PCN Determination

Case Studies and Observations of the FAA PCN Method

LIFECYCLE SOLUTIONS

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Outline

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Cumulative Damage Factor Approach (CDF)

Rigid pavement case studies

Case Study 1

- **FAARFIELD compatibility**
- **Traffic sensitivity**

Case Study 2

- **MR sensitivity**
- **Thickness sensitivity**

Flexible pavement case studies

- **Closely designed pavement- Case Study 3**
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Misc issues

- **Equivalent thickness for flexible pavements**
- **Over designed pavement PCN determination**
- **COMFAA-FAARFIELD compatibility for flexible pavements**

Background

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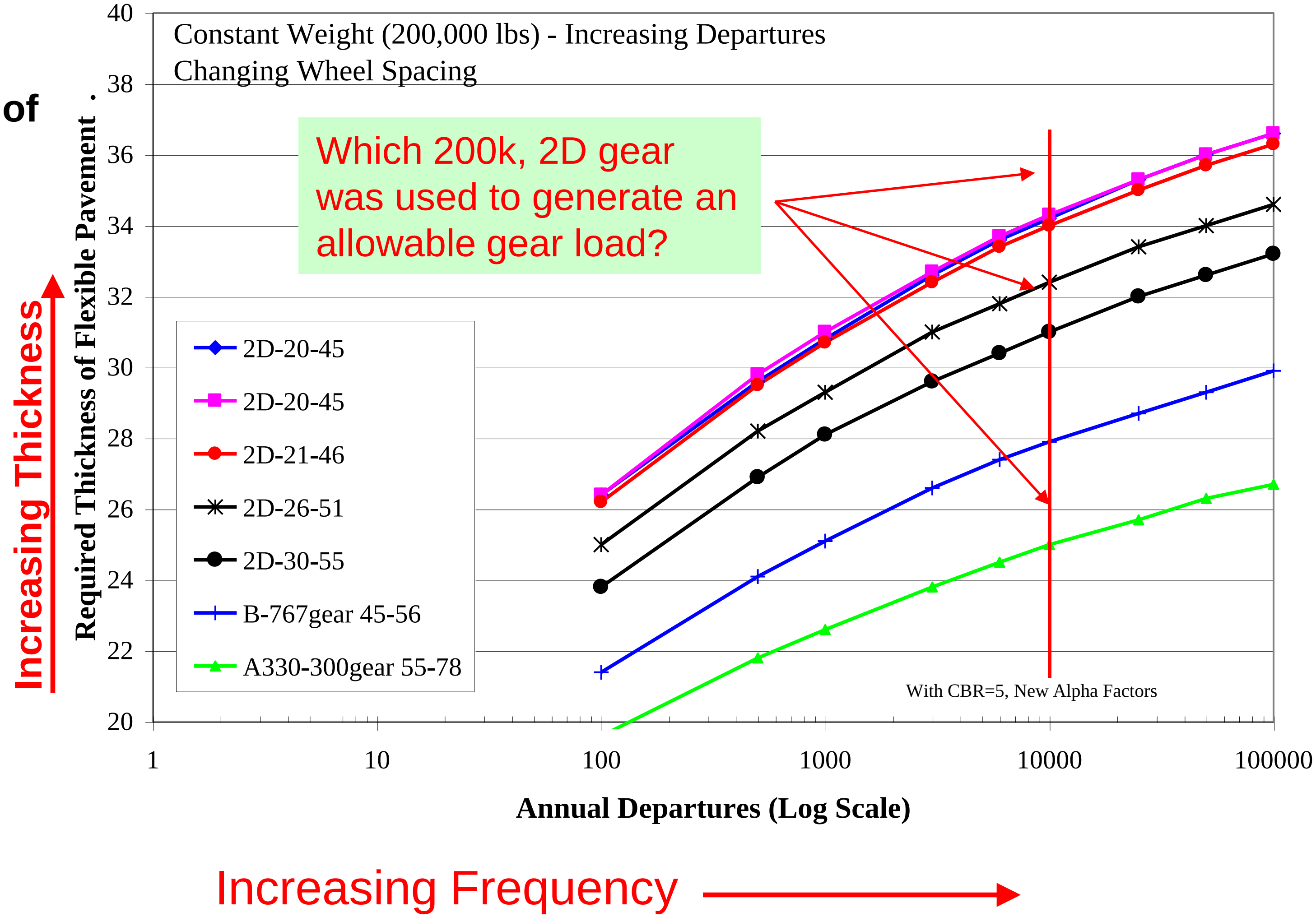
- Current FAA pavement rating system based on gear type ratings- led to confusion within the industry and with airlines.
- First release of advisory circular 150/5335-5A in 2006 did not produce reasonable PCN’s. Pavements designed to handle current traffic did not yield PCN’s high enough to accept all traffic.
- PCN working group formed in 2008 tasked with developing new PCN methodology and analysis software.
- Draft release of 150/5335-5B in 2009 has now been officially released as of August 26, 2011.

FAA Gear Rating System

2D landing gears

Constant gross load of 200,000 lbs

<u>Same gear type</u> but with different wheel spacing



Issues Using 5335-5A Procedure

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AIRPLANE	Gross Wt lbs	Annual Departures	Individual Required Thickness In
A300-b4 std	375,000	3,102	12.84
B737-800	174,700	111,952	16.76
A380 basic body	1,235,000	75	10.60
A380 basic wing	1,235,000	75	11.59
B727-100 alt	170,000	382	11.94
B737-400	150,500	83,884	16.26
B747-400	873,000	918	12.12
B757-200	256,000	19,851	11.40
B787-8	478,000	9,875	14.80
B777-300 baseline	662,000	6,141	12.64
DC8-63/73	358,000	299	11.68
DC9-51	122,000	32	9.64
DC-10-10	458,000	1,726	12.10
MD-11ER	633,000	166	12.10

Thickest Requirement

Per current AC 5335-5A procedure (edge case) – this would become the “design” airplane

Issues Using 5335-5A Procedure Gear Conversion Factors

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Gear type to "Critical" gear type conversion factors

$$0.8^{(M-N)}$$

M=# wheels on critical airplane gear

N=# wheels on converted airplane gear

To Convert From (N)	To (M)	Multiply Traffic Cycles By
S	D	0.80
S	2D	0.51
S	3D	0.33
D	S	1.33
D	2D	0.64
D	3D	0.41
2D	S	1.95
2D	D	1.56
2D	3D	0.64
3D	S	3.05
3D	D	2.44
3D	2D	1.56
2D/2D2	D	1.56
2D/2D2	2D	1.00
2D/2D2	3D	0.64

Issues Using 5335-5A Procedure Wheel Load Factors

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Equivalent Traffic Cycle conversion

R_1= Equivalent Traffic cycles of critical airplane

R_2= Traffic cycles of given airplane expressed in terms of critical gear

W_1=Wheel load of critical airplane

W_2=Wheel load of airplane in question

$$R1 = R2^{A^{1/2}}$$

A= (W2 / W1)^1/2

Airplane	(W2) Single Wheel Load, lb	(R2) (2D) TC	$(A)^{1/2}$ Wheel Load Ratio	(R1) Equivalent 747-400 TC
727-200	43,938	256	0.950	194
737-300	30,875	3,840	0.796	716
A319-100	34,438	768	0.841	268
747-400	48,688	3,000	1.000	3000
767-200ER	43,938	2,000	0.950	1,368
DC8-63	39,188	800	0.897	403
A300-B4	43,938	1,500	0.950	1,041
777-200	47,500	468	0.988	434
		12,632		7,424

PCN Working Group Members

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Cumulative Damage Factor Method

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New cumulative damage factor (CDF) procedure to determine equivalent annual coverages using COMFAA

The damage induced in a pavement is proportional to the number of load applications (coverages) divided by the number of load applications (coverages) required to fail the pavement. Each aircraft uses up a fraction of pavement life. Failure models are CBR method for flexible pavements and Westergaard edge case method for rigid pavements.

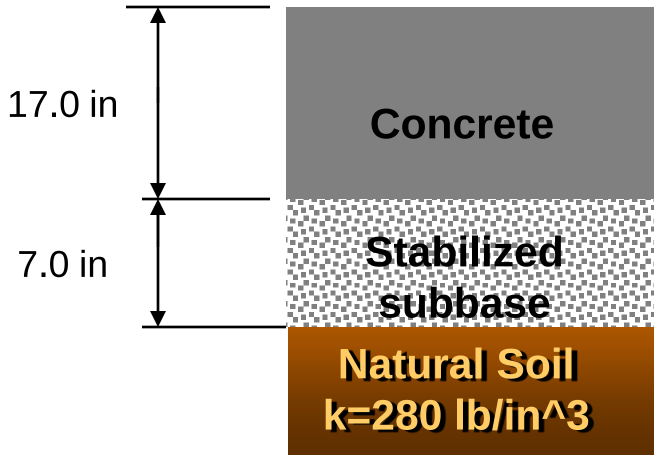
$$\frac{C_1}{C_{1F}} = \frac{\text{equivalent coverages of the critical aircraft}}{\text{coverages to fail the pavement when loaded by the critical aircraft}}$$

$$\frac{C_2}{C_{2F}} = \frac{\text{coverages of the conversion aircraft}}{\text{coverages to fail the pavement when loaded by the conversion aircraft}}$$

$$C_1 = \frac{C_{1F}}{C_{2F}} C_2$$ ⟶ Total equivalent coverages

The total CDF for the traffic mix is the summation of the CDF’s of all aircraft in the traffic mix. If total CDF > 1, then pavement expected to fail within 20 yr design life.

