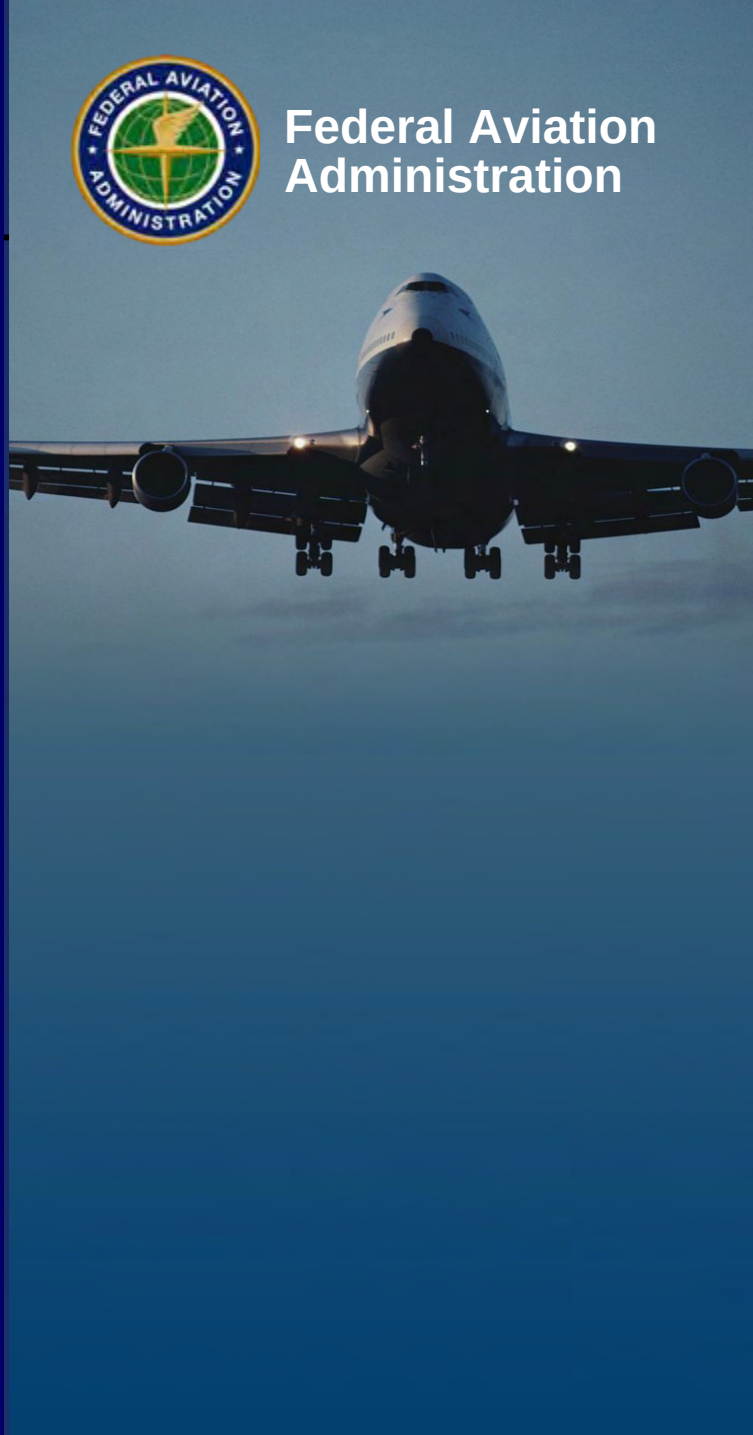
ACN-PCN System
AC 150/5335-5A



Federal Aviation Administration

Presentation to: Great Lakes Region – Airports Conference

Name: Rodney Joel - Airport Engineering Division

Date: November, 2008

Annex 14 to the Convention on International Civil Aviation

INTERNATIONAL STANDARDS
AND RECOMMENDED PRACTICES

AERODROMES

ANNEX 14

TO THE CONVENTION ON INTERNATIONAL CIVIL AVIATION

VOLUME I
AERODROME DESIGN AND OPERATIONS

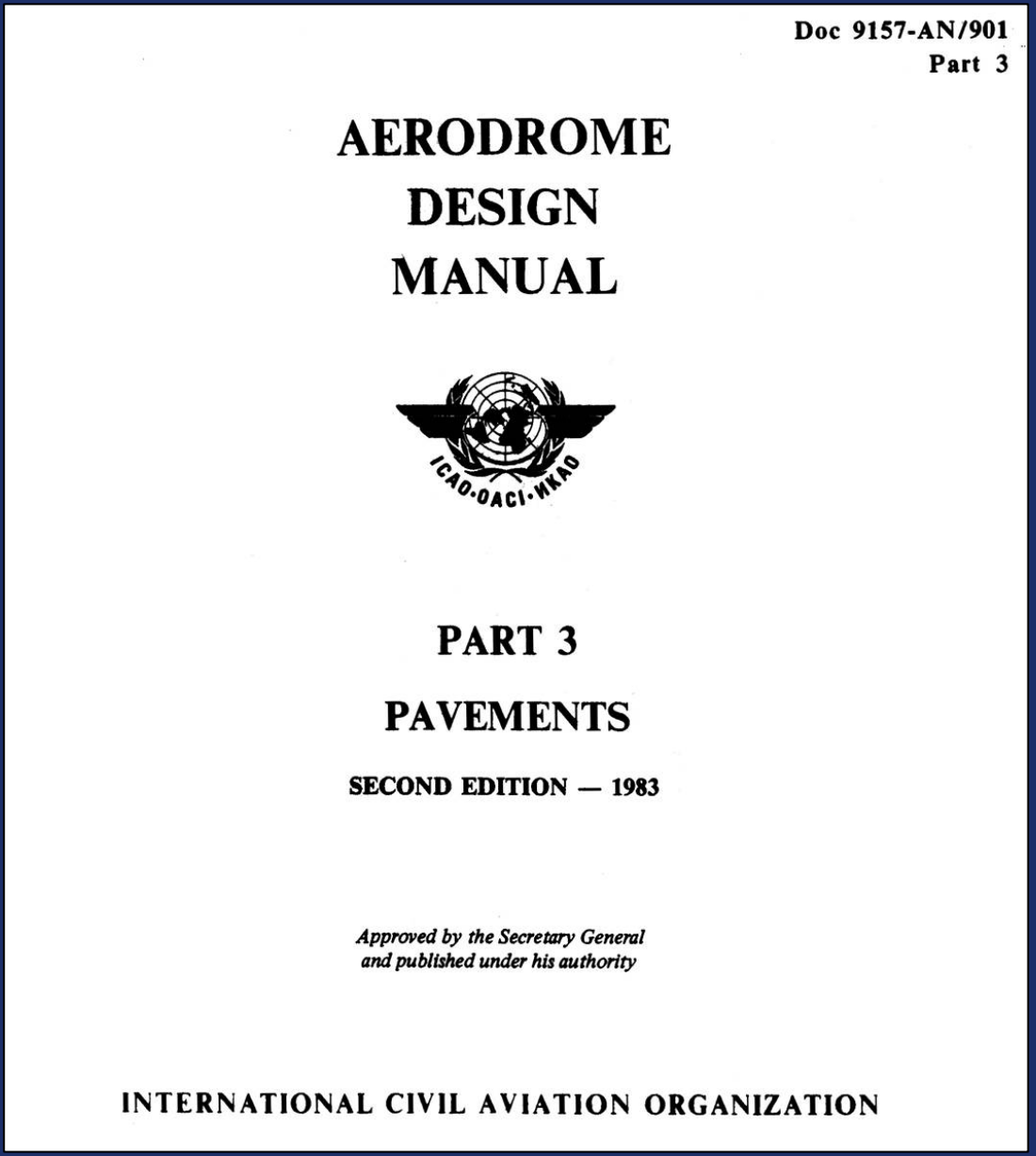
THIRD EDITION — JULY 1999

This edition incorporates all amendments to Annex 14, Volume I, adopted by the Council prior to 6 March 1999 and supersedes on 4 November 1999 all previous editions of Annex 14, Volume I.

For information regarding the applicability of the Standards and Recommended Practices, *see* Chapter 1, 1.2 and Foreword.

INTERNATIONAL CIVIL AVIATION ORGANIZATION

ICAO Aerodrome Design Manual Part 3 – Pavements



Doc 9157-AN/901
Part 3

AERODROME
DESIGN
MANUAL

PART 3

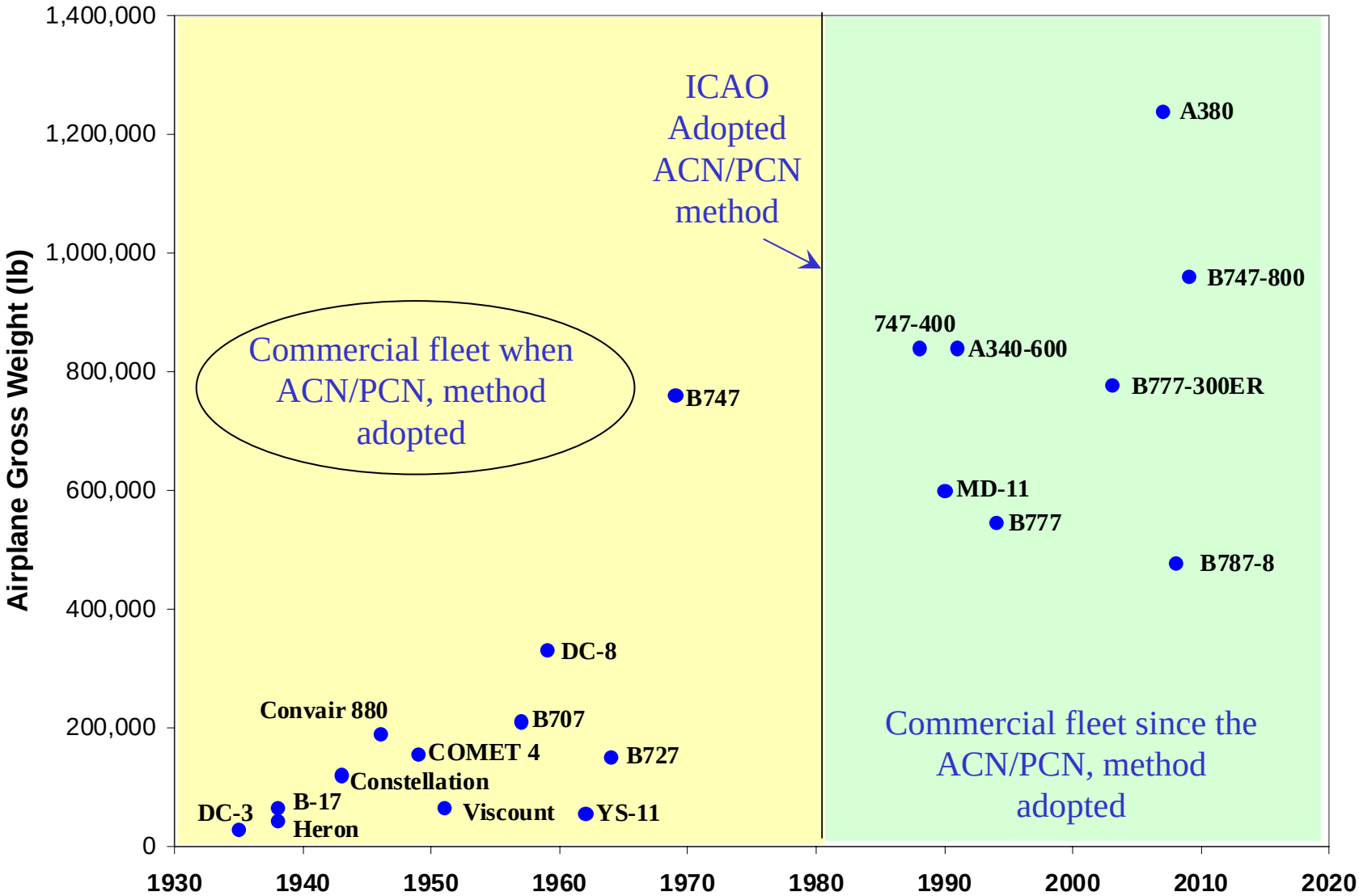
PAVEMENTS

SECOND EDITION — 1983

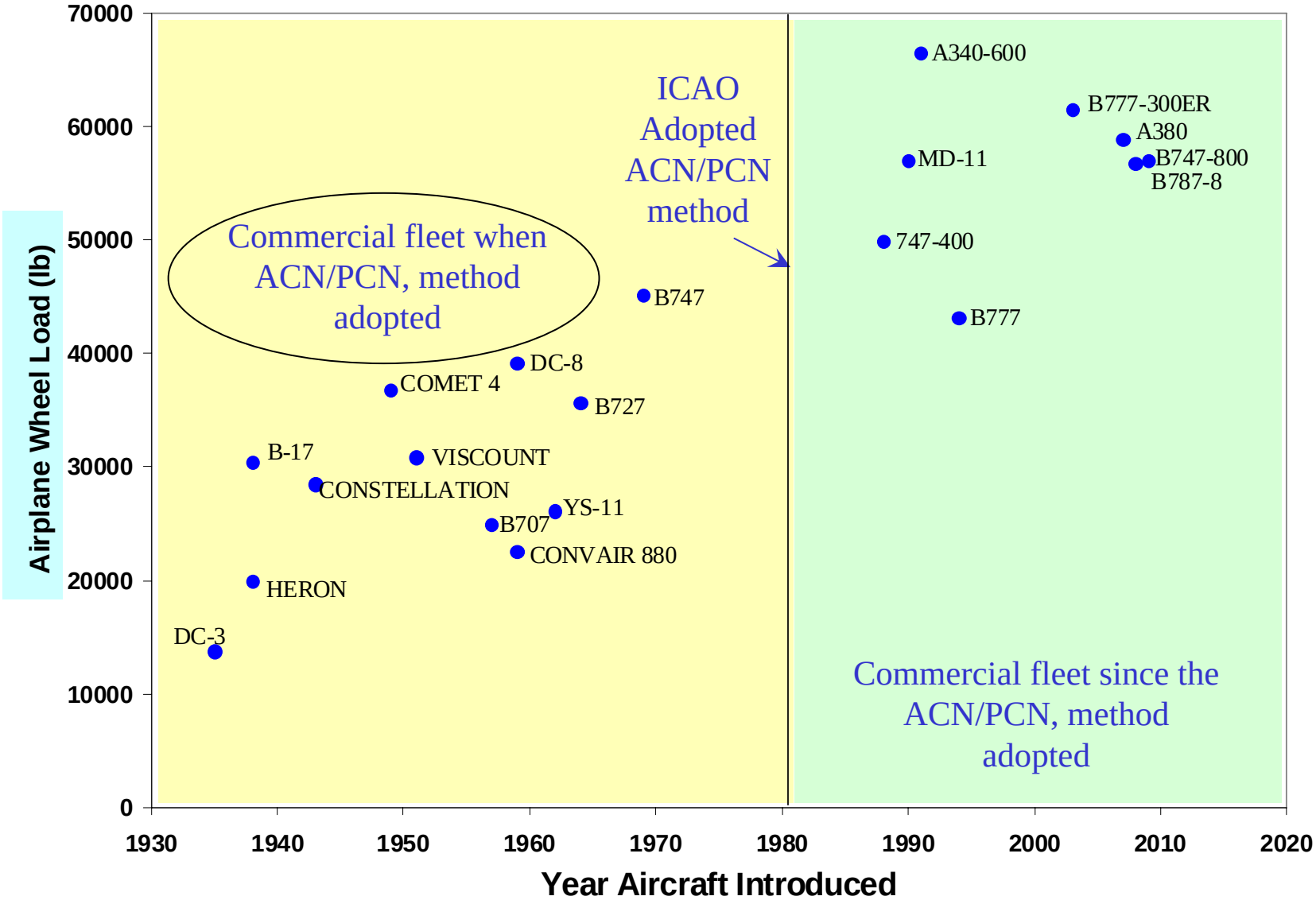
Approved by the Secretary General and published under his authority

INTERNATIONAL CIVIL AVIATION ORGANIZATION

ACN-Aircraft Timeline (Gross Wt)



ACN-Aircraft Timeline (Wheel load)



FAA Guidance on ACN-PCN

AC 150/5335-5A

STANDARDIZED METHOD OF REPORTING AIRPORT PAVEMENT STRENGTH – PCN

Revised September, 2006

2005 - PCN field re-activated in 5010 Database

ACN/PCN Definitions

- ACN

  "A number expressing the relative effect of an aircraft on a pavement for a specified standard subgrade strength."

- PCN

  "A number expressing the bearing strength of a pavement for unrestricted operations."

Aerodrome Design Manual, Part 3 Pavements, Chapter 1

ACN/PCN System - Concept

A pavement with a given PCN can support without weight restriction, an airplane with an ACN rating equal to or less than the pavement PCN value.

ACN/PCN System

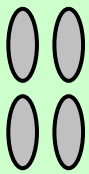
- Why not use allowable “Gear” load?

- Pavement thickness design requires not only the load magnitude but also the frequency of application. Therefore if an allowable gear load is reported, some knowledge about the frequency of load application is necessary for proper implementation.
  - For airport pavement applications we use the term “annual departures” to discuss frequency

ACN/PCN System

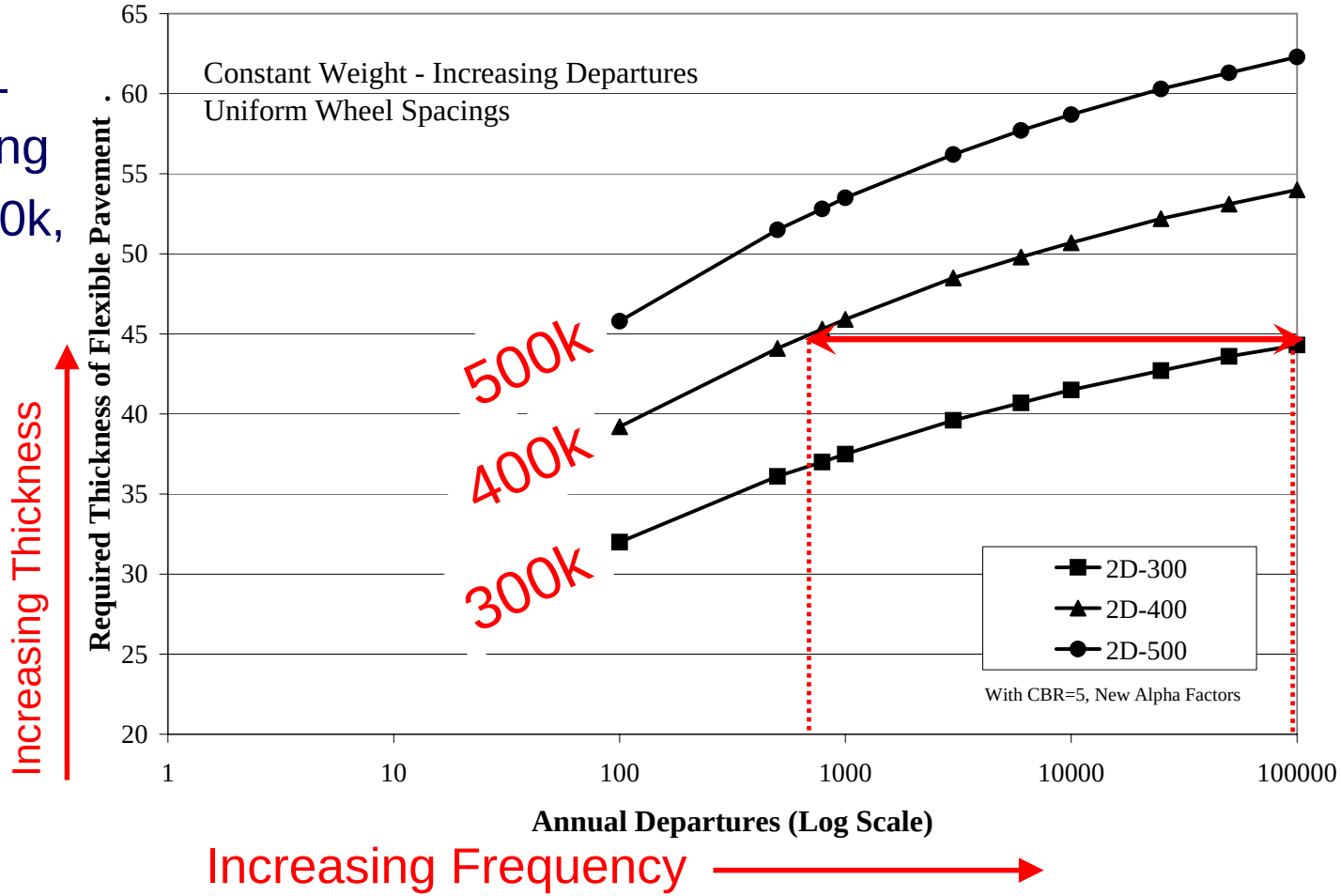
2D landing gear – fixed wheel spacing

Weights 300k, 400k, & 500k



2 Duals in Tandem

2D

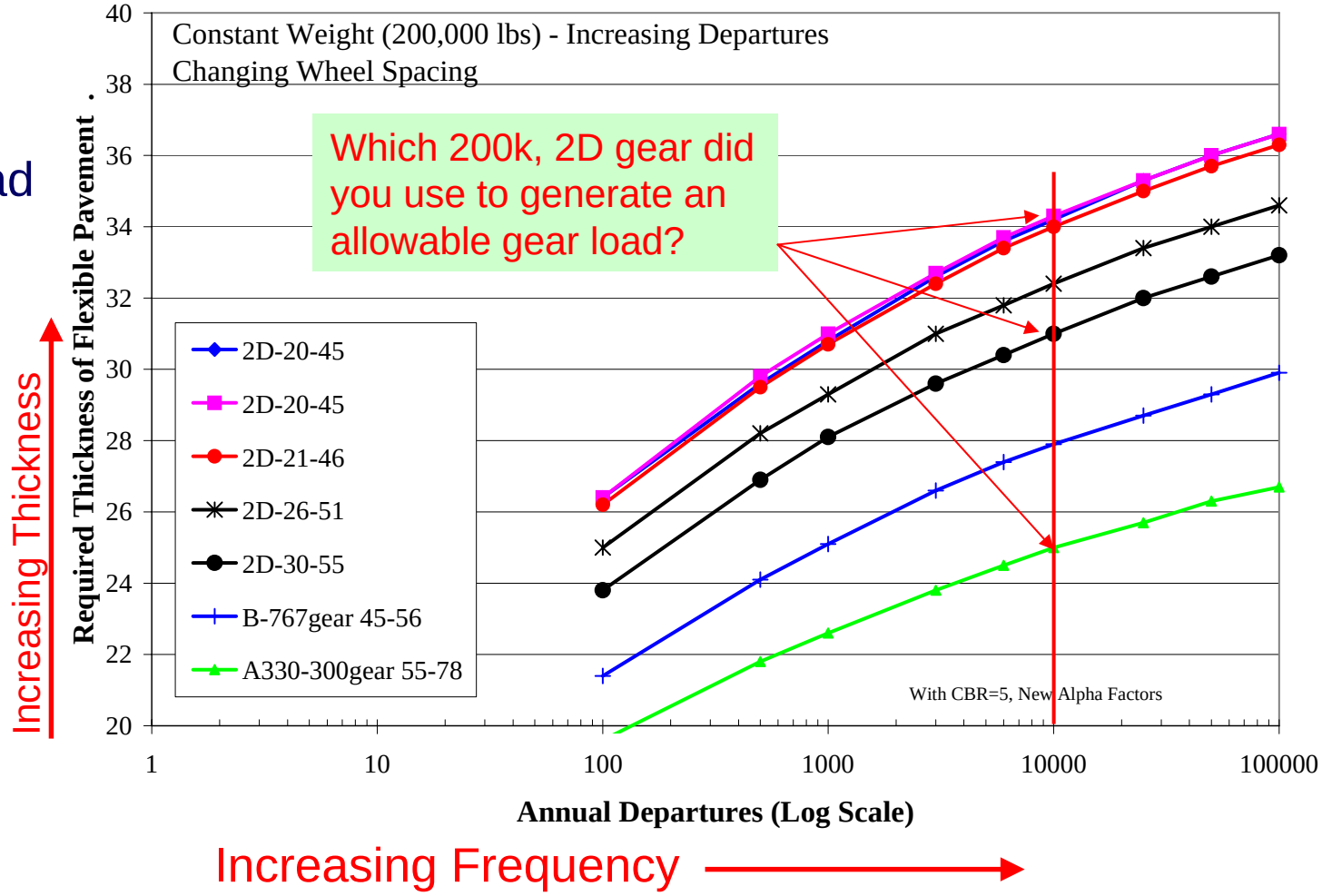


ACN/PCN System

2D landing gears

Constant gross load of 200,000 lbs

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



ACN/PCN System - Concept

ACN – PCN procedure standardizes the frequency issue by making calculations of ACN/PCN at 10,000 coverages

(Due to airplane wander, It takes more than one pass of an airplane to equal a full coverage)

ACN-PCN Application

- Applies only to pavements with bearing strengths of 12,500 pounds (5,700 kg) or greater.

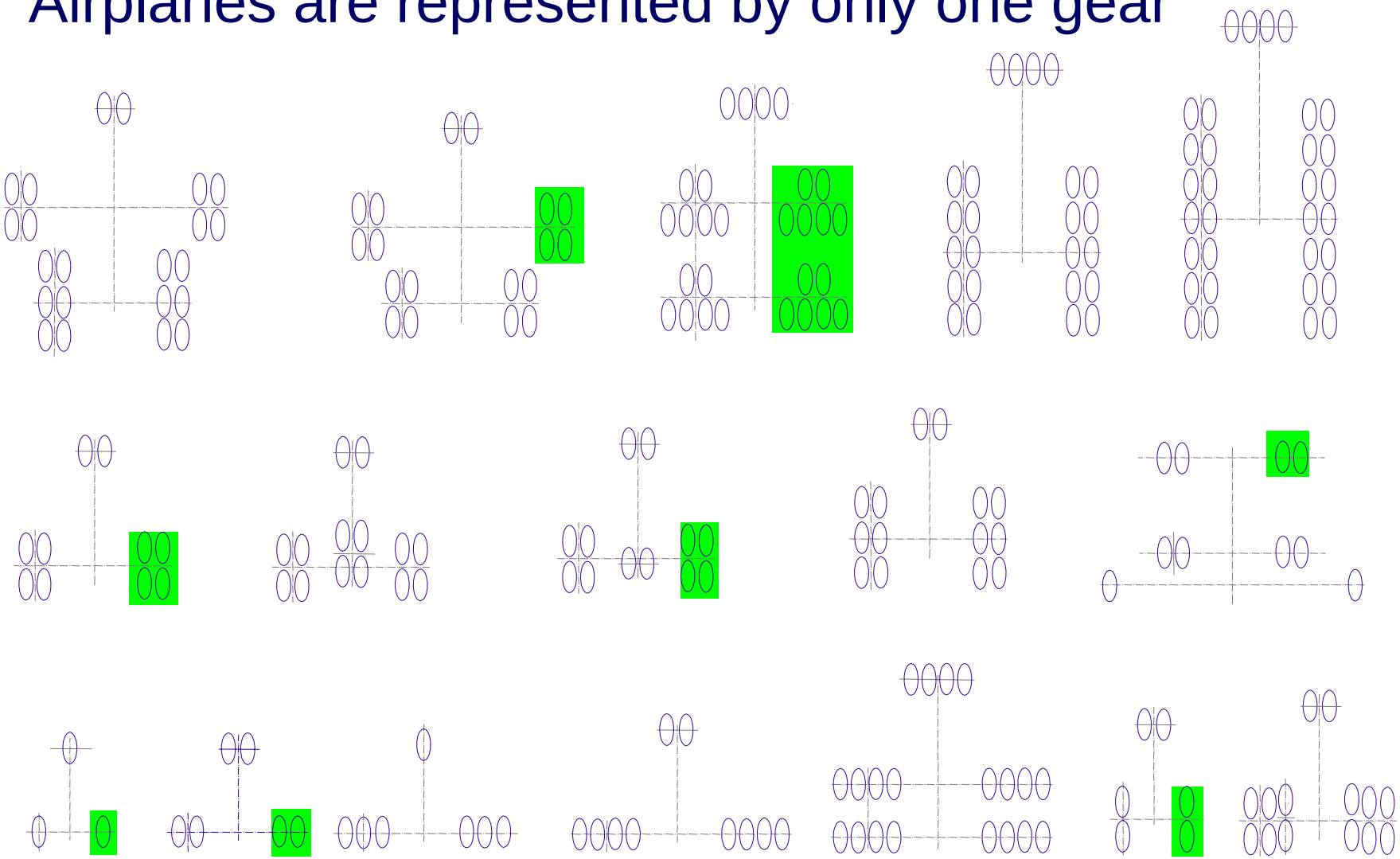
- The method of reporting pavement bearing strength for pavements of less than 12,500 pounds (5,700 kg) remains unchanged.

ACN/PCN System - Limitations

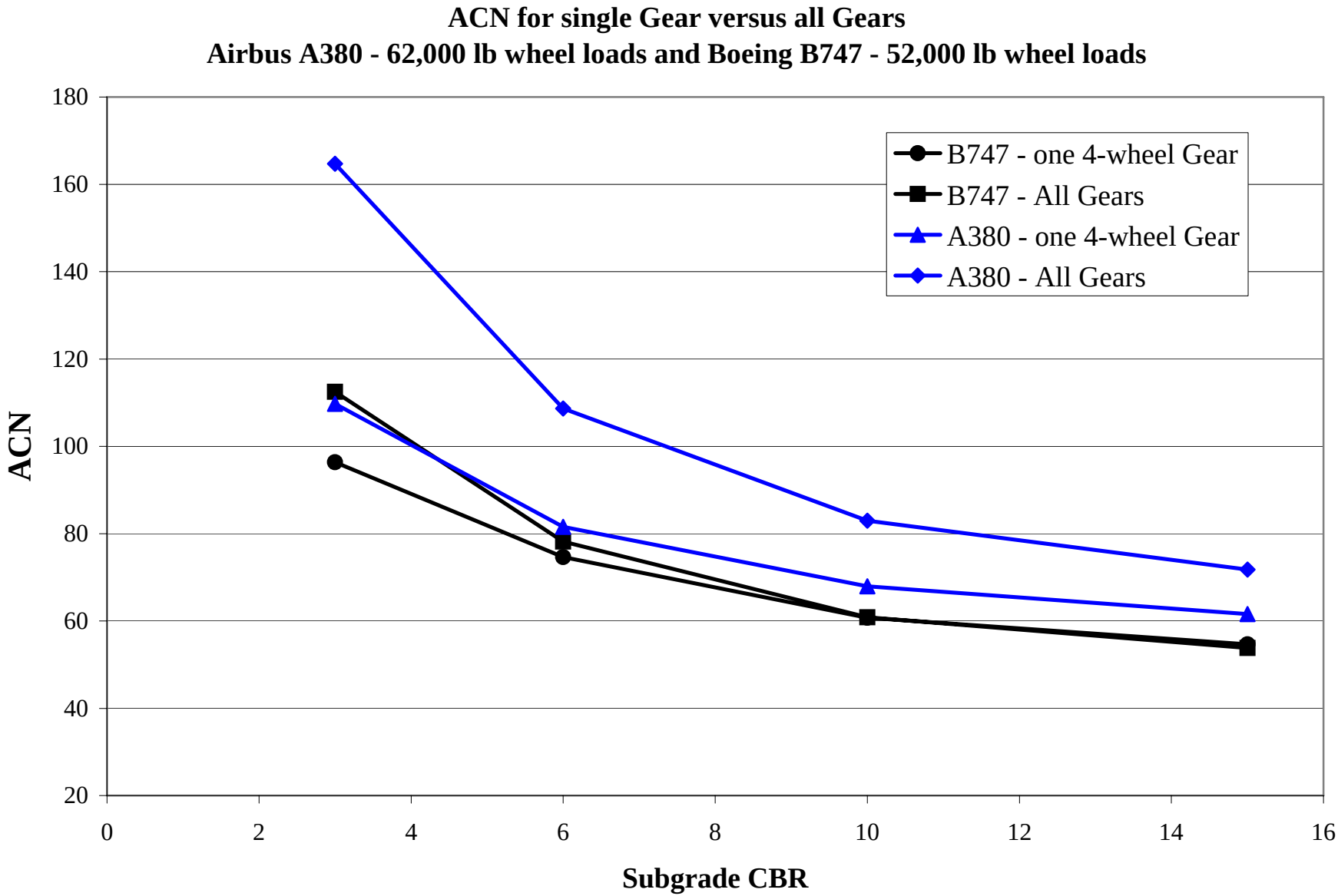
- Only intended as a method for airport operators to evaluate acceptable operations of airplanes
- It provides a load, or damage rating relative to a specified reference load.
- ACN is not a pavement design procedure.

ACN/PCN System - Limitations

Airplanes are represented by only one gear



ACN/PCN System –Flexible Pavement One Gear versus All Gears (06 alphas)



ACN/PCN System – Rigid Pavement

- Westergaard solution for loaded elastic plate on a Winkler foundation
- Interior load (PCA method)
- Concrete working stress = 2.75 MPa (399 psi)
- 4 Subgrade strengths

High (A)	=	150 MN/m^3 (554 pci)
Medium (B)	=	80 MN/m^3 (296 pci)
Low (C)	=	40 MN/m^3 (148 pci)
Ultra low (D)	=	20 MN/m^3 (74 pci)

ACN/PCN System –Flexible Pavement

- California Bearing Ratio (CBR) Method
- 4 Subgrade Strengths

High (A)	=	CBR 15
Medium (B)	=	CBR 10
Low (C)	=	CBR 6
Ultra low (D)	=	CBR 3

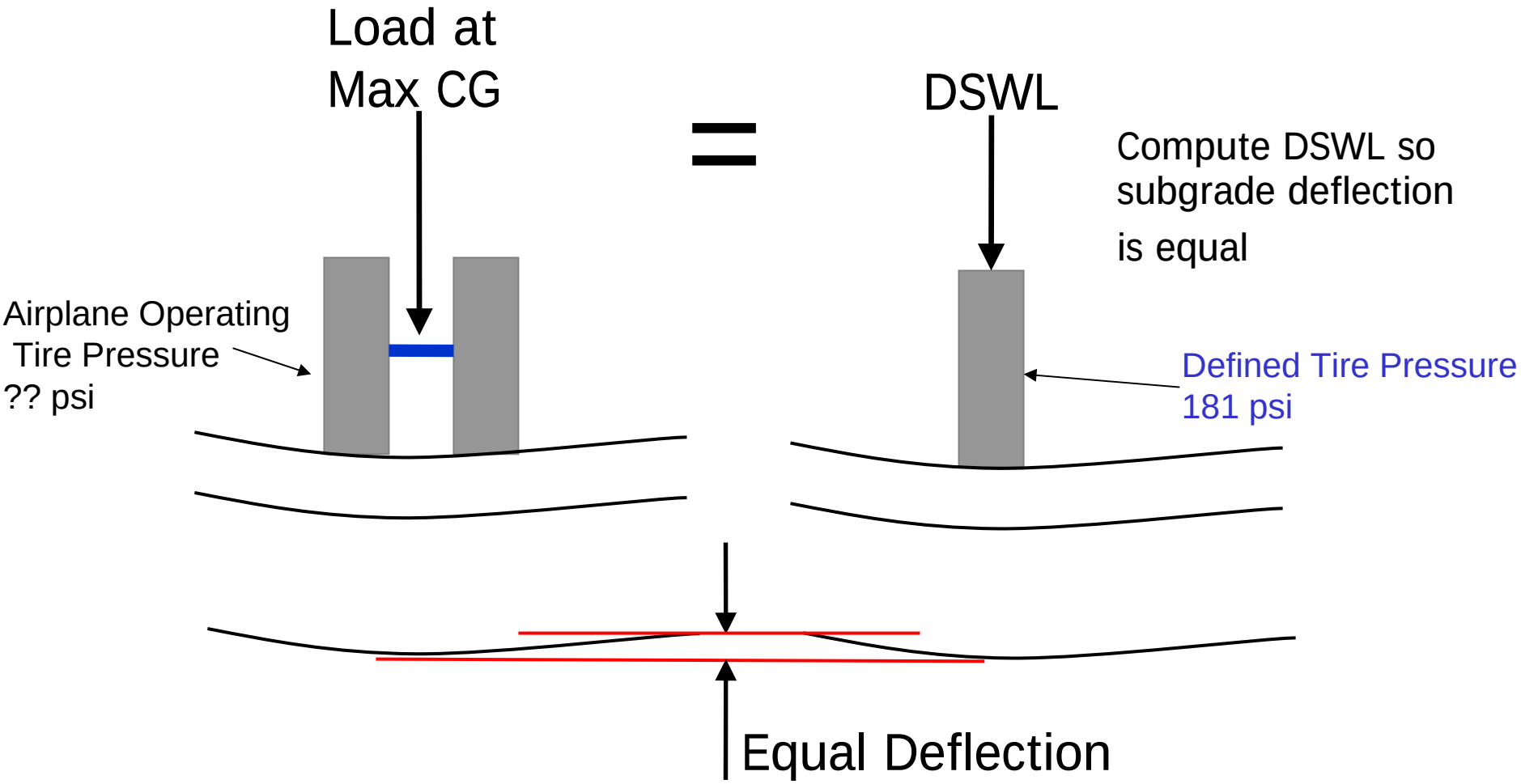
ACN/PCN System

- A Derived Single Wheel load (DSWL) at 1.25 MPa (181 psi) is computed for each subgrade.
  - Found by equating thickness for DSWL to design thickness for airplane gear

- ACN = DSWL in kilograms divided by 500

  Calculated at maximum main gear loading – i.e. maximum ramp weight and corresponding maximum center of gravity

Historic Flexible Design Parameter Derived Single Wheel Load (DSWL)



ACN/PCN System – Official ACN

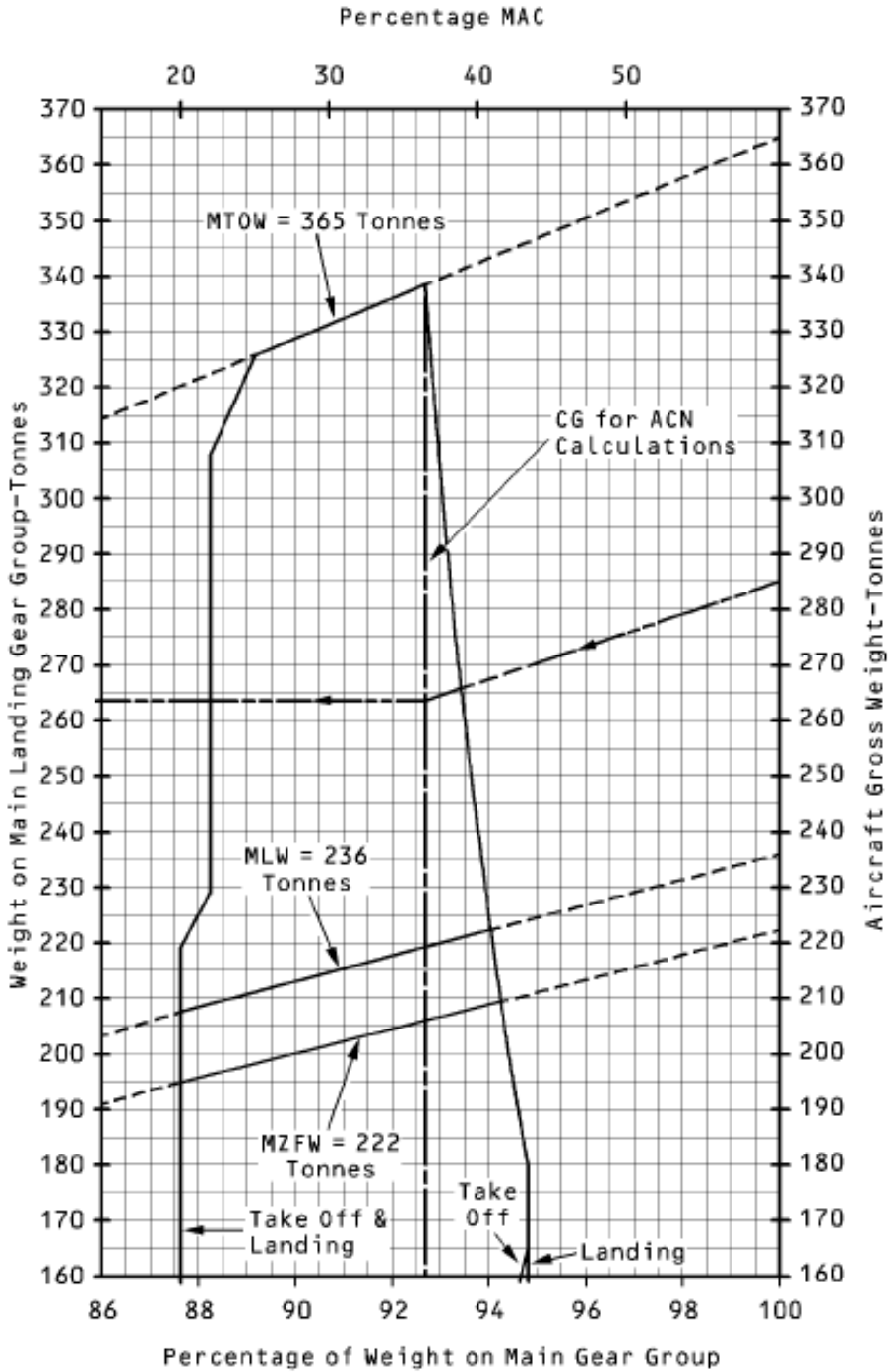
- Official ACN values are provided by the Aircraft Manufacturer

Airplane Characteristics for Airport Planning

ACN/PCN System

- Airplane Characteristics manual report official center of gravity and max gross load for ACN calculation.

- Tire pressure (used in ACN calculation) is also reported for standard configuration

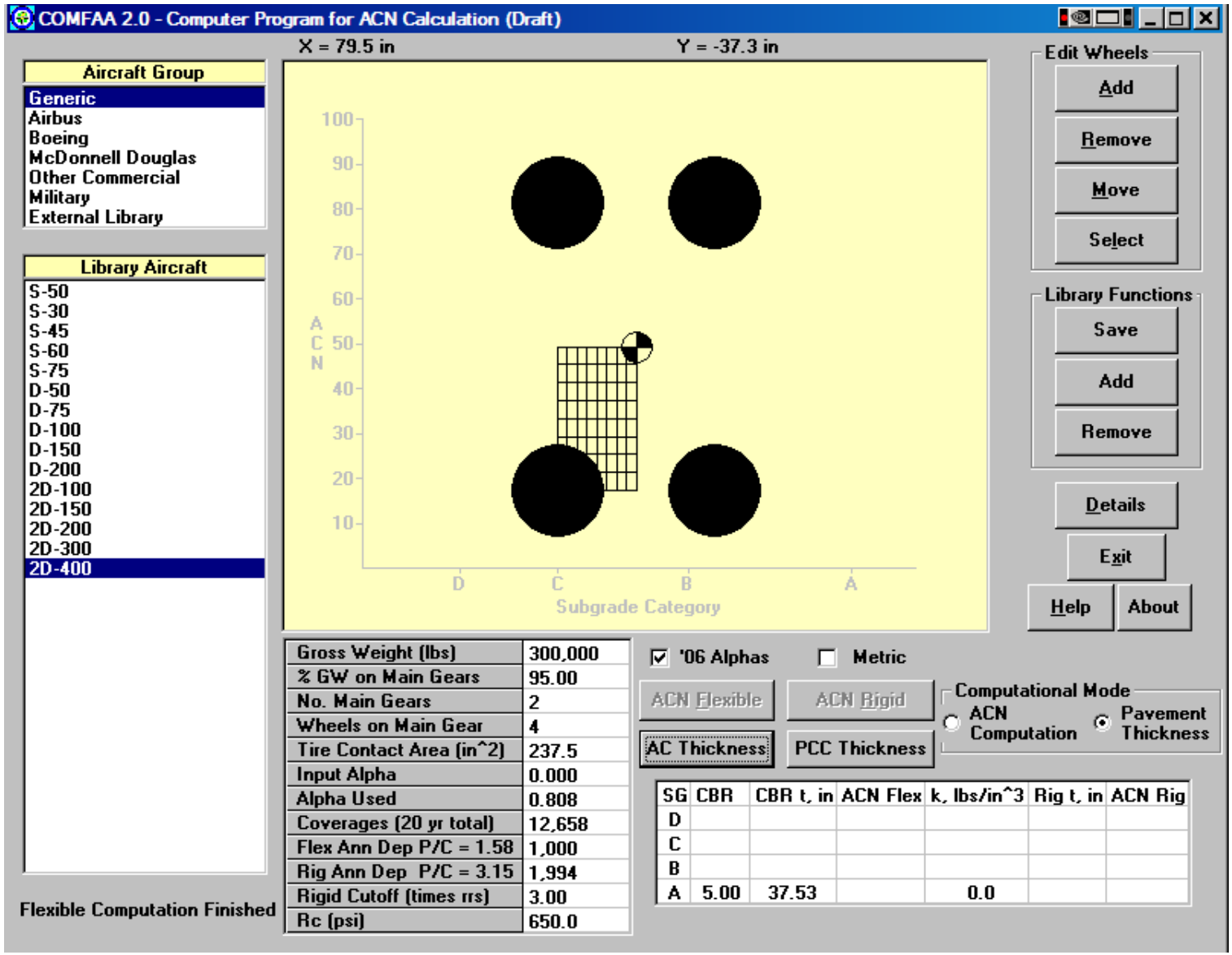


FAA Guidance on ACN-PCN

AC 150/5335-5A *STANDARDIZED METHOD OF REPORTING AIRPORT PAVEMENT STRENGTH – PCN*

- AC introduces the COMFAA program.
- COMFAA can be used to calculate ACN values for any airplanes.
- Manufacturer's have provided CG and max load data for ACN determination.

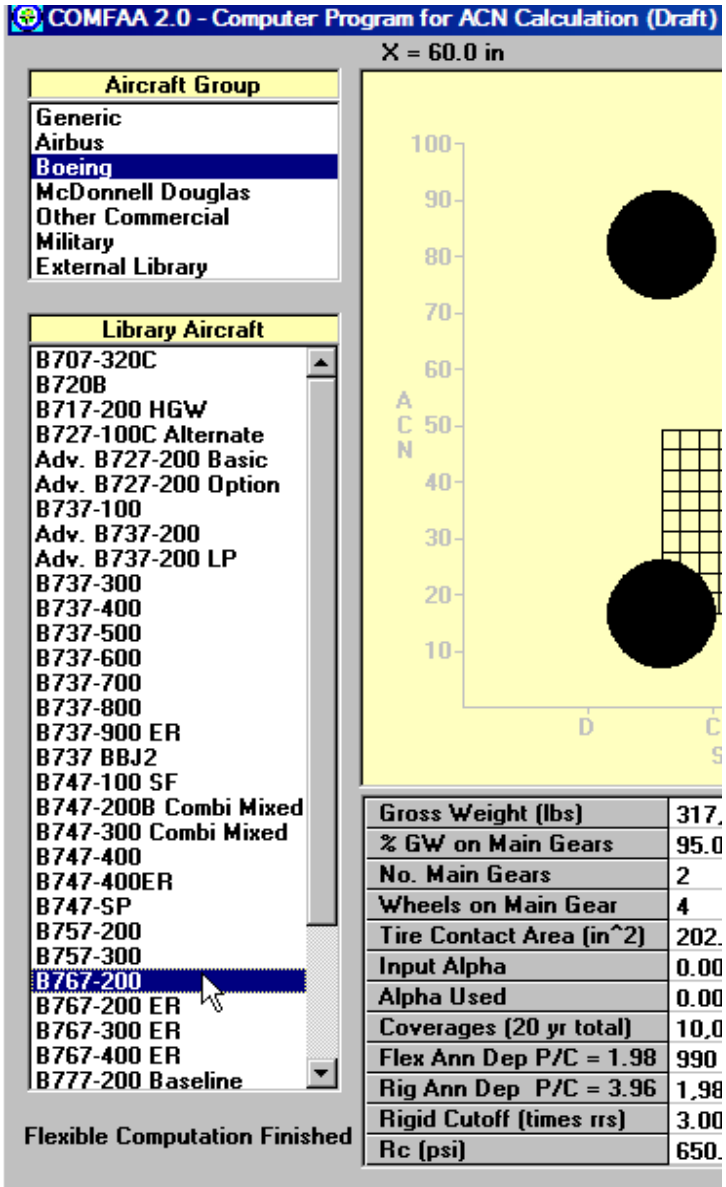
COMFAA 2.0 Program



COMFAA 2.0 Program

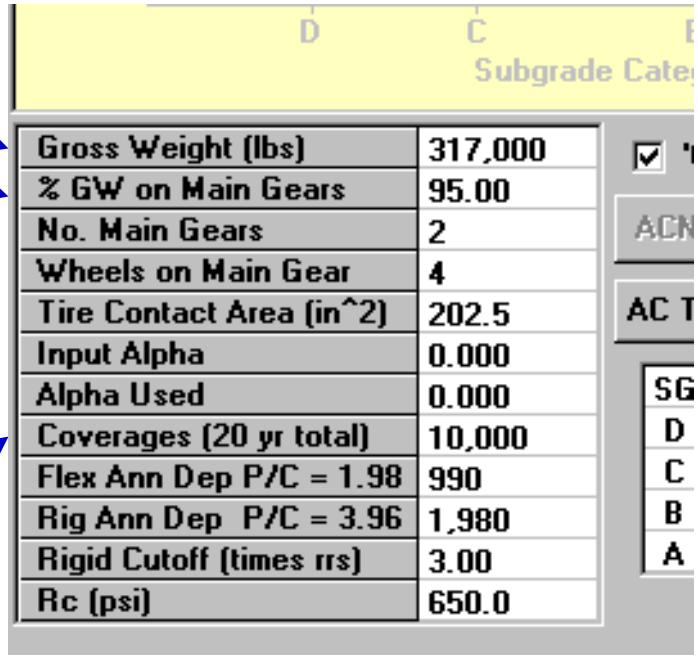
Select desired aircraft group

Select desired airplane



COMFAA 2.0 Program

The internal aircraft library in COMFAA contains the manufacturers data for ACN determination.



Coverages is set to 10,000 per ICAO procedure.

