DESIGN PROGRAM BASED PCN EVALUATION OF AIRCRAFT PAVEMENTS

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LARSEN & TOUBRO LIMITED
TRANSPORTATION INFRASTRUCTURE IC

FAA-Worldwide Airport Technology Transfer Conference 2014 – New Jersey , USA

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10 Airport Projects Executed in Design and Build Contracts

MUMBAI INTERNATIONAL AIRPORT

ABU DHABI INTERNATIONAL AIRPORT

DELHI INTERNATIONAL AIRPORT

HYDERABAD INTERNATIONAL AIRPORT

SALALAH INTERNATIONAL AIRPORT

BENGALURU INTERNATIONAL AIRPORT

INTRODUCTION

- ACN: A number expressing the relative effect of an aircraft on a pavement for a standard subgrade strength
- PCN: Publication in AIP
- ICAO ACN – PCN Method
  - Pavement Mgmt Tool - Not recommended for design
  - ICAO - Permits any design / evaluation method
- Design & PCN Evaluation
  - Should be based on same principle
- COMFAA & FAARFIELD are not
- Alternative Approach proposed in the Paper
  - PCN Reporting based on design principle / software

PCN EVALUATION METHODS

- PCN Reporting – 50/R/C/W/T OR 50/F/B/X/U
- ICAO ACN METHOD
  - Based on reference thickness required for ACN specified by manufacturer
  - Reference thickness for particular aircraft weight
  - Tire pressure 1.25MPa

FLEXIBLE PAVEMENT

REFERENCE THICKNESS COMPUTATION

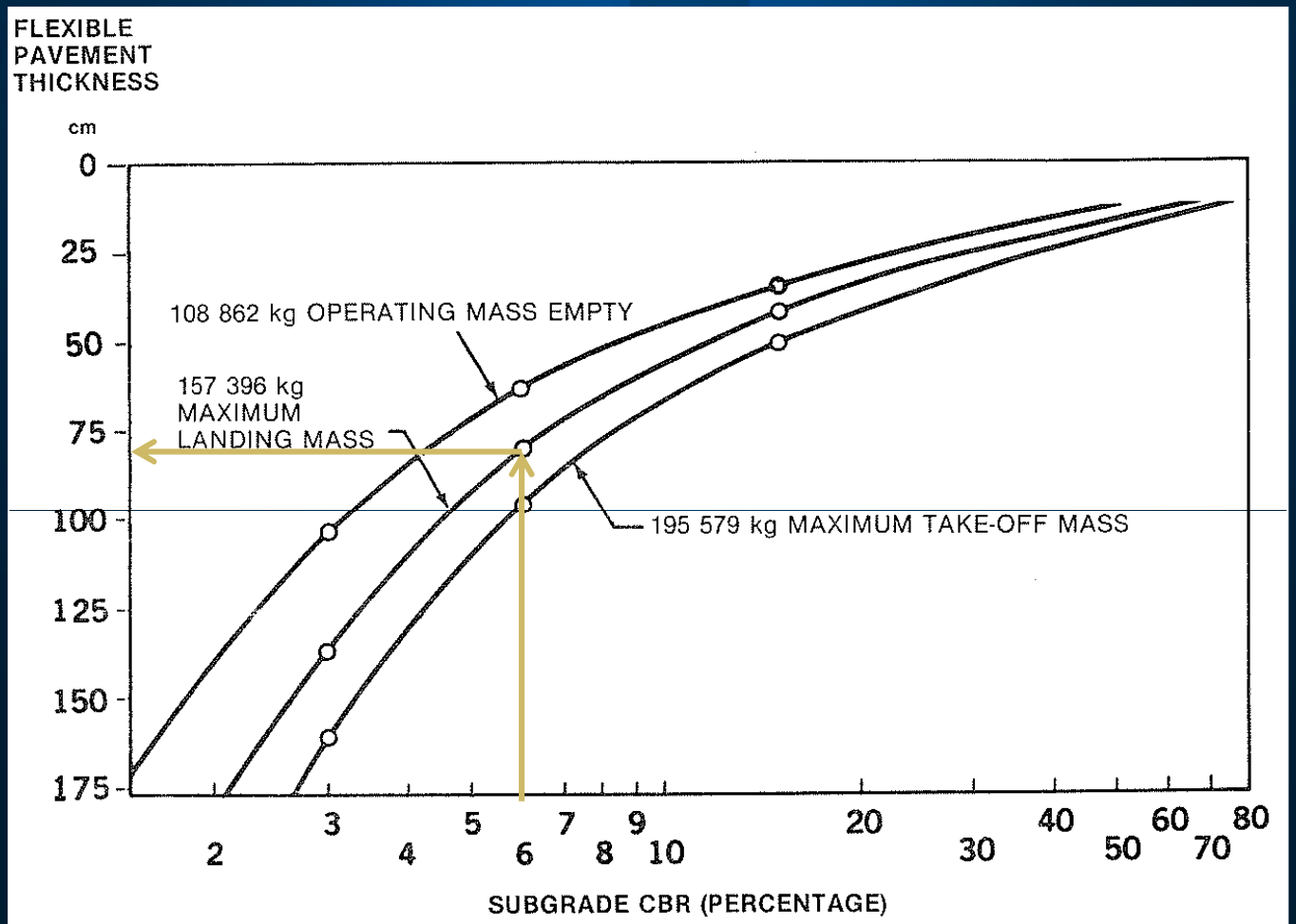


Figure 1-8. DC10-10 Flexible Pavement Requirements
10 000 Coverages aft c.g.

ICAO – ADM Part 3 – Pavements 1983

FLEXIBLE PAVEMENT

ACN DETERMINATION

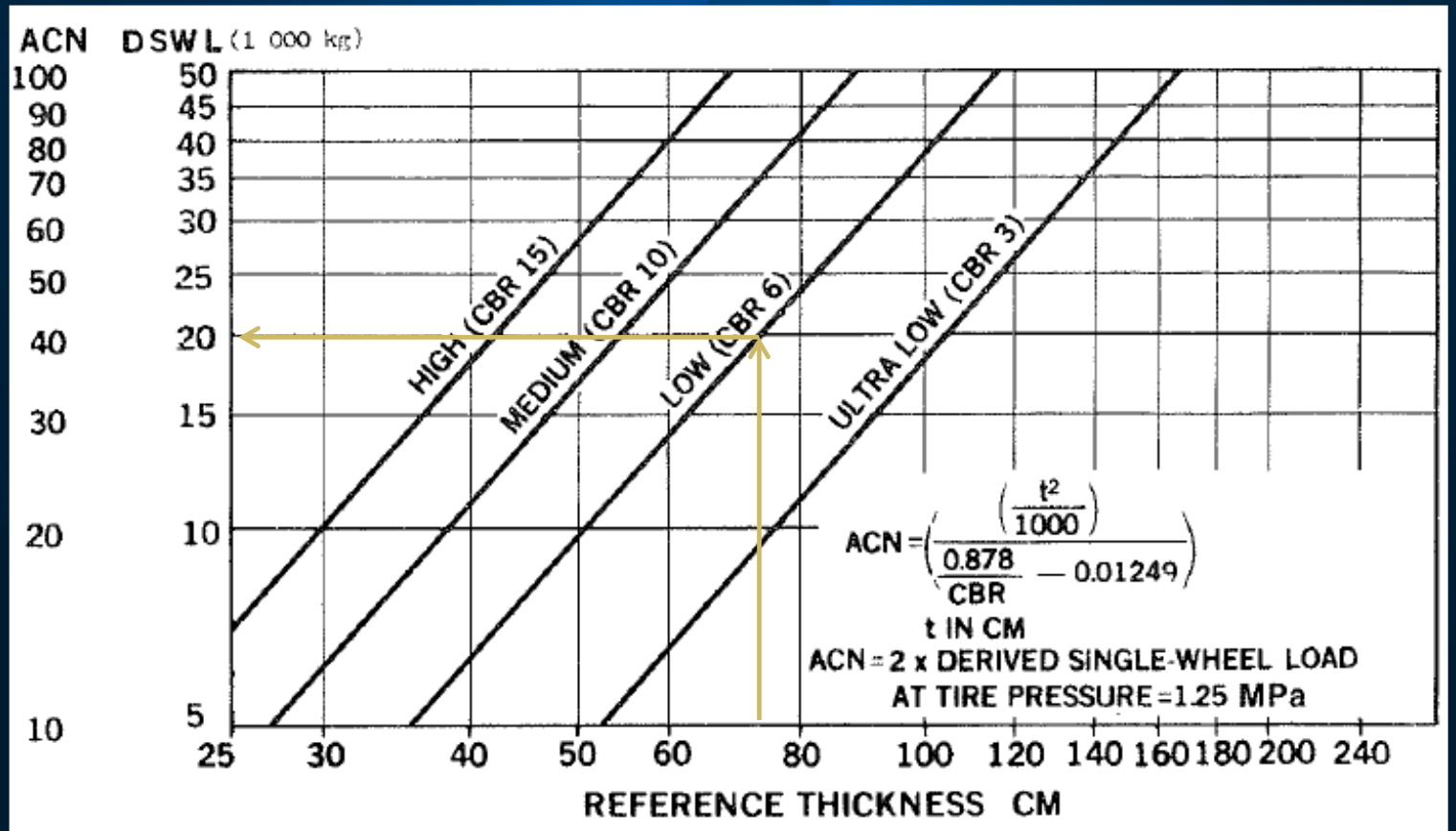
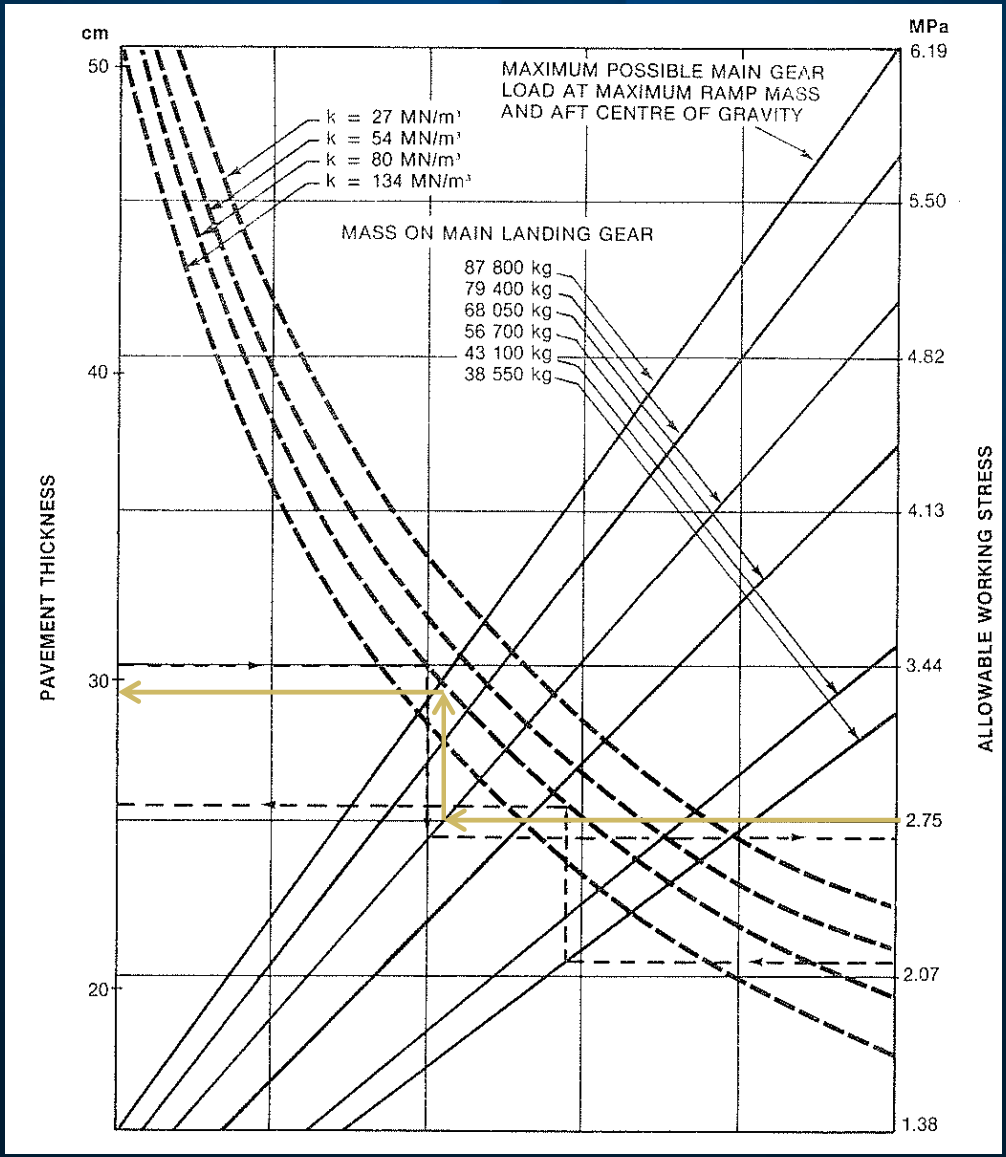