Rigid Pavement- Case Study 1



<u>Concrete Properties:</u>

Modulus of Rupture	**650 psi**
Slab thickness	**17.0 in**
Elastic Modulus	**4.0 E+06 psi**
Effective k value	**390 pci**

Existing large domestic airport with both narrow body & widebody traffic. Overdesigned for current traffic.

Case study 1:Dual-Wheel Aircraft Traffic

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	Airplane	GW	TP	AD	20 yr Coverages	-6D t
1	**DC9-51**	**122,000**	**172**	**4,388**	**24,062**	**12.21**
2	**MD90-30ER**	**168,500**	**193**	**20**	**120**	**11.66**
3	**MD83**	**161,000**	**195**	**1,349**	**7,887**	**13.32**
4	**DC9-32**	**109,000**	**155**	**1,258**	**6,859**	**10.43**
9	**A321-200**	**197,093**	**212**	**68**	**393**	**12.88**
10	**A320-200**	**162,922**	**200**	**3,708**	**19,932**	**13.58**
11	**A319-100**	**141,978**	**173**	**3,273**	**17,573**	**12.16**
12	**A318-100**	**124,341**	**148**	**52**	**279**	**9.13**
13	**B737-800**	**174,700**	**205**	**1,658**	**9,321**	**13.66**
14	**B737-700**	**155,000**	**205**	**1,053**	**5,524**	**12.24**
15	**B737-500**	**134,000**	**194**	**176**	**912**	**10.84**
16	**B737-300**	**140,000**	**201**	**556**	**2,873**	**11.49**
25	**B717-200**	**122,000**	**164**	**302**	**1,700**	**10.61**
	Maximums	197,093	212	4,388	24,062	13.66

Case Study 1: Widebody Traffic

	Airplane	GW	TP	AD	20 yr Coverages	-6D t
5	**A340-300**	**608,245**	**206**	**13**	**138**	**11.26**
6	**A340-200**	**568,563**	**191**	**42**	**450**	**11.15**
7	**A330-300**	**509,047**	**206**	**377**	**4,025**	**12.61**
8	**A330-200**	**509,047**	**206**	**133**	**1,413**	**12.14**
17	**B777-200LR**	**768,800**	218	**81**	**413**	**11.39**
18	**B777-200**	**537,000**	**185**	**156**	**736**	**9.23**
19	**B767-400ER**	**451,000**	**215**	**68**	**375**	**11.97**
20	**B767-300ER**	**413,000**	**200**	**111**	**608**	**11.12**
21	**B767-200**	**317,000**	**190**	**137**	**674**	**9.46**
22	**B757-300**	**271,000**	**195**	**465**	**2,351**	**10.03**
23	**B757-200**	**256,000**	**183**	**2,311**	**11,631**	**10.19**
24	**B747-400**	877,000	**200**	**153**	**877**	**11.69**
	Maximums	877,000	218	2,311	11,361	12.61

Case Study 1– Table 2 results from COMFAA

	Airplane	Critical Aircraft equivalent coverages	Thickness required for total equivalent coverages	Maximum. allowable. GW	PCN FB	CDF
1	DC9-51	1,118,119	15.08	152,731	48.0	0.0016
2	MD90-30ER	28,191	14.70	221,336	74.1	0.0003
3	MD83	39,931	14.74	210,131	70.5	0.0150
4	DC9-32	>5,000,000	15.22	134,446	40.2	0.0001
9	A321-200	9,423	14.56	265,412	84.6	0.0032
10	A320-200	87,827	14.83	210,977	62.5	0.0173
11	A319-100	782,945	15.04	180,231	49.2	0.0017
12	A318-100	>5,000,000	15.25	153,034	37.7	0.0000
13	B737-800	30,481	14.71	231,456	72.3	0.0233
14	B737-700	135,320	14.88	199,178	59.0	0.0031
15	B737-500	497,754	15.00	170,980	51.4	0.0001
16	B737-300	312,351	14.96	180,081	54.1	0.0007
25	B717-200	1,263,942	15.09	152,621	47.8	0.0000
	Maximums		15.25		84.6	0.0233

Table 2, continued

	Airplane	Crit. Aircraft equiv. coverages	Thickness for total equiv. coverages	Max. allow. GW	PCN FB	CDF
5	**A340-300**	**60,674**	**14.79**	**800,966**	**89.4**	**0.0002**
6	**A340-200**	**166,631**	**14.90**	**743,274**	**79.1**	**0.0002**
7	**A330-300**	**56,854**	**14.79**	**670,554**	**90.2**	**0.0054**
8	**A330-200**	**62,550**	**14.80**	**670,233**	**89.0**	**0.0017**
17	**B777-200LR**	**101,588**	**14.85**	**953,437**	**118.2**	**0.0003**
18	**B777-200**	**>5,000,000**	**15.29**	**653,745**	**64.9**	**0.0000**
19	**B767-400ER**	**35,388**	**14.73**	**562,746**	**94.6**	**0.0008**
20	**B767-300ER**	**215,777**	**14.93**	**511,161**	**77.9**	**0.0002**
21	**B767-200**	**>5,000,000**	**15.24**	**385,518**	**51.2**	**0.0000**
22	**B757-300**	**>5,000,000**	**15.21**	**322,684**	**53.2**	**0.0000**
23	**B757-200**	**>5,000,000**	**15.32**	**300,228**	**46.1**	**0.0000**
24	**B747-400**	**98,570**	**14.85**	**1,092,324**	**86.4**	**0.0007**
	Maximums		15.32		118.2	0.0054

PCN Calculation

PCN Calculation

CDF= 20 yr coverages / theoretical coverages to failure

Determine theoretical coverages to failure for each aircraft based on the design thickness- 17 inches.

Determine the critical aircraft total equivalent coverages.

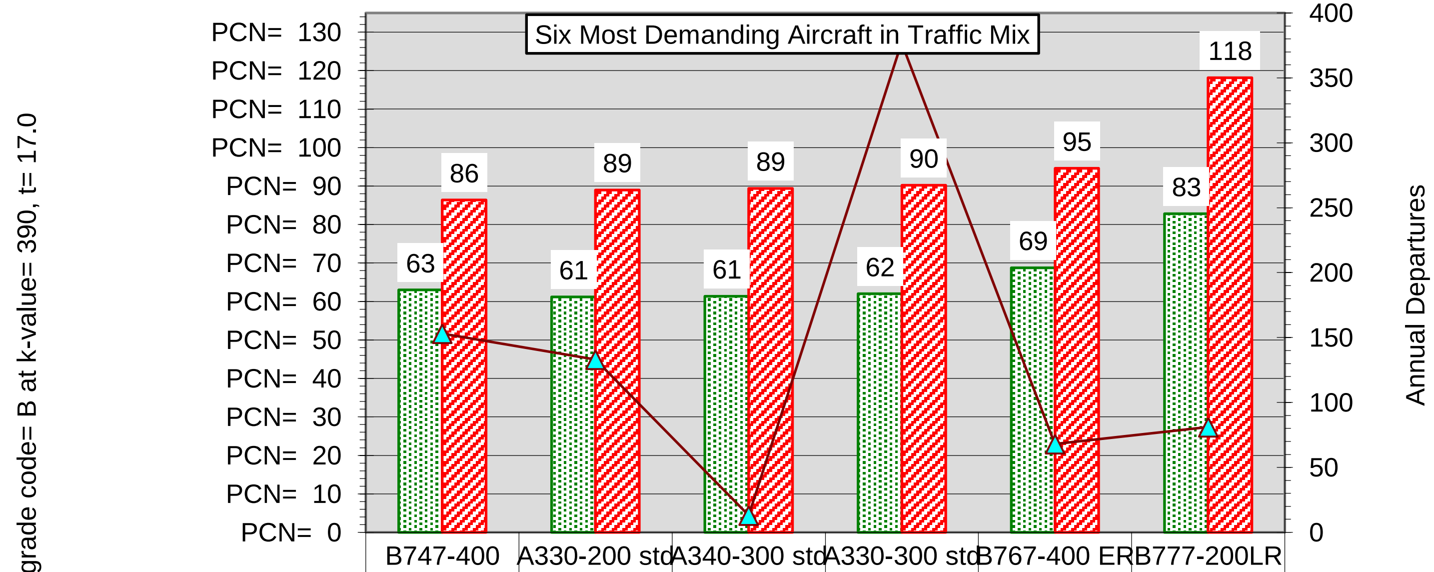
$$\text{Equiv. Coverages} = \sum \frac{\text{Coverages to failure\_crit a/c}}{\text{coverages to failure\_a/c(i)}} (\text{20 yr coverages a/c(i)}) + \text{20 yr coverages\_crit a/c}$$

