ICAO AERODROME PAVEMENT WORKSHOP

ACR/PCR Discussion Topics

Presented to: ICAO ACR/PCR Workshop
Dakar, Senegal

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Date: October 2024

Federal Aviation Administration

ACR/PCR Discussion Topics

- Criteria for occasional overloads
- Tire pressure limitations
- Overlay structures
- Using Aircraft PCR example
- Resources
- Open discussion

Criteria for Occasional Overloads

Occasional Overloads

- **The PCR should not be considered as a “hard” limit, nor as the maximum absolute pavement bearing strength.**
- **Annex 14 allows overload operations when ACR>PCR:**
  - “ICAO allowance” is increased to 10% of the PCR for both flexible and rigid pavements
  - Overloads in excess of 10% may be allowed if justified through a technical analysis of the impact on pavement damage.

Annex 14 on Overloads

20.1.1 … 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;*

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

20.1.2 Such overload movements should not normally be permitted on pavement 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.*

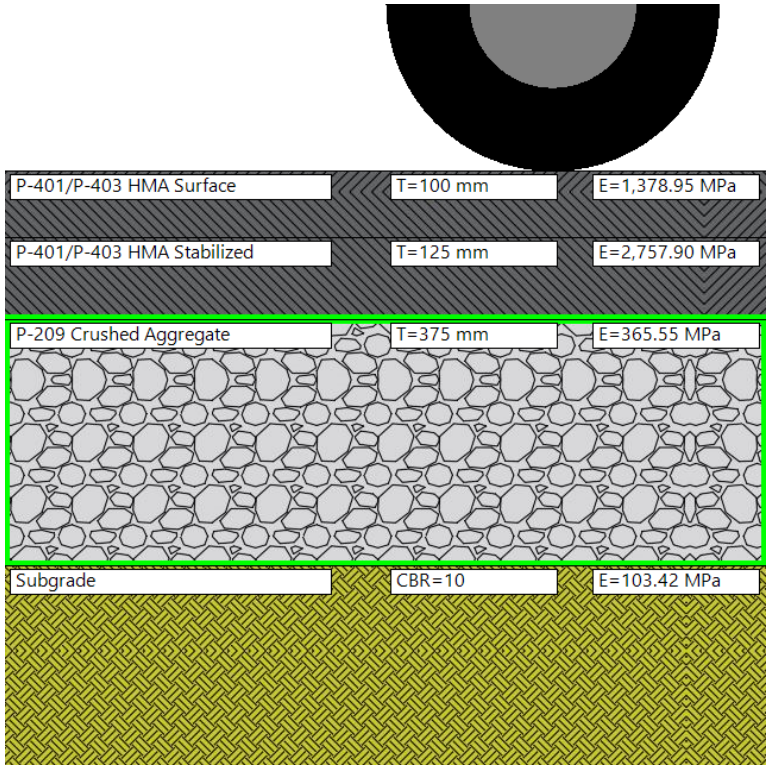
Overloads – Key Points

- **ICAO Annex 14 criteria are suggested. State criteria can and do deviate from these in practice.**
- **Allows technical analysis in lieu of default criteria.**
- **Amendment 15 increased allowable overload for rigid pavements from 5% to 10% (ACR over reported PCR).**
  - Provides parity with flexible pavements.
  - Based on R&D performed at FAA Technical Center.
- **Allowable annual overload movements set at approximately 5% of total movements.**
  - Total excludes “light” aircraft that do not contribute significantly to CDF.
  - “Light aircraft” not defined.

Overload Example

- **Consider a flexible pavement section.**
- **Existing Traffic:**

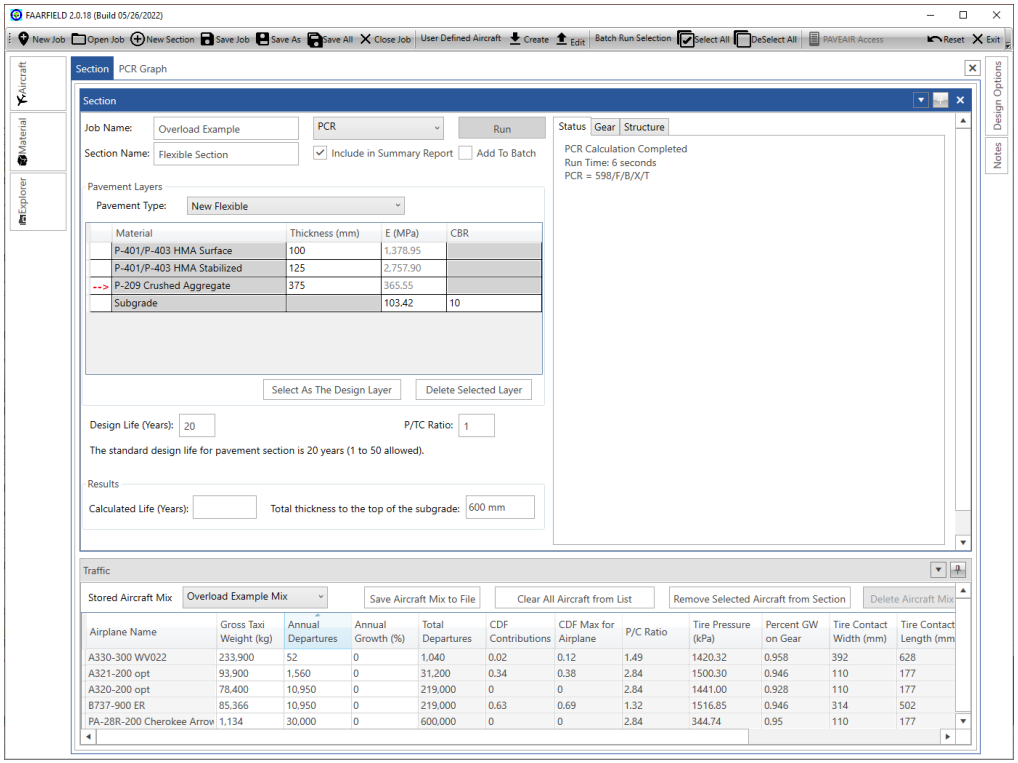
No.	Aircraft	Gross Wt., kg	Annual Departures
1	A330-300 WV 022	233,900	52
2	A321-200 opt	93,900	1,560
3	A320-200 opt	78,400	10,950
4	B737-900 ER	85,366	10,950
5	PA-28-R-200 Cherokee Arrow	1,134	30,000



