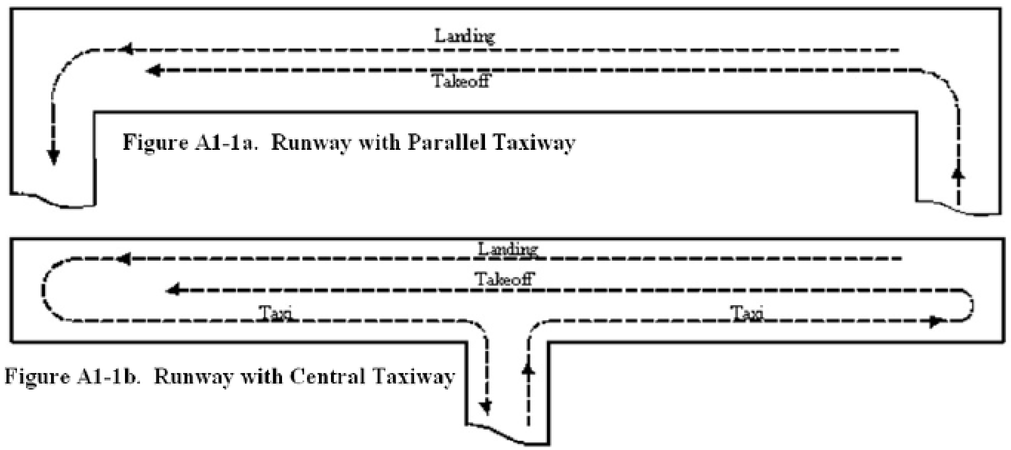
FAARFIELD TECHNICAL CONCEPTS

- Arrivals (landing) - Departures (take-off)

The FAA pavement design procedure only considers departures and ignores the arrival traffic count because aircraft arrive with a smaller amount of fuel.

- **Pass:** is a single movement of the aircraft over the runway pavement. It can be an arrival, a departure, a taxi operation or all three, depending on the magnitude of the load and the location of the taxiways.

Figure A-1. Traffic Load Distribution Patterns

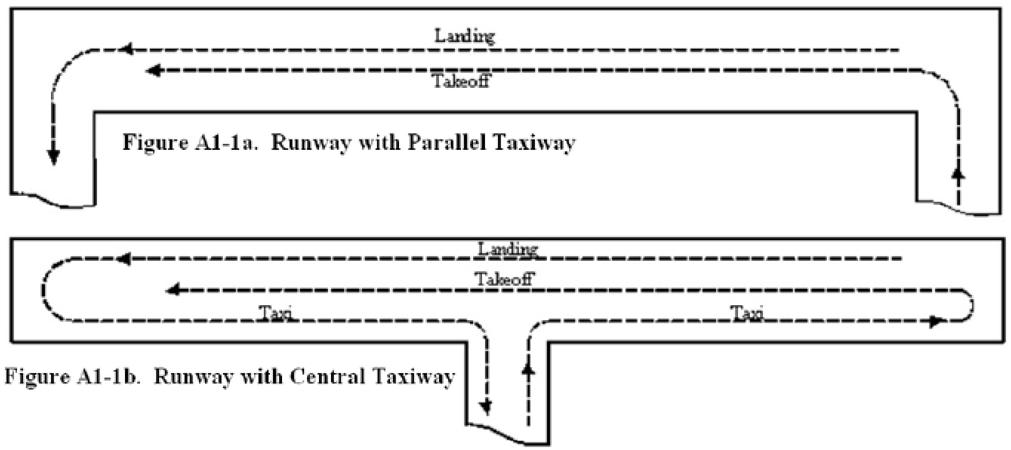


Parallel taxiway: figure A1-1a

- ✓ If the aircraft is refueled at the airport, a traffic cycle consists of a single pass, since the landing stress load is considered to be at a reduced level, which is a fractional equivalence. In this condition, only the take-off pass is counted, and the ratio of passes to traffic cycles (P/TC) is 1.
- ✓ If the aircraft does not obtain fuel at the airport, both landing and take-off passes will be counted, and a traffic cycle consists of two passes with the same load. In this case, the P/TC ratio is 2.

FAARFIELD TECHNICAL CONCEPTS

Figure A-1. Traffic Load Distribution Patterns



Center taxiway: figure A1-1b

- ✓ If the aircraft is refueled at the airport, both takeoff and taxi-to-takeoff passes must be accounted for, as they result in a traffic cycle consisting of two passes at maximum load. In this situation, the P/TC ratio is 2.
- ✓ If the aircraft does not obtain fuel at the airport, both landing and takeoff passes will be counted, along with the taxi pass, and a traffic cycle consists of three passes with loads of equal magnitude. In this case, the P/TC ratio is 3.

Table A-1. Standard P/TC Ratio Summary (see note)

Taxiway Serving the Runway	P/TC Fuel Obtained at the Airport (i.e. departure gross weight more than arrival gross weight.)	P/TC No Fuel Obtained at the Airport (i.e. departure gross weight same as arrival gross weight.)
Parallel	1	2
Central	2	3

Note: The standard P/TC ratios are whole numbers 1, 2, and 3. The range of values that can be entered in the software is 0.001 thru 10.0. This feature allows flexibility in those instances where a fraction of the total traffic may use different runways or other pavements. For example, a P/TC ratio of 0.5 multiplies the coverages of each aircraft by 0.5, which will increase the PCR of the pavement.

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FAARFIELD TECHNICAL CONCEPTS

- Coverage

✓ A coverage occurs when a wheel of the aircraft's main landing gear travels a unit area of the runway.
✓ Due to the aircraft's circulation deviation, the wheel may not cover this unit area every time the aircraft is on the runway. The number of passes required to statistically cover the unit area once on the pavement is expressed by the ratio of passes to coverage (P/C).
✓ The P/C ratio is necessary to convert the passes to coverages used in the program. This ratio varies for each aircraft due to the number of wheels, main landing gear configuration, tire contact areas and the load on the landing gear. The FAARFIELD program automatically determines the P/C ratio of any aircraft, and the user only has to define the passes.

FAARFIELD TECHNICAL CONCEPTS

- Fatigue failure in FAARFIELD is expressed by the CDF. The CDF is a form of Miner's rule, a cumulative damage model for fatigue failure. Using Miner's rule, the total CDF is determined by adding the damage of each individual aircraft.
- The CDF is a number that represents the amount of structural fatigue life that has been used. Mathematically, the CDF is the sum of N terms, where each term is the ratio between the repetitions applied and the repetitions allowed to fail for one of the N aircraft in the traffic mix.
- For a pavement design, the pavement structure thickness is adjusted until the CDF = 1 for the given traffic mix and structural design life. For a single aircraft (N = 1) and constant annual departures, the CDF can be expressed as follows:

$$\text{CDF} = \frac{\text{number of applied load repetitions}}{\text{number of allowable repetitions to failure}}$$

or

$$\text{CDF} = \frac{(\text{annual departures}) \times (\text{life in years})}{(P/C) \times (\text{coverages to failure})}$$

or

$$\text{CDF} = \frac{\text{applied coverages}}{\text{coverages to failure}}$$

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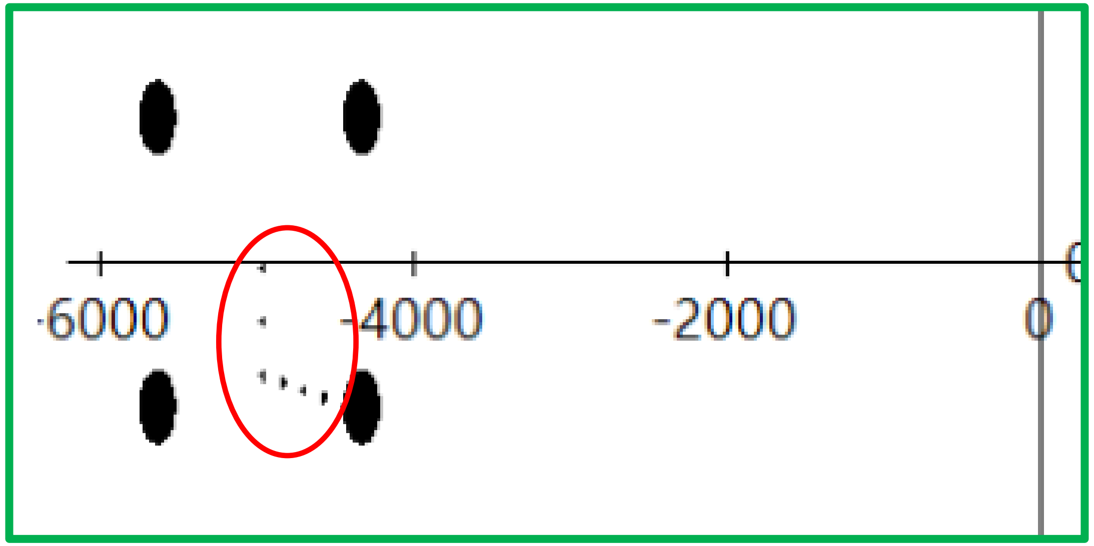
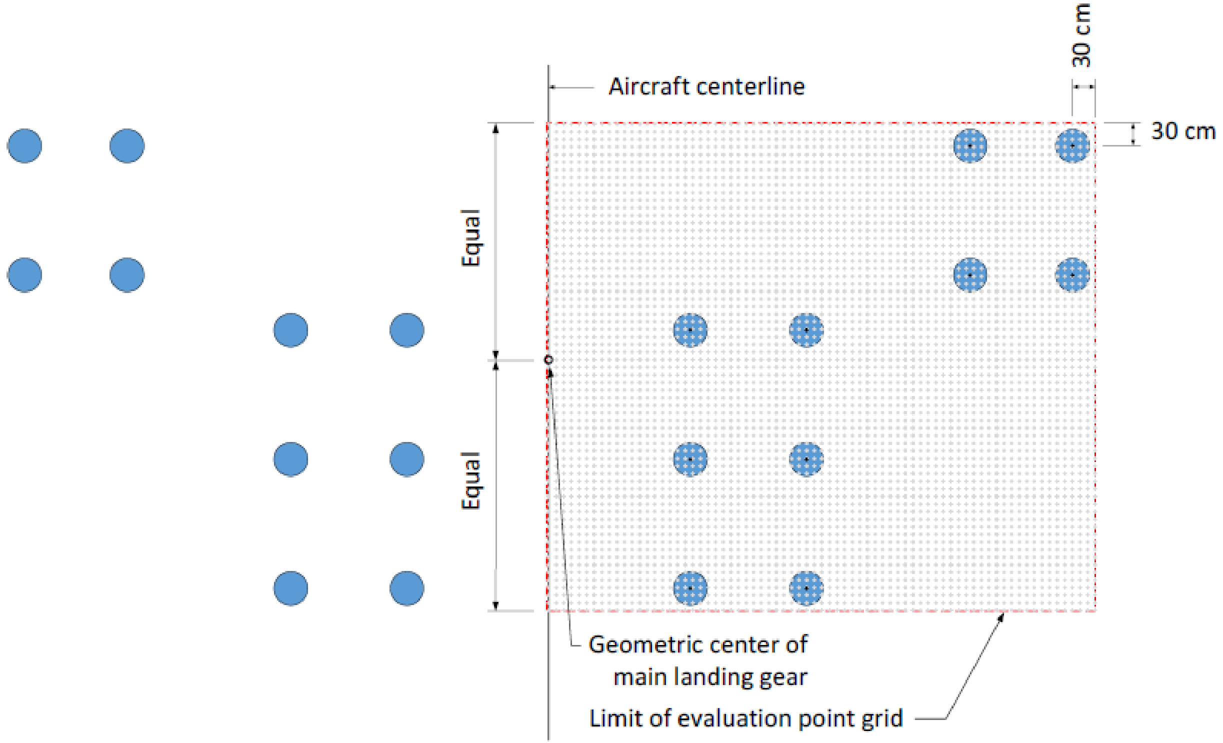
EVALUATION POINTS (COMPLEX GEAR)

- ALL main gear wheels contribute to calculated deformation.
- Tension is EVALUATED on the point grid.





Airplane Name	Gross Taxi Weight (kg)	Annual Departures	Annual Growth (%)	Total Departures	CDF Contributions	CDF Max for Airplane	P/C Ratio	Tire Pressure (kPa)	Percent GW on Gear
B747-8	449,056	1,200	0	24,000	0	0	0	1523.74	0.475
B747-8 Belly	449,056	1,200	0	24,000	0	0	0	1523.74	0.475
A380-800 WV000	562,000	1,200	0	24,000	0	0	0	1503.06	0.38
A380-800 WV000 Belly	562,000	1,200	0	24,000	0	0	0	1503.06	0.57

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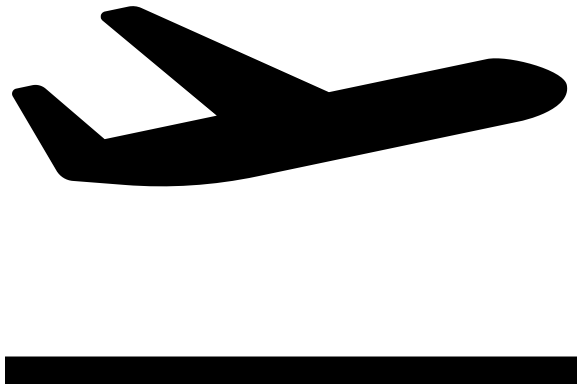
Traffic by element

Aircraft Type



Maximum take-off weight

A.2.1 Arrival (Landing) and Departure (Takeoff).

Typically, aircraft arrive at an airport with a lower amount of fuel than is used at takeoff. As a consequence, the stress loading of the wheels on the runway pavement is less when landing than at takeoff due to the lower weight of the aircraft as a result from the fuel used during flight and the lift on the wings. This is true even at the touchdown impact in that there is still lift on the wings, which alleviates the dynamic vertical force. Because of this, the FAA pavement design procedure only considers departures and ignores the arrival traffic count. However, if the aircraft do not receive additional fuel at the airport, then the landing weight will be substantially the same as the takeoff weight (discounting the changes in passenger count and cargo), and the landing

Growth Rates

Traffic

Stored Aircraft Mix | Save Aircraft Mix to File

Airplane Name	Gross Taxi Weight (kg)	Annual Departures	Annual Growth (%)	Total Departures
A310-200	142.900	500	1	11,000
B737-200	52.617	1,000	1	22,000
B737-700	70.307	800	1	17,600

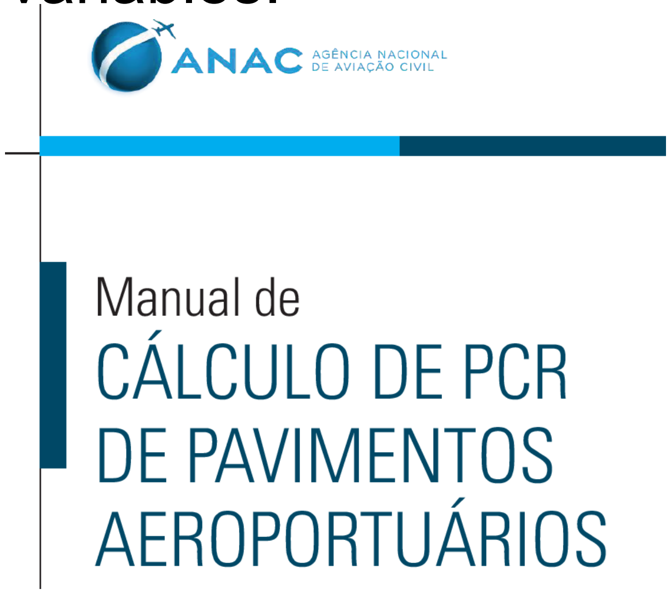
Traffic discriminated by element: Runway, taxiways, positions, etc.

The FAA only takes into account departures and ignores the count of arriving traffic; except for a few considerations. The P/TC value should be analyzed

TECHNICAL EVALUATION

CHARACTERISTICS OF THE MATERIALS

- **Determination of the CBR or modulus of elasticity of the subgrade:**
  - Laboratory tests, based on samples collected in the field;
  - Plate tests, which can be performed on site (in situ);
  - By non-destructive testing, in which the modulus is deduced from retroanalysis;
  - Make use of correlation equations between the modulus (E) and the CBR or modulus of subgrade reaction "k" variables.

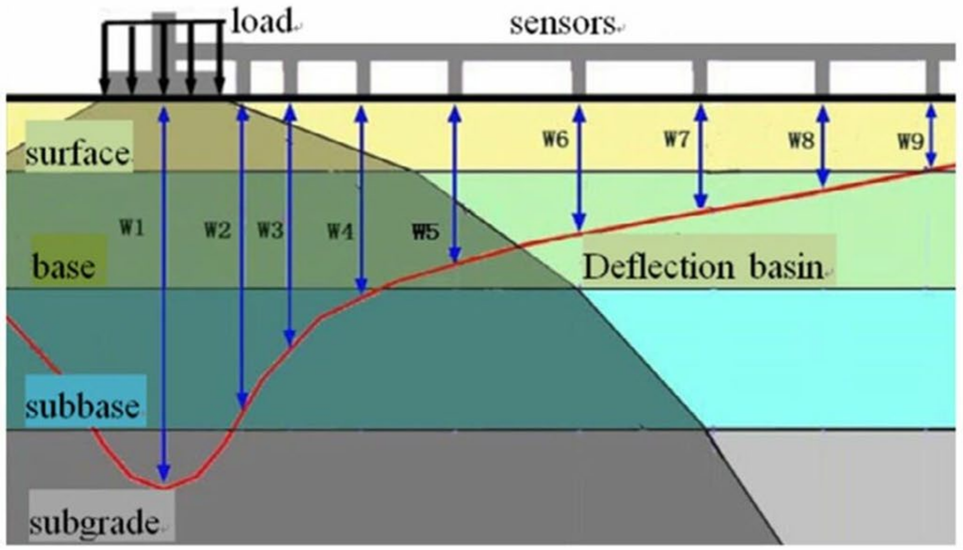


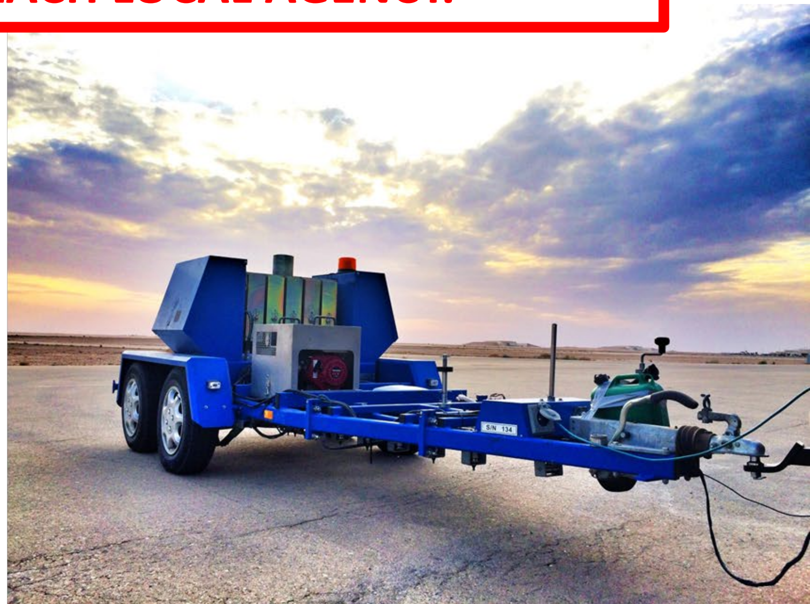
CHARACTERISTICS OF THE MATERIALS

Destructive testing

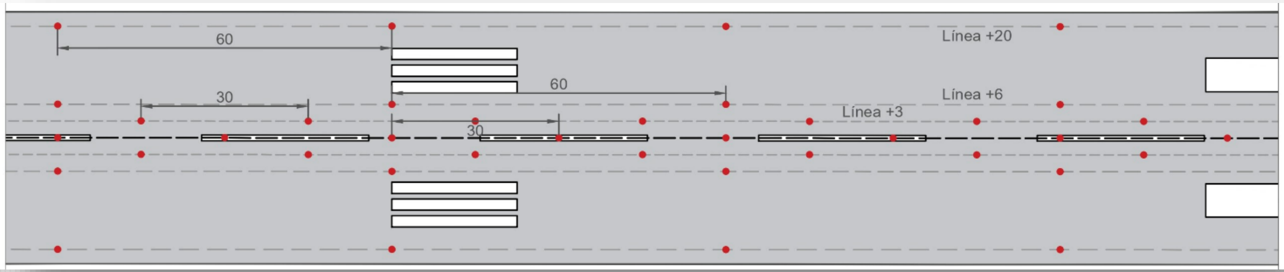
THE COMBINATION WILL DEPEND ON THE REQUIREMENTS OF EACH LOCAL AGENCY.

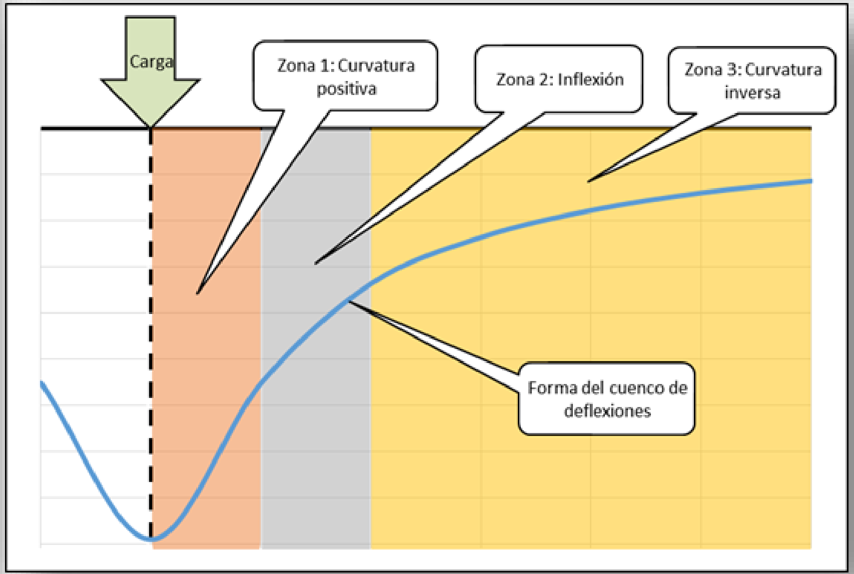
Nondestructive testing





Structural evaluation
Technology used: HWD deflectometry.