COMFAA 2.0 Program

ACN Flexible | ACN Rigid | AC Thickness | PCC Thickness

Computational Mode: ACN Computation / Pavement Thickness

SG	CBR	CBR t, in	ACN Flex	k, lbs/in^3	Rig t, in	ACN Rig
D	3.0	51.21	60.4	73.7	14.15	54.0
C	6.0	30.14	43.8	147.4	12.64	46.5
B	10.0	20.93	37.5	294.7	11.10	39.0
A	15.0	15.69	34.5	552.6	9.82	33.2

Flexible Rigid

In ACN Computation mode, ACN values are calculated for 4 standard subgrade conditions using the identified airplane data

ACN-PCN SYSTEM – PCN Values

- PCN values are reported in a coded format using 5 parts separated by "/"

  Sample 39/R/B/W/T

- Information includes
  - Numerical PCN Value
  - Pavement Type
  - Subgrade Category
  - Allowable Tire pressure
  - Method used to determine the PCN value

ACN-PCN SYSTEM

39/R/B/W/T

PCN Numerical value

- PCN Numerical value is a relative indication of the load carrying capacity of a pavement in terms of a standard single wheel load 181 psi (1.25 MPa)
- PCN value derived from the ACN value of the most demanding airplane.
- PCN values can be determined in two ways
  - Using Aircraft
  - Technical Evaluation

ACN-PCN SYSTEM

39/R/B/W/T

Pavement Type

- Pavement may be either Rigid (R) or Flexible (F)
  - Rigid – Single Stiff Layer to support and distribute load
  - Flexible – Multiple flexible layers to distribute load
- Composite pavements (overlays etc.) are reported as the type which most accurately reflects the structural action

ACN-PCN SYSTEM

39/R/B/W/T

Subgrade Category

Subgrade Strength Category	CODE	RIGID k-Value* pci (MN/m3)	FLEXIBLE CBR-Value
High	A	552.6 (150)	15
Medium	B	294.7 (80)	10
Low	C	147.4 (40)	6
Ultra Low	D	73.7 (20)	3

*Effective k-value

ACN-PCN SYSTEM

39/R/B/W/T

Allowable Tire Pressure

Category	Code	Tire Pressure Range
High	W	No pressure limit
Medium	X	Pressure limited to 218 psi (1.5 MPa)
Low	Y	Pressure limited to 145 psi (1.00 MPa)
Very Low	Z	Pressure limited to 73 psi (0.50 MPa)

Recent request to ICAO have proposed modifying this table to increase allowable tire pressures

ACN-PCN SYSTEM

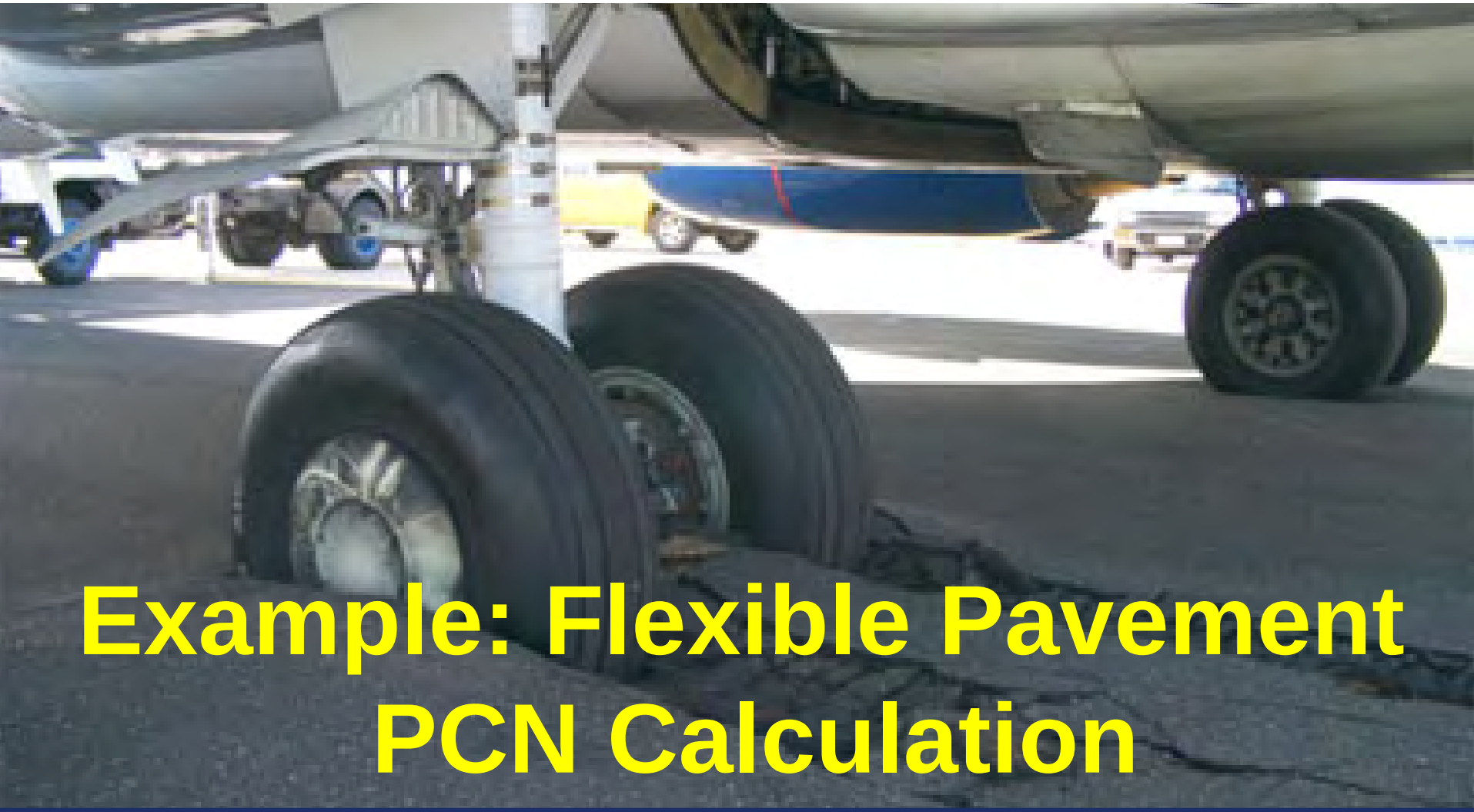
39/R/B/W/T

Method used to determine PCN

PCN values can be determined in two ways

- U =Using Aircraft
  - Simply select highest ACN from all airplanes using facility
- T = Technical Evaluation
  - PCN based on technical study of pavement structure and traffic data.

ACN-PCN – Technical Evaluation



Example: Flexible Pavement PCN Calculation

ACN-PCN – Technical Evaluation

Basic Steps to Determine Pavement Classification Number

1) Identify pavement features and properties
2) Determine traffic mixture
3) Convert traffic to equivalent traffic of “critical” airplane
4) Determine allowable operating weight of critical airplane
5) Determine ACN of critical airplane at allowable weight
6) Report PCN

ACN-PCN – Technical Evaluation

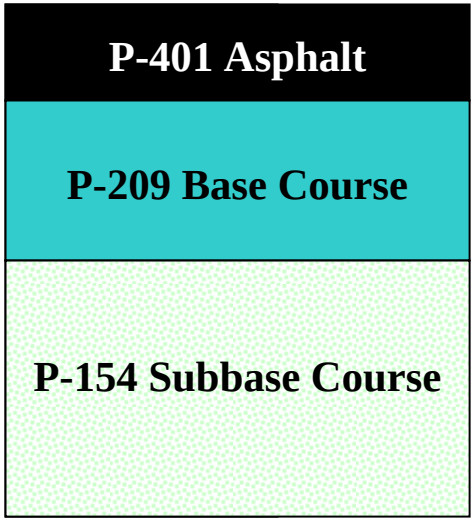
1) Identify pavement features and properties

The pavement must be referenced to a standard pavement section for evaluation purposes

Minimum required asphalt surface layer

Minimum required P-209 layer (CBR +80)

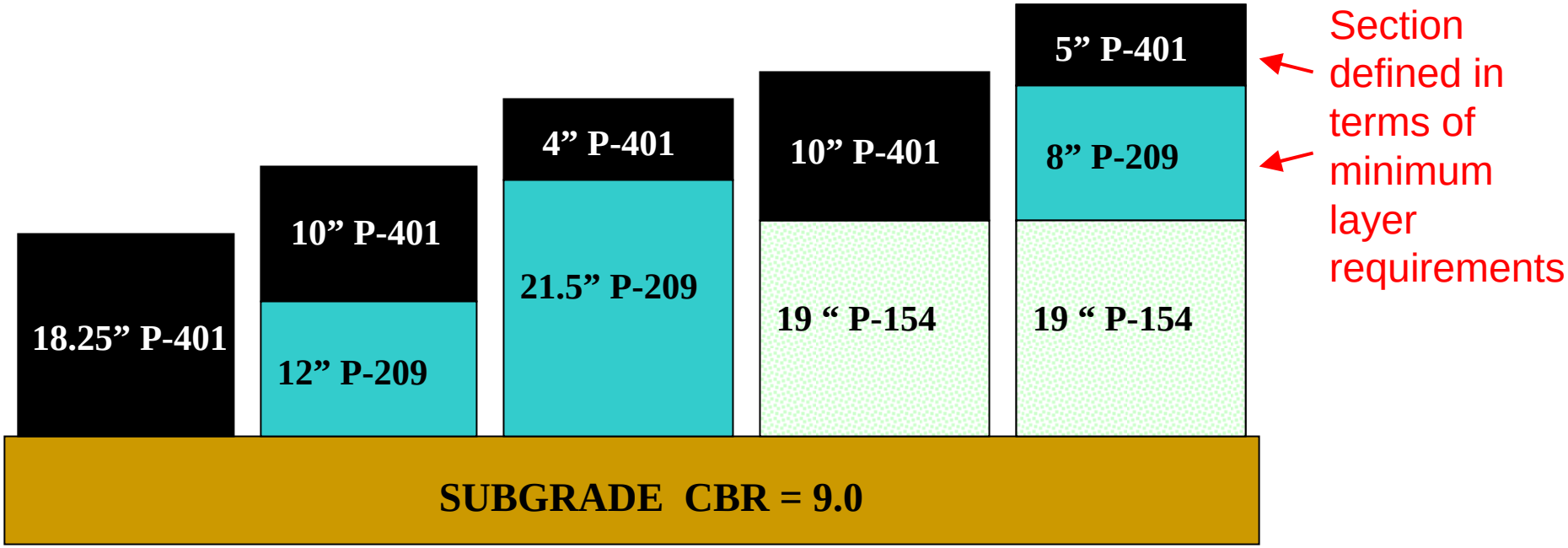
Variable P-154 layer (CBR +20)



Minimum requirements defined in AC 150/5320-6D

ACN-PCN – Technical Evaluation

For this example assume the following existing pavement structure (must express in terms of minimum layer requirements)



All sections are structurally equivalent to 32 inch pavement

ACN-PCN – Technical Evaluation

2) Determine Traffic Mixture

Identify the airplanes that have or plan to use the airport during the pavement design period

Include all significant traffic

- Non-scheduled events
- Charters
- Etc.

ACN-PCN – Technical Evaluation

For this example assume the following traffic mixture

Airplane	Operating Weight, (lbs)	Tire Pressure (psi)	Annual Departures
B727-200	185,000	148	400
B737-300	130,000	195	6,000
A319-100	145,000	196	1,200
B747-400	820,000	200	3,000
B767-300ER	370,000	190	2,000
DC8-63	330,000	194	800
A300-B4	370,000	217	1,500
B777-200	600,000	215	300

ACN-PCN – Technical Evaluation

3) Convert traffic to equivalent traffic of critical airplane

a) Determine traffic volume in terms of traffic cycles

b) Determine the pavement thickness necessary for each individual airplane

The airplane requiring the thickest pavement becomes the critical airplane

c) Traffic conversion performed in two stages

Equivalent departures based on gear type

Ratio of wheel loads

ACN-PCN - Coverages

Pavement design calculations require knowing how many times the pavement is fully loaded. One full load application is called a “Coverage”.

However, airplane operations are easily counted by how many times the airplane “passes” over a pavement

Because airplanes seldom travel along the exact same line of pavement, It may take many passes to fully load a unique point in the pavement

The ratio of Passes to Coverages (P/C) is used to convert counted passes to coverages. The ratio is unique for each airplane.

ACN-PCN - Coverages

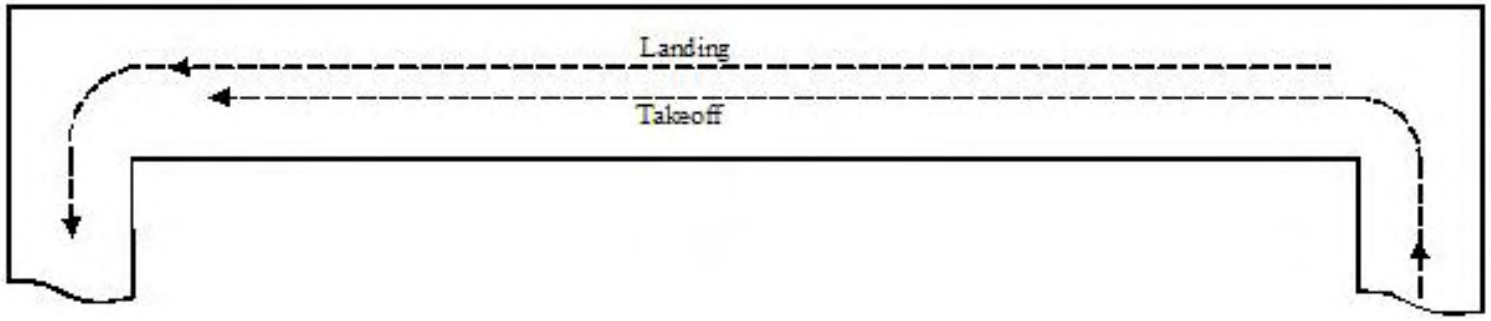
FAA pavement design procedures use “Annual Departures” as the traffic count for design purposes.

- Arrival traffic is ignored

-- One landing and takeoff = one Annual Departure

This may not be the best representation of the airport traffic depending upon airport operations

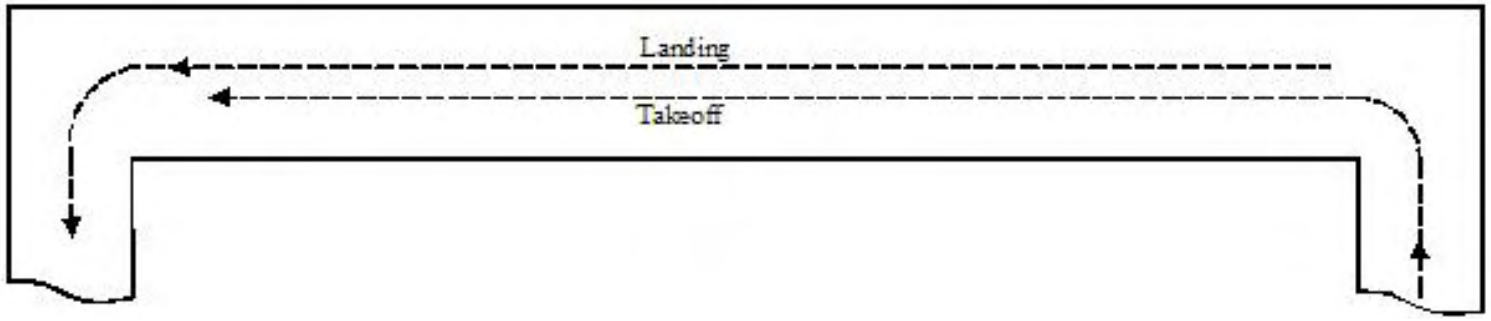
ACN-PCN - Coverages



Assumed procedure for FAA pavement design

- Airplane is refueled – arrival weight **<** departure weight
- Arrival traffic is ignored and only the departure is counted
- One plane will load the pavement ~ 1 time (P/TC = 1)
- Departures are converted to coverages by the Pass-to-coverage ratio (P/C)/(P/TC) or (P/C)/1

ACN-PCN - Coverages



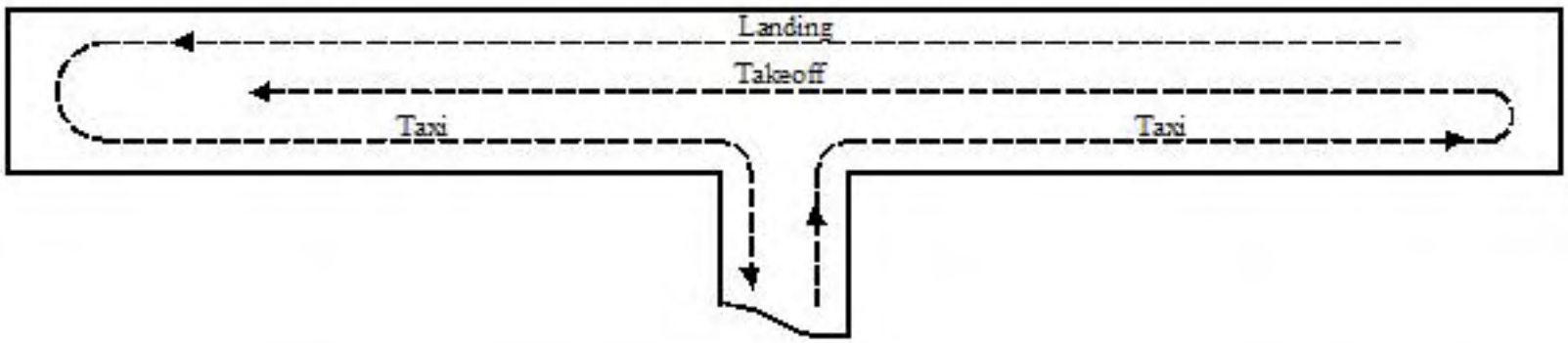
If the airplane is not refueled

Arrival weight ~= departure weight

One plane will load the pavement ~ 2 times (P/TC = 2)

Annual Departures are converted to coverages by the Pass-to-coverage ratio (P/C)/(P/TC) or (P/C)/2

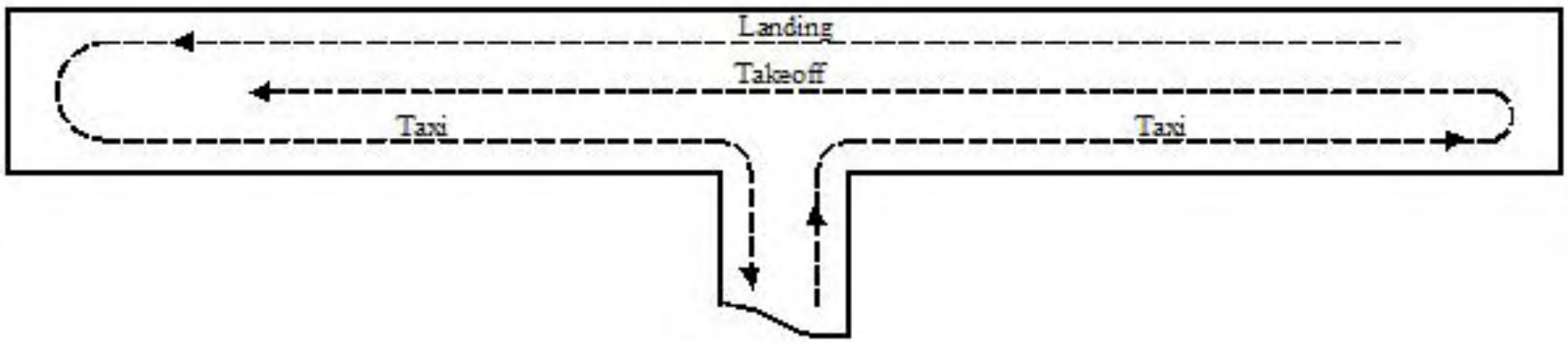
ACN-PCN - Coverages



Center entrance/exit - Airplane is refueled

- Arrival weight < departure weight
- Arrival is ignored
- One plane will load the pavement ~ 2 times (P/TC = 2)
- Annual Departures are converted to coverages by the Pass-to-coverage ratio (P/C)/(P/TC) or (P/C)/2

ACN-PCN - Coverages

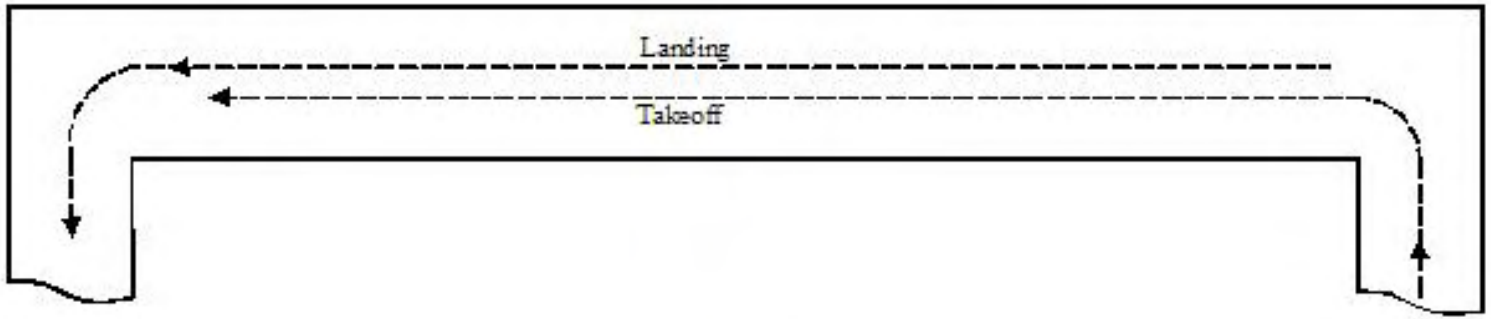


Center entrance/exit - Airplane is not refueled

- Arrival weight ~= departure weight
- One plane will load the pavement ~ 3 times (P/TC = 3)
- Annual Departures are converted to coverages by the Pass-to-coverage ratio (P/C)/(P/TC) or (P/C)/3

See AC 150/5335-5A for further details

ACN-PCN - Coverages



Design example

Annual Departures are converted to coverages by the Pass-to-coverage ratio (P/C)/1

Total coverages = {Ann. Departures/(P/C)/1} x 20 years

ACN-PCN System

For a technical evaluation, a most demanding or “critical” airplane must be determined

Using the current procedure identified in AC 150/5335-5A the airplane which requires the thickest pavement based on its own demand is considered the critical airplane

ACN-PCN – Technical Evaluation

Determine total thickness requirements for each Airplane in the traffic mixture

Airplane	Operating Weight, (lbs)	Tire Pressure (psi)	Annual Departures	Flexible P/C	20 year Total Coverages
B727-200	185,000	148	400	2.92	2,740
B737-300	130,000	195	6,000	3.79	31,662
A319-100	145,000	196	1,200	3.18	7,547
B747-400	820,000	200	3,000	1.73	34,682
B767-300ER	370,000	190	2,000	1.80	22,222
DC8-63	330,000	194	800	1.68	9,524
A300-B4	370,000	217	1,500	1.75	17,143
B777-200	600,000	215	300	1.42	4,225

ACN-PCN – Technical Evaluation

Determine total thickness requirements for each airplane

For example:

B747-400

3,000 Annual Departures

820,000 lbs Max gross operating weight

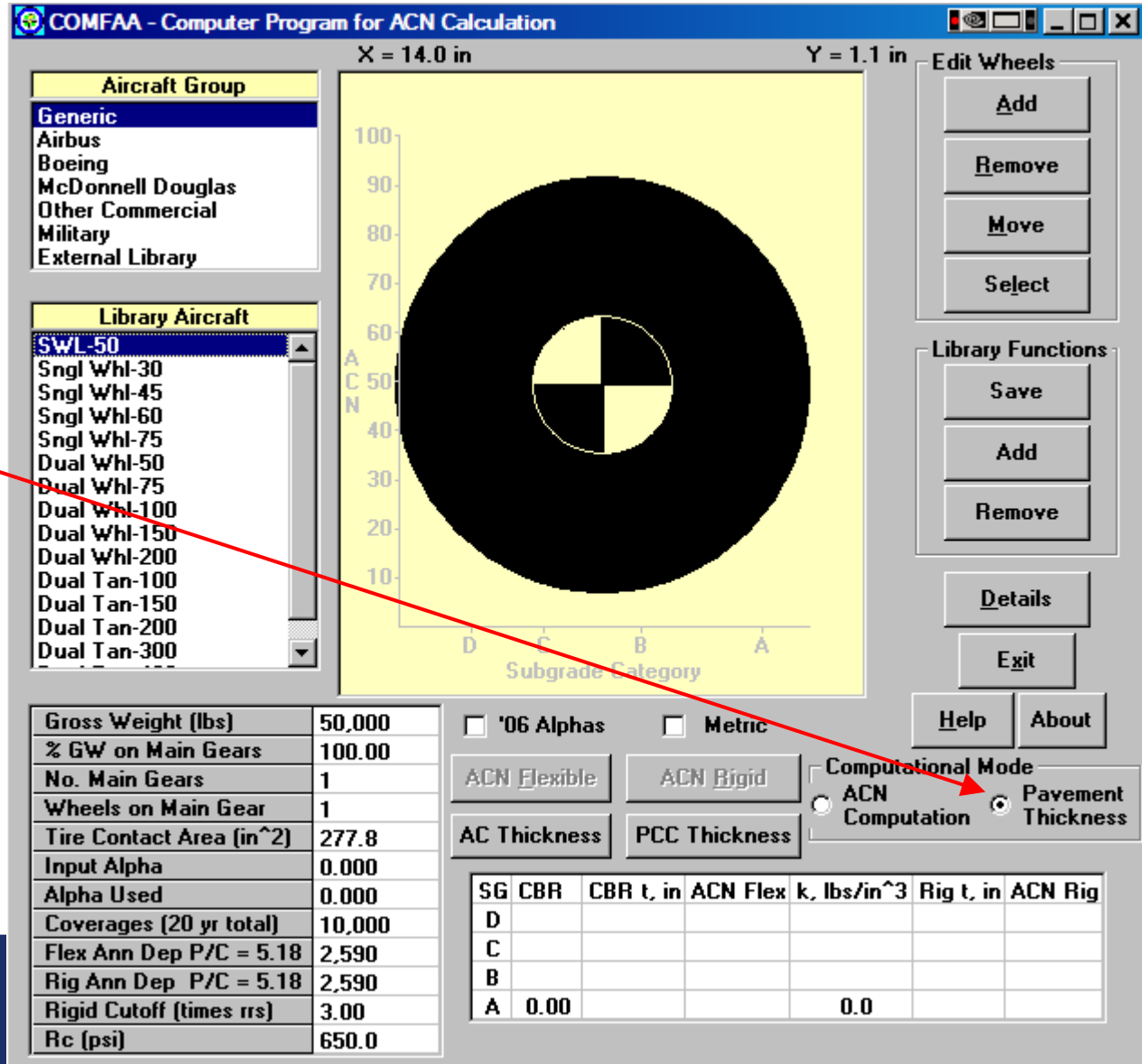
Subgrade CBR = 9.0

USE THE COMFAA PROGRAM

ACN-PCN – Technical Evaluation

Start the COMFAA program

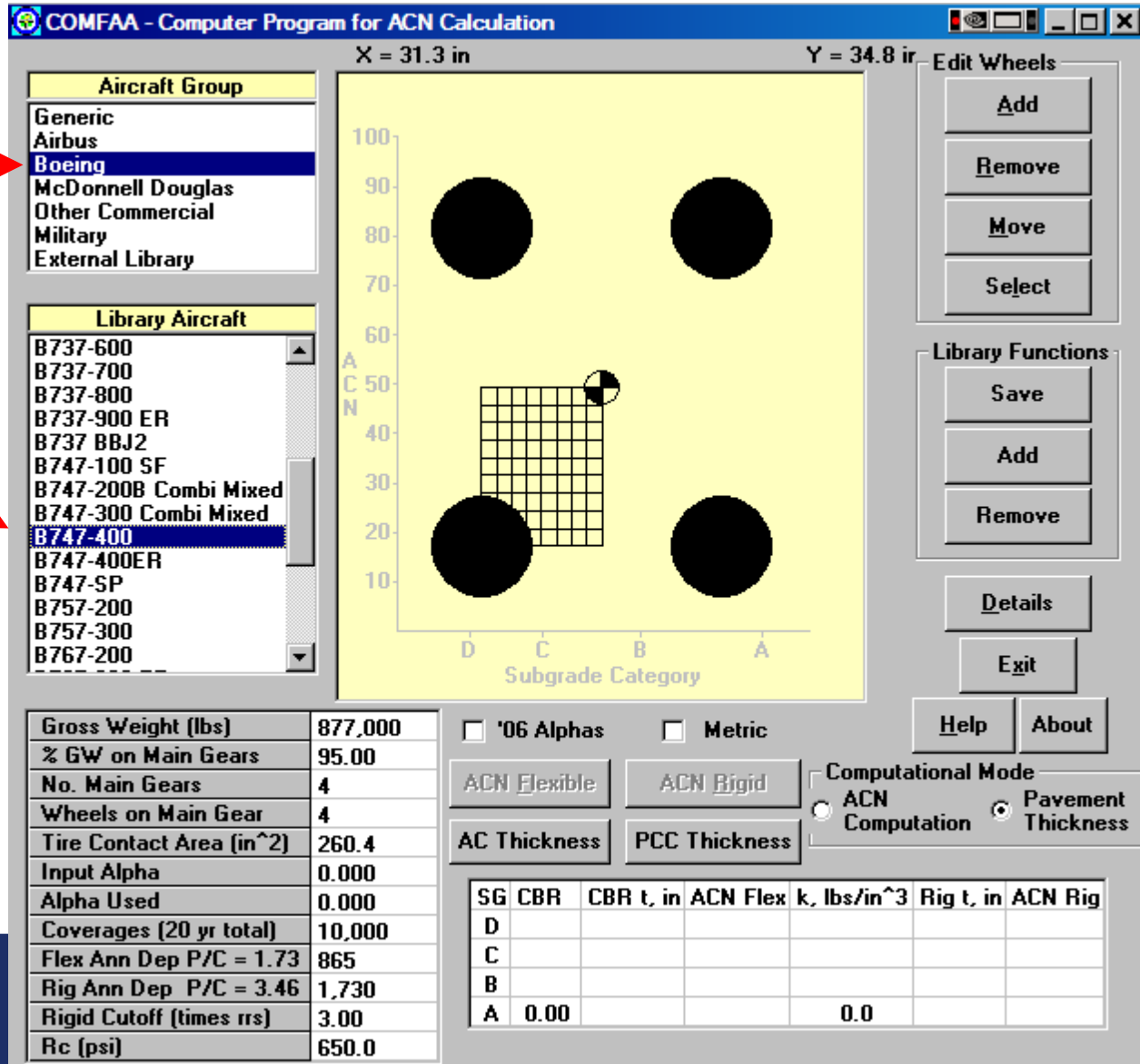
Begin by switching to “Pavement Thickness” mode



ACN-PCN – Technical Evaluation

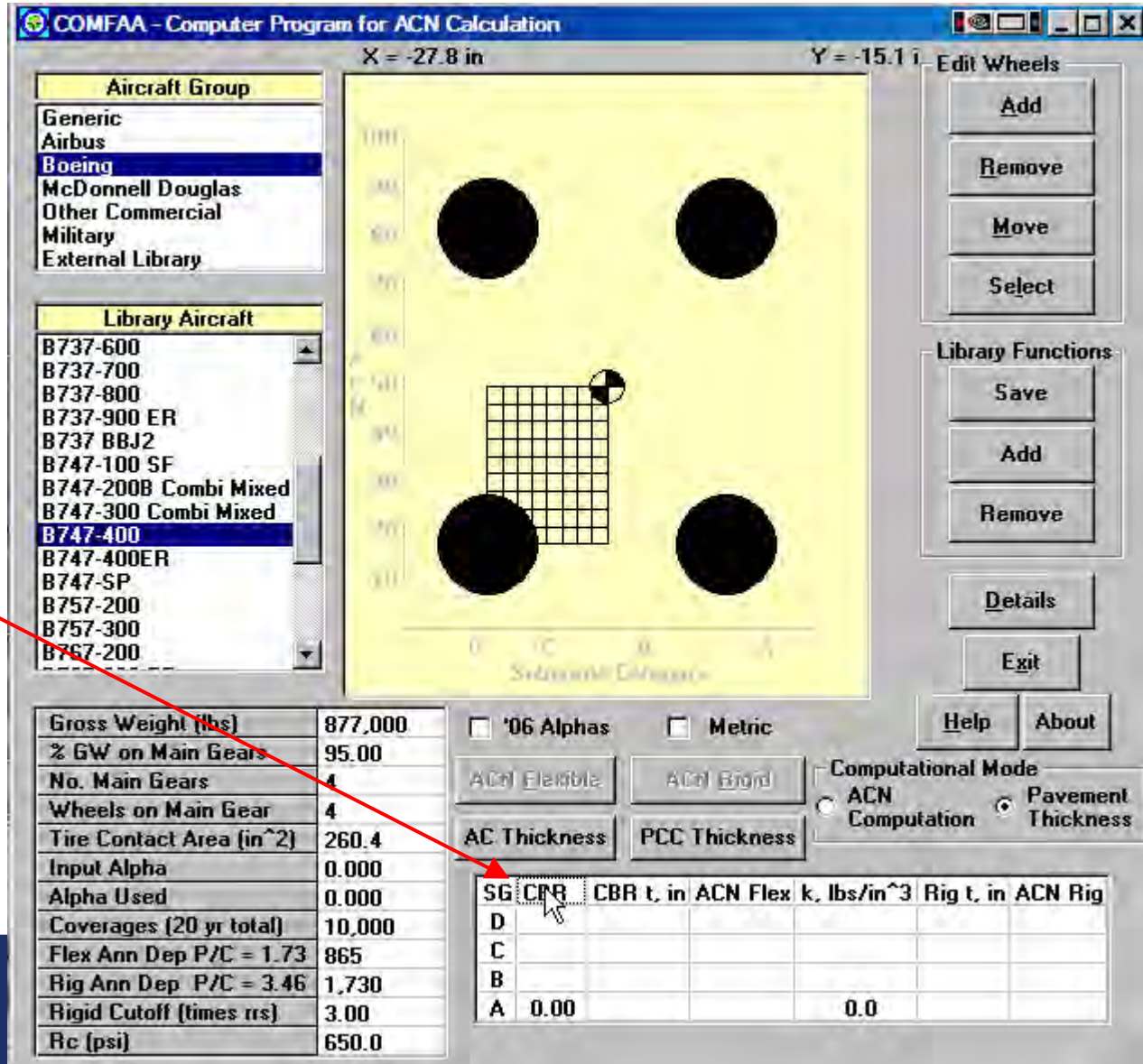
Select "Boeing" from the Aircraft groups

Select the B747-400



ACN-PCN – Technical Evaluation

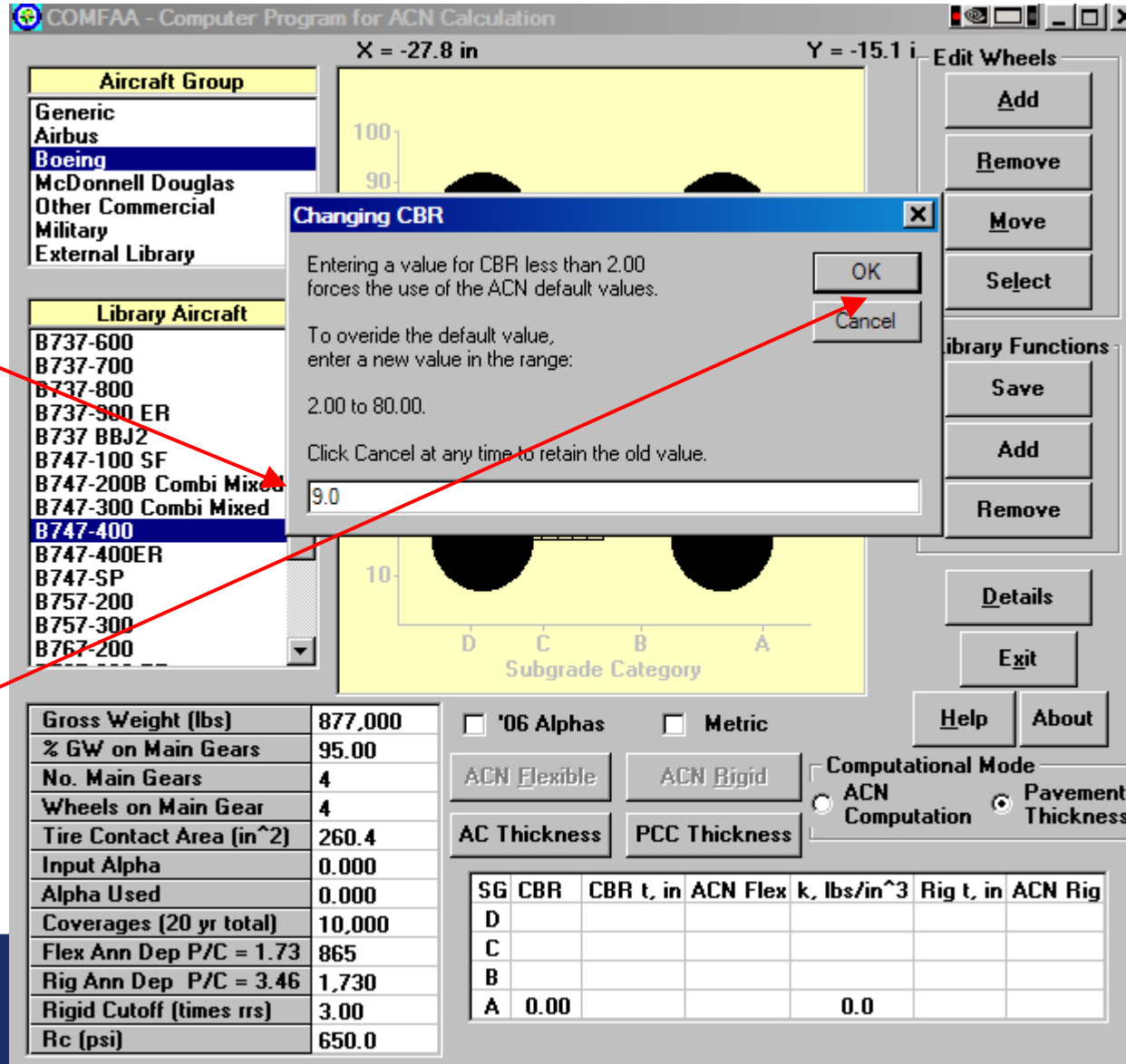
Click on “CBR” to enter the subgrade CBR value



ACN-PCN – Technical Evaluation

Enter subgrade CBR value

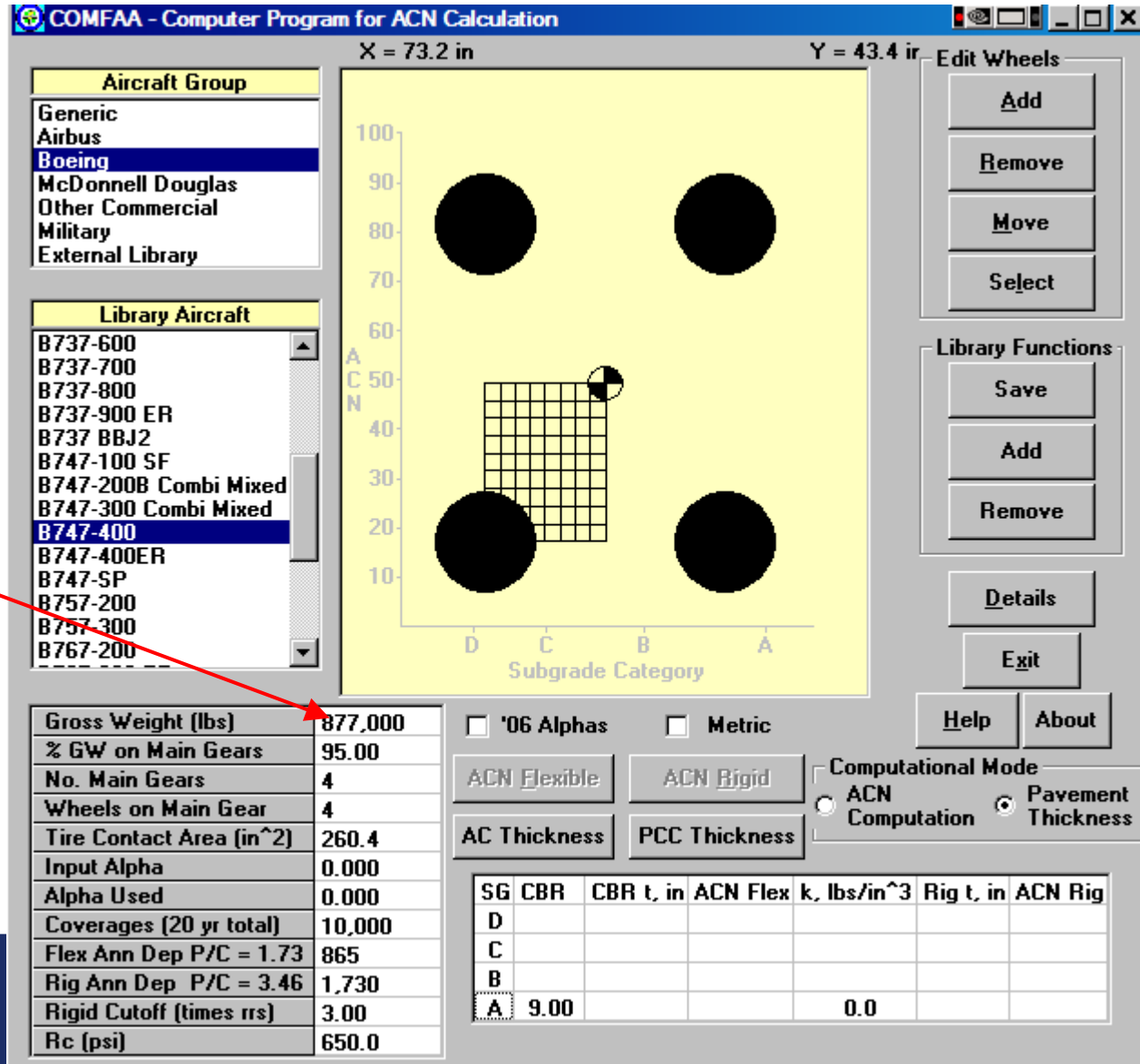
Click “OK”



ACN-PCN – Technical Evaluation

Adjust the airplane weight to the known/permitted operating weight

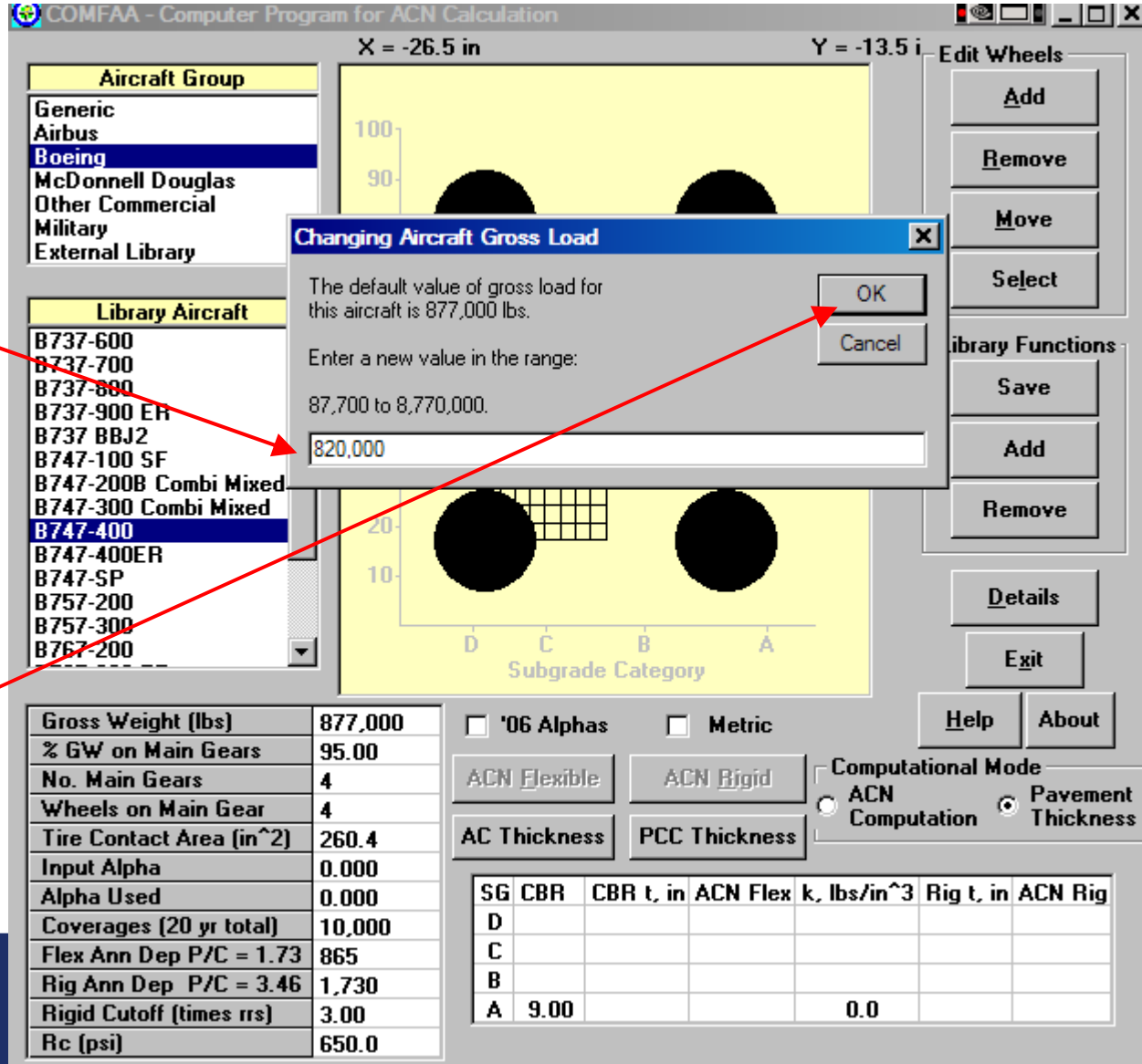
Start by clicking on the box containing gross weight



ACN-PCN – Technical Evaluation

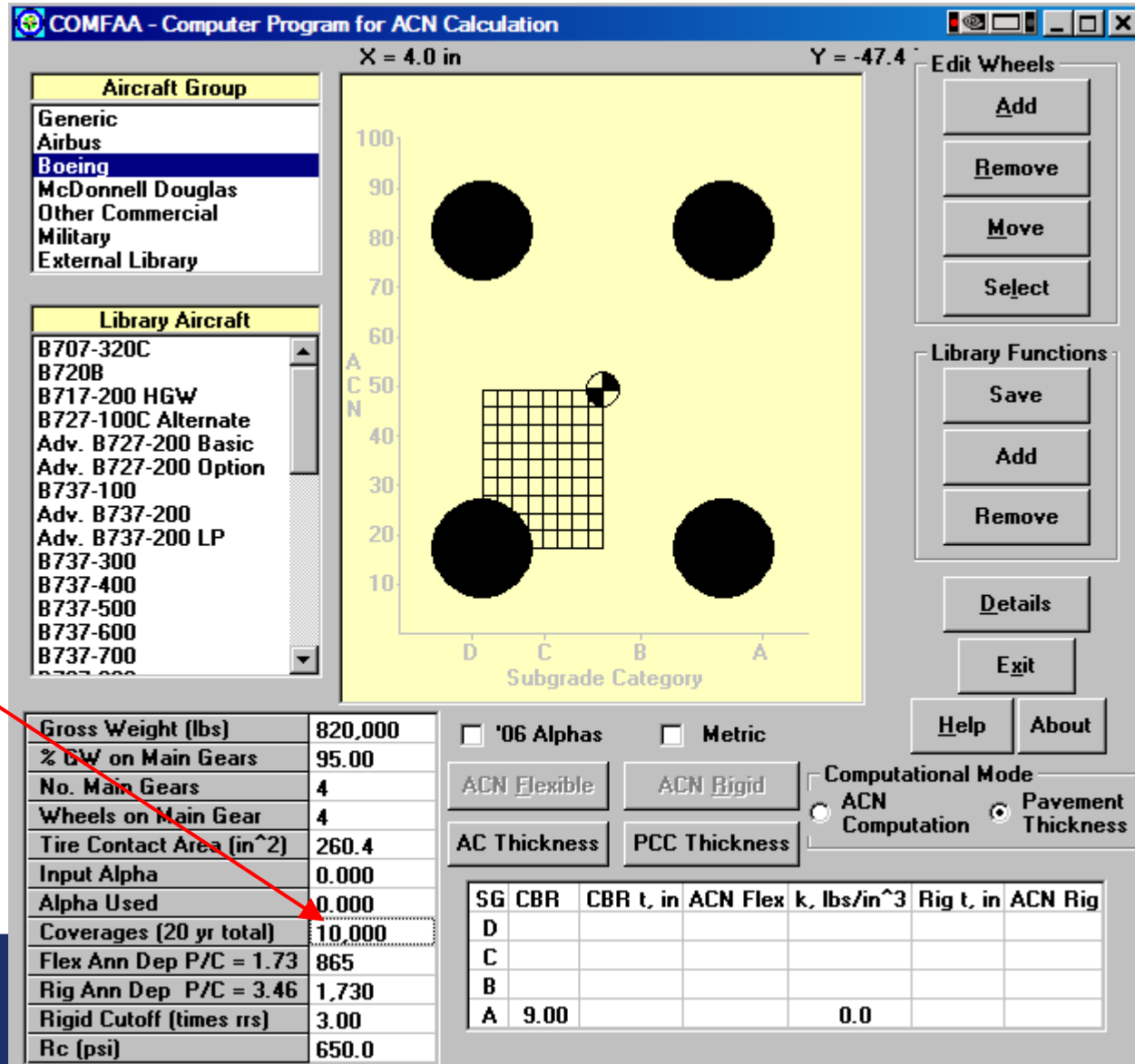
Enter Gross Weight (lbs)

Click “OK”



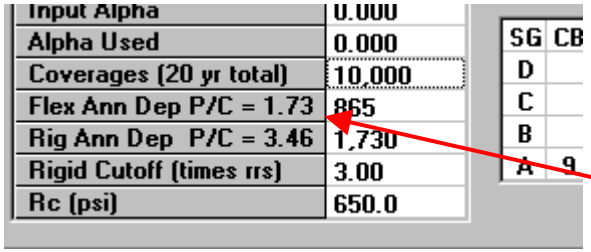
ACN-PCN – Technical Evaluation

Click on the coverages to enter the desired 20-year total number of coverages for this airplane



ACN-PCN – Technical Evaluation

Determine total coverages for the B747



Input Alpha	0.000
Alpha Used	0.000
Coverages (20 yr total)	10,000
Flex Ann Dep P/C = 1.73	865
Rig Ann Dep P/C = 3.46	1,730
Rigid Cutoff (times rrs)	3.00
Rc (psi)	650.0

SG	CB
D	
C	
B	
A	9

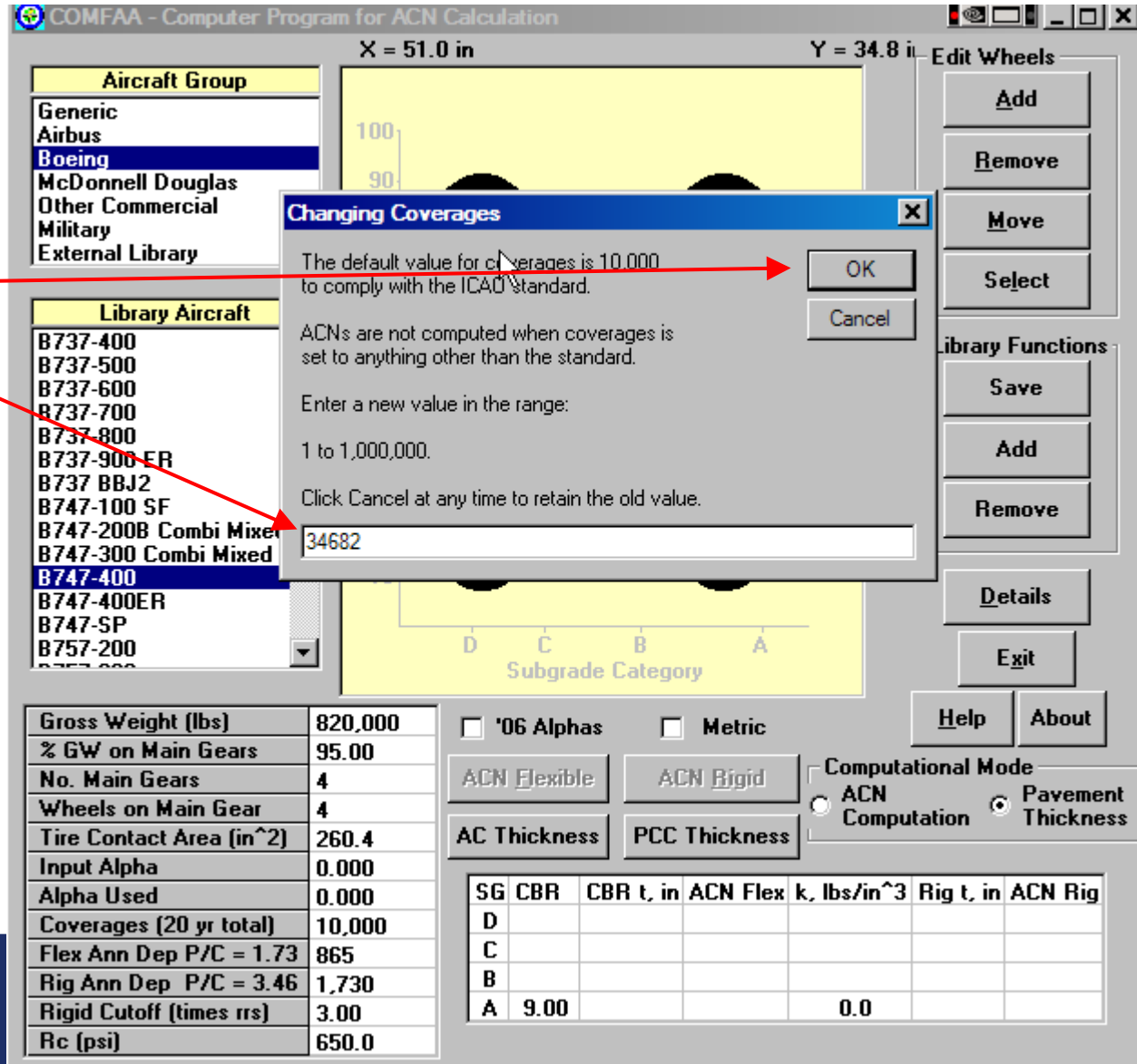
Find P/C ratio from COMFAA (use flexible value = 1.73)