- **Q: Can airport operate 52 annual departures of B777-300 ER?**

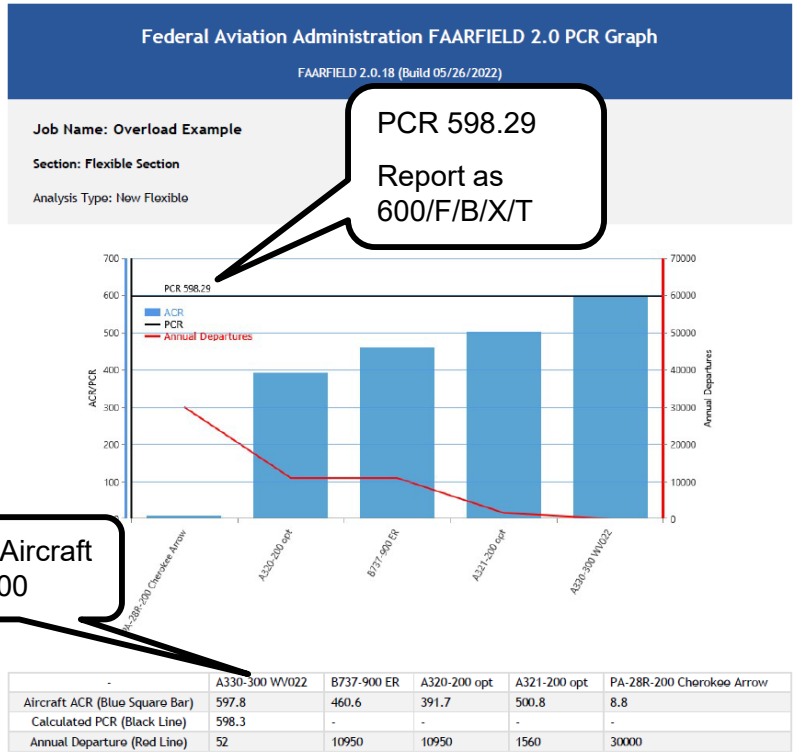
Overload Example

- **For existing traffic, FAARFIELD gives PCR 598/F/B/X/T.**
  - No restrictions on existing traffic.
  - A330-300 is the critical aircraft.
  - Report as **600/F/B/X/T**.
- **Allowable ACR for overloads is 1.1 × 600 = 660/F/B.**
- **Allowable number of overload operations = 0.05 × 23,512 = 1,176 (say 1200 ops per year).**
- **Disregard 30,000 annual departures of “light aircraft” Piper Cherokee.**



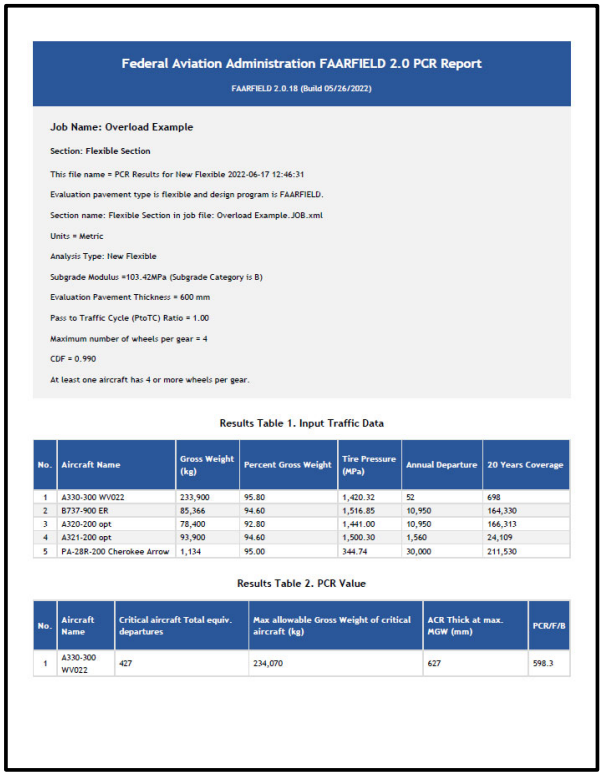
Overload Example (continued)

PCR GRAPH



-	A330-300 WV022	B737-900 ER	A320-200 opt	A321-200 opt	PA-28R-200 Cherokee Arrow
Aircraft ACR (Blue Square Bar)	597.8	460.6	391.7	500.8	8.8
Calculated PCR (Black Line)	598.3	-	-	-	-
Annual Departure (Red Line)	52	10950	10950	1560	30000

PCR REPORT



Federal Aviation Administration FAARFIELD 2.0 PCR Report

FAARFIELD 2.0.18 (Build 05/26/2022)

Job Name: Overload Example

Section: Flexible Section

This file name = PCR Results for New Flexible 2022-06-17 12:46:31

Evaluation pavement type is flexible and design program is FAARFIELD.

Section name: Flexible Section in job file: Overload Example.JOB.xml

Units = Metric

Analysis Type: New Flexible

Subgrade Modulus =103.42MPa (Subgrade Category is B)

Evaluation Pavement Thickness = 600 mm

Pass to Traffic Cycle (PtoTC) Ratio = 1.00

Maximum number of wheels per gear = 4

CDF = 0.990

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	A330-300 WV022	233,900	95.80	1,420.32	52	698
2	B737-900 ER	85,366	94.60	1,516.85	10,950	164,330
3	A320-200 opt	78,400	92.80	1,441.00	10,950	166,313
4	A321-200 opt	93,900	94.60	1,500.30	1,560	24,109
5	PA-28R-200 Cherokee Arrow	1,134	95.00	344.74	30,000	211,530