IT IS NOT RECOMMENDED TO USE OLD STRUCTURAL EVALUATION DATA OLDER THAN **5 YEARS**.

CHARACTERISTICS OF THE MATERIALS

- **Non-destructive testing, structural capacity of the pavement**

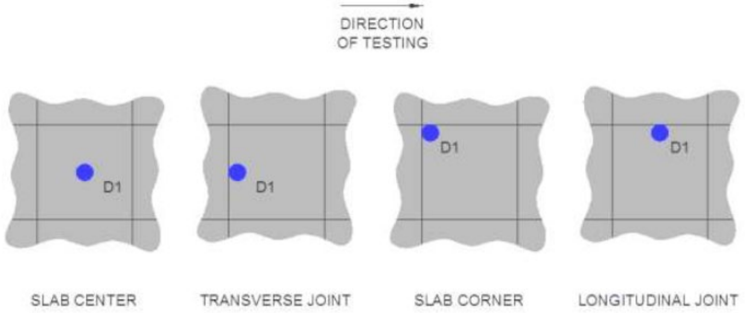


Figure 16. NDT Test Locations within a PCC Slab

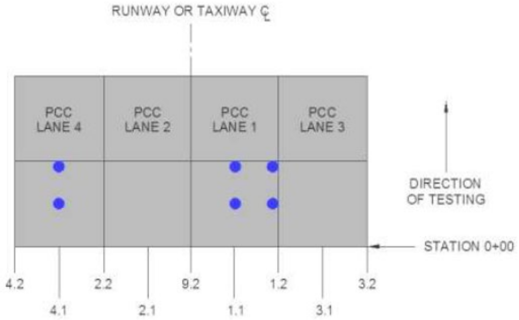


Figure 18. Example Runway or Taxiway Sketch When Centerline Lies on Slab Joint

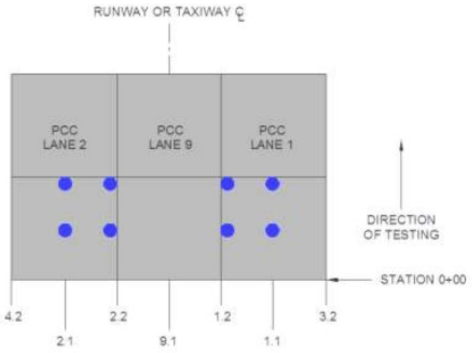


Figure 19. Example Runway or Taxiway Sketch When Centerline Does Not Lie on Slab Joint

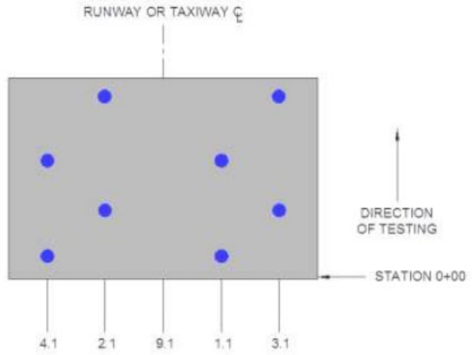


Figure 20. Example Runway or Taxiway Sketch for HMA Pavements

Table 5. Typical Runway and Taxiway Test Locations and Spacing, Feet (m)

Test Type	Jointed PCC and HMA Overlaid PCC				HMA			
	Project Level		Network Level		Project Level		Network Level	
	Offset ft (m)	Spacing ft (m)	Offset ft (m)	Spacing ft (m)	Offset ft (m)	Spacing ft (m)	Offset ft (m)	Spacing ft (m)
Center	10 (3) 30 (9) 65 (20)	100 (30) 100 - 200 (30 - 60) 400 (120)	10 (3)	200 - 400 (60 - 120)	200 - 400 (60 - 120)	100 (30) 100 - 200 (30 - 60) 200 - 400 (60 - 120)	10 (3)	200 - 400 (60 - 120)
Tran. Joint	10 (3) 30 (9) 65 (20)	100 - 200 (30 - 60) 200 - 400 (60 - 120) 400 (120)	10 (3)					
Long. Joint	20 (6) 40 (12) 60 (18)	200 (60) 400 (120) 400 (120)						
Corner	20 (6) 40 (12) 60 (18)	200 (60) 400 (120) 400 (120)						

For each centerline offset, there are two NDT passes, one to the left and one to the right; spacing is staggered between adjacent NDT passes; and a minimum of two NDT tests should be conducted per pavement section.

Subject: Use of Nondestructive Testing in the Evaluation of Airport Pavements	**Date:** 9/30/11 **Initiated by:** AAS-100	**AC No.:** 150/5370-11B **Change:**

Structural evaluation
Destructive and laboratory testing

- ✓ Subgrade bearing capacity
- ✓ Triaxial tests for the determination of the modulus of granular materials.
- ✓ Modulus testing of asphalt mixes

IT IS NOT RECOMMENDED TO USE OLD STRUCTURAL EVALUATION DATA OLDER THAN **5 YEARS**.

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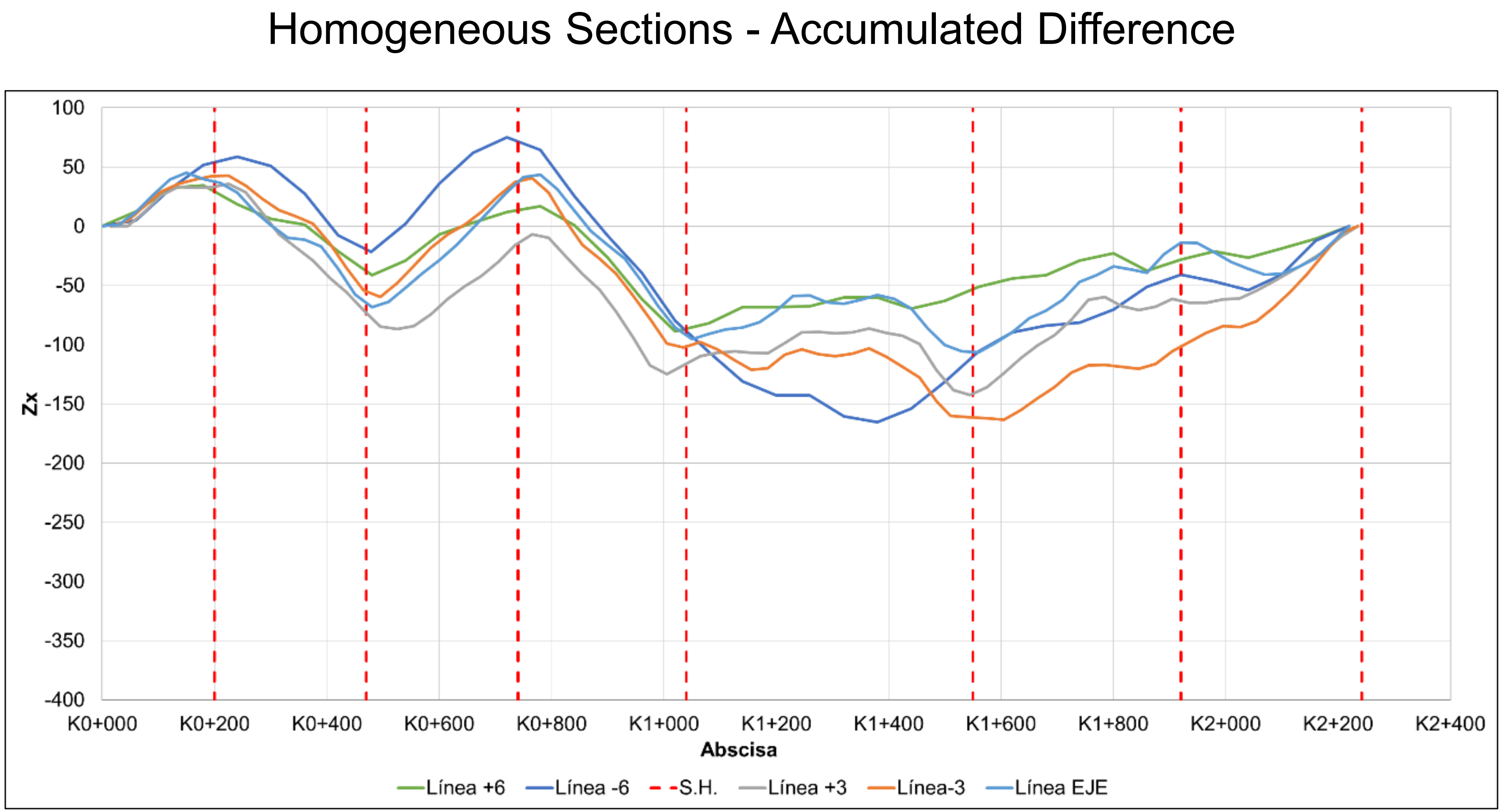
Determination of homogeneous cross-sections



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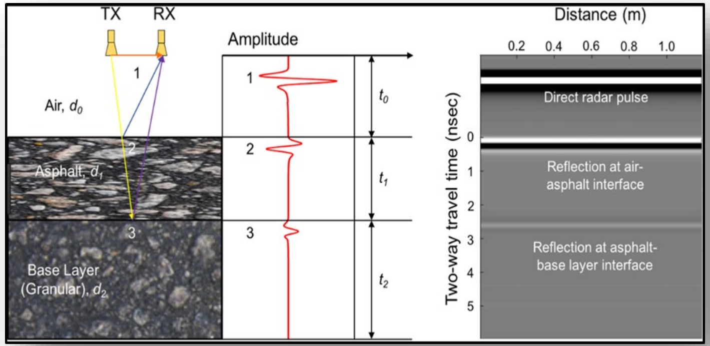
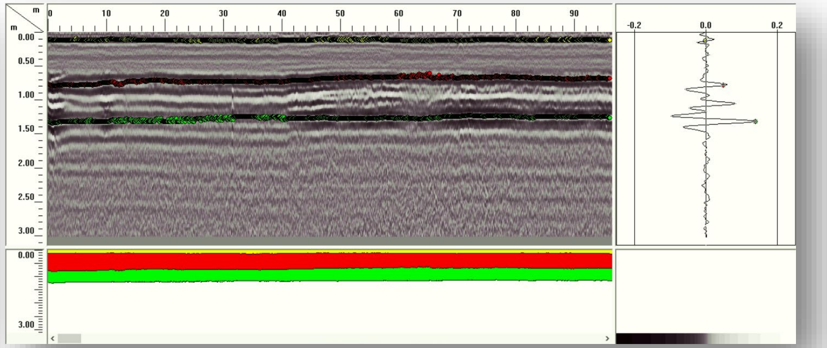
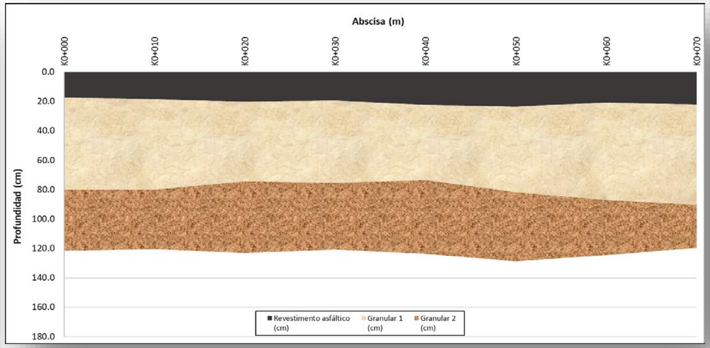
Thickness evaluation:
Technology used: Geo-radar







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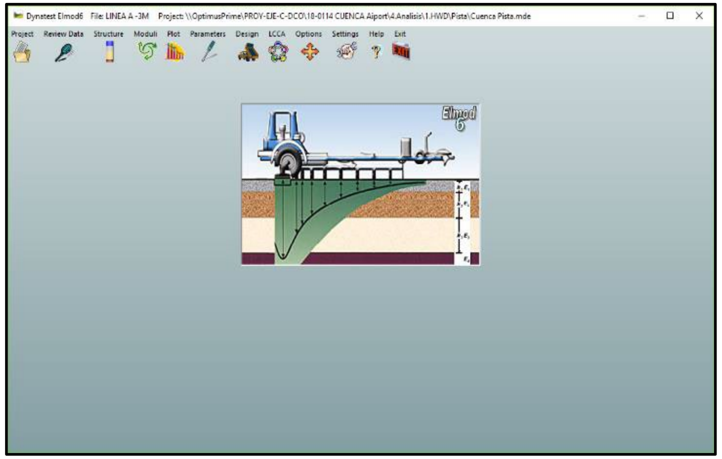
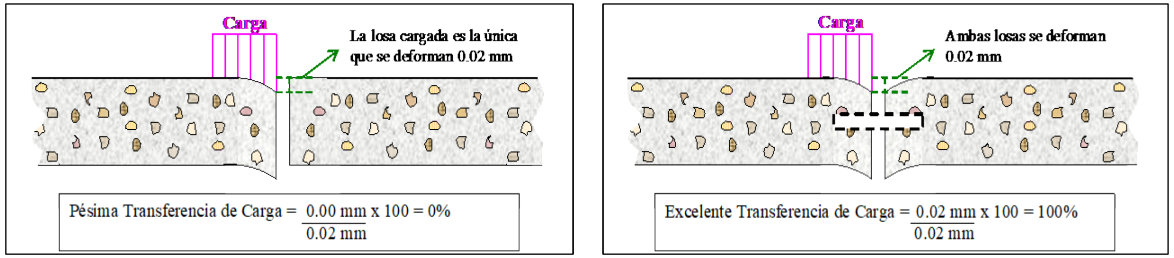
Determination of Modules

ELMOD 6 backcalculation software interface



Load Transfer Efficiency Extreme Cases



Laboratory tests

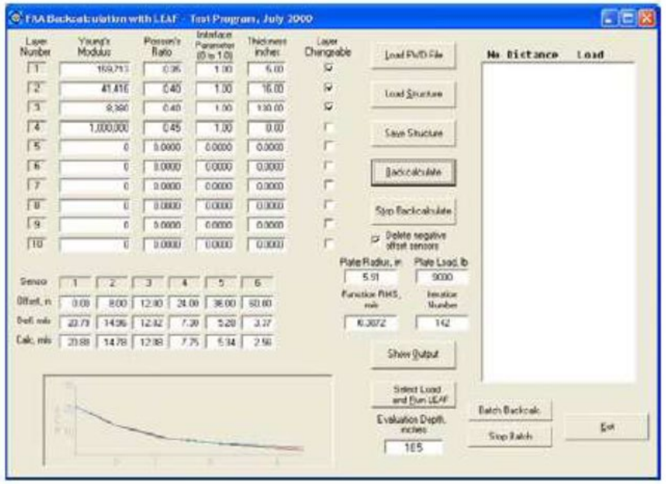
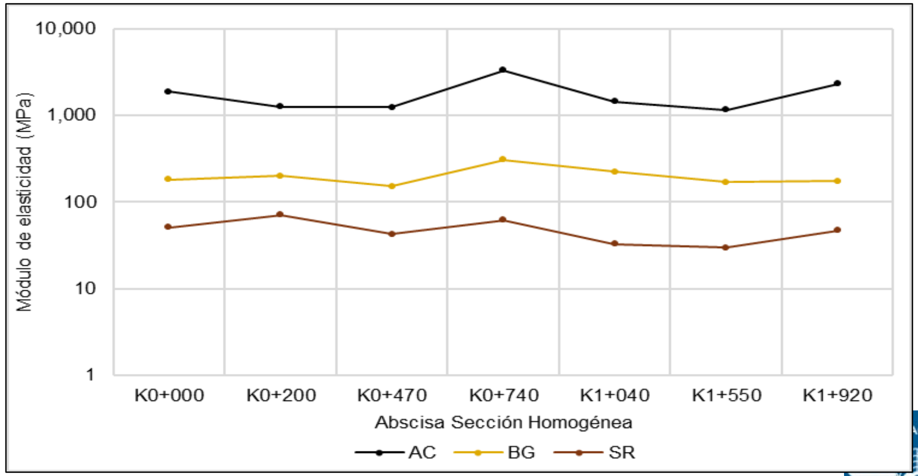


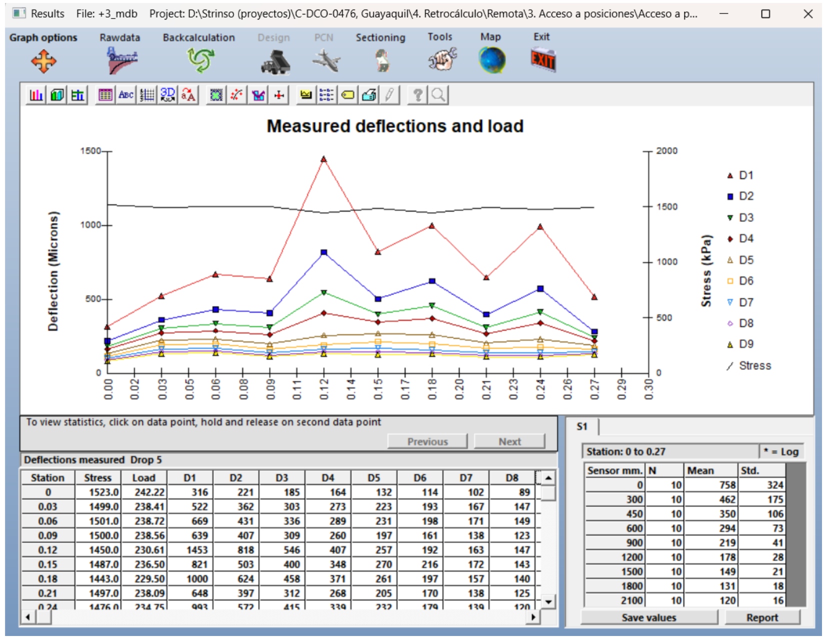
Figure 32. Initial BAKFAA Run for Example 2

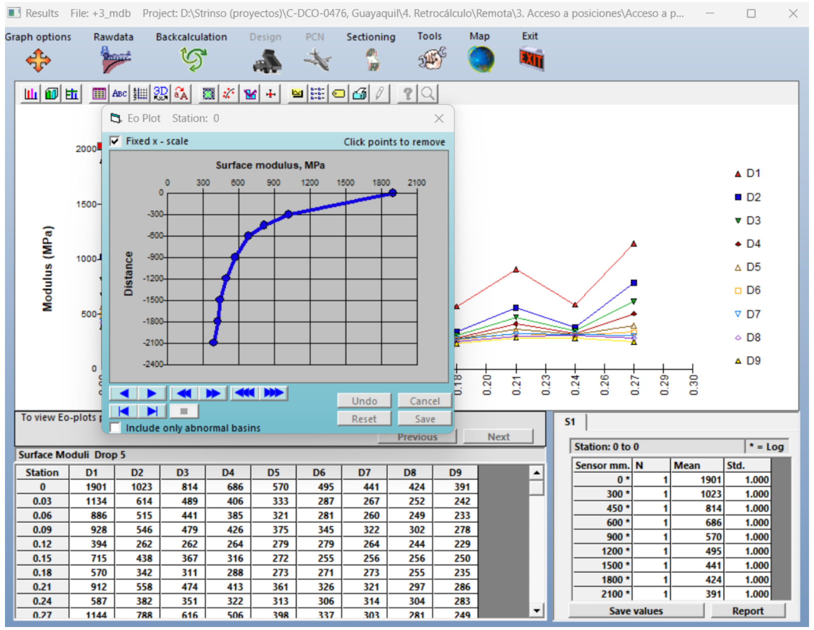
Elastic modulus per layer

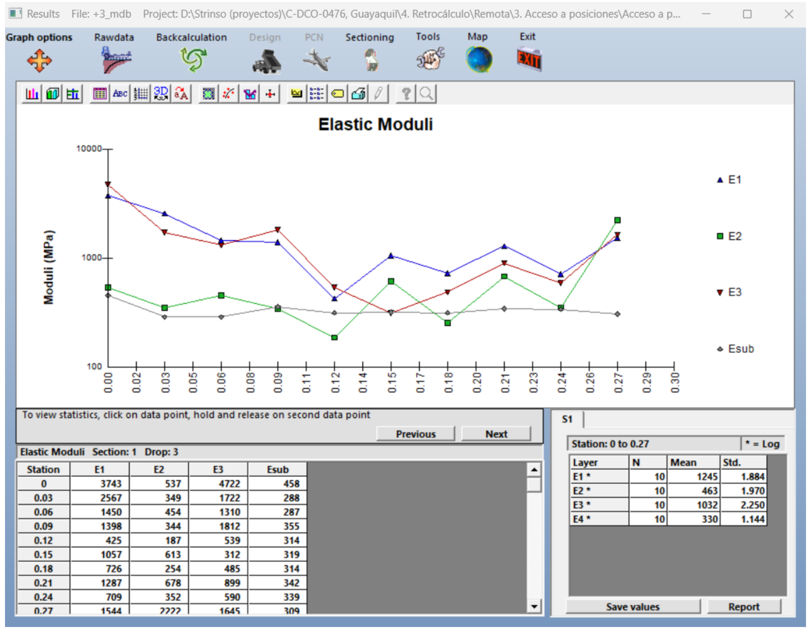


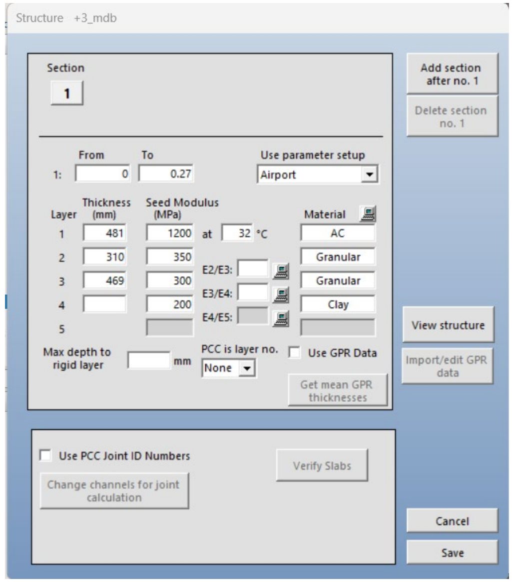
Determination of Modules

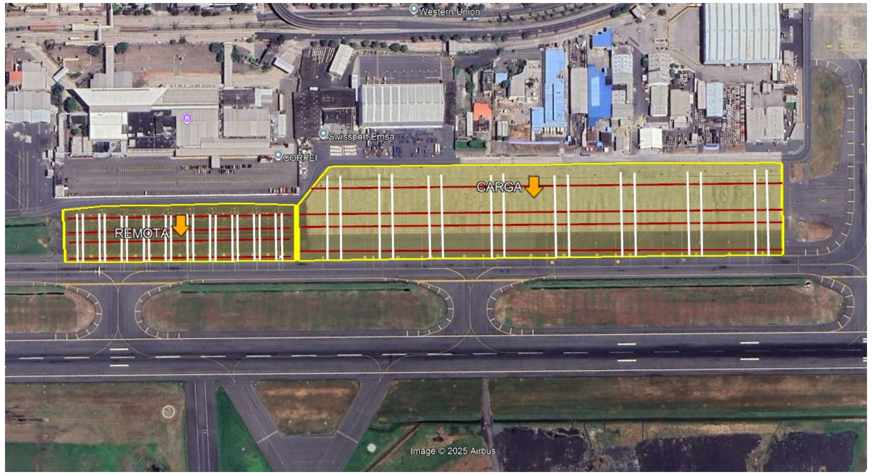
ELMOD 6 backcalculation software interface