Coverages = annual departures/{(P/C)/(P/TC)} *years in design

Total coverages = 3000 ann. departures/1.73/1}*20 = 34,682

ACN-PCN – Technical Evaluation

Enter the desired coverages and click OK

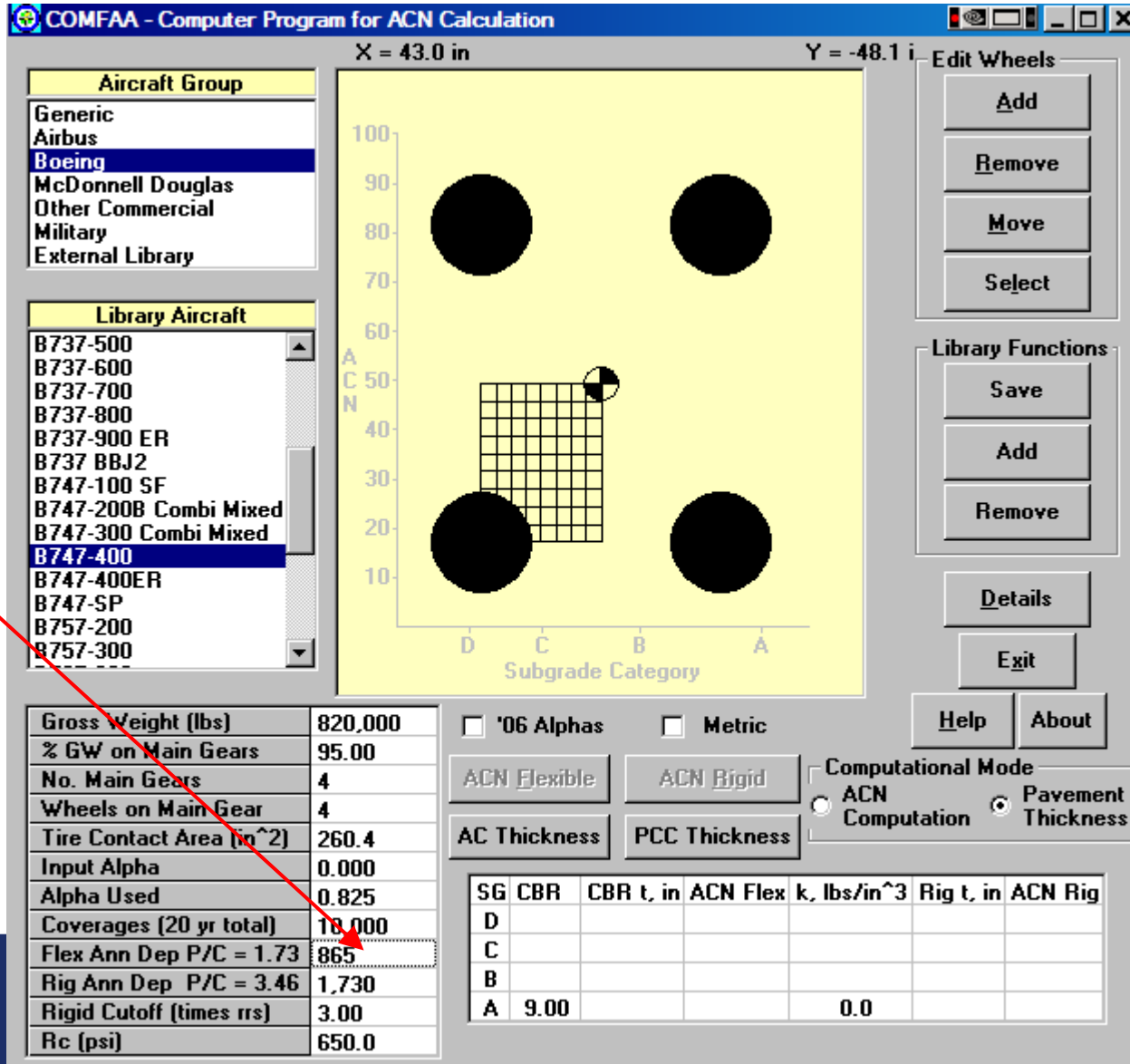


ACN-PCN – Technical Evaluation

OPTIONAL PROCEDURE if TC = 1

Click on the annual departure to enter the desired annual departures for this airplane

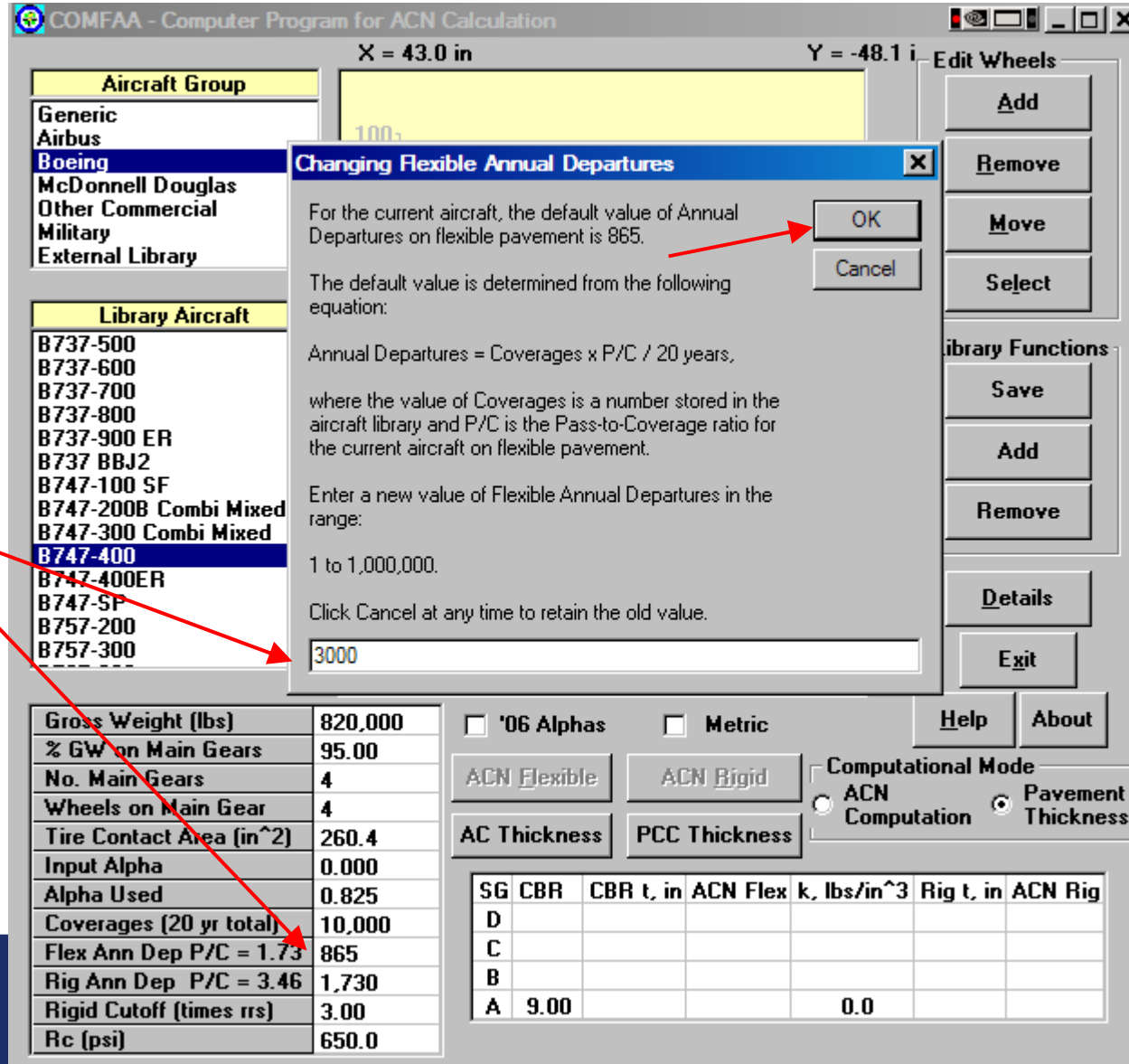
Note that this example uses the Flexible annual departures



ACN-PCN – Technical Evaluation

Since our example has TC=1

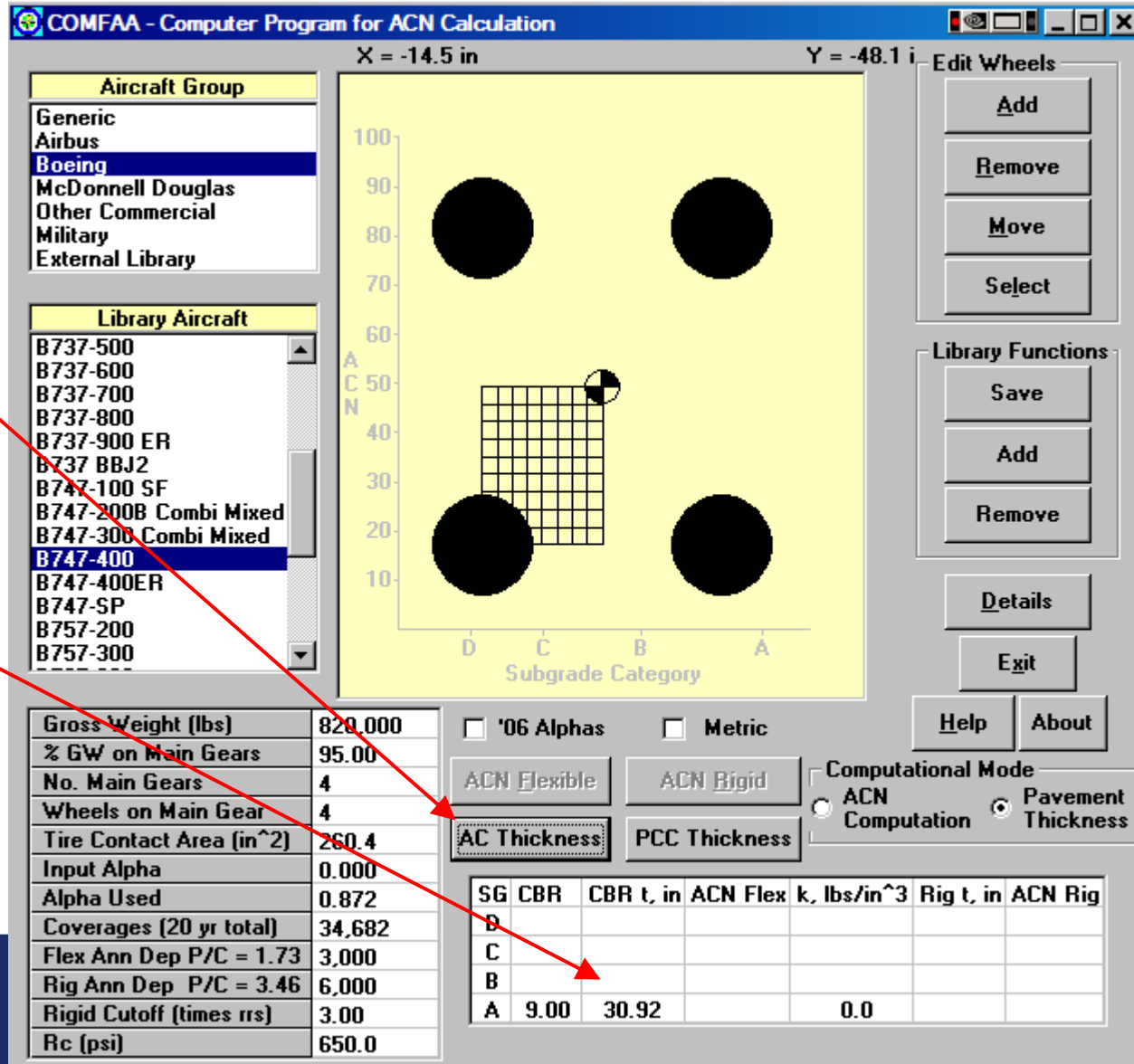
Click on annual departures and enter the desired annual departures for this airplane



ACN-PCN – Technical Evaluation

Click on “AC Thickness” to calculate the flexible pavement thickness requirement

Repeat for each airplane



ACN-PCN – Technical Evaluation

airplane Data – required thickness determination

Airplane	Operating Weight, (lbs)	Tire Pressure (psi)	Annual Departures	Flexible **P/C	Required t, (in.)
B727-200	185,000	148	400	2.92	22.6
B737-300	130,000	195	6,000	3.79	22.7
A319-100	145,000	196	1,200	3.18	20.3
B747-400	**820,000**	**200**	**3,000**	**1.73**	**30.9**
B767-300ER	370,000	190	2,000	1.80	27.9
DC8-63	330,000	194	800	1.68	26.6
A300-B4	370,000	205	1,500	1.75	29.1
B777-200	600,000	215	300	1.42	28.0

** P/C ratio provided by COMFAA while in pavement thickness mode

ACN-PCN – Technical Evaluation

3c) Convert traffic to equivalent traffic of the critical airplane

Two step process

1. Convert departures based on gear type
2. Complete conversion using wheel load ratio equation

I

ACN-PCN – Technical Evaluation

Gear type to "Critical" gear type conversion factors

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

M=# wheels on critical airplane gear

N=# wheels on converted airplane gear

AC 150/5335-5A paragraph 1.2, App. 1

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	244
3D	2D	1.56
2D/2D2	D	1.56
2D/2D2	2D	1.00
2D/2D2	3D	0.64

ACN-PCN – Technical Evaluation

Sample conversion to B747 gear type

(2D since procedure only uses one gear of the 2D/2D2 configuration)

Airplane	Gear Type	Annual Traffic Cycles (TC)	Conversion Factor	Equivalent (2D) TC
727-200	D	400	0.64	256
737-300	D	6,000	0.64	3,840
A319-100	D	1,200	0.64	768
747-400	2D/2D2	3,000	1.0	3,000
767-200ER	2D	2,000	1.0	2,000
DC8-63	2D	800	1.0	800
A300-B4	2D	1,500	1.0	1,500
777-200	3D	300	1.56	468
		15,200		12,632

ACN-PCN – Technical Evaluation

Equivalent Traffic Cycle conversion

$$\text{Log}\, R_1 = \text{Log}\, R_2 \times \sqrt{\frac{W_2}{W_1}}$$

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

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

ACN-PCN – Technical Evaluation

Spreadsheet for calculation of equivalent traffic

clear all data

ANNUAL DEPARTURE CONVERSION TO DESIGN AIRCRAFT ANNUAL DEPARTURES

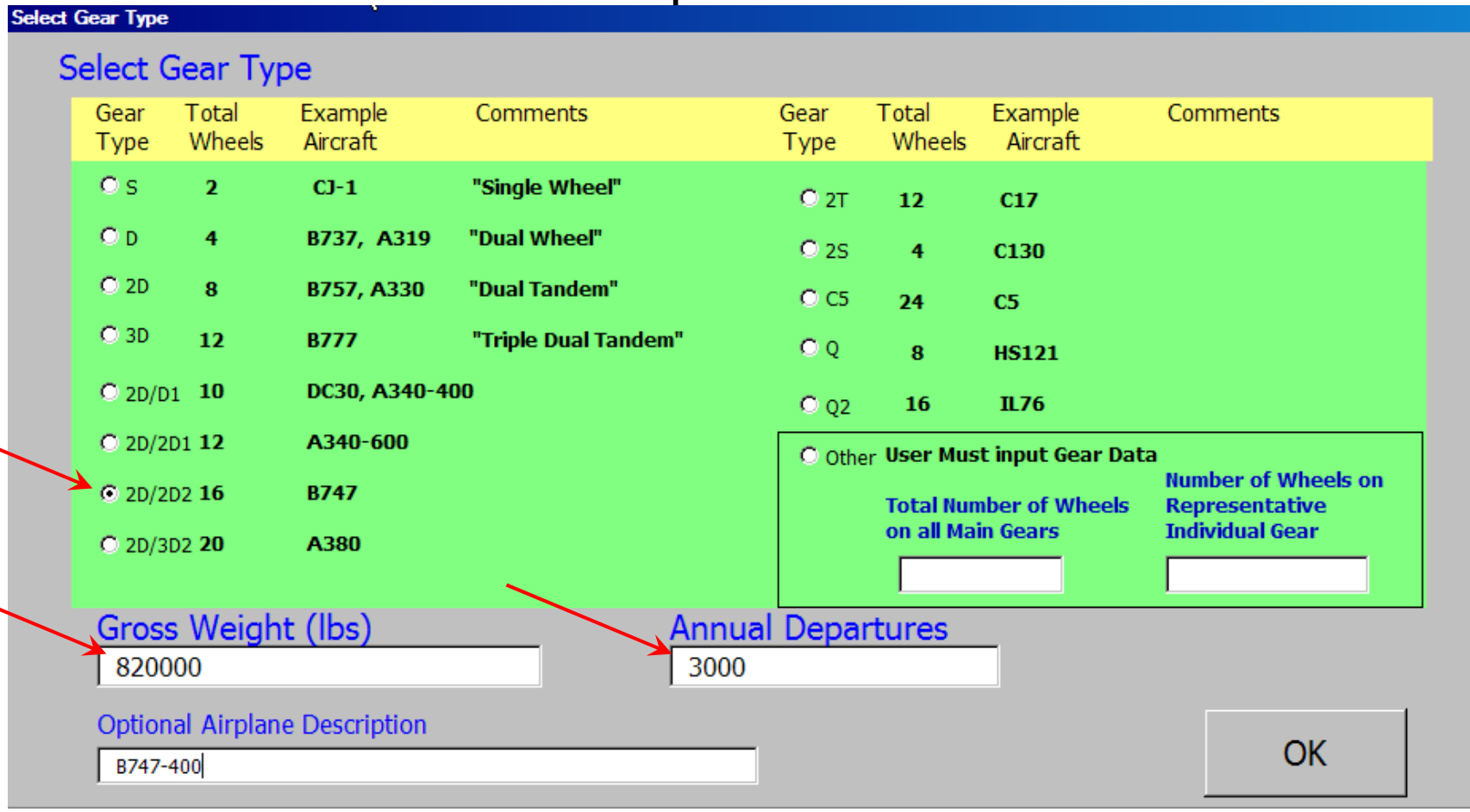
(following procedure specified in AC 150/5335-5A i.e. Direct wheel load calculations for each aircraft)

This procedure is NOT the same as the procedure specified in AC 150/5320-6D and will produce different results

		INPUT VALUES							CALCULATED VALUES				
		Optional information for Aircraft	Gear Type (code)	Max Takeoff weight MTOW	Annual Departures	Total Wheels on Main Gears	Wheels on Representative Gear		Gear Factor	Departures of equiv gear	Computed wheel Load of aircraft	Equiv. annual departures of design Aircraft	NOTES
Design Aircraft	Design Aircraft	B747-400	2D/2D2	820000	3,000	16	4			3,000	48,688	3,000.00	
Additional Aircraft	Aircraft 1	B727-200	D	185,000	400	4	2		0.64	256	43,938	194	
	Aircraft 2	B737-300	D	130000	6,000	4	2		0.64	3,840	30,875	716	
	Aircraft 3	A319-100	D	145,000	1,200	4	2		0.64	768	34,438	268	
	Aircraft 4	B767-300ER	2D	370,000	2,000	8	4		1	2,000	43,938	1,368	
	Aircraft 5	DC8-63	2D	330,000	800	8	4		1	800	39,188	403	
	Aircraft 6	A300-B4	2D	370,000	1,500	8	4		1	1,500	43,938	1,041	
	Aircraft 7	B777-200	3D	600,000	300	12	6		1.56	468	47,500	434	
	Aircraft 8											0	
	Aircraft 9											0	
	Aircraft 23											0	
	Aircraft 24											0	
	Aircraft 25											0	
			Equivalent Annual Departures of the B747-400									7,424	

ACN-PCN – Technical Evaluation

Spreadsheet for calculation of equivalent traffic



ACN-PCN – Technical Evaluation

4) Determine allowable operating weight of critical airplane

Using COMFAA

- In pavement thickness mode,
- Enter the critical airplane at the equivalent departure level
- Iterate to the known pavement thickness by changing the airplane weight

ACN-PCN – Technical Evaluation

Determine the maximum gross weight permitted on the known pavement section for the “critical” airplane.

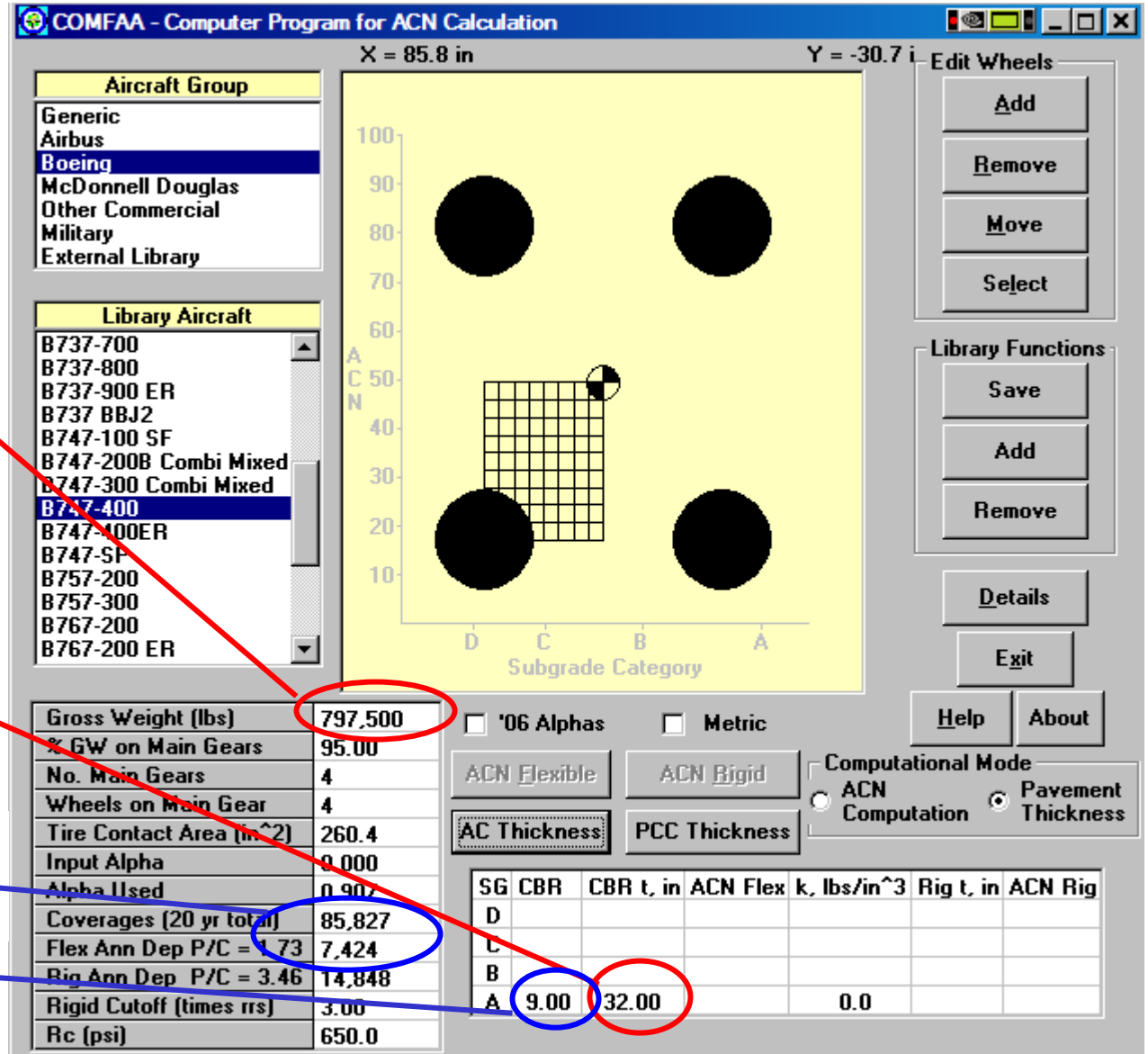
Critical airplane	747-400
Known pavement thickness	32.0 inches
Subgrade CBR	9.0 (Code *B*)
Tire pressure	200 psi (Code *X*)
Percent Weight on the main gear	95.0 %
P/C ratio	1.73
Pavement life	20 years
Annual equivalent departures (TC)	7,424
Total Coverages (TC/1.73) x 20	85,827

ACN-PCN – Technical Evaluation

In pavement thickness mode

Iterate to find allowable weigh which produces the know pavement thickness

Enter total coverage or departure level and CBR



ACN-PCN – Technical Evaluation

4) Determine ACN of critical airplane at allowable weight

Using COMFAA

- In ACN Computation mode,
- Enter the critical airplane at the allowable operation weight

  Note that coverages defaults to 10,000 per ICAO procedure
- Calculate ACN

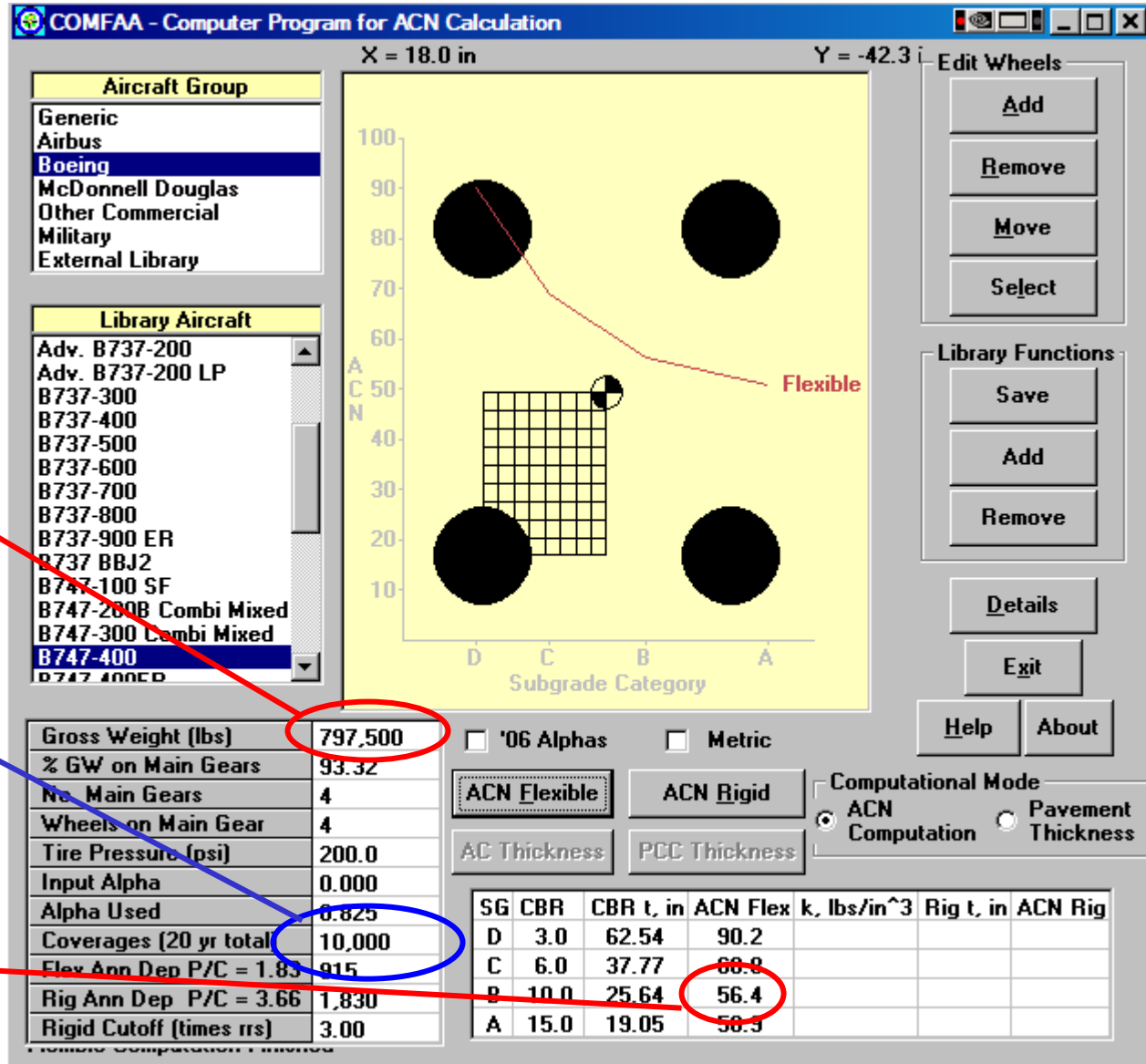
ACN-PCN – Technical Evaluation

In ACN Computation mode

Enter allowable operating weight

coverage will default to 10,000

Read ACN for desired subgrade category



ACN-PCN – Technical Evaluation

Using the previous parameters, the B747 could operate at 797,500 lbs

From COMFAA, determine ACN values at this weight.

= 56/F/B/X/T

This evaluation would suggest minor restriction of 2 airplanes with ACN's over the PCN value

ACN-PCN – Using Technical Method

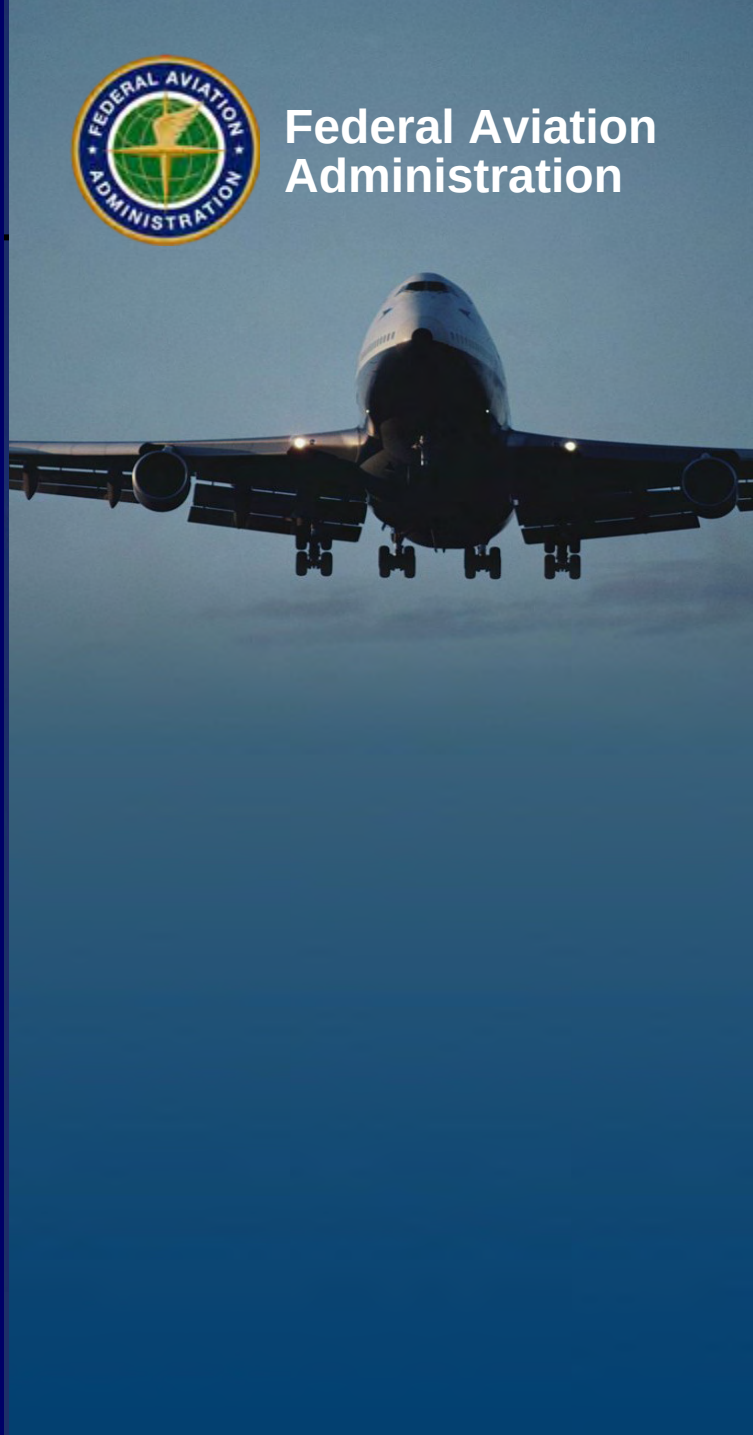
Using Technical Method of PCN (flexible example)

PCN = 56/F/B/X/T

Airplane	Operating Weight, lbs	Tire Pressure (psi)	% GW Main Gear For ACN	ACN F/B	Annual Departures
B727-200	185,000	148	96.00	48	400
B737-300	130,000	195	90.86	32	6,000
A319-100	145,000	196	92.60	34	1,200
B747-400	820,000	200	93.32	59	3,000
B767-300ER	370,000	190	92.40	50	2,000
DC8-63	330,000	194	96.12	53	800
A300-B4	370,000	205	94.00	57	1,500
B777-200	600,000	215	95.42	52	300

Questions or Comments?

ACN-PCN System
AC 150/5335-5A



Federal Aviation Administration

Presentation to: Great Lakes Region – Airports Conference

Name: Rodney Joel - Airport Engineering Division

Date: November, 2008

Annex 14 to the Convention on International Civil Aviation

INTERNATIONAL STANDARDS
AND RECOMMENDED PRACTICES

AERODROMES

ANNEX 14

TO THE CONVENTION ON INTERNATIONAL CIVIL AVIATION

VOLUME I
AERODROME DESIGN AND OPERATIONS

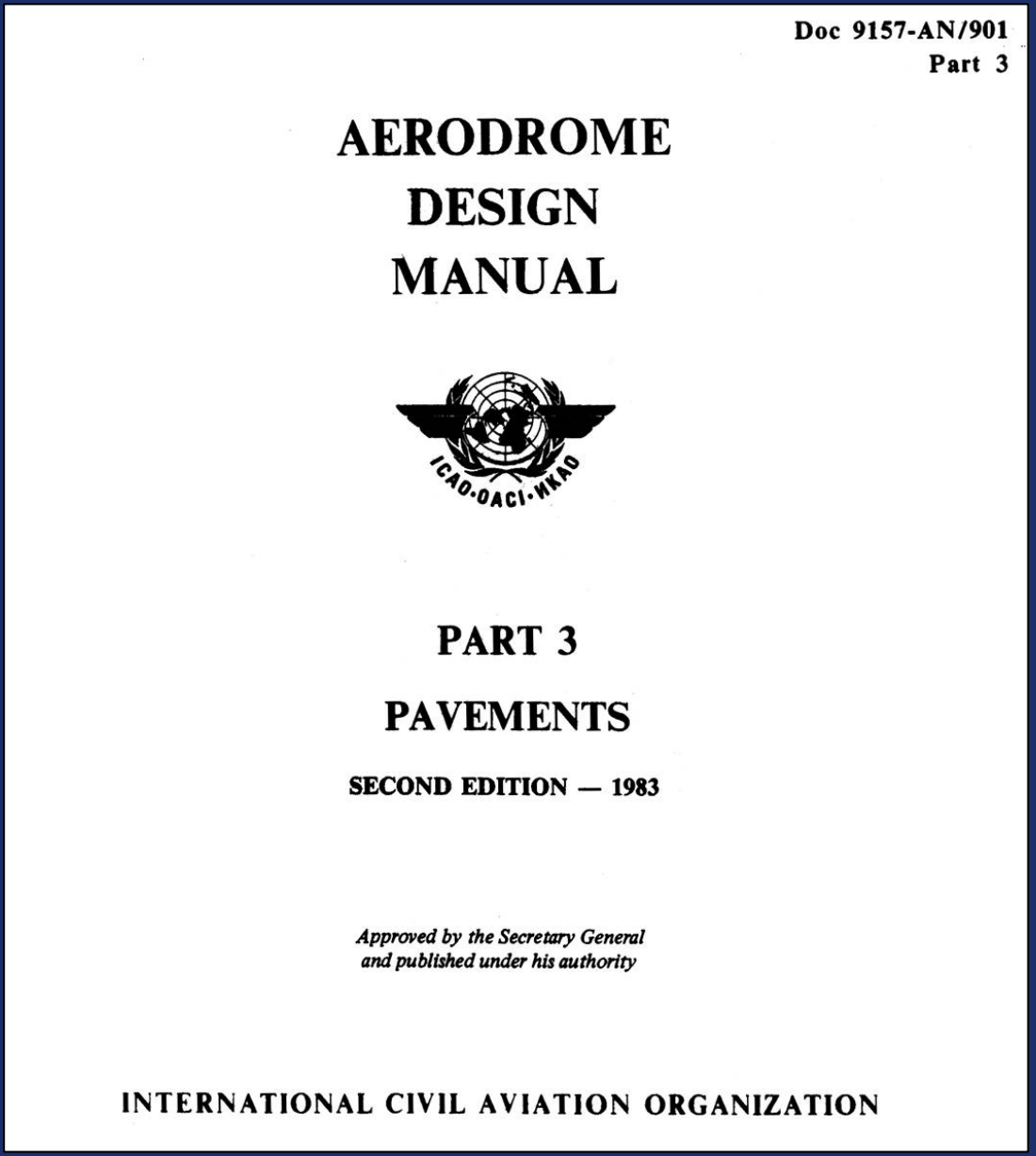
THIRD EDITION — JULY 1999

This edition incorporates all amendments to Annex 14, Volume I, adopted by the Council prior to 6 March 1999 and supersedes on 4 November 1999 all previous editions of Annex 14, Volume I.

For information regarding the applicability of the Standards and Recommended Practices, *see* Chapter 1, 1.2 and Foreword.

INTERNATIONAL CIVIL AVIATION ORGANIZATION

ICAO Aerodrome Design Manual Part 3 – Pavements



Doc 9157-AN/901
Part 3

AERODROME
DESIGN
MANUAL

PART 3

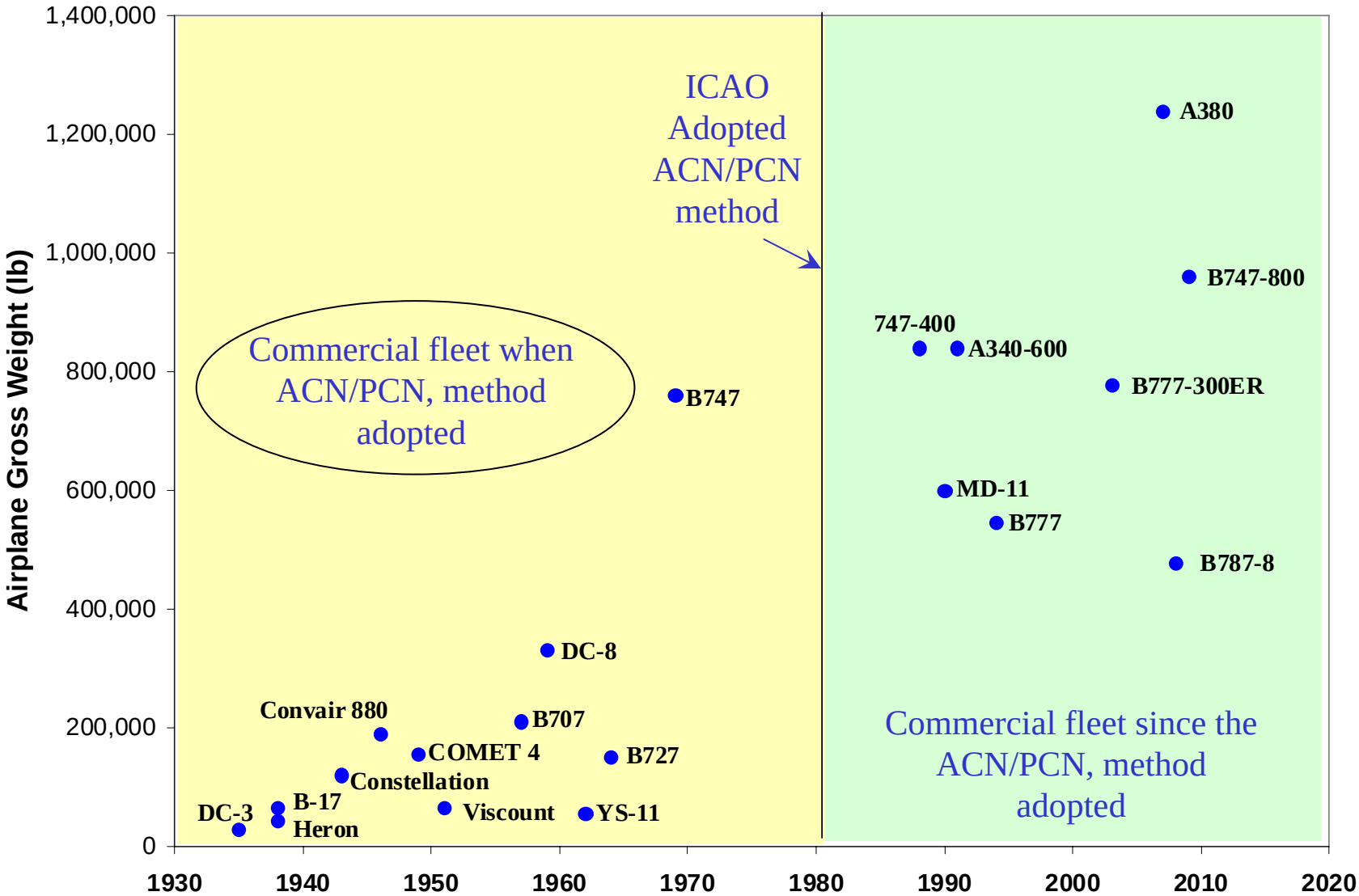
PAVEMENTS

SECOND EDITION — 1983

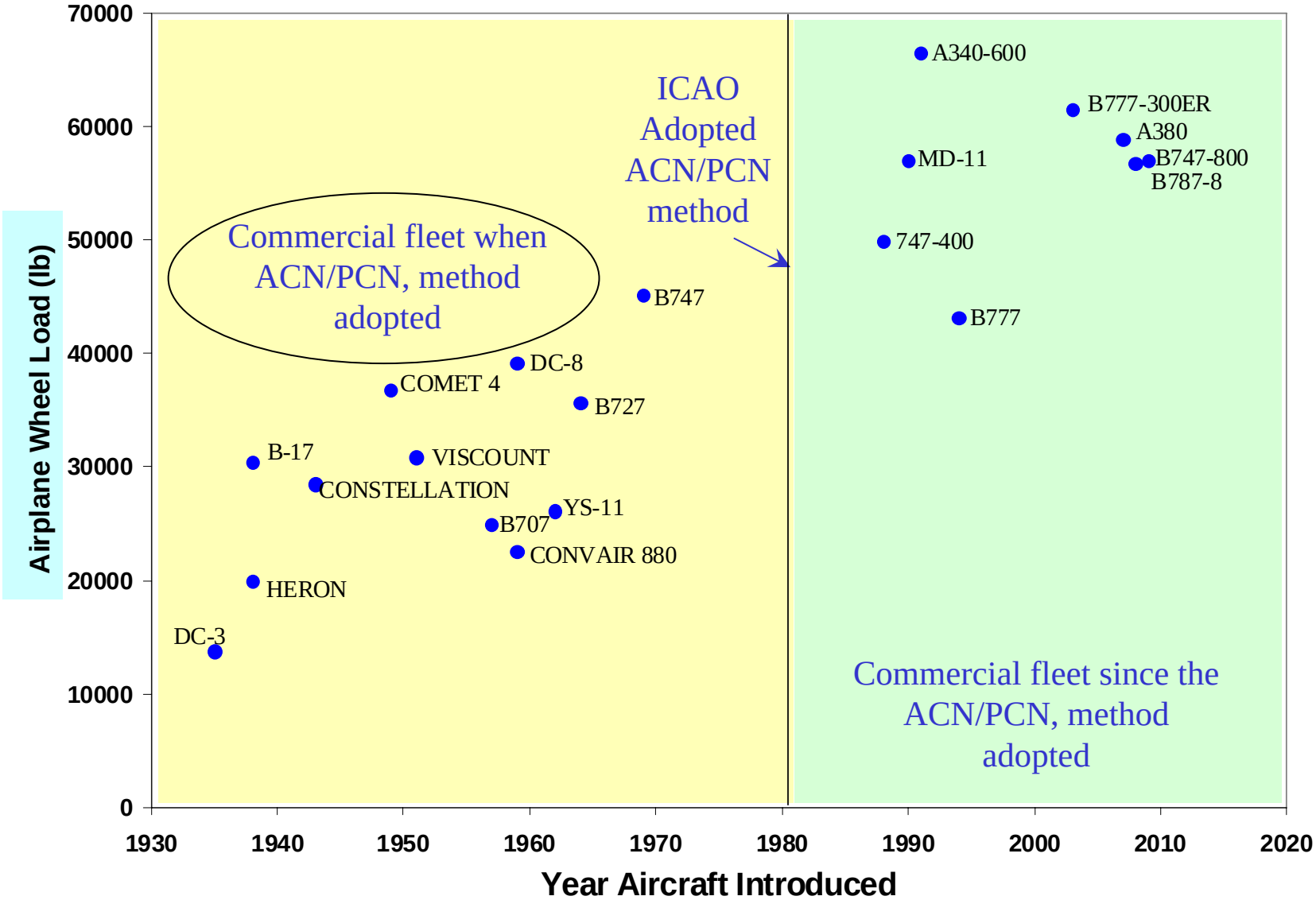
Approved by the Secretary General and published under his authority

INTERNATIONAL CIVIL AVIATION ORGANIZATION

ACN-Aircraft Timeline (Gross Wt)



ACN-Aircraft Timeline (Wheel load)



FAA Guidance on ACN-PCN

AC 150/5335-5A

STANDARDIZED METHOD OF REPORTING AIRPORT PAVEMENT STRENGTH – PCN

Revised September, 2006

2005 - PCN field re-activated in 5010 Database

ACN/PCN Definitions

- ACN

  "A number expressing the relative effect of an aircraft on a pavement for a specified standard subgrade strength."

- PCN

  "A number expressing the bearing strength of a pavement for unrestricted operations."

Aerodrome Design Manual, Part 3 Pavements, Chapter 1

ACN/PCN System - Concept

A pavement with a given PCN can support without weight restriction, an airplane with an ACN rating equal to or less than the pavement PCN value.

ACN/PCN System

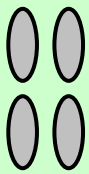
- Why not use allowable “Gear” load?

- Pavement thickness design requires not only the load magnitude but also the frequency of application. Therefore if an allowable gear load is reported, some knowledge about the frequency of load application is necessary for proper implementation.
  - For airport pavement applications we use the term “annual departures” to discuss frequency

ACN/PCN System

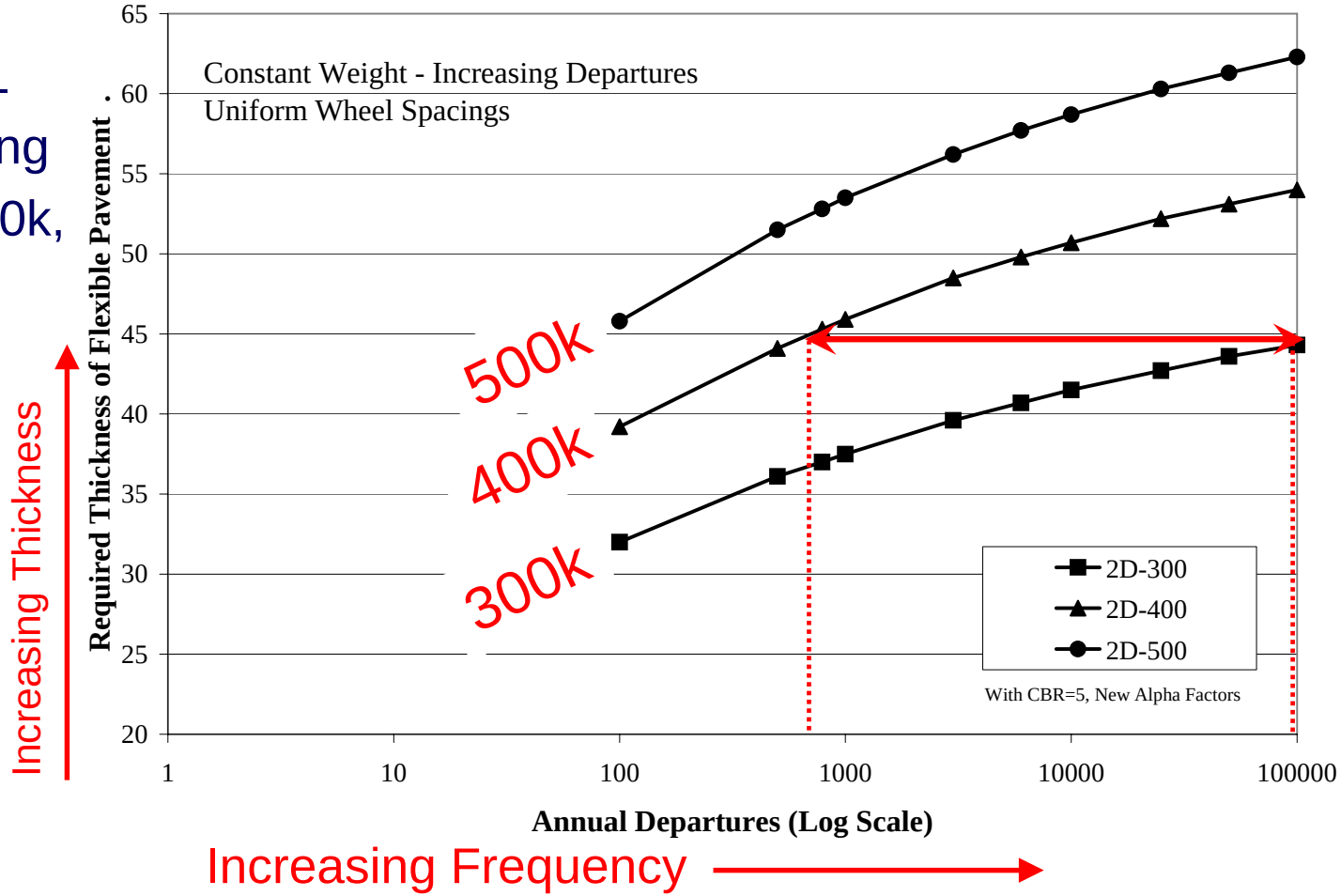
2D landing gear – fixed wheel spacing

Weights 300k, 400k, & 500k



2 Duals in Tandem

2D

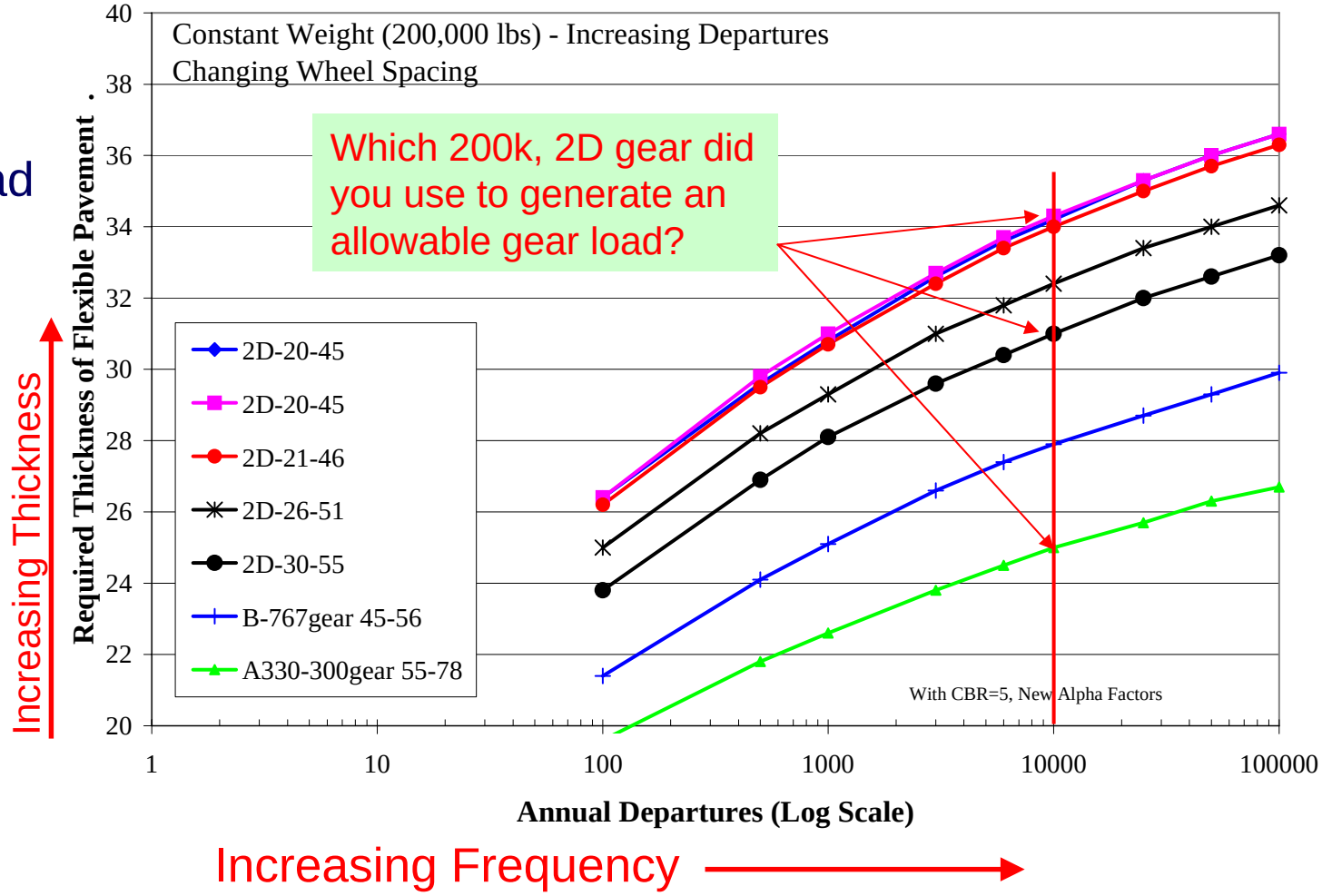


ACN/PCN System

2D landing gears

Constant gross load of 200,000 lbs

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



ACN/PCN System - Concept

ACN – PCN procedure standardizes the frequency issue by making calculations of ACN/PCN at 10,000 coverages

(Due to airplane wander, It takes more than one pass of an airplane to equal a full coverage)

ACN-PCN Application

- Applies only to pavements with bearing strengths of 12,500 pounds (5,700 kg) or greater.