Results Table 2. PCR Value

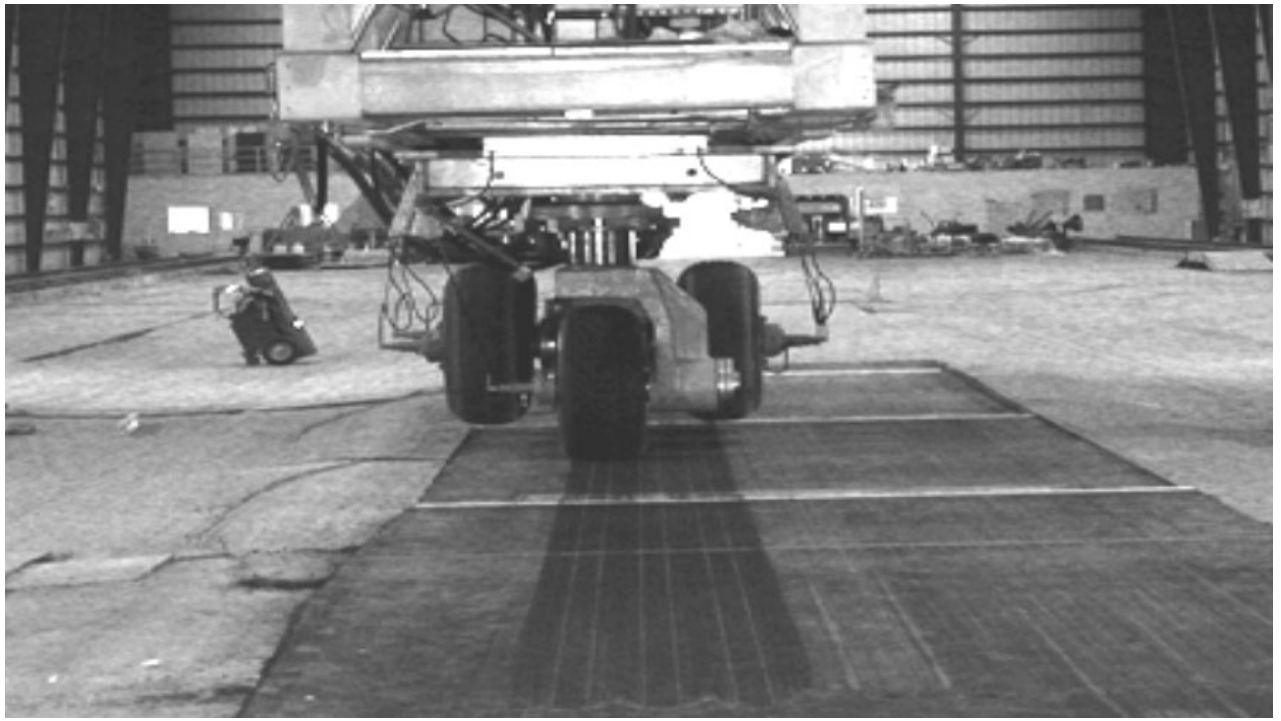
No.	Aircraft Name	Critical aircraft Total equiv. departures	Max allowable Gross Weight of critical aircraft (kg)	ACR Thick at max. MGW (mm)	PCR/F/B
1	A330-300 WV022	427	234,070	627	598.3

Overload Example (continued)

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) (B)	ACR/F/B
1	A330-300 WV022	233,900	95.8	1,420.32	627	597.8
2	B737-900 ER	85,366	94.6	1,516.85	561	460.6
3	A320-200 opt	78,400	92.8	1,441.00	526	391.7
4	A321-200 opt	93,900	94.6	1,500.30	579	500.8
5	PA-28R-200 Cherokee Arrow	1,134	95	344.74	117	8.8
6	B777-300 ER	352,441	92.4	1,503.06	638	628.8

- **In FAARFIELD 2.0, compute ACR of B777-300 ER at operating weight 352,441 kg = 628.8/F/B**
- **Since ACR 629 < 660, overload operations are allowed.**
- **The proposed number of annual overload operations (52) is less than the limit of 1200.**
- **The airport should nevertheless inspect the pavement for damage after each overload op.**



Tire Pressure Limitations

ACR-PCR Tire Pressure Categories

OLD ACN/PCN Tire Pressure Categories (Modified by ICAO State Letter in 2011)

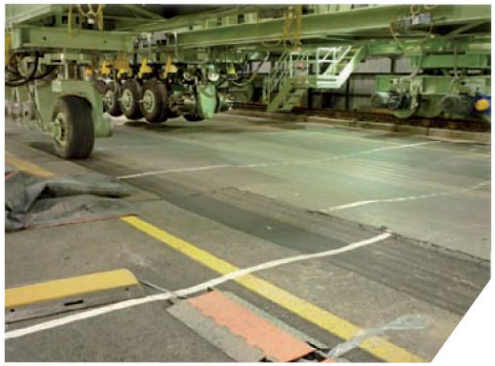
Category	Code	Range
Unlimited	W	No limit
High	X	< 1.50 MPa
Medium	Y	< 1.00 MPa
Low	Z	< 0.5 MPa

NEW Tire Pressure Categories (No Change in ACR/PCR System)

Category	Code	Range
Unlimited	W	No limit
High	X	< 1.75 MPa
Medium	Y	< 1.25 MPa
Low	Z	< 0.5 MPa

High Tire Pressure Full-Scale Testing Program

- **Arose from concerns among aircraft manufacturers that:**
  "The four tire pressure categories assigned to the PCN rating, which may have been representative of the aircraft existing at its inception, are no longer representative of the current fleet of large wide bodied aircraft operating with higher wheel loads and higher tire pressures."
  M.J. Roginski, Effects of Aircraft Tire Pressures on Flexible Pavements, PIARC 2007,
  https://proceedings-paris2007.piarc.org/ressources/files/3/AP01-ROGINSKI-E.pdf
- **High Tire Pressure tests conducted at FAA NAPTF, 2007 and 2009 (heated).**
- **Pavement Experimental Programme (PEP) tests by Airbus at Toulouse (2009 – 2010)**



High Tire Pressure Full Scale Tests

- **Test results from NAPTF HTP tests concluded that:**
  "*Increasing tire pressure from 210 psi (1.45 MPa) to 245 psi (1.66 MPa) had an insignificant effect on the amount of rutting caused by trafficking at two different wheel loads on two different asphalt mixes, one straight asphalt and the other polymer modified.*"
  I. Song, "Full-Scale High Tire Pressure Tests on Heated Pavement," Report to ICAO AOSWG, 2010.
- **Airbus PEP came to a similar conclusion.**
- **Annex 14 amendment revising tire pressure code limits was applicable in November 2012.**