Determine maximum allowable CDF gross weight based on equivalent coverages

PCN = ACN @ max allowable weight

PCN Determination

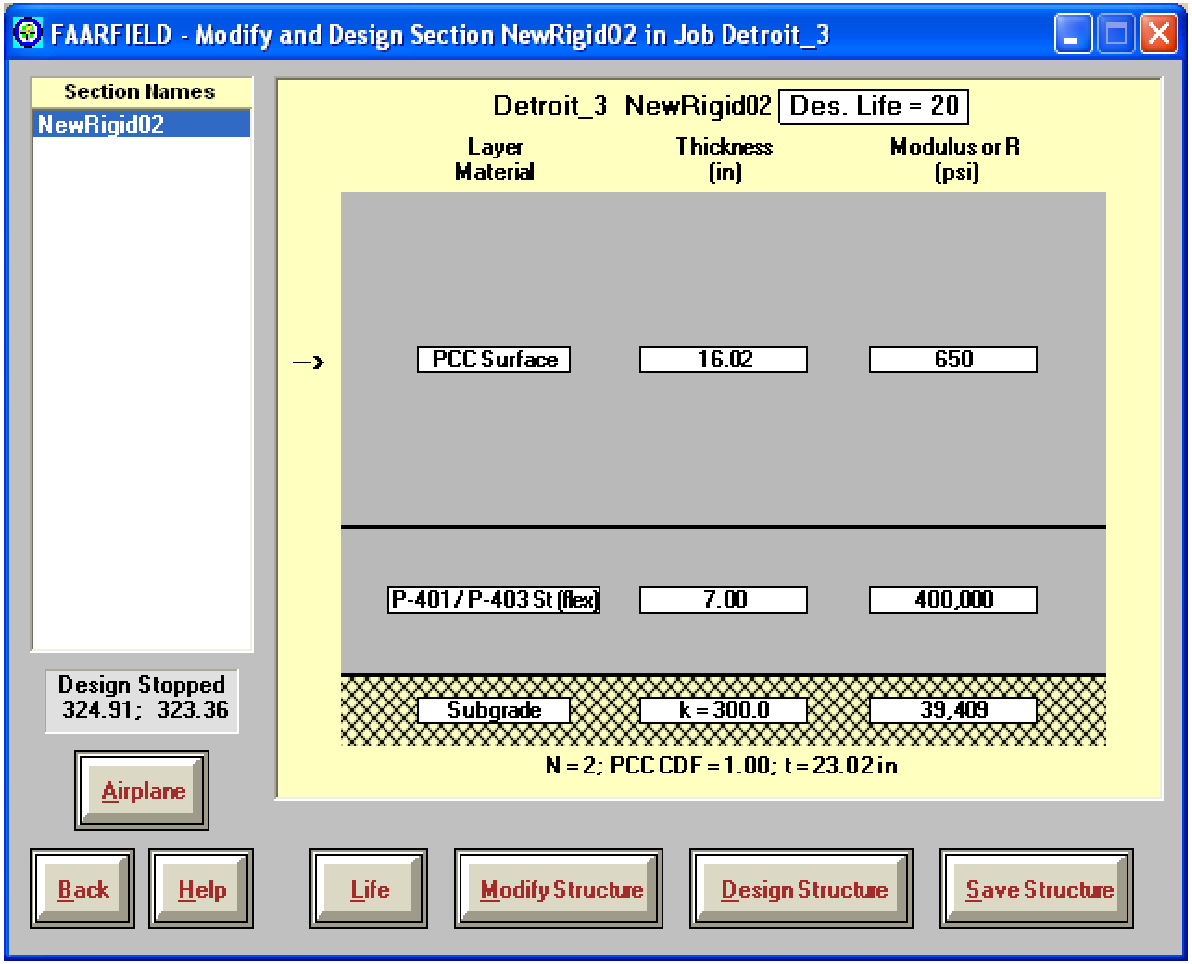
Case 1



	B747-400	A330-200 std	A340-300 std	A330-300 std	B767-400 ER	B777-200LR
1. Aircraft ACN at traffic mix GW	63.0	61.2	61.4	62.0	68.8	82.8
2. Calculated PCN at CDF max. GW	86.4	89.0	89.4	90.2	94.6	118.2
3. Annual Departures from traffic mix	153	133	13	377	68	81

PCN 118/ R/B/W/T based on 777-200LR

Case Study 1- FAARFIELD design



FAARFIELD thickness designs typically very close (i.e. 0-.75") to COMFAA Westergaard edge case requirements

Case Study 1- Traffic Sensitivity

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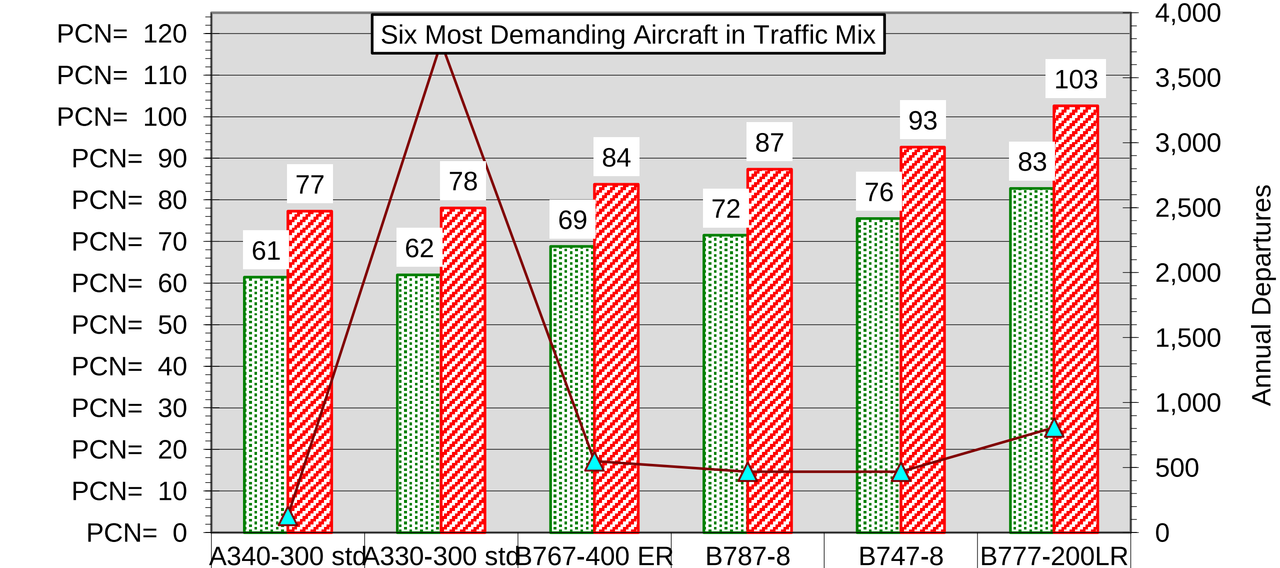
		Combined		Min	Max	Max	Max CDF	PCN	Max
Run	Combine	GW	AD	Equiv t		CDF	APL	APL	PCN
1	Original			14.58	15.33	0.0233	B737-800	B777-200LR	118.2
2	B737-800,-700 = 737-800	174,700	2731	14.72	15.43	0.0384	B737-800	B777-200LR	115.3
3	A318,319,321 = A320	169,922	7101	14.89	15.50	0.0384	B737-800	B777-200LR	113.3
4	B737-300,-500 = 737-300	140,000	732	14.90	15.50	0.0384	B737-800	B777-200LR	113.3
5	MD90,83 = MD83	161,000	1369	14.89	15.50	0.0384	B737-800	B777-200LR	113.3
6	10x B747-8	978,000	470	14.99	15.54	0.0384	B737-800	B777-200LR	111.5
7	10x B787-8	503,500	470	15.05	15.61	0.0384	B737-800	B777-200LR	110.4
8	B757-300,=200 = 757-300	256,000	2776	15.11	15.61	0.0384	B737-800	B777-200LR	110.4
9	10xA330,340			15.46	15.89	0.0539	A330-300	B777-200LR	103.4
10	10xB77-200LR	768,800	810	15.48	15.89	0.0539	A330-300	B777-200LR	103.2
11	10xB767 all			15.51	15.94	0.0539	A330-300	B777-200LR	102.6

In this run, similar dual wheel aircraft were grouped together and widebody traffic was increased tenfold.

Case Study 1- Effect of Combining Traffic



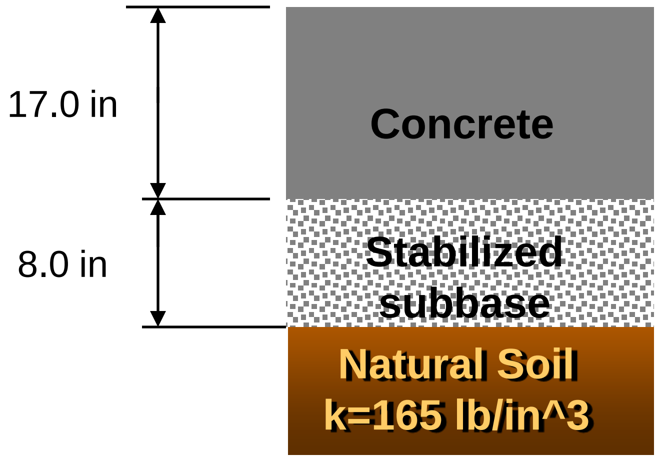
	A340-300 std	A330-300 std	B767-400 ER	B787-8	B747-8	B777-200LR
1. Aircraft ACN at traffic mix GW	61.4	62.0	68.8	71.5	75.5	82.8
2. Calculated PCN at CDF max. GW	77.3	78.1	83.8	87.4	92.7	102.6
3. Annual Departures from traffic mix	130	3,770	550	470	470	810

PCN 103 /R/B/W/T. For this overdesigned pavement, a large increase in traffic only reduced PCN ~ 10%.