Figure 1-5. ACN Flexible Pavement Conversion Chart

ICAO – ADM Part 3 – Pavements 1983

RIGID PAVEMENT

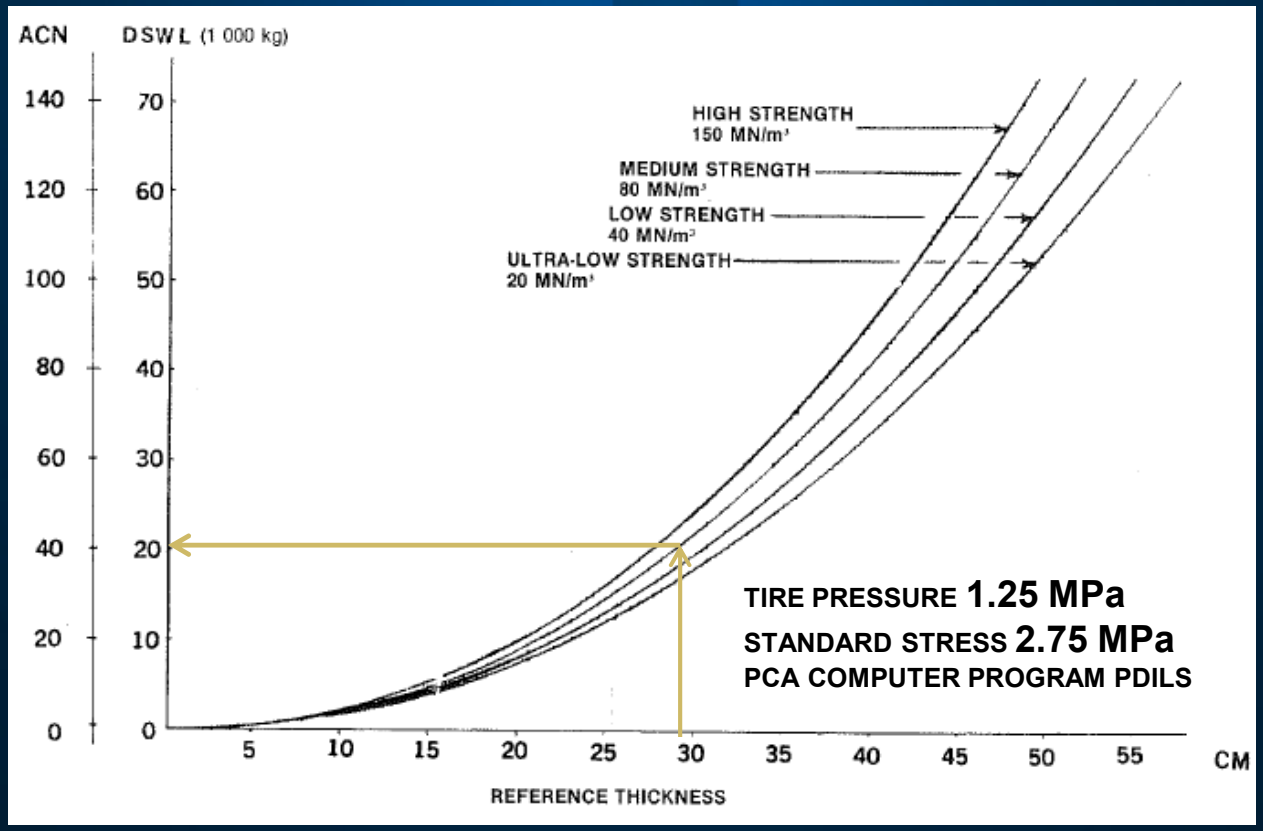
REFERENCE THICKNESS COMPUTATION



ICAO – ADM Part 3 – Pavements 1983

RIGID PAVEMENT

ACN DETERMINATION



ICAO – ADM Part 3 – Pavements 1983

ACN FOR REFERENCE THICKNESS

PCN for evaluation thickness is based on allowable weight in relation to ACN for reference thickness

FAA – PCN EVALUATION & REPORTING METHOD

- FAA AC/5335-5B - COMFAA PROGRAM

- For evaluation structure – Flexible and Rigid
  - Max. allowable weight computed for eq. coverages
  - ACN for 10000 coverages at max. allowable weight
  - ACN computed for each aircraft separately considering each as critical
  - Max. ACN = PCN

DESIGN COMPARISON - FLEXIBLE

Methods – FAA 6D, COMFAA and FAARFIELD

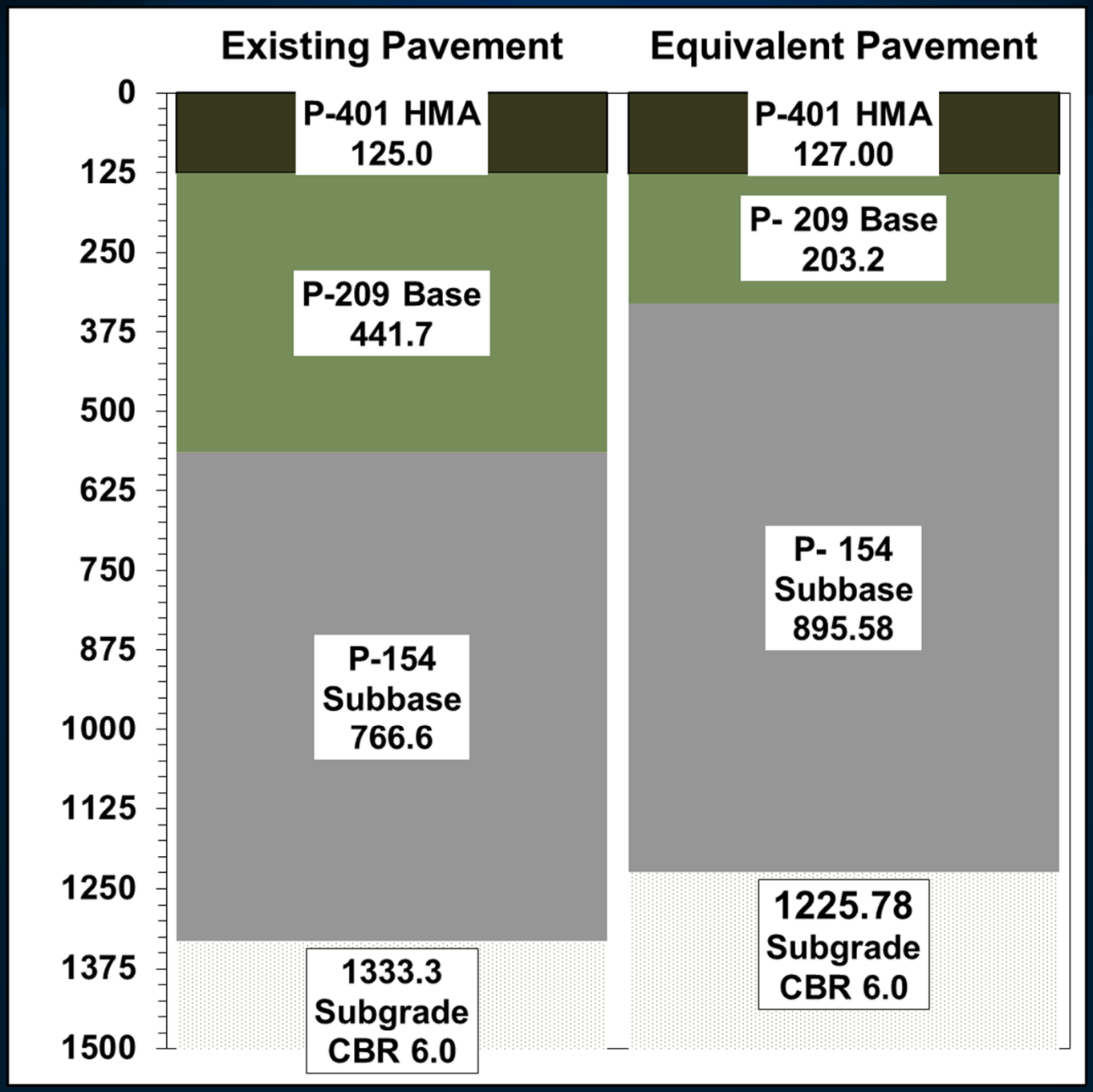
- DESIGN PARAMETERS
  - CBR 6%, Design Life 20 Years
  - DESIGN TRAFFIC

AIRCRAFT	MTOW (TONNES)	ANNUAL DEPARTURES		AIRCRAFT	MTOW (TONNES)	ANNUAL DEPARTURES	
		FLEET MIX 1	FLEET MIX 2			FLEET MIX 1	FLEET MIX 2
A320-200 Twin std	77	10,951	17,155	B737-900	79	2,393	26,171
A321-200 std	89	1,157	2,373	B767-400 ER	204	0	694
A300-B4 std	171	0	1,314	B747-400B Combi	397	110	730
A330-300 std	230	5,419	1,314	B777-300 Baseline	300	0	1,007
A340-300 std	275	0	511	B777-300 ER	353	221	416
A340-600 std	368	0	250	MD11ER	285	0	219
A380-800	560	365	37	B787-8 (Preliminary)	228	673	0

DESIGN COMPARISON - FLEXIBLE

FLEXIBLE PAVEMENT LAYERS	THICKNESS (mm)					
	FLEET MIX 1			FLEET MIX 2		
	FAA 6D	COMFAA	FAARFIELD	FAA 6D	COMFAA	FAARFIELD
P-401/ P-403 HMA Surface	125	127	125	125	127	125
P-209 Cr Ag	383	203	450.4	408	203	441.7
P-154 UnCr Ag	765	826.9	687.1	826	881.5	766.6
Total	1273	1157	1262.5	1359	1211.5	1333.3

Reduced Design Thickness by COMFAA - Due to Layer Equivalency Conversion


Existing Pavement
Equivalent Pavement
0
125
250
375
500
625
750
875
1000
1125
1250
1375
1500
P-401 HMA
125.0
P-209 Base
441.7
P-154
Subbase
766.6
1333.3
Subgrade
CBR 6.0
P-401 HMA
127.00
P- 209 Base
203.2
P- 154
Subbase
895.58
1225.78
Subgrade
CBR 6.0

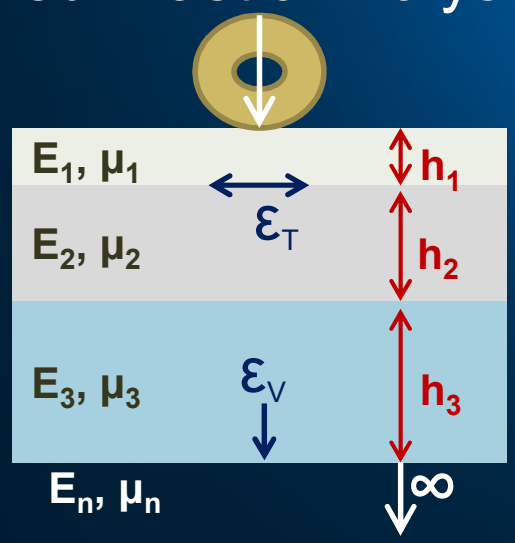
DESIGN COMPARISON - FLEXIBLE

Flexible Pavement layers	Thickness (mm)	
	FAARFIELD	COMFAA SUPPORT SPREADSHEET
P-401/ P-403 HMA SURFACE	125	127
P-209 CRUSHED AGGREGATE	441.7	203.2
P-154 UNCRUSHED AGGREGATE	766.6	895.6
TOTAL	1333.3	1225.8
DESIGN LIFE BY FAARFIELD	20 YEARS	5.3 YEARS

COMPARISON OF PAVEMENT DESIGN

FLEXIBLE PAVEMENTS

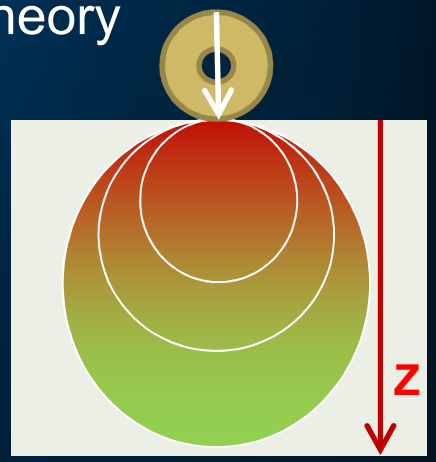
- AC 150/5320 – 6E - FAARFIELD
- Layered Elastic Analysis



- Vertical subgrade strain for each Aircraft
- CDF Optimized to 1

- AC 150/5320 – 6D - COMFAA
- US Corps of Engrs – CBR ESWL Method

Boussinesq's Theory



- Eq. coverages for critical Aircraft
- Total Pavement Thickness over Subgrade CBR, with α factors
- Sub-layering Theory not utilized

DESIGN COMPARISON - RIGID

DESIGN PARAMETERS

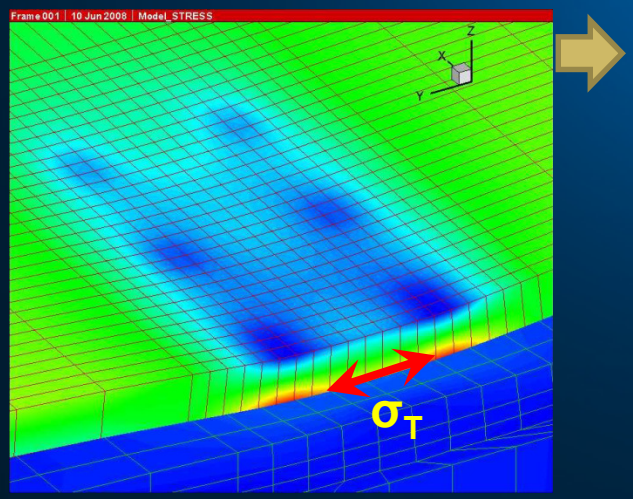
- Design life 20 years
- Design traffic – same as considered for flexible
- k Subgrade = 25.8 MN/m^3 for CBR 6%
- k = 91 MN/m^3, by COMFAA Support Sheet , beneath slab.