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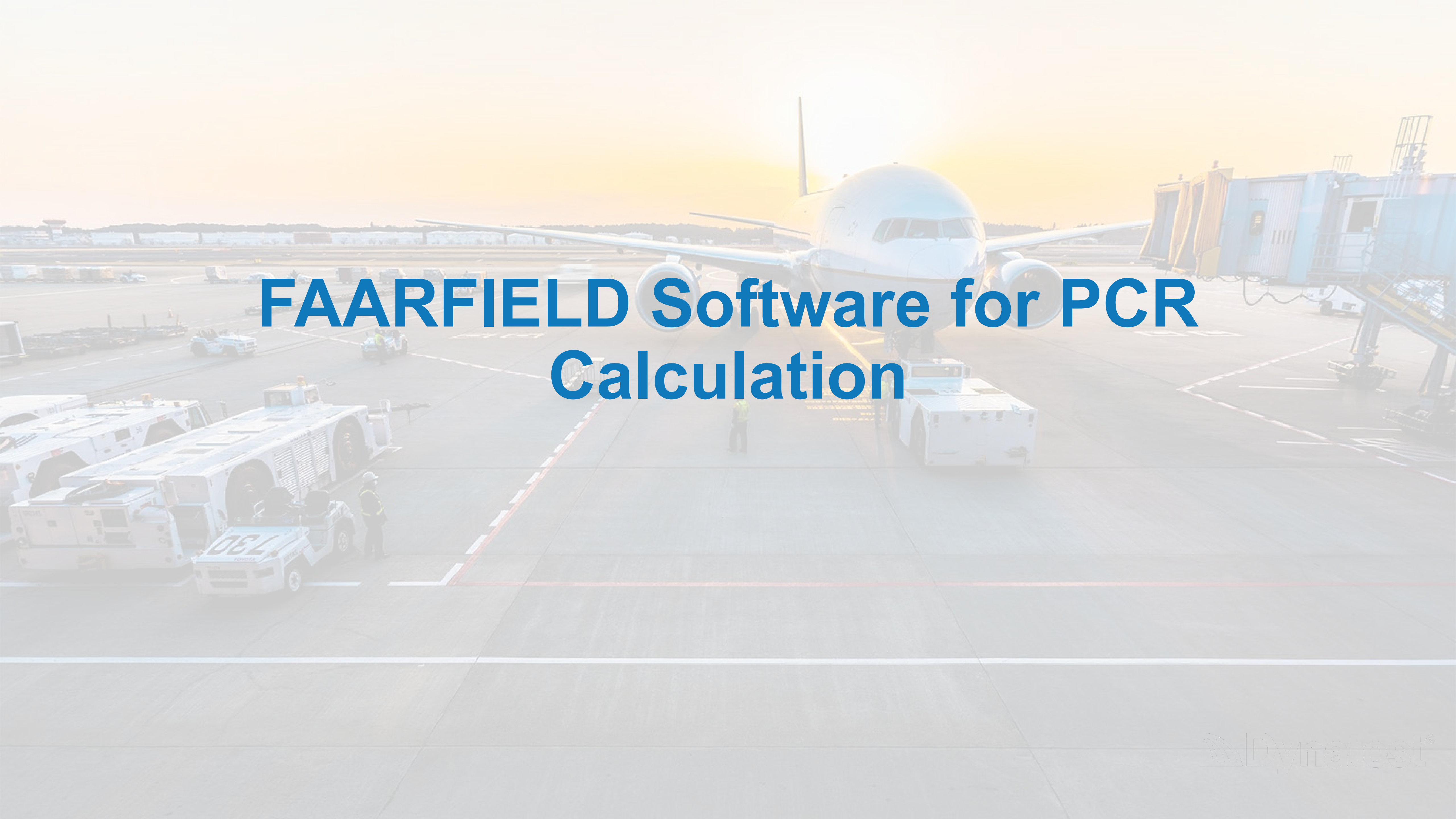
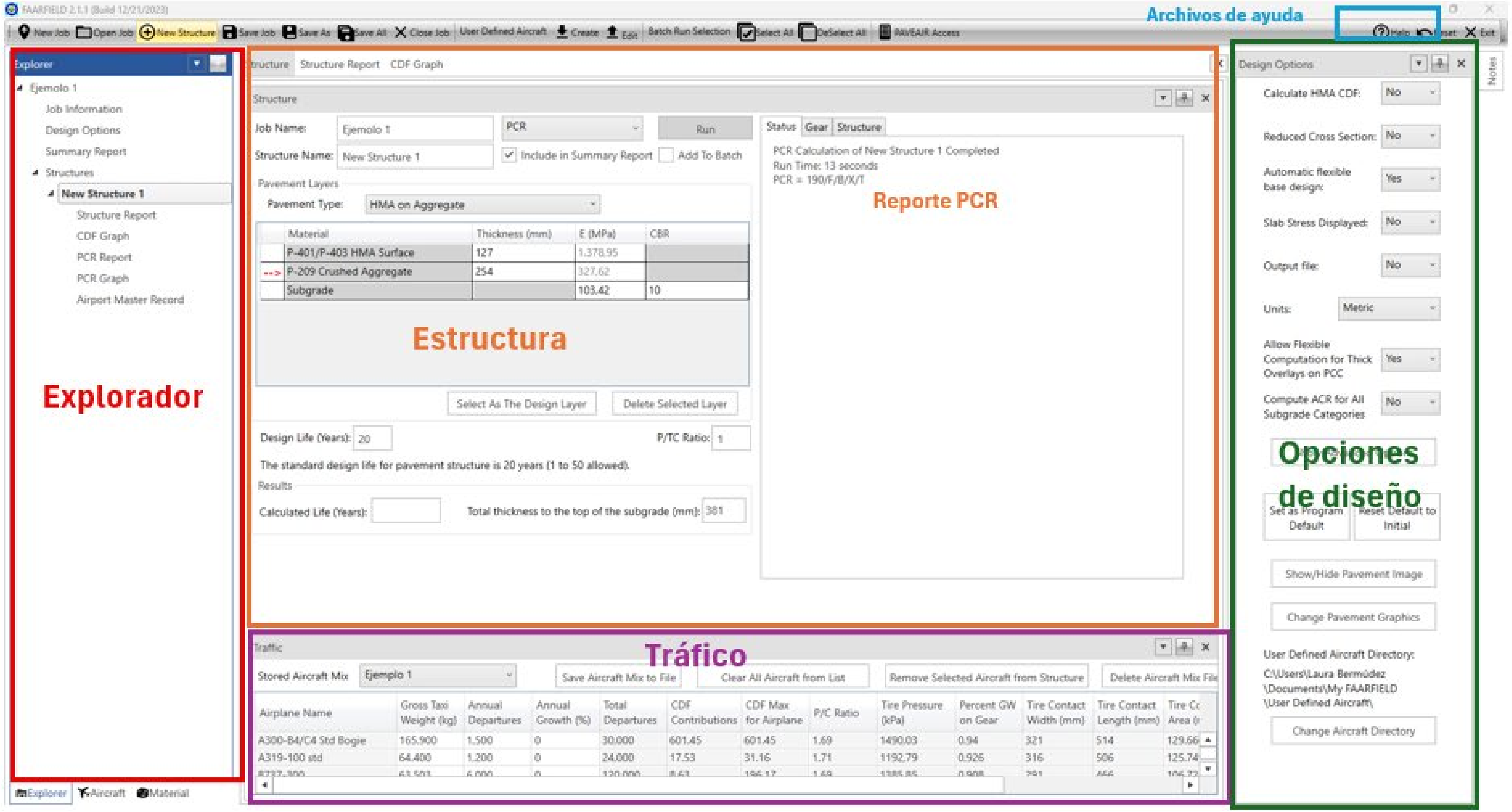
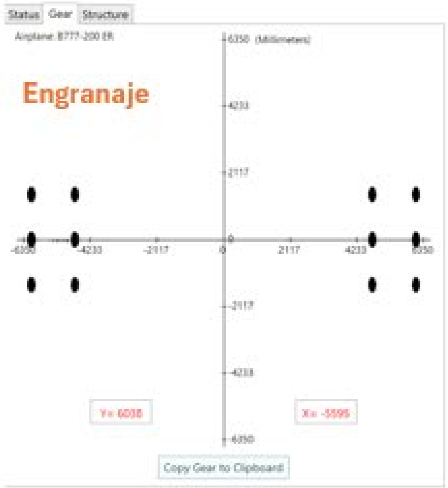


FAARFIELD Software for PCR Calculation

FAARFIELD SOFTWARE





Source: AC 150/5335-5D

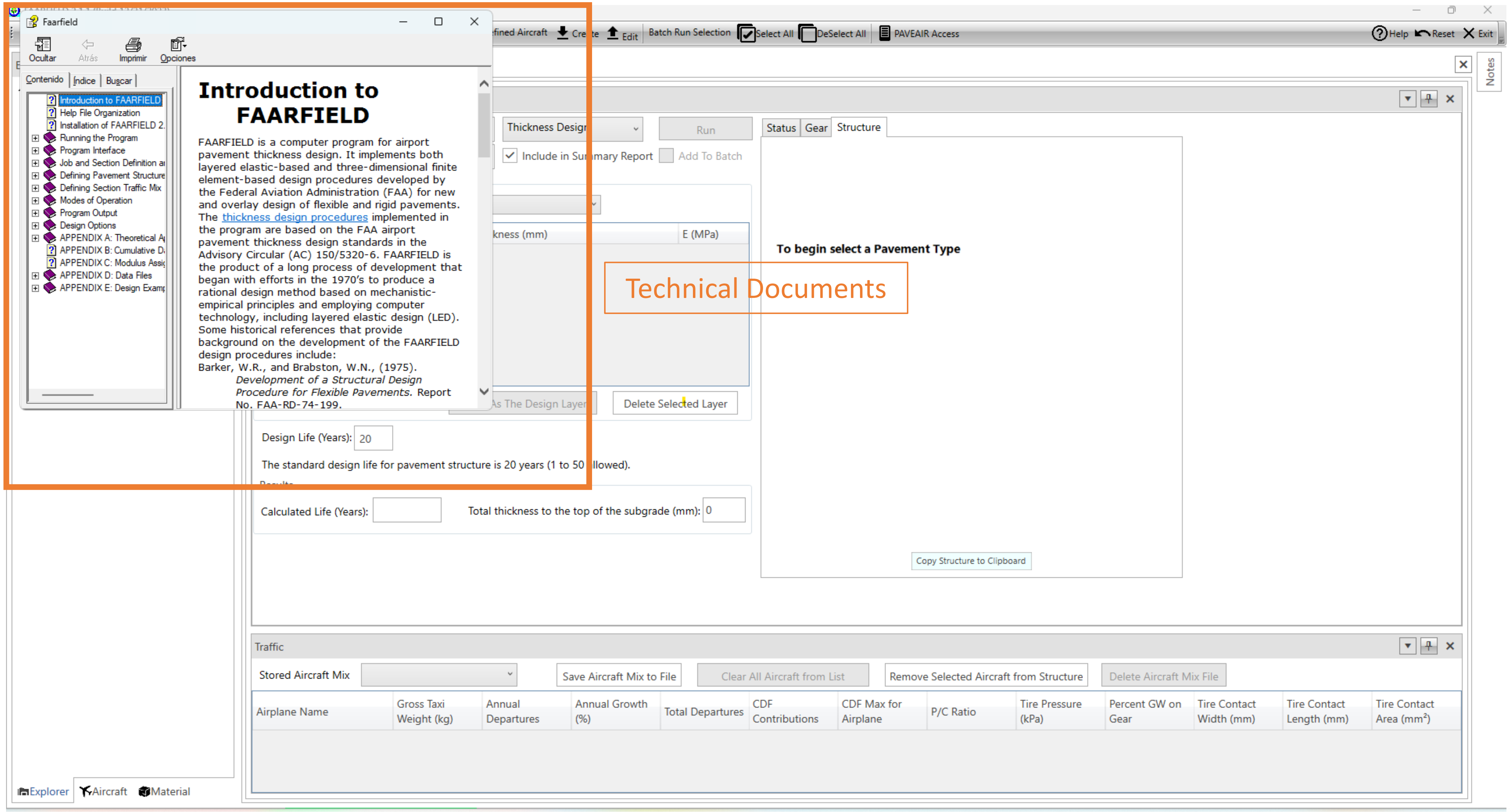
FAARFIELD modeling

In the main program window, perform the following steps:

- ✓ Select the type of pavement from the drop-down list,
- ✓ Enter the materials and thicknesses of the pavement structure.
- ✓ In the *Aircraft* tab select the aircraft to add to an external file to be saved on the computer.
- ✓ Confirm the physical properties of each individual aircraft in the traffic mix.
- ✓ Enter annual departures or aircraft coverages
- ✓ In the drop-down list select PCR and then click on the "Run" button.

Source: AC 150/5335-5D

FAARFIELD modeling



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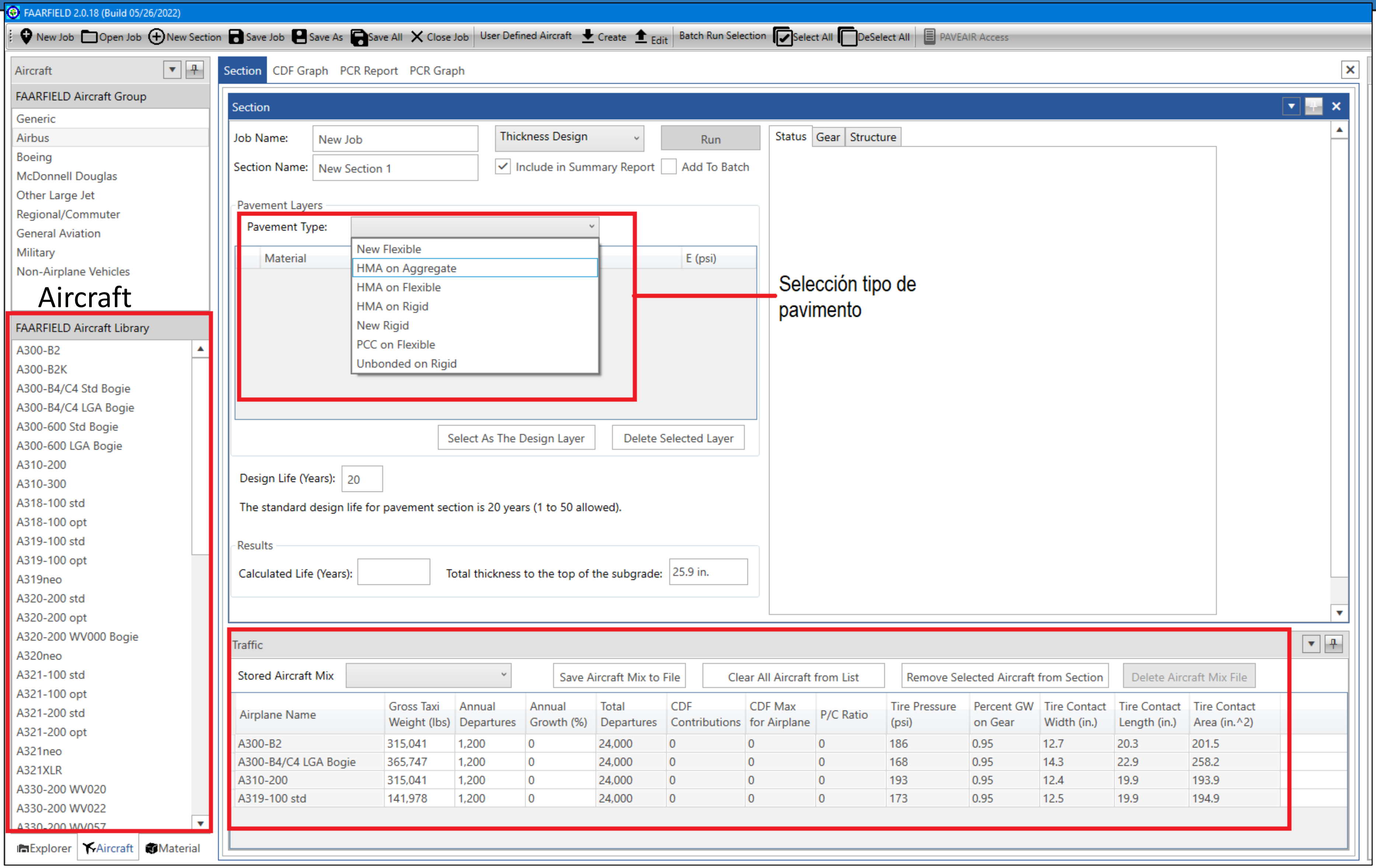
FAARFIELD modeling



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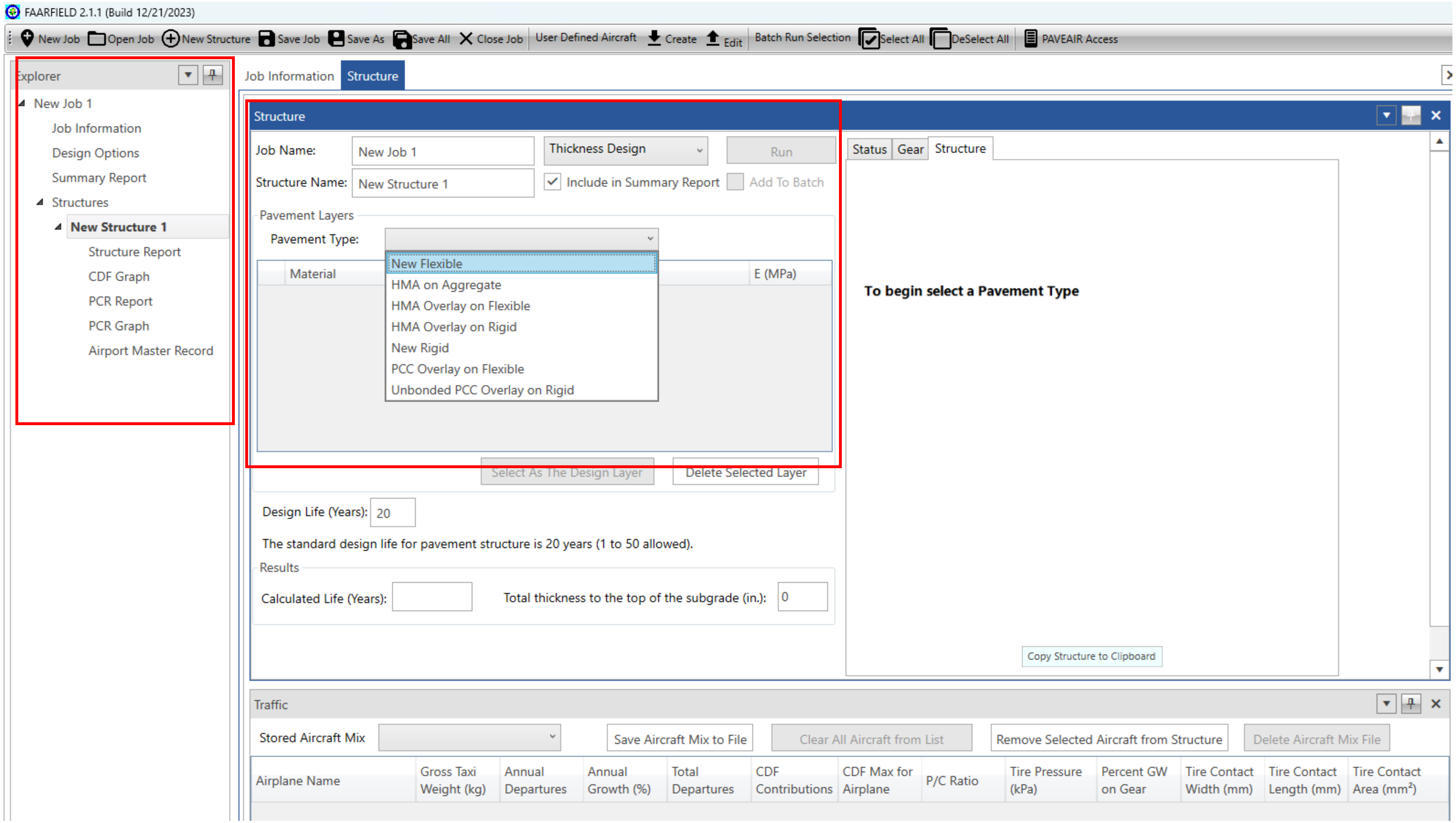
FAARFIELD modeling