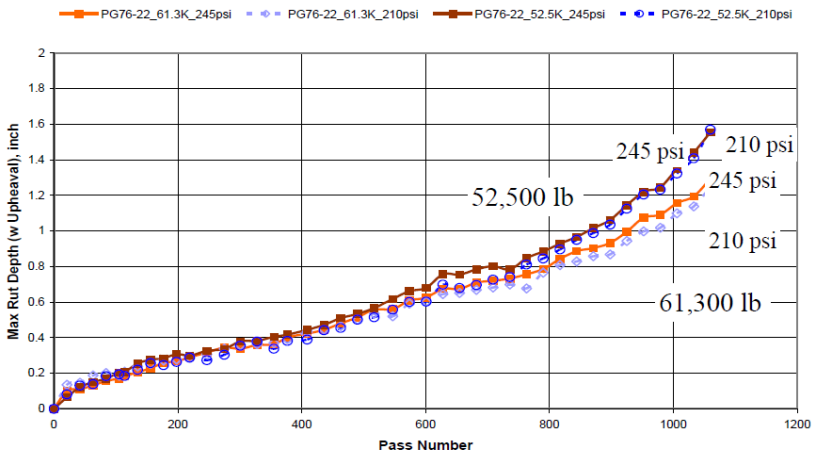


Figure 9. Rut depth changes with different tire pressures and load magnitudes in the PG 76-22 test items.

Overlay PCR Example

Overlay PCR Example

- **Like ACN/PCN, the ACR/PCR system does not recognize "composite" or overlay pavements for reporting purposes.**
- **Pavements are categorized as either flexible (F) or rigid (R).**
- **The general rule is, report the type that most accurately reflects the structural behavior of the pavement.**
  - Pavement type does not necessarily correspond to the wearing surface material.
  - FAARFIELD will consider a rigid pavement overlaid with asphalt to be type "R" if the overlay thickness < the PCC thickness.
  - If the overlay thickness matches or excess the PCC thickness, FAARFIELD determines the correct type (R or F) based on life computation.

Overlay PCR Example

- **Medium-hub airport in the U.S.**
- **Runway 9-27 is 2,896 m (9,500 ft.) long and 46 m (150 ft.) wide.**
  - The surface is HMA, except for a 1352-m (155-foot) length at the intersection with a crossing runway, which is PCC.
  - Runway was constructed in 1968 as a PCC pavement. At the time of initial construction, the PCC section was 25.4 cm (10 in.), except for 152-m (500-ft.) long sections at each runway end, where the PCC thickness was increased to 30.5 m (12 in.).
  - Subsequent overlays in 1981, 1997 and 2012 increased the total HMA thickness to approximately 25,4 m (10 inches).
- **The PCN for this composite pavement is reported on the AMR as 65/F/D/W/T.**

01L/19R | 01R/19L | 09/27

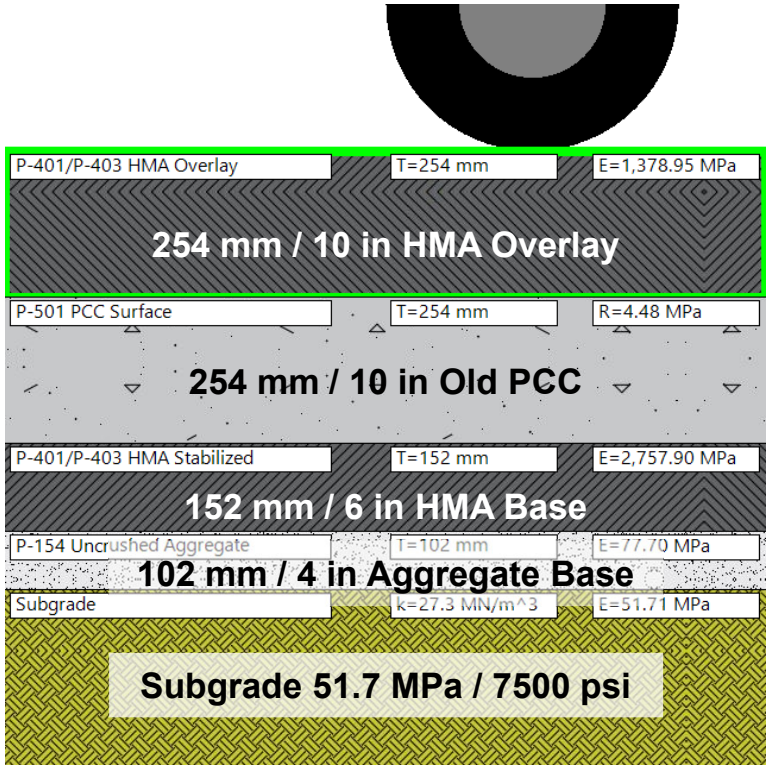
Runway Data		Obstruction Data	
Runway Identification	09/27	FAR 77 Category	PIR/PIR
Length	9,501	Displaced Threshold	/
Width	150	Controlling Obstruction	/
Surface Type-Condition	ASPH-G	Obstruction Marked/Lighted	/
Surface Treatment	GRVD	Height Above Runway End	/
Gross Weight (In Thousands)		Distance From Runway End	/
Single Wheel (S)	75.0	Centerline Offset & Direction	/
Dual Wheel (D)	125.0	Obstruction Clearance Slope	50/50
2 Dual Wheels in Tandem (2D)	180.0	Close-In Obstruction	N/N
2 Dual Wheels in Tandem/ 2 Dual Wheels in Double Tandem (2D/2D2)	260.0		
Pavement Classification Number (PCN)	65 /F/D/W/T		