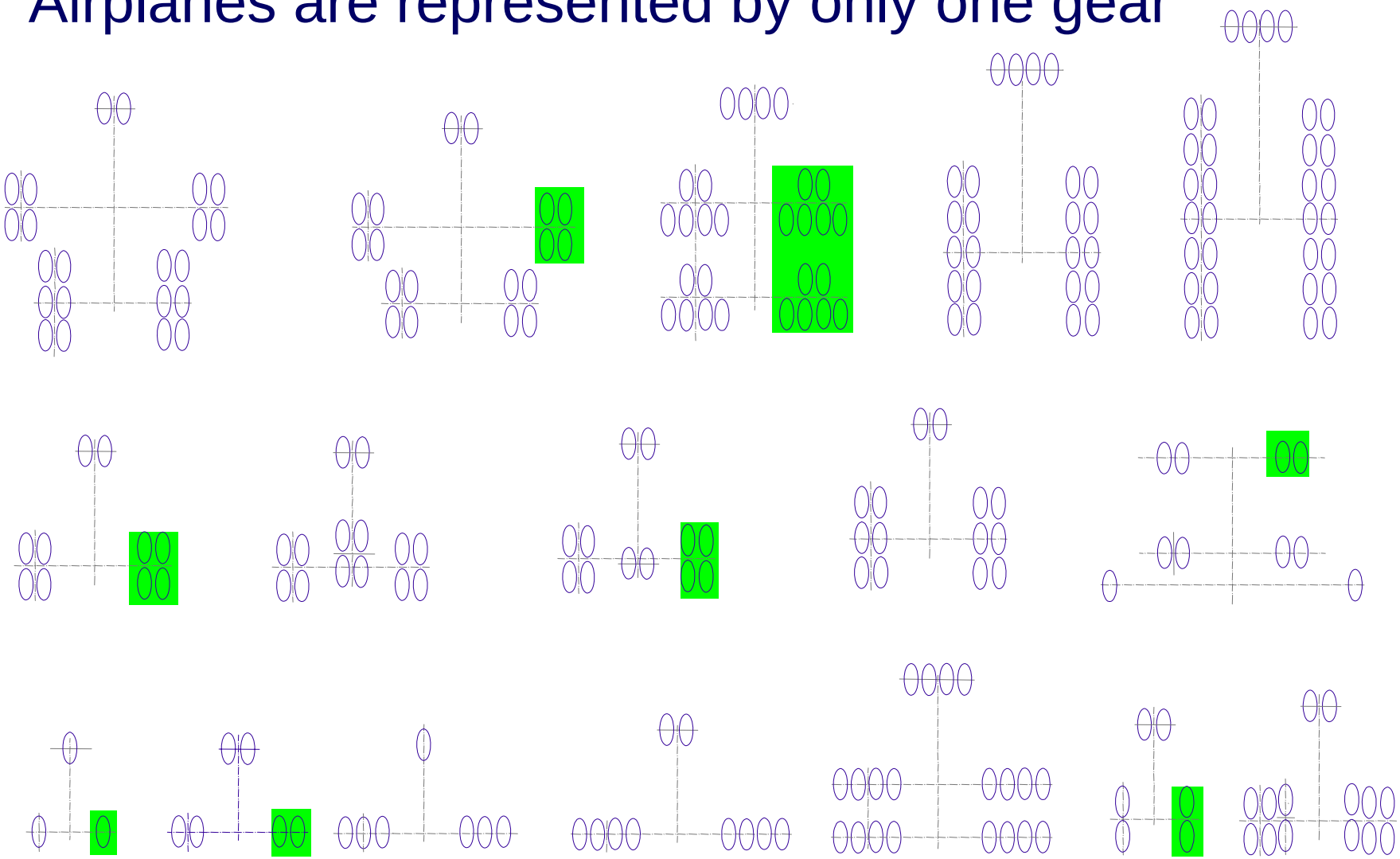
- The method of reporting pavement bearing strength for pavements of less than 12,500 pounds (5,700 kg) remains unchanged.

ACN/PCN System - Limitations

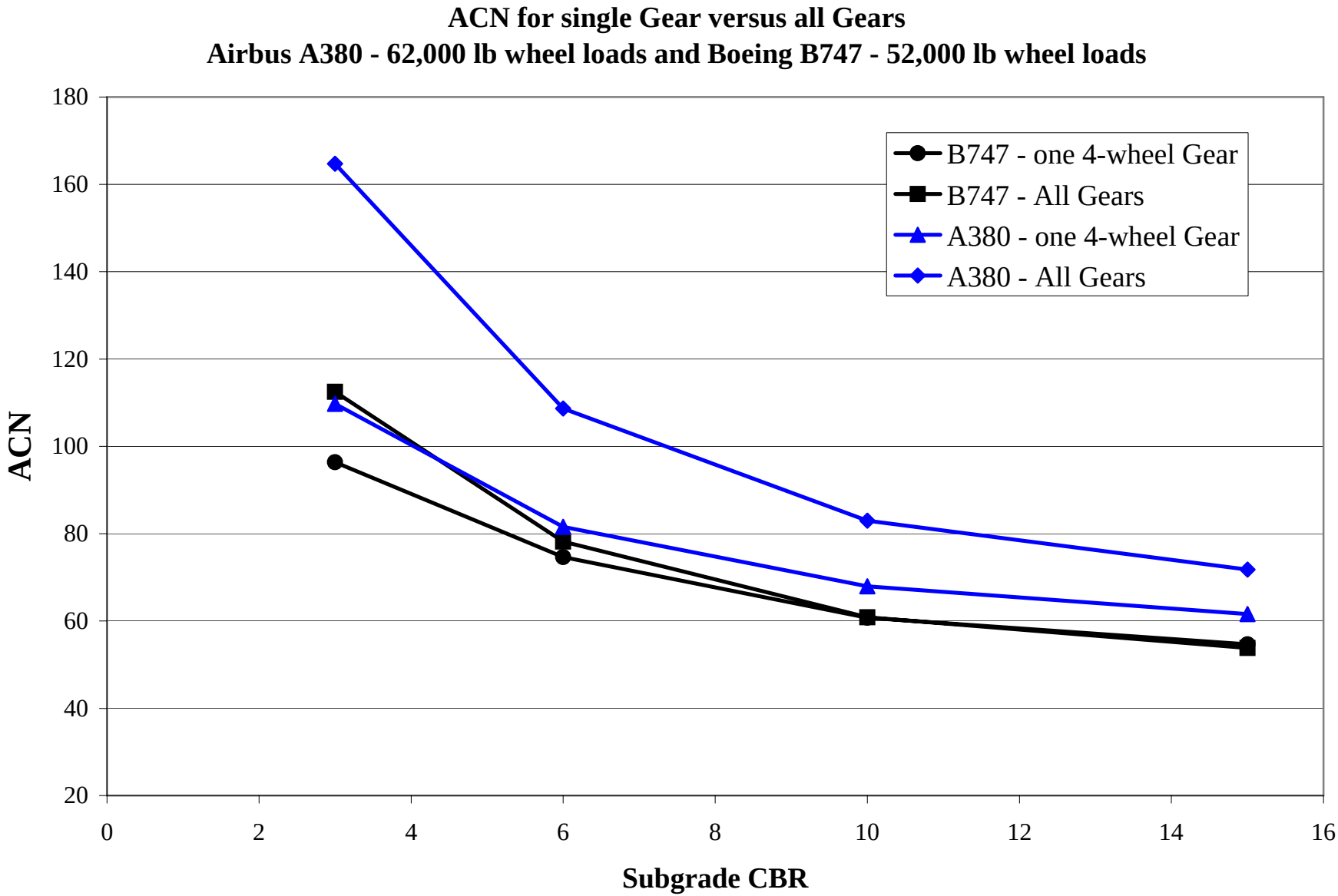
- Only intended as a method for airport operators to evaluate acceptable operations of airplanes
- It provides a load, or damage rating relative to a specified reference load.
- ACN is not a pavement design procedure.

ACN/PCN System - Limitations

Airplanes are represented by only one gear



ACN/PCN System –Flexible Pavement One Gear versus All Gears (06 alphas)



ACN/PCN System – Rigid Pavement

- Westergaard solution for loaded elastic plate on a Winkler foundation
- Interior load (PCA method)
- Concrete working stress = 2.75 MPa (399 psi)
- 4 Subgrade strengths

High (A)	=	150 MN/m^3 (554 pci)
Medium (B)	=	80 MN/m^3 (296 pci)
Low (C)	=	40 MN/m^3 (148 pci)
Ultra low (D)	=	20 MN/m^3 (74 pci)

ACN/PCN System –Flexible Pavement

- California Bearing Ratio (CBR) Method
- 4 Subgrade Strengths

High (A)	=	CBR 15
Medium (B)	=	CBR 10
Low (C)	=	CBR 6
Ultra low (D)	=	CBR 3

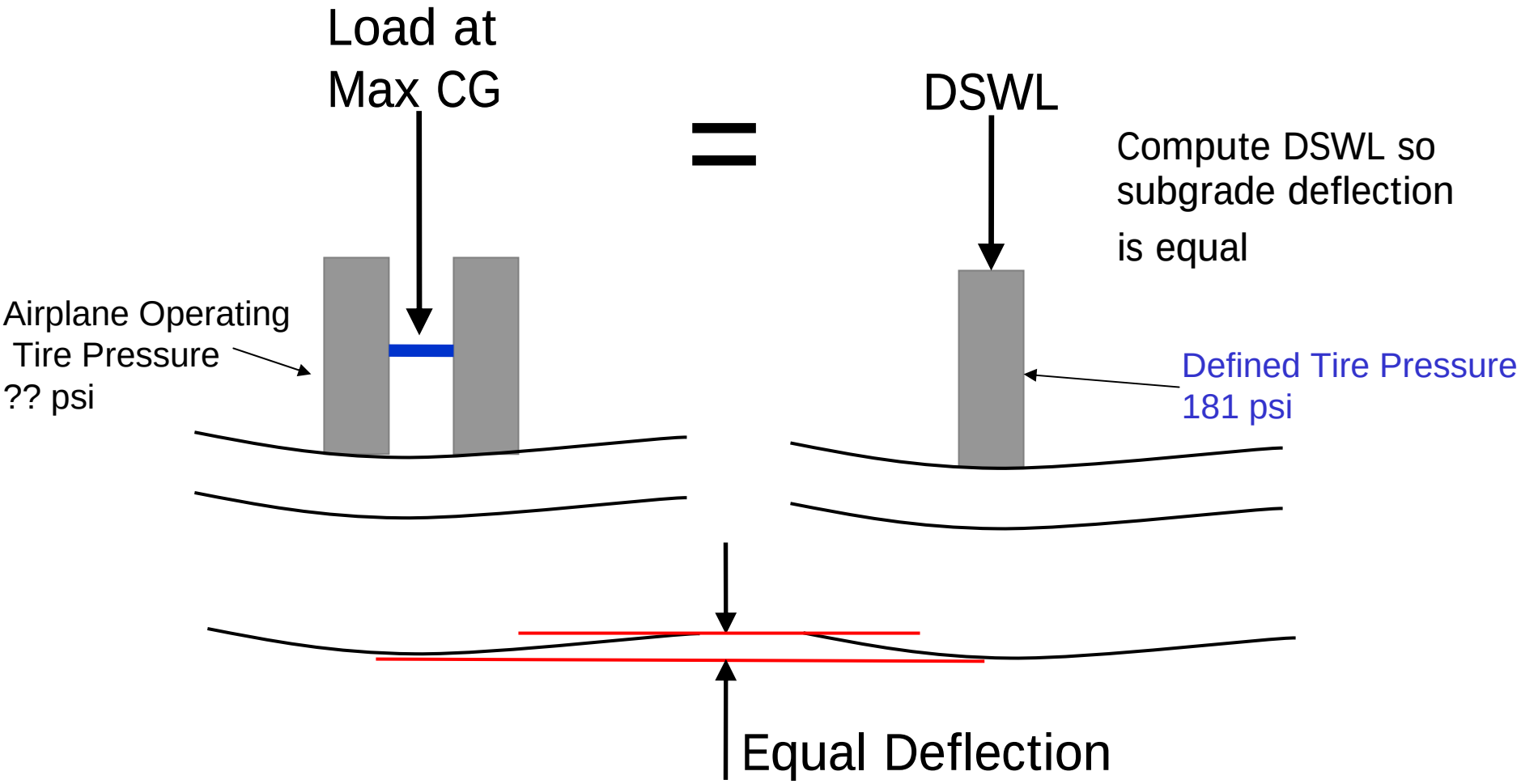
ACN/PCN System

- A Derived Single Wheel load (DSWL) at 1.25 MPa (181 psi) is computed for each subgrade.
  - Found by equating thickness for DSWL to design thickness for airplane gear

- ACN = DSWL in kilograms divided by 500

  Calculated at maximum main gear loading – i.e. maximum ramp weight and corresponding maximum center of gravity

Historic Flexible Design Parameter Derived Single Wheel Load (DSWL)



ACN/PCN System – Official ACN

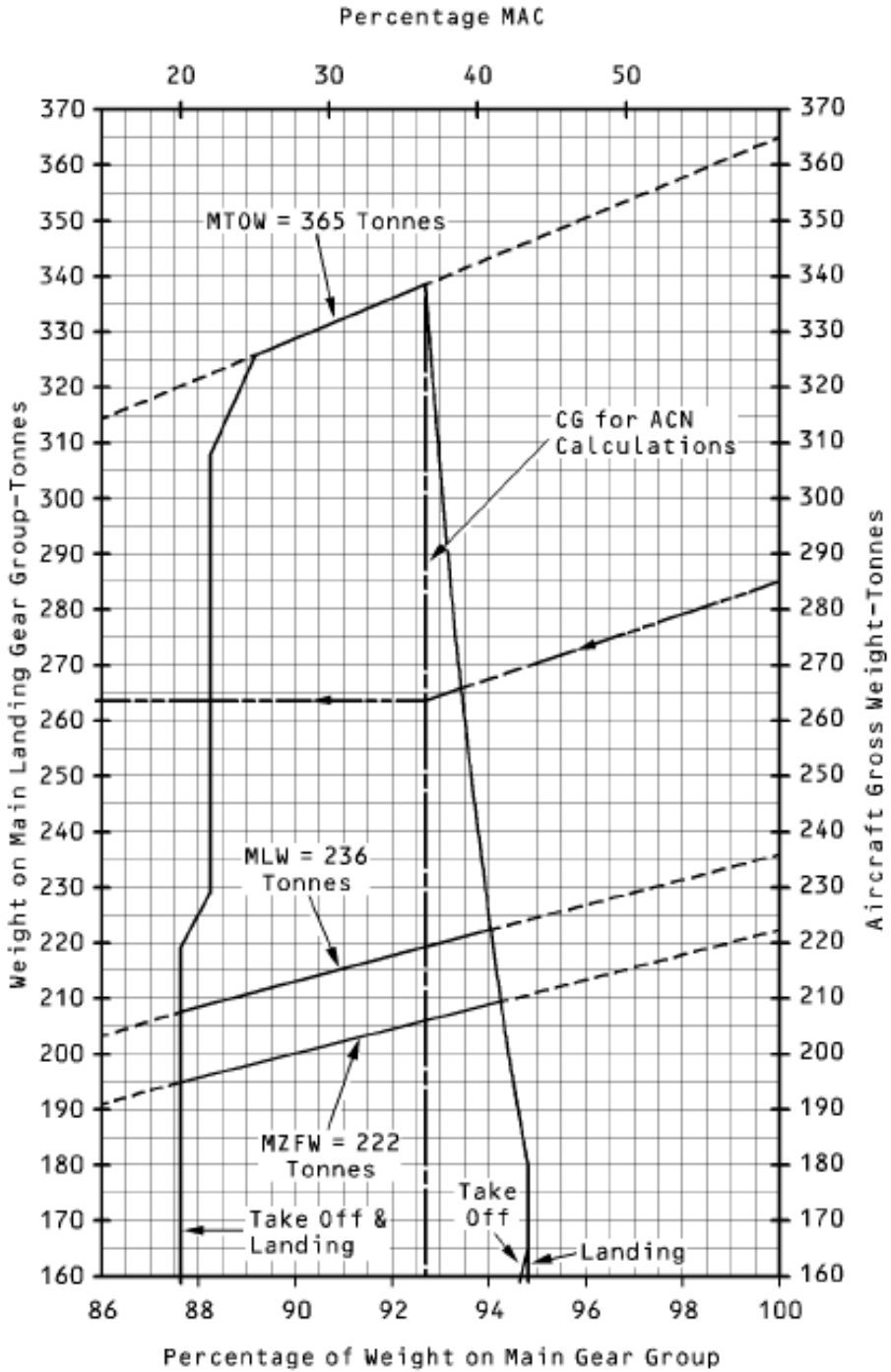
- Official ACN values are provided by the Aircraft Manufacturer

Airplane Characteristics for Airport Planning

ACN/PCN System

- Airplane Characteristics manual report official center of gravity and max gross load for ACN calculation.

- Tire pressure (used in ACN calculation) is also reported for standard configuration

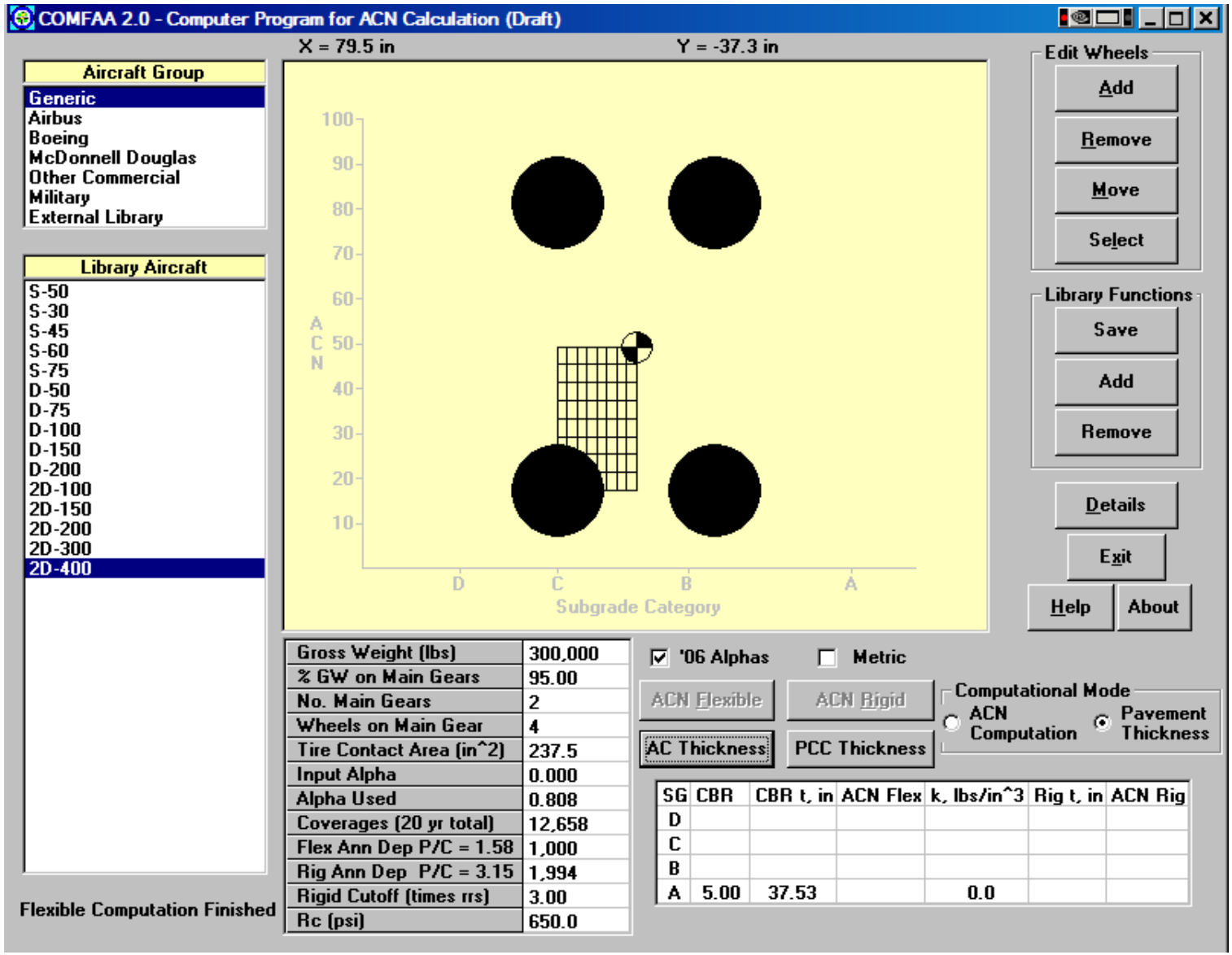


FAA Guidance on ACN-PCN

AC 150/5335-5A *STANDARDIZED METHOD OF REPORTING AIRPORT PAVEMENT STRENGTH – PCN*

- AC introduces the COMFAA program.
- COMFAA can be used to calculate ACN values for any airplanes.
- Manufacturer's have provided CG and max load data for ACN determination.

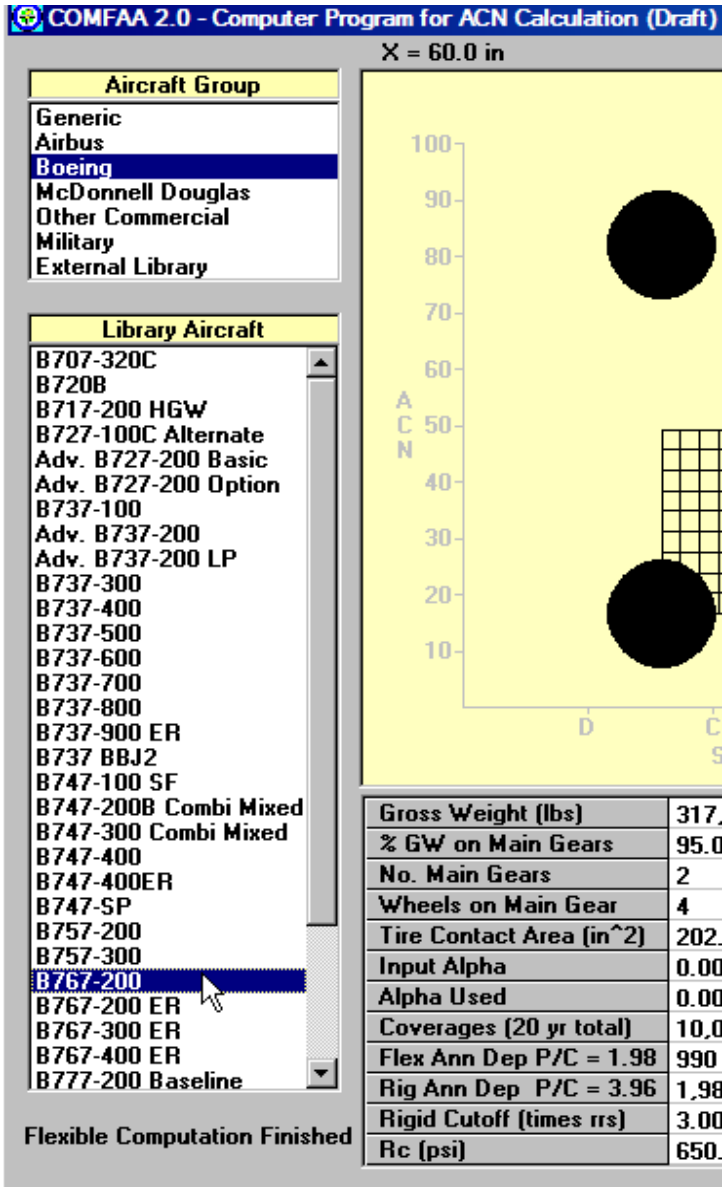
COMFAA 2.0 Program



COMFAA 2.0 Program

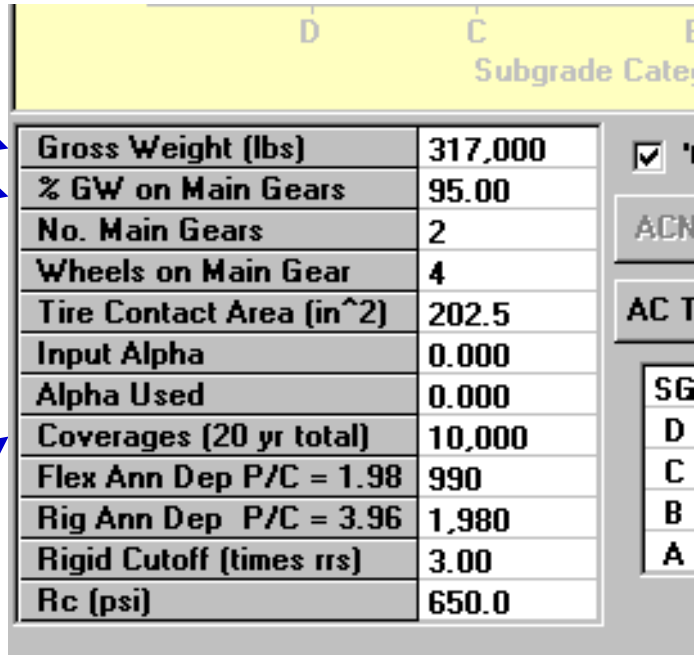
Select desired aircraft group

Select desired airplane



COMFAA 2.0 Program

The internal aircraft library in COMFAA contains the manufacturers data for ACN determination.



Coverages is set to 10,000 per ICAO procedure.

COMFAA 2.0 Program

ACN Flexible | ACN Rigid | AC Thickness | PCC Thickness

Computational Mode: ACN Computation / Pavement Thickness

SG	CBR	CBR t, in	ACN Flex	k, lbs/in^3	Rig t, in	ACN Rig
D	3.0	51.21	60.4	73.7	14.15	54.0
C	6.0	30.14	43.8	147.4	12.64	46.5
B	10.0	20.93	37.5	294.7	11.10	39.0
A	15.0	15.69	34.5	552.6	9.82	33.2

Flexible Rigid

In ACN Computation mode, ACN values are calculated for 4 standard subgrade conditions using the identified airplane data

ACN-PCN SYSTEM – PCN Values

- PCN values are reported in a coded format using 5 parts separated by "/"

  Sample 39/R/B/W/T

- Information includes
  - Numerical PCN Value
  - Pavement Type
  - Subgrade Category
  - Allowable Tire pressure
  - Method used to determine the PCN value

ACN-PCN SYSTEM

39/R/B/W/T

PCN Numerical value

- PCN Numerical value is a relative indication of the load carrying capacity of a pavement in terms of a standard single wheel load 181 psi (1.25 MPa)
- PCN value derived from the ACN value of the most demanding airplane.
- PCN values can be determined in two ways
  - Using Aircraft
  - Technical Evaluation

ACN-PCN SYSTEM

39/R/B/W/T

Pavement Type

- Pavement may be either Rigid (R) or Flexible (F)
  - Rigid – Single Stiff Layer to support and distribute load
  - Flexible – Multiple flexible layers to distribute load
- Composite pavements (overlays etc.) are reported as the type which most accurately reflects the structural action

ACN-PCN SYSTEM

39/R/B/W/T

Subgrade Category

Subgrade Strength Category	CODE	RIGID k-Value* pci (MN/m3)	FLEXIBLE CBR-Value
High	A	552.6 (150)	15
Medium	B	294.7 (80)	10
Low	C	147.4 (40)	6
Ultra Low	D	73.7 (20)	3

*Effective k-value

ACN-PCN SYSTEM

39/R/B/W/T

Allowable Tire Pressure

Category	Code	Tire Pressure Range
High	W	No pressure limit
Medium	X	Pressure limited to 218 psi (1.5 MPa)
Low	Y	Pressure limited to 145 psi (1.00 MPa)
Very Low	Z	Pressure limited to 73 psi (0.50 MPa)

Recent request to ICAO have proposed modifying this table to increase allowable tire pressures

ACN-PCN SYSTEM

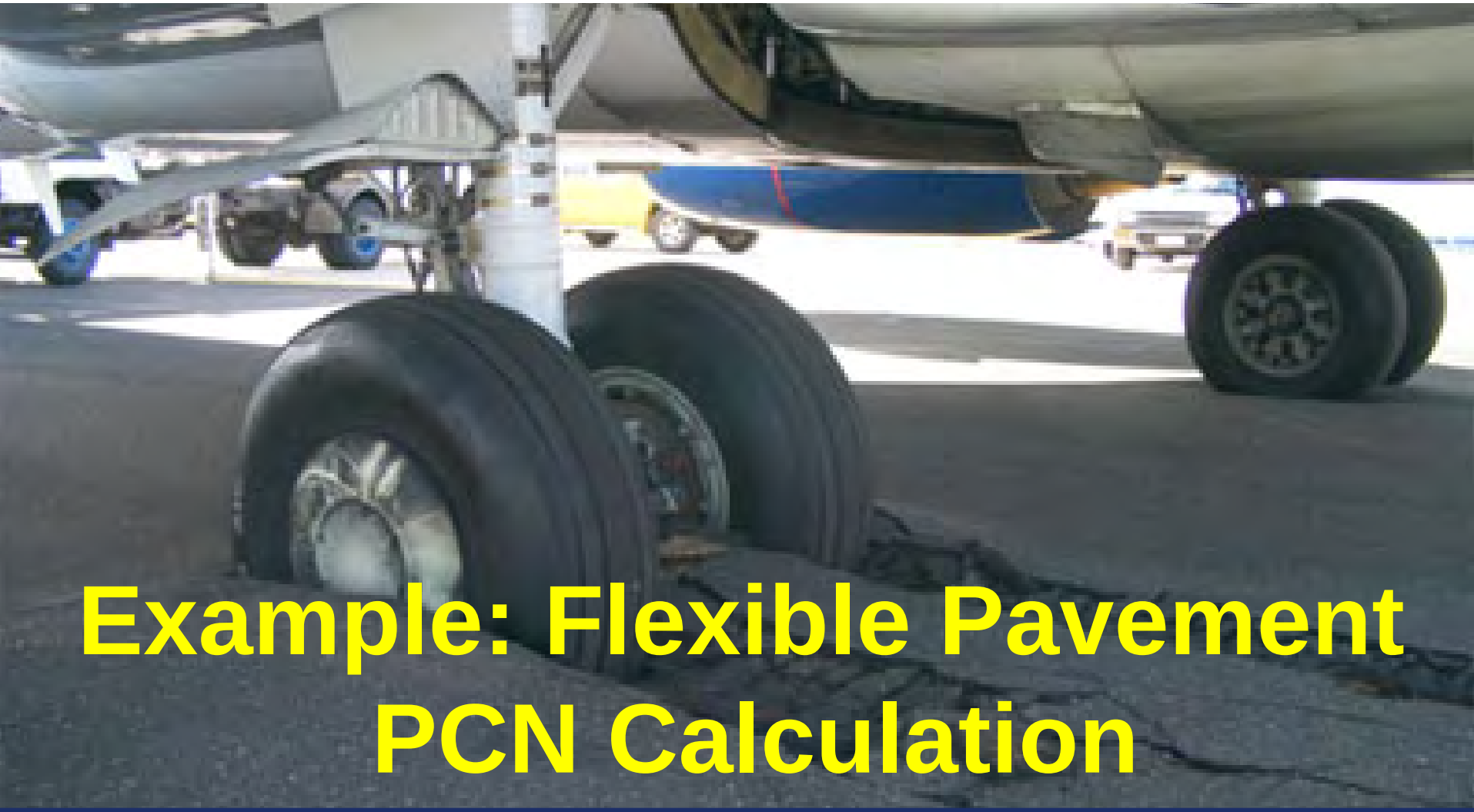
39/R/B/W/T

Method used to determine PCN

PCN values can be determined in two ways

- U =Using Aircraft
  - Simply select highest ACN from all airplanes using facility
- T = Technical Evaluation
  - PCN based on technical study of pavement structure and traffic data.

ACN-PCN – Technical Evaluation



Example: Flexible Pavement PCN Calculation

ACN-PCN – Technical Evaluation

Basic Steps to Determine Pavement Classification Number

1) Identify pavement features and properties
2) Determine traffic mixture
3) Convert traffic to equivalent traffic of “critical” airplane
4) Determine allowable operating weight of critical airplane
5) Determine ACN of critical airplane at allowable weight
6) Report PCN

ACN-PCN – Technical Evaluation

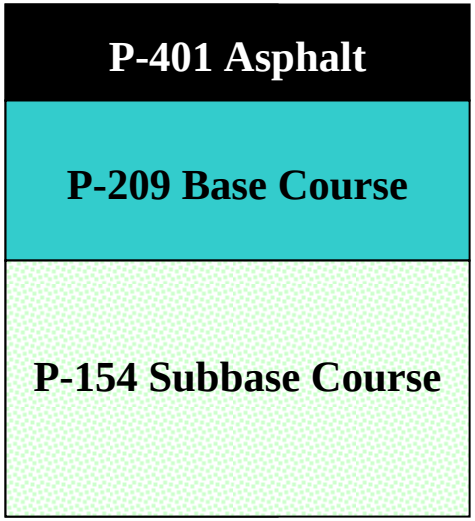
1) Identify pavement features and properties

The pavement must be referenced to a standard pavement section for evaluation purposes

Minimum required asphalt surface layer

Minimum required P-209 layer (CBR +80)

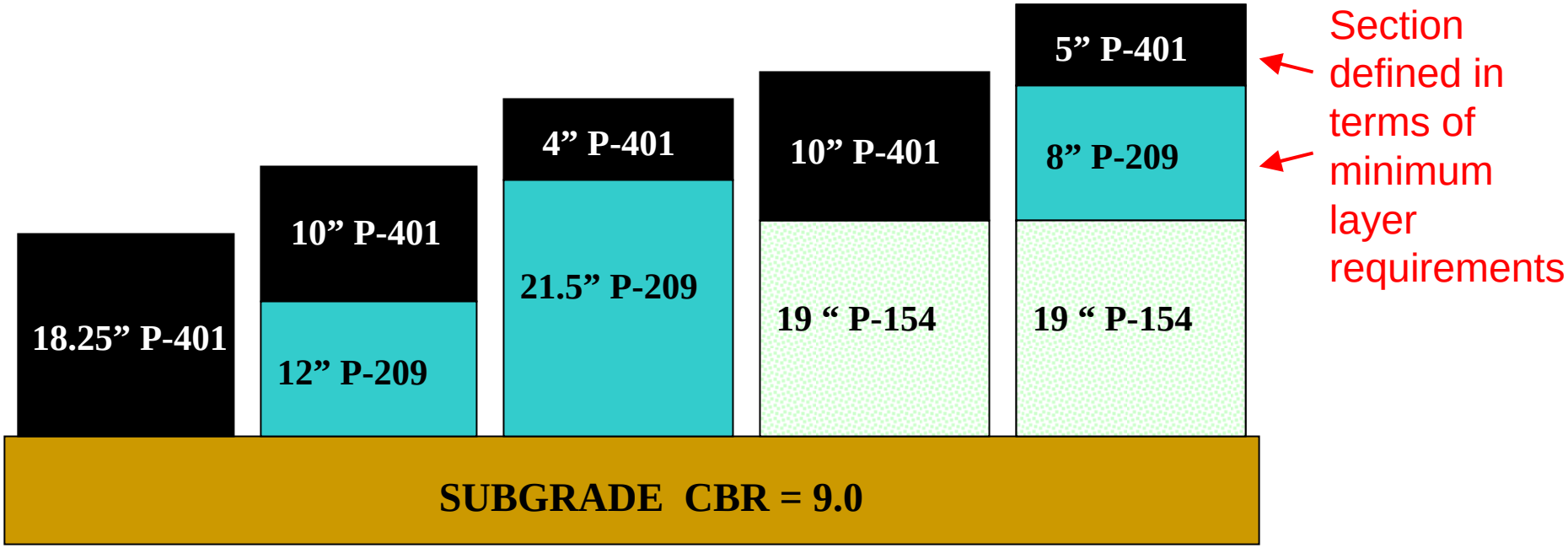
Variable P-154 layer (CBR +20)



Minimum requirements defined in AC 150/5320-6D

ACN-PCN – Technical Evaluation

For this example assume the following existing pavement structure (must express in terms of minimum layer requirements)



All sections are structurally equivalent to 32 inch pavement

ACN-PCN – Technical Evaluation

2) Determine Traffic Mixture

Identify the airplanes that have or plan to use the airport during the pavement design period

Include all significant traffic

- Non-scheduled events
- Charters
- Etc.

ACN-PCN – Technical Evaluation

For this example assume the following traffic mixture

Airplane	Operating Weight, (lbs)	Tire Pressure (psi)	Annual Departures
B727-200	185,000	148	400
B737-300	130,000	195	6,000
A319-100	145,000	196	1,200
B747-400	820,000	200	3,000
B767-300ER	370,000	190	2,000
DC8-63	330,000	194	800
A300-B4	370,000	217	1,500
B777-200	600,000	215	300

ACN-PCN – Technical Evaluation

3) Convert traffic to equivalent traffic of critical airplane

a) Determine traffic volume in terms of traffic cycles

b) Determine the pavement thickness necessary for each individual airplane

The airplane requiring the thickest pavement becomes the critical airplane

c) Traffic conversion performed in two stages

Equivalent departures based on gear type

Ratio of wheel loads

ACN-PCN - Coverages

Pavement design calculations require knowing how many times the pavement is fully loaded. One full load application is called a “Coverage”.

However, airplane operations are easily counted by how many times the airplane “passes” over a pavement

Because airplanes seldom travel along the exact same line of pavement, It may take many passes to fully load a unique point in the pavement

The ratio of Passes to Coverages (P/C) is used to convert counted passes to coverages. The ratio is unique for each airplane.

ACN-PCN - Coverages

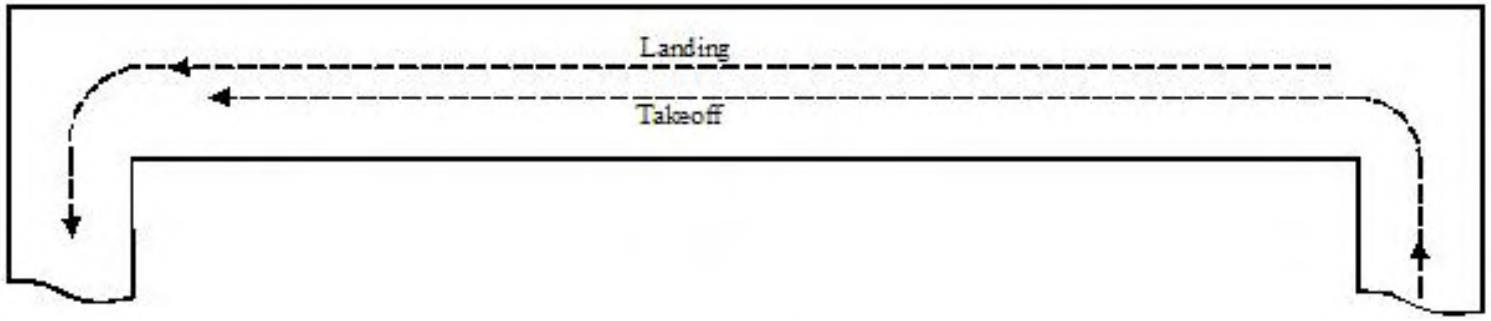
FAA pavement design procedures use “Annual Departures” as the traffic count for design purposes.

- Arrival traffic is ignored

-- One landing and takeoff = one Annual Departure

This may not be the best representation of the airport traffic depending upon airport operations

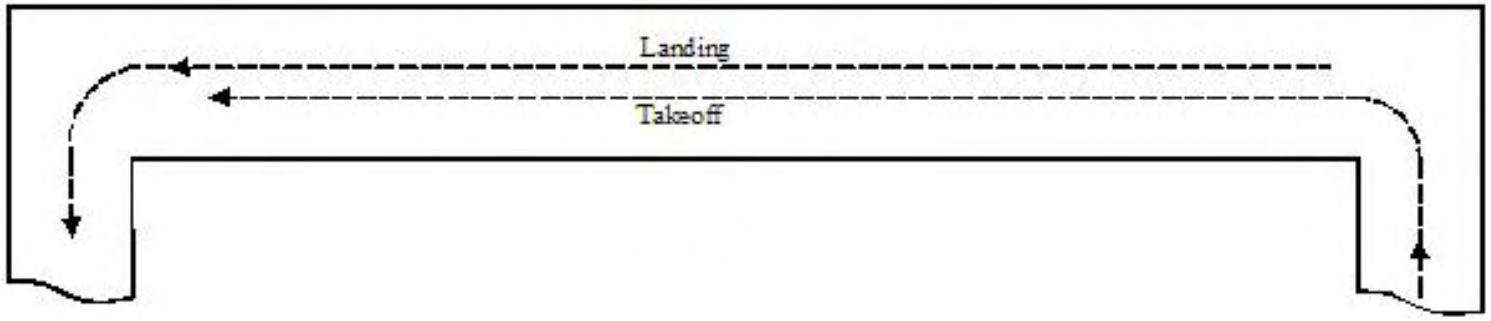
ACN-PCN - Coverages



Assumed procedure for FAA pavement design

- Airplane is refueled – arrival weight **<** departure weight
- Arrival traffic is ignored and only the departure is counted
- One plane will load the pavement ~ 1 time (P/TC = 1)
- Departures are converted to coverages by the Pass-to-coverage ratio (P/C)/(P/TC) or (P/C)/1

ACN-PCN - Coverages



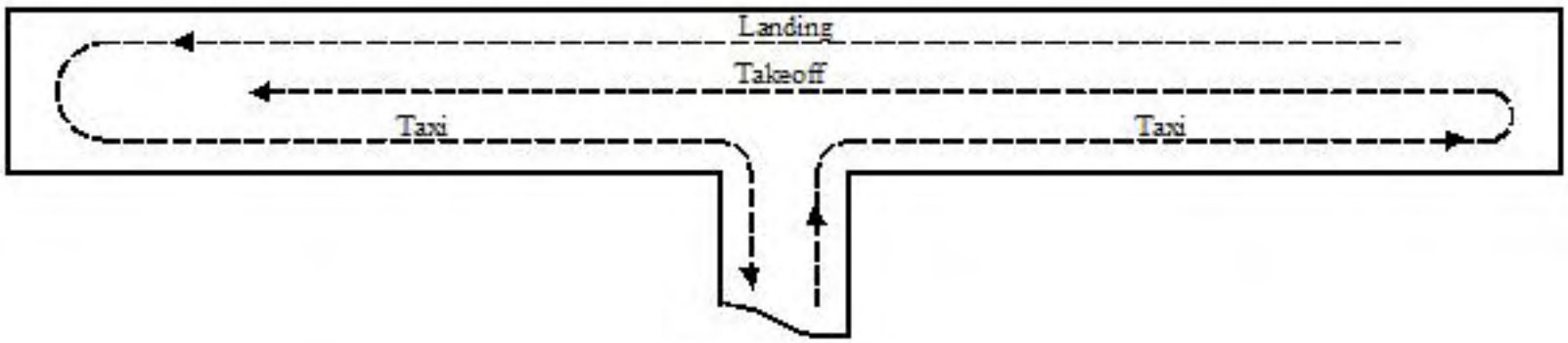
If the airplane is not refueled

Arrival weight ~= departure weight

One plane will load the pavement ~ 2 times (P/TC = 2)

Annual Departures are converted to coverages by the Pass-to-coverage ratio (P/C)/(P/TC) or (P/C)/2

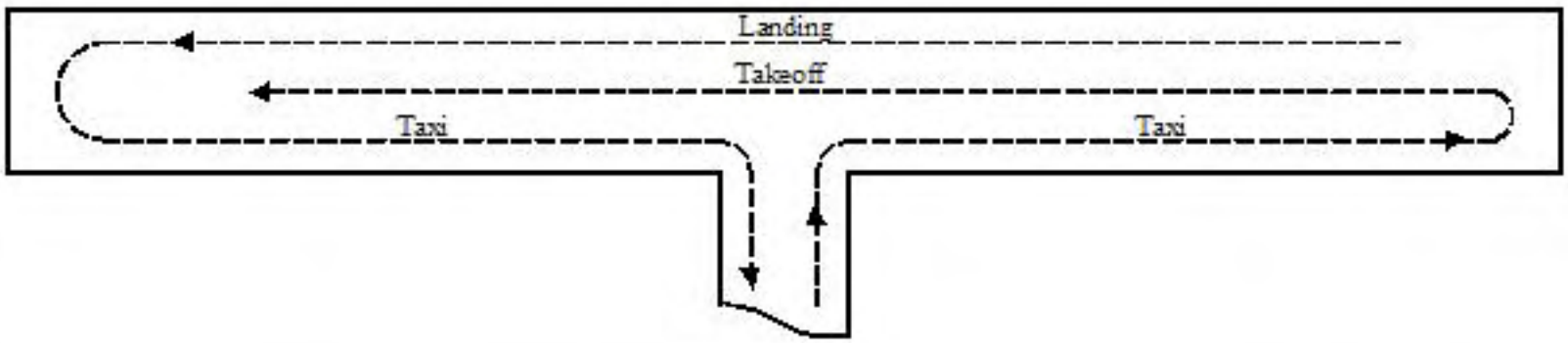
ACN-PCN - Coverages



Center entrance/exit - Airplane is refueled

- Arrival weight < departure weight
- Arrival is ignored
- One plane will load the pavement ~ 2 times (P/TC = 2)
- Annual Departures are converted to coverages by the Pass-to-coverage ratio (P/C)/(P/TC) or (P/C)/2

ACN-PCN - Coverages

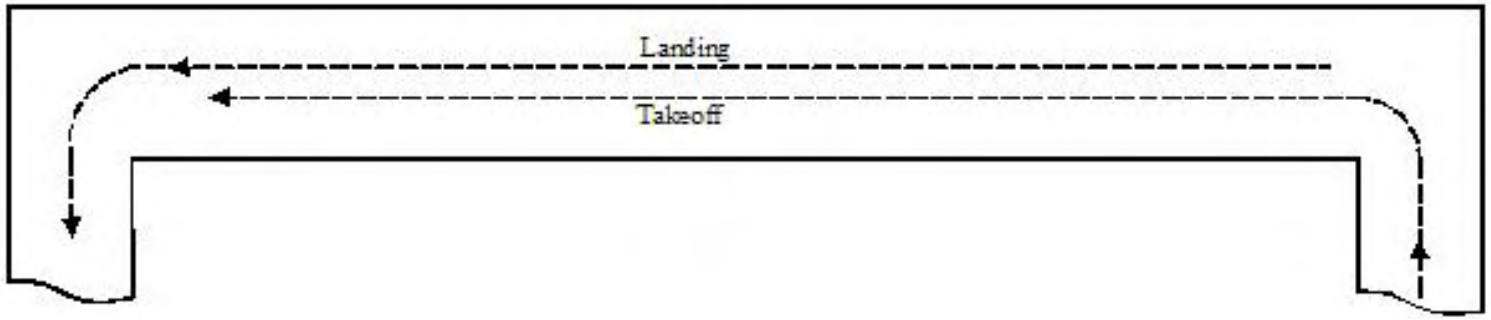


Center entrance/exit - Airplane is not refueled

- Arrival weight ~= departure weight
- One plane will load the pavement ~ 3 times (P/TC = 3)
- Annual Departures are converted to coverages by the Pass-to-coverage ratio (P/C)/(P/TC) or (P/C)/3

See AC 150/5335-5A for further details

ACN-PCN - Coverages



Design example

Annual Departures are converted to coverages by the Pass-to-coverage ratio (P/C)/1

Total coverages = {Ann. Departures/(P/C)/1} x 20 years

ACN-PCN System

For a technical evaluation, a most demanding or “critical” airplane must be determined

Using the current procedure identified in AC 150/5335-5A the airplane which requires the thickest pavement based on its own demand is considered the critical airplane

ACN-PCN – Technical Evaluation

Determine total thickness requirements for each Airplane in the traffic mixture

Airplane	Operating Weight, (lbs)	Tire Pressure (psi)	Annual Departures	Flexible P/C	20 year Total Coverages
B727-200	185,000	148	400	2.92	2,740
B737-300	130,000	195	6,000	3.79	31,662
A319-100	145,000	196	1,200	3.18	7,547
B747-400	820,000	200	3,000	1.73	34,682
B767-300ER	370,000	190	2,000	1.80	22,222
DC8-63	330,000	194	800	1.68	9,524
A300-B4	370,000	217	1,500	1.75	17,143
B777-200	600,000	215	300	1.42	4,225

ACN-PCN – Technical Evaluation

Determine total thickness requirements for each airplane

For example:

B747-400

3,000 Annual Departures

820,000 lbs Max gross operating weight

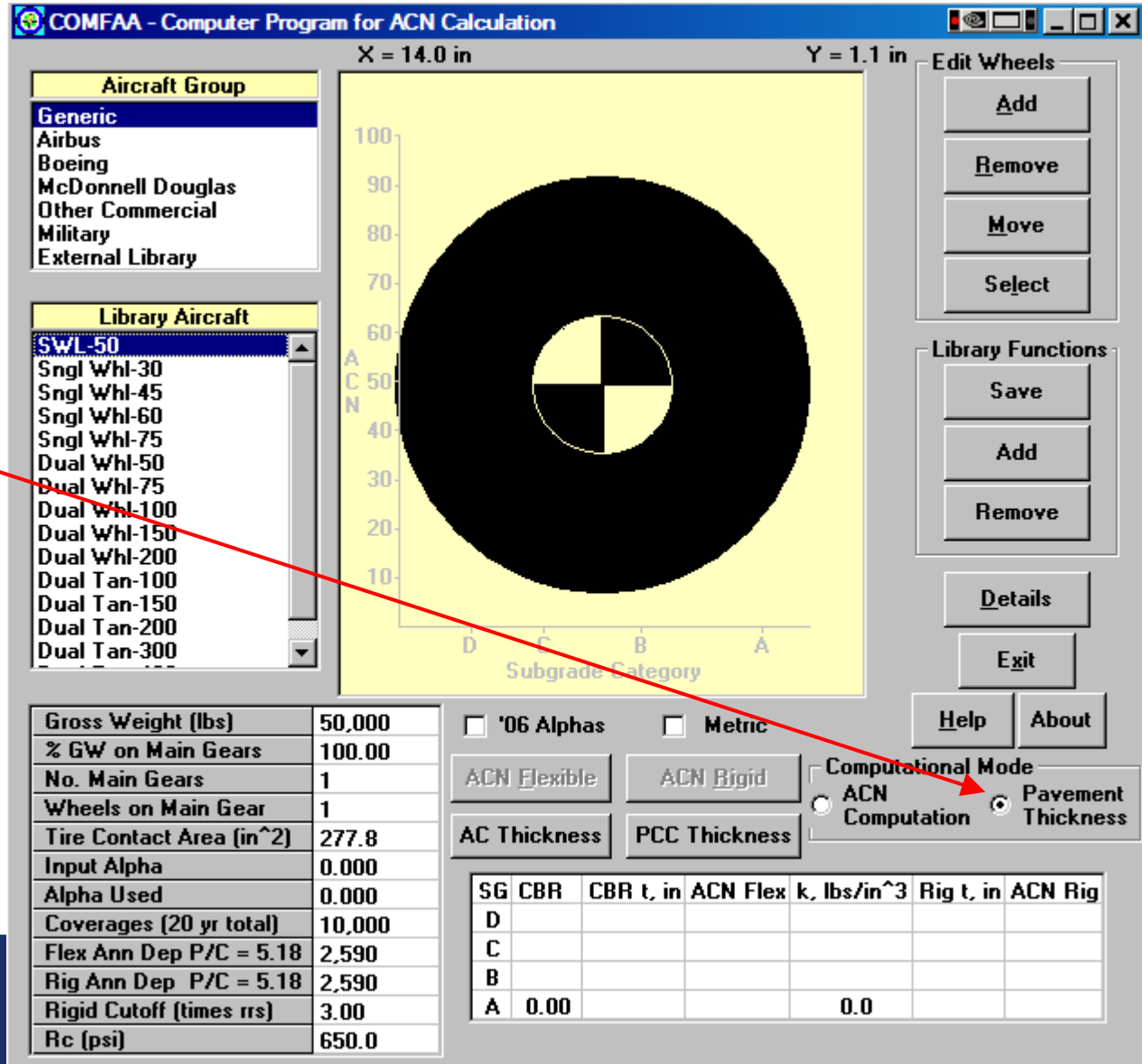
Subgrade CBR = 9.0

USE THE COMFAA PROGRAM

ACN-PCN – Technical Evaluation

Start the COMFAA program

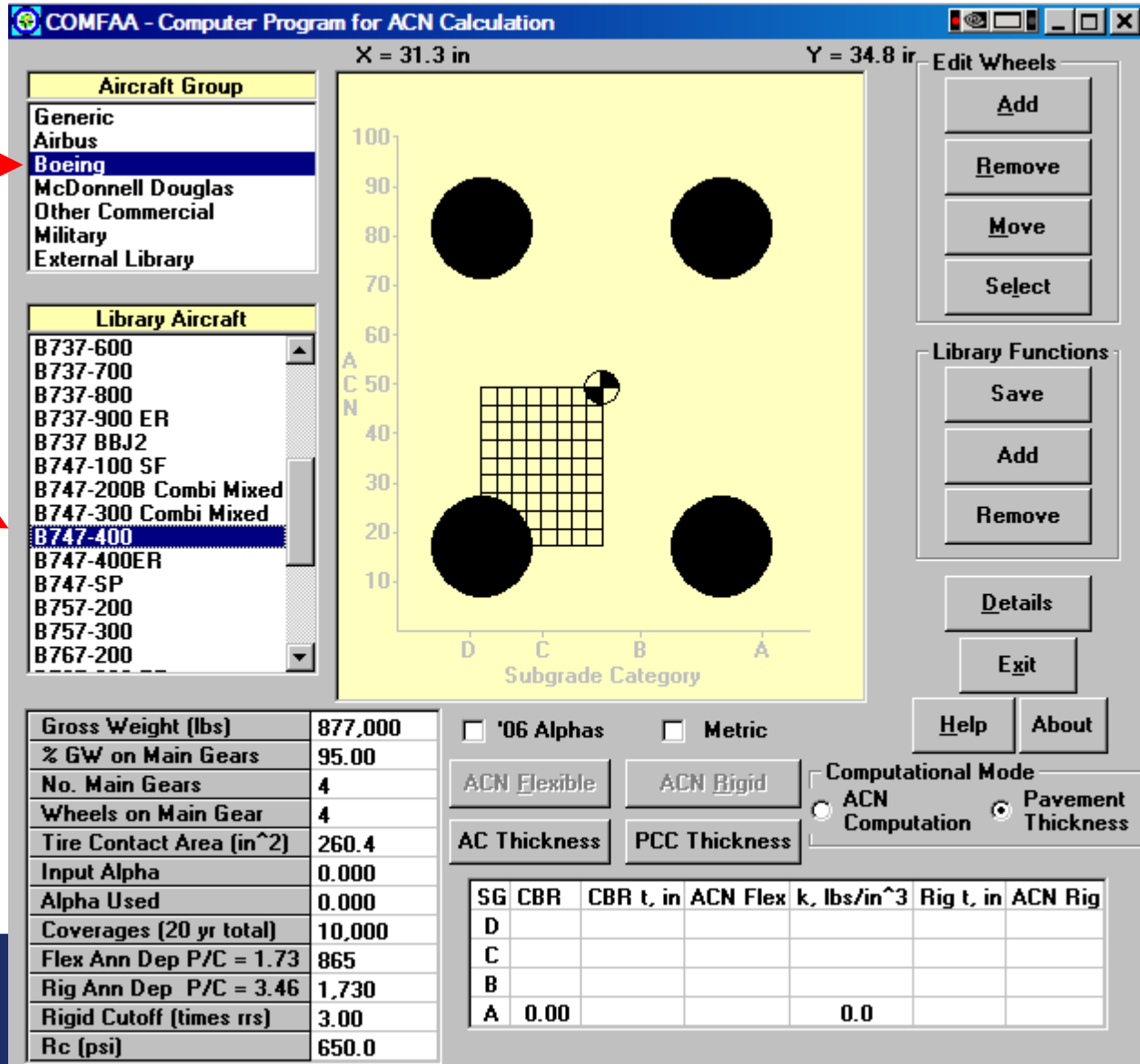
Begin by switching to “Pavement Thickness” mode



ACN-PCN – Technical Evaluation

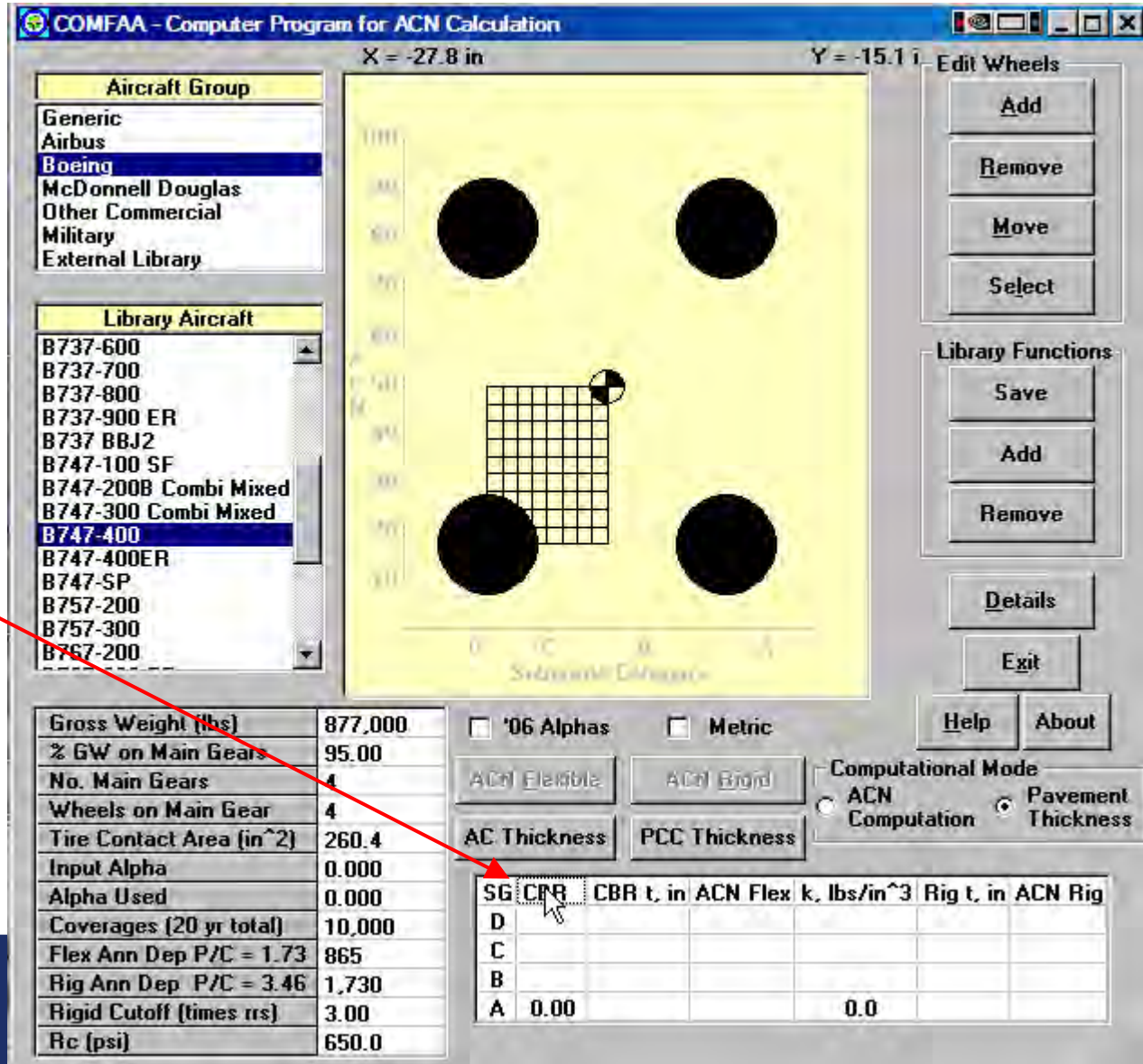
Select "Boeing" from the Aircraft groups

Select the B747-400



ACN-PCN – Technical Evaluation

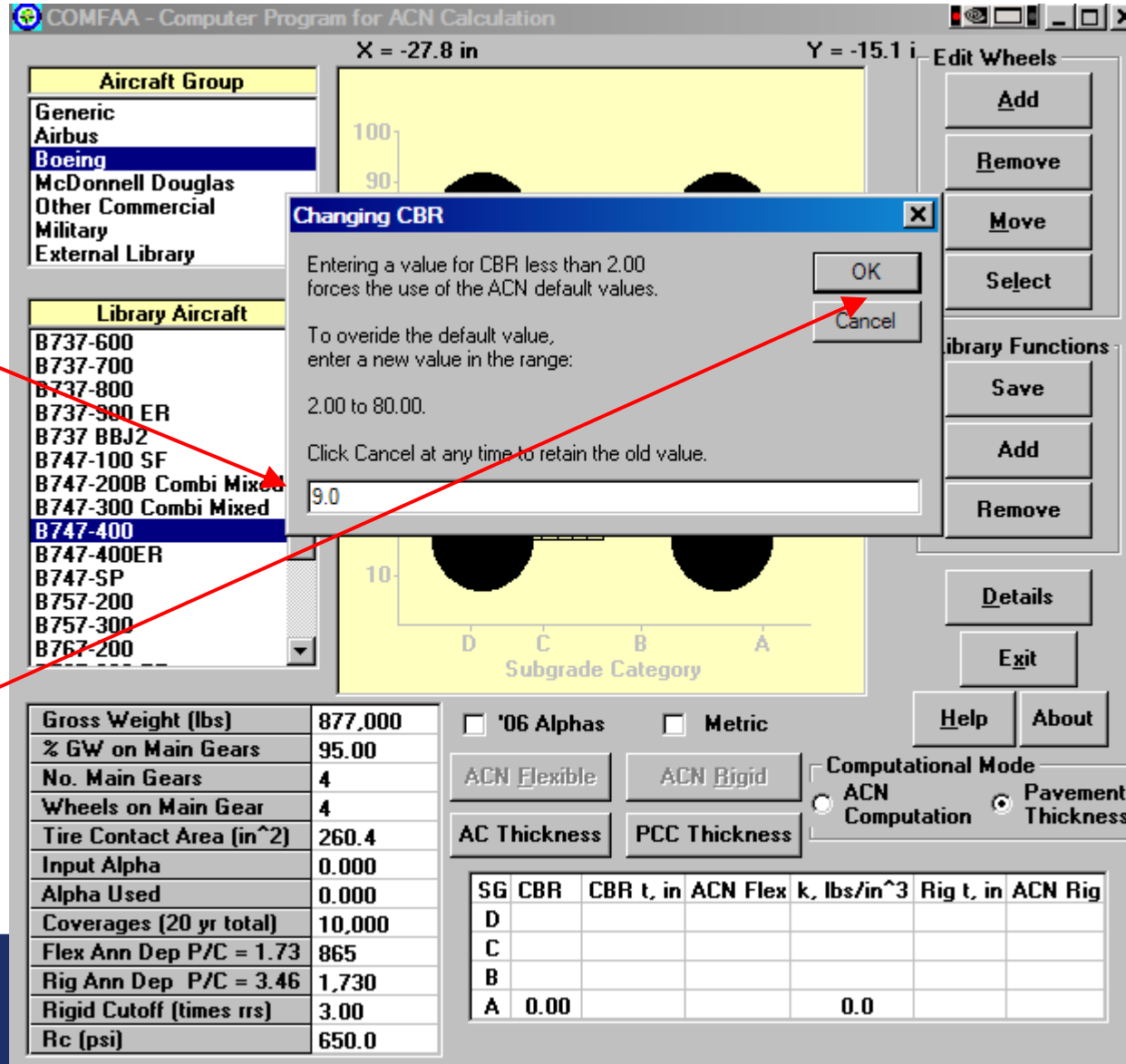
Click on “CBR” to enter the subgrade CBR value



ACN-PCN – Technical Evaluation

Enter subgrade CBR value

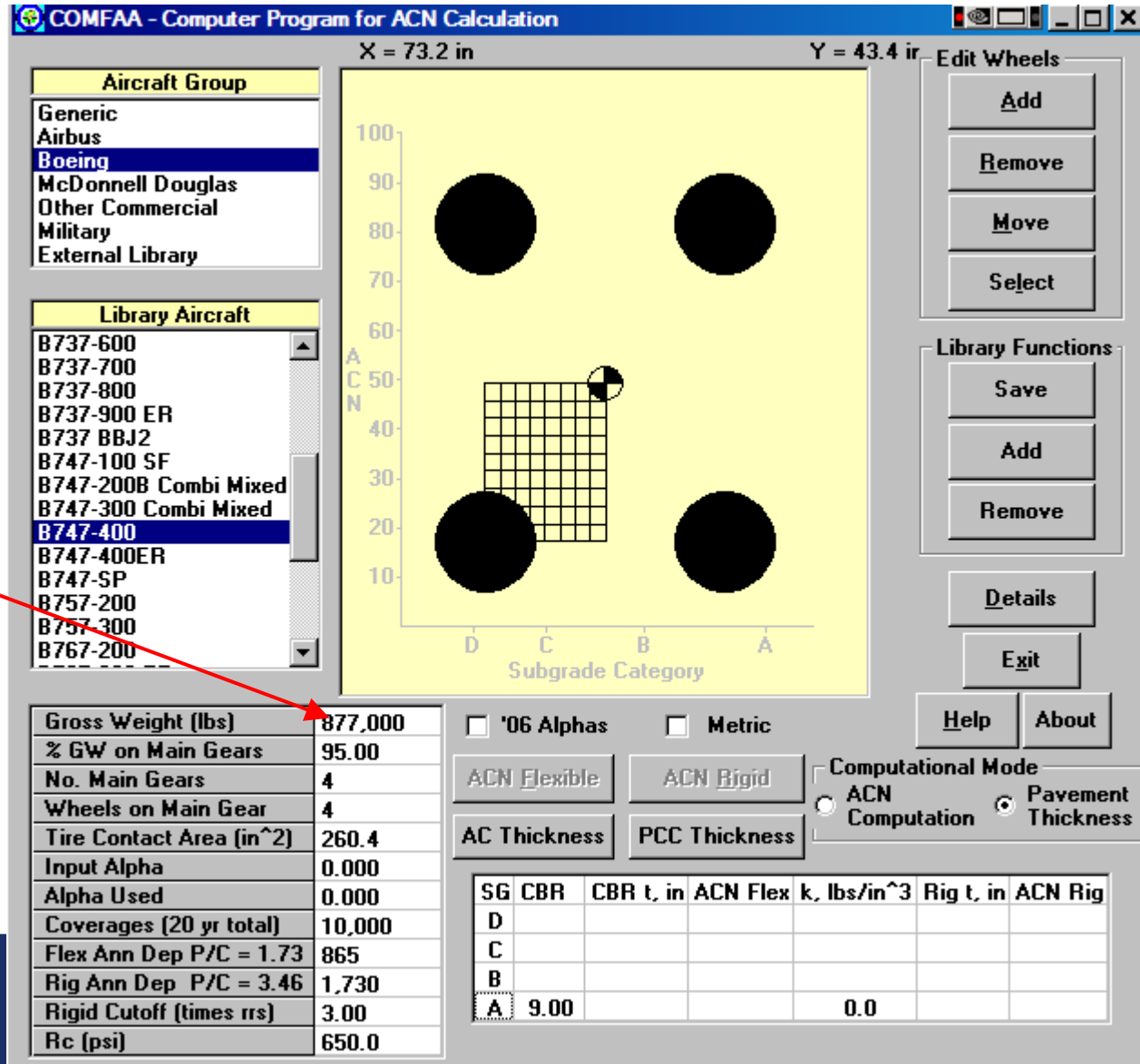
Click “OK”



ACN-PCN – Technical Evaluation

Adjust the airplane weight to the known/permitted operating weight

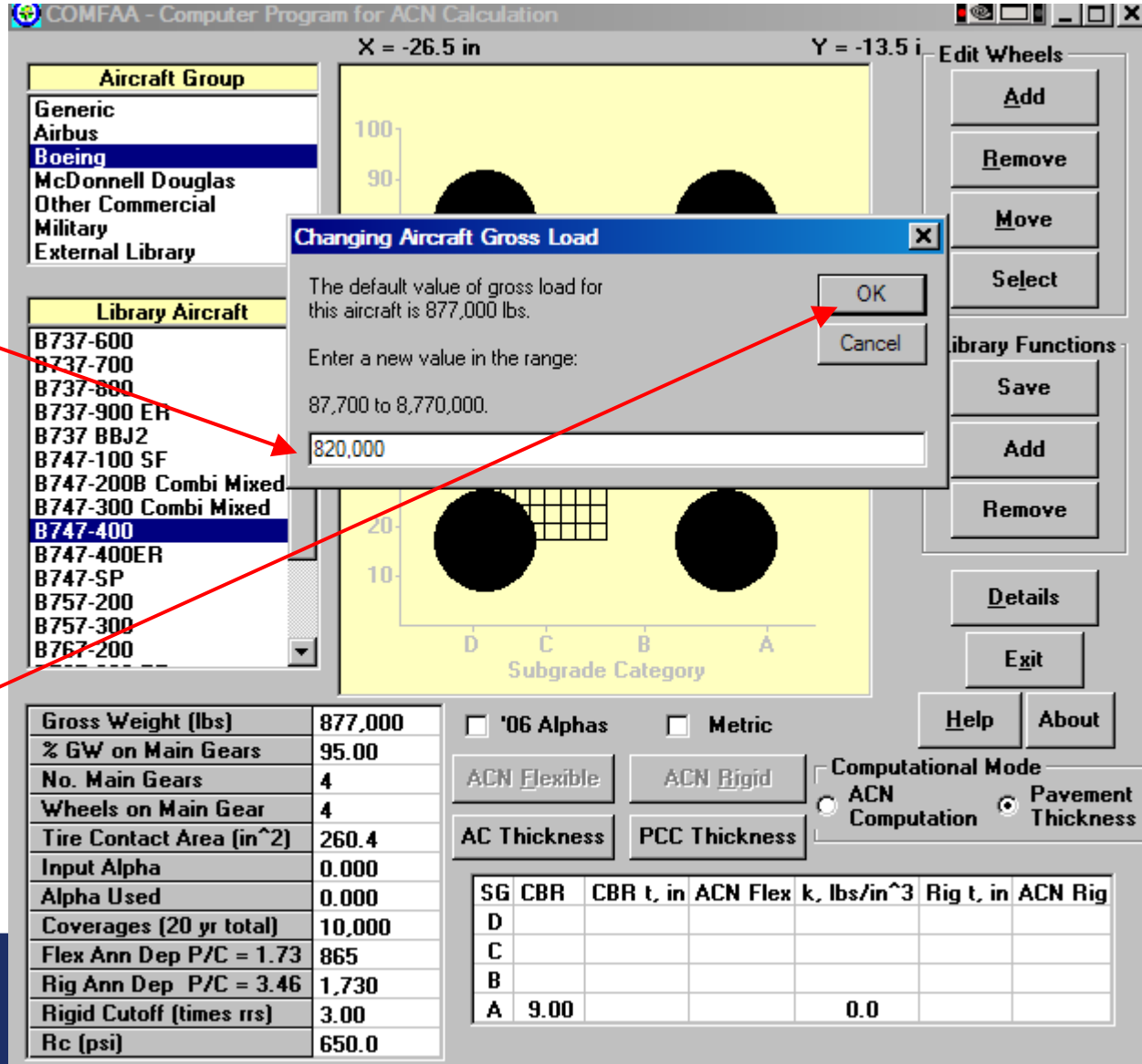
Start by clicking on the box containing gross weight



ACN-PCN – Technical Evaluation

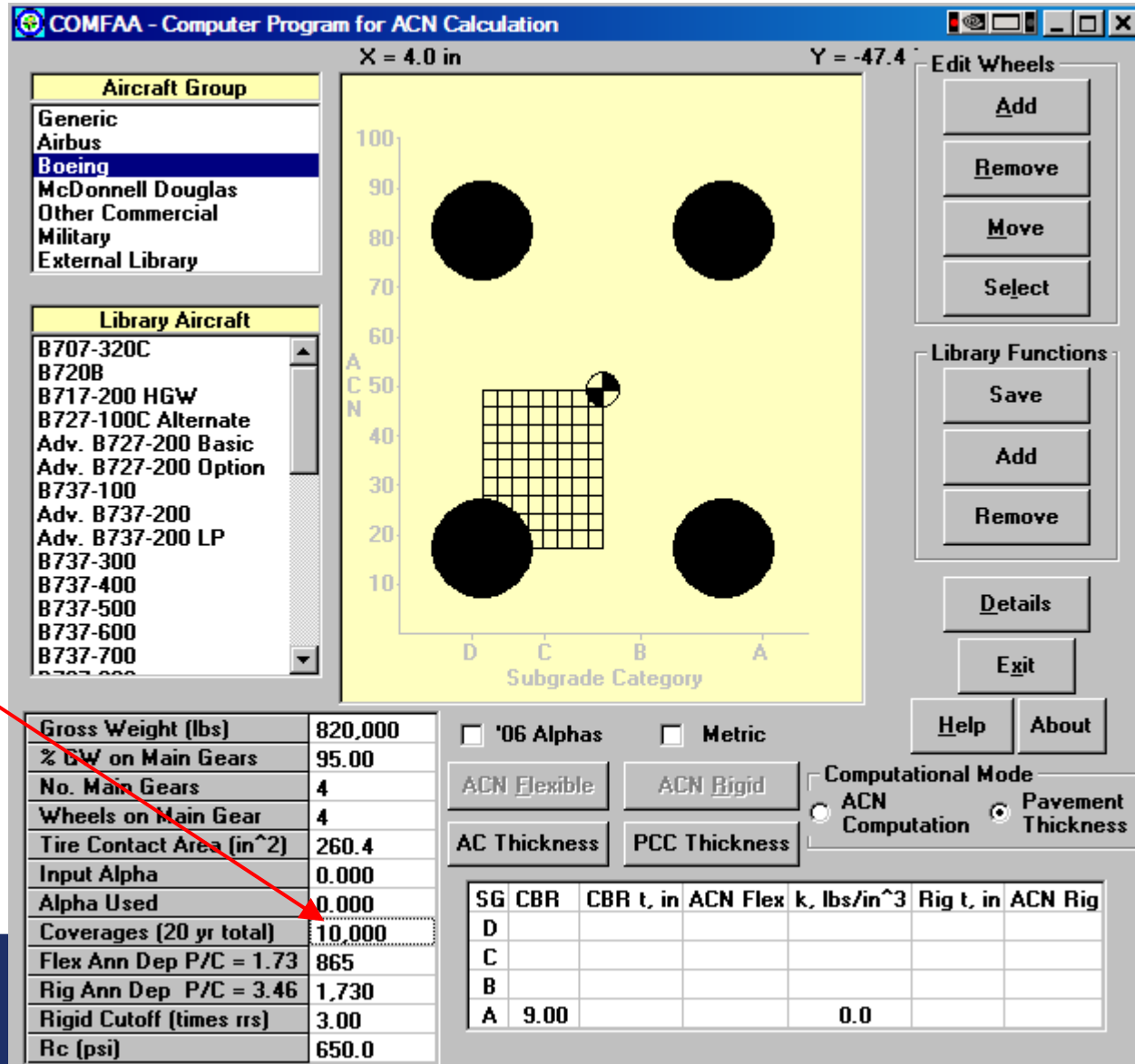
Enter Gross Weight (lbs)

Click “OK”



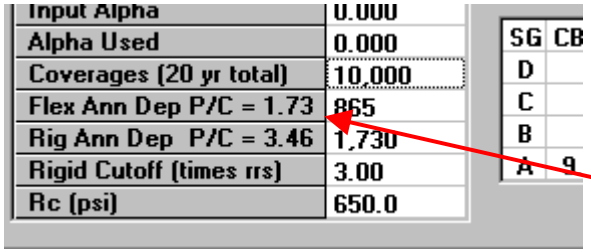
ACN-PCN – Technical Evaluation

Click on the coverages to enter the desired 20-year total number of coverages for this airplane



ACN-PCN – Technical Evaluation

Determine total coverages for the B747



Input Alpha	0.000
Alpha Used	0.000
Coverages (20 yr total)	10,000
Flex Ann Dep P/C = 1.73	865
Rig Ann Dep P/C = 3.46	1,730
Rigid Cutoff (times rrs)	3.00
Rc (psi)	650.0

SG	CB
D	
C	
B	
A	9

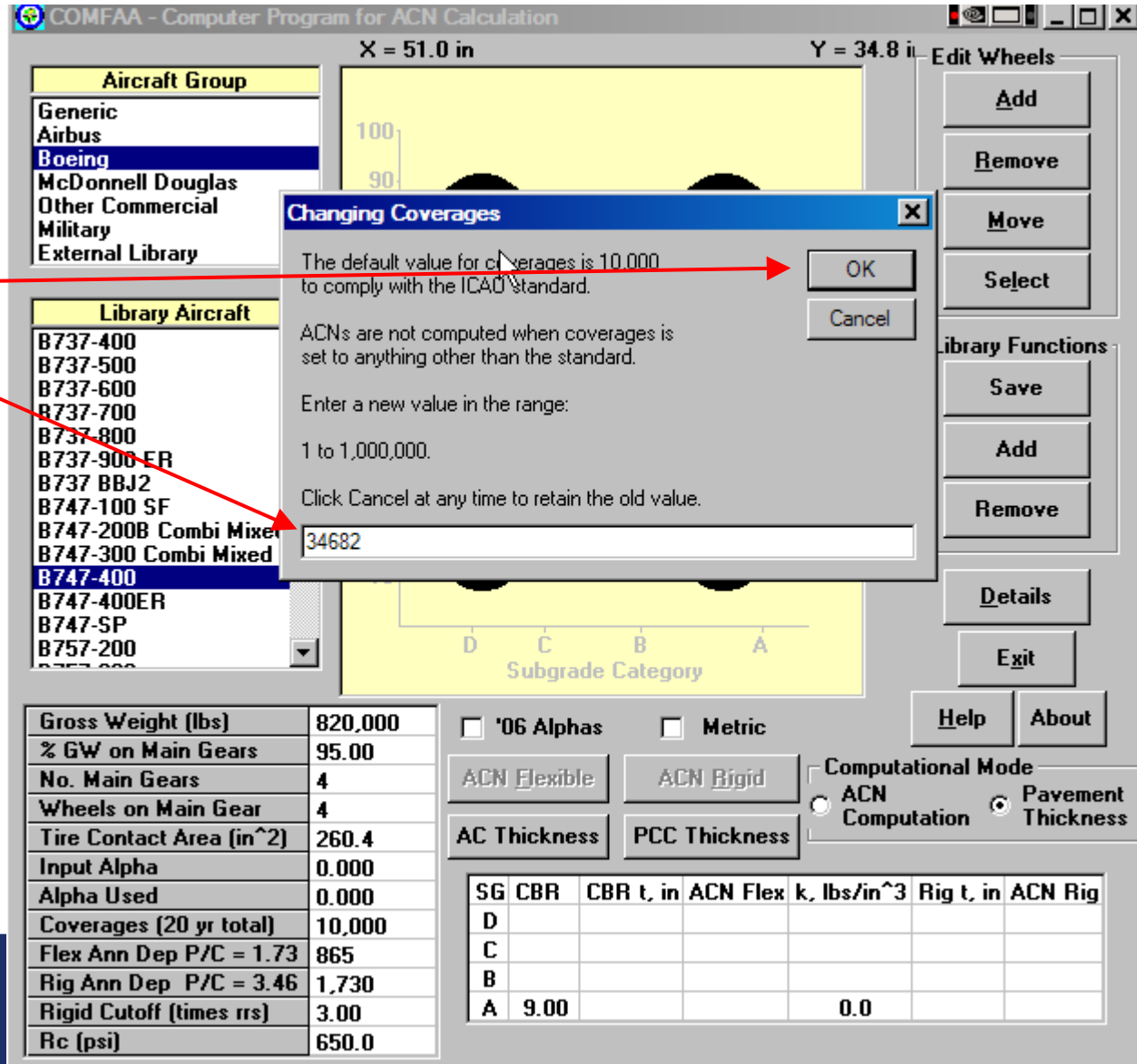
Find P/C ratio from COMFAA (use flexible value = 1.73)

Coverages = annual departures/{(P/C)/(P/TC)} *years in design

Total coverages = 3000 ann. departures/1.73/1}*20 = 34,682

ACN-PCN – Technical Evaluation

Enter the desired coverages and click OK

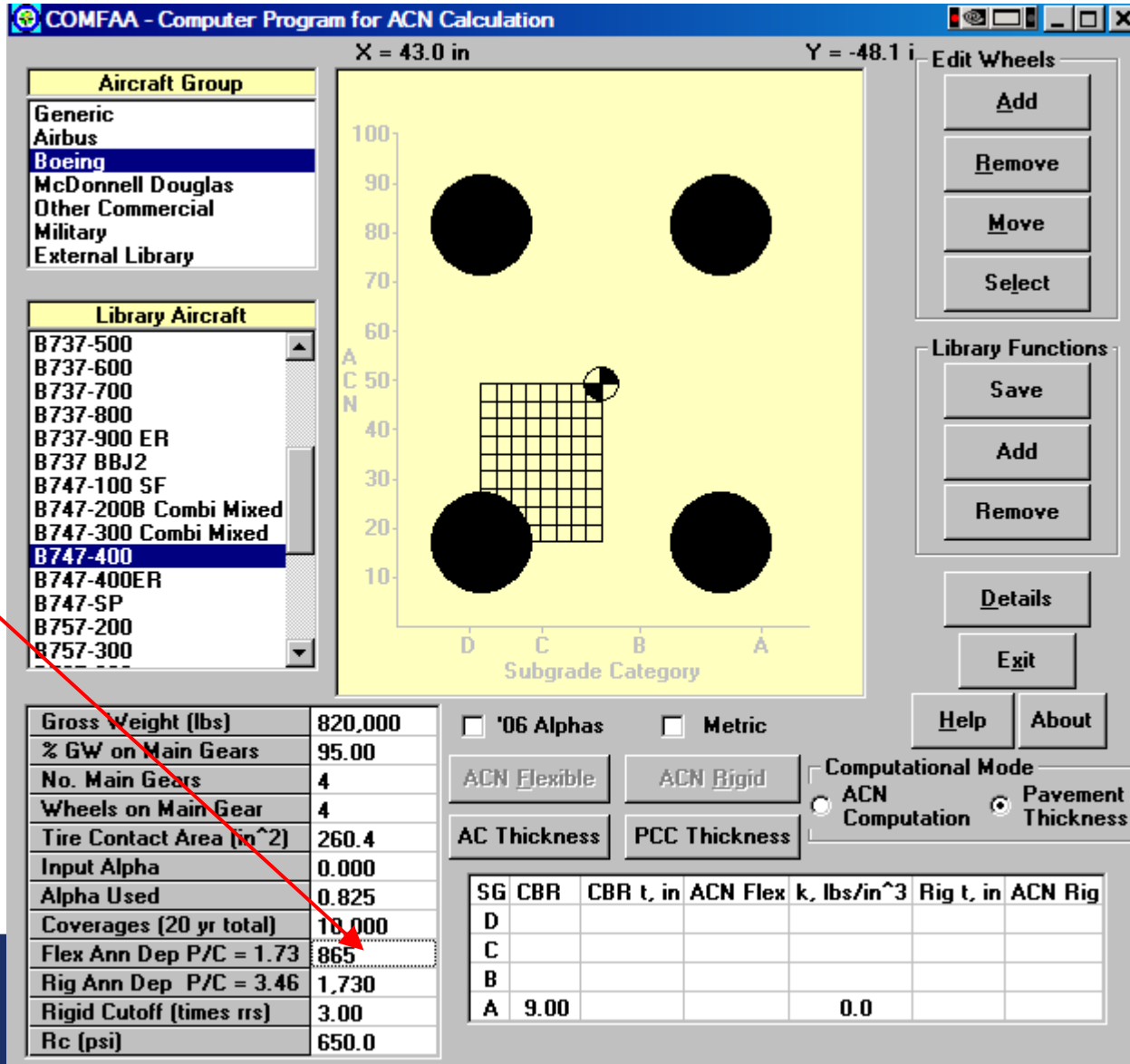


ACN-PCN – Technical Evaluation

OPTIONAL PROCEDURE if TC = 1

Click on the annual departure to enter the desired annual departures for this airplane

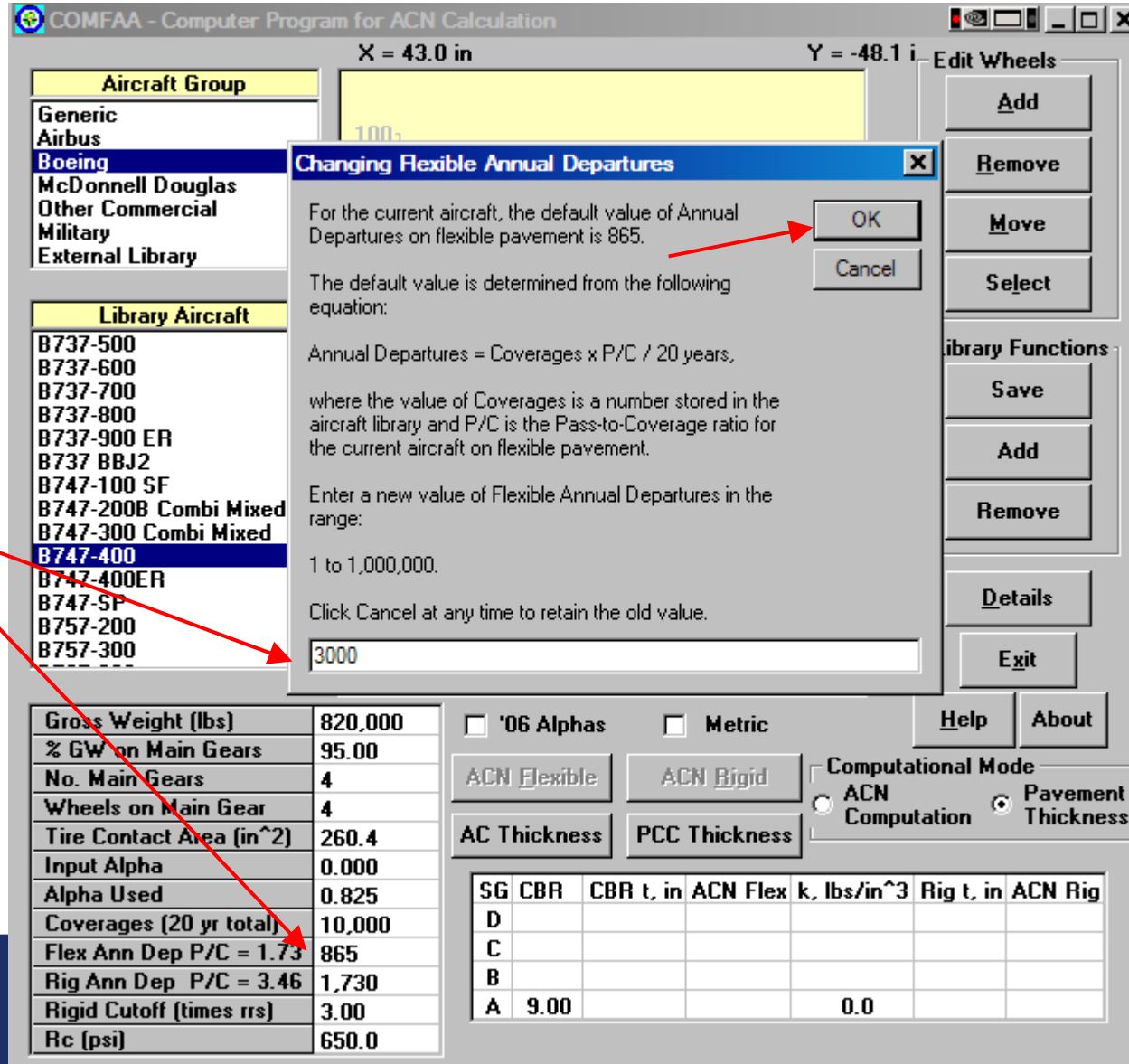
Note that this example uses the Flexible annual departures



ACN-PCN – Technical Evaluation

Since our example has TC=1

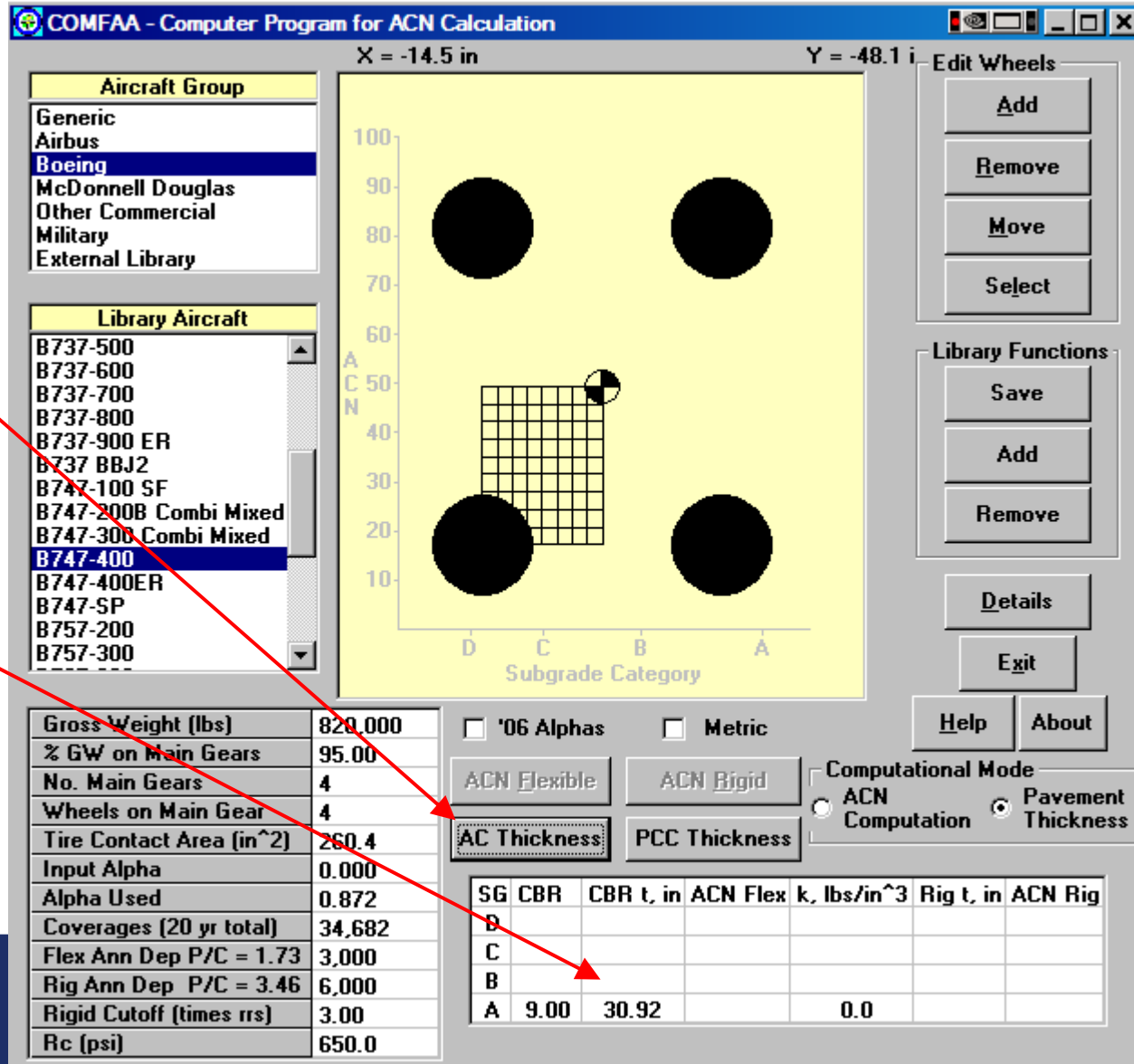
Click on annual departures and enter the desired annual departures for this airplane



ACN-PCN – Technical Evaluation

Click on “AC Thickness” to calculate the flexible pavement thickness requirement

Repeat for each airplane



ACN-PCN – Technical Evaluation

airplane Data – required thickness determination

Airplane	Operating Weight, (lbs)	Tire Pressure (psi)	Annual Departures	Flexible **P/C	Required t, (in.)
B727-200	185,000	148	400	2.92	22.6
B737-300	130,000	195	6,000	3.79	22.7
A319-100	145,000	196	1,200	3.18	20.3
B747-400	**820,000**	**200**	**3,000**	**1.73**	**30.9**
B767-300ER	370,000	190	2,000	1.80	27.9
DC8-63	330,000	194	800	1.68	26.6
A300-B4	370,000	205	1,500	1.75	29.1
B777-200	600,000	215	300	1.42	28.0

** P/C ratio provided by COMFAA while in pavement thickness mode

ACN-PCN – Technical Evaluation

3c) Convert traffic to equivalent traffic of the critical airplane

Two step process

1. Convert departures based on gear type
2. Complete conversion using wheel load ratio equation

I

ACN-PCN – Technical Evaluation

Gear type to "Critical" gear type conversion factors

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

M=# wheels on critical airplane gear

N=# wheels on converted airplane gear

AC 150/5335-5A paragraph 1.2, App. 1

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	244
3D	2D	1.56
2D/2D2	D	1.56
2D/2D2	2D	1.00
2D/2D2	3D	0.64

ACN-PCN – Technical Evaluation

Sample conversion to B747 gear type

(2D since procedure only uses one gear of the 2D/2D2 configuration)

Airplane	Gear Type	Annual Traffic Cycles (TC)	Conversion Factor	Equivalent (2D) TC
727-200	D	400	0.64	256
737-300	D	6,000	0.64	3,840
A319-100	D	1,200	0.64	768
747-400	2D/2D2	3,000	1.0	3,000
767-200ER	2D	2,000	1.0	2,000
DC8-63	2D	800	1.0	800
A300-B4	2D	1,500	1.0	1,500
777-200	3D	300	1.56	468
		15,200		12,632

ACN-PCN – Technical Evaluation

Equivalent Traffic Cycle conversion

$$\text{Log}\, R_1 = \text{Log}\, R_2 \times \sqrt{\frac{W_2}{W_1}}$$

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

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

ACN-PCN – Technical Evaluation

Spreadsheet for calculation of equivalent traffic

clear all data

ANNUAL DEPARTURE CONVERSION TO DESIGN AIRCRAFT ANNUAL DEPARTURES

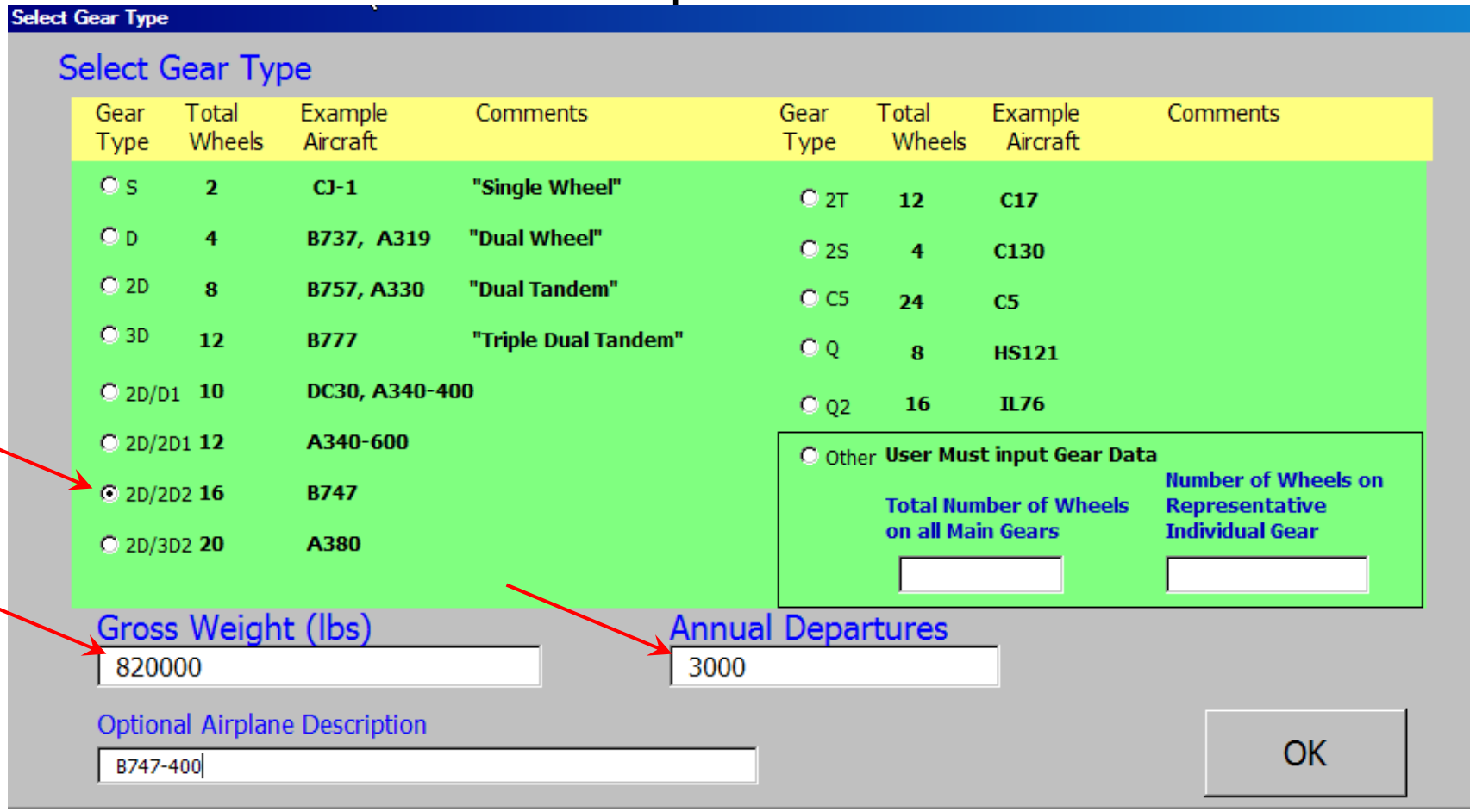
(following procedure specified in AC 150/5335-5A i.e. Direct wheel load calculations for each aircraft)

This procedure is NOT the same as the procedure specified in AC 150/5320-6D and will produce different results

		INPUT VALUES							CALCULATED VALUES				
		Optional information for Aircraft	Gear Type (code)	Max Takeoff weight MTOW	Annual Departures	Total Wheels on Main Gears	Wheels on Representative Gear		Gear Factor	Departures of equiv gear	Computed wheel Load of aircraft	Equiv. annual departures of design Aircraft	NOTES
Design Aircraft	Design Aircraft	B747-400	2D/2D2	820000	3,000	16	4			3,000	48,688	3,000.00	
Additional Aircraft	Aircraft 1	B727-200	D	185,000	400	4	2		0.64	256	43,938	194	
	Aircraft 2	B737-300	D	130000	6,000	4	2		0.64	3,840	30,875	716	
	Aircraft 3	A319-100	D	145,000	1,200	4	2		0.64	768	34,438	268	
	Aircraft 4	B767-300ER	2D	370,000	2,000	8	4		1	2,000	43,938	1,368	
	Aircraft 5	DC8-63	2D	330,000	800	8	4		1	800	39,188	403	
	Aircraft 6	A300-B4	2D	370,000	1,500	8	4		1	1,500	43,938	1,041	
	Aircraft 7	B777-200	3D	600,000	300	12	6		1.56	468	47,500	434	
	Aircraft 8											0	
	Aircraft 9											0	
	Aircraft 23											0	
	Aircraft 24											0	
	Aircraft 25											0	
			Equivalent Annual Departures of the B747-400									7,424	

ACN-PCN – Technical Evaluation

Spreadsheet for calculation of equivalent traffic



ACN-PCN – Technical Evaluation

4) Determine allowable operating weight of critical airplane

Using COMFAA

- In pavement thickness mode,
- Enter the critical airplane at the equivalent departure level
- Iterate to the known pavement thickness by changing the airplane weight

ACN-PCN – Technical Evaluation

Determine the maximum gross weight permitted on the known pavement section for the “critical” airplane.