Definition of the type of structure



FAARFIELD modeling

Thickness definition and material characterization

Job Information | Structure

Structure

Job Name: New Job 1 | Thickness Design | Run

Structure Name: New Structure 1 | ☑ Include in Summary Report | ☐ Add To Batch

Pavement Layers

Pavement Type: HMA on Aggregate

	Material	Thickness (mm)	E (MPa)	CBR
	P-401/P-403 HMA Surface	102	1.378,95	
	P-209 Crushed Aggregate	254	517,11	
-->	P-154 Uncrushed Aggregate	152	275,79	
	Subgrade		103,42	10

Select As The Design Layer | Delete Selected Layer

Design Life (Years): 20

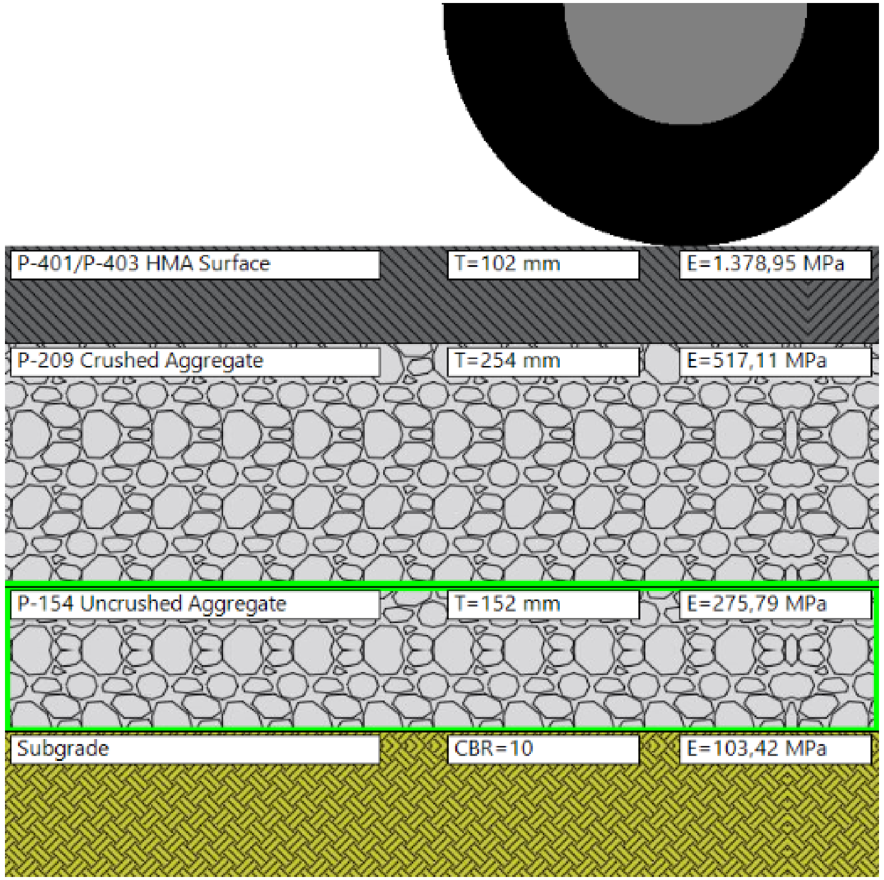
The standard design life for pavement structure is 20 years (1 to 50 allowed).

Results

Calculated Life (Years):

Total thickness to the top of the subgrade (in.): 508

Status | Gear | Structure



Copy Structure to Clipboard

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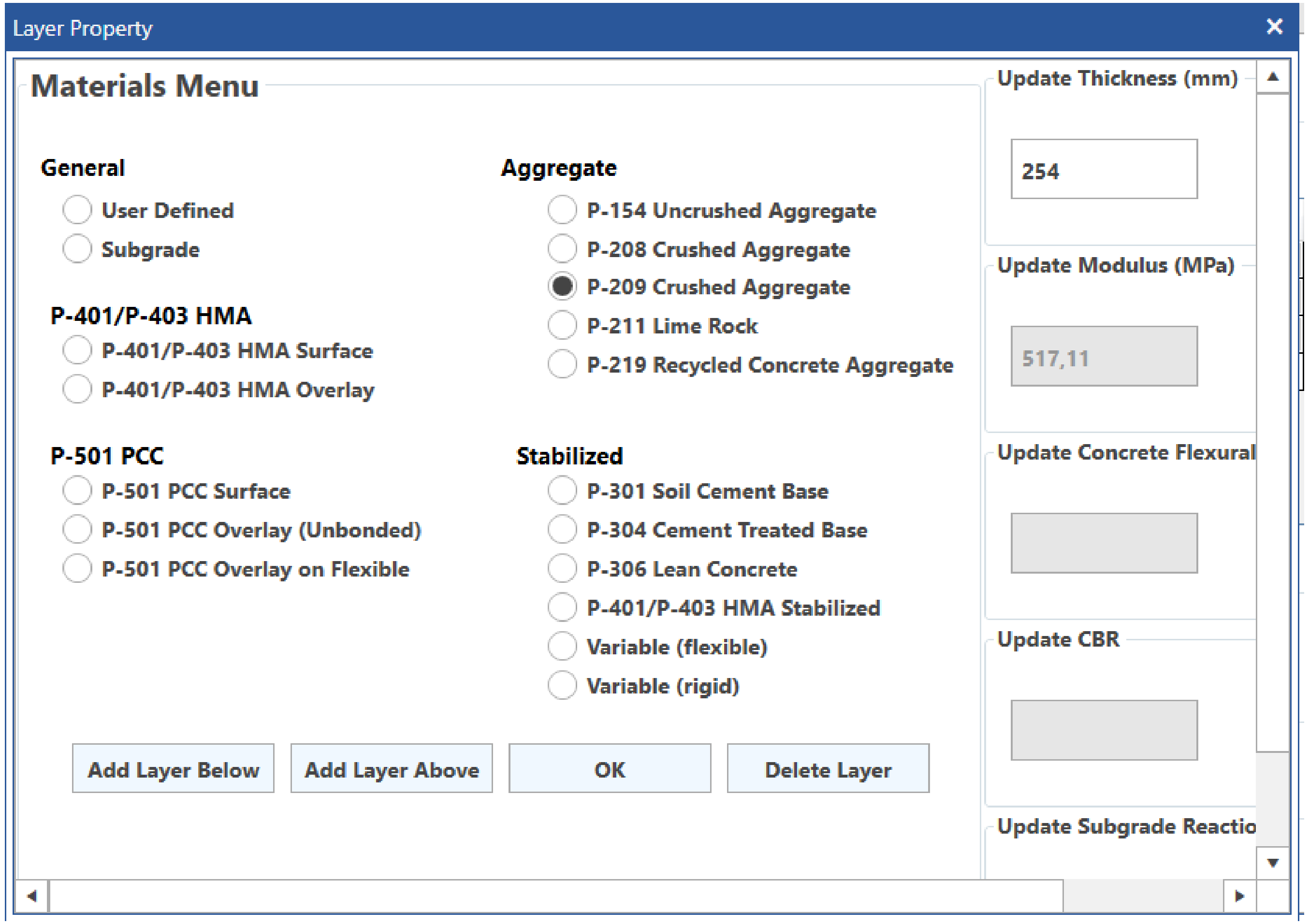
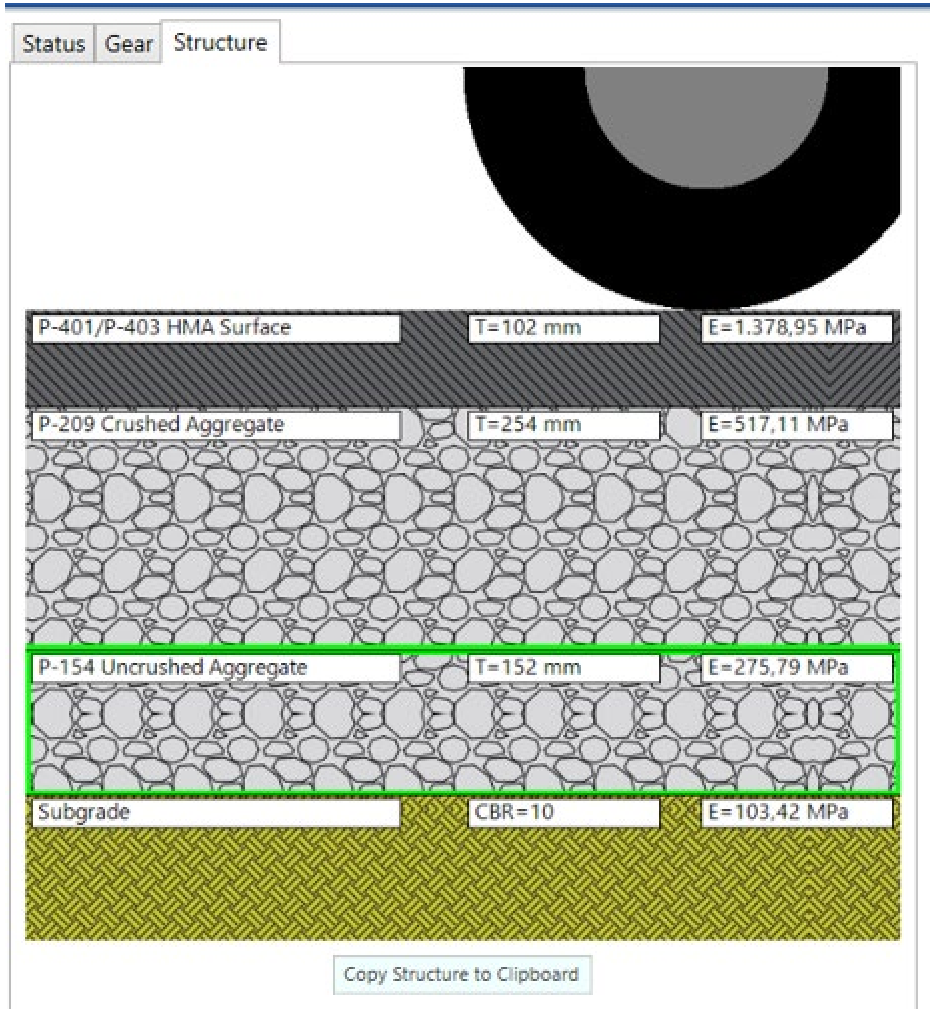
FAARFIELD modeling

Thickness definition and material characterization





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Definition of aircraft fleet

Aircraft

FAARFIELD Aircraft Group

- Generic
- Airbus
- **Boeing**
- McDonnell Douglas
- Other Large Jet
- Regional/Commuter
- General Aviation
- Military
- Non-Airplane Vehicles

Aircraft Group

FAARFIELD Aircraft Library

- B717-200 HGW
- B727-200 Advanced Basic
- B727-200 Advanced Option
- B737-100
- B737-200 Advanced QC
- B737-200
- B737-300
- B737-400
- B737-500
- B737-600
- B737-700
- B737-800
- B737-900
- B737-900 ER
- B737 BBJ
- B737 BBJ2
- B737-7 MAX
- B737-8/8-200/BBJ MAX 8

Aircraft bookstore

Explorer | Aircraft | Material

Traffic

Stored Aircraft Mix | Save Aircraft Mix to File | Clear All Aircraft from List | Remove Selected Aircraft from Structure | Delete Aircraft Mix File

Airplane Name	Gross Taxi Weight (kg)	Annual Departures	Annual Growth (%)	Total Departures	CDF Contributions	CDF Max for Airplane	P/C Ratio	Tire Pressure (kPa)	Percent GW on Gear	Tire Contact Width (mm)	Tire Contact Length (mm)	Tire Contact Area (mm^2)	ACR Thick	ACR
A310-200	142.900	1,200	0	24,000	0	0	0	1330,00	0.95	316	505	125.122	0	0.0
B737-200	52.617	1,200	0	24,000	0	0	0	1089,37	0.95	299	479	112.495	0	0.0
B737-700	70.307	1,200	0	24,000	0	0	0	1358,27	0.95	310	496	120.558	0	0.0

List of loaded aircraft

Note: FAARFIELD automatically loads the correct tire pressure and %GW into the Main Landing Gear for PCR calculations. These may differ from the design thicknesses.

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Traffic by element

Example distribution of annual runway movements and taxiways

Aircraft name	Maximum weight (kg)	departures + arrivals	Distribution of annual transactions					
			RWY Loaded Zone	RWY Not Loaded Zone	Turn 07	Turn 25	TWY A	TWY B
A319-100 std	64,400	1200	100%	20%	50%	50%	50%	50%
A320-200 std	73,900	500						
A321-100 std	83,400	100						
Cessna 208B Grand Caravan EX	3,969	20						
CRJ100/200	21,636	1000						
S-10	4,800	500						
S-12.5	5,900	1200						
ERJ-145 EP	21,090	500						
EMB-175 STD	37,660	100						
S-15	6,950	20						
D-25	10,886	1000						
Saab 340B	13,154	500						
Cessna 414/414A Chancellor	2,812	1200						
B737-200	52,617	500						
B737-700	70,307	100						
B737-800	79,242	20						
D-50	22,800	1000						

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Traffic by element

Example distribution of annual transactions Positions

Departures: IC

Abbreviations	Type ACFT	Aircraft	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	Departures	Departures + arrivals	Runway	Runway	Taxiways	Rigid taxiways
			Commercial Aviation					Av. General															
A319	AIRBUS 319	A319-100 std	0	225	76	2	0	0	0	0	0	0	0	0	0	0	0	379	758	758		379	0
A320	AIRBUS 320	A320-200 std	0	2	65	0	0	0	0	0	0	0	0	0	0	0	0	67	134	134		67	0
A321	AIRBUS 321	A321-100 std	0	0	18	0	0	0	0	0	0	0	0	0	0	0	0	18	36	36		18	0
AT75	ATR 72	D-50	2	11	196	114	27	0	0	0	0	0	0	0	0	0	0	330	660	660		330	54
B200	B737-200	B737-200	55	7	1	42	2	0	0	0	0	0	0	0	0	0	0	107	214	214		107	4
B700	B737-700	B737-700	0	0	16	0	0	0	0	0	0	0	0	0	0	0	0	16	32	32		16	0
B800	B737-800	B737-800	51	68	370	32	2	0	0	0	0	0	0	0	0	0	0	543	1086	1086		543	4
C208	Cessna 208B	Cessna 208B	7	79	103	193	58	1	0	0	0	0	0	0	0	1	2	384	768	768		384	224
C402	Cessna 402	Cessna 414/414A	530	526	536	517	2	0	0	200	200	0	200	200	0	0	200	3089	6178	6178		3089	2082
CRJ100/200	CRJ100/200	CRJ100/200	88	25	38	6	74	0	0	0	0	0	0	0	0	0	0	231	462	462		231	148
E300	IP - Phenom 3	S-10	0	2	0	1	0	0	0	0	0	0	0	0	0	0	0	3	6	6		3	0
E110	E110	S-12.5	7	35	92	268	64	9	10	14	15	9	8	9	11	14	35	616	1232	1232	1984	997	664
E145	ERJ-145	ERJ-145 EP	2	13	24	6	2	0	0	0	0	0	0	0	0	0	0	47	94	94		47	4
E175	EMB-175	EMB-175 STD	0	5	18	0	0	0	0	0	0	0	0	0	0	0	0	23	46	46	88	44	0
E75L		EMB-175 STD	0	10	10	1	0	0	0	0	0	0	0	0	0	0	0	21	42	42			0
JS31	JETSTREAM 31	S-15	277	487	273	85	341	98	69	94	73	55	43	45	108	149	196	2253	4506	4506	5344	2672	3896
JS32		S-15	35	57	29	21	82	17	13	16	13	9	34	9	28	31	40	419	838	838			554
JS41	JETSTREAM 41	D-25	95	110	86	20	19	4	2	0	0	1	0	0	1	1	1	340	680	680		340	58
SF340	SAAB 340	Saab 340B	105	148	147	432	230	30	53	14	4	18	34	91	46	24	5	1385	2770	2770		1385	1106
TWIN	S12.5	S-12.5	5	26	67	365	35	7	0	3	12	18	11	9	32	9	0	381	762	762			238
			1239	1896	2097	1985	920	266	155	341	377	112	330	351	235	249	486	10644	21288	21296			
			10569															21288	42576	42592			
			7517																				
			-3052																				

FAARFIELD 2.1 PCR calculation

Job Information | Structure

Structure

Job Name: New Job 1 | PCR | Run

Structure Name: New Structure 1 | ☑ Include in Summary Report | ☐ Add To Batch

Pavement Layers

Pavement Type: HMA on Aggregate

	Material	Thickness (mm)	E (MPa)	CBR
	P-401/P-403 HMA Surface	102	1.378,95	
	P-209 Crushed Aggregate	250	412,76	
-->	P-154 Uncrushed Aggregate	300	143,93	
	Subgrade		103,42	10

Select As The Design Layer | Delete Selected Layer

Design Life (Years): 20

P/TC Ratio: 1

The standard design life for pavement structure is 20 years (1 to 50 allowed).

Results

Calculated Life (Years):

Total thickness to the top of the subgrade (mm): 652

Status | Gear | Structure

PCR Calculation of New Structure 1 Completed
Run Time: 5 seconds
PCR = 490/F/B/X/T

PCR calculation

ACR calculation

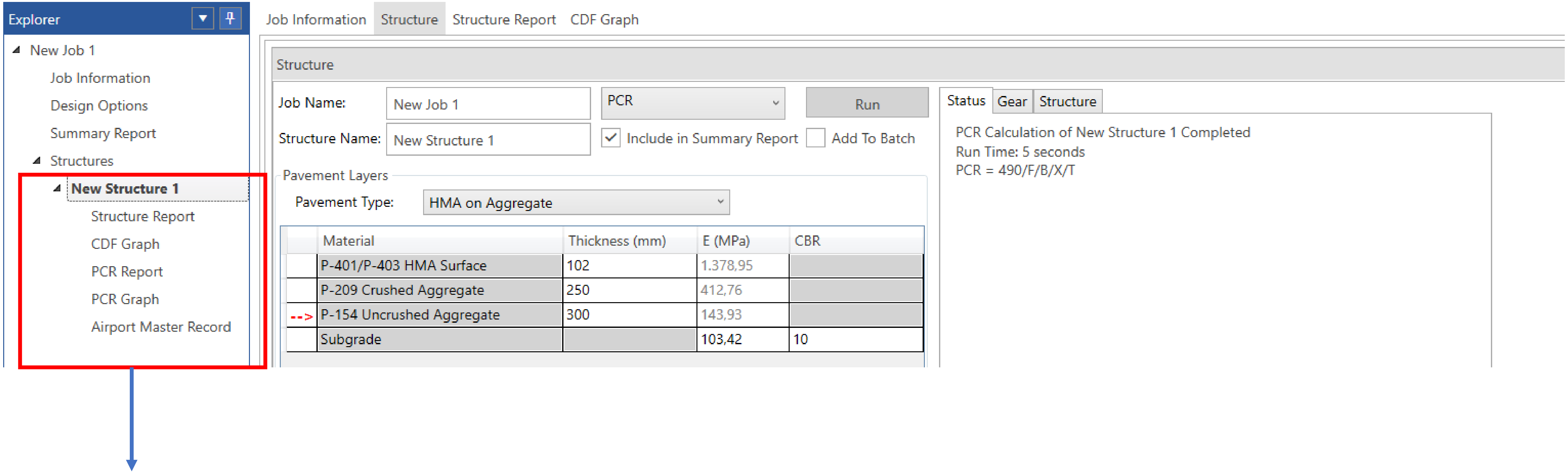
Traffic

Stored Aircraft Mix | Save Aircraft Mix to File | Clear All Aircraft from List | Remove Selected Aircraft from Structure | Delete Aircraft Mix File

Airplane Name	Gross Taxi Weight (kg)	Annual Departures	Annual Growth (%)	Total Departures	CDF Contributions	CDF Max for Airplane	P/C Ratio	Tire Pressure (kPa)	Percent GW on Gear	Tire Contact Width (mm)	Tire Contact Length (mm)	Tire Contact Area (mm²)	ACR Thick (mm) (B)	ACR/F/B
A310-200	142.900	200	1	4,400	0	0.01	1.28	1330,00	0.932	316	505	125.122	511	368.1
B737-200	52.617	1,000	1	22,000	0	0	1.37	1089,37	0.928	299	479	112.495	432	247.6
B737-700	70.307	800	1	17,600	0	0	1.32	1358,27	0.918	310	496	120.558	500	345.1

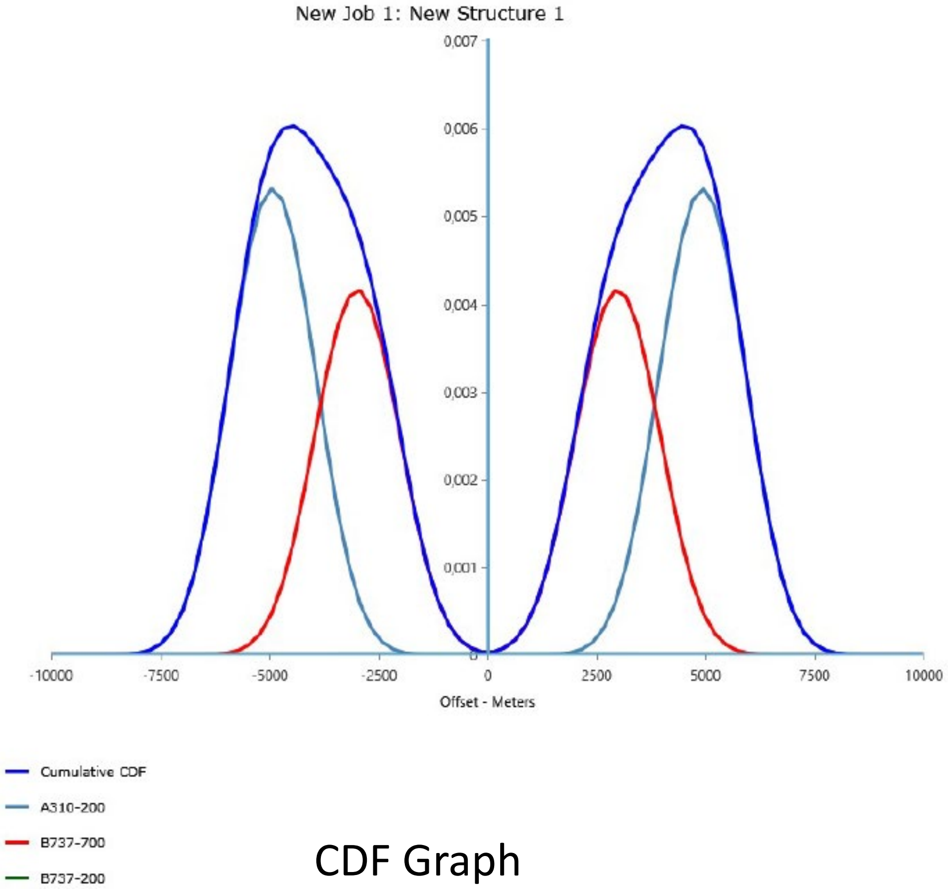
OACI

FAARFIELD 2.1 Reports



Reports

FAARFIELD 2.1 Reports



CDF Graph

PCR Report

Analysis Type: HMA on Aggregate

Subgrade Modulus =103,42MPa (Subgrade Category is B)

Evaluation Pavement Thickness = 652 mm

Pass to Traffic Cycle (PtoTC) Ratio = 1,00

Maximum number of wheels per gear = 4

CDF = 0,000

At least one aircraft has 4 or more wheels per gear.