Overlay PCR Example – Input Data

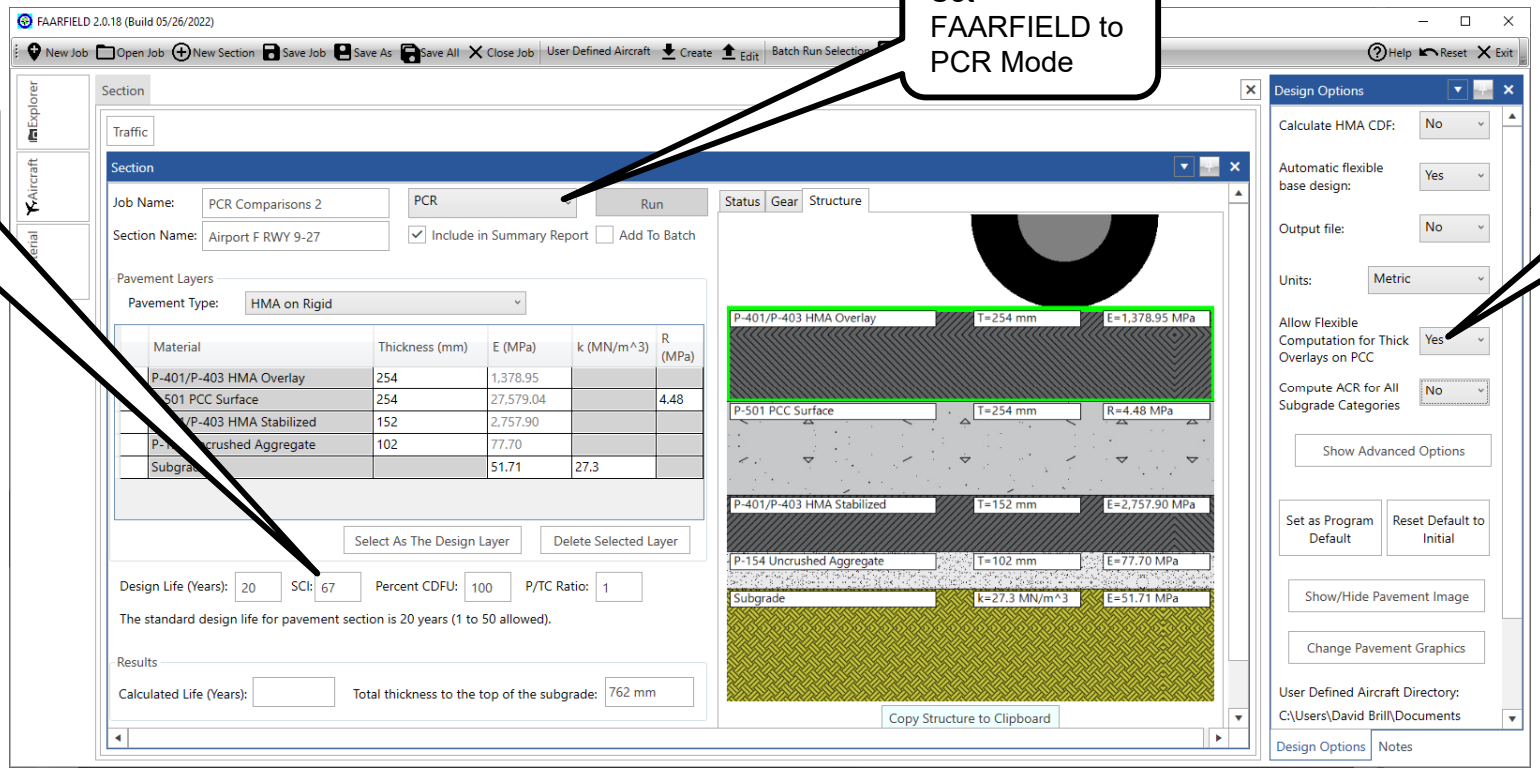
Design Aircraft Traffic

No.	Aircraft	Gross Wt., lbs.	Annual Departures
1	A300-600 Std Bogie	380,518	18
2	A318-100 opt	141,978	553
3	A320-200 std	150,796	170
4	A321-100 std	183,866	28
5	B717-200 HGW	122,000	111
6	B727-200 Advanced Basic	185,200	5
7	B737-300	140,000	651
8	B737-700	155,000	2000
9	B737-800	174,700	235
10	B737-900 ER	188,200	53
11	B757-200	256,000	137
12	B767-400 ER	451,000	4
13	B787-9	555,000	4
14	CRJ100/200	47,450	102
15	CRJ700	72,500	473
16	DC/MD-10-10/10F	458,000	10
17	DC9-32	109,000	9
18	Q400/Dash 8 Series 400	64,700	122
19	ERJ-145 ER	45,635	143
20	ERJ-145 XR	53,352	187
21	EMB-170 STD	79,697	864
22	EMB-190 STD	105,712	11
23	MD-11	633,000	17
24	MD-83	161,000	209
25	MD-90-30 ER	168,500	235