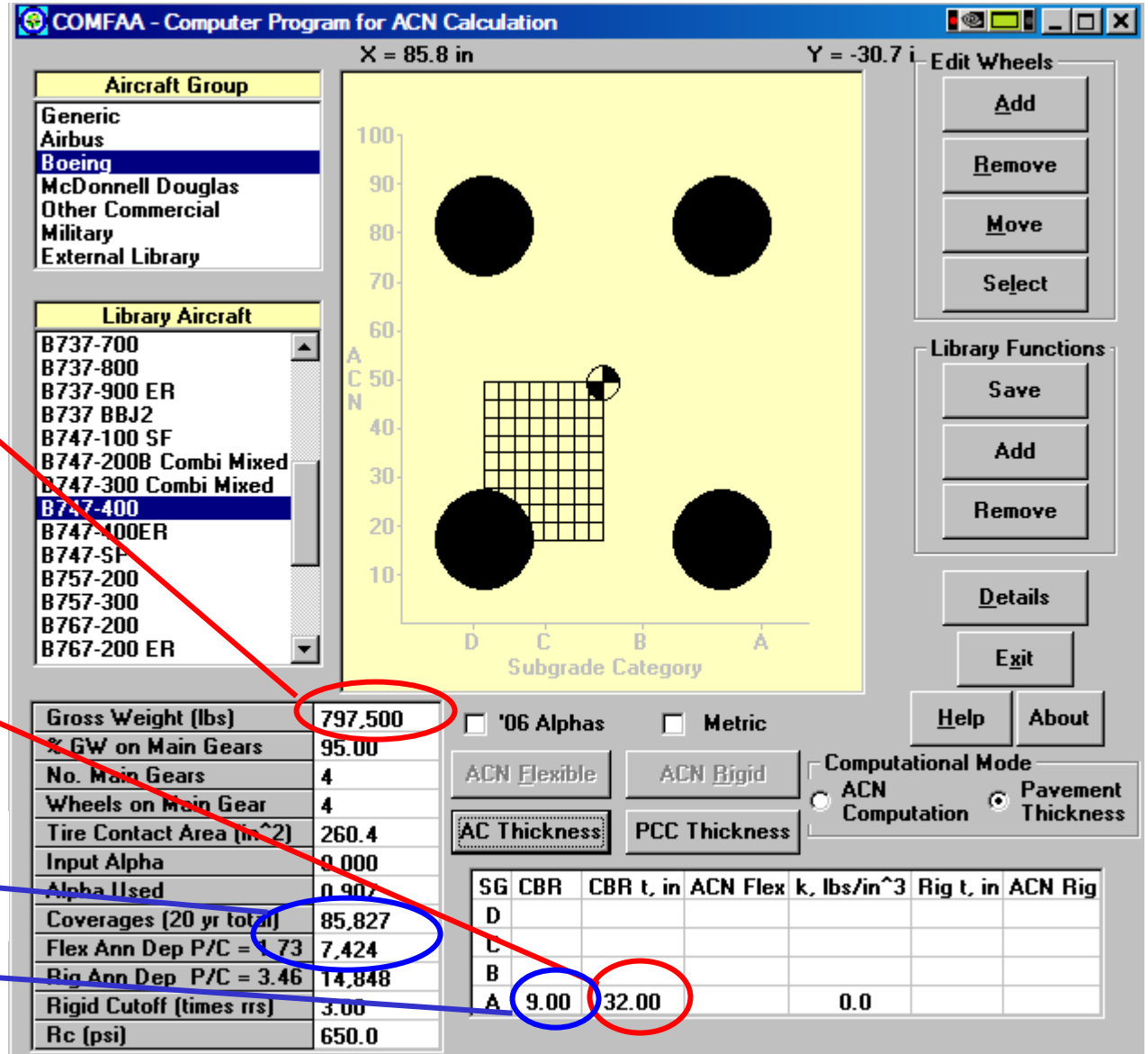
Critical airplane	747-400
Known pavement thickness	32.0 inches
Subgrade CBR	9.0 (Code *B*)
Tire pressure	200 psi (Code *X*)
Percent Weight on the main gear	95.0 %
P/C ratio	1.73
Pavement life	20 years
Annual equivalent departures (TC)	7,424
Total Coverages (TC/1.73) x 20	85,827

ACN-PCN – Technical Evaluation

In pavement thickness mode

Iterate to find allowable weigh which produces the know pavement thickness

Enter total coverage or departure level and CBR



ACN-PCN – Technical Evaluation

4) Determine ACN of critical airplane at allowable weight

Using COMFAA

- In ACN Computation mode,
- Enter the critical airplane at the allowable operation weight

  Note that coverages defaults to 10,000 per ICAO procedure
- Calculate ACN

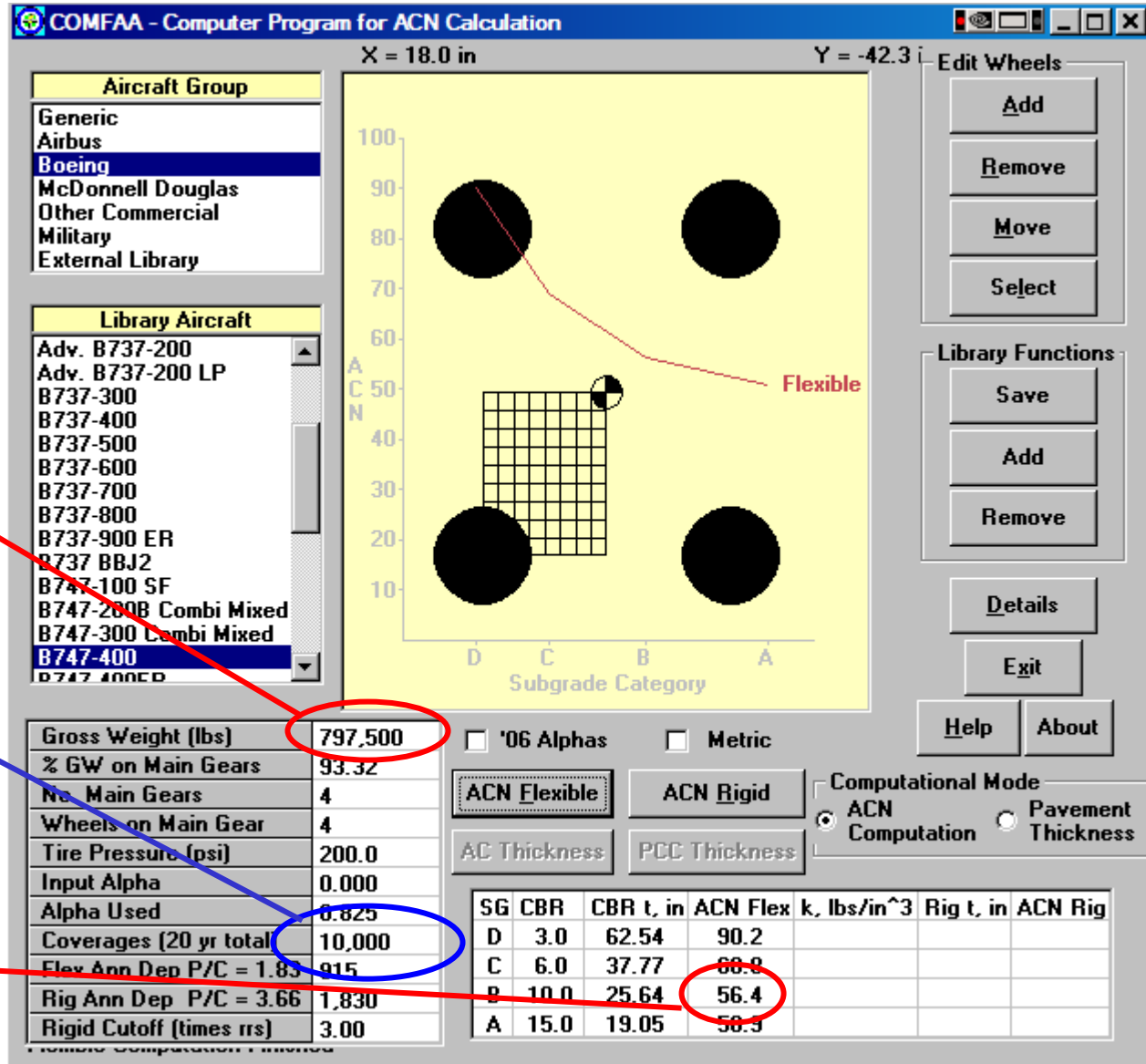
ACN-PCN – Technical Evaluation

In ACN Computation mode

Enter allowable operating weight

coverage will default to 10,000

Read ACN for desired subgrade category



ACN-PCN – Technical Evaluation

Using the previous parameters, the B747 could operate at 797,500 lbs

From COMFAA, determine ACN values at this weight.

= 56/F/B/X/T

This evaluation would suggest minor restriction of 2 airplanes with ACN's over the PCN value

ACN-PCN – Using Technical Method

Using Technical Method of PCN (flexible example)

PCN = 56/F/B/X/T

Airplane	Operating Weight, lbs	Tire Pressure (psi)	% GW Main Gear For ACN	ACN F/B	Annual Departures
B727-200	185,000	148	96.00	48	400
B737-300	130,000	195	90.86	32	6,000
A319-100	145,000	196	92.60	34	1,200
B747-400	820,000	200	93.32	59	3,000
B767-300ER	370,000	190	92.40	50	2,000
DC8-63	330,000	194	96.12	53	800
A300-B4	370,000	205	94.00	57	1,500
B777-200	600,000	215	95.42	52	300

Questions or Comments?

FAA Pavement Design

AC 150/5320-6E and FAARFIELD

Presented to: FAA GREAT LAKES REGION AIRPORTS CONFERENCE

By: Rodney N. Joel, P.E.
Civil Engineer / Airfield Pavement
Airport Engineering Division

Date: November, 2008

Federal Aviation Administration

FAA Pavement Design

AC 150/5320-6E, Airport Pavement Design and Evaluation

Note that this presentation will address significant changes to FAA pavement design procedures and is not intended to convey a complete overview of the pavement design procedure

FAA Pavement Design

AC 150/5320-6E, Airport Pavement Design and Evaluation

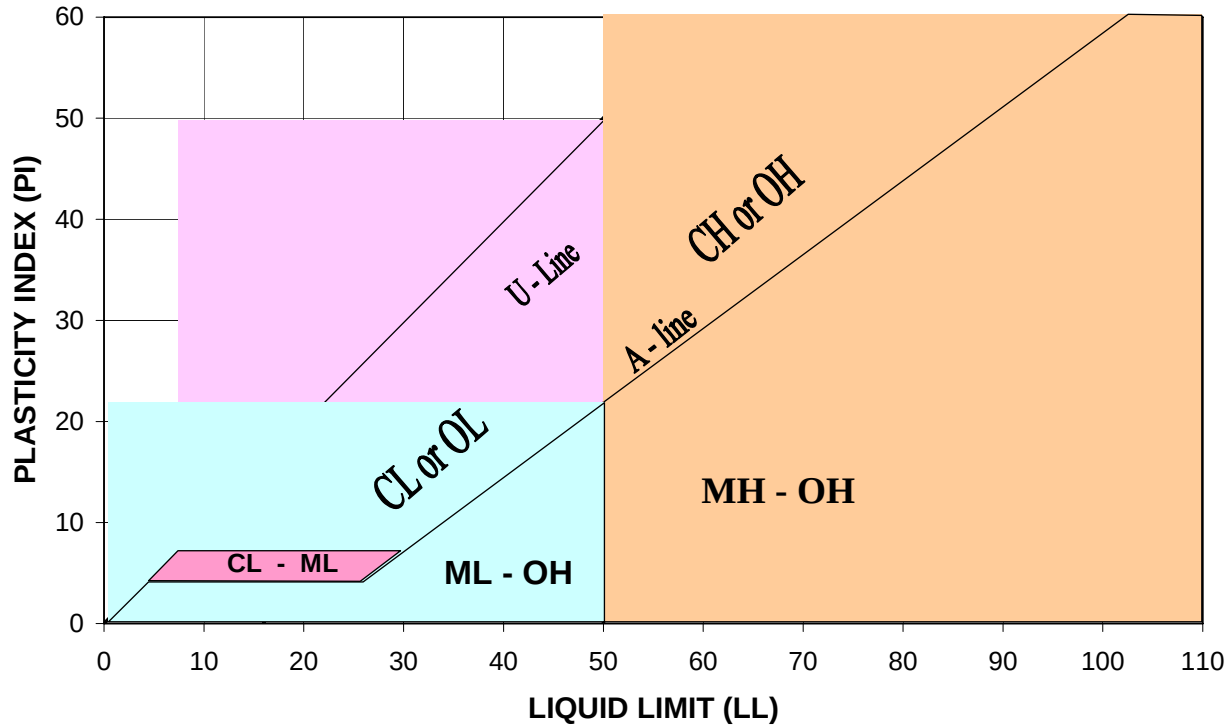
- Completely revised in 2008
- New design methodologies for Rigid and Flexible pavements
- Software dependent design procedures
- Addresses modern airplane parameters

Chapter 2
Soil Investigations and Evaluation

Chapter 2
Soil Investigations and Evaluation

- **Very few significant changes**
- **Still uses Unified Soil Classification (USC) system**
  - Reference to ASTM 2487

GW	CL
GP	ML
GM	OL
GC	CH
SW	MH
SP	OH
SM	PT
SC	



Chapter 2
Soil Investigations and Evaluation

Same minimum subsurface boring recommendations

Same soil testing recommendations

AREA	Minimum spacing	Minimum depth
RWY/TWY	200 ft interval	10 ft
Other areas	1 per 10,000 sq ft	10 ft
Borrow areas	As necessary	As necessary

Chapter 2
Soil Investigations and Evaluation

Continues to split soil compaction requirements based upon 60,000 lb gross weight airplane

< 60,000 ASTM D 698 Standard Proctor

> 60,000 ASTM D 1557 Modified Proctor

Soil Strength Parameter for FLEXIBLE pavement

Subgrade Modulus (E psi) or CBR

CBR

- Design value – One Standard Deviation below the Mean
- Lowest practical value CBR = 3

  Otherwise stabilize or replace

Soil Strength Parameter for RIGID pavement

Resilient Modulus E (psi) or

Modulus of Subgrade Reaction – k-value (pci)

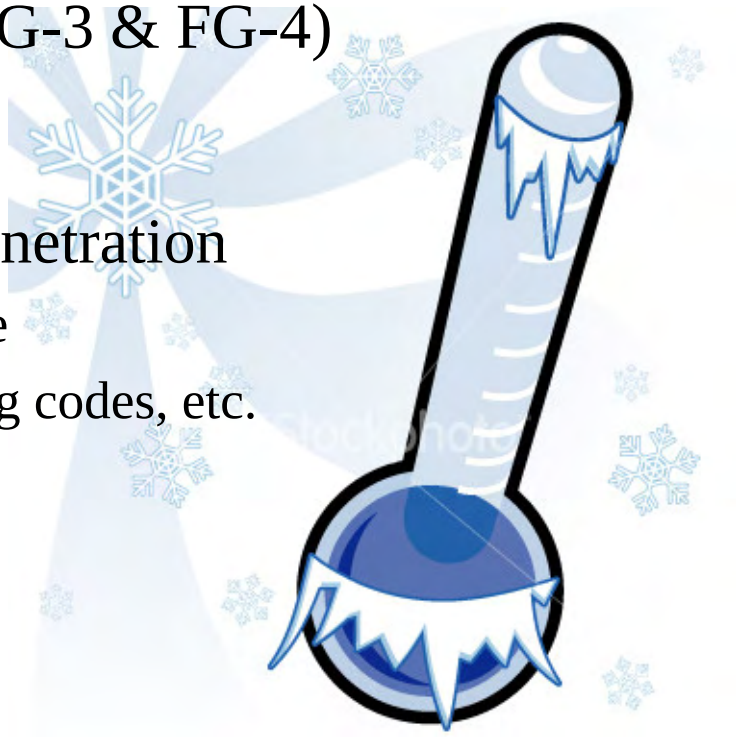
- Design value – "conservative selection"
- K-value can be estimated from CBR

$$k = \left[\frac{1500 \times \mathrm{CBR}}{26} \right]^{0.7788} \qquad (k \text{ in pci})$$

Seasonal Frost

- Same Frost Groups (FG-1, FG-2, FG-3 & FG-4)

- Determination of Depth of Frost Penetration
  - Based on local Engineering experience
  - i.e. local construction practice, building codes, etc.
  - No nomographs or programs provided



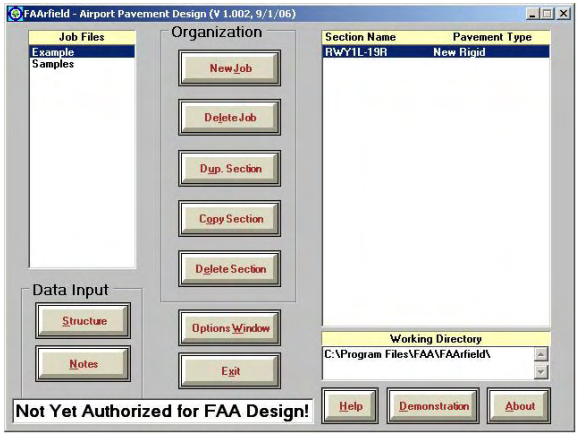
Chapter 3
Pavement Design

Chapter 3 - Pavement Design

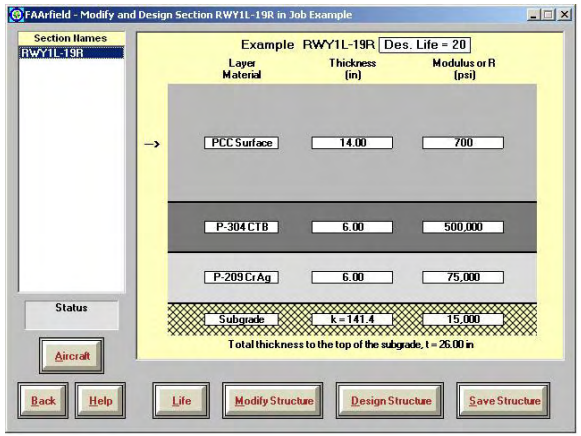
- Completely New Chapter
- Covers standard pavement design procedures for both flexible and rigid pavement
- Applies to pavement designed for airplanes with gross weights exceeding 30,000 lbs
- Design procedure requires the use of computer program, i.e. FAARFIELD

Chapter 3 - Pavement Design
FAARFIELD 1.0 – Screen Shots

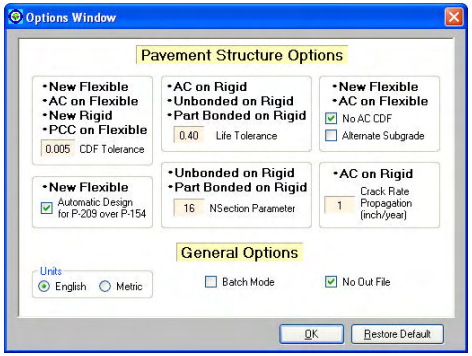
Main Window



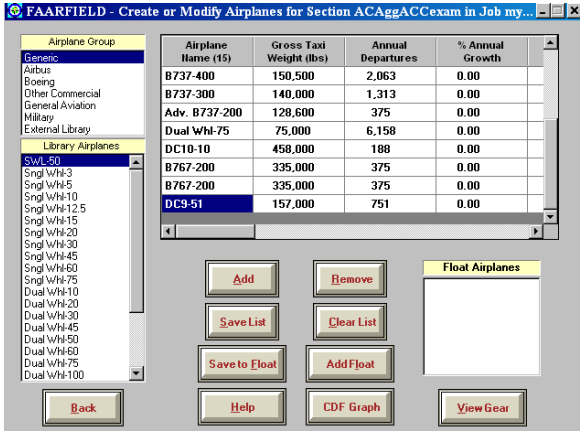
Structure Window

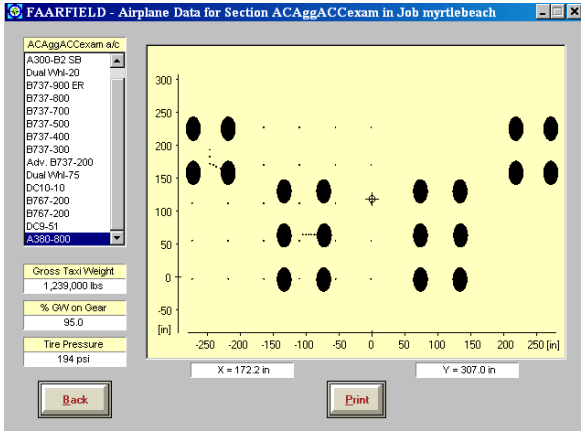


Options Window

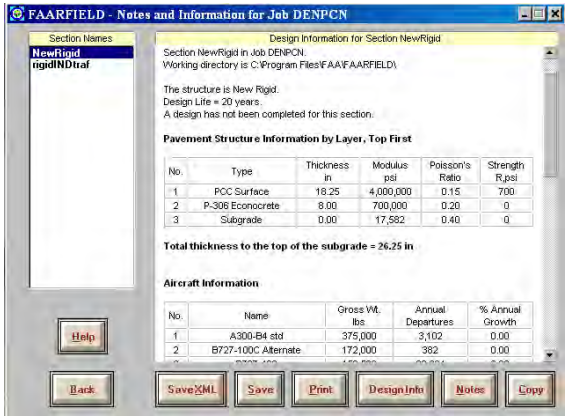


Aircraft Data Windows





Notes Window



Chapter 3 - Pavement Design

- **Flexible Pavement Design based on Layered Elastic design procedure**
  - US Corp of Engineers CBR Method no longer used
- **Rigid Pavement Design based on 3-Dimensional Finite Element model**
  - Westergaard design procedure no longer used.

Traffic Models

- New procedures require that ALL anticipated traffic be included in the traffic model.
- Concept of “design aircraft” is no longer used
- Cumulative Damage Factor (CDF) replaces need for design aircraft procedure.

Traffic Model - Cumulative Damage Factor

- Sums Damage From ***Each*** Aircraft
  - Based upon its unique pavement loading characteristics and
  - Location of the main gear from centerline

- DOES NOT use the “design aircraft” method of consolidating all aircraft into one design model

Traffic Model - Cumulative Damage Factor

- Sums Damage From ***Each*** Aircraft - Not From "Design Aircraft"

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

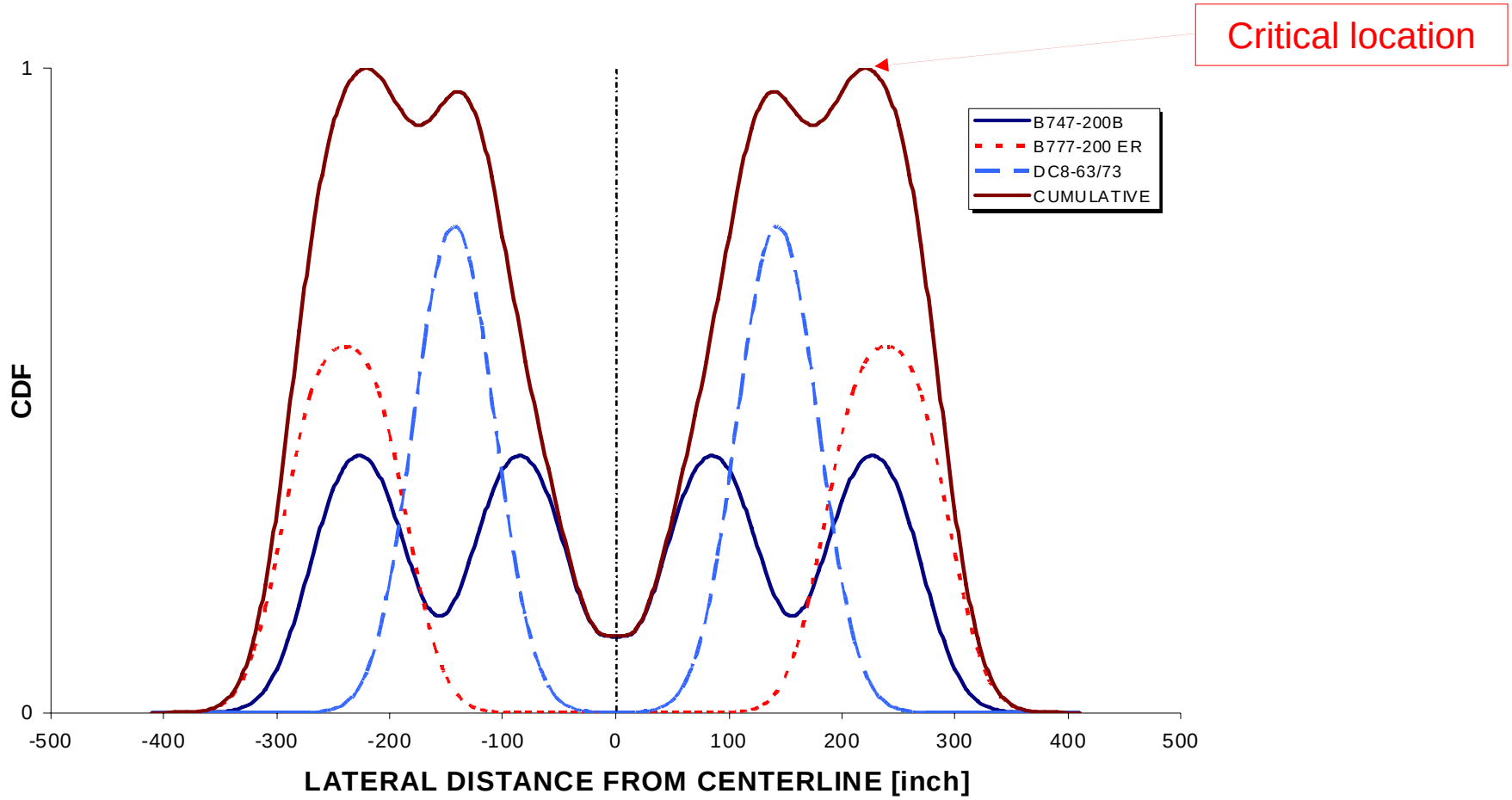
- When CDF = 1, Design Life is Exhausted

Traffic Model - Cumulative Damage Factor

- CDF is Calculated for each 10 inch wide strip over a total 820 inch width.
- Gear location and wander considered for each aircraft
- Use Miner's rule to sum damage for each strip

➢ **Must Input Traffic Mix, NOT "Design Aircraft"**

Traffic Model - Cumulative Damage Factor

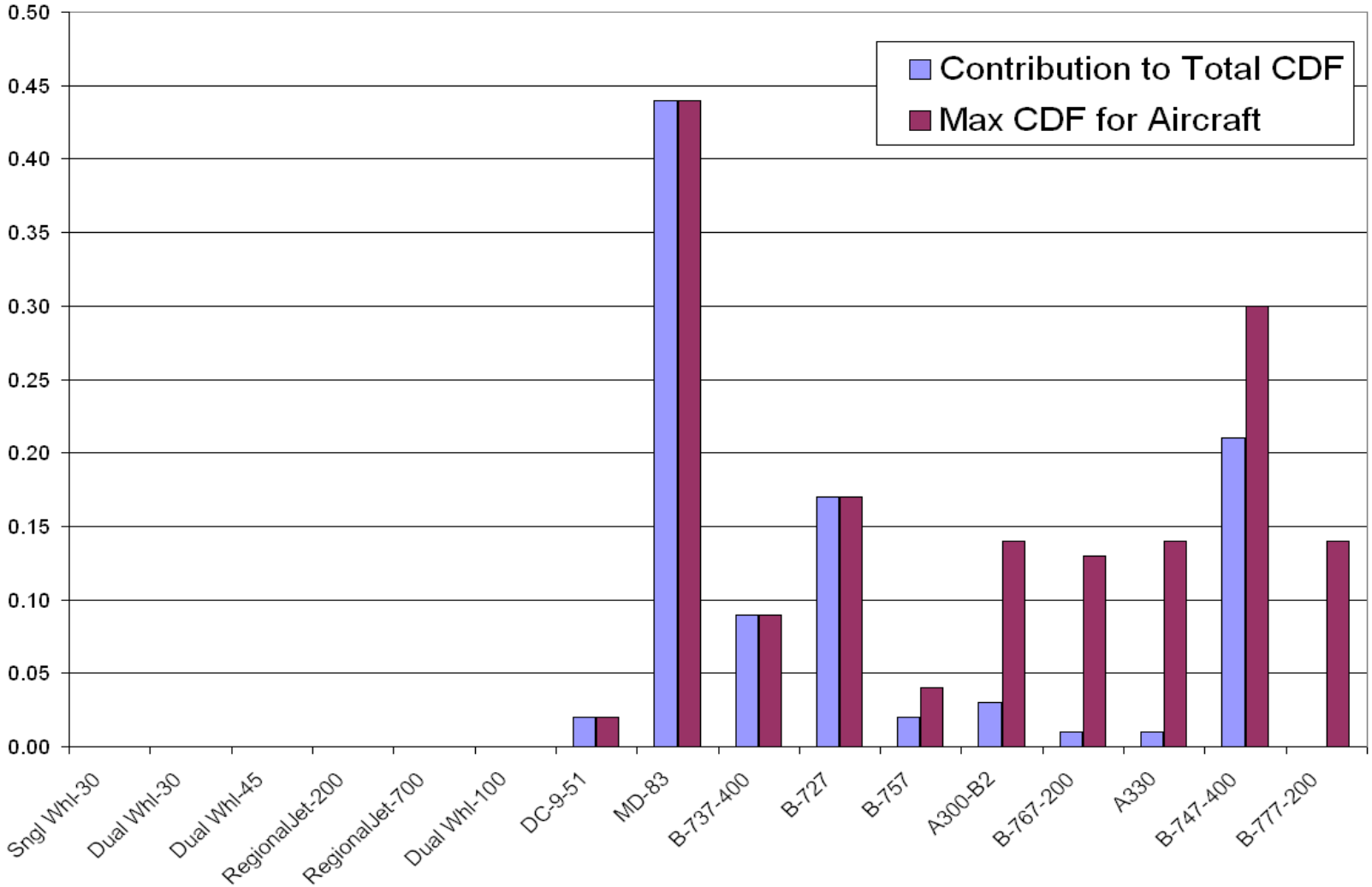


Sample Aircraft Traffic Mix CDF Contribution

Aircraft Name	Gross Weight	Annual Departures	CDF Contribution	CDF Max For Aircraft
Sngl Whl-30	30,000	1,200	0.00	0.00
Dual Whl-30	30,000	1,200	0.00	0.00
Dual Whl-45	45,000	1,200	0.00	0.00
RegionalJet-200	47,450	1,200	0.00	0.00
RegionalJet-700	72,500	1,200	0.00	0.00
Dual Whl-100	100,000	1,200	0.00	0.00
DC-9-51	122,000	1,200	0.02	0.02
MD-83	161,000	1,200	0.44	0.44
B-737-400	150,500	1,200	0.09	0.09
B-727	172,000	1,200	0.17	0.17
B-757	250,000	1,200	0.02	0.04
A300-B2	304,000	1,200	0.03	0.14
B-767-200	335,000	1,200	0.01	0.13
A330	469,000	100	0.01	0.14
B-747-400	873,000	100	0.21	0.30
B-777-200	537,000	500	0.00	0.14

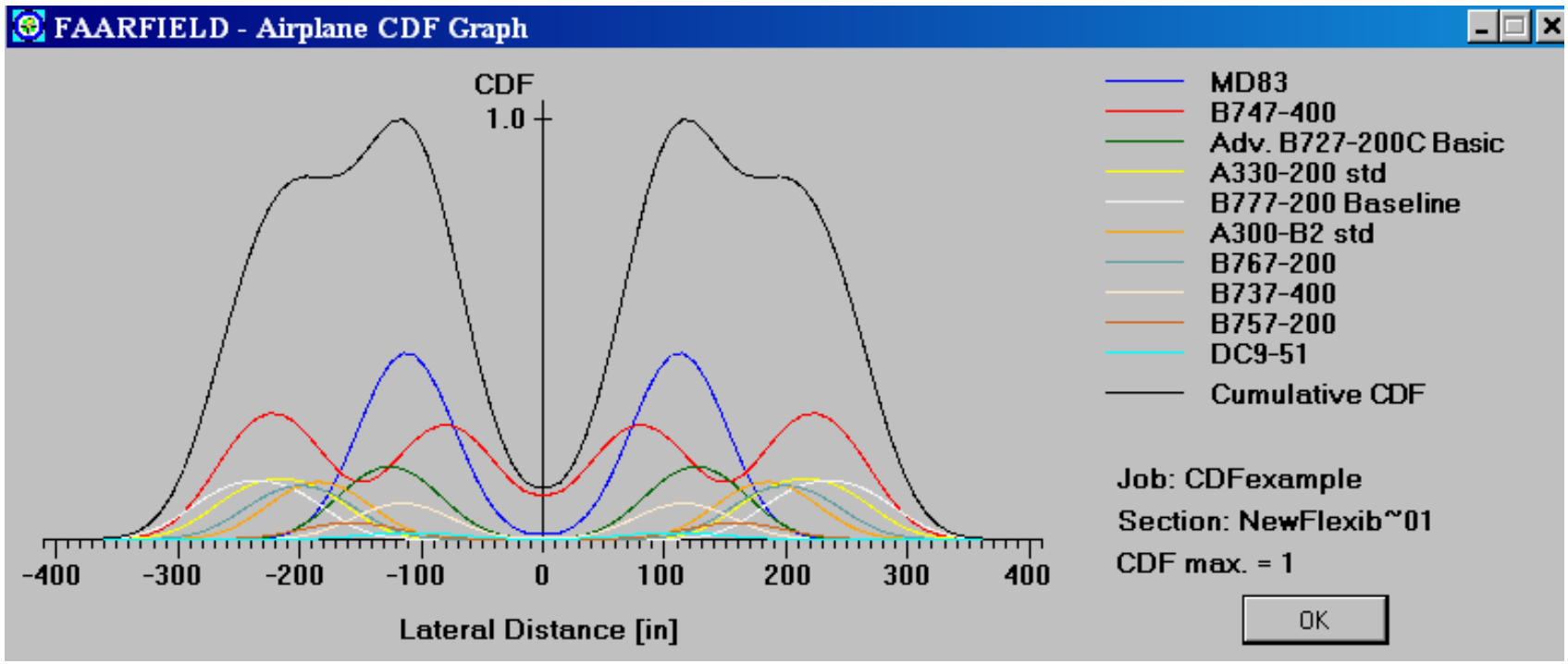
Condition specific and not a general representation of noted aircraft

Sample Aircraft Traffic Mix CDF Contribution



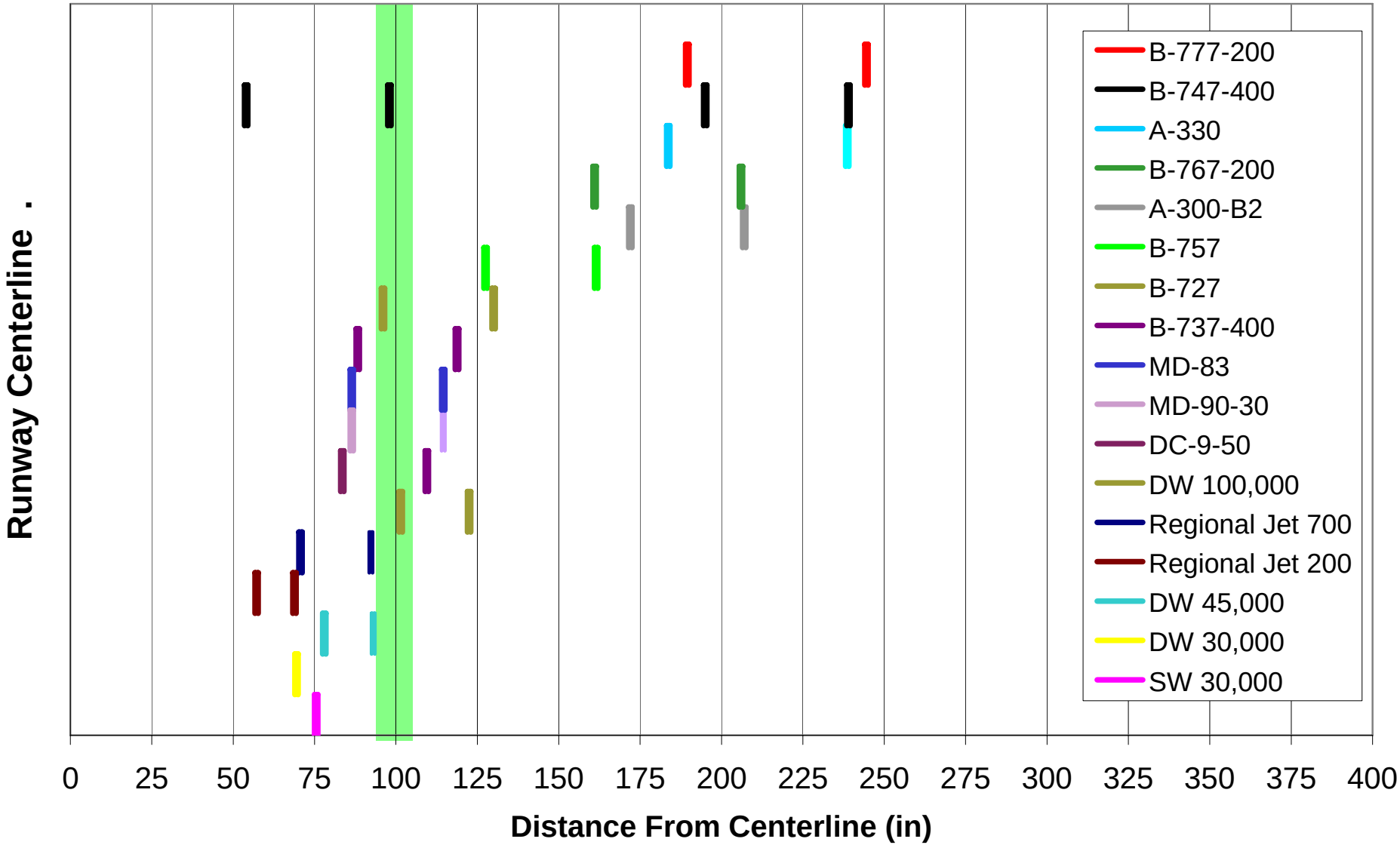
Condition specific and not a general representation of noted aircraft

Sample Aircraft Traffic Mix CDF Contribution



Condition specific and not a general representation of noted aircraft

Large Aircraft Traffic Mix Gear Locations

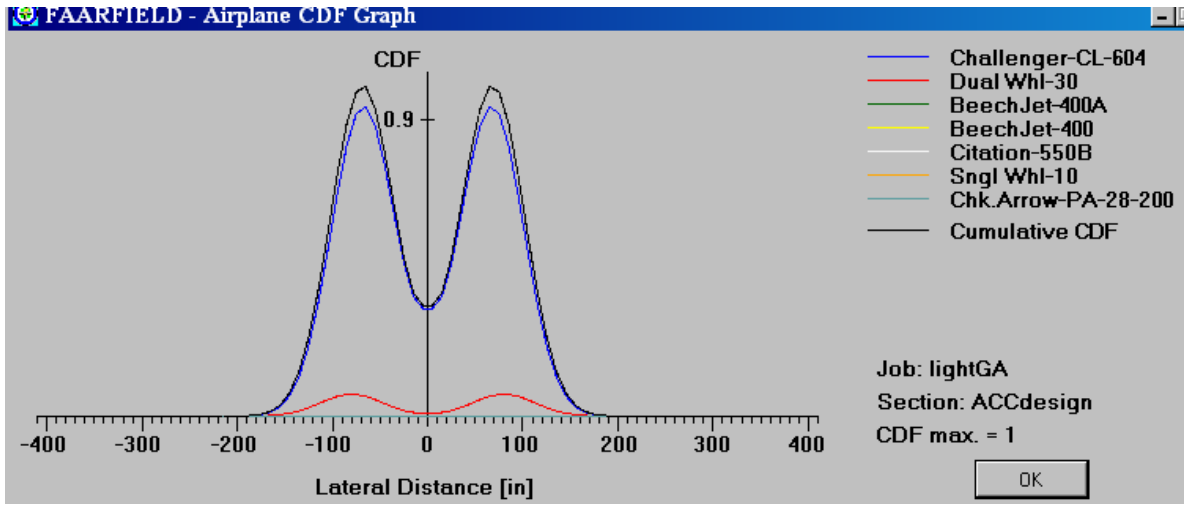


Sample Aircraft Traffic Mix CDF Contribution

Common Issue with GENERAL AVIATION Traffic mixes

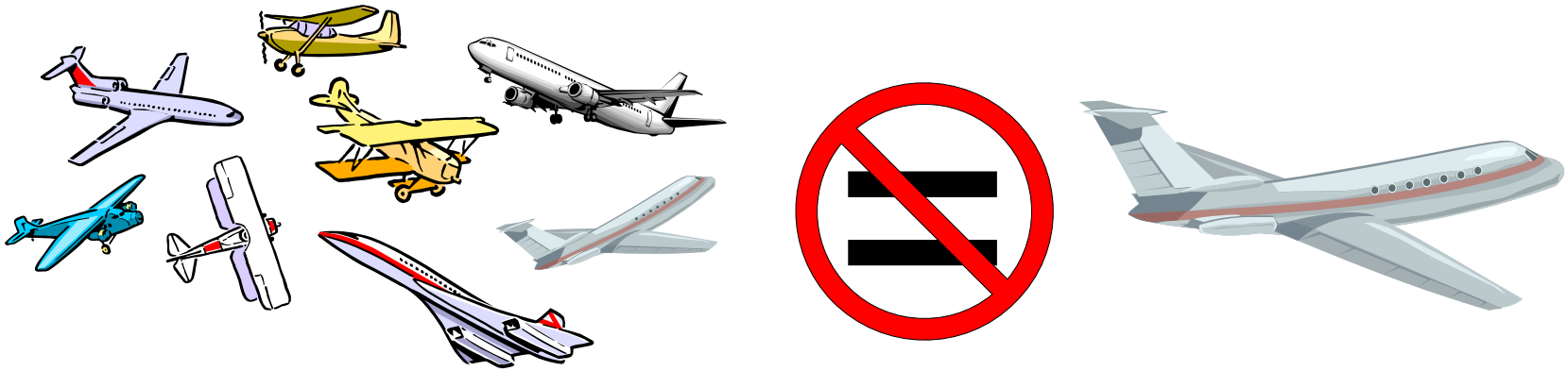
Airplane Name	Gross Wt. lbs	Annual Departures	CDF Contribution	CDF Max for Airplane
Chk.Arrow-PA-28-200	2,500	3,000	0	0
Citation-550B	15,000	3,000	0	0
Challenger-CL-604	48,200	500	0.94	0.94
BeechJet-400A	16,300	3,000	0	0
BeechJet-400	15,500	3,000	0	0
Sngl Whl-10	10,000	5,000	0	0
Dual Whl-30	30,000	3,000	0.06	0.07

One Airplane easily controls the design – even at a low departure levels



Condition specific and not a general representation of noted aircraft

Remember



Must use the entire traffic mixture

No more "Design Aircraft"

Comparisons between new and previous design procedures using "design aircraft" for the traffic model will result in significant errors

Traffic Model – Airplane Characteristics

- FAARFIELD program currently provides 198 different aircraft models
- Each model is unique with respect to gross load, load distribution, wheel spacing, and tire pressure
- Gear types identified in accordance with FAA Order 5300.7
  - Eliminates “widebody” terminology

Traffic Model – Gear Naming Convention

Main Gear Designation **Body/Belly Gear Designation**

 # X # / # X #

# of gear types in tandem
(A value of 1 is omitted for simplicity.)

Gear type, e.g. S, D, T, or Q

# of main gears in line on one side of the aircraft
(Assumes gear is present on both sides. The value indicates number of gears on one side. A value of 1 is omitted for simplicity.)

Total # of body/belly gears
(Because body/belly gear may not be symmetrical, the gear must identify the total number of gears present and a value of 1 is not omitted if only one gear exists.)

Gear type, e.g. S, D, T, or Q

# of gear types in tandem
(A value of 1 is omitted for simplicity.)

Traffic Model – Gear Naming Convention

Single	Dual	Triple	Quadruple
S	**D**	**T**	**Q**

Traffic Model – Gear Naming Convention

Single
S

Dual
D

Triple
T

Quadruple
Q

2 Singles in Tandem
2S

2 Duals in Tandem
2D

2 Triples in Tandem
2T

2 Quadruples in Tandem
2Q

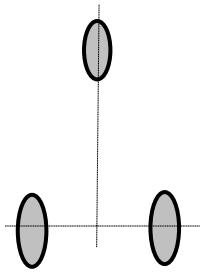
3 Singles in Tandem
3S

3 Duals in Tandem
3D

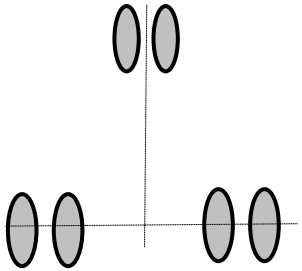
3 Triples in Tandem
3T

3 Quadruples in Tandem
3Q

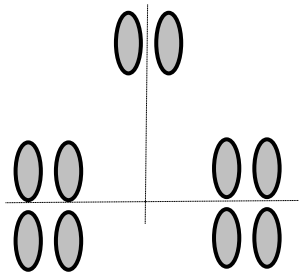
Chapter 3 - Pavement Design -- Examples



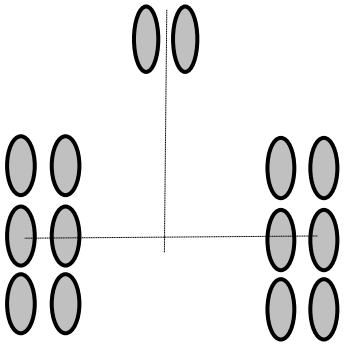
S
Single Wheel



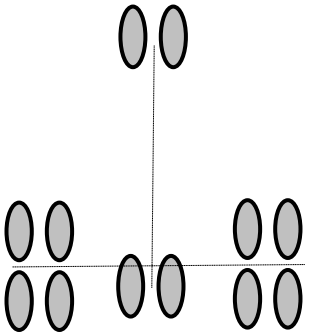
D
Dual Wheel



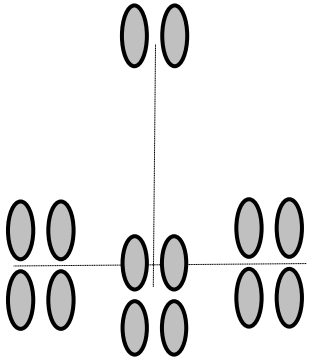
2D
Dual Tandem



3D
B777

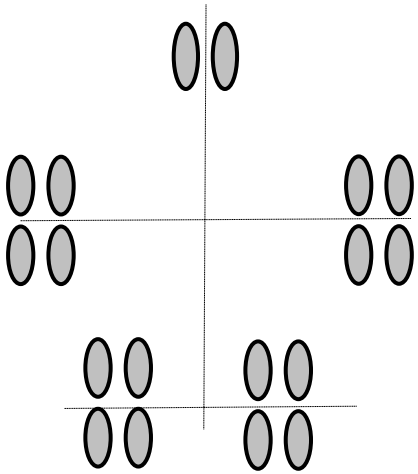


2D/D1
DC-10

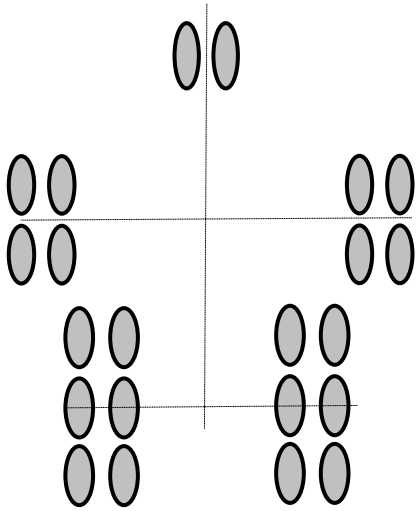


2D/2D1
A340-600

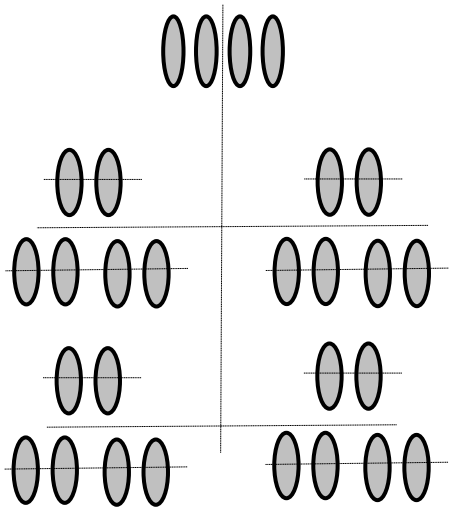
Chapter 3 - Pavement Design -- Examples



2D/2D2
B747



2D/3D2
A380



C5
Lockheed C5

Traffic Model – Pass to Coverage (P/C) Ratio

- Lateral movement is known as airplane wander and is modeled by statistically normal distribution.
  - Standard Deviation = 30.435 inches (773 mm)
- (P/C) -The ratio of the number of trips (or passes) along the pavement for a specific point on the pavement to receive one full-load application.
- -6E utilizes new procedure for determining P/C

Traffic Model – Pass to Coverage (P/C) Ratio

- Rigid Pavement

  One Coverage = One full stress application to the bottom of the PCC layer

- Flexible Pavement

  One Coverage = One repetition of maximum strain at the top of the subgrade layer

Traffic Model – Pass to Coverage (P/C) Ratio

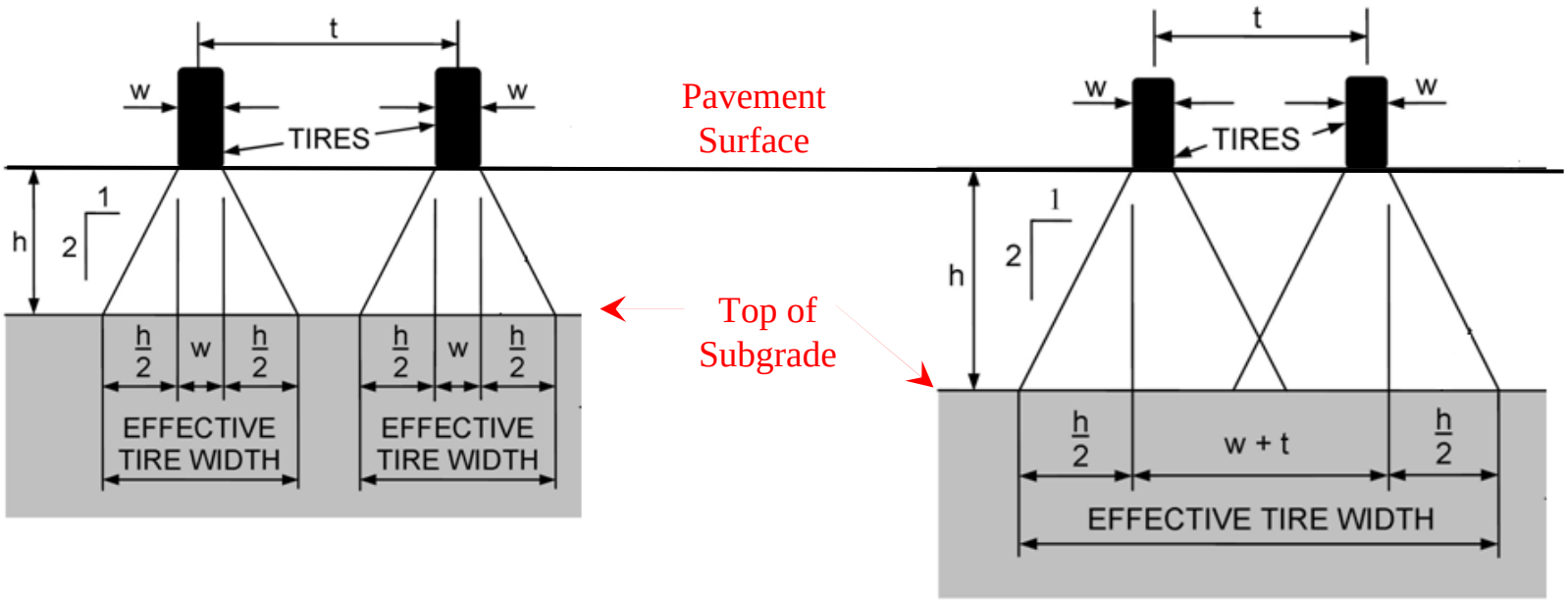
- -6E (FAARFIELD) uses the concept of "Effective Tire Width"
- Rigid Pavement – Effective width is defined at the surface of the pavement (equal to tire contact patch)

  (same as previous P/C procedures)

- Flexible Pavement – Effective width is defined at the surface of the subgrade layer

Traffic Model – Pass to Coverage (P/C) Ratio

Flexible pavement P/C ratio varies with depth of pavement



Chapter 3 - Pavement Design – Frost Design

FROST DESIGN - 3 options

- Complete Frost Protection
  - Remove frost susceptible materials to below frost depth
- Limited Frost Protection
  - Remove frost-susceptible material to 65% frost depth
  - Limits frost heave to tolerable level
- Reduced Subgrade Strength
  - Reduce subgrade support value
  - Design adequate load carrying capacity for weakened condition

Chapter 3 - Pavement Design – Typical Sections

- **Airport pavements are generally constructed in uniform, full width sections**

- **Variable sections are permitted on runway pavements**

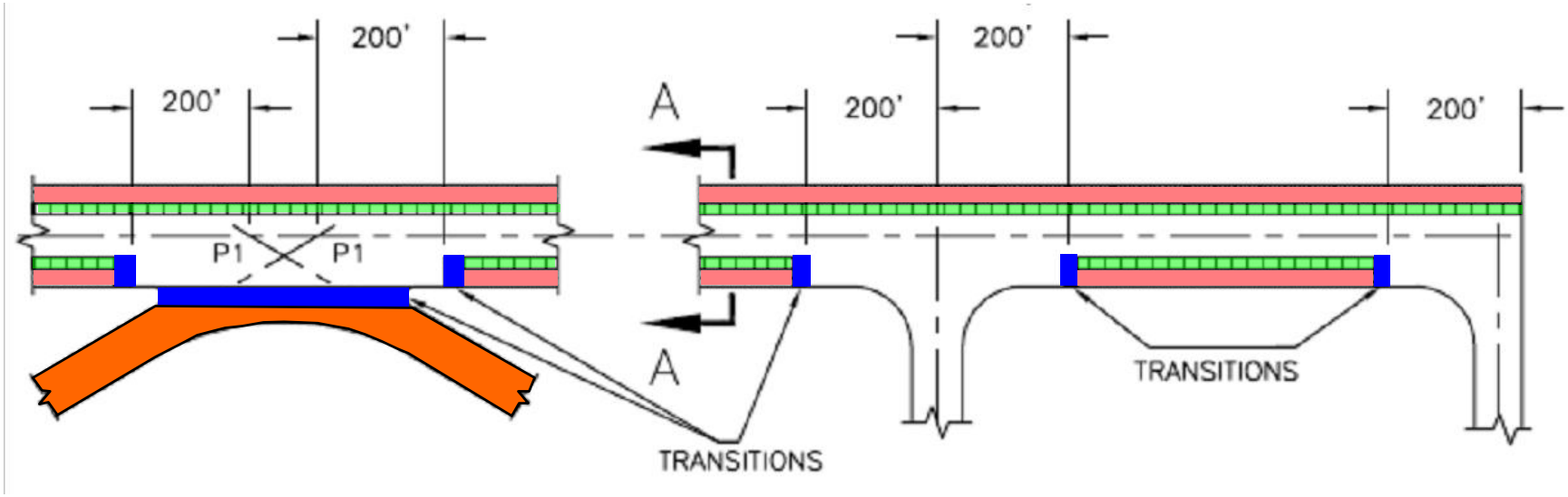
  Designer should consider:

  Practical feasibility – complex construction operations

  Economical feasibility – cost of complex construction

Chapter 3 - Pavement Design – Typical Sections

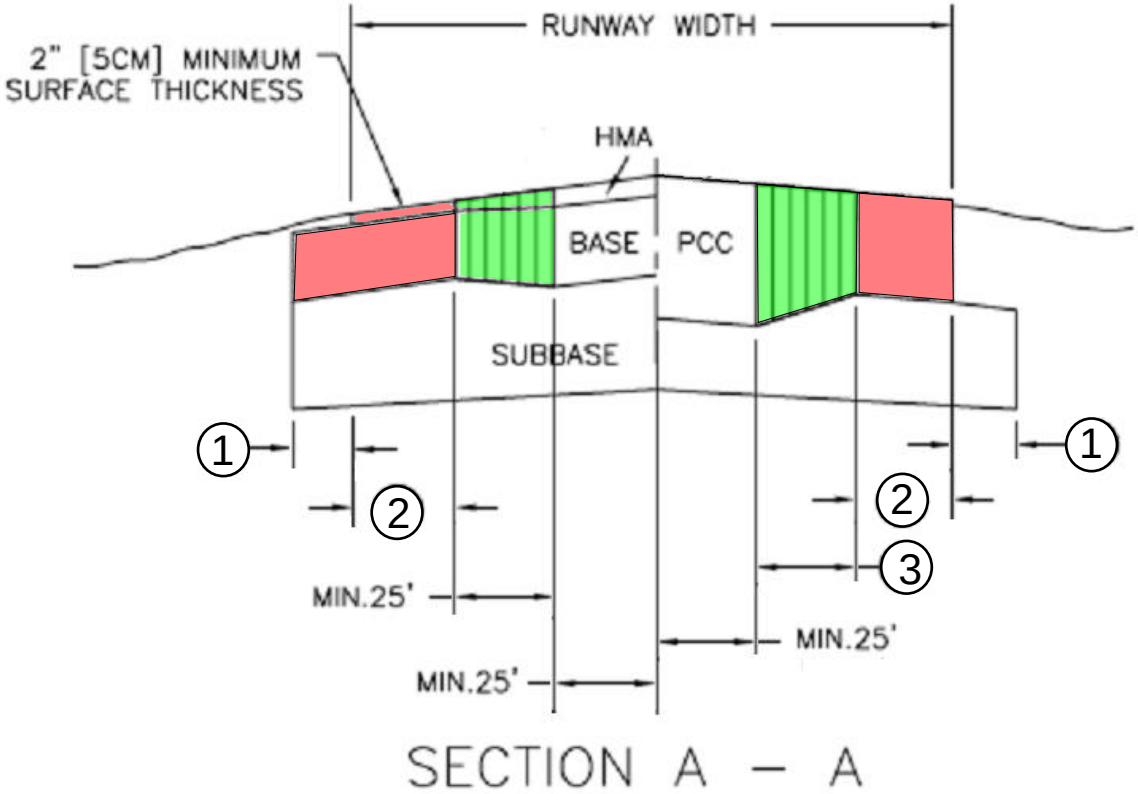
Variable sections permitted on runway pavements



- Full pavement thickness
- Outer edge thickness (based on 1% of normal traffic)
- Pavement thickness tapers to outer edge thickness
- Transitions
- Design using arrival traffic only

Chapter 3 - Pavement Design – Typical Sections

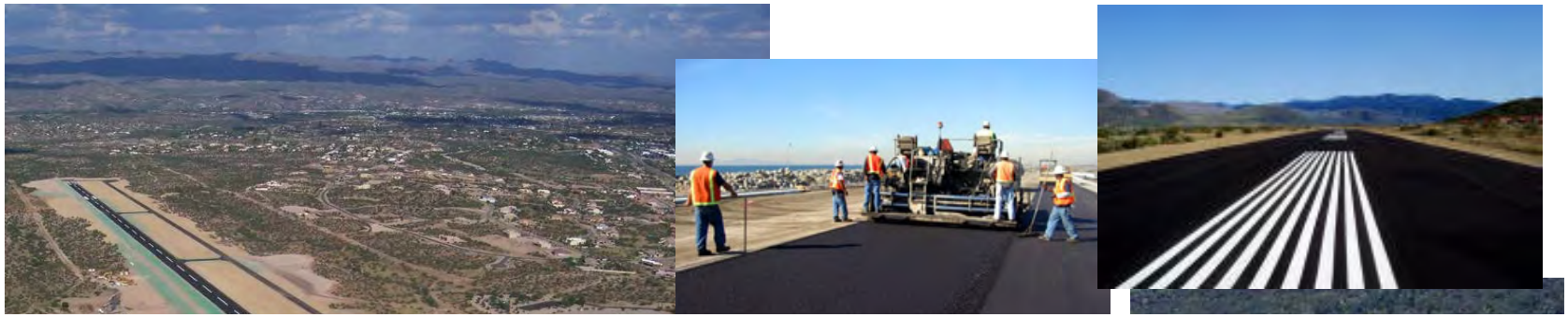
Variable sections permitted on runway pavements



1. Minimum 12” up to 36”
2. For runways wider than 150’, this dimension will increase.
3. Width of tapers and transitions on rigid pavements must be an even multiple of slabs, minimum one slab width.