Conclusions from Rigid Case Study 1

- **The pavement appears to be overdesigned for the traffic.**
- **Maximum CDF's are from dual wheel aircraft due to high departure levels, but are relatively insignificant due to over design.**
- **PCN determined from 777-200LR and its high value indicates the true pavement bearing capacity is more than sufficient to handle all traffic.**
- **FAARFIELD rigid designs typically compatible with COMFAA results.**
- **Increase in traffic did not alter PCN significantly ~ 10%, future re-evaluation probably not necessary in this case.**

Rigid Pavement- Case Study 2



Concrete Properties:

Modulus of Rupture	**700 psi**
Slab thickness	**17.0 in**
Elastic Modulus	**4.0 E+06 psi**
Effective k value	**310 pci**

Existing large domestic airport with both narrow body & widebody traffic. Good design for current traffic.

Case Study 2- Narrow Body Traffic

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	Airplane	GW	TP	AD	20 yr Coverages	-6D t
1	MD83	161,000	195	435	2,543	12.41
2	MD87	140,000	195	2	11	9.55
3	A319-100	154,322	200	8,432	43,559	13.36
4	A320-200	162,000	200	13,131	70,385	14.29
5	A321-100	181,220	197	3,798	21,882	14.26
6	B727-200	209,500	173	371	2,473	13.34
7	B717-200	119,000	164	4,253	23,645	11.72
8	B737-500	133,500	194	6,461	33,435	12.60
9	B737-700/800	155,500	205	45,953	241,454	15.09
10	Canadair RJ	75,000	183	12,499	53,990	10.23
11	DC9-51	121,000	172	13	71	9.36
12	B757-200	255,000	183	28,436	142,842	11.73
	Maximums					**15.09**

Significant dual wheel annual departures

Case Study 2- Wide Body Traffic

LIFECYCLE SOLUTIONS

	Airplane	GW	TP	AD	20 yr Coverages	-6D t
13	A300-B4	363,763	168	1,260	7,649	11.01
14	A340-300	566,575	206	502	5,155	12.04
15	B747-400ER	750,000	230	2,330	11,553	12.19
16	B747-8	978,000	221	175	982	12.81
17	B787-8	503,500	228	4,098	21,362	14.53
18	DC10-30/40	555,000	177	2	11	9.14
19	MD-11ER	633,000	206	731	3,972	12.80
20	B767-300ER	407,000	200	5,598	30,427	13.13
21	B777-300ER	750,000	221	2,330	11,695	12.92
22	L-1011	496,000	193	5	28	10.31
23	A380-800 W	1,239,000	218	373	1,956	12.34
24	A380-800 B	1,239,000	218	373	1,759	11.30
	Maximums					**14.53**

Good distribution of widebody traffic at fairly high departure levels

Case Study 2– Table 2 results from COMFAA

	Airplane	Critical Aircraft equivalent coverages	Thickness for total equivalent coverages	Maximum allowable GW	PCN FB	CDF
1	MD83	232,975	15.97	181,005	59.0	0.0033
2	MD87	1,097,885	16.05	155,773	49.3	0.0000
3	A319-100	1,316,274	16.06	172,074	47.6	0.0100
4	A320-200	581,031	16.02	180,965	52.1	0.0367
5	A321-100	149,809	15.95	204,294	61.3	0.0442
6	B727-200	57,482	15.90	239,241	71.8	0.0130
7	B717-200	>5,000,000	16.14	131,049	39.8	0.0006
8	B737-500	3,374,386	16.10	148,664	43.5	0.0030
9	B737-700/800	777,941	16.03	173,914	50.3	0.0939
10	Canadair RJ	>5,000,000	16.29	81,254	25.3	0.0000
11	DC9-51	>5,000,000	16.13	133,421	40.9	0.0000
12	B757-200	>5,000,000	16.23	273,890	40.4	0.0003
	Maximums		**16.29**		**71.8**	**0.0939**

Thickness requirement, regardless of aircraft type, all within a very tight band. Typical for a well designed pavement.

Case Study 2– Table 2 results from COMFAA

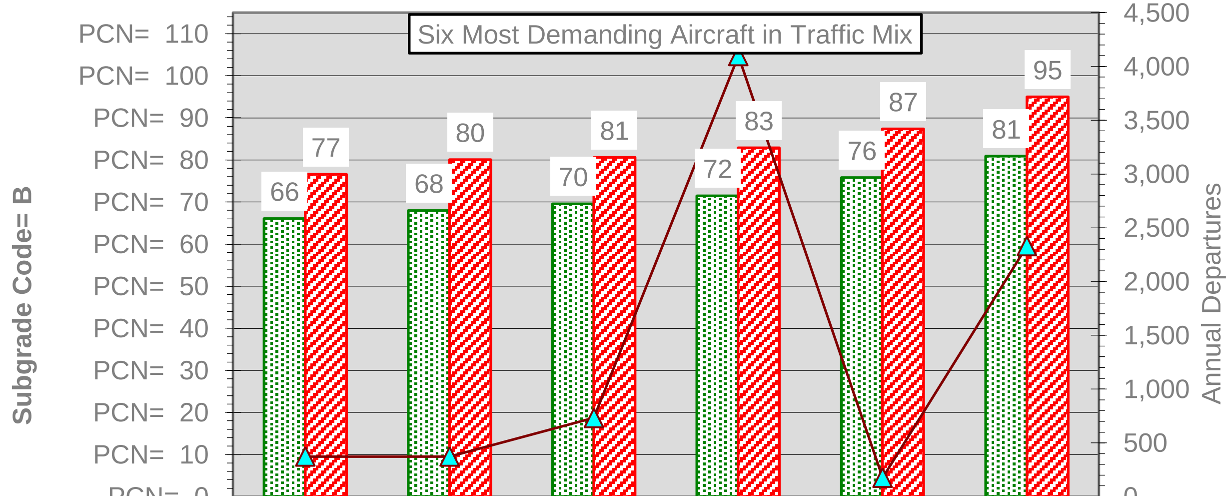
LIFECYCLE SOLUTIONS

	Airplane	Critical Aircraft equivalent coverages	Thickness for total equivalent coverages	Maximum allowable GW	PCN FB	CDF
13	A300-B4	>5,000,000	16.13	397,532	55.4	0.0003
14	A340-300	695,440	16.03	636,470	65.2	0.0022
15	B747-400ER	1,649,301	16.07	824,534	60.4	0.0021
16	B747-8	71,153	15.91	1,079,997	87.4	0.0042
17	B787-8	101,573	15.93	558,552	82.9	0.0636
18	DC10-30/40	2,839,577	16.09	613,041	60.2	0.0000
19	MD-11ER	167,161	15.96	702,513	80.6	0.0072
20	B767-300ER	1,218,110	16.05	448,570	64.6	0.0076
21	B777-300ER	488,536	16.01	827,368	95.0	0.0072
22	L-1011	459,926	16.01	552,526	72.5	0.0000
23	A380-800 W	221,609	15.97	1,377,858	76.6	0.0027
24	A380-800 B	1,272,572	16.05	1,374,765	80.1	0.0004
	Maximums		**16.13**		**95.0**	**0.0636**