Results Table 1. Input Traffic Data

No.	Aircraft Name	Gross Weight (kg)	Percent Gross Weight	Tire Pressure (MPa)	Annual Departure	20 Years Coverage
1	A310-200	142.900	93,20	1.330,00	200	6.851
2	B737-200	52.617	92,80	1.089,37	1.000	32.222
3	B737-700	70.307	91,80	1.358,27	800	26.723

Results Table 2. PCR Value

No.	Aircraft Name	Critical aircraft Total equiv. departures	Max allowable Gross Weight of critical aircraft (kg)	ACR Thick at max. MGW (mm)	PCR/F/B
1	A310-200	454	177.503	575	487,0

Results Table 3. HMA on Aggregate ACR at Indicated Gross Weight and Strength

No.	Aircraft Name	Gross Weight (kg)	Percent Gross Weight on Main Gear	Tire Pressure (MPa)	ACR Thick (mm) (B)	ACR/F/B
1	A310-200	142.900	93,2	1.330,00	511	368,1
2	B737-200	52.617	92,8	1.089,37	432	247,6
3	B737-700	70.307	91,8	1.358,27	500	345,1

FAARFIELD 2.1 Reports

PCR Graph

All Project aircraft have ACR < PCR

No.	Aircraft Name	Aircraft ACR	Calculated PCR	Annual Departure
1	A310-200	368,1	487,0	200
2	B737-700	345,1	-	800
3	B737-200	247,6	-	1.000

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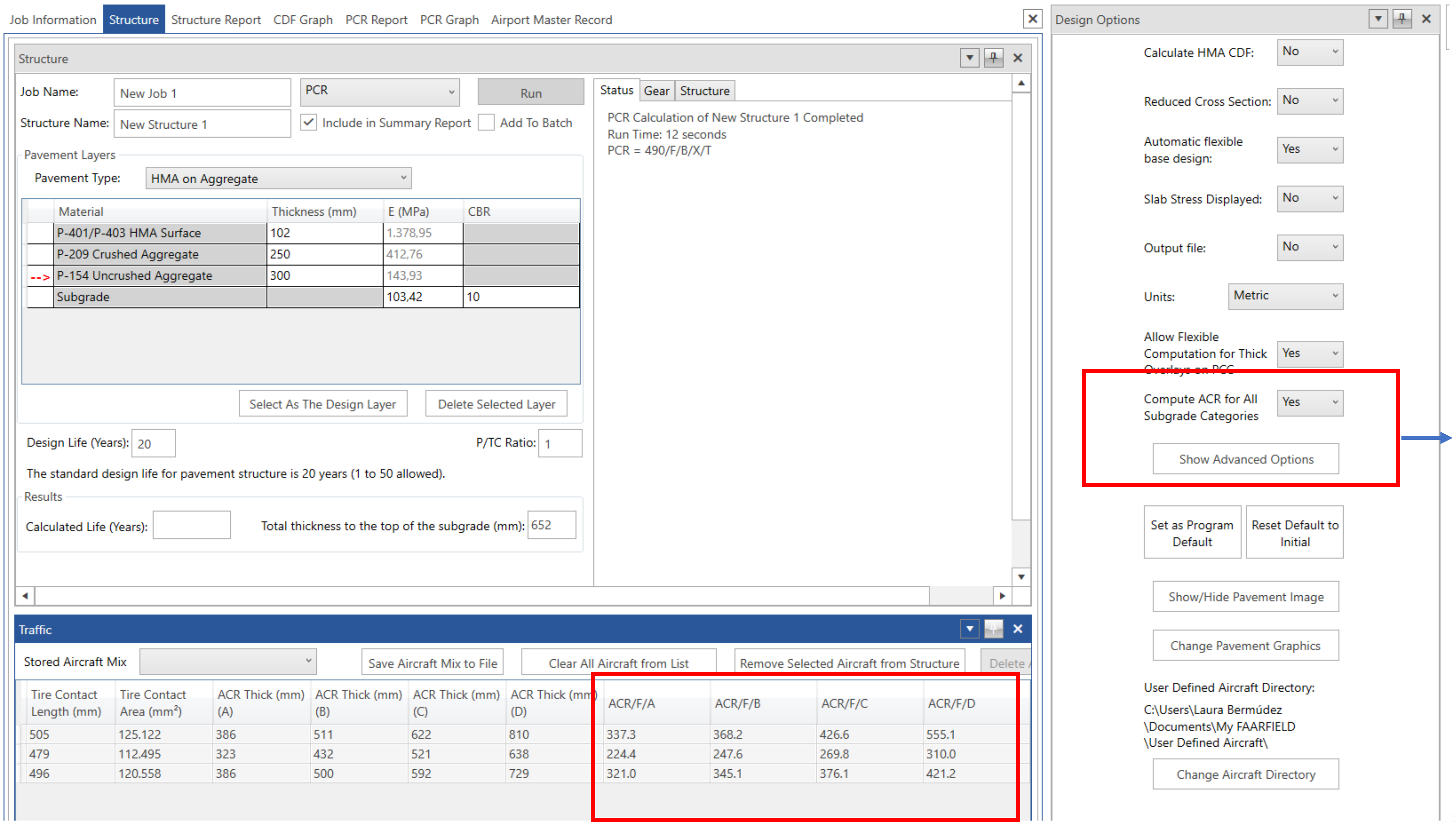
FAARFIELD 2.1 PCR calculation



ACR calculation for all types of SR

ACR / all types of SR

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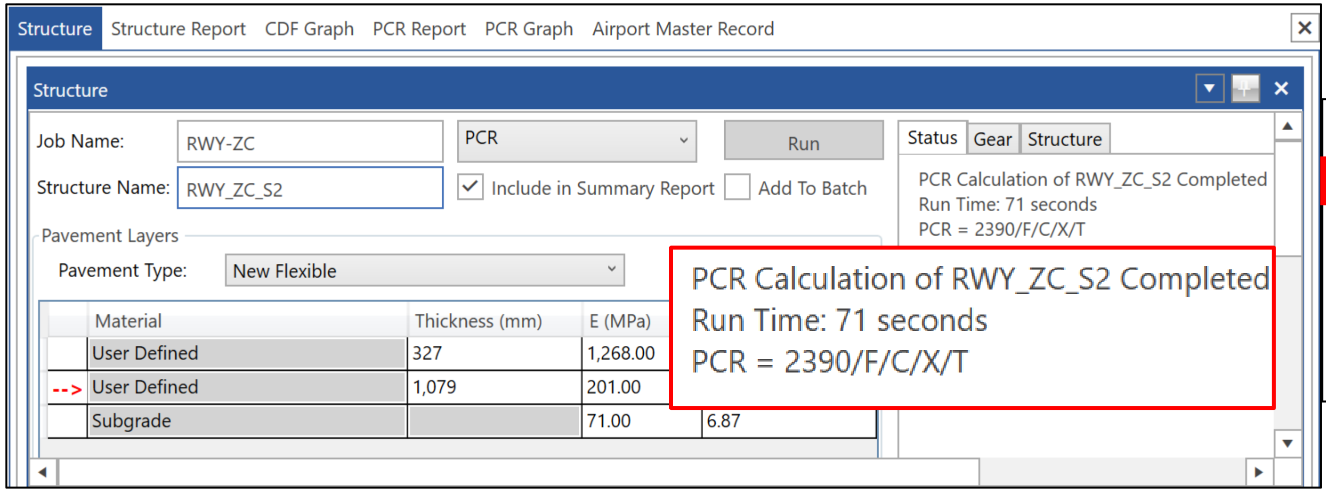
PCR value:



No.	Aircraft Name	Aircraft ACR	Calculated PCR
1	A321-100 std	474.8	2388.2
2	B737-800	447.9	-
3	A320-200 std	399.6	-
4	B737-700	376.1	-
5	A319-100 std	326.1	-
6	B737-200	269.8	-
7	EMB-175 STD	188.1	-

FOR ELEVATED PCR VALUES, THE CIRCULAR RECOMMENDS REPORTING THE VALUE OF THE CRITICAL ACR +25%:

PCR = 1.25 * ACR

590/F/C/C/X/T = 1.25 * 470

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Case study 1: Flexible pavement

- ✓ An airport has a runway with a flexible pavement (asphalt surface).
- ✓ Estimated subgrade strength of **CBR 8%.**
- ✓ Existing pavement structure:

Coating / Material		e (in)	e (mm)	CBR (%)
Asphalt surface course	P-401	4	102	
Cement-stabilized base	P-304	5	127	
Granular base	P-209	6	152	
granular subbase	P-154	17	432	
Subgrade				8

Case study 1: Flexible pavement

Air traffic, departures only

No.	Aircraft Name	Gross Weight, lbs.	Annual Departures	Tire Pressure, psi
1	A300-B4 Std	365,747	1,500	216.1
2	A319-100 Std	141,978	1,200	172.6
4	B737-300	140,000	6,000	201.0
5	B747-400	877,000	1,000	200.0
6	B767-200 ER	396,000	2,000	190.0
7	B777-200 ER	657,000	1,000	205.0
8	DC8-63	330,000	3,000	194.0

Case study 1: Flexible pavement

Applying the correlation E = 1500 × CBR yields an estimated modulus, E, of 12,000 psi = 83 MPa.

Subgrade strength wing category = "C".

Categoría de resistencia de la subrasante	Soporte de la subrasante E (Modulo elástico) psi (MPa)	Representación E psi (MPa)	Código designado
Alto	29008 (200)	E ≥ 21,756 (≥ 150)	A
Medio	17405 (120)	21,756 > E ≥ 14,504 (150 > E ≥100)	B
Bajo	11603 (80)	14,504 > E ≥ 8,702 (100 > E ≥ 60)	C
Muy Bajo	7252 (50)	E < 8,702 (E< 60)	D

❑ Operating considerations

- Fuel is obtained at the airport
- The runway has a parallel taxiway therefore the P/TC = 1.0

Figure A-1. Traffic Load Distribution Patterns

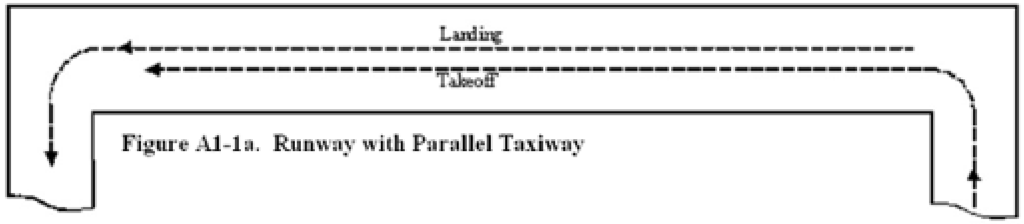
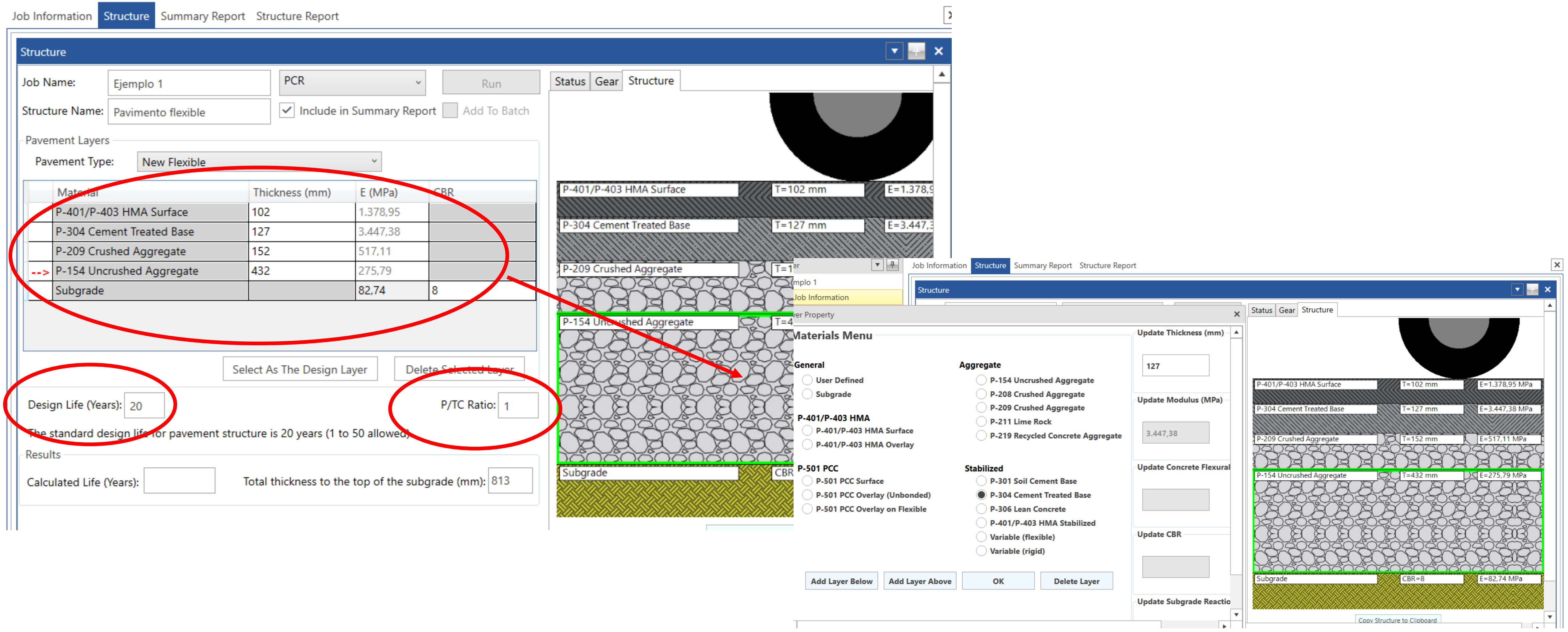


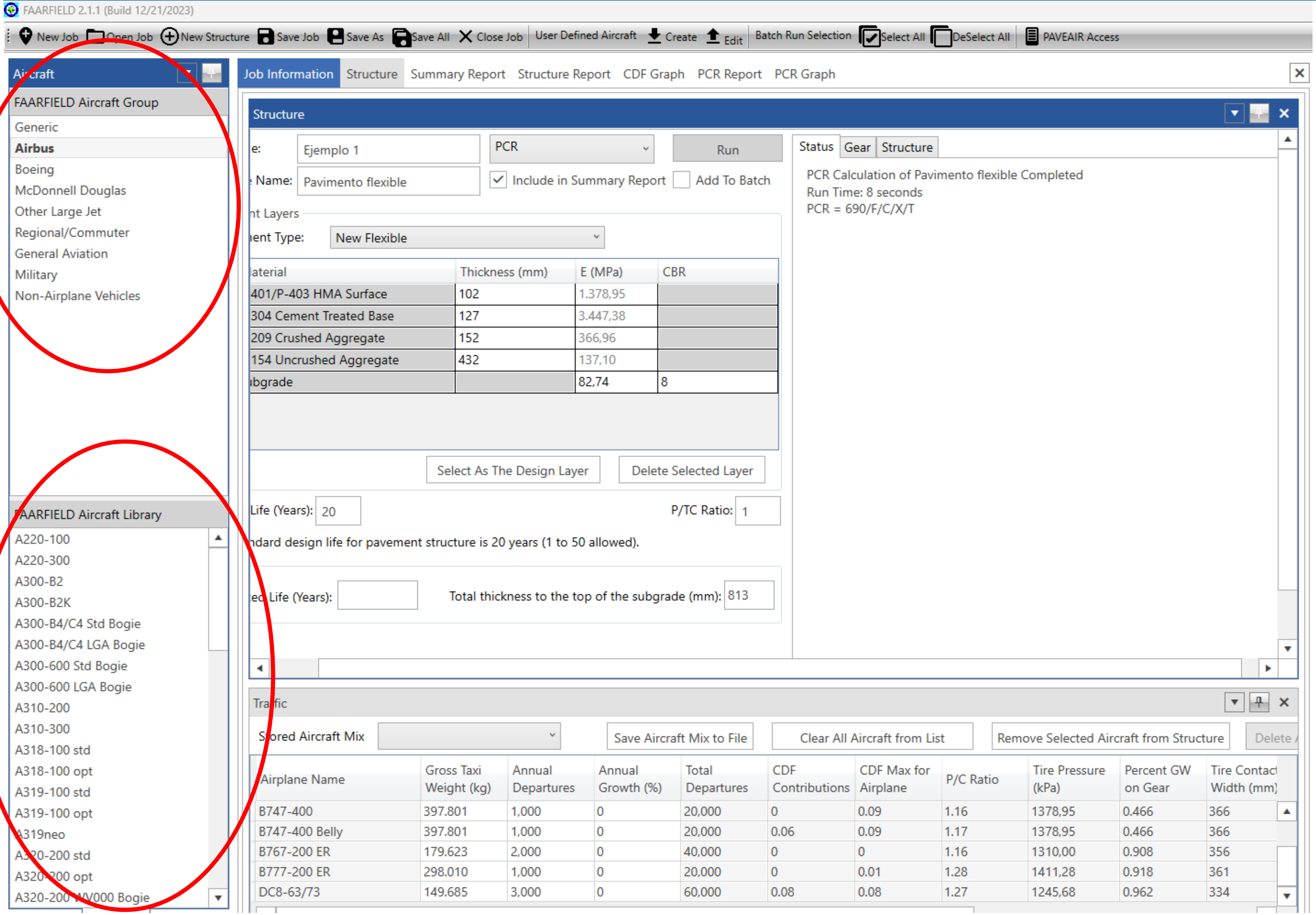
Figure A1-1a. Runway with Parallel Taxiway