- Full pavement thickness
- Outer edge thickness (1% traffic)
- Pavement thickness tapers to outer edge thickness

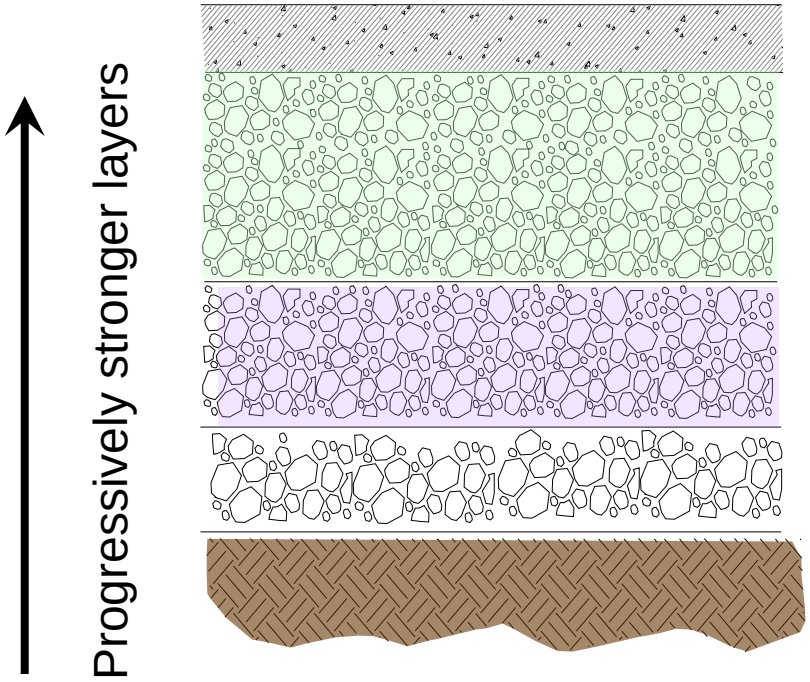
FLEXIBLE PAVEMENT DESIGN



AC 150/5320-6E, Airport Pavement Design and Evaluation

CHAPTER 3, Section 2 – Flexible Pavement Design

Typical Flexible Pavement



Hot-Mix Asphalt Surface

Base Course (Minimum CBR=80)
(May Require Stabilization)

Subbase (Minimum CBR=20)
(May Require Stabilization)

Frost Protection (As Appropriate)

Subgrade

Chapter 3 Section 2 – Flexible Pavement Design

Surface	BASE	SUBBASE	SUBGRADE
P-401	P-209	P-154	P-152
P-403	P-208	P-210	P-155*
	P-211	P-212	P-157*
	P-304*	P-213	P-158*
	P-306*	P-301*	
	P-401*		
	P-403*		
	Rubblized PCC		

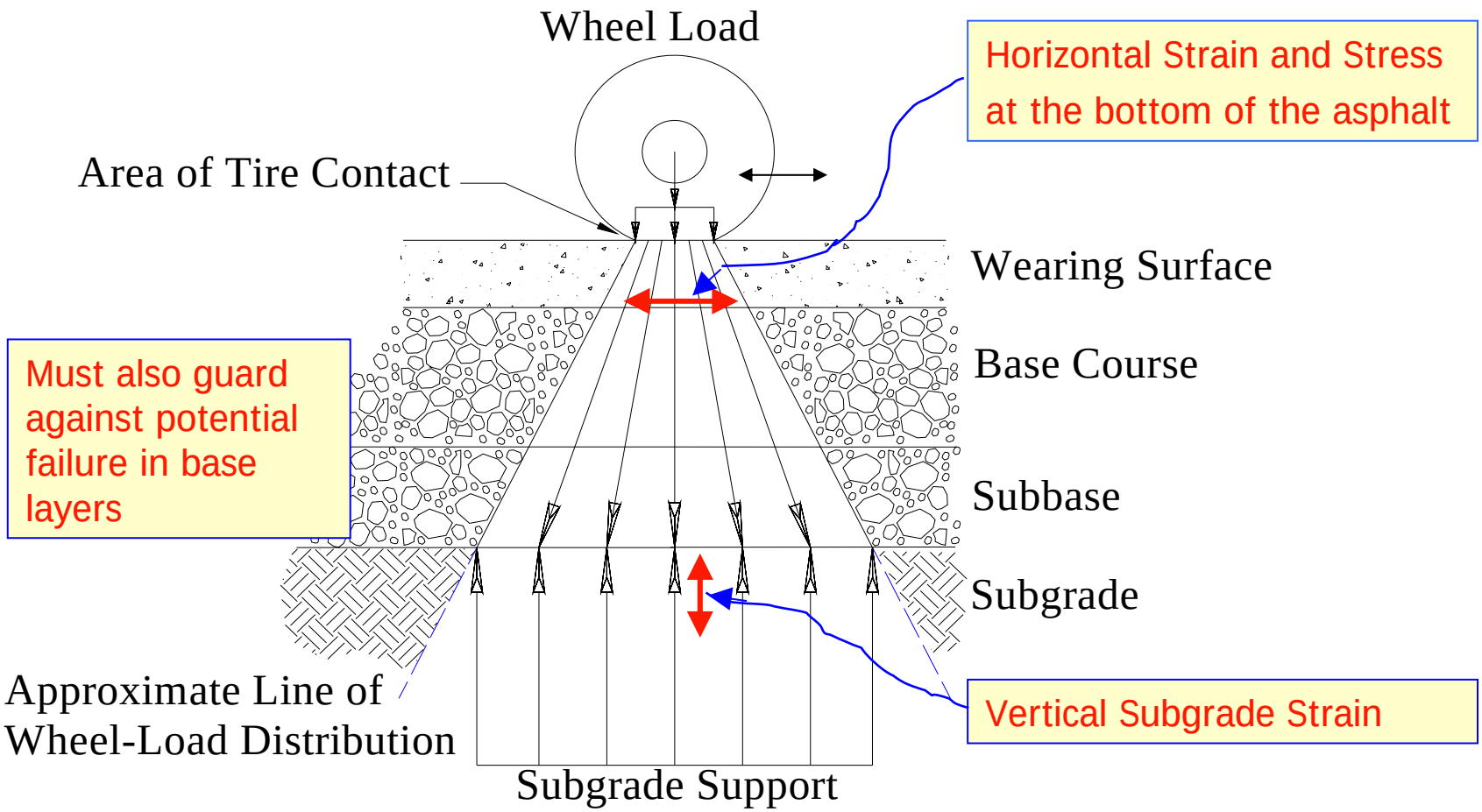
* Chemically Stabilized Materials

Flexible Pavement Design based on Layered Elastic Design (LED)

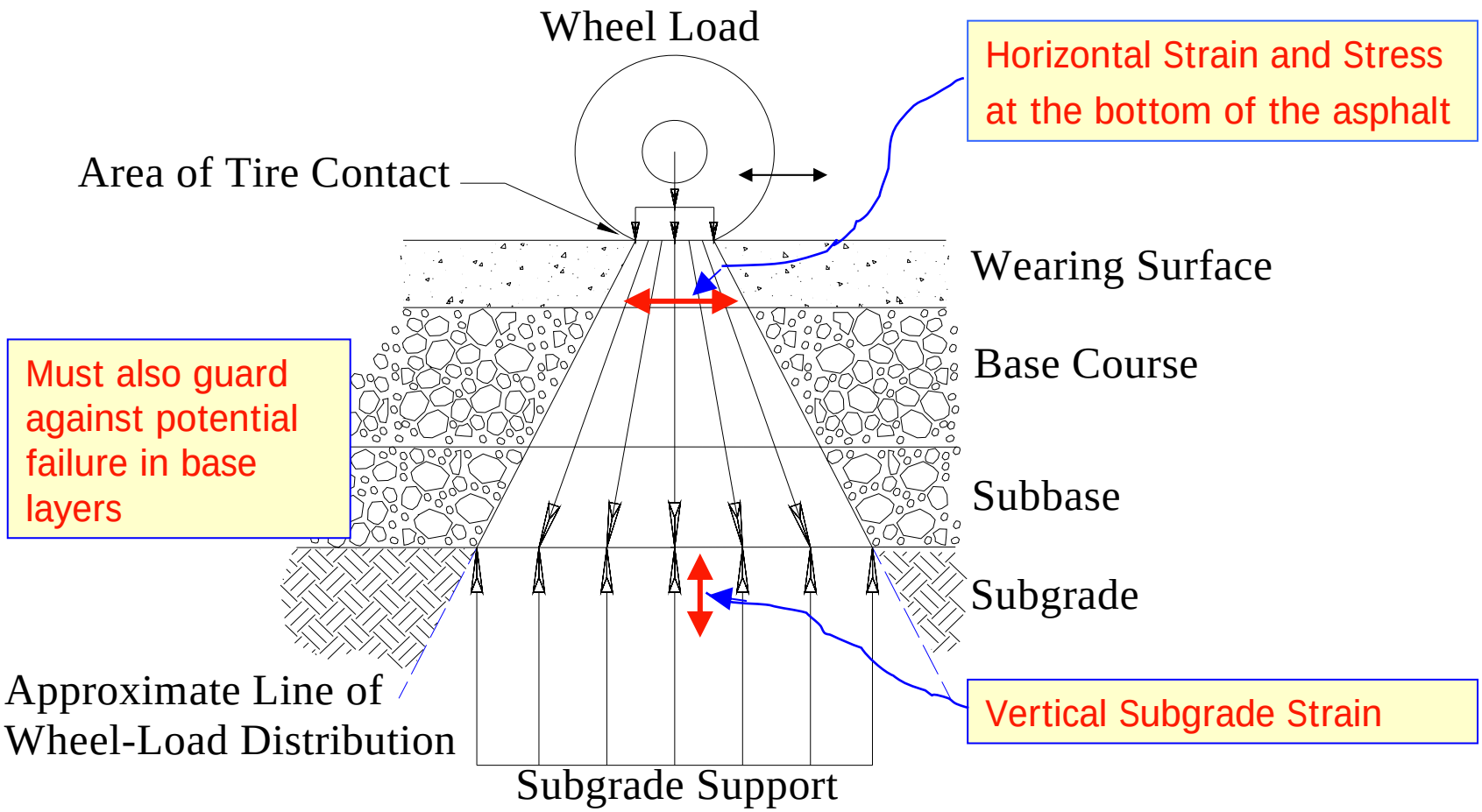
- Same as previously permitted in Chp 7 of -6D
  - Predictors of pavement life (FAARFIELD)
    - Maximum vertical strain at the top of subgrade and
    - Maximum horizontal strain at bottom of asphalt surface layer

      **By default, FAARFIELD does not automatically check horizontal stain in asphalt surface layer. Users can select this manually

Chapter 3 Section 2 – Flexible Pavement Design

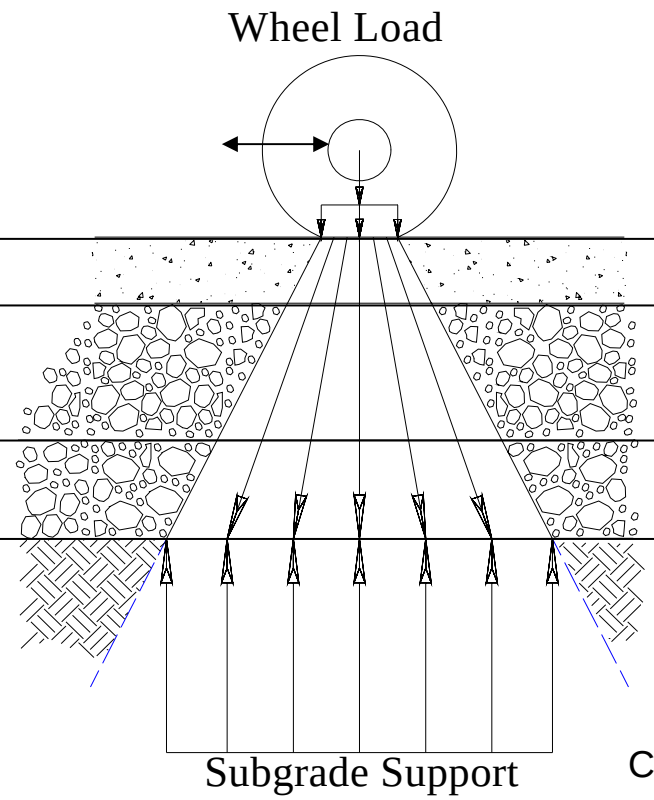


Chapter 3 Section 2 – Flexible Pavement Design



Flexible Pavement Layer Parameters- LED vs CBR

LAYERED ELASTIC METHOD		CBR Method
SURFACE	E_S, μ_S, h	*Not Defined*
BASE	E_B, μ_B, h_B	*CBR*
SUBBASE	E_{SB}, μ_{SB} h_{SB}	*CBR*
SUBGRADE	E_{SG}, μ_{SG} h_{SG}	*CBR*



E = Elastic Modulus
h = thickness
μ = Poisson's Ratio

CBR = California Bearing Ratio

FAARFIELD Default Values

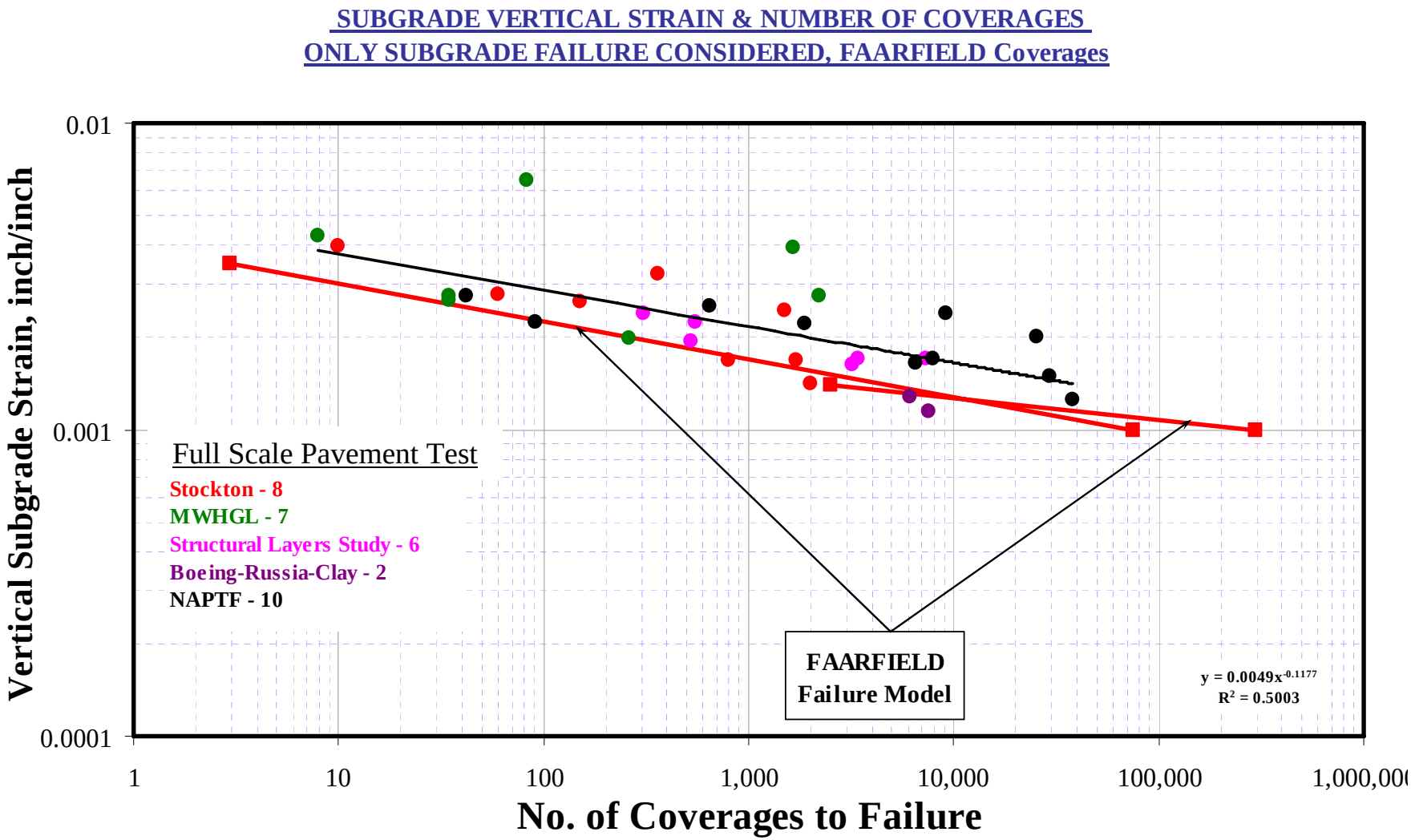
LAYER	ITEM	E (psi)	POISSON'S	FAA EQUIV
AC Surface	P401/403	200,000	0.35	NA
PCC Surface	P501	4,000,000	0.15	NA
Aggregate Base	P209	MODULUS	0.35	NA
Aggregate Subbase	P154	MODULUS	0.35	NA
AC Base	P401/403	400,000	0.35	1.6
AC Base (min)	Variable	150,000	0.35	1.2
AC Base (max)	Variable	400,000	0.35	1.6
CTB (min)	P301	250,000	0.20	NA
CTB	P304	500,000	0.20	NA
CTB (max)	P306	700,000	0.20	NA
Undefined (min)		1,000	0.35	NA
Undefined (max)		4,000,000	0.35	NA
Rubblized PCC (min)	EB66	200,000*	0.35	NA
Rubblized PCC (max)	EB66	400,000*	0.35	NA

** Still subject to change

Pavement Structural Design Life

- Default “design life” is for 20 years
- Structural design life indicates pavement performance in terms of allowable load repetitions before subgrade failure is expected.
- Structural life is determined based upon annual departures multiplied by 20 (yrs). This value may or may not correlate with calendar years depending upon actual pavement use.
- Pavement performance in terms of surface condition and other distresses which might affect the use of the pavement by airplanes is not directly reflected in the structural design life.

Chapter 3 Section 2 – Flexible Pavement Design



Chapter 3 Section 2 – Flexible Pavement Design

Vertical Strain at top of subgrade

$$C = \left(\frac{0.004}{\varepsilon_v} \right)^{8.1}$$

When C ≤ 12,100

$$C = \left(\frac{0.002428}{\varepsilon_v} \right)^{14.21}$$

When C > 12,100

Horizontal Strain at Bottom of Surface Layer

$$Log_{10}(C) = 2.68 - 5 \times Log_{10}(\varepsilon_h) - 2.665 \times Log_{10}(E_A)$$

REQUIRED INPUT VARIABLES

- Subgrade support conditions
  - CBR or Modulus
- Material properties of each layer
  - Modulus
  - Thickness for most layers
  - Poisson's Ratio -- fixed in FAARFIELD
- Traffic
  - Frequency of load application
  - Airplane characteristics
    - Wheel load, wheel locations, & tire pressure

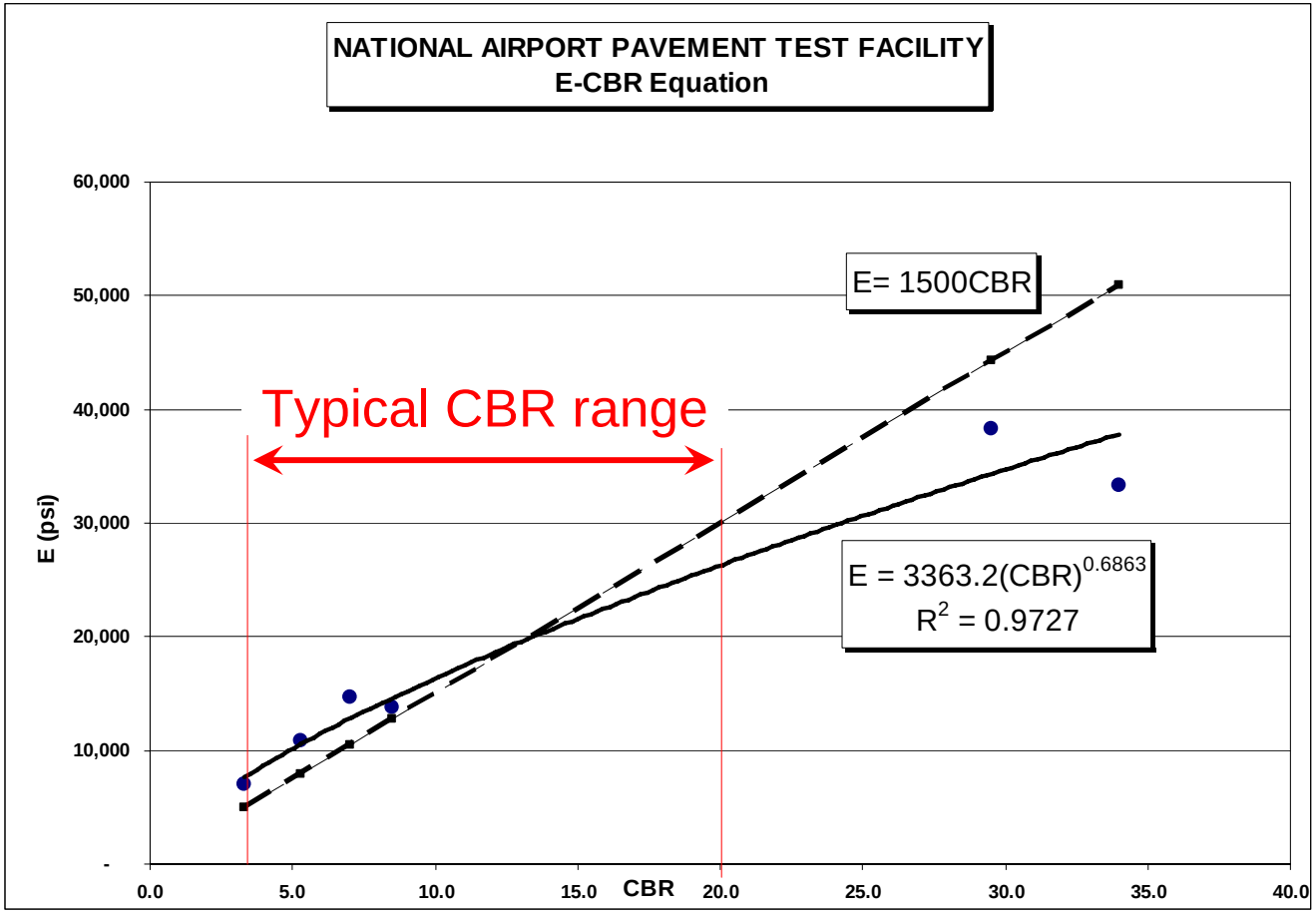
Subgrade Characteristics

- Subgrade assumed to have infinite thickness
- FAARFIELD will accept Elastic Modulus E (psi) or CBR values
- CBR is widely accepted and used by the industry
  - Relationship between E and CBR

$$E = 1500 \times CBR \quad (E \text{ in psi})$$

Subgrade Characteristics

E = 1500 X CBR



Subgrade Compaction Requirements – Table 3-4

Determined by airplane (in the traffic mix) with greatest demand

Indicates depth of compaction below subgrade

CRITICAL AIRCRAFT	Gross Weight Lb.	NON-COHESIVE SOILS Depth of Compaction, inch				COHESIVE SOILS Depth of Compaction, inch			
		100%	95%	90%	85%	95%	90%	85%	80%
S	30,000	8	8-18	18-32	32-44	6	6-9	9-12	12-17
	50,000	10	10-24	24-36	36-48	6	6-9	9-16	16-20
	75,000	12	12-30	30-40	40-52	6	6-12	12-19	19-25
D (incls. 2S)	50,000	12	12-28	28-38	38-50	6	6-10	10-17	17-22
	100,000	17	17-30	30-42	42-55	6	6-12	12-19	19-25
	150,000	19	19-32	32-46	46-60	7	7-14	14-21	21-28
	200,000	21	21-37	37-53	53-69	9	8-16	16-24	24-32
2D/D1, 2D/2D1 (incls. B757, B767, A-300, DC-10, L1011,A-340)	100,000	14	14-26	26-38	38-49	5	6-10	10-17	17-22
	200,000	17	17-30	30-43	43-56	5	6-12	12-18	18-26
	300,000	20	20-34	34-48	48-63	7	7-14	14-22	22-29
	400,000 – 600,000	23	23-41	41-59	59-76	9	9-18	18-27	27-36
2D/2D2 (incls. B747 series)	800,000	23	23-41	41-59	59-76	9	9-18	18-27	27-36
	975,000	24	24-44	44-62	62-78	10	10-20	20-28	28-37
3D (incls. B777 series)	550,000	20	20-36	36-52	52-67	6	6-14	14-21	21-29
	650,000	22	22-39	39-56	56-70	7	7-16	16-22	22-30
	750,000	24	24-42	42-57	57-71	8	8-17	17-23	23-30
2D/3D2 (incls. A380 series)	1,250,000	24	24-42	42-61	61-78	9	9-18	18-27	27-36
	1,350,000	25	25-44	44-64	64-81	10	10-20	20-29	29-38

Subgrade Compaction Requirements –Example

Cohesive soil,

Given the following traffic mixture

Airplane	Gross Weight (lbs)	Annual Departures
Sngl Whl-45	50,000	1000
A318-100 std	122,000	2000
B737-400	150,500	3000
B747-400	877,000	1600
B777-300 Baseline	662,000	1750
A330-300 opt	515.661	1500

Subgrade Compaction Requirements –Example

Cohesive soil,

Required depth of compaction from Table 3-4

Airplane	Gross Weight (lbs)	Annual Departures	95%	90%	85%	80%
Sngl Whl-45	50,000	1000	6	6-9	9-16	12-17
A318-100 std	122,000	2000	6	6-12	12-19	19-25
B737-400	150,500	3000	7	7-14	14-21	21-28
B747-400	877,000	1600	10	10-20	20-28	28-37
B777-300 Baseline	662,000	1750	7	7-16	16-22	22-30
A330-300 opt	515.661	1500	9	9-18	18-27	27-36

Asphalt Surface Layer Characteristics

- Minimum material requirements
  - P-401 or P-403
- Modulus fixed at 200,000 psi in FAARFIELD
  - Conservatively chosen to correspond to pavement surface temperature of 90° F
- 4 inch minimum thickness
- Asphalt as overlay has the same properties except for minimum thickness

Base Layer Characteristics

- Minimum material requirements
  - P-209, P-208, P-211, P-304, P-306, P-401, P-403, & rubblized PCC
- Design assumes minimum strength – CBR $\geq$ 80
- Aggregate layer modulus dependent on thickness
  - Modulus calculated by FAARFIELD is dependent on thickness
- Stabilization required - airplane gross weight > 100,000 lbs
- Minimum thickness requirements – by airplane

Chapter 3 Section 2 – Flexible Pavement Design

Minimum Aggregate Base Layer Thickness Requirements

Determined by the airplane in the traffic mix with greatest demand

Determination of minimum base layer thickness is automated in FAARFIELD

TABLE 3-9. Minimum Aggregate Base Course Thickness

Gear Type	Design Load Range lbs	Minimum Base Course (P-209) Thickness in.
S	30,000 - 50,000	4
	50,000 - 75,000	6
D	50,000 - 100,000	6
	100,000 - 200,000*	8
2D	100,000 - 250,000*	6
	250,000 - 400,000*	8
2D (B757, B767)	200,000 - 400,000*	6
2D/D1 (DC10, L1011)	400,000 - 600,000*	8
2D/2D2 (B747)	400,000 - 600,000*	6
	600,000 - 850,000*	8
2D/2D1 (A340)	568,000 – 840,400	10
2S (C130)	75,000 - 125,000	4
	125,000 - 175,000*	6
3D (B777)	537,000 – 777,000*	10
3D (A380)	1,239,000 – 1,305,125*	9

*Values are listed for reference. When traffic mixture contains airplanes exceeding 100,000 lbs gross weight, a stabilized base is required.

Base Layer Characteristics –When stabilization is required

FAARFIELD automates this process

- Changes section to P-401 on P-209 over CBR=20
- Determines P-209 thickness requirement
- Converts P-209 to stabilized material using 1.6 conversion factor
- Reconstructs section with minimum base and finishes design

User can disable this feature of FAARFIELD and do this process manually if desired.

Subbase Layer Characteristics

- Minimum material requirements
  - P-154, P-210, P-212, P-213, P-301,
- Design assumes minimum strength – CBR > 20
- Aggregate layer modulus dependent on thickness
  - Modulus calculated by FAARFIELD is dependent on thickness
- Thickness requirement determined as design solution

Subbase Layer Characteristics – When Stabilization is required

- Minimum material requirements
  - P-208 or P-209, or any stabilized base material
- Thickness requirement determined as design solution

Traffic Input for Flexible Pavement Design

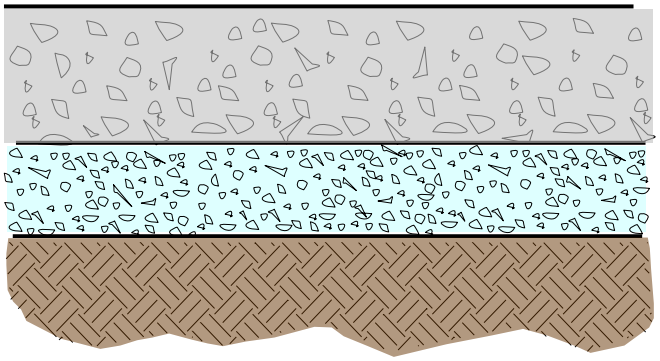
- Airplane characteristics
  - 198 Airplane models currently available in FAARFIELD
  - Wheel load – determined automatically based on gross weight
  - wheel locations – Internal to FAARFIELD aircraft library
  - tire pressure – Internal to FAARFIELD aircraft library
- Frequency of load application
  - Entered as annual departures
    - Arrival traffic ignored

RIGID PAVEMENT DESIGN

AC 150/5320-6E, Airport Pavement Design and Evaluation

CHAPTER 3, Section 3 – Rigid Pavement Design

Typical Rigid Pavement



Portland Cement Concrete (PCC)

Subbase Course **

Subgrade

** Stabilization required when airplanes exceeding 100,000 lbs are in the traffic mixture.

Chapter 3 Section 3 – Rigid Pavement Design

Surface	SUBBASE	SUBGRADE
P-501	P-154	P-152
	P-208	P-155*
	P-209	P-157*
	P-211	
	P-301	
	P-304*	
	P-306*	
	P-401*	
	P-403*	
	Rubblized PCC	

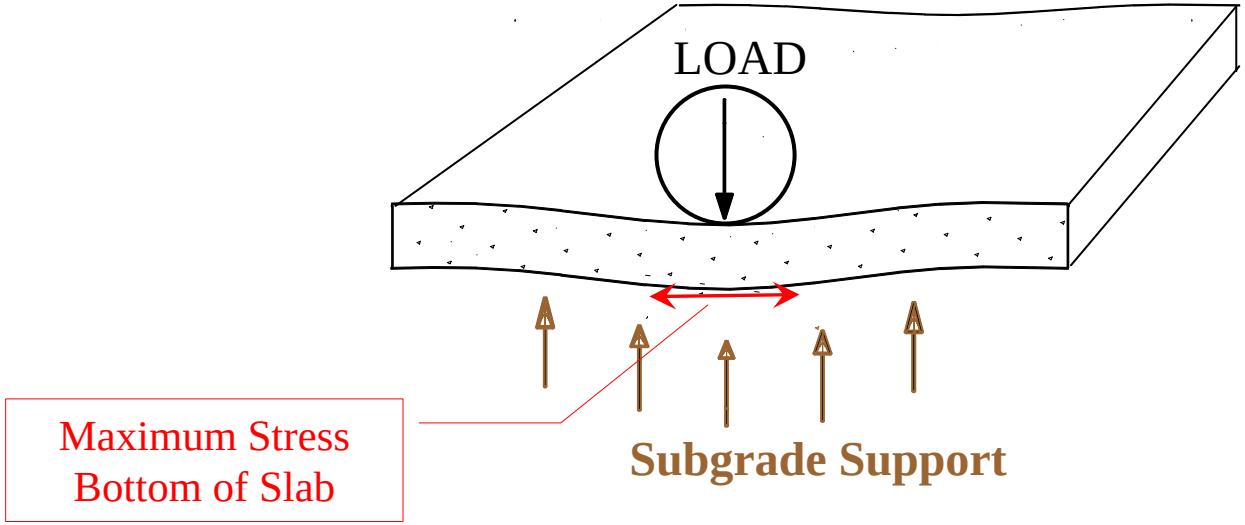
* Chemically Stabilized Materials

3-Dimensional Finite Element Design

- NEW procedure
- Rigid design uses 3-D finite element method (3D-FEM) for direct calculation of stress at the edge of a concrete slab.
- Predictor of pavement life
  - Maximum Stress at pavement edge
  - Assumed position – bottom at slab edge

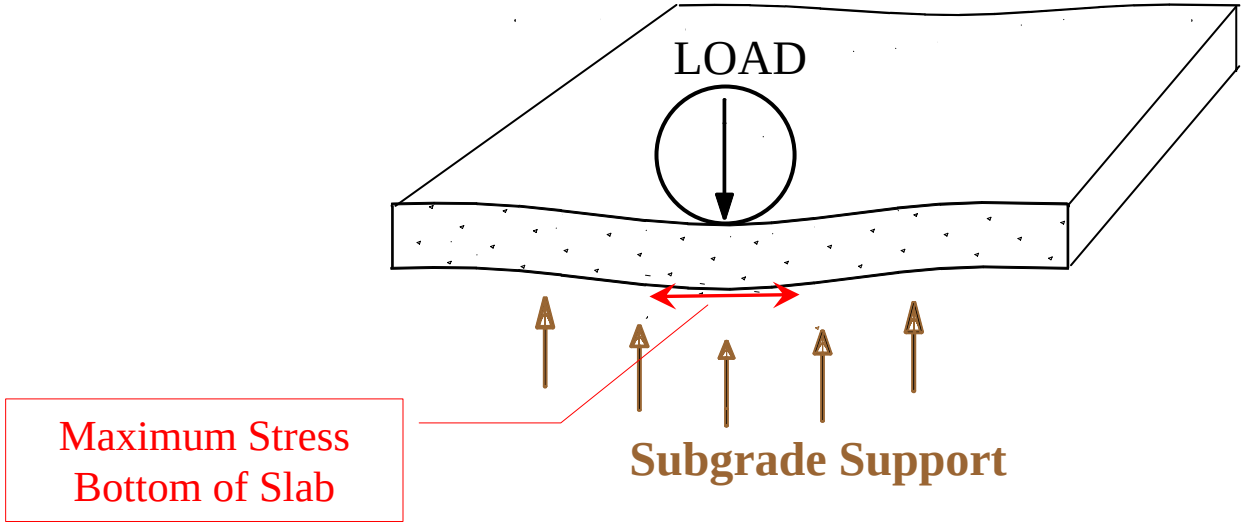
CRITICAL LOAD CONDITION ASSUMPTIONS

- Maximum stress at pavement edge
- 25% Load Transfer to adjacent slab



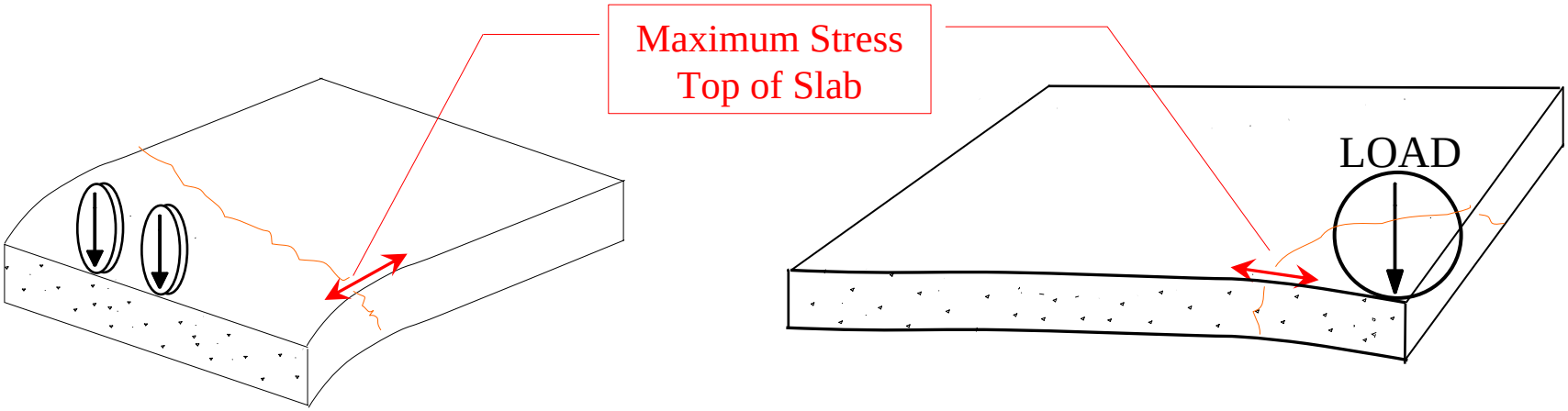
CRITICAL LOAD CONDITION ASSUMPTIONS

- Maximum stress at pavement edge
- 25% Load Transfer to adjacent slab

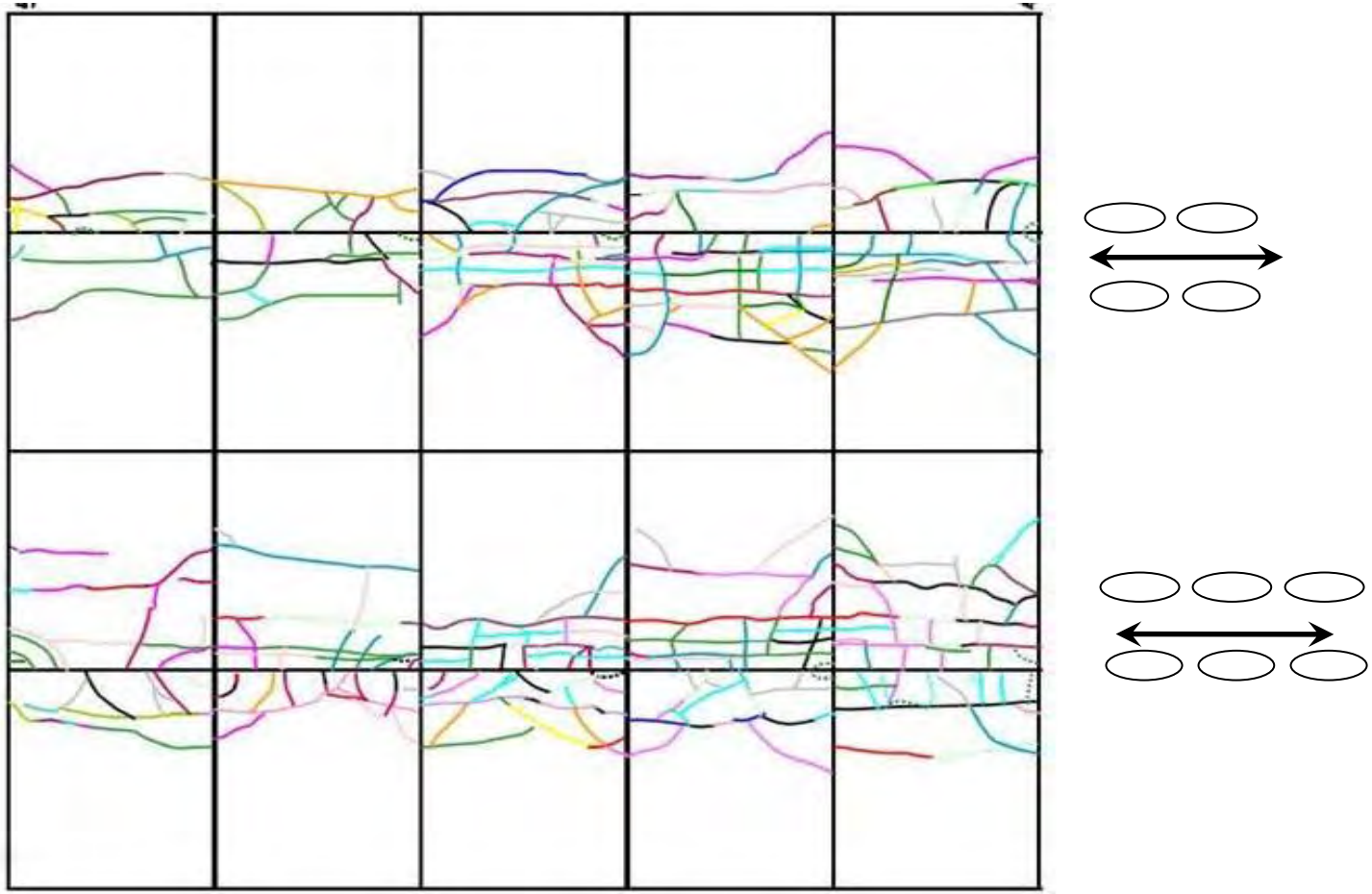


TOP DOWN CRACKING DUE TO EDGE OR CORNER LOADING NOT INCLUDED IN DESIGN

- Maximum stress due to corner or edge loading condition
- Risk increases with large multi-wheel gear configurations
- These conditions may need to be addressed in future procedures



Chapter 3 Section 3 – Rigid Pavement Design
Observed Cracking at NAPTF



Pavement Structural Design Life

- Default “design life” is for 20 years
- Structural design life indicates pavement performance in terms of allowable load repetitions before “First Crack” i.e. SCI = 80.
- Structural life is determined based upon annual departures multiplied by 20 (yrs). This value may or may not correlate with calendar years depending upon actual pavement use.
- Pavement performance in terms of surface condition and other distresses which might affect the use of the pavement by airplanes is not directly reflected in the structural design life.