FAARFIELD Representation of Evaluation Structure

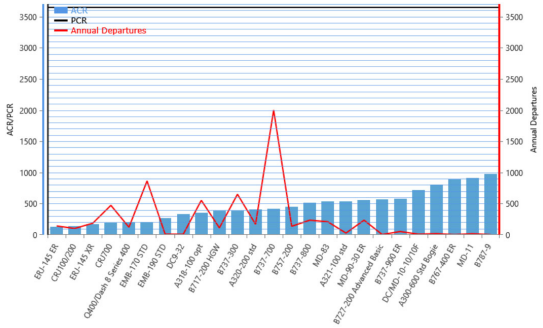


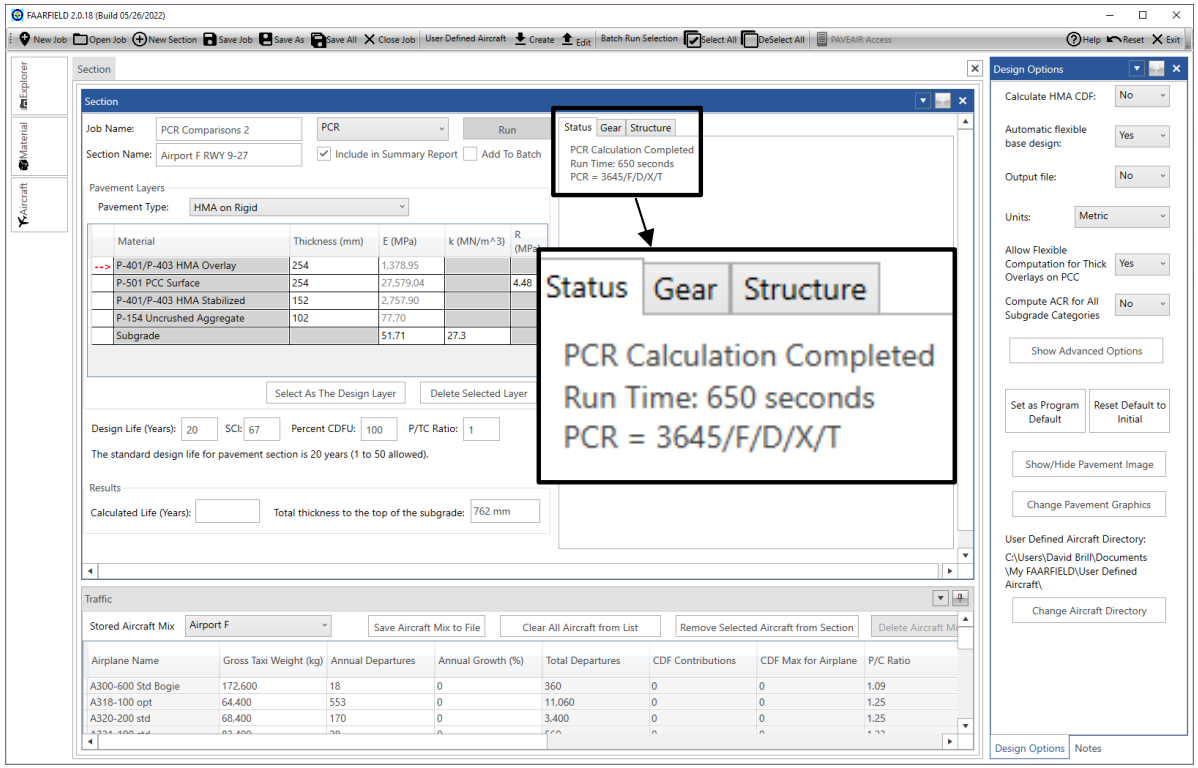
Overlay PCR Example – FAARFIELD 2.0



Overlay PCR Example – FAARFIELD 2.0

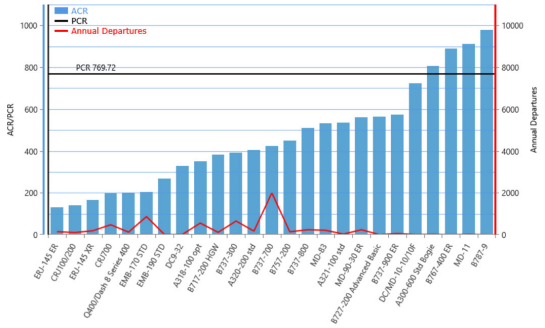
- **FAARFIELD computes PCR <u>3650/F/D</u>.**
- **No operating weight restrictions**
- **Since the overlay thickness matches that of the existing PCC, FAARFIELD can compute flexible PCR, by converting the PCC to a high-stiffness user-defined layer.**

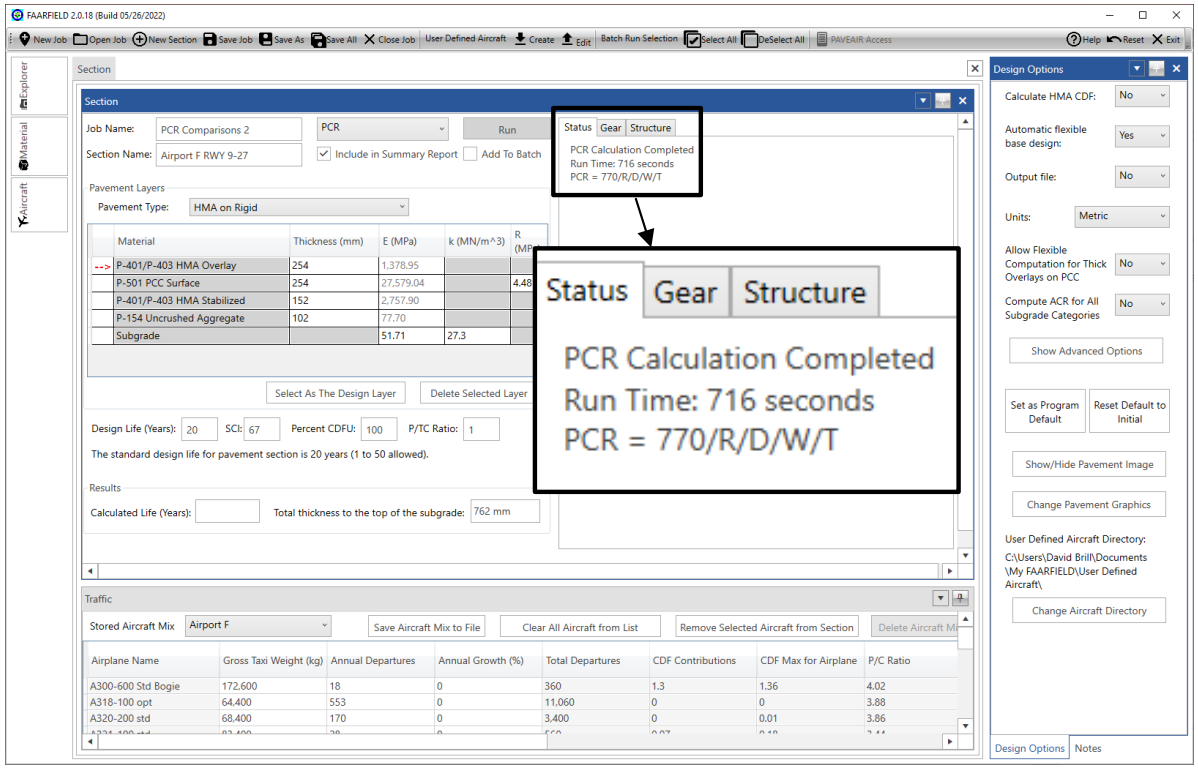




Overlay PCR Example – FAARFIELD 2.0

- **Alternatively, if the flexible option is disabled, then FAARFIELD computes PCR 770/R/D.**
- **Does not take advantage of the available strength by treating pavement as a flexible structure.**
- **Much lower rigid PCR would require operating weight restrictions on several mix aircraft.**