RIGID PAVEMENT LAYERS	THICKNESS (mm)					
	FLEET MIX 1			FLEET MIX 2		
	FAA 6D	COMFAA PCA	FAARFIELD	FAA 6D	COMFAA PCA	FAARFIELD
PCC Surface	421	370.1	425.1	425	379.5	427
P-304 CTB	150	150	150	150	150	150
P-209 Cr Ag	200	200	200	200	200	200
P-154 UnCr Ag	200	200	200	200	200	200

COMPARISON OF PAVEMENT DESIGN

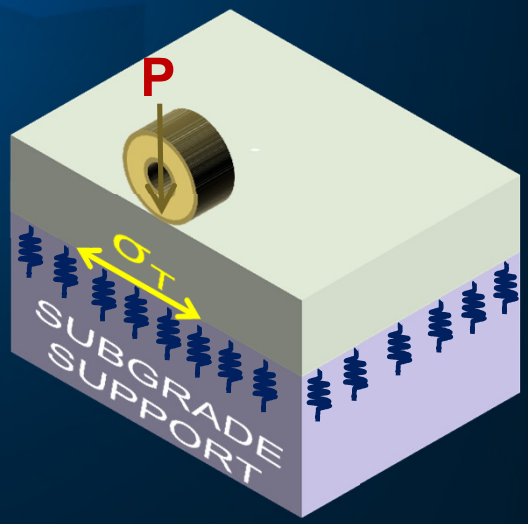
RIGID PAVEMENTS

- AC 150/5320 – 6E – FAARFIELD
- Finite Element Analysis



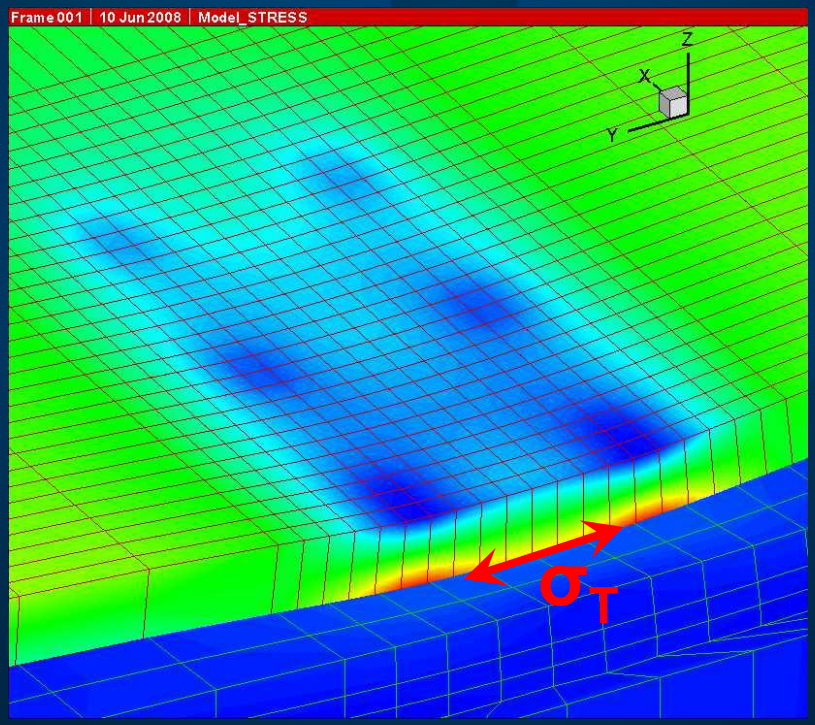
- Horizontal edge stress separately for each aircraft
- CDF optimized to 1

- AC 150/5320 – 6D – COMFAA
- Westergaard's Solutions



- Equivalent coverages of Critical aircraft
- Limitation – Modelling complex aircraft gear assemblies

FINITE ELEMENT ANALYSIS



- Rigid slab in 8 node brick, incompatible solid elements of thickness same as the slab
- Extended stepped subbase foundation, with a sliding interface
- Infinite subgrade

MODULUS OF SUBGRADE REACTION (k) CONSIDERATION

- PLATE LOAD TEST
  - Inconvenient test procedure
  - Worst moisture condition

- k Value correlated from CBR
  - Simple to conduct in lab
  - Saturated state
  - PCA correlation k & CBR (ICAO ADM PART 3) CHART
  - k Directly beneath concrete slab CHART
  - Applicable for ICAO – ACN
    - COMFAA – PCN Analysis ?

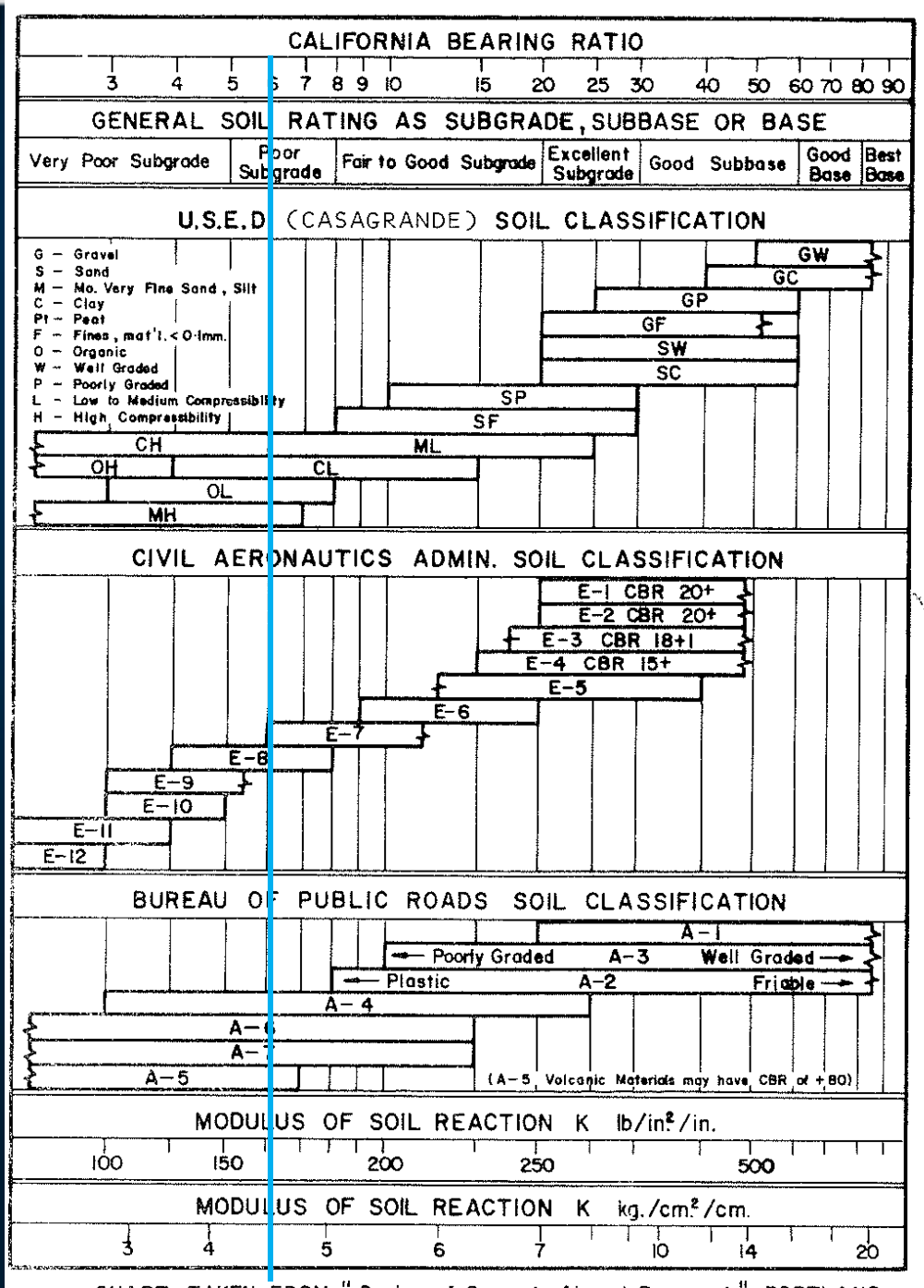
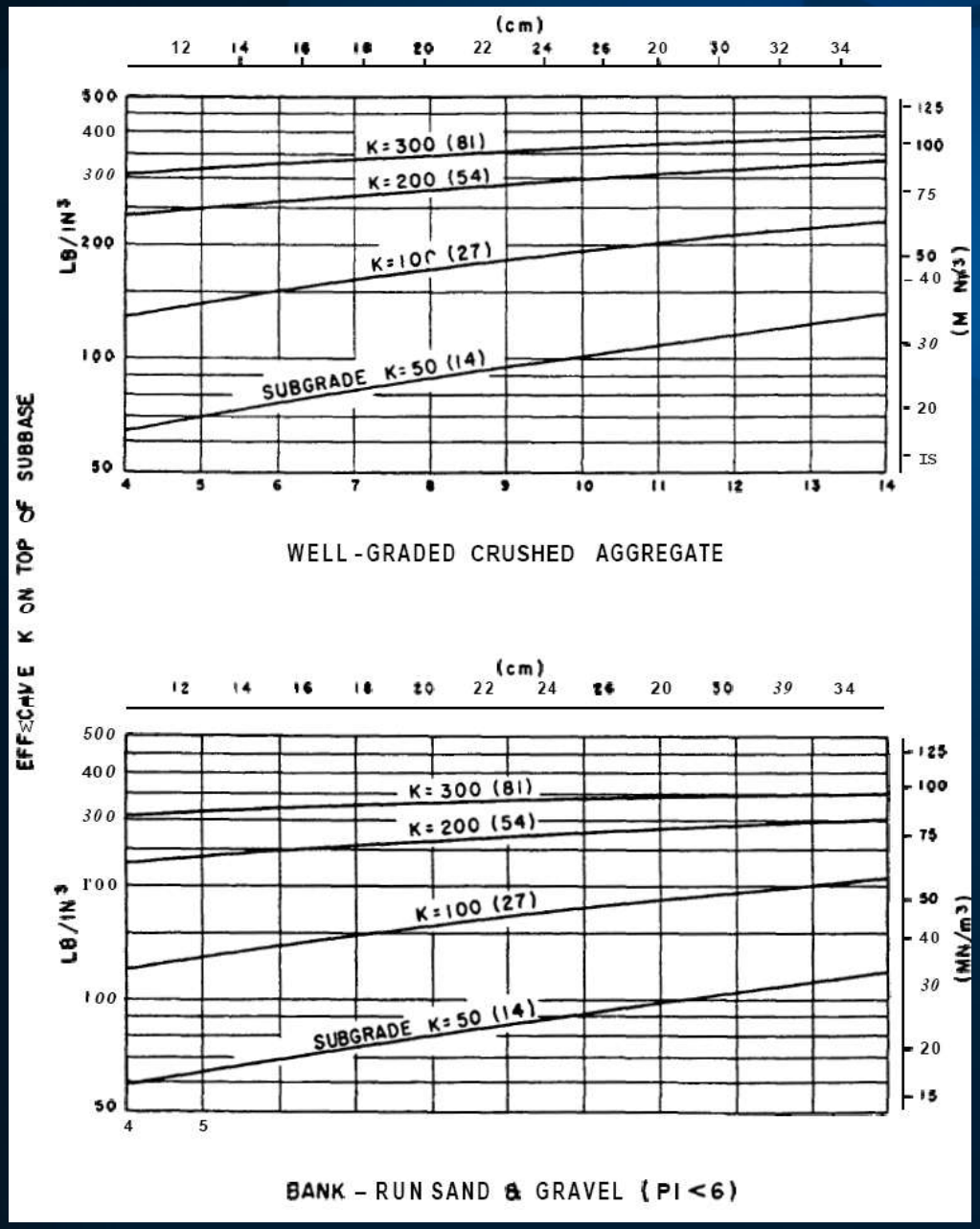
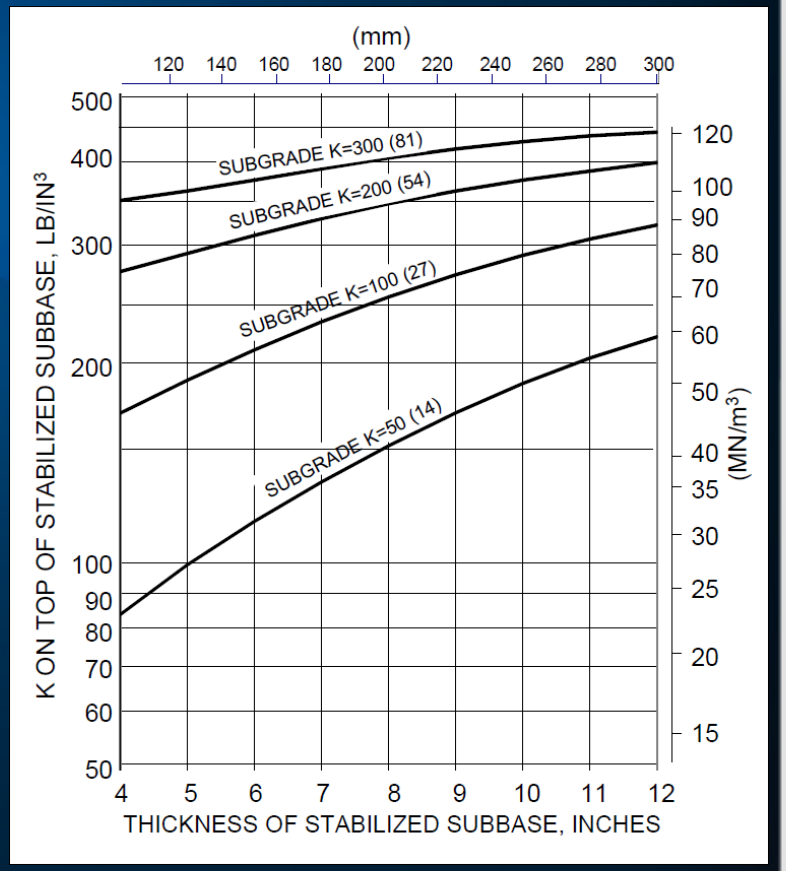


CHART TAKEN FROM "Design of Concrete Airport Pavement" PORTLAND CEMENT ASSOCIATION.