CDF values all very low, total CDF well below 1.0

Case Study 2- PCN Determination

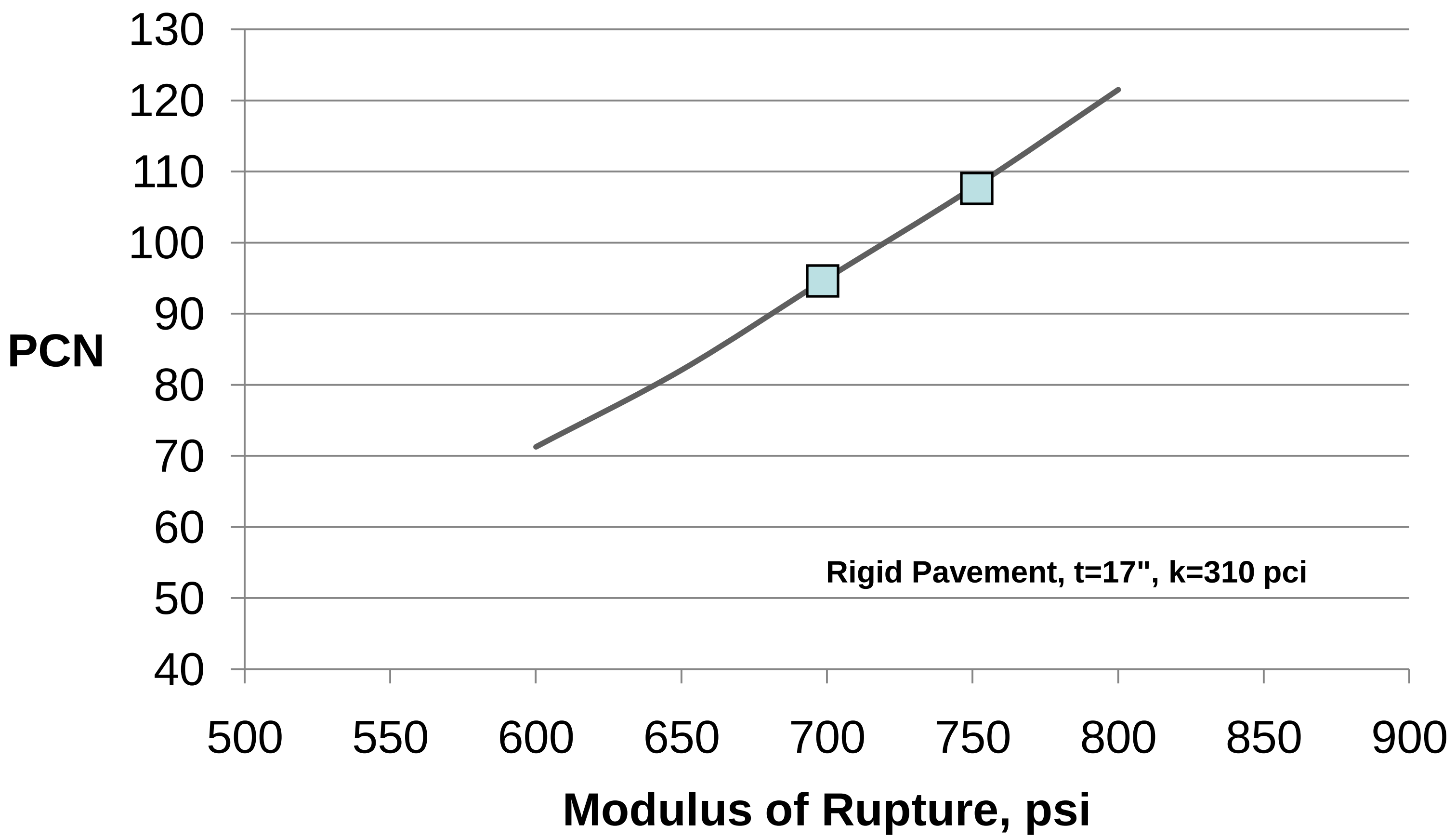
MR =700 psi, k-value = 310 pci



	A380-800 wing	A380-800 Body	MD-11ER	B787-8	B747-8	B777-300 ER
1. Aircraft ACN at traffic mix GW	66.1	68.0	69.6	71.5	75.8	80.9
2. Calculated PCN at CDF max. GW	76.6	80.1	80.6	82.9	87.4	95.0
3. Annual Departures from traffic mix	373	373	731	4,098	175	2,330

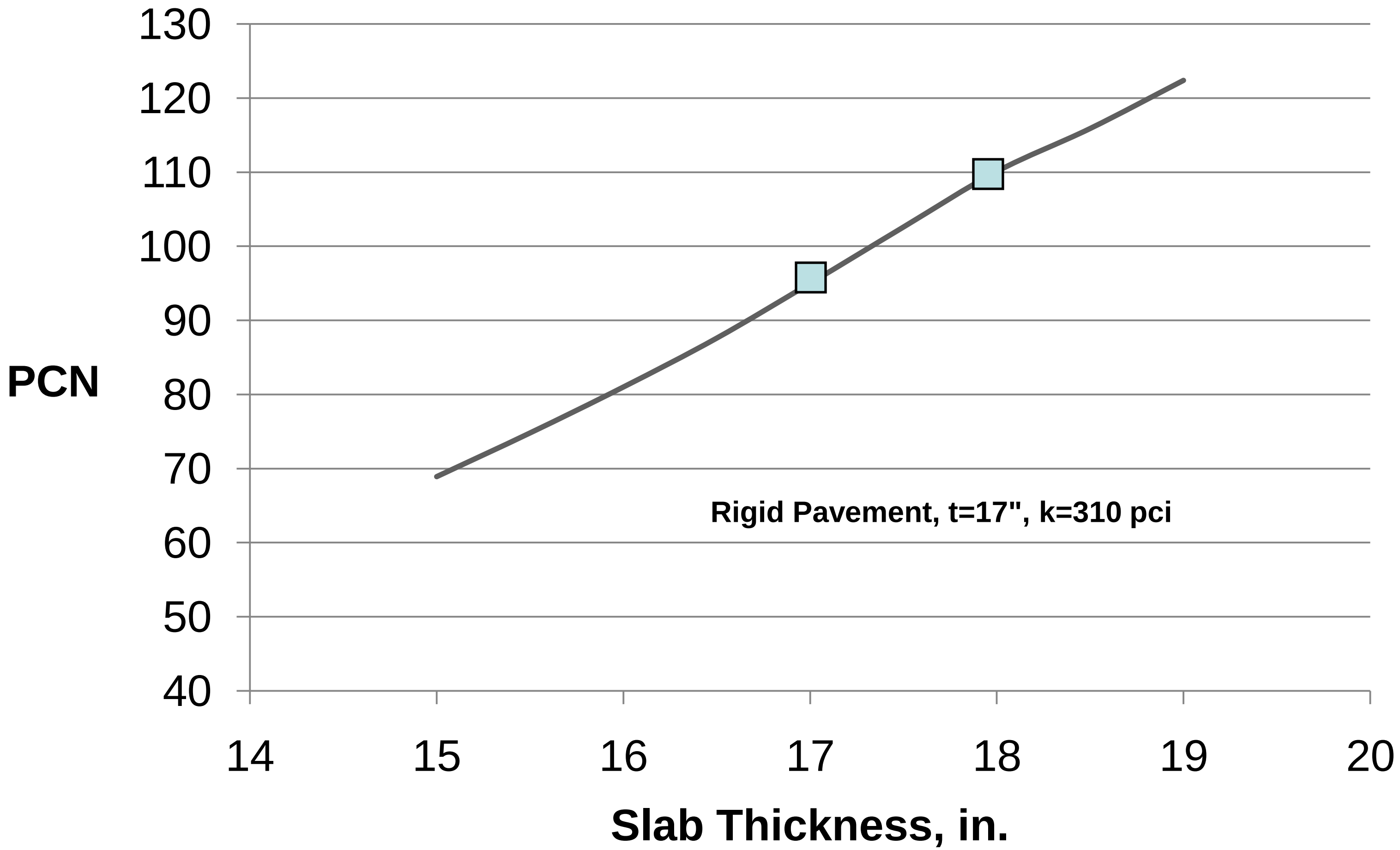
PCN 95 /R/B/W/T based on 777-300ER

Effect of Modulus of Rupture on PCN



MR effect significant- increase to 750 psi results in ~ 15% increase in PCN

Effect of Slab Thickness on PCN



Increase in slab thickness of 1” equivalent to 50 psi increase in MR- important to get design parameters correct.

Flexible Pavement – Case no. 3

- Pavement is closely designed for the anticipated traffic
- Existing airport with both narrow body & widebody traffic
- Pavement Cross-section: 10” HMA over 14” P-209 base
- Equivalent Thickness, T = 33.6”
- CBR = 7

Reference Guidance AC 150/5335-5B Appendix A-2

Flexible Pavement Structure Items	Fig. A2-2 Convert to P-209	Figs. A2-1, A2-2 Convert to P-154	Existing Flexible Pavement Layers	Existing Layer Thickness		Convert to P-209	8" P-209 Req'd	Excess for P-154	Equiv. to P-154
P-401 and/or P-403	1.6	2.0	ENTER P-401 and/or P-403	10.5	in.	8.80	8.00	0.50	1.00
P-306	1.2	1.6	ENTER P-306	0.0	in.	0.00	8.00	0.00	0.00
P-304	1.2	1.6	ENTER P-304	0.0	in.	0.00	8.00	0.00	0.00
P-209	1.0	1.4	ENTER P-209	14.0	in.	14.00	8.00	14.00	19.60
P-208 and/or P-211	1.0	1.0	ENTER P-208 and/or P-211	0.0	in.	0.00	8.00	0.00	0.00
P-301	n/a	1.0	ENTER P-301	0.0	in.	n/a	n/a	0.00	0.00
P-154	n/a	1.0	ENTER P-154	0.0	in.	n/a	n/a	0.00	0.00
							8.0		20.6

Equivalent Thickness, in.	
P-401 and/or P-403	5.0
P-209	8.0
P-154	20.6
Total	33.6

ENTER Subgrade CBR 7.0

Total thickness 24.5

**P-154 Converted to P-401 if P-401<5" and/or Converted to P-209 if P-209<8" 0.0

COMFAA Evaluation Criteria

Evaluation thickness t = 33.6 in.