Using Aircraft PCR Example

Using Aircraft PCR Determination

- **Method based on experience with "using aircraft"**
  - Limited knowledge of the existing traffic and runway characteristics
  - Considered when technical evaluation is not economical or feasible
- **A pavement satisfactorily support aircraft using it, can accept other aircraft if they are no more demanding than the using aircraft.**
- **Inaccuracies:**
  - Accuracy depends on having records of past aircraft traffic
  - *Significant over-estimation of the pavement capacity can result if an excessively damaging aircraft, which uses the pavement infrequently, is used to determine PCR.*
  - *Significant underestimation of the pavement capacity can lead to uneconomic use of the pavement by preventing acceptable traffic*
- **Airport authorities should exercise more care when applying a Using Aircraft PCR than they would with a Technical PCR.**

Using Aircraft Evaluation Process

- **Basic Process**
  - **Identify the pavement type of- Flexible or Rigid**
    - Will have to consider both ACR's if runway include both pavement types
  - **Determine the subgrade category of the pavement**
    - Use available data to establish subgrade strength
    - *Use subgrade category **C** if no information is available*
  - **Determine the ACR for each aircraft in the traffic mix using the pavement**
    - The FAA recommends that an aircraft be considered to "regularly use" an airport if they have 250 annual departures. Use engineering judgement for seasonal or occasional use aircraft
  - **Assign the highest ACR value as the PCR**
    - Consider adjustments based on local experience & condition
  - **Monitor pavement performance**

ACR Determination

- **The Aircraft Manufacturer provides the official computation of ACR values for an aircraft type**
  - Boeing and Airbus are updating their aircraft characteristics documents and software to incorporate ACR curves
- **Computation of ACR requires detailed information on the operational characteristics of the aircraft such as center of gravity, weight, wheel spacing and tire pressure**
- **Each aircraft will report 8 ACRs at a give operational load**
  - 4 flexible, one for each subgrade category
  - 4 rigid, one for each subgrade category
- **ICAO ACR has been developed as software to computer ACRs for aircraft based on manufacturer data.**

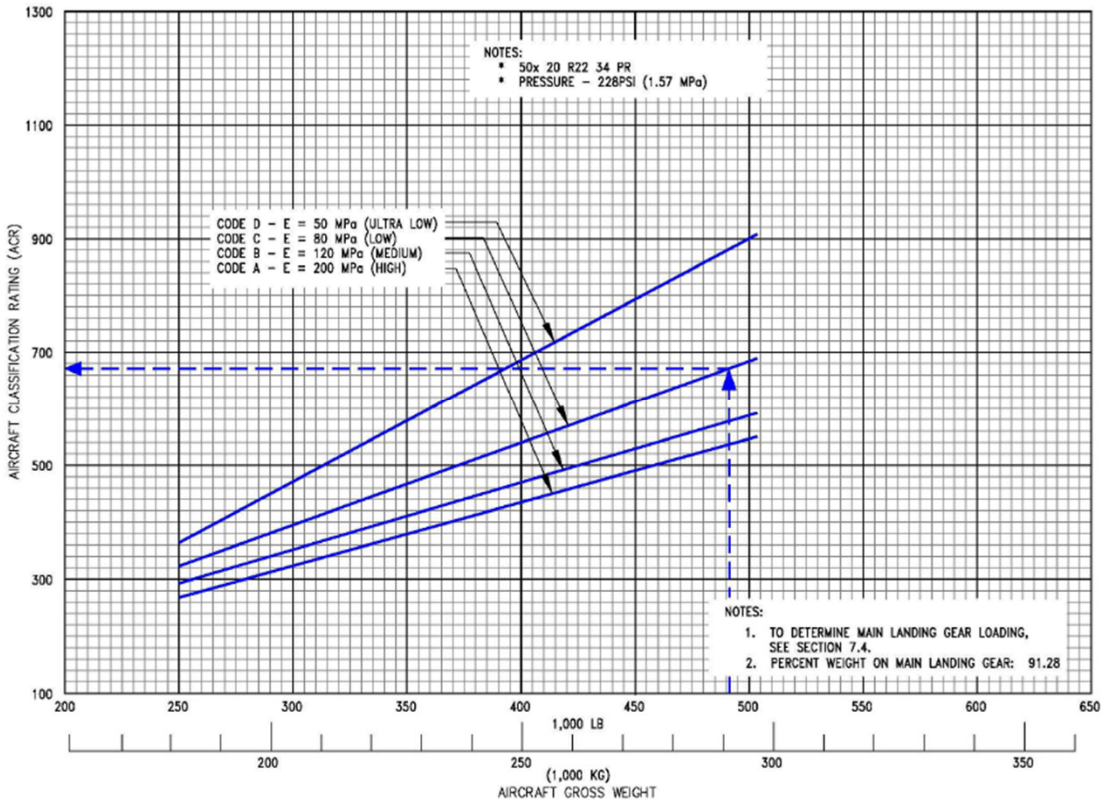
Manufacturer ACR Data

787 Airplane Characteristics for Airport Planning

DOCUMENT NUMBER: **D6-58333** REVISION: **REV O** REVISION DATE: **February 2023**

AIRCRAFT TYPE	MAXIMUM TAXI WEIGHT MINIMUM WEIGHT *[1] LB (KG)	LOAD ON ONE MAIN GEAR LEG (%)	TIRE PRESSURE PSI (MPa)	ACR FOR RIGID PAVEMENT SUBGRADES				ACR FOR FLEXIBLE PAVEMENT SUBGRADES			
				HIGH E = 200 MPa	MEDIUM E = 120 MPa	LOW E = 80 MPa	ULTRA LOW E = 50 MPa	HIGH E = 200 MPa	MEDIUM E = 120 MPa	LOW E = 80 MPa	ULTRA LOW E = 50 MPa
787-8	503,500 (228,383)	45.64	228 (1.57)	670	790	870	970	550	590	690	910
	250,000 (113,398)			270	290	320	360	270	270	280	310
787-9	563,000 (255,373)	46.11	229 (1.58)	740	860	960	1070	620	660	750	970
	250,000 (113,398)			260	280	310	340	270	270	280	290
787-10	561,500 (254,692)	46.63	224 (1.54)	740	870	970	1080	620	660	760	990
	250,000 (113,398)			260	280	310	350	270	270	280	300