(cm)
12 14 16 18 20 22 24 26 20 30 32 34
500 400 300 200 100 50
LB/IN³
K=300 (81)
K=200 (54)
K=100 (27)
SUBGRADE K=50 (14)
125 100 75 50 40 30 20 15
(MN/m³)
4 5 6 7 8 9 10 11 12 13 14
WELL-GRADED CRUSHED AGGREGATE
EFFECTIVE K ON TOP OF SUBBASE
(cm)
12 14 16 18 20 22 24 26 20 30 39 34
500 400 300 100 100 50
LB/IN³
K=300 (81)
K=200 (54)
K=100 (27)
SUBGRADE K=50 (14)
125 100 75 50 40 30 20 15
(MN/m³)
4 5
BANK – RUN SAND & GRAVEL (PI<6)


(mm)
120 140 160 180 200 220 240 260 280 300
500 400 300 200 100 90 80 70 60 50
K ON TOP OF STABILIZED SUBBASE, LB/IN³
SUBGRADE K=300 (81)
SUBGRADE K=200 (54)
SUBGRADE K=100 (27)
SUBGRADE K=50 (14)
120 100 90 80 70 60 50 40 35 30 25 20 15
(MN/m³)
4 5 6 7 8 9 10 11 12
THICKNESS OF STABILIZED SUBBASE, INCHES

MODULUS OF SUBGRADE REACTION (k) CONSIDERATION

- In FE Analysis
  - Pavement support characterized by **E, μ**
  - "E" Is derived from input k Value

$$k\ (pci) = \left(\frac{E\ (psi)}{26}\right)^{0.7788}$$

∴ Difference in consideration for subgrade support

- If design k from input *CBR [E (psi) = 1500 CBR]* and above equation
  - Different from k for COMFAA analysis

e.g. FOR CBR = 6%

USING EQUATION, E = 9000 psi, **k = 95 pci**

USING PCA CORRELATION CHART **k = 163 pci**

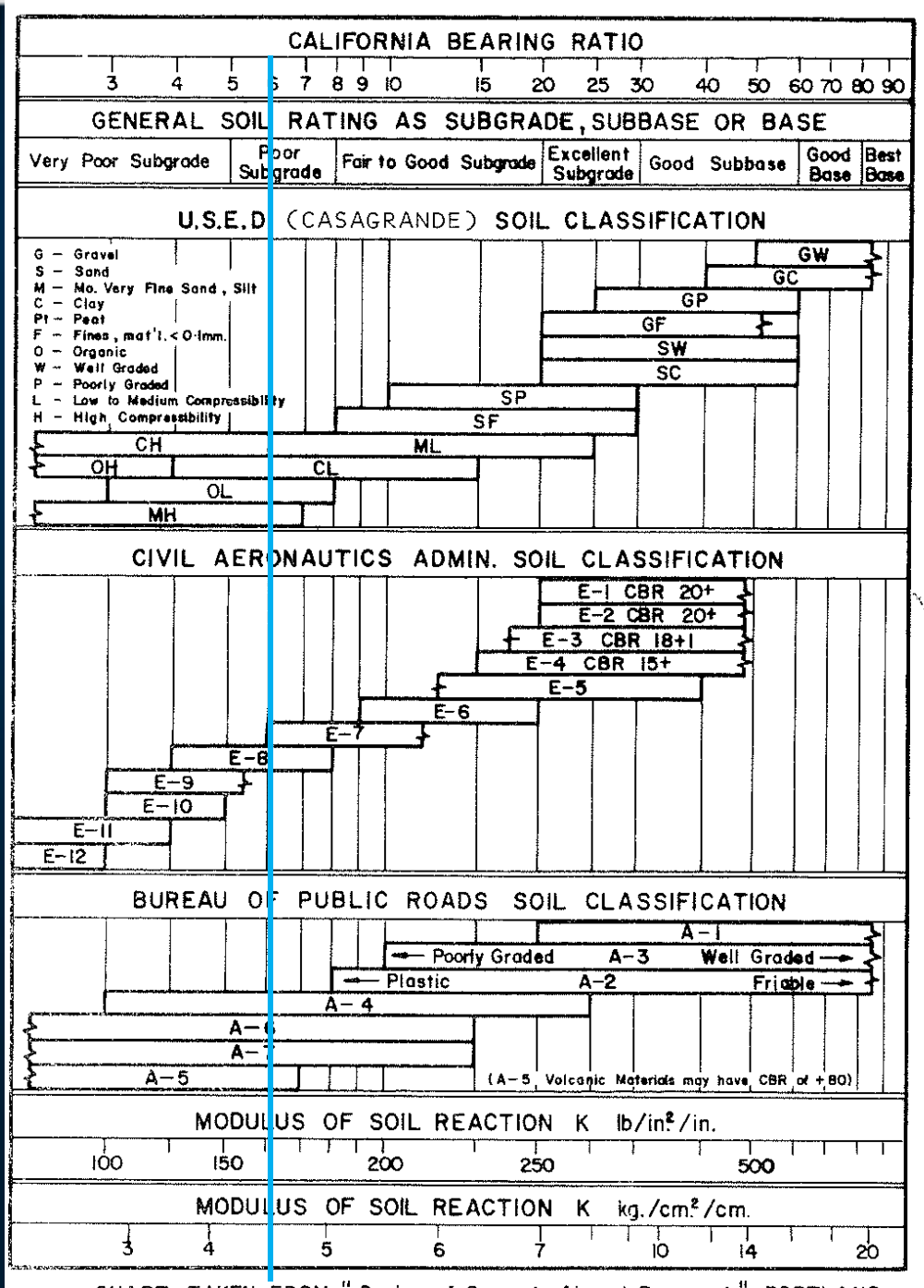


CHART TAKEN FROM "Design of Concrete Airport Pavement" PORTLAND CEMENT ASSOCIATION.

PCN CORELATION ISSUES

- Design thickness differ
- Though rendered comparable by calibration of FAARFIELD with FAA 6D design thicknesses
- Principle of pavement analysis differs between FAARFIELD (M-E) & COMFAA / FAA 6D

∴ Related PCN correlation issues between design & PCN analysis by COMFAA

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 >= P-209 to P-209	Converted =P-209 an < P-209 to P-154	Convert All Layers Directly to P-154	HMA, Base 127mm,203.2mm Based on ref. section	<100kip>? Convert All to Req'd
P-401 P-403 HMA	1.5 / 1.6	1.6	1 / 1.1	1.0	P-401	125.0	mm	200.0		125.0	264.2	1159.7
P-306 ECONOCRTE	1 / 1.1	1.0	1.4 / 1.5	1.4	P-306	0.0	mm	0.0		0.0	COMFAA HMA t	127.0
P-304 CEM. TRTD	1 / 1.1	1.0	1.2 / 1.3	1.0	P-304	0.0	mm	0.0		0.0	Existing/Req'd<0.5? 0.47	
P-209 Crush	1.0		1 / 1.1	1.3	P-209	441.7	mm	441.7	834.2	574.2	264.2	895.6
P-208 AGG, P-211	1.0		1 / 1.1	1.0	P-208	0.0	mm	0.0		0.0	COMFAA Base t	203.2
P-301 SOIL-CEM.	n/a		0.9 / 1	0.9	P-301	0.0	mm	n/a	0.0	0.0	COMFAA Subbase t	895.6
P-154 Subbase	n/a		1.2 / 1.3	1.3	P-154	766.6	mm	n/a	589.7	589.7	1423.90	
n/a	>100kip					0.00	Total	641.70	1423.90	1288.90	P-209 to P-154	
					Subgrade CBR...	6.0					Total COMFAA t	1225.78

Direct to P-154

Aircraft GW > 100kip?

Equivalent Thickness, mm

P-401	127.0
P-209	203.2
P-154	895.6
Total	1225.8

English

Metric

Clear Saved Data

Zero Layer Data

Save Data

Format Chart

COMFAA Parameters for

Evaluation thickness t = 1,226 mm

Evaluation CBR = 6.0

Recommended PCN Codes: F/C/Y

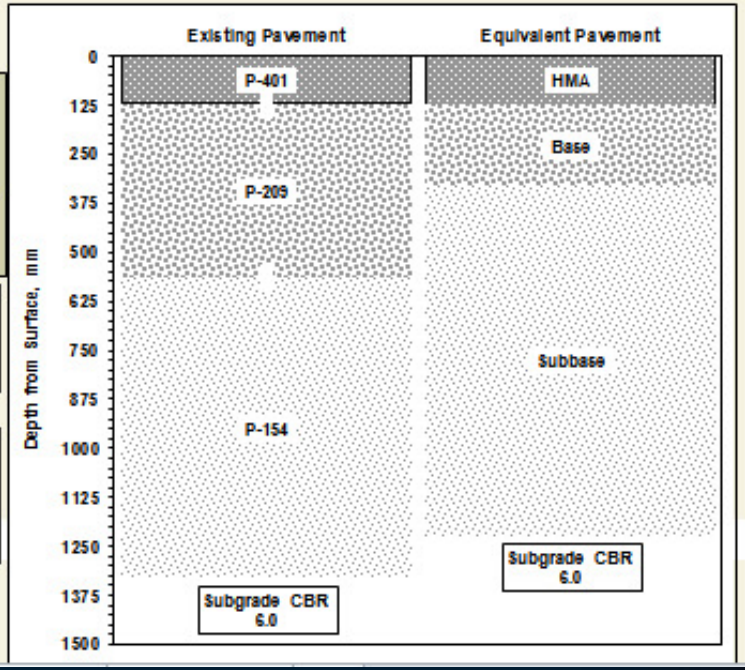
Airport Loc_ID	Pavement ID
LAX	5-23

Project Details

Examples

ENTER Reference Section Requirements

P-401 reference t	127.00	mm
P-209 reference t	203.20	mm



Reference Guidance AC 150/5335-5B Appendix A-2			Existing Flexible Pavement Layers	Existing Layer Thickness		Convert >= P-209 to P-209	Converted =P-209 an < P-209 to P-154	Convert All Layers Directly to P-154	HMA, Base 127mm,203.2mm Based on ref. section	<100kip>? Convert All to Req'd
Flexible Pavement Structure Items	Fig. A2-2 Convert to P-209	Figs. A2-1, A2-2 Convert to P-154								
P-401 P-403 HMA	1.6	1.0	P-401	125.0	mm	200.0		125.0	264.2	1336.7
P-306 ECONOCRTE	1.0	1.4	P-306	0.0	mm	0.0		0.0	COMFAA HMA t	127.0
P-304 CEM. TRTD	1.0	1.0	P-304	0.0	mm	0.0		0.0	Existing/Req'd<0.5? 0.47	
P-209 Crush	1.0	1.3	P-209	441.7	mm	441.7	834.2	574.2	264.2	1072.5
P-208 AGG, P-211	1.0	1.0	P-208	0.0	mm	0.0		0.0	COMFAA Base t	203.2
P-301 SOIL-CEM.	n/a	0.9	P-301	0.0	mm	n/a	0.0	0.0	COMFAA Subbase t	1072.5
P-154 Subbase	n/a	1.0	P-154	766.6	mm	n/a	766.6	766.6	1600.81	
n/a	100kip <			0.00	Total	641.70	1600.81	1465.81	P-209 to P-154	
			Subgrade CBR...	6.0					Total COMFAA t	1402.69

Direct to P-154

Aircraft GW > 100kip?

Equivalent Thickness, mm

P-401	127.0
P-209	203.2
P-154	1072.5
Total	1402.7

English

Metric

Clear Saved Data

Zero Layer Data

Save Data

Format Chart

COMFAA Parameters for

Evaluation thickness t = 1,403 mm

Evaluation CBR = 6.0

Recommended PCN Codes: F/C/Y

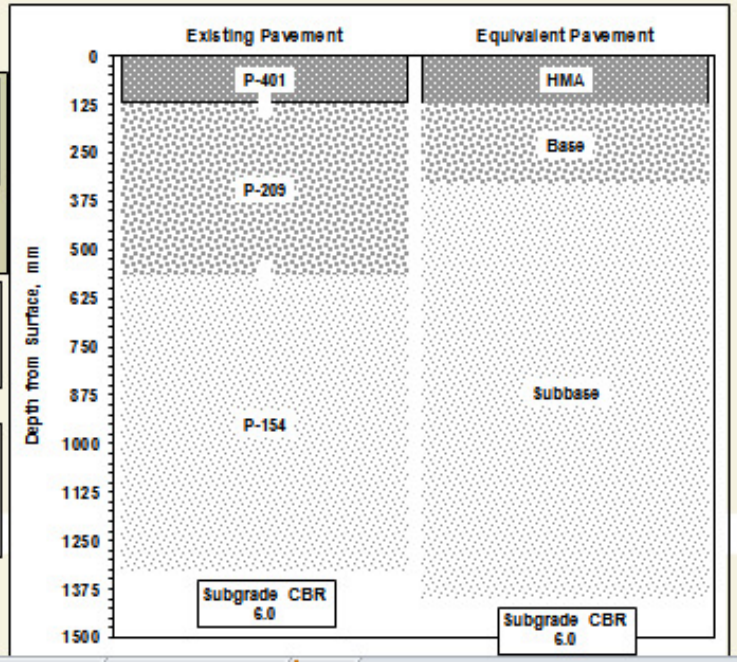
Airport Loc_ID	Pavement ID
LAX	5-23

Project Details

Examples

ENTER Reference Section Requirements

P-401 reference t	127.00	mm
P-209 reference t	203.20	mm



PCN ANALYSIS BY COMFAA

FLEXIBLE PAVEMENT

AIRCRAFT NAME	MGTOW (TONNES)	THICKNESS FOR ACTUAL INDIVIDUAL COVS.	ACN AT MGTOW	CRITICAL AIRCRAFT TOTAL EQUIV. COVS.	THICKNESS FOR TOTAL EQUIV. COVS.	MAXIMUM ALLOWABLE GROSS WEIGHT FOR EVALUATION THICKNESS (TONNES)	PCN C(6)
A320-200 Twin std	77	909.7	47.6	>5,000,000	1201.18	79.81	49.9
A321-200 std	89	894.1	57.3	>5,000,000	1166.78	97.052	63.7
A300-B4 STD	171	964.95	66.6	>5,000,000	1186.55	179.045	71.3
A330-300 std	230	996.07	[illegible]	[illegible]	1157.25	248.13	79.8
A340-300 std	275	927.91	[illegible]	[illegible]	1166.07	293.76	76.5
A340-600 wing	368	964.54	83.6	21,474	1103.6	422.286	103
A380-800 Basic1 Wing	560	767.69	74.[illegible]	[illegible]	1135.64	618.168	87.4
B737-900 ER	79	958.12	51.2	>5,000,000	1191.68	83.099	54.5
B767-400 ER	204	1014.22	79.7	46,397	1122.3	229.89	95.8
B747-400	397	987.26	74.4	179,612	1143.77	435.527	85.7
B777-300 Baseline	300	1002.03	72.6	>5,000,000	1211.25	304.602	74.4
B777-300 ER	353	1094.7	93.6	11,682	1127.37	392.018	110.8
MD11ER	285	936.43	80.5	31,209	1108.65	323.646	98.6