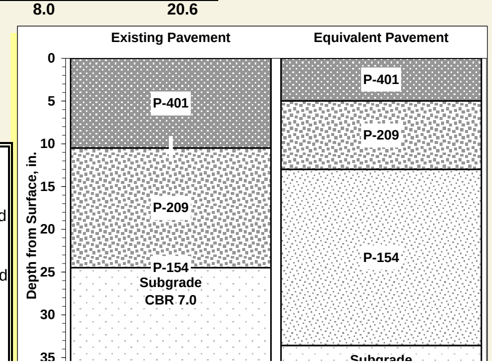
Evaluation CBR = 7.0

Recommended PCN Codes: F/C/W or

Recommended PCN Codes: F/C/X

Project Details

Huntsville Flexible Pavement Runway 18R. Subgrade CBR is 7, surface thickness is 10.5 inches, subbase thickness is 14 inches. Fuel is obtained before departure, except for Military touch & go. Runway has a parallel taxiway. The pavement life is estimated to be 20 years from 1992.



Flexible Pavement – Case study 3

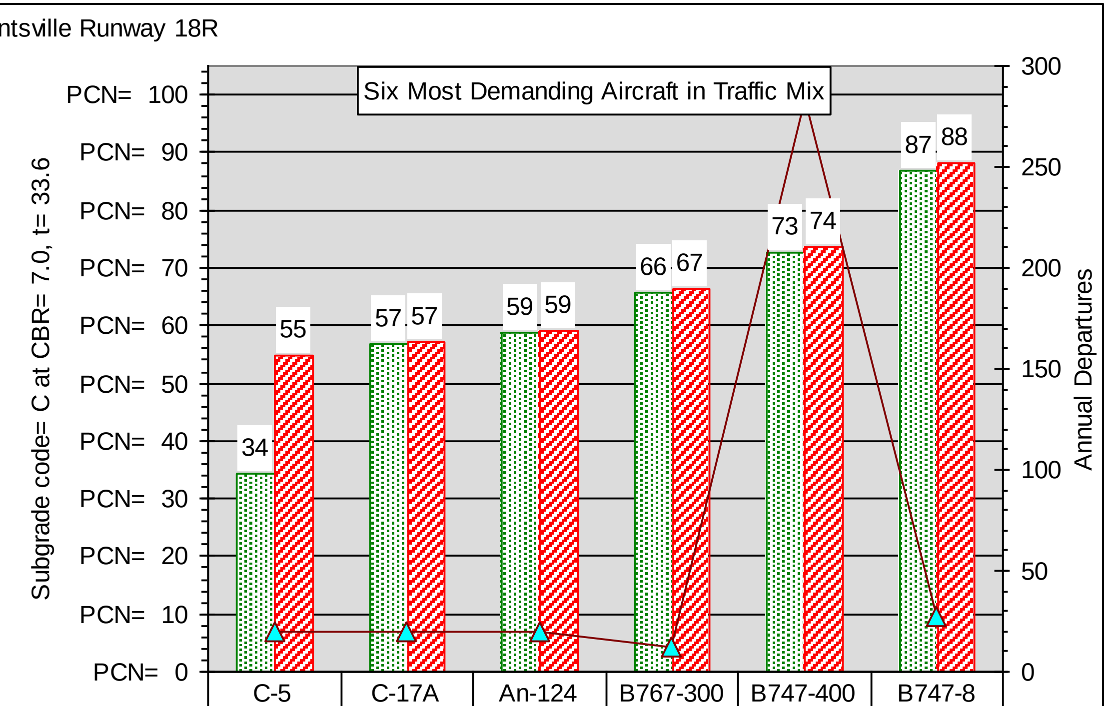
LIFECYCLE SOLUTIONS

Airplane	GW	AD	20 yr Coverages	CDF	Thickness required for Total Equivalent coverages
AN-124	877,430	20	631	.0015	33.56
B717-200	122,000	131	737	.0000	33.53
B737-400	150,500	12	68	.0001	33.49
B737-800	174,700	29	163	.0014	33.45
B747-400	877,000	284	3,257	.4660	33.39
B747-8	978,000	27	305	.1366	33.33
B757-200	256,000	178	1,792	.0000	33.56
B767-300	413,000	12	131	.0082	33.42
C-130	155,000	3,182	27,521	.0000	33.57
C-17	585,000	20	306	.0014	33.54
KC-135	322,500	3,400	40,364	.2597	33.49
MD88	150,500	438	2,477	.0073	33.48
C-5	769,000	20	493	.0000	26.49
MD83	161,000	626	3,660	.0281	33.46

Total CDF=1.0

PCN Determination

CBR = 7

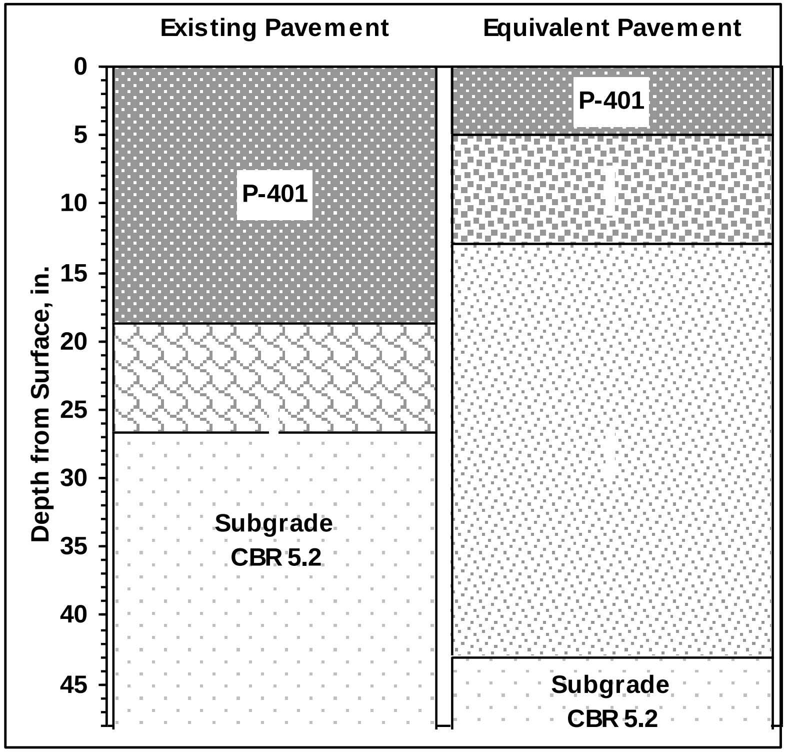


	C-5	C-17A	An-124	B767-300	B747-400	B747-8
1. Aircraft ACN at traffic mix GW	34.2	56.8	58.8	65.8	72.6	86.8
2. Calculated PCN at CDF max. GW	54.9	57.1	59.0	66.5	73.6	88.3
3. Annual Departures from traffic mix	20	20	20	12	284	27

PCN 88/ F/C/W/T, just exceeds ACN of 87 FC indicating well designed pavement

Flexible Pavement – Case study 4

- Marginal design for anticipated traffic
- Existing airport with both narrow body & widebody traffic
- Airport not quite sure of soil strength variation throughout the airport, reported CBR=5.2 as average value.
- Equivalent t = 43”- 19” P-401 on top of 8” CTB.