Case study 1: Flexible pavement

- ✓ Create project
- ✓ Define pavement structure

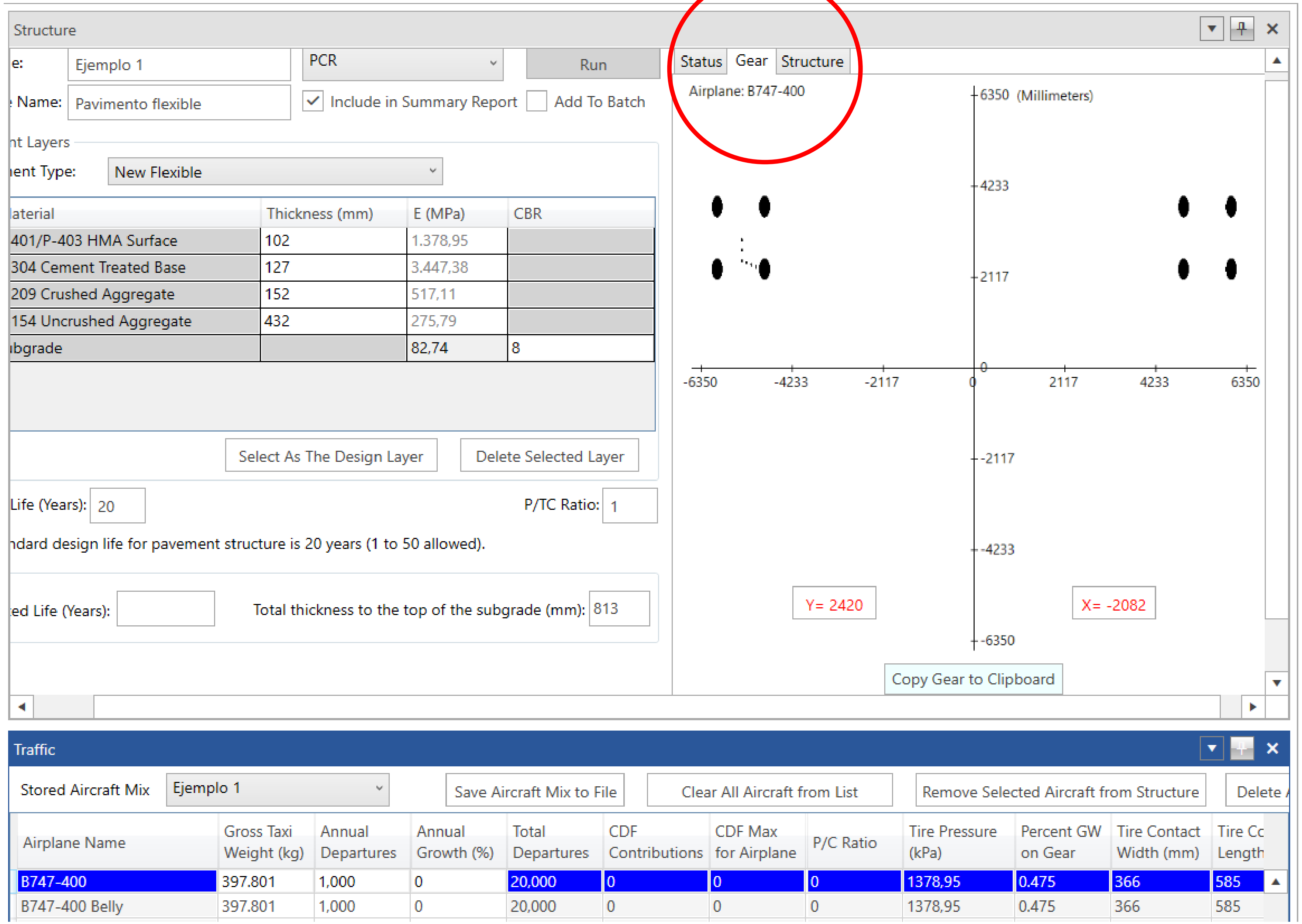


Case study 1: Flexible pavement



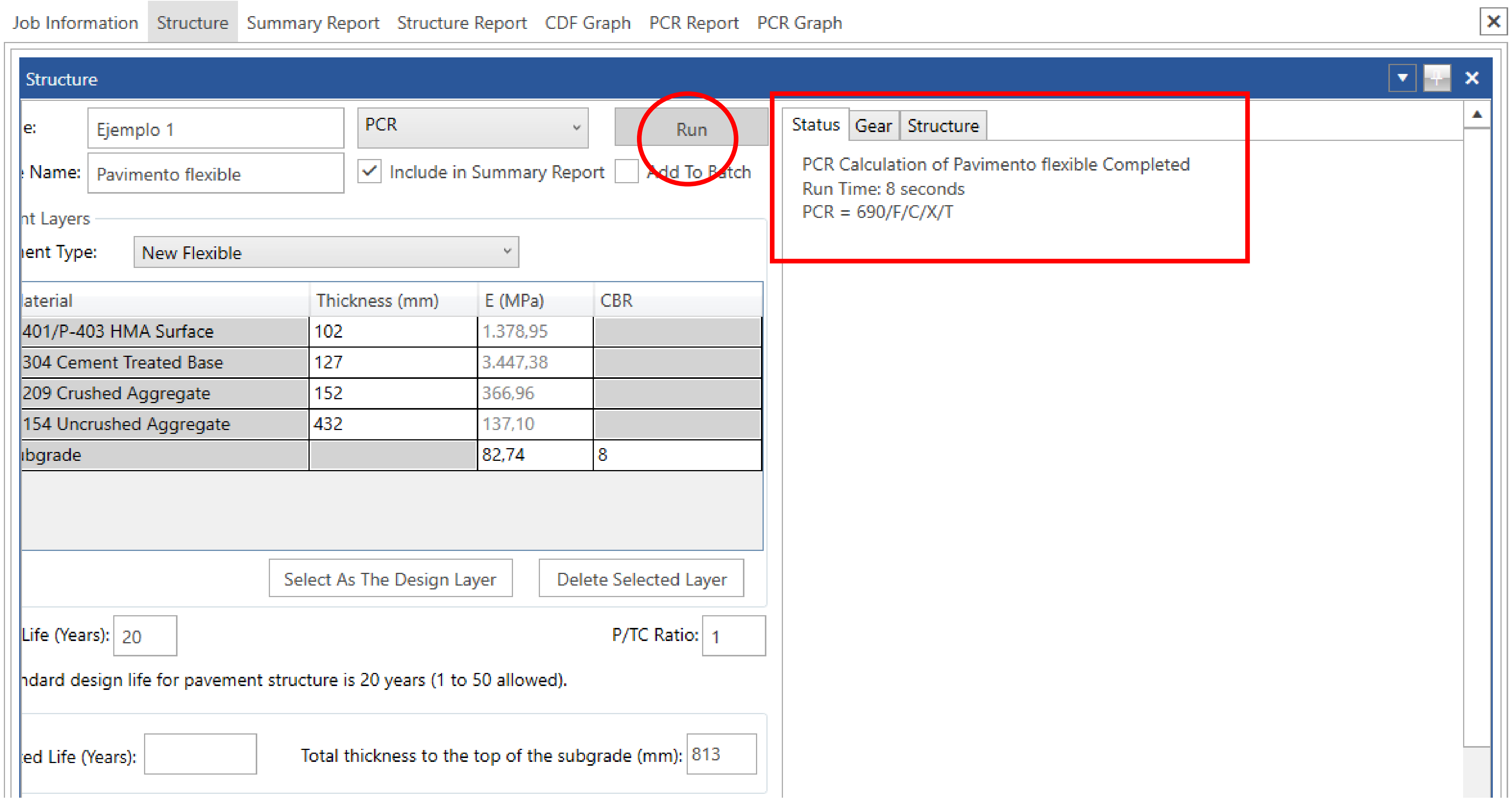
Define aircraft fleet

Case study 1: Flexible pavement



Display train configuration

Case study 1: Flexible pavement



PCR calculation

PCR = 690/F/C/C/X/T

F: Flexible

C: SR category, low

X: Pressure, high (lim 254 psi, 1.75 MPa)

T: technical

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Case study 1: Flexible pavement

Traffic

Stored Aircraft Mix | Save Aircraft Mix to File | Clear All Aircraft from List | Remove Selected Aircraft from Structure | Delete

Airplane Name	Gross Taxi Weight (kg)	Annual Departures	Annual Growth (%)	Total Departures	CDF Contributions	CDF Max for Airplane	P/C Ratio	Tire Pressure (kPa)	Percent GW on Gear	Tire Contact Width (mm)
A300-B4/C4 Std Bogie	165.900	1,500	0	30,000	0.01	0.04	1.22	1490,03	0.94	321
A319-100 std	64.400	1,200	0	24,000	0	0	1.23	1192,79	0.926	316
B737-300	63.503	6,000	0	120,000	0	0	1.3	1385,85	0.908	291
B747-400	397.801	1,000	0	20,000	0	0.09	1.16	1378,95	0.466	366
B747-400 Belly	397.801	1,000	0	20,000	0.06	0.09	1.17	1378,95	0.466	366
B767-200 ER	179.623	2,000	0	40,000	0	0	1.16	1310,00	0.908	356
B777-200 ER	298.010	1,000	0	20,000	0	0.01	1.28	1411,28	0.918	361
DC8-63/73	149.685	3,000	0	60,000	0.08	0.08	1.27	1245,68	0.962	334

Tire Pressure (psi)
216
173
201
200
200
190
205
181

PCR = 620/F/C/X/T

F: Flexible

C: SR category, low

X: Pressure, high (lim 254 psi, 1.75 MPa)

T: technical

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Case study 1: Flexible pavement

Reports

Pavement Structure Information by Layer

No.	Type	Thickness (in.)	Modulus (psi)	CBR	Poisson's Ratio	Strength R (psi)
1	P-401/P-403 HMA Surface	4,0	200.000	0	0.35	0
2	P-304 Cement Treated Base	5,0	500.000	0	0.2	0
3	P-209 Crushed Aggregate	6,0	53.224	0	0.35	0
4	P-154 Uncrushed Aggregate	17,0	19.885	0	0.35	0
5	Subgrade	0	12.000	8	0.35	0

Airplane Information

No.	Name	Gross Wt. (lbs)	Annual Departures	% Annual Growth
1	A300-B4/C4 Std Bogie	365.747	1.500	0
2	A319-100 std	141.978	1.200	0
3	B737-300	140.000	6.000	0
4	B747-400	877.000	1.000	0
5	B747-400 Belly	877.000	1.000	0
6	B767-200 ER	396.000	2.000	0
7	B777-200 ER	657.000	1.000	0
8	DC8-63/73	330.000	3.000	0

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Case study 1: Flexible pavement

Reports

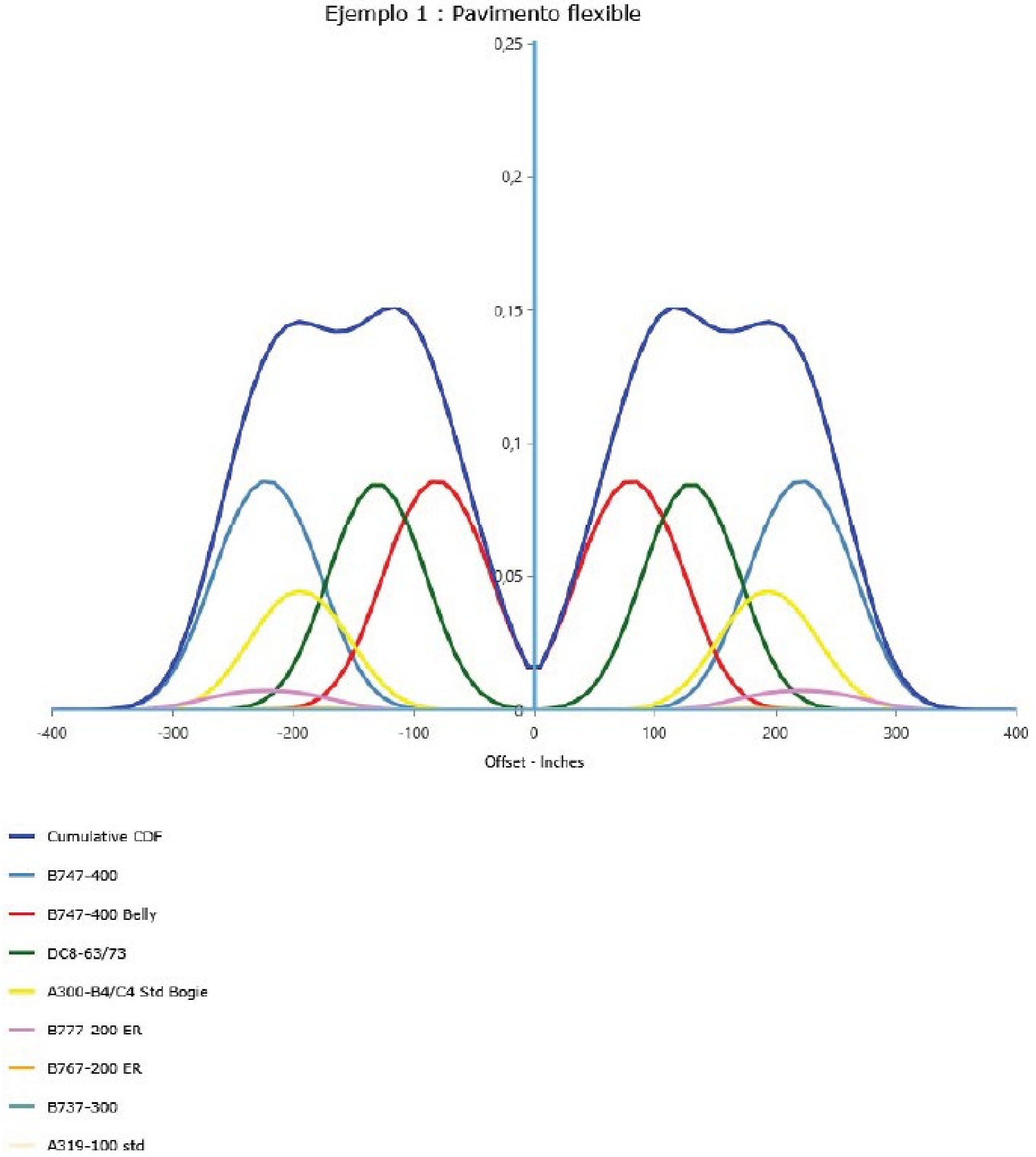
Additional Airplane Information

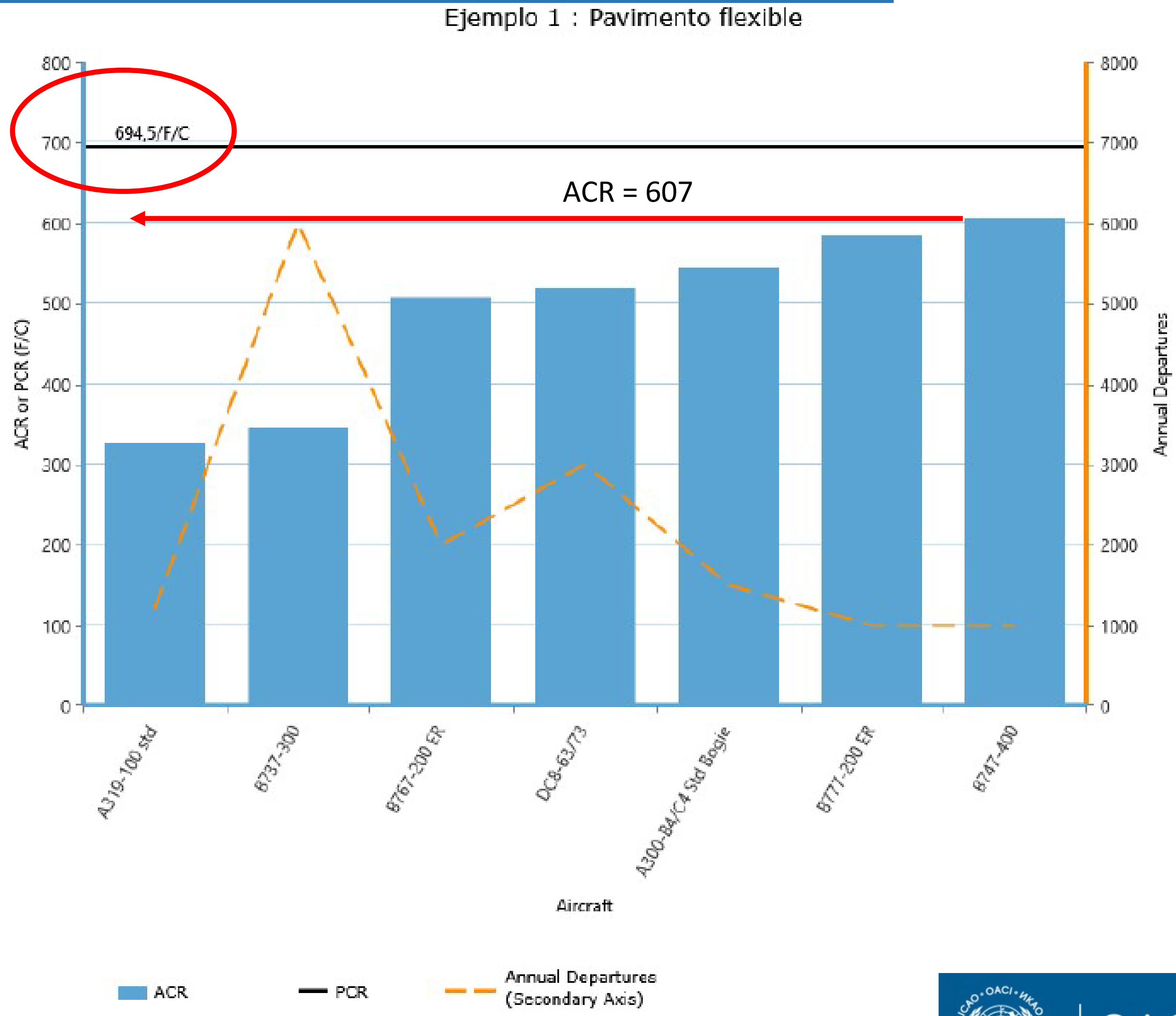
Subgrade CDF

No.	Name	CDF Contribution	CDF Max for Airplane	P/C Ratio
1	A300-B4/C4 Std Bogie	0,01	0,04	1,22
2	A319-100 std	0,00	0,00	1,23
3	B737-300	0,00	0,00	1,3
4	B747-400	0,00	0,09	1,16
5	B747-400 Belly	0,06	0,09	1,17
6	B767-200 ER	0,00	0,00	1,16
7	B777-200 ER	0,00	0,01	1,28
8	DC8-63/73	0,08	0,08	1,27

Case study 1: Flexible pavement

Reports





OACI

Case study 1: Flexible pavement

Reports

Results Table 1. Input Traffic Data

No.	Aircraft Name	Gross Weight (kg)	Percent Gross Weight	Tire Pressure (MPa)	Annual Departure	20 Years Coverage
1	A300-B4/C4 Std Bogie	165.900	94,00	1.490,03	1.500	24.506
2	A319-100 std	64.400	92,60	1.192,79	1.200	19.572
3	B737-300	63.503	90,80	1.385,85	6.000	92.625
4	B747-400	397.801	46,60	1.378,95	1.000	17.186
5	B747-400 Belly	397.801	46,60	1.378,95	1.000	17.152
6	B767-200 ER	179.623	90,80	1.310,00	2.000	34.479
7	B777-200 ER	298.010	91,80	1.411,28	1.000	15.662
8	DC8-63/73	149.685	96,20	1.245,68	3.000	47.357

Results Table 2. PCR Value

No.	Aircraft Name	Critical aircraft Total equiv. departures	Max allowable Gross Weight of critical aircraft (kg)	ACR Thick at max. MGW (mm)	PCR/F/C
1	B747-400	1.755	429.916	770	694,5

Results Table 3. New Flexible ACR at Indicated Gross Weight and Strength

No.	Aircraft Name	Gross Weight (kg)	Percent Gross Weight on Main Gear	Tire Pressure (MPa)	ACR Thick (mm) (C)	ACR/F/C
1	A300-B4/C4 Std Bogie	165.900	94	1.490,03	691	545,9
2	A319-100 std	64.400	92,6	1.192,79	559	326,1
3	B737-300	63.503	90,8	1.385,85	572	345,6
4	B747-400	397.801	93,2	1.378,95	724	607,1
5	B767-200 ER	179.623	90,8	1.310,00	668	507,9
6	B777-200 ER	298.010	91,8	1.411,28	714	585,5
7	DC8-63/73	149.685	96,2	1.245,68	676	520,8

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Case study 1: Flexible pavement

Reports

Calculation of ACR for all subgrade categories

Results Table 3. Continue

No.	Aircraft Name	ACR Thick (mm)(A)	ACR Thick (mm)(B)	ACR Thick (mm)(C)	ACR Thick (mm)(D)	ACR/F/A	ACR/F/B	ACR/F/C	ACR/F/D
1	A300-B4/C4 Std Bogie	426,72	558,8	690,88	906,78	413,3	456,7	545,9	738,3
2	A319-100 std	360,68	472,44	558,8	685,8	280,9	302,5	326,1	364,8
3	B737-300	368,3	480,06	571,5	703,58	291,4	313,4	345,6	388,7
4	B747-400	457,2	589,28	723,9	955,04	473,8	518,3	607,1	832,9
6	B767-200 ER	424,18	551,18	668,02	871,22	407,4	442,5	507,9	664
7	B777-200 ER	457,2	581,66	713,74	975,36	469,9	501,6	585,5	878
8	DC8-63/73	403,86	541,02	675,64	891,54	368,6	421,7	520,8	708,6

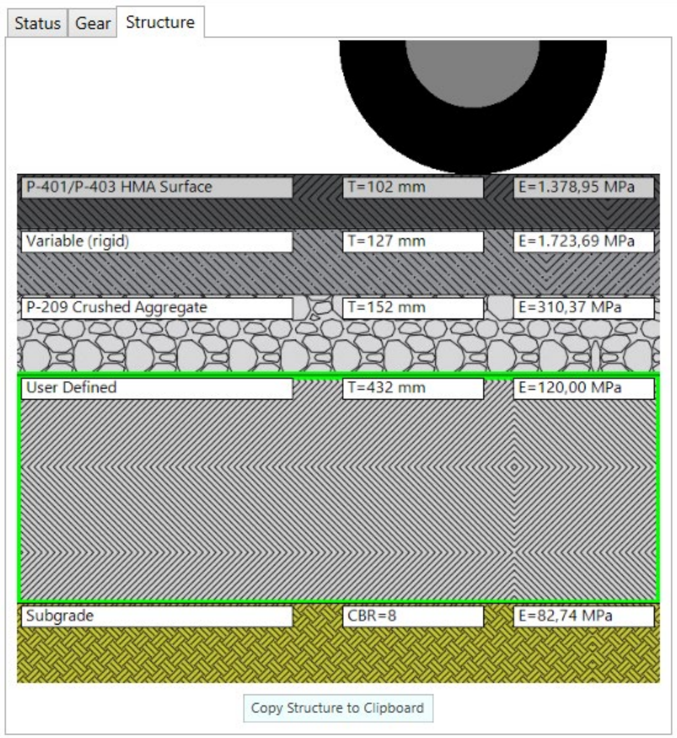
Case study 1: Flexible pavement

Reports

Layer module definition

Back-calculated modules:

Layer / Material ------------Modulus (MPa)	
Asphalt surface course	1300
Cement-stabilized base	1500
Granular base	250
granular subbase	120
Subgrade	84

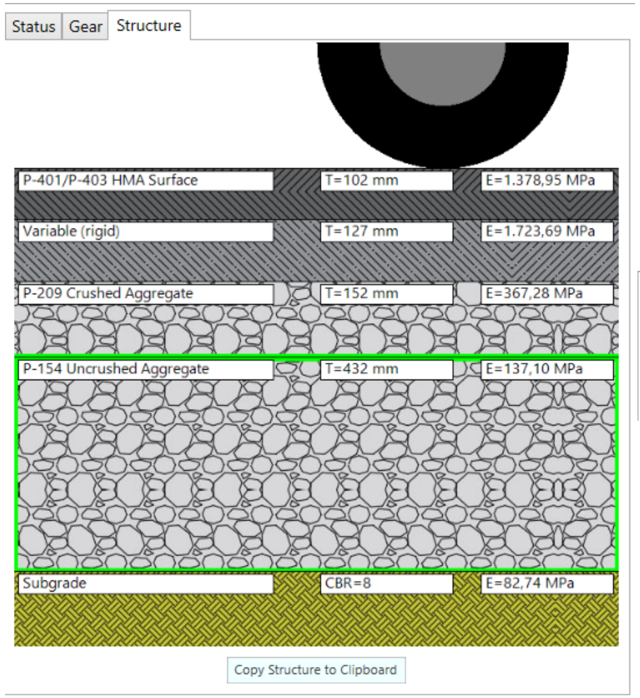


Option 1

Status Gear Structure

PCR Calculation of New Structure 1 Completed
Run Time: 8 seconds
PCR = 590/F/C/X/T

ACR super at 3% = ok



Option 2

Status Gear Structure

PCR Calculation of New Structure 1 Completed
Run Time: 7 seconds
PCR = 600/F/C/X/T

ACR exceeds 1% = ok

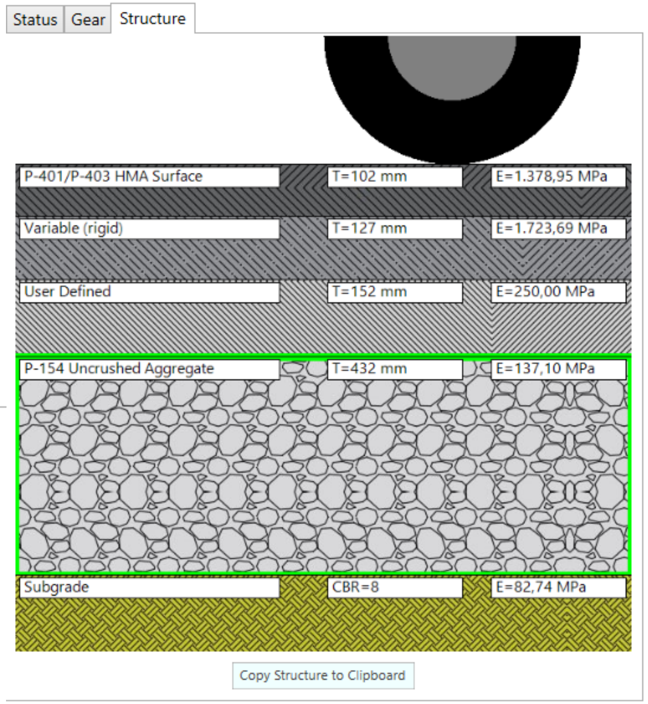
ACR = 607

Option 3

Status Gear Structure

PCR Calculation of New Structure 1 Completed
Run Time: 8 seconds
PCR = 580/F/C/X/T

ACR exceeds 5% = ok



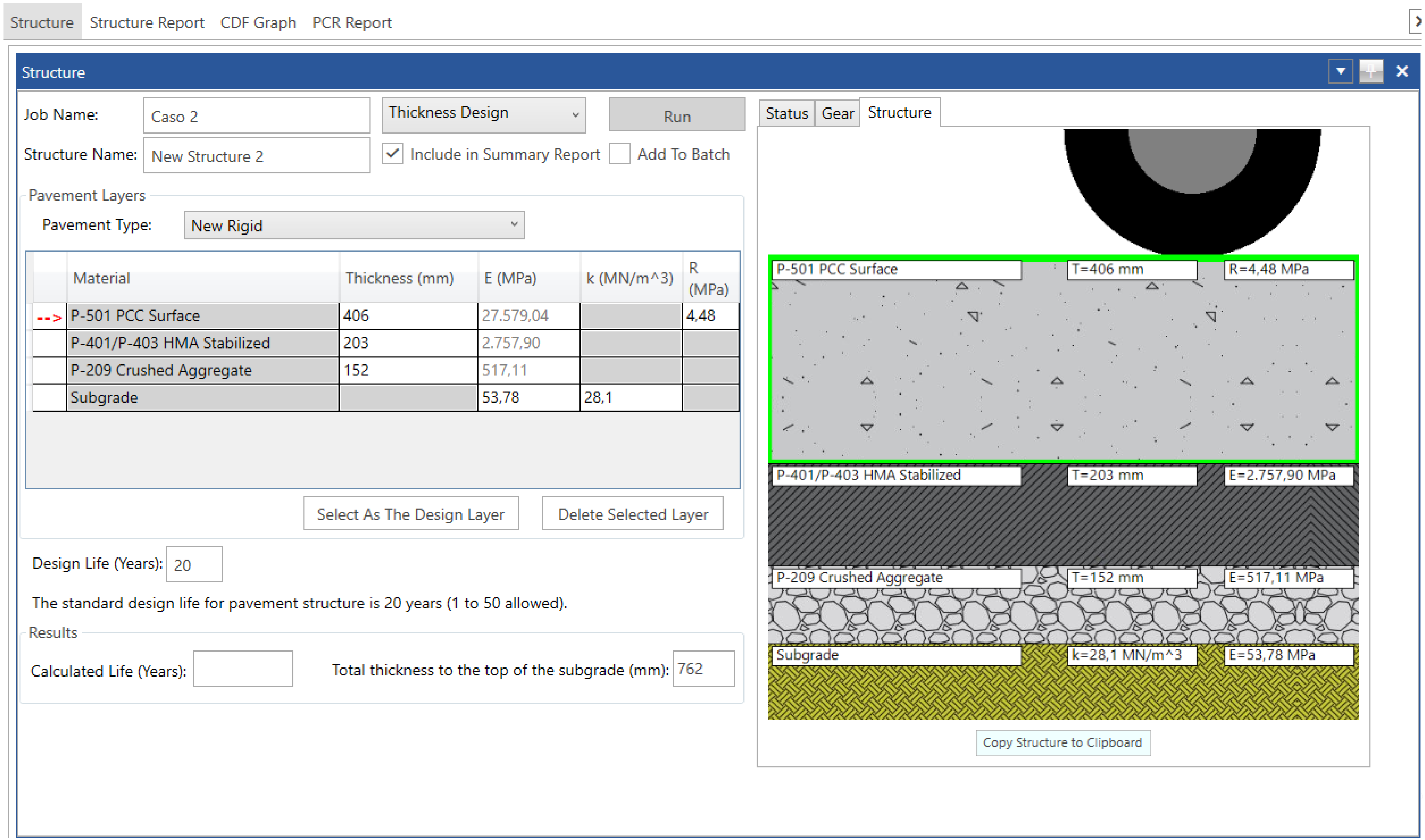
Case study 2: Rigid pavement

One airport has a runway with a hydraulic concrete surface.

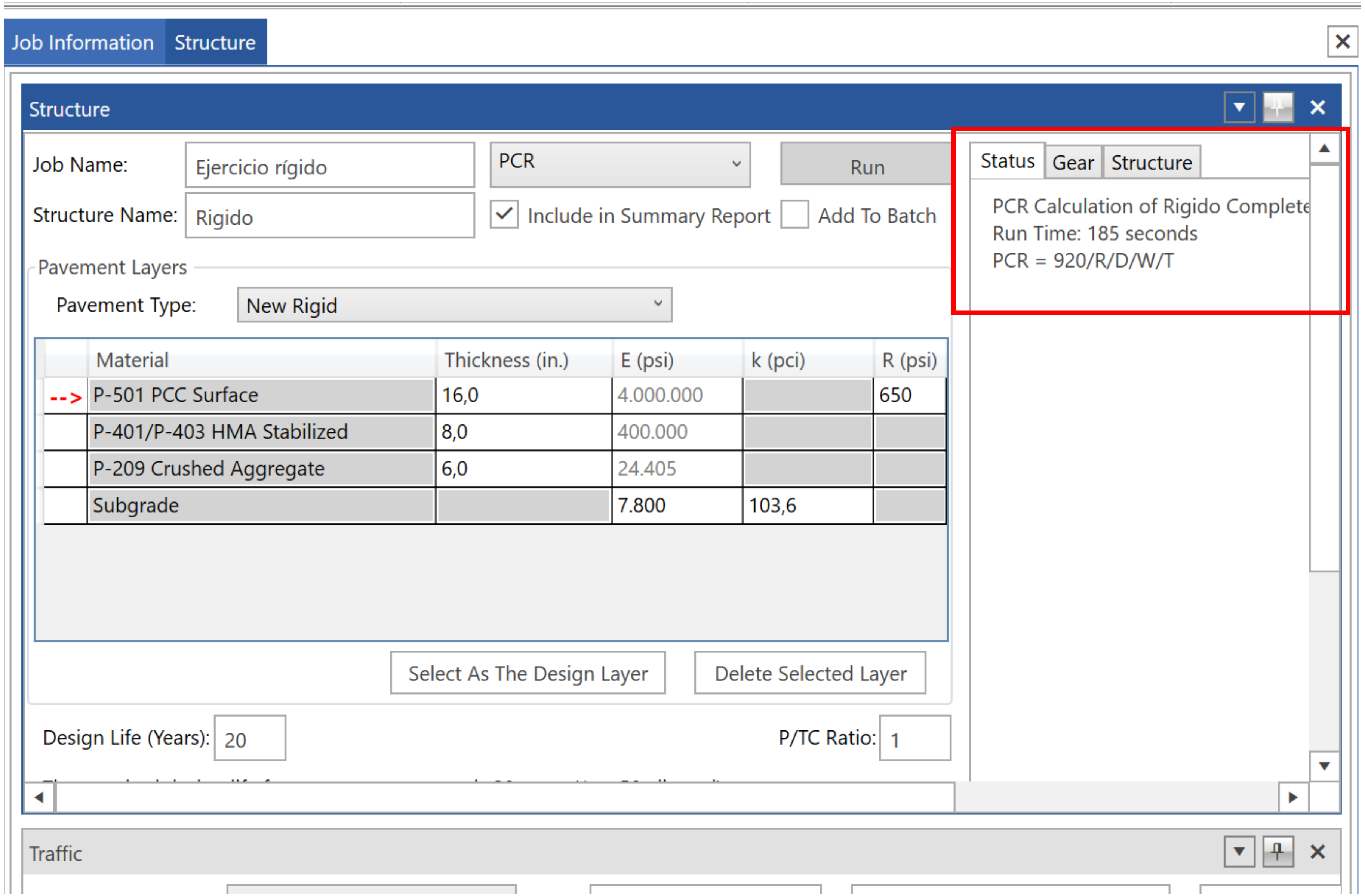
The breaking strength of concrete is 650 psi = 4.5 MPa.
From the deflectometry study, a SR modulus of 7800 psi = 54 MPa was obtained.

Coating / Material		e (in)	e (mm)	E psi (MPa)
Hydraulic concrete layer	P-501	16	406	
Asphalt-stabilized base	P-403	8	203	
Granular base	P-209	6	152	
Subgrade				7800 (54)

Case study 2: Rigid pavement



Case study 2: Rigid pavement



Case study 2: Rigid pavement

Results Table 2. PCR Value

No.	Aircraft Name	Critical aircraft Total equiv. departures	Max allowable Gross Weight of critical aircraft (lbs)	ACR Thick at max. MGW (in.)	PCR/R/D
1	B777-200 ER	1.206	606.194	18,8	917,3

Results Table 3. New Rigid ACR at Indicated Gross Weight and Strength

No.	Aircraft Name	Gross Weight (lbs)	Percent Gross Weight on Main Gear	Tire Pressure (psi)	ACR Thick (in.) (D)	ACR/R/D
1	A300-B4/C4 Std Bogie	365.747	94	216	16,8	738,5
2	A319-100 std	141.978	92,6	173	12,5	412,3
3	B737-300	140.000	90,8	201	12,8	429,2
4	B747-400	877.000	93,2	200	18,1	855,5
5	B767-200 ER	396.000	90,8	190	16,6	714,8
6	B777-200 ER	658.000	91,8	205	20,0	1042,5
7	DC8-63/73	358.000	96,2	196	17,1	765,4

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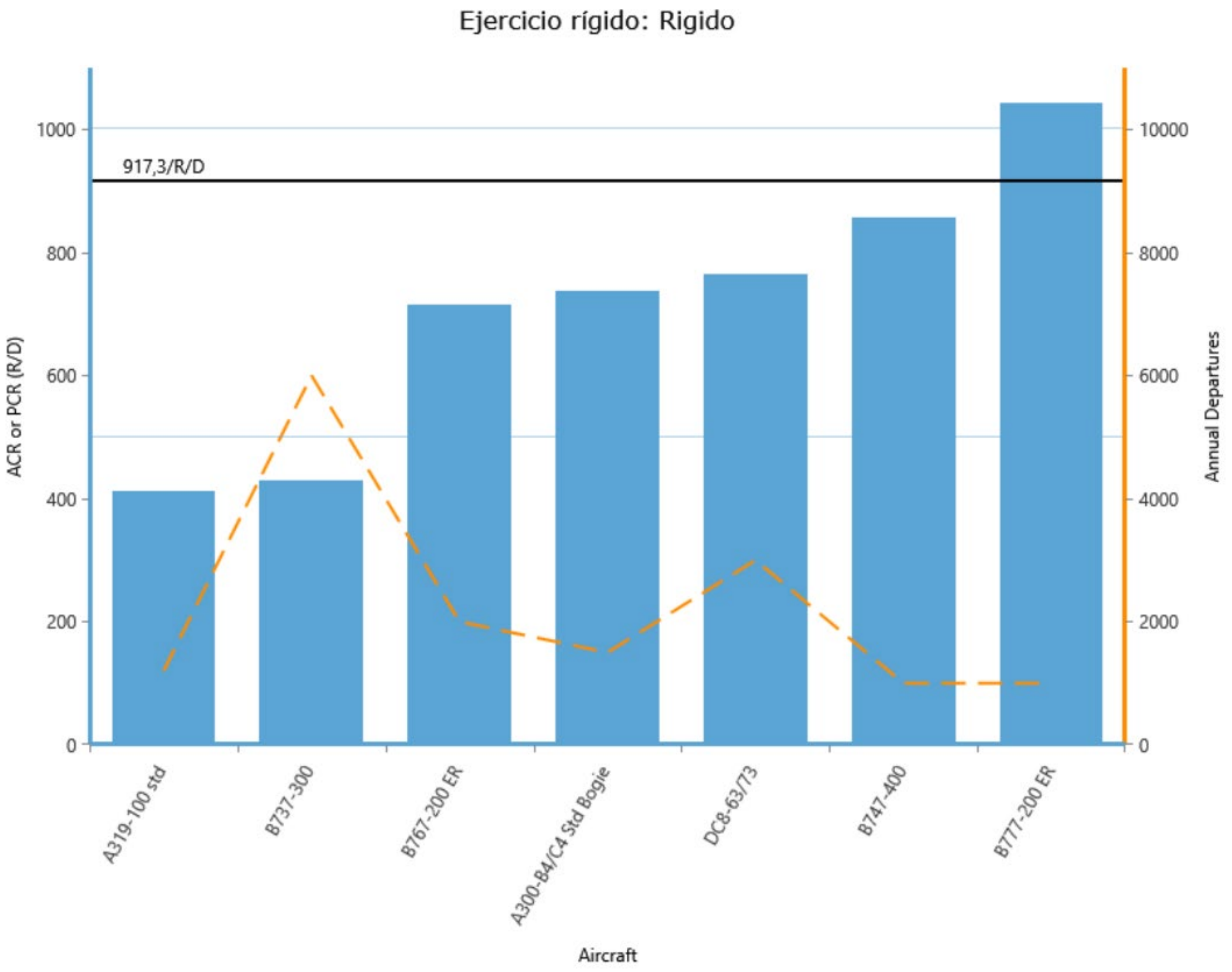
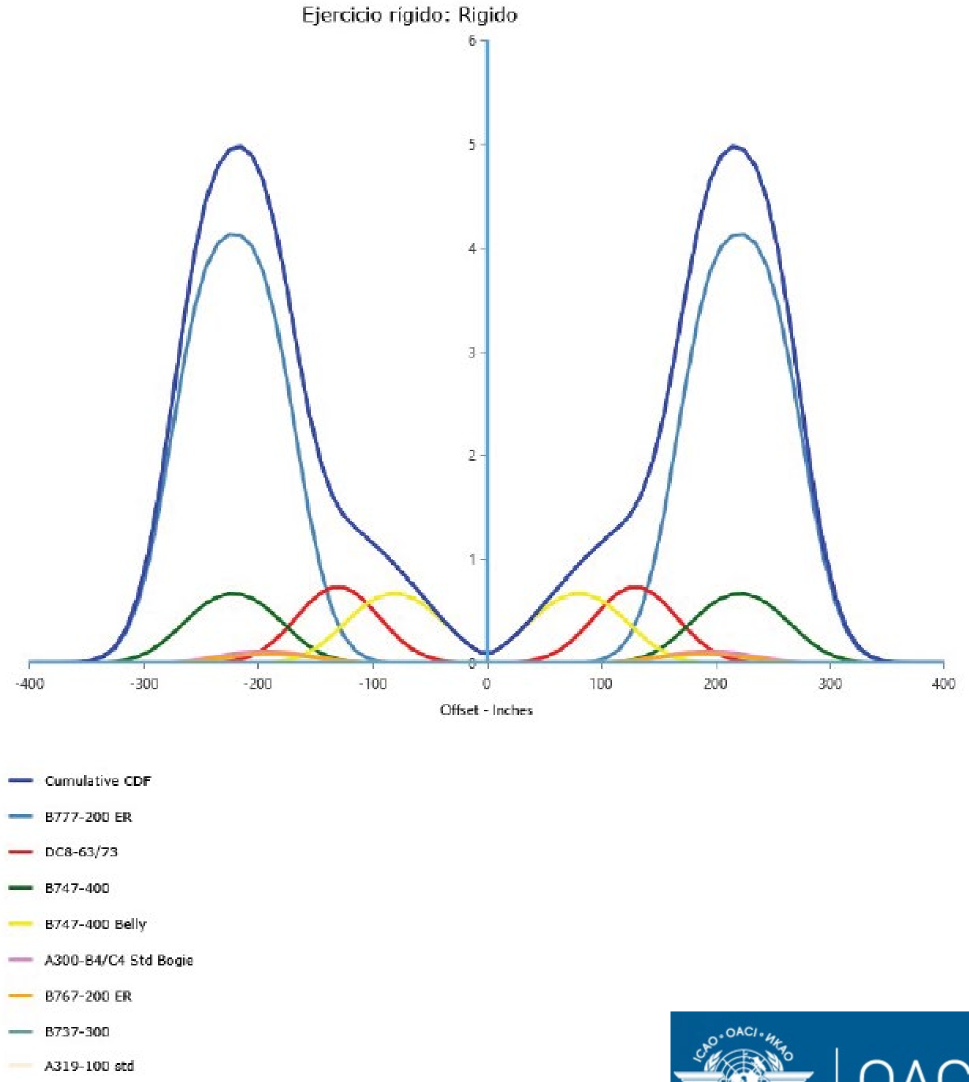
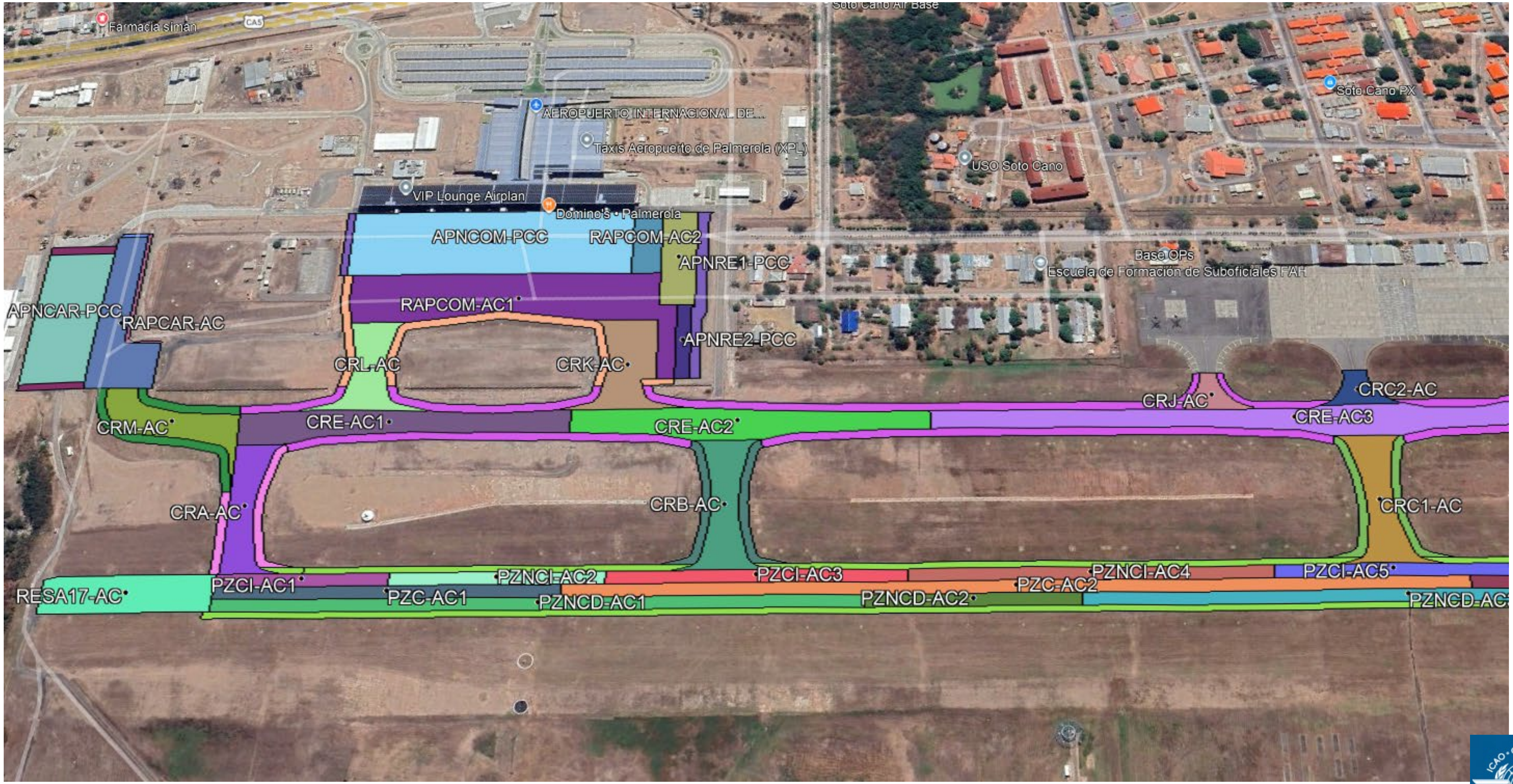
Case study 2: Rigid pavement