B777-300 Baseline CDF=0.18

B777-300ER CDF=0.65

PCN by COMFAA = 110/F/C/W/T

PCN ANALYSIS BY COMFAA

RIGID PAVEMENT – PCA METHOD

AIRCRAFT NAME	MGTOW (TONNES)	THICKNESS FOR ACTUAL INDIVIDUAL COVS.	ACN AT MGTOW	CRITICAL AIRCRAFT TOTAL EQUIV. COVS.	THICKNESS FOR TOTAL EQUIV. COVS.	MAXIMUM ALLOWABLE GROSS WEIGHT FOR EVALUATION THICKNESS (TONNES)	PCN
							B
A320-200 Twin std	77	329.11	49.6	1,514,182	374.5	97.878	65.9
A321-200 std	89	330.46	59	377,664	379.5	110.331	76.2
A300-B4 STD	171	321.7	60.9	177,680	374.4	208.667	81.1
A330-300 std	230	[illegible]	[illegible].9	172,007	373.7	284.326	81.2
A340-300 std	275	[illegible]	[illegible].5	206,922	373.1	340.877	79.5
A340-600 wing	368	336.97	73.6	38,421	378.8	445.445	95.6
A380-800 Basic1 Wing	560	[illegible]	[illegible]	124,544	373.8	687.013	84.2
B737-900 ER	79	[illegible]	[illegible]	1,001,342	376.2	99.502	69
B767-400 ER	204	332.3	69.7	59,463	376.9	246.172	91.3
B747-400	397	321.16	64.4	109,812	374.7	483.236	85.4
B777-300 Baseline	300	328.69	68.9	52,479	371.4	360.878	93.3
B777-300 ER	353	356.81	89.9	6,700	376.9	415.476	117.8
MD11ER	285	314.21	68.7	65,211	376	346.337	90.5

A321-200 std
CDF=0.05

B777-300ER
CDF=0.27

PCN BY COMFAA = 117/R/B/W/T

PCN ANALYSIS BY COMFAA

RIGID PAVEMENT – FAA METHOD

AIRCRAFT NAME	MGTOW (TONNES)	THICKNESS FOR ACTUAL INDIVIDUAL COVS.	ACN AT MGTOW	CRITICAL AIRCRAFT TOTAL EQUIV. COVS.	THICKNESS FOR TOTAL EQUIV. COVS.	MAXIMUM ALLOWABLE GROSS WEIGHT FOR EVALUATION THICKNESS (TONNES)	PCN
							B
A320-200 Twin std	77	399.92	49.6	460,708	436.17	74.027	47.3
A321-200 std	89	385.77	59	110,960	436.92	85.14	56
A300-B4 STD	171	329.81	60.9	949,865	435.83	165.646	58.3
A330-300 std	230	351.77	60.9	613,014	436.03	220.704	57.7
A340-300 std	275	327.54	59.5	729,050	435.95	263.997	56.4
A340-600 wing	368	351.68	73.6	124,005	436.85	352.719	69.6
A380-800 Basic1 Wing	560	294.35	63.1	714,070	435.96	538.838	59.9
B737-900 ER	79	423.83	53.4	245,481	436.49	75.7	50.8
B767-400 ER	204	342.55	69.7	245,401	436.49	197.414	66.5
B747-400	397	326.44	64.4	639,776	436.01	383.776	61.3
B777-300 Baseline	300	303.2	68.9	3,056,010	435.33	290.999	65.6
B777-300 ER	353	329.15	89.9	367,942	436.28	340.364	84.7
MD11ER	285	325.37	68.7	321,180	436.35	274.84	65.3

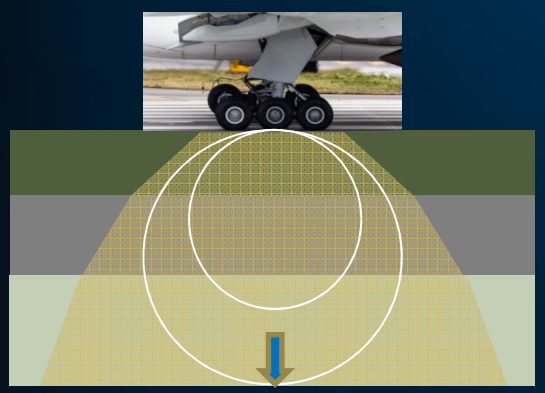
- **PCN by COMFAA = 84.7/R/B/W/T**
- **WEIGHT RESTRICTION ON B777-300ER**

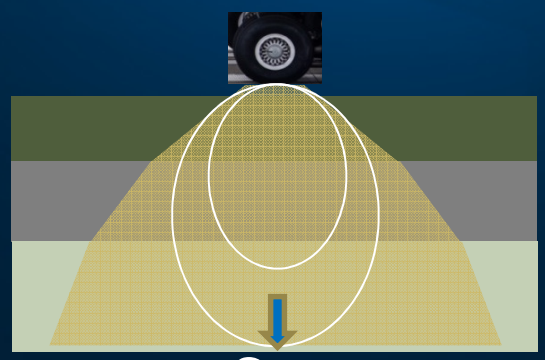
ALTERNATIVE APPROACH

- Design program based PCN evaluation & reporting
- DEFINITION OF ACN BY ICAO

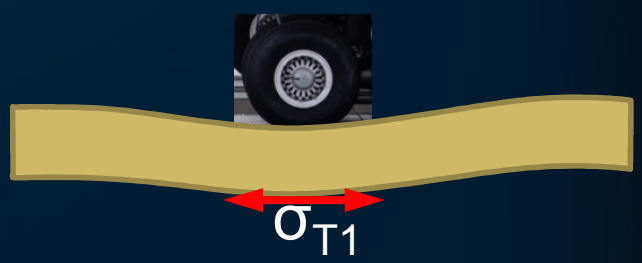
  The ACN of an aircraft is numerically defined as two times the Derived Single Wheel Load (DSWL) expressed in thousands of kilogram with a standard tire pressure of 1.25 MPa
- DSWL Identified as SWL which causes -