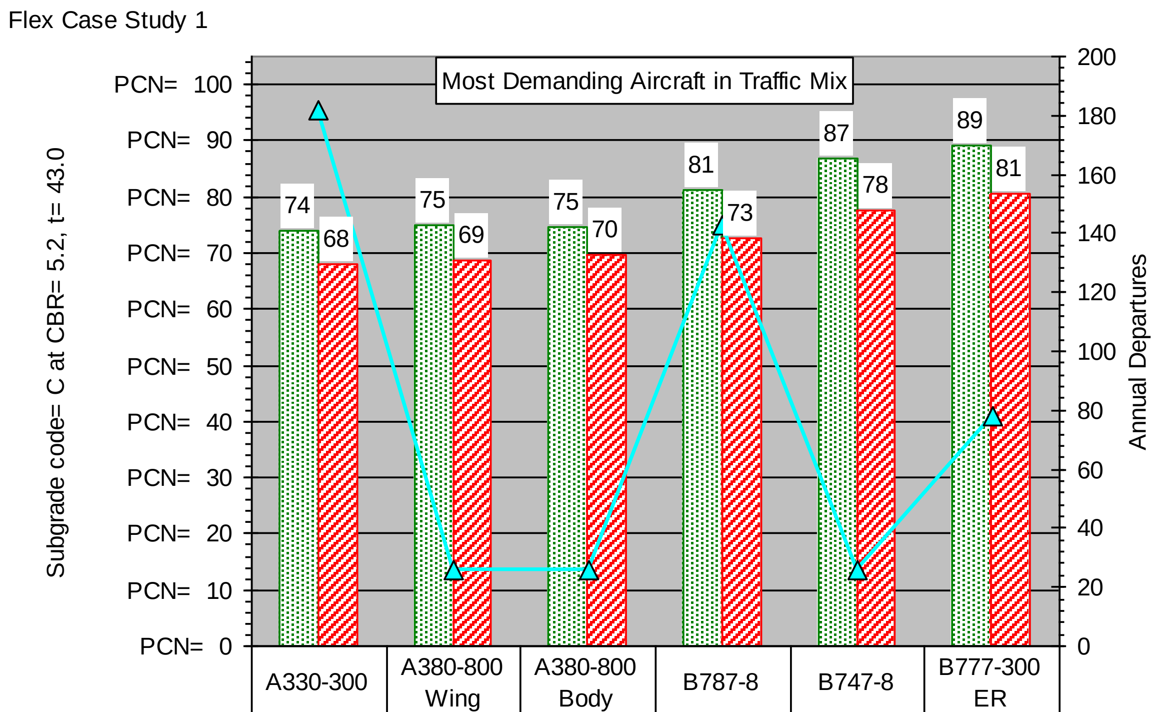
Aircraft Traffic

	Airplane	GW	AD	20 yr Coverages	Thickness required for total equivalent coverages
1	A300-B4	365,747	130	1,583	42.46
2	A310-200	315,041	1,040	11,163	40.73
3	A319-100	150,796	1,222	6,241	39.63
4	A320 Twin	172,842	5,876	31,677	41.21
5	A330-300	515,661	182	1,935	45.40
6	A340-200	568,563	468	5,010	43.80
7	A380-800 Body	1,234,589	26	366	44.41
8	A380-800 Wing	1,234,589	26	272	46.02
9	B737-800	174,700	702	3,947	41.54
10	B747-8	978,000	26	294	48.03
11	B767-300 ER	413,000	78	854	44.50
13	B777-300	662,000	156	2,267	44.22
14	B777-300 ER	777,000	78	1,195	47.26
15	B787-8	503,500	143	1,491	47.29
16	MD90-30 ER	168,500	182	1,089	41.42
17	747-400	877,000	26	298	45.54

Thickness requirement for several aircraft exceeds 43” indicating under designed pavement

PCN Determination-CBR Sensitivity

CBR = 5.2

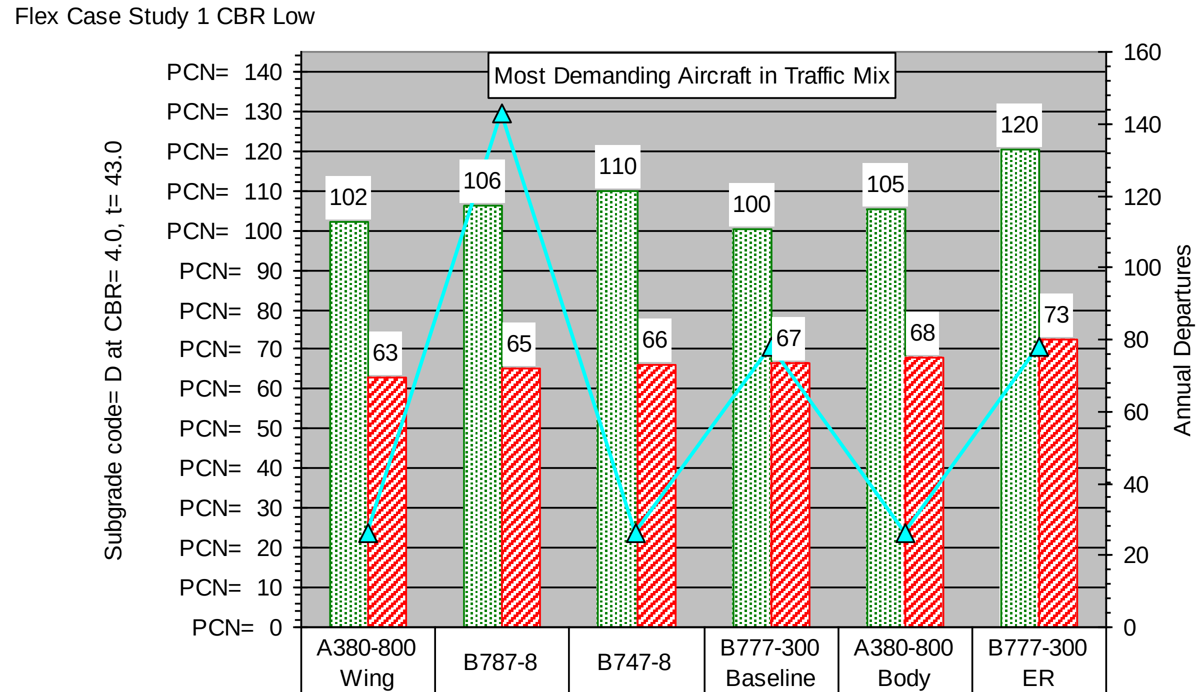


	A330-300	A380-800 Wing	A380-800 Body	B787-8	B747-8	B777-300 ER
1. Aircraft ACN at traffic mix GW	74.0	75.1	74.7	81.2	86.8	89.3
2. Calculated PCN at CDF max. GW	68.1	68.6	69.8	72.7	77.5	80.7
3. Annual Departures from traffic mix	182	26	26	143	26	78

PCN 81/ F/C/W/T would not allow unrestricted 747-8 and 777-300ER operations

PCN Determination-CBR Sensitivity

CBR = 4

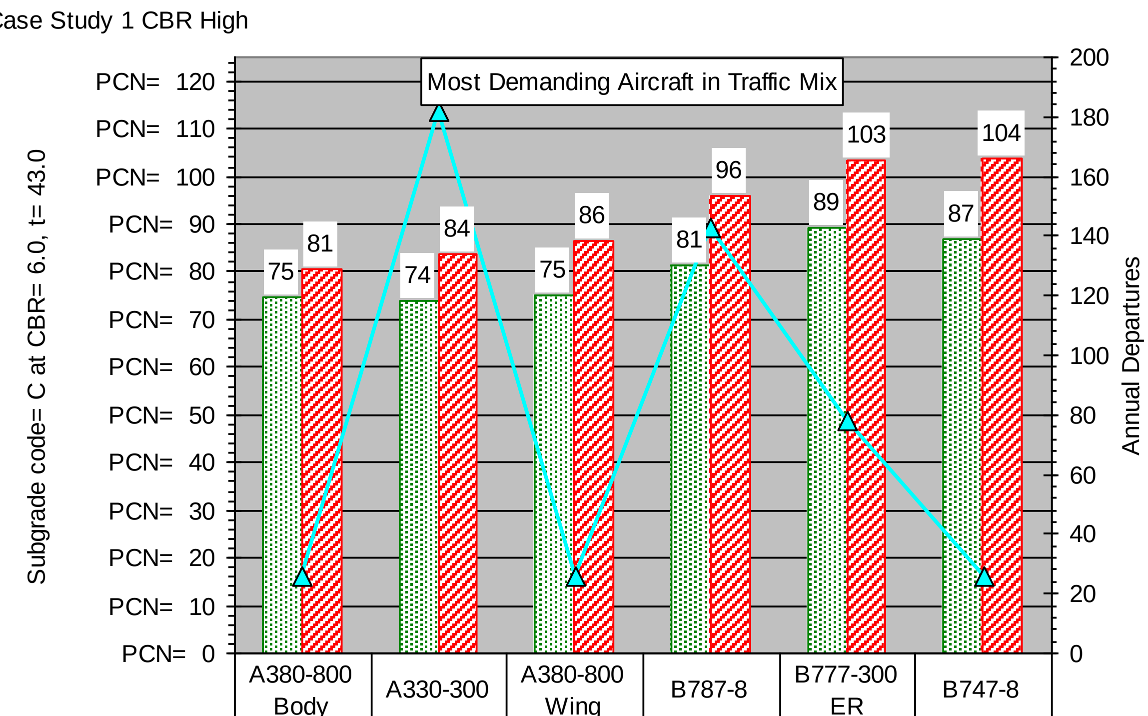


	A380-800 Wing	B787-8	B747-8	B777-300 Baseline	A380-800 Body	B777-300 ER
1. Aircraft ACN at traffic mix GW	102.1	106.2	109.9	100.2	105.2	120.3
2. Calculated PCN at CDF max. GW	62.8	65.0	66.3	66.5	67.8	72.5
3. Annual Departures from traffic mix	26	143	26	78	26	78

PCN 73/ F/D/W/T would not allow any aircraft to operate

PCN Determination-CBR Sensitivity

CBR = 6



	A380-800 Body	A330-300	A380-800 Wing	B787-8	B777-300 ER	B747-8
1. Aircraft ACN at traffic mix GW	74.7	74.0	75.1	81.2	89.3	86.8
2. Calculated PCN at CDF max. GW	80.5	83.6	86.3	95.8	103.2	103.6
3. Annual Departures from traffic mix	26	182	26	143	78	26

PCN 104/ F/C/W/T allows all aircraft to operate

Flexible Case Studies Conclusions

LIFECYCLE SOLUTIONS

- COMFAA PCN computation is very sensitive to CBR, as seen by variation from CBR 4-6 either allowing or not allowing all traffic to operate.
- COMFAA PCN computation is well behaved, i.e. thickness requirement regardless of aircraft match quite well when pavement is well designed, i.e. CDF~1.0 in case study 3.
- PCN based on B747-8 is 88 FCWT in case study 3. Stresses importance of accounting for new aircraft added to a traffic mix. Prior to 747-8 operations, PCN of 74 FC based on 747-400 would be insufficient, even though pavement is capable of handling all aircraft.
- Current FAA ratings of DT 300 and DDT 850 for case study 3 would not allow 747 nor 767 at their maximum weights.