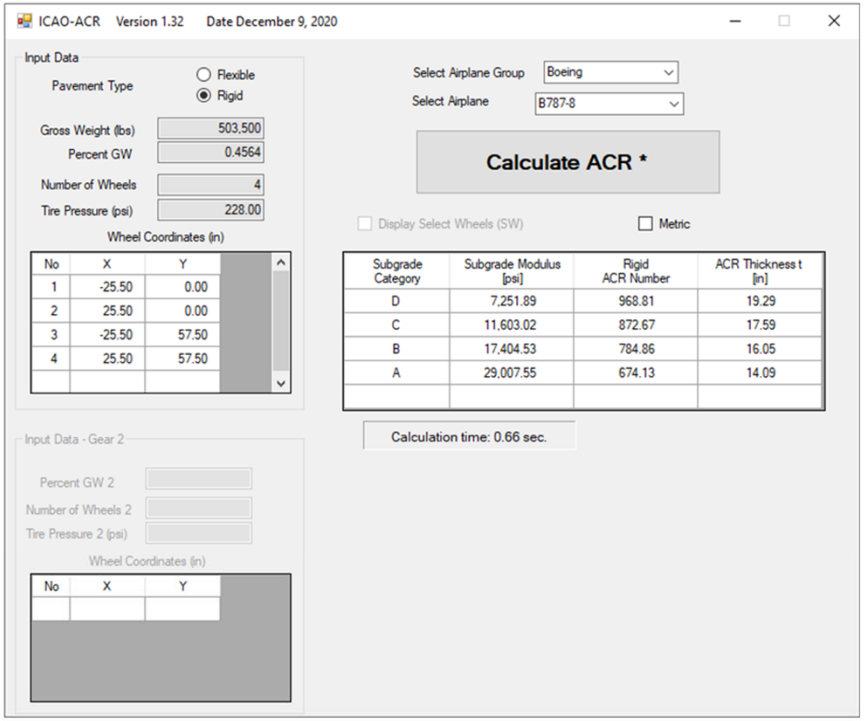
*[1] Minimum weight used solely as a baseline for ACR curve generation.



- **787-8 ACR Example= 680/F/C**

ICAO- ACR Determination

- **FAA Developed Program**
- **Calculates standard ACRs for aircraft**
  - Remember Manufacturer Data is official
- **Core library can be linked to other programs that compute PCR**
- **Backbone of FAARFIELD 2.0 PCR Module**



http://www.airporttech.tc.faa.gov/Products/Airport-Pavement-Software-Programs/Airport-Software-Detail/ArtMID/3708/ArticleID/2838/ICAO-ACR-13

Example- Using Aircraft PCR

- **Muñiz airport has an asphalt runway with the known traffic mix shown in below pavement with an estimated**
- **Subgrade strength is Unkown**
- **Flexible**

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

Process

- **Pavement type F or R**
- Subgrade Category
- ACR for each aircraft
- Determine highest ACR
- Report PCR
- Monitor pavement performance

Example- Using Aircraft PCR

- **Determine Subgrade Category**
  - **No information available**

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

Process

- ~~Pavement type F or R~~
- **Subgrade Category**
- ACR for each aircraft
- Determine highest ACR
- Report PCR
- Monitor pavement performance

Example- Using Aircraft PCR

- **Determine the ACR for each aircraft**
  - What resources can I use?

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

Process

- ~~Pavement type F or R~~
- ~~Subgrade Category~~
- **ACR for each aircraft**
- Determine highest ACR
- Report PCR
- Monitor pavement performance

Example- Using Aircraft PCR

- **Utilize ICAO-ACR Software**

No.	Aircraft Name	Gross weight Kg	Annual Departures	ACR (Flex-C)
1	A300-B4 Std	166049	1500	
2	A319-100 Std	64458	1200	
4	B737-300	63560	6000	
5	B747-400	398158	1000	
6	B767-200 ER	179784	2000	
7	B777-200 ER	298278	1000	
8	DC8-63	149820	3000	

Process

- ~~Pavement type F or R~~
- ~~Subgrade Category~~
- **ACR for each aircraft**
- Determine highest ACR
- Report PCR
- Monitor pavement performance

Example- Using Aircraft PCR

- **Determine the highest ACR**

No.	Aircraft Name	Gross weight Kg	Annual Departures	ACR (Flex-C)
1	A300-B4 Std	166049	1500	***548***
2	A319-100 Std	64458	1200	***326***
4	B737-300	63560	6000	***346***
5	B747-400	398158	1000	***607***
6	B767-200 ER	179784	2000	***508***
7	B777-200 ER	298278	1000	***587***
8	DC8-63	149820	3000	***523***

Process

- ~~Pavement type F or R~~
- ~~Subgrade Category~~
- ~~ACR for each aircraft~~
- **Determine highest ACR**
- Report PCR
- Monitor pavement performance

Example- Using Aircraft PCR

- **Reporting the PCR**
  - **Flexible Pavement**
  - **Subgrade C**
  - **Highest ACR of Traffic Mix 607**

<u>Recommended Runway PCR</u>

610/F/C/X/U

- ***Actively monitor pavement performance!!!***

<u>Process</u>

- Pavement type F or R
- Subgrade Category
- ACR for each aircraft
- Determine highest ACR
- Report PCR
- **Monitor pavement performance**

Questions?

Resources- Videos

1. FAARFIELD Overview (8:45)
2. Quick Start Pavement Design (10:32)
3. User Defined Aircraft (9:55)
4. Flexible Pavement Design, Part 1, Flexible GA (7:59)
5. Flexible Pavement Design, Part 2< Modified Subgrade (6:57)
6. Rigid Pavement Design (6:35)
7. Flexible Overlays (12:06)
8. Rigid Overlays (6:20)
9. Pavement Classification Rating (13:59)

Resources- Videos

- **AC 150/5335-5D**

Open Discussion

Example- Using Aircraft PCR

- **Determine the highest ACR for Rigid Section**

No.	Aircraft Name	Gross weight Kg	Annual Departures	ACR (Flex-C)	ACR (Rigid-C)
1	A300-B4 Std	166049	1500	548	667
2	A319-100 Std	64458	1200	326	396
4	B737-300	63560	6000	346	416
5	B747-400	398158	1000	607	767
6	B767-200 ER	179784	2000	508	635
7	B777-200 ER	298278	1000	587	885
8	DC8-63	149820	3000	523	693

Process

- ~~Pavement type F or R~~
- ~~Subgrade Category~~
- ~~ACR for each aircraft~~
- **Determine highest ACR**
- Report PCR
- Monitor pavement performance