FLEXIBLE PAVEMENT



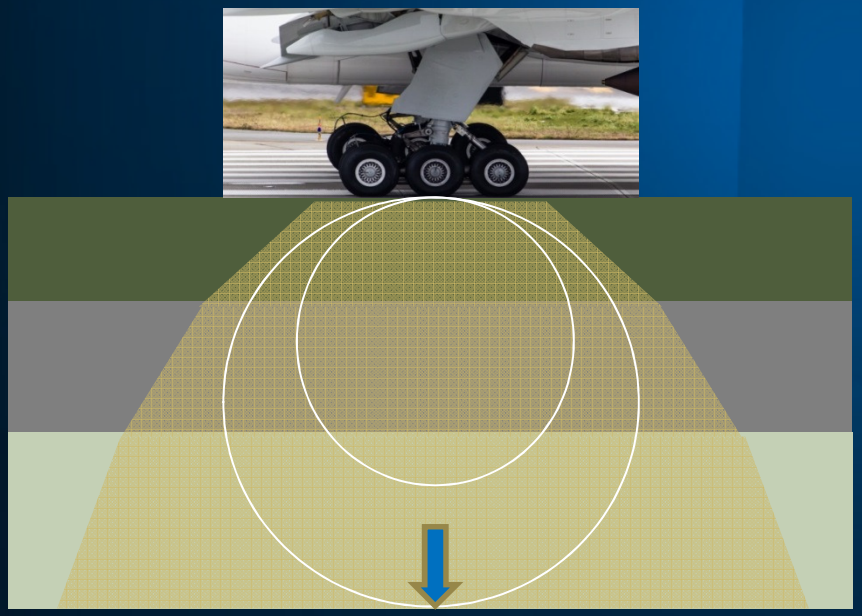


RIGID PAVEMENT

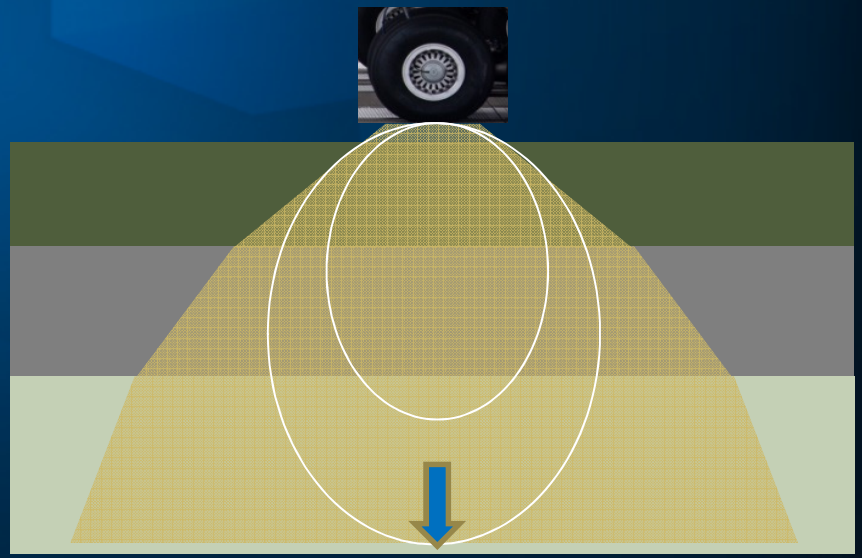


- DESIGN PROGRAM – For deriving the SWL for PCN

DSWL FOR FLEXIBLE PAVEMENT

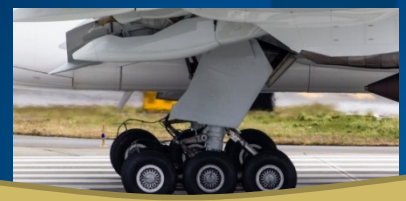


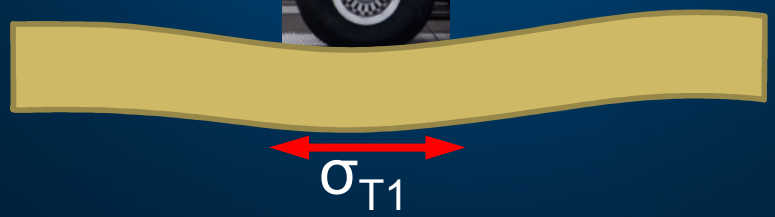
ε_{V1}



ε_{V1}

DSWL FOR RIGID PAVEMENT



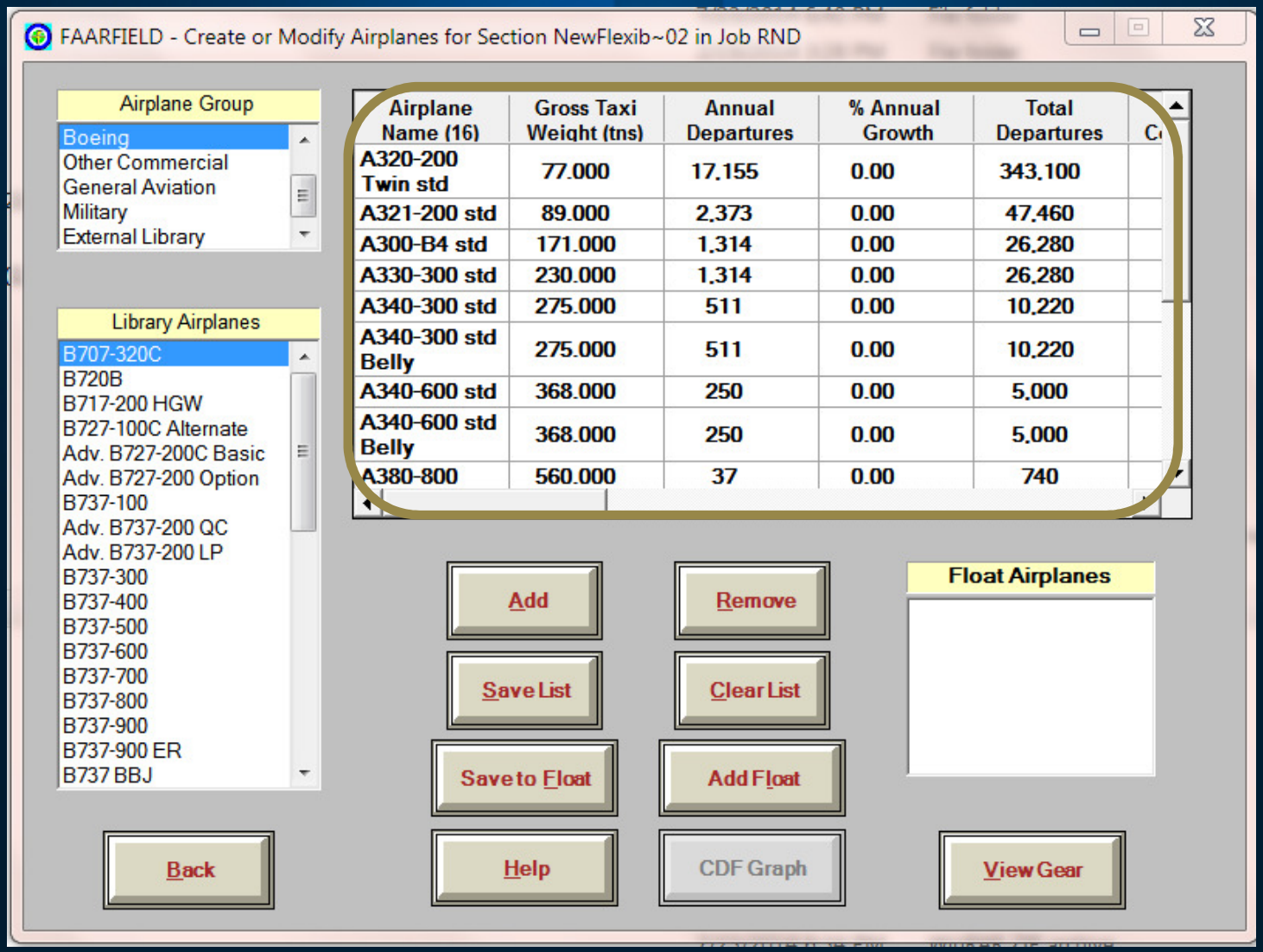


ALTERNATIVE APPROACH

COMMON DESIGN PRINCIPLE & DESIGN PROGRAM BASED PCN EVALUATION

DSWL DETERMINATION

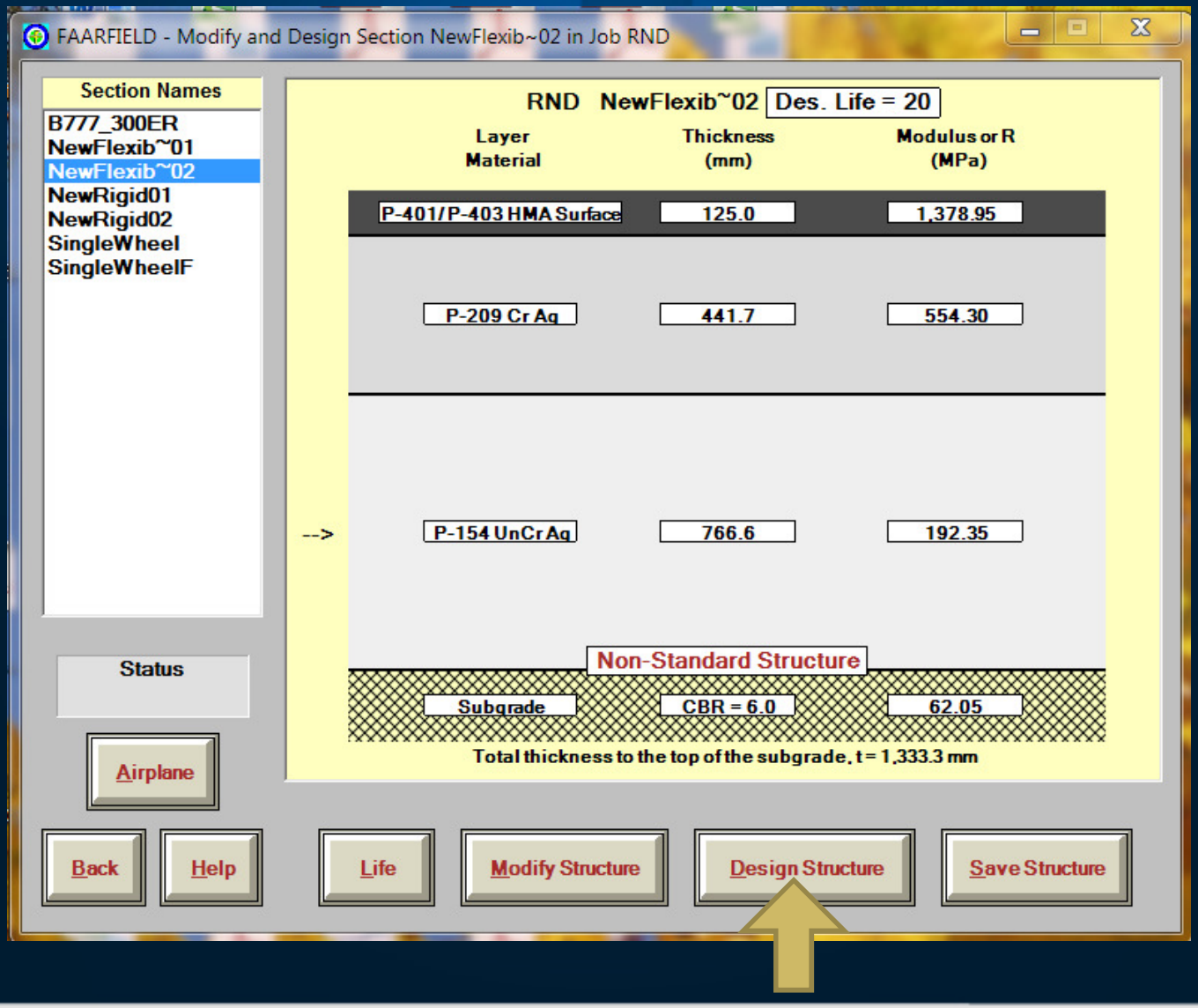
- FLEXIBLE PAVEMENT



Airplane Name (16)	Gross Taxi Weight (tns)	Annual Departures	% Annual Growth	Total Departures
A320-200 Twin std	77.000	17,155	0.00	343,100
A321-200 std	89.000	2,373	0.00	47,460
A300-B4 std	171.000	1,314	0.00	26,280
A330-300 std	230.000	1,314	0.00	26,280
A340-300 std	275.000	511	0.00	10,220
A340-300 std Belly	275.000	511	0.00	10,220
A340-600 std	368.000	250	0.00	5,000
A340-600 std Belly	368.000	250	0.00	5,000
A380-800	560.000	37	0.00	740

DSWL DETERMINATION

- FLEXIBLE PAVEMENT



DSWL DETERMINATION

- FLEXIBLE PAVEMENT

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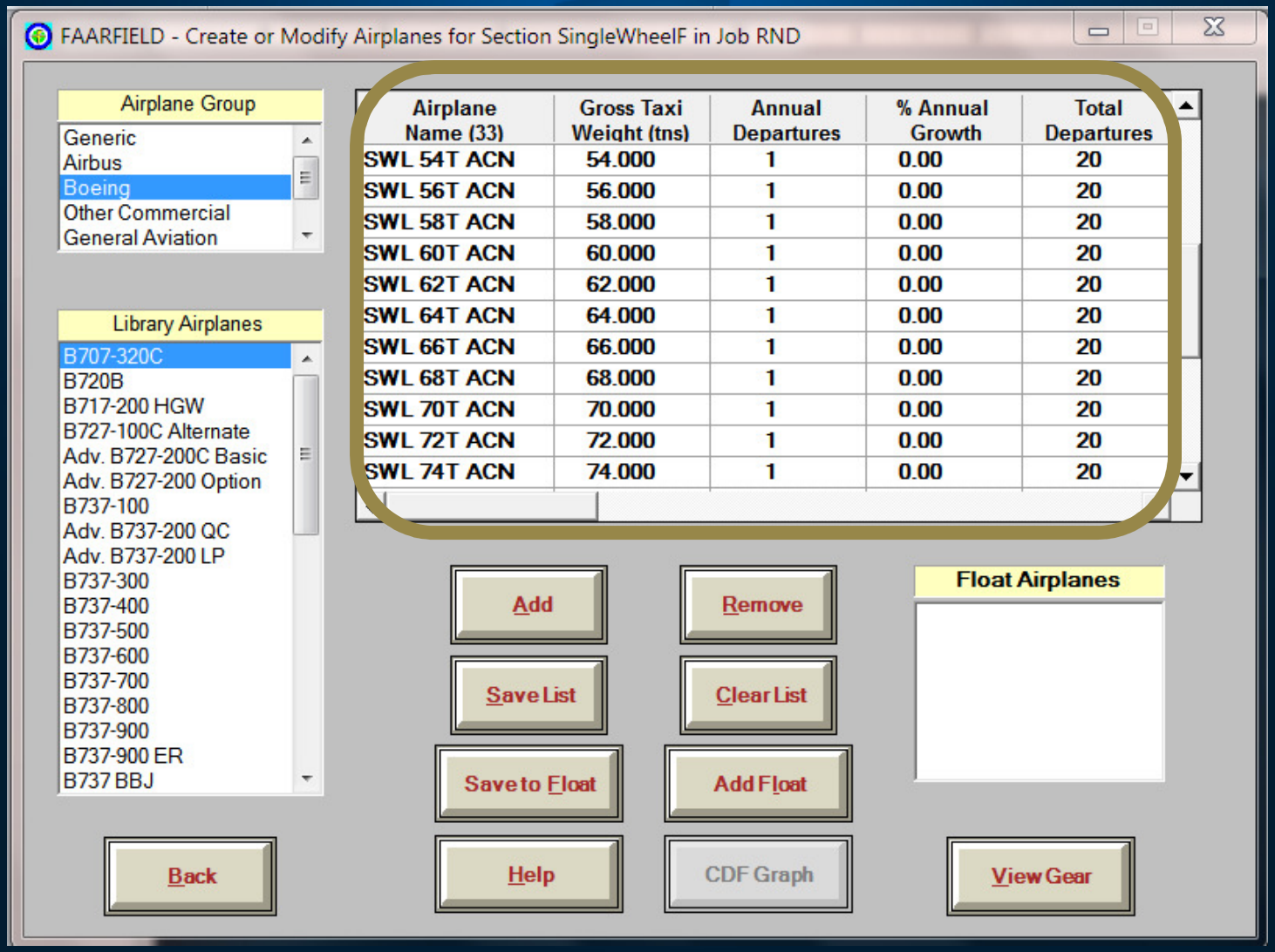
```
          Aircraft No. 14  B777-300 ER
 Eval Point =    1        Layer No. =    8
 X-Coord.   =   27.500    Y-Coord.  =    0.000   Z-Depth =  52.497627

          VERT STR     HOR Y STR    HOR X STR    XZ SHEAR     YZ SHEAR     XY SHEAR
Stress -1.07341E+01 -1.09260E+00 -2.62934E-01 -2.14387E+00  0.00000E+00  1.05887E-17
Strain -1.13997E-03  3.06264E-04  4.30714E-04 -6.43161E-04  0.00000E+00  3.17661E-21
Displt  1.70398E-01  0.00000E+00  1.23963E-02

          PRIN 1       PRIN 2       PRIN 3      MAX SHEAR    OCT NORMAL   OCT SHEAR
Stress -1.11561E+01 -1.09260E+00  1.59000E-01 -5.65753E+00 -4.02989E+00  5.06481E+00
Strain -1.20326E-03  3.06264E-04  4.94004E-04
```

```
 Eval Point =    4        Layer No. =    8
 X-Coord.   =   11.000    Y-Coord.  =    0.000   Z-Depth =  52.497627

          VERT STR     HOR Y STR    HOR X STR    XZ SHEAR     YZ SHEAR     XY SHEAR
Stress -1.12914E+01 -1.17519E+00 -2.71041E-01 -7.19773E-01 -1.12946E-16 -2.82365E-17
Strain -1.19836E-03  3.19075E-04  4.54697E-04 -2.15932E-04 -3.38838E-20 -8.47096E-21
Displt  1.76302E-01  0.00000E+00  4.96117E-03

          PRIN 1       PRIN 2       PRIN 3      MAX SHEAR    OCT NORMAL   OCT SHEAR
Stress -1.13382E+01 -1.17519E+00 -2.24229E-01 -5.55700E+00 -4.24589E+00  5.03005E+00
Strain -1.20538E-03  3.19075E-04  4.61719E-04

 Eval Point =    5        Layer No. =    8
 X-Coord.   =    5.500    Y-Coord.  =    0.000   Z-Depth =  52.497627
```