Misc Issues- Over-designed pavement

PCN Results Flexible 12-23-2009.txt - Notepad

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CBR = 17.00 (Recommended ICAO Code Designation is A)
Evaluation pavement thickness = 85.30 in

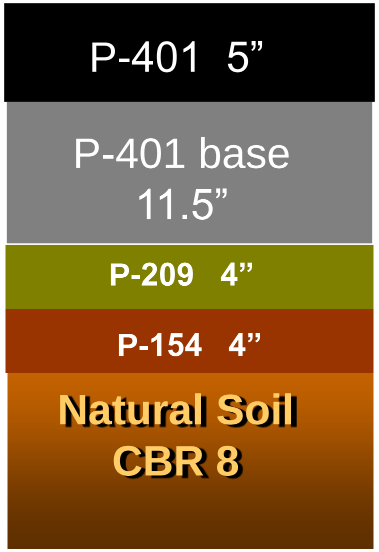
No.	Aircraft Name	Gross Weight	Percent Gross Wt	Tire Press	Annual Deps	20-yr Coverages	6D Thick
1	An-124	877,430	95.00	149.0	3	95	11.52
2	B727-100	170,000	95.30	165.0	178	1,109	13.36
3	B727-200	185,200	96.00	148.0	27	186	11.37
4	B737-200	128,600	91.92	182.0	3,580	18,738	14.08
5	B737-700	155,000	91.70	205.0	1,632	8,561	14.74
6	B737-900 ER	188,200	94.58	220.0	874	4,949	16.25
7	B747-100	738,000	92.48	232.0	5	49	9.81
8	B747-200	836,000	90.96	190.0	1	11	7.66
9	B747-200F	836,000	90.96	190.0	575	6,523	16.60
10	B747-400	877,000	93.32	200.0	1	11	8.00
11	B747-400F	877,000	93.32	200.0	443	5,081	17.20
12	B747-8	978,000	94.69	221.0	443	4,971	18.55
13	B757-200	256,000	91.18	183.0	874	8,798	13.25
14	B767-200	317,000	92.30	190.0	874	8,604	14.32
15	DC-4	73,002	93.60	76.9	183	1,131	6.82
16	HS748	46,500	87.20	85.6	88	425	5.36
17	L-100	155,801	96.40	104.4	81	709	10.30
18	L-1011	432,000	94.80	192.9	3	32	9.78
19	MD80	161,000	94.76	195.0	1,492	8,723	15.87
20	Mk500	43,601	95.00	78.3	182	934	5.50

When computing the numbers of coverages to failure, the coverages for none of the aircraft converged at a pavement thickness greater than 99 percent of the evaluation thickness. This means that the life of the pavement is unlimited and the pavement is very strong in relation to the aircraft loading. The relative aircraft load evaluations are also unreliable. Consider reviewing the procedures used to determine the evaluation thickness and the strength of the support. The thicknesses for unlimited operations of each of the aircraft are as follows.

An-124	17.38
B727-100	26.08
B727-200	27.48
B737-200	22.04
B737-700	24.20
B737-900 ER	28.16
B747-100	21.41
B747-200	22.76
B747-200F	22.76
B747-400	23.98
B747-400F	23.98
B747-8	26.13
B757-200	17.87
B767-200	19.10
DC-4	12.78
HS748	10.90
L-100	19.63
L-1011	22.54
MD80	26.76

Program notes that since the pavement is so strong it cannot converge upon a value as to when the pavement would theoretically fail. The relative aircraft load evaluations and resulting PCN's are unreliable. In this case we recommended a PCN that was 10-25% above highest ACN aircraft to accommodate any future traffic, which the airport accepted.

Misc Issues- Equivalent Thickness Sensitivity

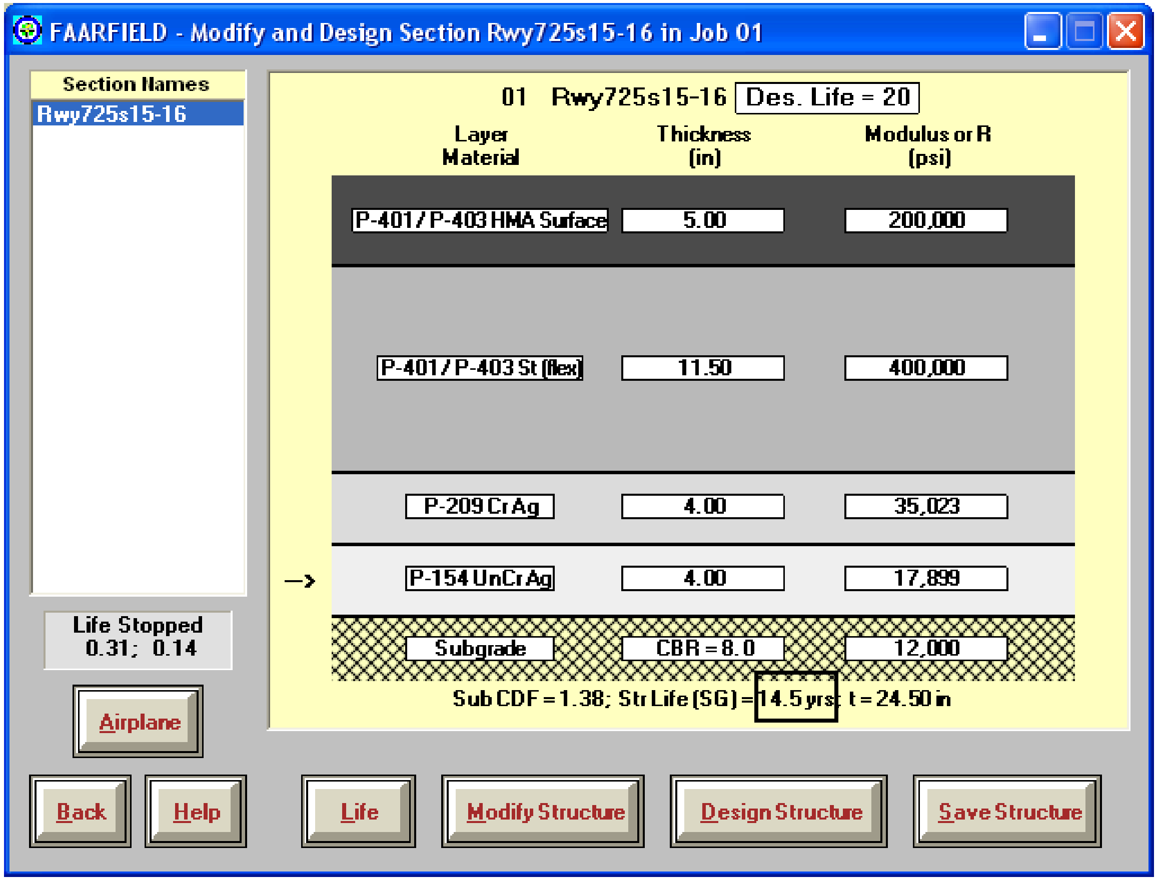


Equivalent thickness varies from 31” to 33” depending on equivalency factors used. New alpha factors from test data were determined based on equivalencies of 1.6 for P-401 and 1.4 for P-209. Reference: Alpha Factor Determination from NAPTF Test Data, AAR-410 report, 2005.

Misc Issues- Equivalent Thickness Sensitivity

Airplane	AD	Coverages to Failure	Thickness req'd for total equiv. coverages	ACN FB	PCN FB	CDF	
737-400	208	3 E6	31.66	40	38.0	0.0003	
727-200	2,412	18,715	32.41	62	57	0.8592	
747-200	24	29,376	32.11	65	60	0.0093	
767-200ER	12	68,805	31.96	60	56	0.0019	31”
747-400ER	108	5,994	32.51	77	70	0.1967	
DC-8/63	1,872	20,940	32.13	65	61	1.0684	
MD83	416	145,487	31.99	50	47	0.0167	
737-400	208	42 E6	32.67	40	41	0.0000	
727-200	2,412	56,039	32.14	62	65	0.2869	
747-200	24	125,438	32.38	65	67	0.0022	
767-200ER	12	386,877	32.48	60	62	0.0003	33”
747-400ER	108	16,854	32.11	77	82	0.0700	
DC-8/63	1,872	87,514	32.38	65	67	0.2556	
MD83	416	738,325	32.45	50	51	0.0033	

Misc Issues- FAARFIELD Design



FAARFIELD results do not match COMFAA precisely (i.e. FF requires thicker pavement), mainly due to calibration of FF to old alpha factors and 'non-standard' pavement structures.

Further Conclusions

LIFECYCLE SOLUTIONS

- For extremely overdesigned pavements engineering judgement must be used to determine a practical PCN value.
- Equivalency factors to be used for flexible pavement designs can influence the results significantly. Based on numerous case studies, 1.6 for P-401 to P-209 conversion, and 1.4 for P-209 to P-154 conversion seem reasonable.
- FAARFIELD new designs for flexible pavements not totally compatible with COMFAA results. Possible recalibration of FF will improve compatibility.

Questions?