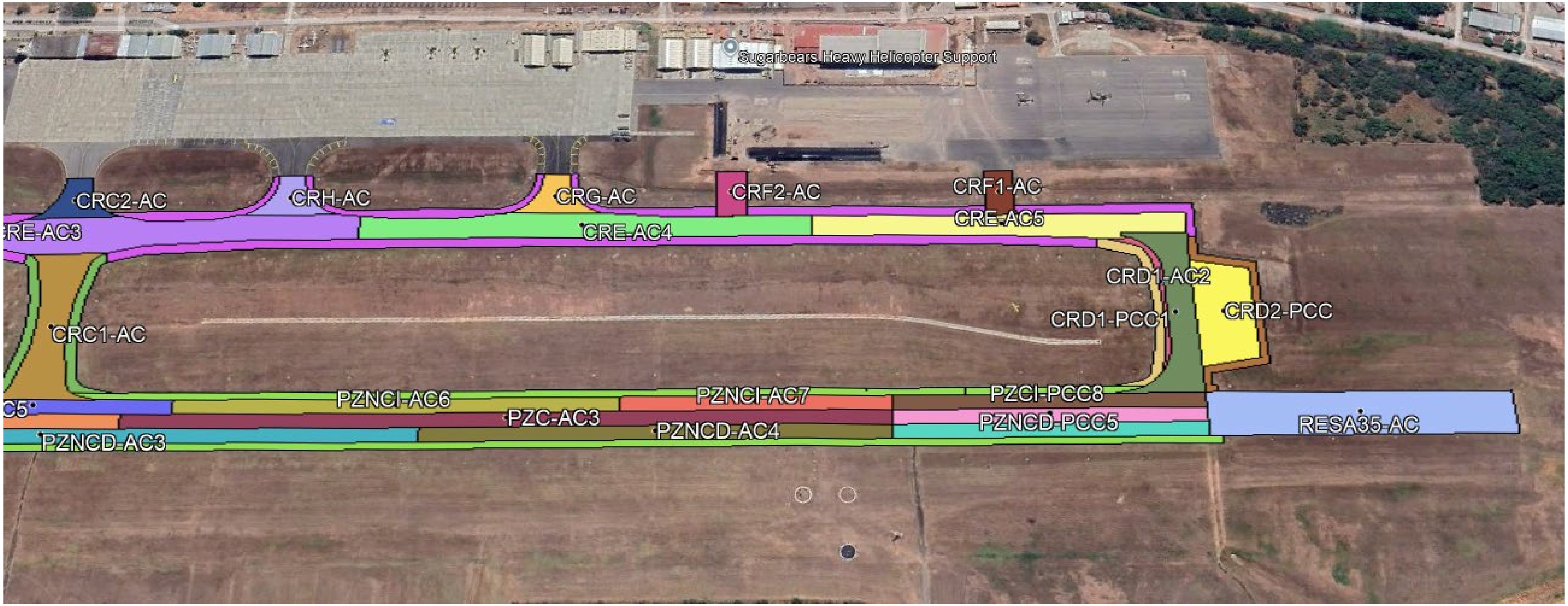
Airport A

Central zone runway (loaded zone)



Airport A

Central zone runway (loaded zone)



OACI

Airport A

Central zone runway (loaded zone)

Results of structural evaluation of the pavement by deflectometry study

Item name	Section ID	Initial Abscissa	Final Abscissa	Surface	Thickness (mm)			Modulus (MPa)			Back-calculated SR modulus deflection (MPa)	CBR (%)	MR (MPa)
					PCC	BG	SBG	PCC	BG	SBG			
Runway	PZC-PCC4	K2+137	K2+442	Rigid	350	240	300	20.789	649	350	176	17	4,1

PCC: concrete slab
BG: Granular Base
SBG: Granular subbase
MR: Modulus of rupture

Aircraft	CANCELED OUTPUTS
A319 neo	7
A320-200 std	150
A320-neo	1717
B737-700	12
B737-800	1973
A350-900	266
A330-300 WV0222	151
B767-300	276
B737-300	139

Airport A

Structure

Job Name: Caso 1 | PCR | Run

Structure Name: New Structure 2 | ☑ Include in Summary Report | ☐ Add To Batch

Status | Gear | Structure

PCR Calculation of New Structure 2 Completed
Run Time: 236 seconds
PCR = 530/R/B/W/T

Pavement Layers

Pavement Type: New Rigid

	Material	Thickness (mm)	E (MPa)	k (MN/m^3)	R (MPa)
-->	P-501 PCC Surface	350	27.579,04		4,10
	P-209 Crushed Aggregate	240	407,97		
	P-154 Uncrushed Aggregate	300	143,93		
	Subgrade		103,42	46,8	

ACR > PCR

830 > 530; in more than 10%.

Aircraft	annual departures	Distribution
A319 neo	7	0,1%
A320-200 std	150	3,2%
A320-neo	1.717	36,6%
B737-700	12	0,3%
B737-800	1.973	42,1%
A350-900	266	5,7%
A330-300 WV0222	151	3,2%
B767-300	276	5,9%
B737-300	139	3,0%
Total	4.691	100%

Results Table 2. PCR Value

No.	Aircraft Name	Critical aircraft Total equiv. departures	Max allowable Gross Weight of critical aircraft (kg)	ACR Thick at max. MGW (mm)	PCR/R/B
1	A350-900	312	195.992	334	529,1

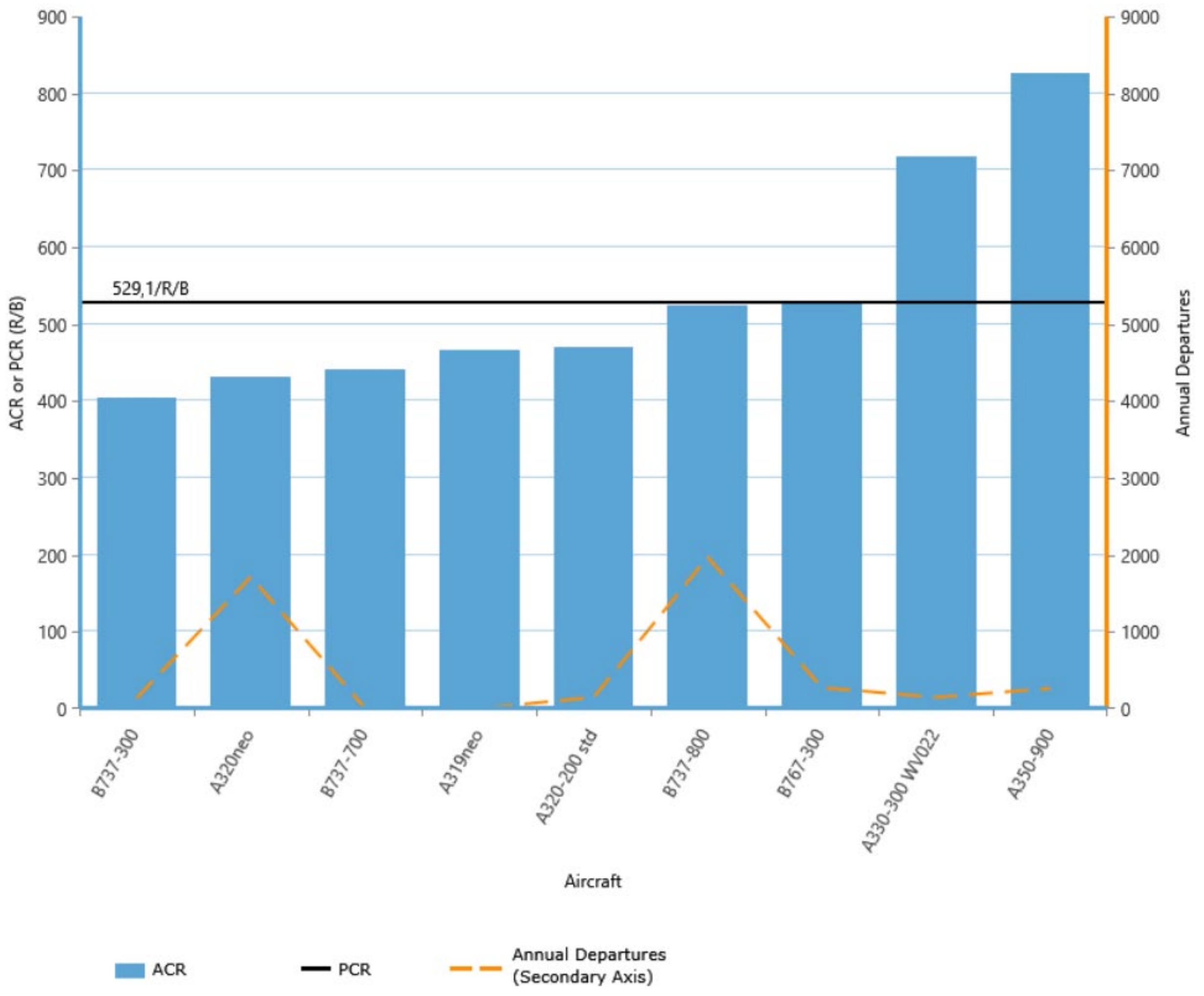
Results Table 3. New Rigid ACR at Indicated Gross Weight and Strength

No.	Aircraft Name	Gross Weight (kg)	Percent Gross Weight on Main Gear	Tire Pressure (MPa)	ACR Thick (mm) (B)	ACR/R/B
1	A319neo	75.900	91,39999	1.310,00	312	465,5
2	A320-200 std	73.900	93,8	1.378,95	315	470
3	A320neo	70.400	93,8	1.220,37	302	432,4
4	B737-700	70.307	91,8	1.358,27	305	441,5
5	B737-800	79.242	93,6	1.406,53	333	524,4
6	A350-900	272.900	94,8	1.661,64	419	825,6
7	A330-300 WV022	233.900	95,6	1.447,90	389	717,3
8	B767-300	163.747	95	1.378,95	333	527,1
9	B737-300	63.503	90,8	1.385,85	292	404

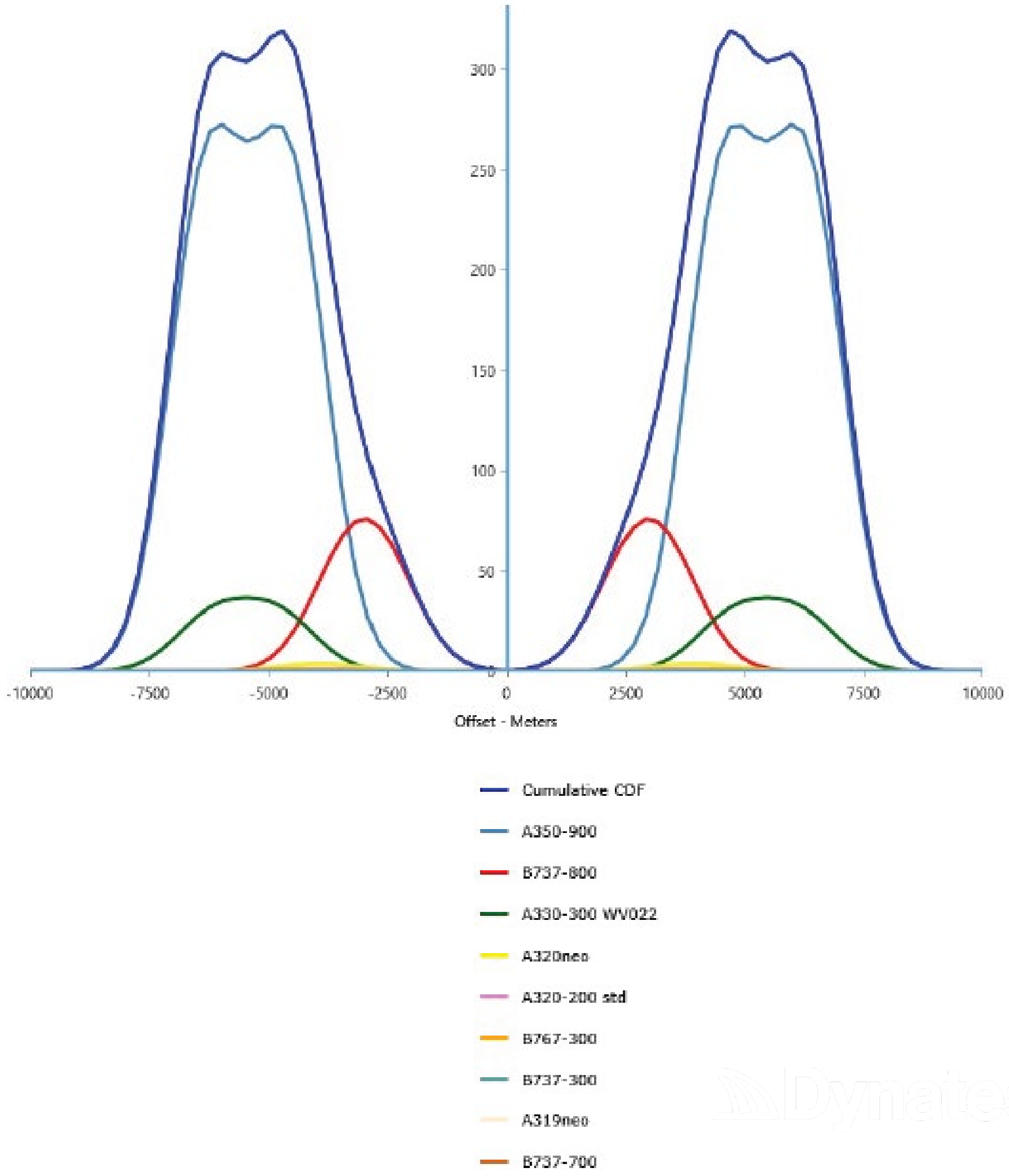
Does not comply

The annual number of overload traffic (A350-900 and A330-300) exceeds 5% of total annual air traffic.

Airport A



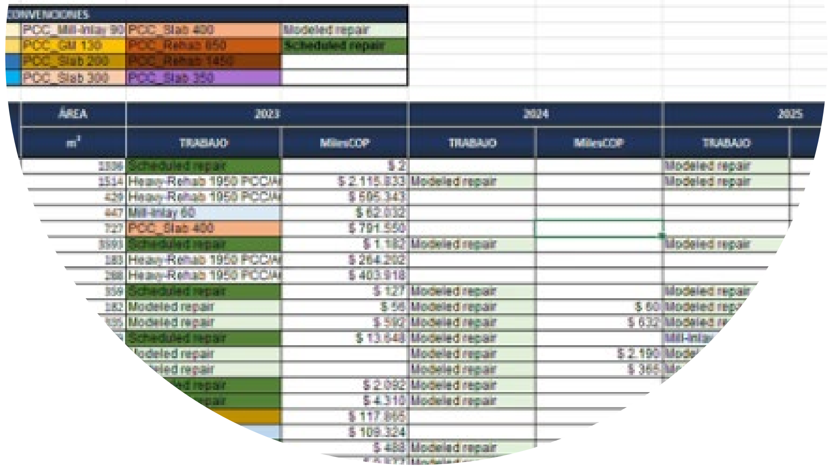
900
800
700
600
500
400
300
200
100
0
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
529,1/R/B
ACR or PCR (R/B)
Annual Departures
B737-300
A320neo
B737-700
A319neo
A320-200 std
B737-800
B767-300
A330-300 WV022
A350-900
Aircraft
ACR
PCR
Annual Departures (Secondary Axis)

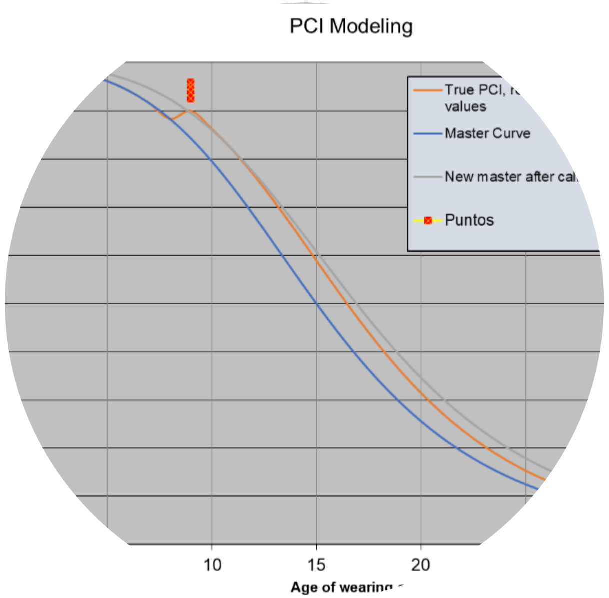


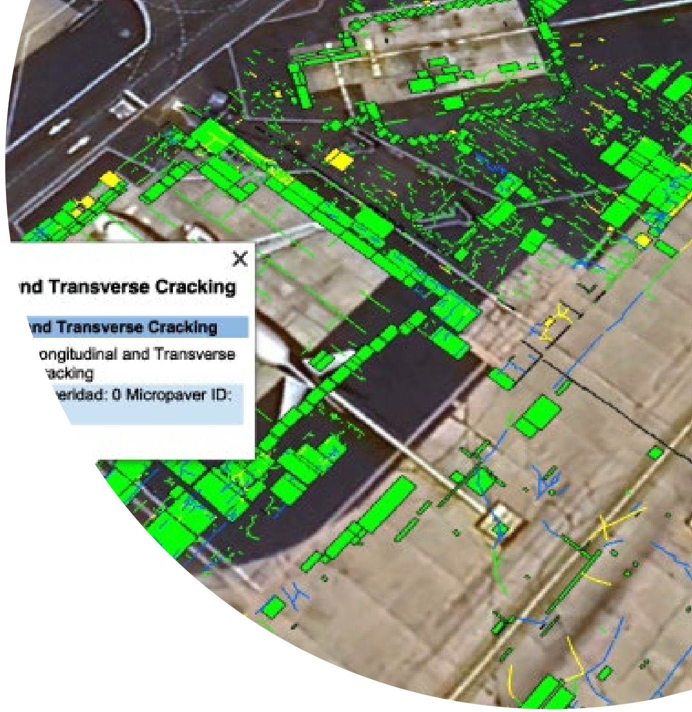
300
250
200
150
100
50
-10000
-7500
-5000
-2500
0
2500
5000
7500
10000
Offset - Meters
Cumulative CDF
A350-900
B737-800
A330-300 WV022
A320neo
A320-200 std
B767-300
B737-300
A319neo
B737-700

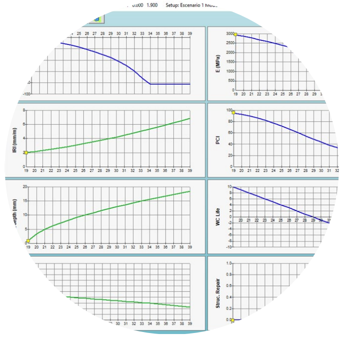

01 Dynatest
THE ROAD FOR FUTURE TRAVEL
4X4
Dynatest
Dynatest

Dynatest

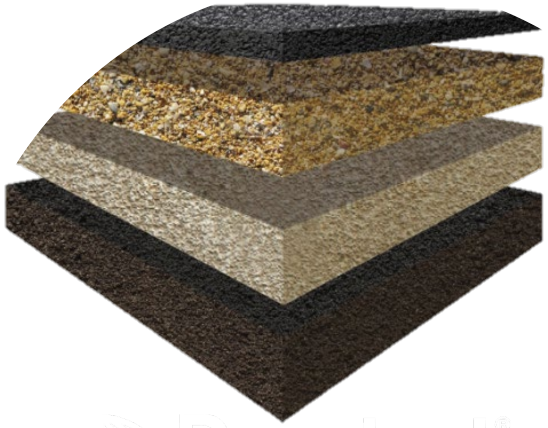








Thank you
Questions?
irodriguez@strinso.com



Gracias!

OACI