DSWL DETERMINATION

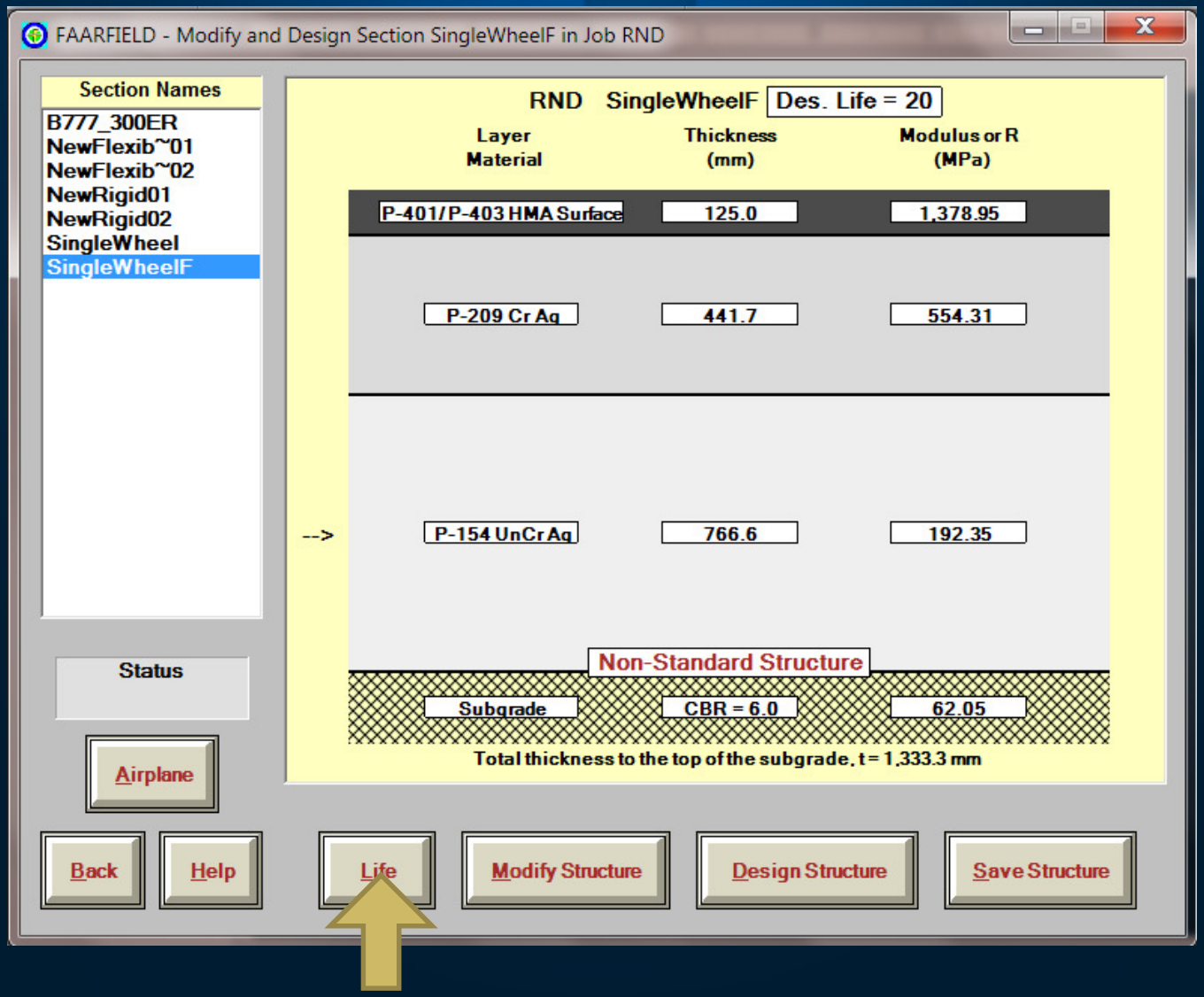
- FLEXIBLE PAVEMENT



Airplane Name (33)	Gross Taxi Weight (tns)	Annual Departures	% Annual Growth	Total Departures
SWL 54T ACN	54.000	1	0.00	20
SWL 56T ACN	56.000	1	0.00	20
SWL 58T ACN	58.000	1	0.00	20
SWL 60T ACN	60.000	1	0.00	20
SWL 62T ACN	62.000	1	0.00	20
SWL 64T ACN	64.000	1	0.00	20
SWL 66T ACN	66.000	1	0.00	20
SWL 68T ACN	68.000	1	0.00	20
SWL 70T ACN	70.000	1	0.00	20
SWL 72T ACN	72.000	1	0.00	20
SWL 74T ACN	74.000	1	0.00	20

DSWL DETERMINATION

- FLEXIBLE PAVEMENT



DSWL DETERMINATION

- FLEXIBLE PAVEMENT

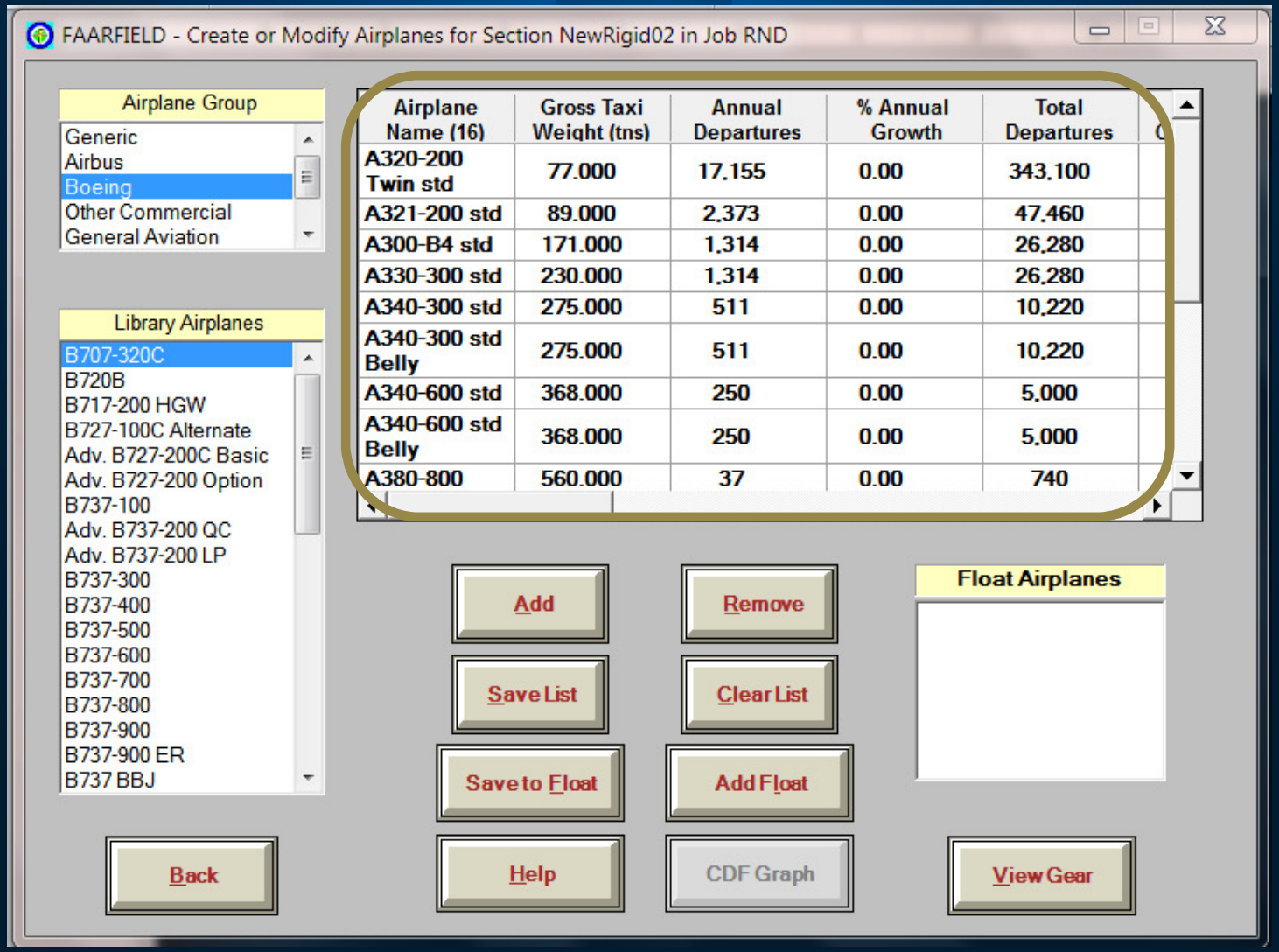
```
          Aircraft No. 17   SWL 62T ACN
 Eval Point =     1        Layer No. =     8
 X-Coord.   =     0.000    Y-Coord.  =     0.000    Z-Depth =  52.497449

          VERT STR      HOR Y STR     HOR X STR     XZ SHEAR      YZ SHEAR      XY SHEAR
Stress -9.82438E+00  1.18552E+00  1.18552E+00  0.00000E+00  0.00000E+00  0.00000E+00
Strain -1.18380E-03  4.67680E-04  4.67680E-04  0.00000E+00  0.00000E+00  0.00000E+00
Displt  8.84571E-02  0.00000E+00  0.00000E+00

          PRIN 1        PRIN 2        PRIN 3       MAX SHEAR     OCT NORMAL    OCT SHEAR
Stress -9.82438E+00  1.18555E+00  1.18549E+00 -5.50493E+00 -2.48444E+00  5.19012E+00
Strain -1.18380E-03  4.67685E-04  4.67676E-04

       -1.19836E-03
          Aircraft No. 18   SWL 64T ACN
 Eval Point =     1        Layer No. =     8
 X-Coord.   =     0.000    Y-Coord.  =     0.000    Z-Depth =  52.497449

          VERT STR      HOR Y STR     HOR X STR     XZ SHEAR      YZ SHEAR      XY SHEAR
Stress -1.01197E+01  1.21663E+00  1.21663E+00  0.00000E+00  0.00000E+00  0.00000E+00
Strain -1.21904E-03  4.81411E-04  4.81411E-04  0.00000E+00  0.00000E+00  0.00000E+00
Displt  9.12455E-02  0.00000E+00  0.00000E+00

          PRIN 1        PRIN 2        PRIN 3       MAX SHEAR     OCT NORMAL    OCT SHEAR
Stress -1.01197E+01  1.21666E+00  1.21660E+00 -5.66814E+00 -2.56214E+00  5.34399E+00
Strain -1.21904E-03  4.81416E-04  4.81406E-04
```

63T

∴ PCN = 126/F/C/W/T

DSWL DETERMINATION

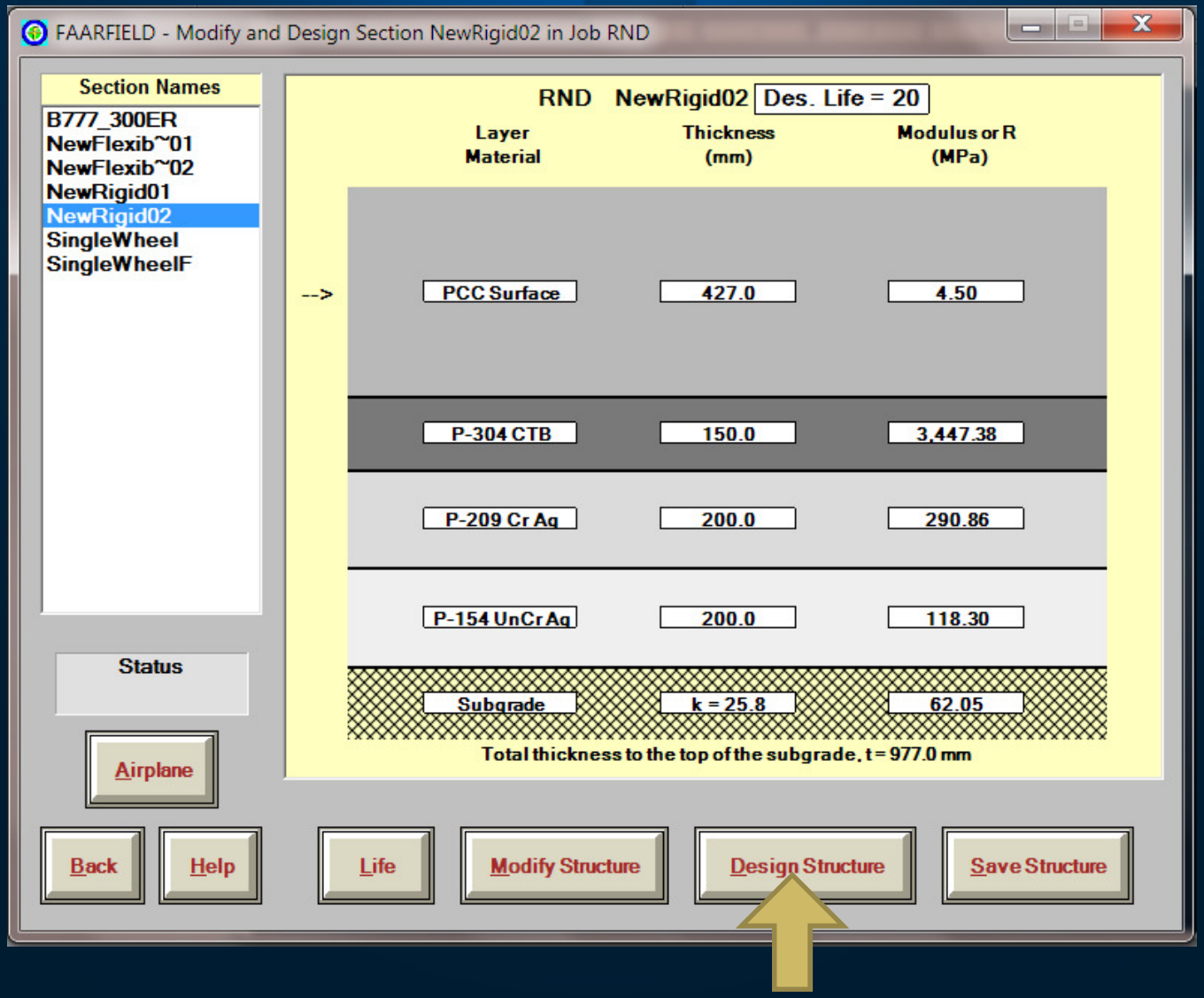
- RIGID PAVEMENT



Airplane Name (16)	Gross Taxi Weight (tns)	Annual Departures	% Annual Growth	Total Departures
A320-200 Twin std	77.000	17,155	0.00	343,100
A321-200 std	89.000	2,373	0.00	47,460
A300-B4 std	171.000	1,314	0.00	26,280
A330-300 std	230.000	1,314	0.00	26,280
A340-300 std	275.000	511	0.00	10,220
A340-300 std Belly	275.000	511	0.00	10,220
A340-600 std	368.000	250	0.00	5,000
A340-600 std Belly	368.000	250	0.00	5,000
A380-800	560.000	37	0.00	740

DSWL DETERMINATION

- RIGID PAVEMENT



DSWL DETERMINATION

- RIGID PAVEMENT

NikePCC - Notepad

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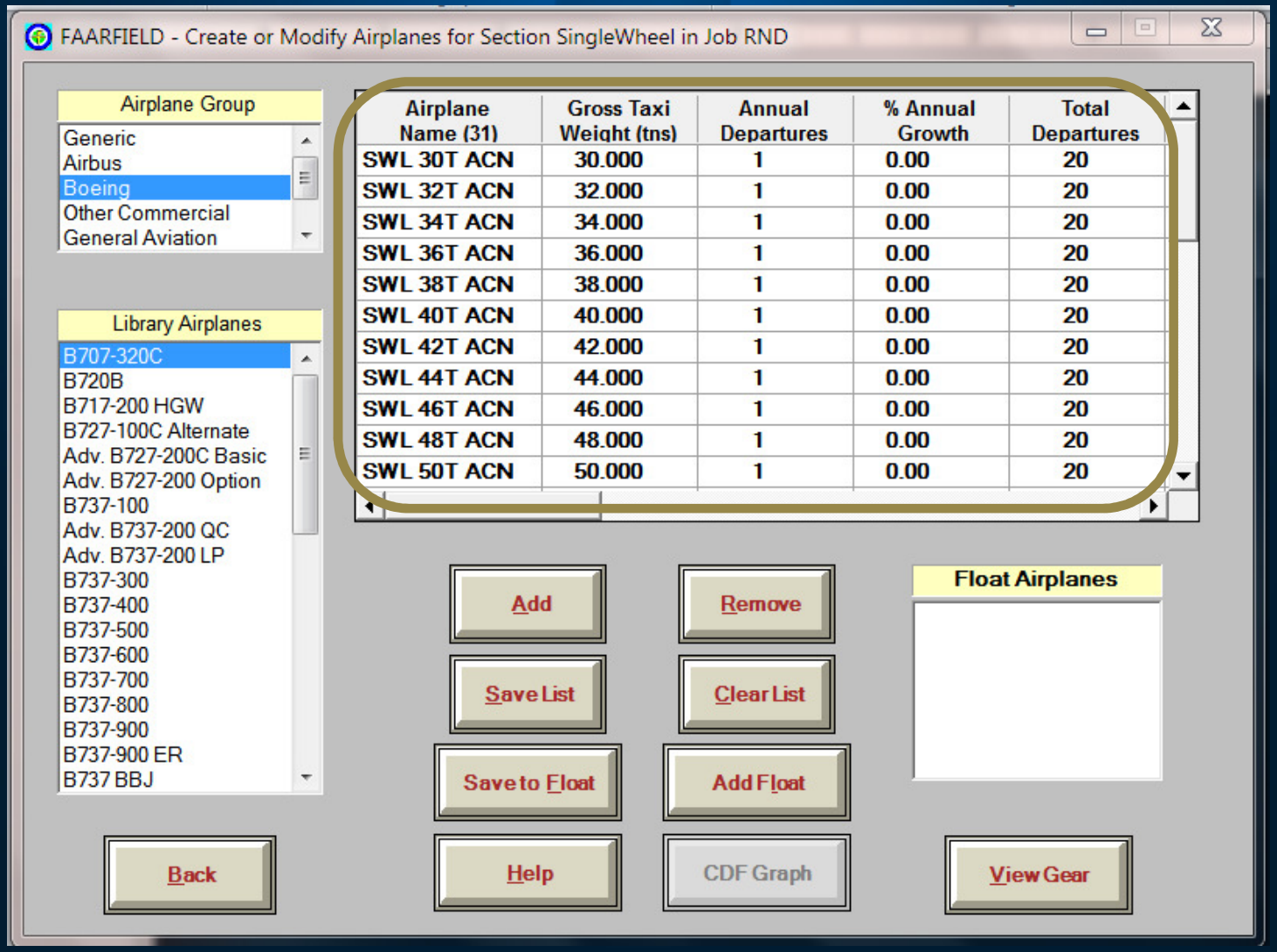
```
        Aircraft No. 12  B747-400B Combi Wing

PCC SLAB HOR STRESS
   314.0472


        Aircraft No. 13  B777-300 Baseline

PCC SLAB HOR STRESS
   317.4156


        Aircraft No. 14  B777-300 ER

PCC SLAB HOR STRESS
   360.6377


        Aircraft No. 15  MD11ER

PCC SLAB HOR STRESS
   322.0052


        Aircraft No. 16  MD11ER Belly

PCC SLAB HOR STRESS
```

DSWL DETERMINATION

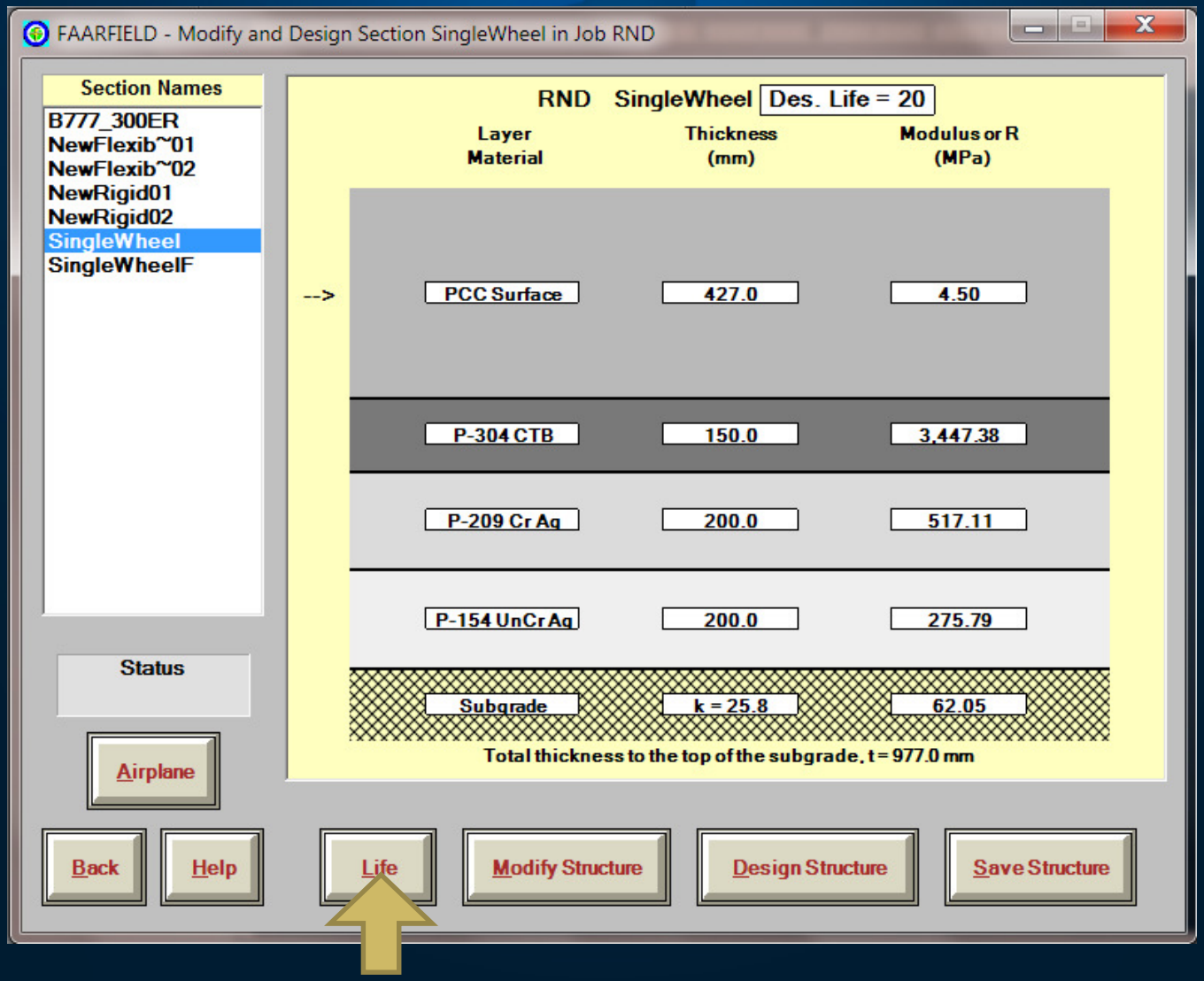
- RIGID PAVEMENT



Airplane Name (31)	Gross Taxi Weight (tns)	Annual Departures	% Annual Growth	Total Departures
SWL 30T ACN	30.000	1	0.00	20
SWL 32T ACN	32.000	1	0.00	20
SWL 34T ACN	34.000	1	0.00	20
SWL 36T ACN	36.000	1	0.00	20
SWL 38T ACN	38.000	1	0.00	20
SWL 40T ACN	40.000	1	0.00	20
SWL 42T ACN	42.000	1	0.00	20
SWL 44T ACN	44.000	1	0.00	20
SWL 46T ACN	46.000	1	0.00	20
SWL 48T ACN	48.000	1	0.00	20
SWL 50T ACN	50.000	1	0.00	20

DSWL DETERMINATION

- RIGID PAVEMENT



DSWL DETERMINATION

- RIGID PAVEMENT

NikePCC - Notepad

File Edit Format View Help

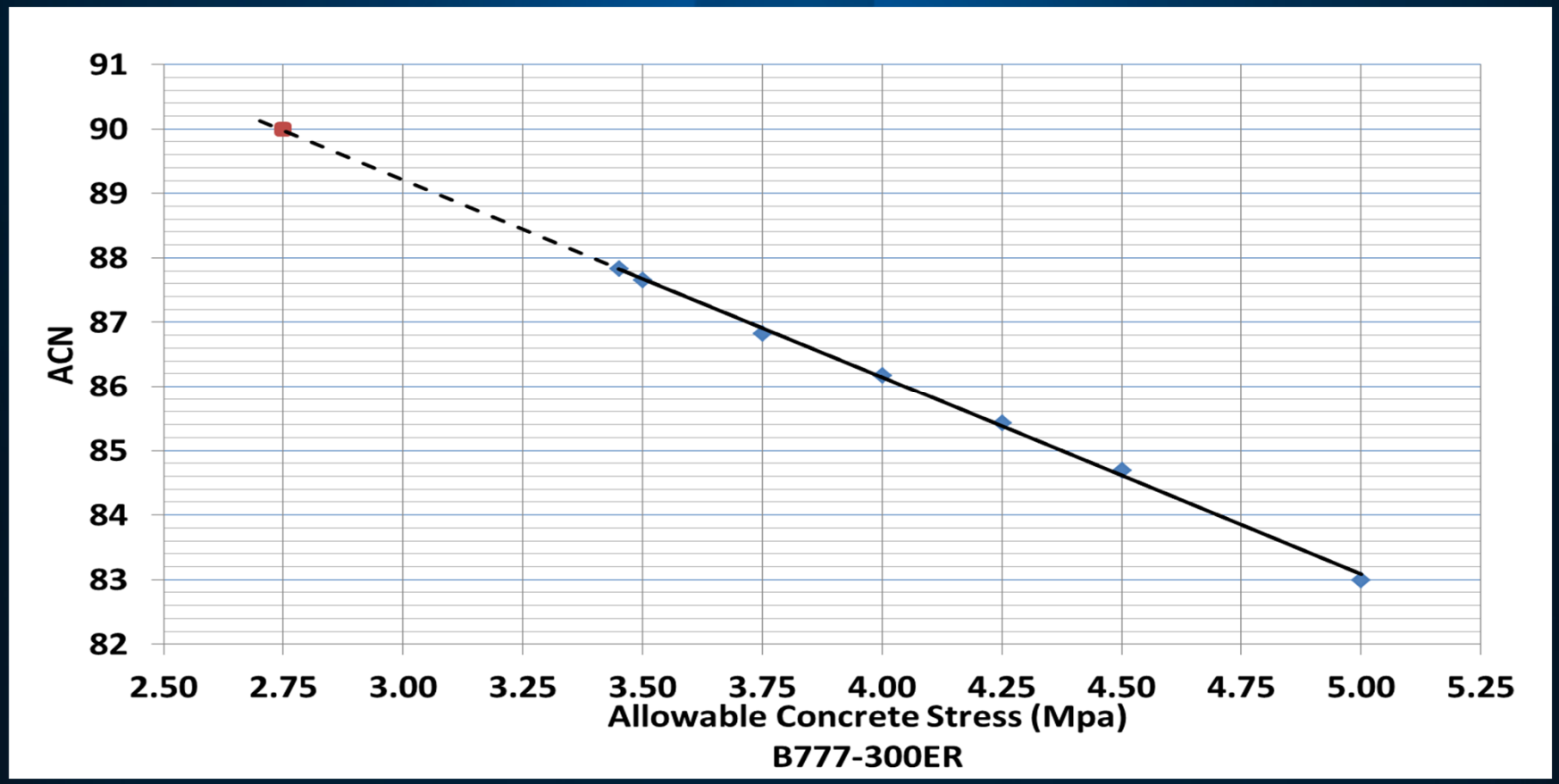
```
        Aircraft No. 5  SWL 38T ACN

PCC SLAB HOR STRESS
   331.6227


        Aircraft No. 6  SWL 40T ACN

PCC SLAB HOR STRESS
   345.1768


        Aircraft No. 7  SWL 42T ACN

PCC SLAB HOR STRESS
   358.2725


        Aircraft No. 8  SWL 44T ACN

PCC SLAB HOR STRESS
   371.7673


        Aircraft No. 9  SWL 46T ACN

PCC SLAB HOR STRESS
   384.7596
```

42.5

∴ PCN = 85/R/B/W/T

B777 300 ER ACN = 90/R/B/W/T at working stress 2.75 MPa

PCN FOR ACN AT 2.75 MPa WORKING STRESS



- PCN AT 2.75 MPa = 90/R/B/W/T

EFFECT OF DESIGN TRAFFIC

- NOT APPRECIABLE

B777-300ER						ACN FOR ALLOWABLE CONCRETE STRESS (MPa)	
P/C RATIO	COVERAGES	DEPARTURES	FOR 4.5 MPA				
			THICK (MM)	HOR STRESS (PSI)	SINGLE WHEEL LOAD (T)	4.5	2.75
3.86	10000	2591	400	439.882	44.056	88	93
	7500	1943	392.2	450.577	43.849	88	93
	5000	1295	381.8	466.643	43.652	88	93

$k = 80\ MN/m^3$

CONCLUSION

- PCN evaluation & reporting based on COMFAA is not matched with pavement analysis principle in FAARFIELD
- Modern day pavement designs are based on Mechanistic – Empirical design principles
- Study highlights unintended implications where designed structure does not cater for all ACNs in the fleet mix
- Alternative approach presented based on first principles
- PCN based on identified ESWL causing same critical stress/strain parameters in rigid/flexible as considered in the pavement analysis for design
- Proposed methodology integrates the Pavement Design & Evaluation by using a common principle of analysis
- Can be adopted for any pavement design method

RECOMMENDATION

- Re-establishment of ACN values based on design flexural strength (4.5 MPa) recommended
- 10000 coverages can still be remain as basis for ACN recommendation by manufacturers.
- Alternative Methodology be further evaluated, refined and adopted.

THANK YOU !

IT'S ALL ABOUT IMAGINEERING