Rigid pavement failure model in FAARFIELD

$$\frac{DF}{F_c} = \left[\frac{F_s' bd}{\left(1 - \frac{SCI}{100}\right)(d - b) + F_s' b} \right] \times \log C + \left[\frac{\left(1 - \frac{SCI}{100}\right)(ad - bc) + F_s' bc}{\left(1 - \frac{SCI}{100}\right)(d - b) + F_s' b} \right]$$

DF **= design factor, defined as the ratio of concrete strength *R* to computed stress**

C **= coverages**

SCI **= structural condition index, defined as a subset of the pavement condition index (PCI) excluding all non-load related distresses from the computation**

a, b, c, d **= parameters**

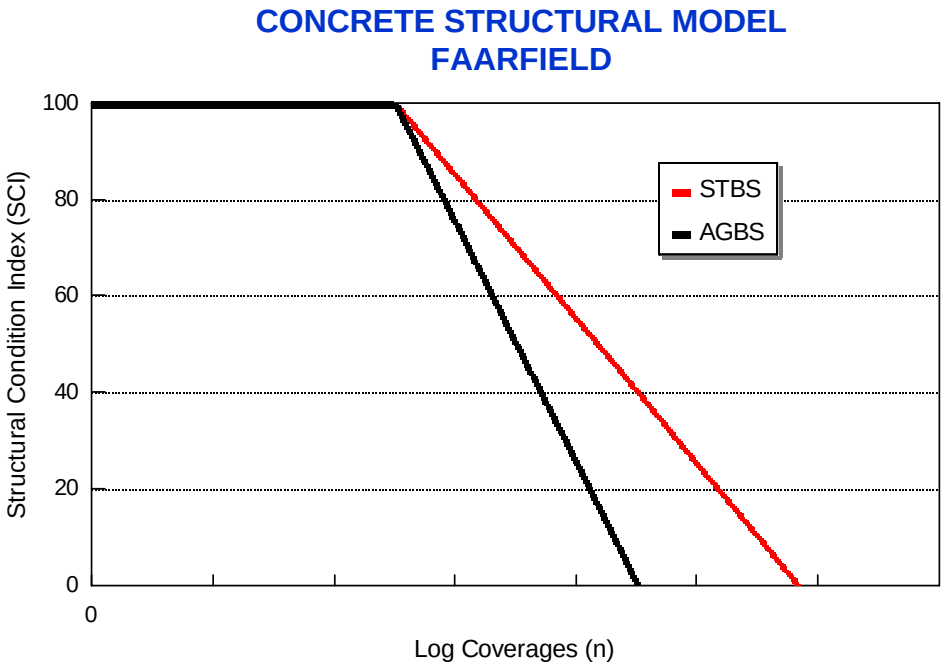
F'_s = compensation factor for high quality and stabilized base

F_c = calibration factor

Rigid pavement failure model in FAARFIELD

Initial cracking occurs at the same time for aggregate and stabilized subbase

Stabilized section performs better (longer life) after initial cracking



REQUIRED INPUT VARIABLES

- Subgrade support conditions
  - k-value or Modulus
- Material properties of each layer
  - Modulus for all layers (flexural strength for PCC)
  - Thickness for all layers except surface PCC
  - Poisson's Ratio – fixed in FAARFIELD
- Traffic
  - Frequency of load application
  - Airplane characteristics
    - Wheel load, wheel locations, & tire pressure

Subgrade Characteristics

- Subgrade assumed to have infinite thickness
- FAARFIELD accepts Resilient Modulus E_{SG} or k-value (only necessary to enter one value)
  - Converts k-value to modulus

$$E_{SG} = 26k^{1.284}$$

E_{SG} = Resilient modulus of subgrade, in psi

k = Foundation modulus of the subgrade, in pci

AASHTO T 222, Nonrepetitive Static Plate Load Test of Soils and Flexible Pavement Components, for Use in Evaluation and Design of Airport and Highway Pavements

Subgrade Characteristics

k-value can be estimated from CBR value

$$k = \left[\frac{1500 \times CBR}{26} \right]^{0.7788}$$

k = Foundation modulus of the subgrade, in pci

Subbase Layer Characteristics

- Minimum material requirements
  - P-154, P-208, P-209, P-211, P-301, P-304, P-306, P-401, P-403, & rubblized PCC
- Up to three subbase layers allowed in FAARFIELD
- Aggregate layer modulus dependent on thickness
  - Modulus calculated by FAARFIELD based on thickness
- 4 inch minimum thickness requirement

Portland Cement Concrete Layer Characteristics

- Minimum material requirements
  - P-501
- Flexural Strength as design variable
  - FAA recommends 600 – 700 psi for design purposes
  - FAARFIELD will allow 500 – 800 psi
  - ASTM C 78 Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading)
  - Modulus fixed at 4,000,000 psi
- 6 Inch minimum thickness requirements
- Thickness rounded to the nearest 0.5 inch

Design Flexural Strength versus P-501 Specification

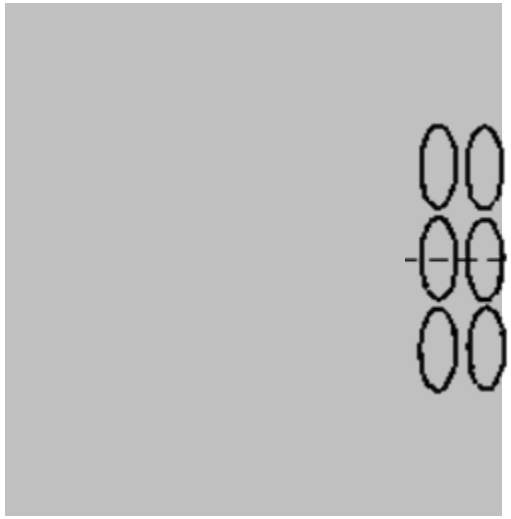
- Design Strength can be 5% greater than P-501 28-day strength
- e.g. P-501 = 650 psi then design at 680 psi
- Factors to Consider:
  - Capability of the industry in a particular area to produce desired strength
  - Flexural strength vs. cement content data from prior projects at the airport
  - Need to avoid high cement contents, which can affect concrete durability
  - Whether early opening requirements necessitate using a lower strength than 28-day

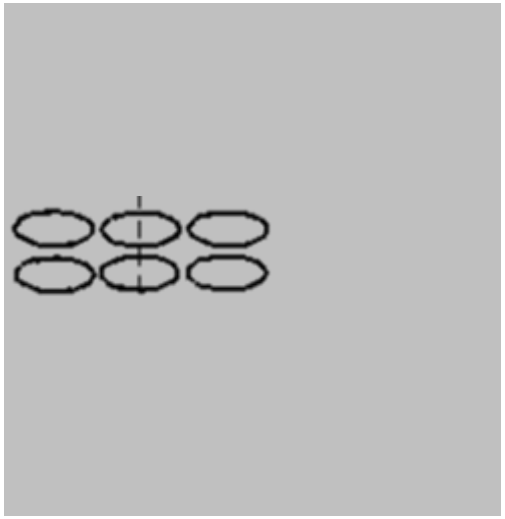
Traffic Input for Rigid Pavement Design

- Airplane characteristics
  - 198 Airplane models currently available in FAARFIELD
  - Wheel load – determined automatically based on gross weight
  - wheel locations – Internal to FAARFIELD aircraft library
  - tire pressure – Internal to FAARFIELD aircraft library
- Frequency of load application
  - Entered as annual departures
    - Arrival traffic ignored
    - User determines percent of total airport volume

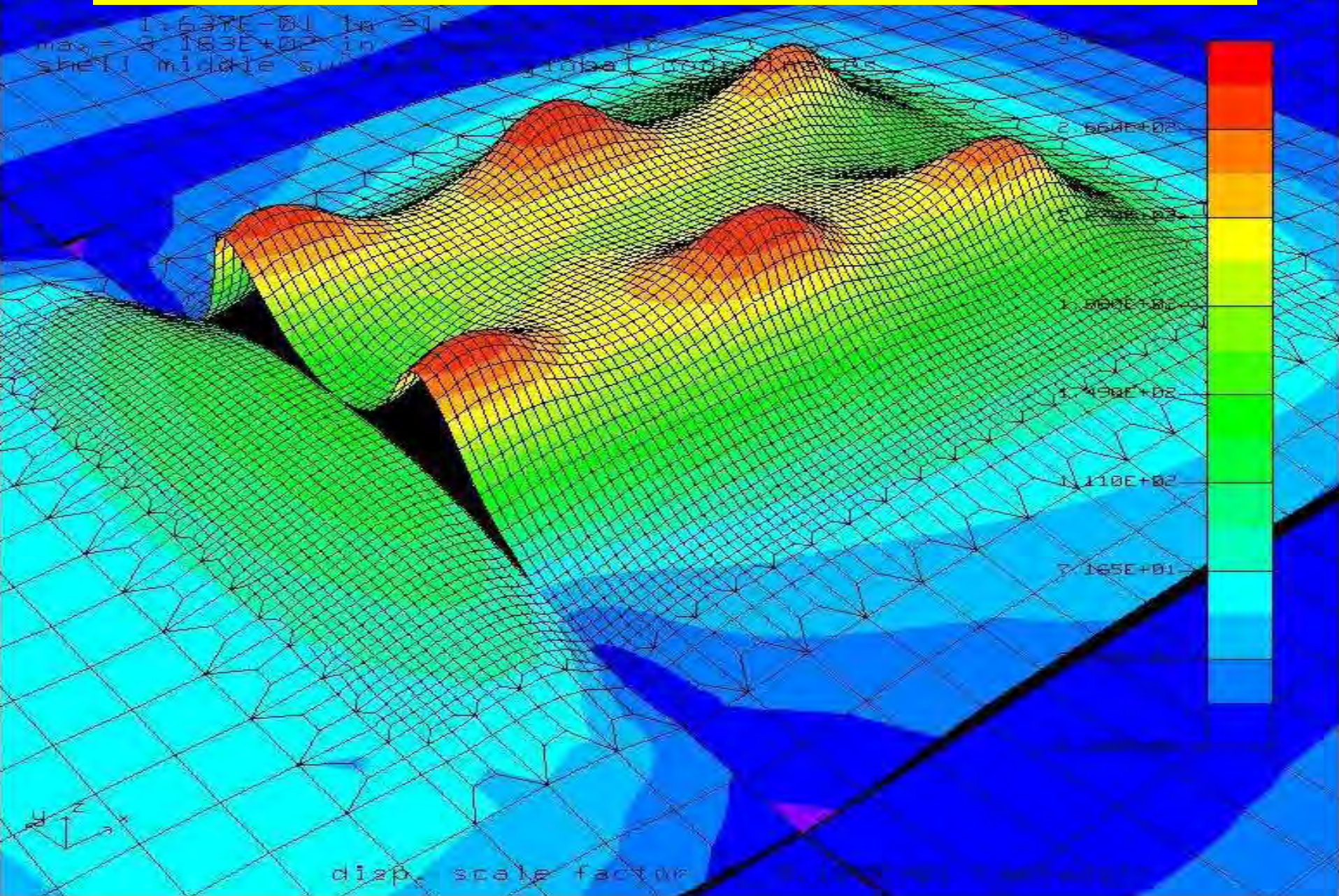
FAArfield – Gear Alignment on slab edge

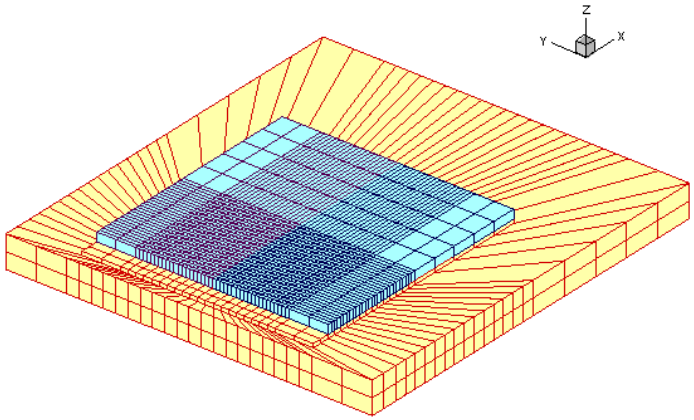
- FAARFIELD either places the gear perpendicular or parallel to the edge of a slab.
- FAARFIELD makes this determination.





3-D Finite Element Model





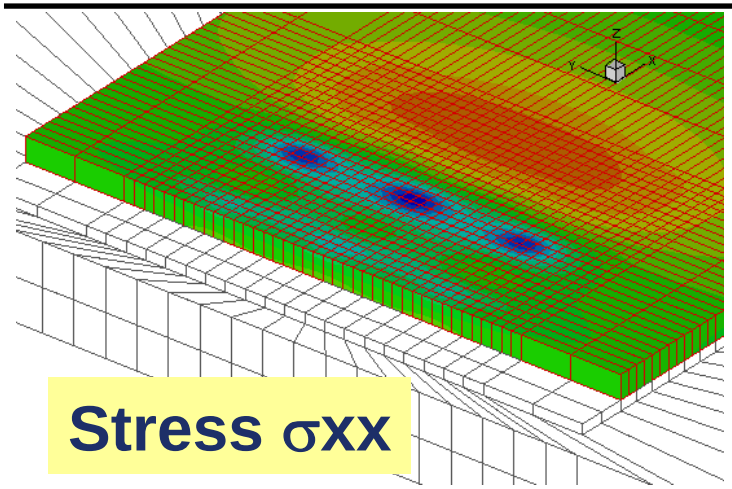
Key Advantages of 3-D Model

- Correctly models rigid pavement features - slab edges and joints.
- Provides the complete stress and displacement fields for the analyzed domain.
- Handles complex load configurations easily.
- No inherent limitation on number of structural layers or material types.
- Not limited to linear elastic analysis.

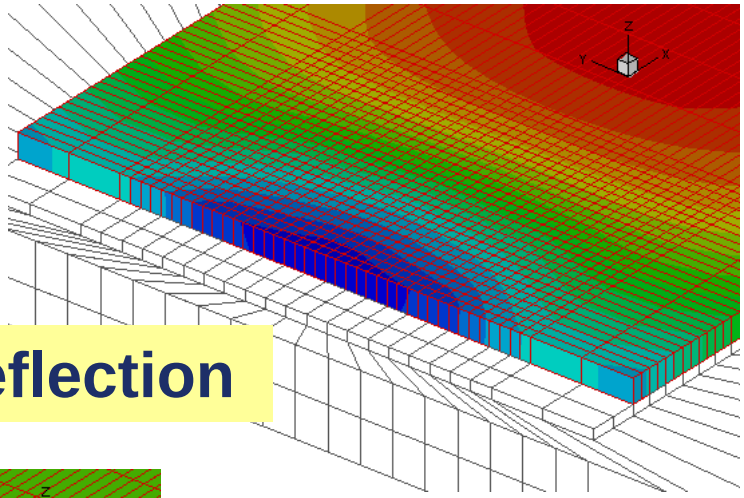
Disadvantages of 3D-FEM

- May require long computation times.
- Pre-processing and post-processing requirements.
- Solution are mesh-dependent.
  - In theory, the solution can always be improved by refining the 3D mesh.
  - Improvement comes at the expense of time.

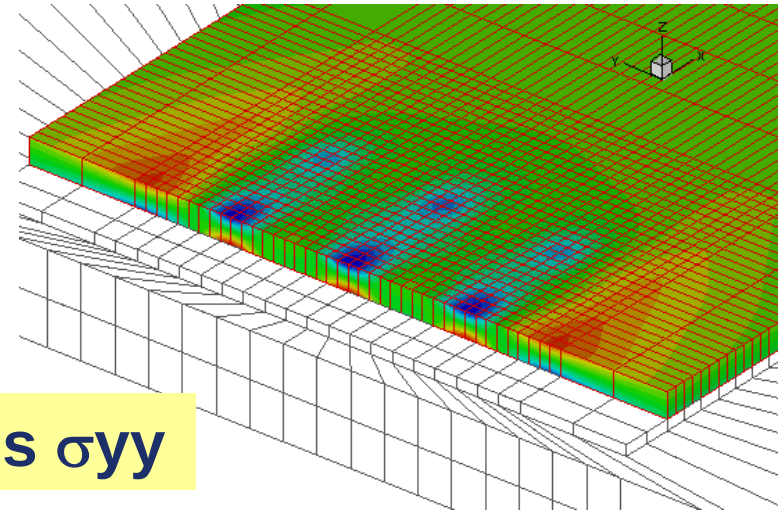
Chapter 3 Section 3 – Rigid Pavement Design
3D-FEM Solution



Stress σxx



Deflection



Stress σyy

3D Finite Element is:

A method of structural analysis.

Applicable to a wide range of physical structures, boundary and loading conditions.

3D Finite Element is <u>not</u>:

A design method or procedure.

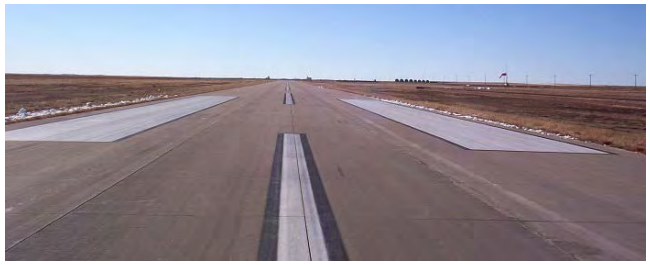
An exact mathematical solution.

Always preferable to other analysis models.

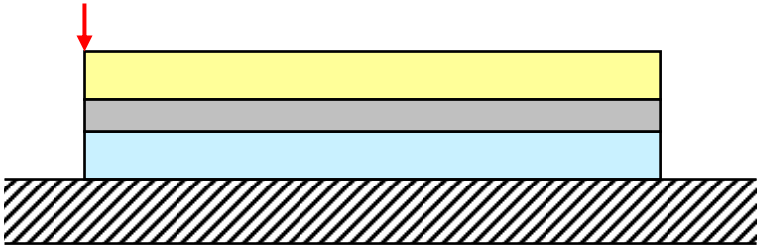
Structures and Models

In finite element analysis, it is important to distinguish:

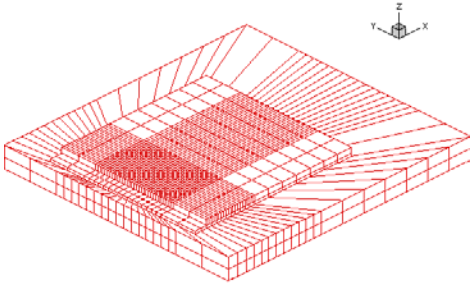
The physical structure



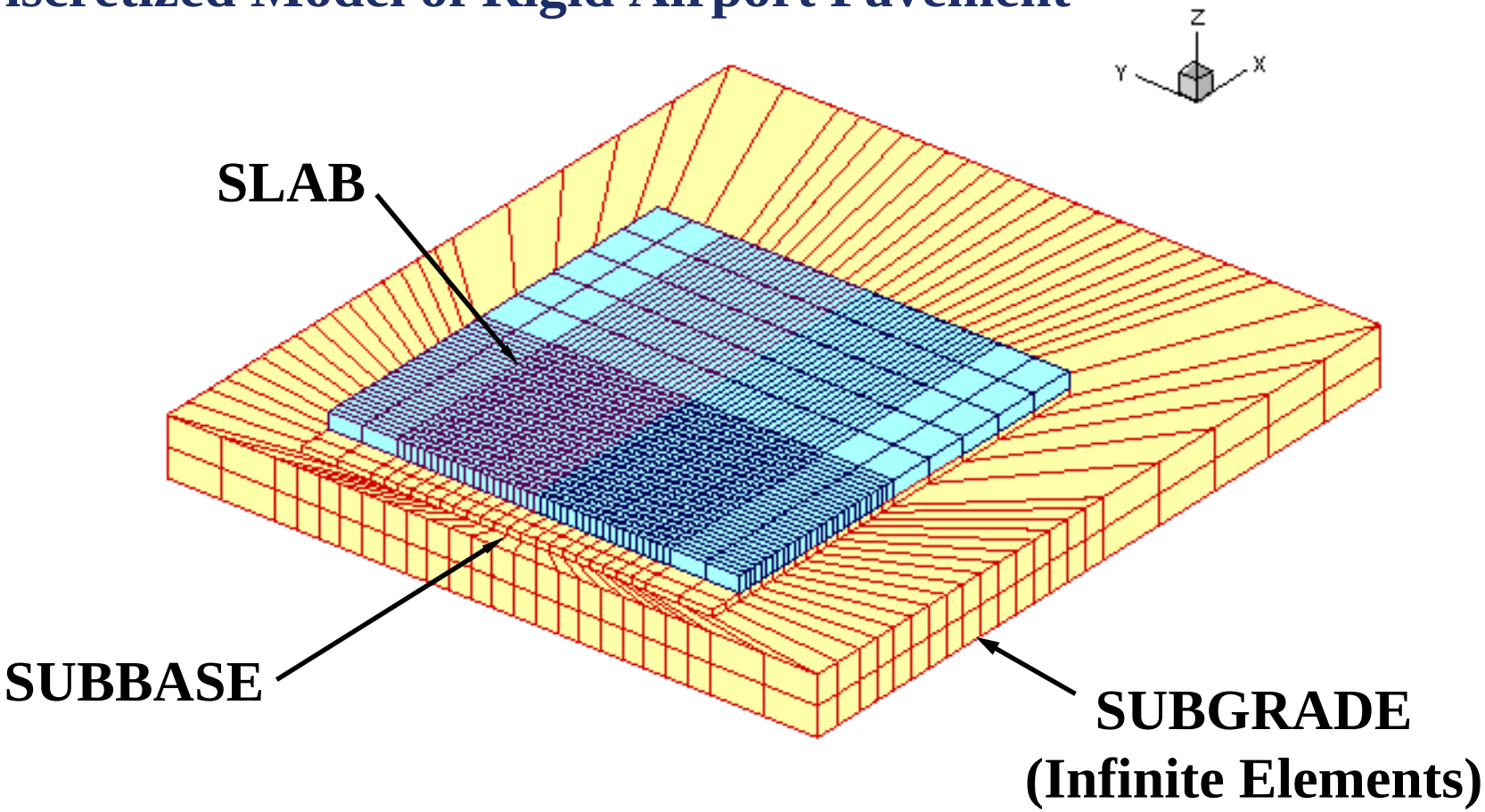
The idealized model



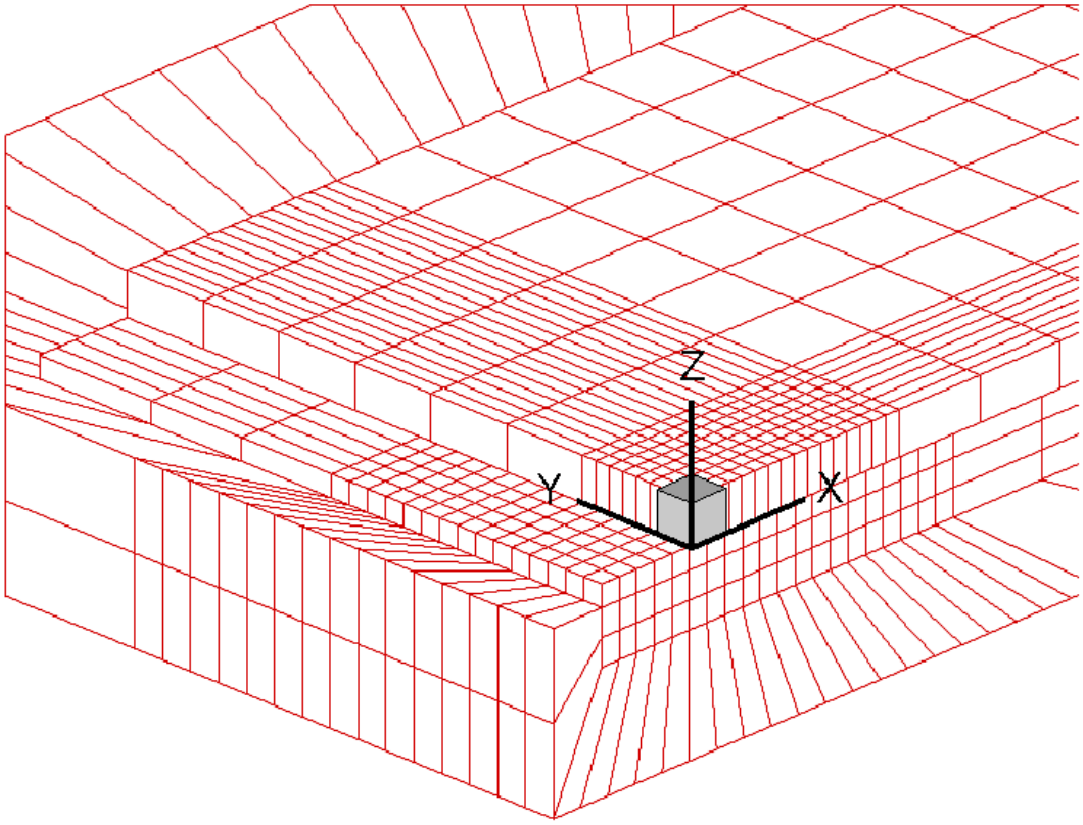
The discretized (approximate) model



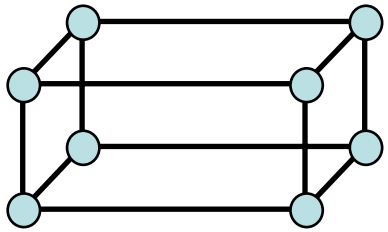
Discretized Model of Rigid Airport Pavement



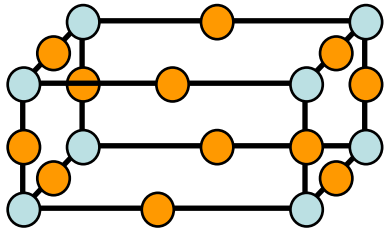
Discretized Model of Rigid Airport Pavement



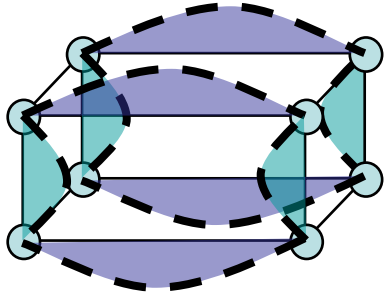
Types of 3D Elements



Linear (8-Node) Brick

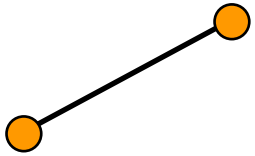


Quadratic (20 -Node) Brick

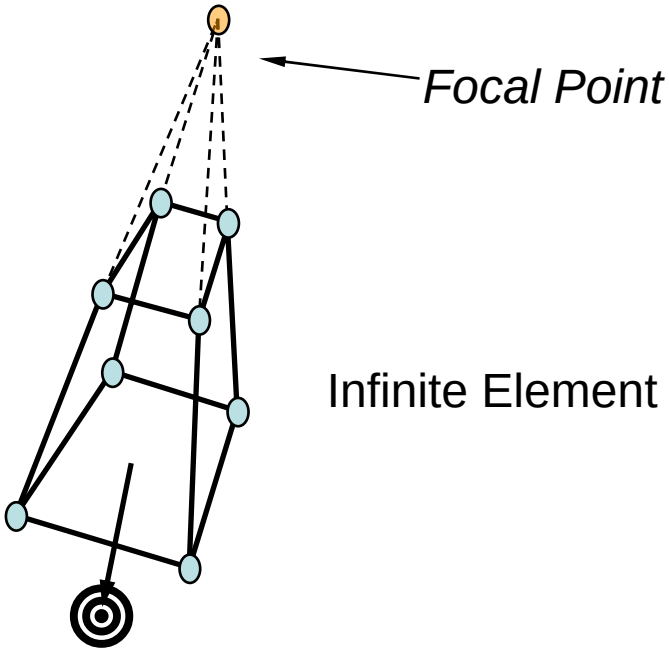


Nonconforming (Incompatible Modes)

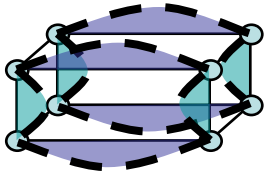
Equal to 6-8 layers of ordinary 8-node element



Axial (1-D)



Infinite Element



8-node Incompatible solid element

Horizontal Mesh Size

6” X 6” mesh size selected for FAARFIELD

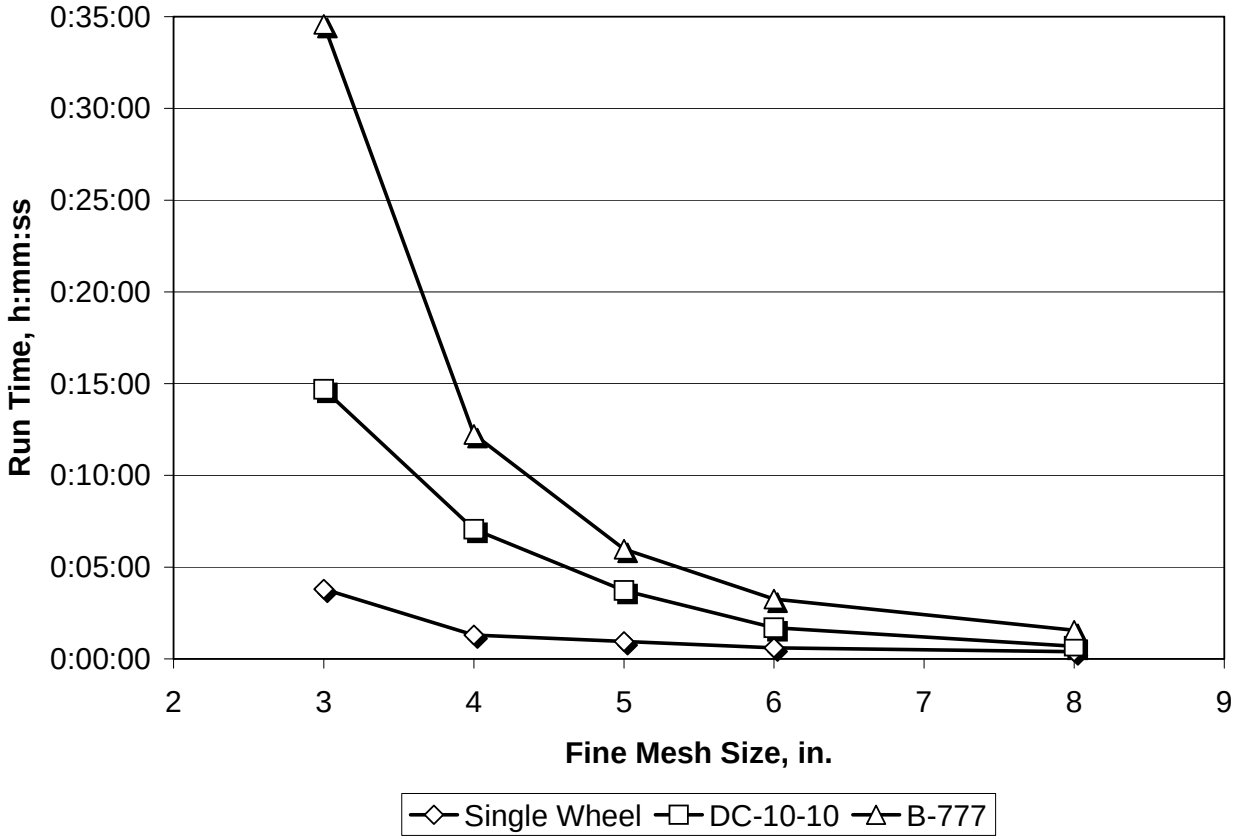
- 96-99% accuracy
- 3 - 6 time faster solution than 4X4 (multiple wheel gear analysis)
- 20 – 55 times faster solution the 2X2 (multiple wheel gear analysis)

Vertical Mesh Size

Single element selected for FAARFIELD (slab thickness)

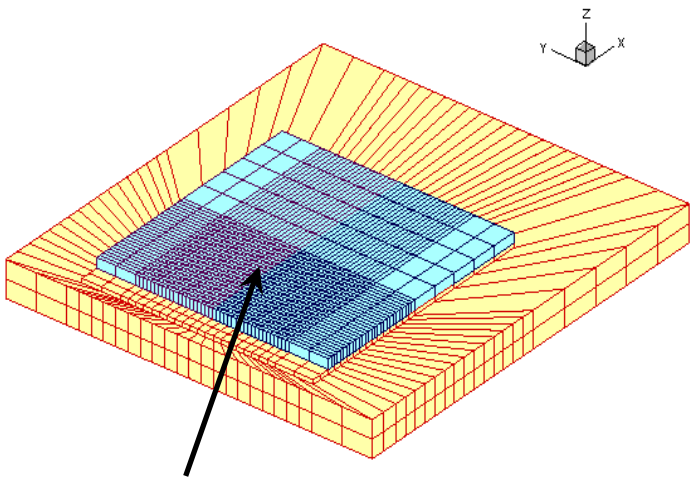
- Produced similar results when compared to 6 element (3”) mesh

Effect of Mesh Size on Run Time (Using Windows XP, Pentium-4, 512MB)

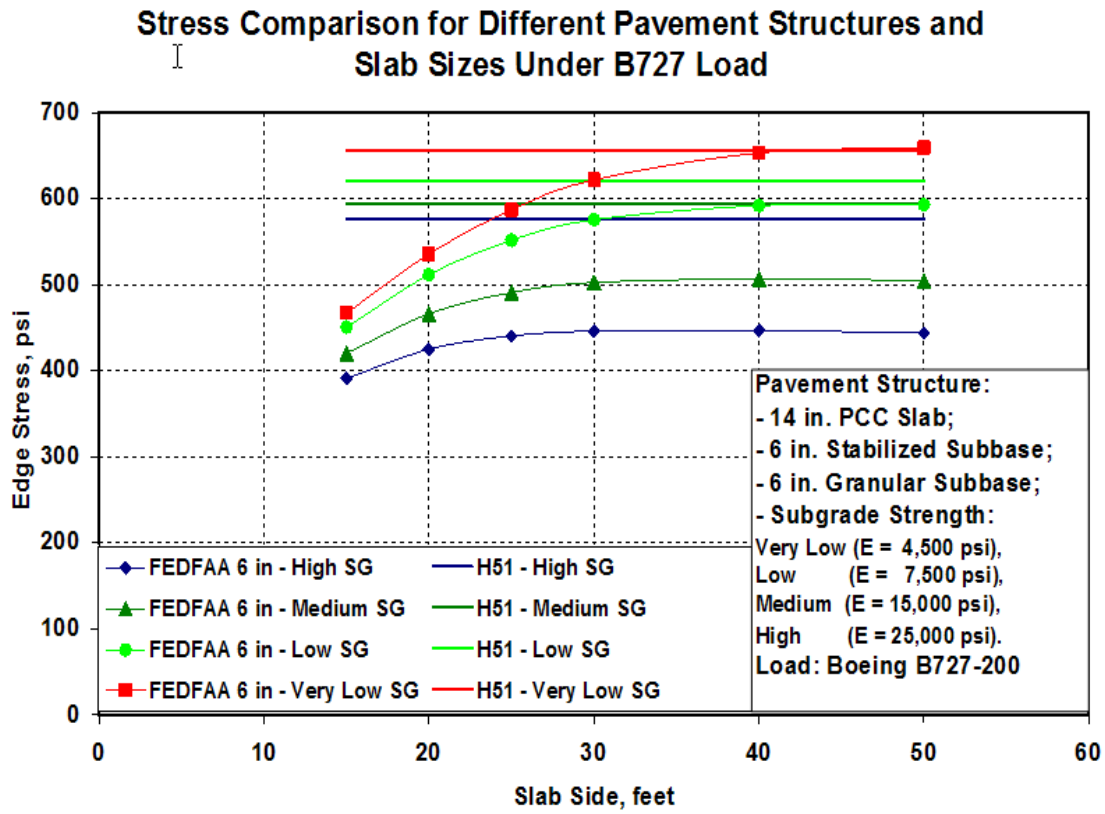


Discretized Model – Slab Size

30ft X 30ft slab size selected for FAARFIELD

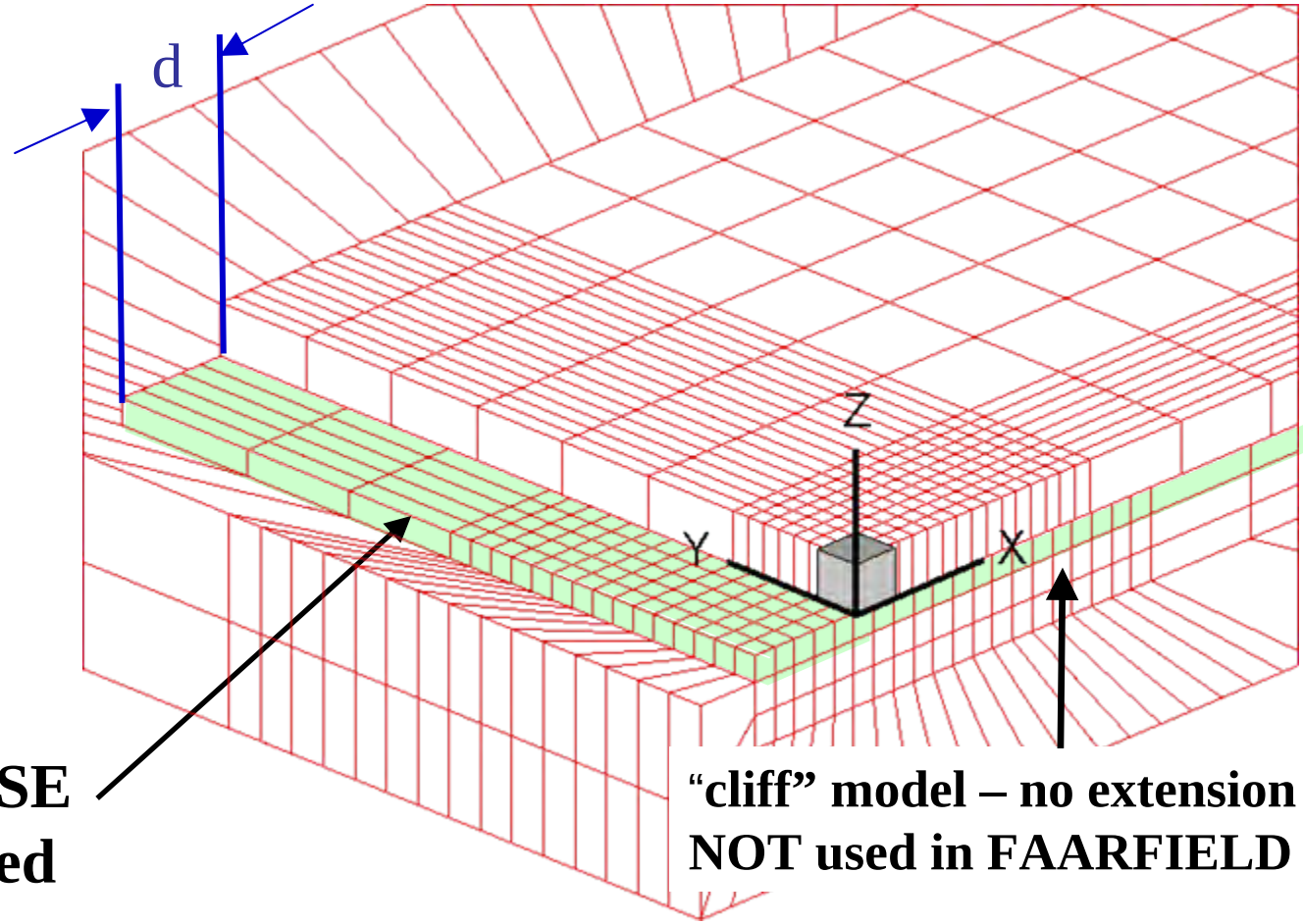


SLAB Size for model



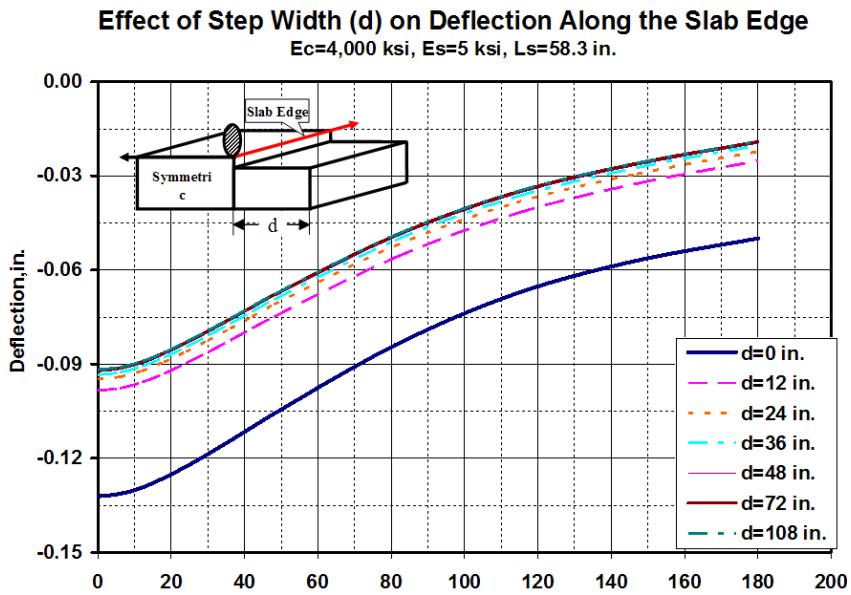
Discretized Model – Subbase Extension

To provide a more realistic model of the edge-loaded slab response, all pavement layers below the slab are extended some distance "d"

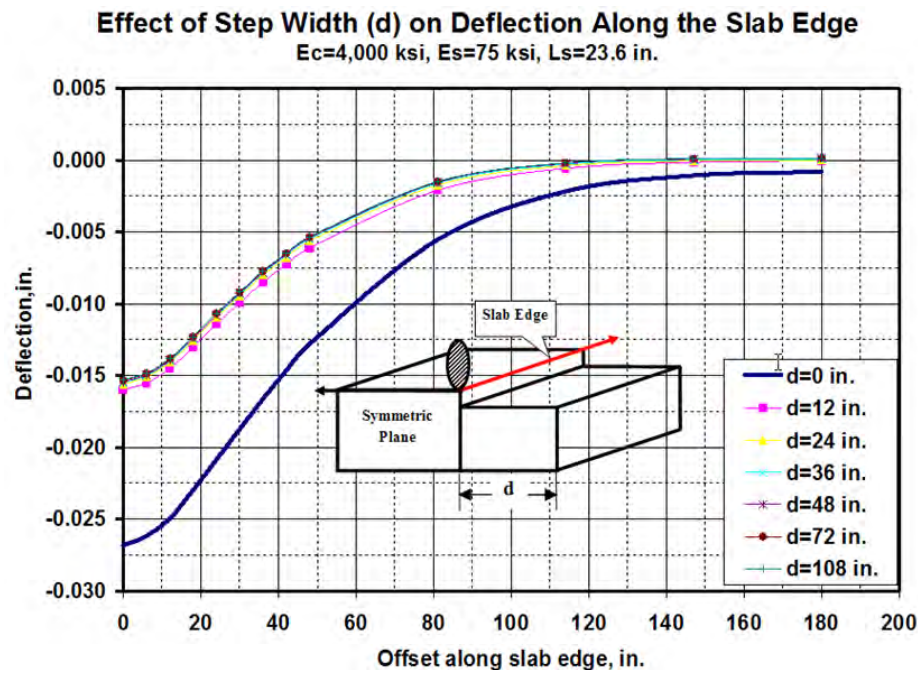


Discretized Model – Subbase Extension
Deflection along the Slab Edge

Low Strength subgrade

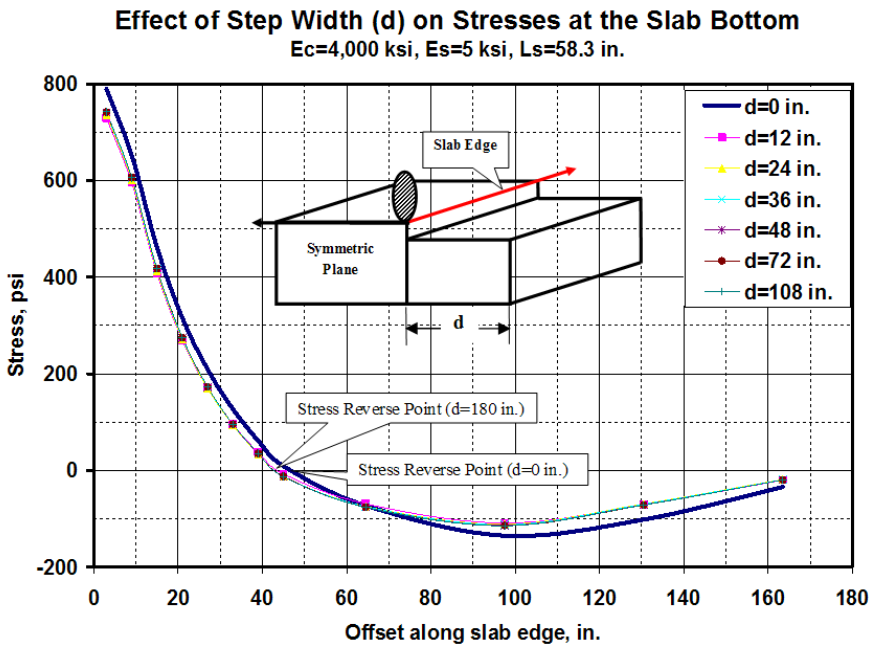


High Strength subgrade

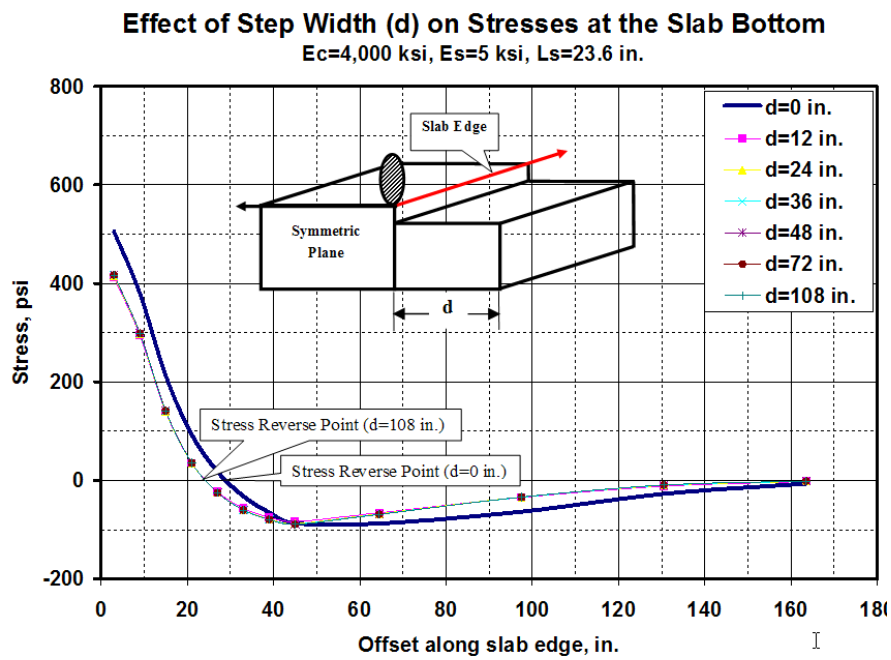


Discretized Model – Subbase Extension
Stress at the Slab Bottom

Low Strength subgrade



High Strength subgrade



Discretized Model – Subbase Extension

The width "d" of the extended step foundation used in FAArfield is 24 inches

The Stress difference using 24 inches or longer is negligible

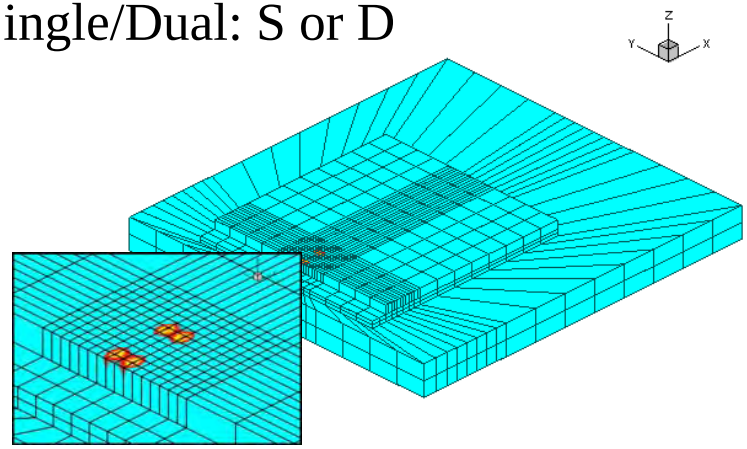
	Step width, *d*		Diff. in %
Responses	***d* = 24 inches**	***d* = 108 inches**	
Critical Stress at the Bottom, l_S = 58.3 inches (psi)	**736.2**	**741.8**	**0.8**
Critical Stress at the Bottom, l_S = 23.6 inches (psi)	**415.6**	**417.0**	**0.3**
Maximum Deflection, l_S = 58.3 inches (inches)	**94.8**	**91.8**	**3.2**
Maximum Deflection, l_S = 23.6 inches (inches)	**15.6**	**15.3**	**2.0**

Handling Mixed Aircraft Traffic in FAARFIELD

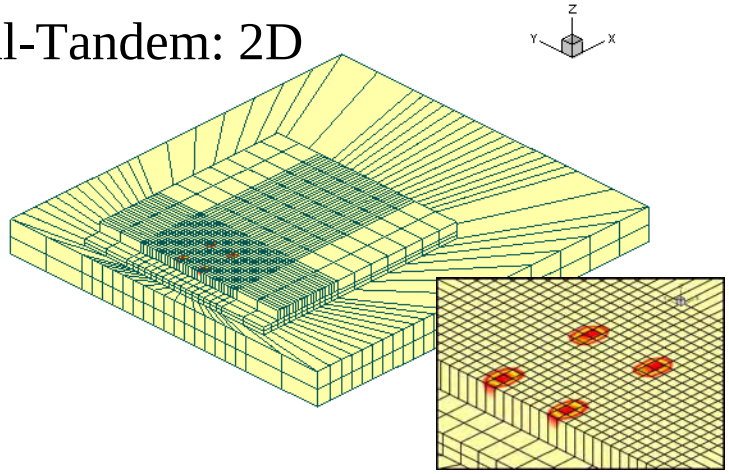
- FAARFIELD groups airplanes into 4 categories:
  - Single wheel, dual wheel (e.g., B-737).
  - Dual tandem (e.g., B-767, B-747).
  - Triple dual tandem (e.g., B-777).
  - Complex gear configuration (C-5, C-17A).
- All airplanes in a category are analyzed with one call to calculation subroutine (NIKE3D), using the same mesh.
- Results in significant savings in computation time.

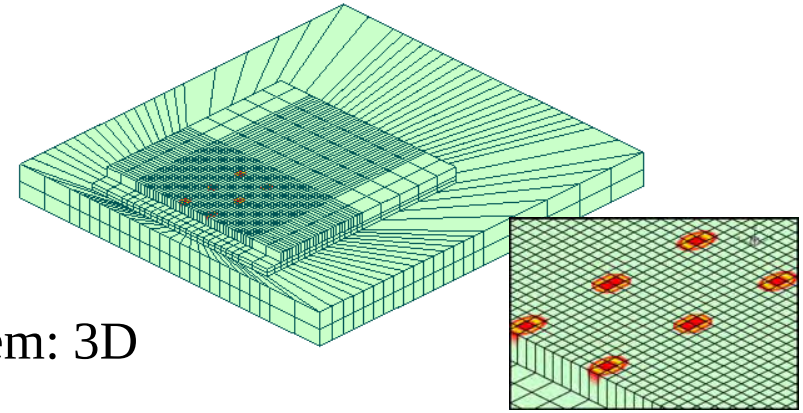
3D FEM Mesh Optimization

Single/Dual: S or D



Dual-Tandem: 2D





Triple Dual Tandem: 3D

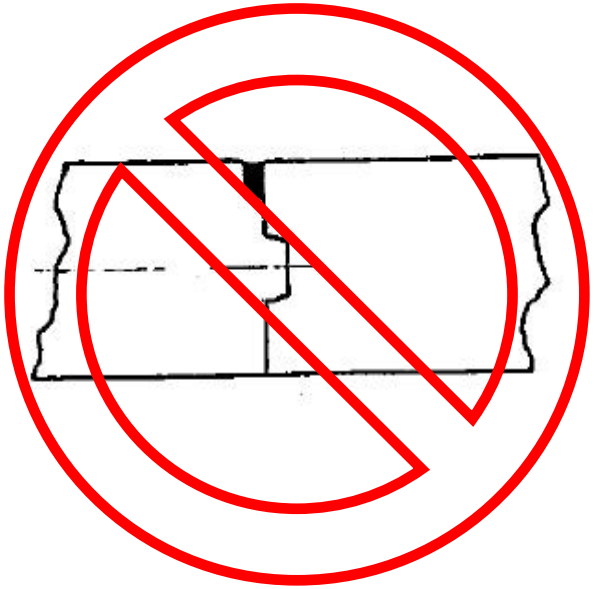
Improvement in Solution Time

- **Approximate time for B-777 stress solution:**
  - July 2000: 4 - 5 hours
  - July 2001: 30 minutes
    (single slab with infinite element foundation)
  - May 2002: 2 - 3 minutes
    (implement new incompatible modes elements)
  - Current version implemented in FAARFIELD:
    10 seconds or less

Rigid Pavement Joint Types and Details

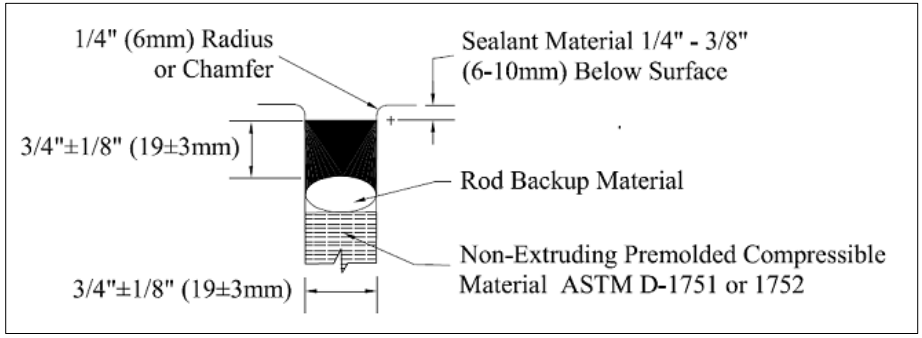
Rigid Pavement Joint Types and Details

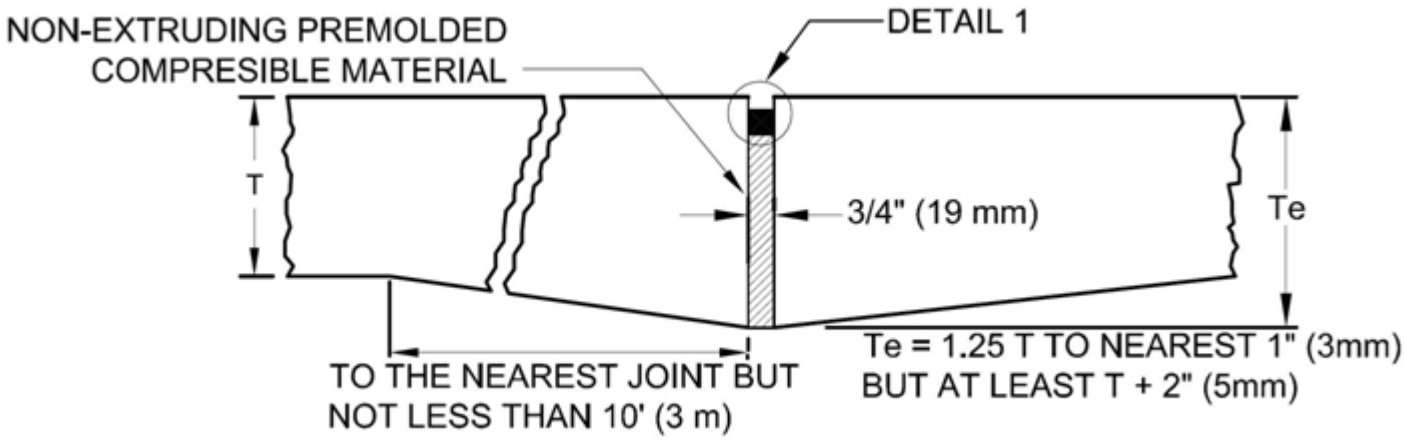
- **5 joint types provided in 5320-6E**
  - Isolation Joints
    - Type A – Thickened Edge
    - Type A-1 Reinforced Isolation Joint
  - Contraction Joints
    - Type B – Hinged
    - Type C – Doweled
    - Type D – Dummy
  - Construction Joints
    - Type E – Doweled



Rigid Pavement Joint Types and Details

- **Isolation Joints**
  - Type A – Thickened Edge



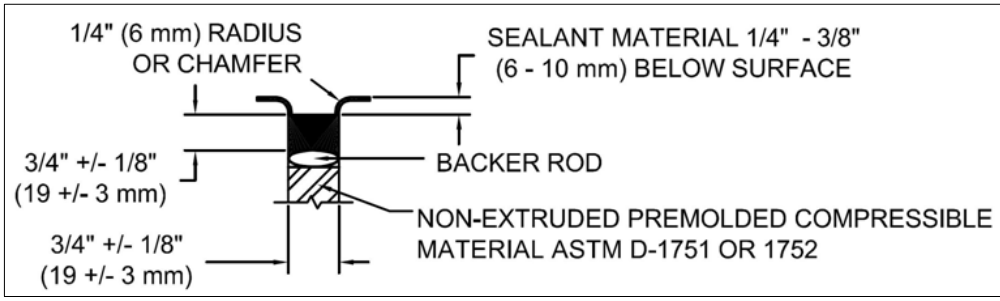


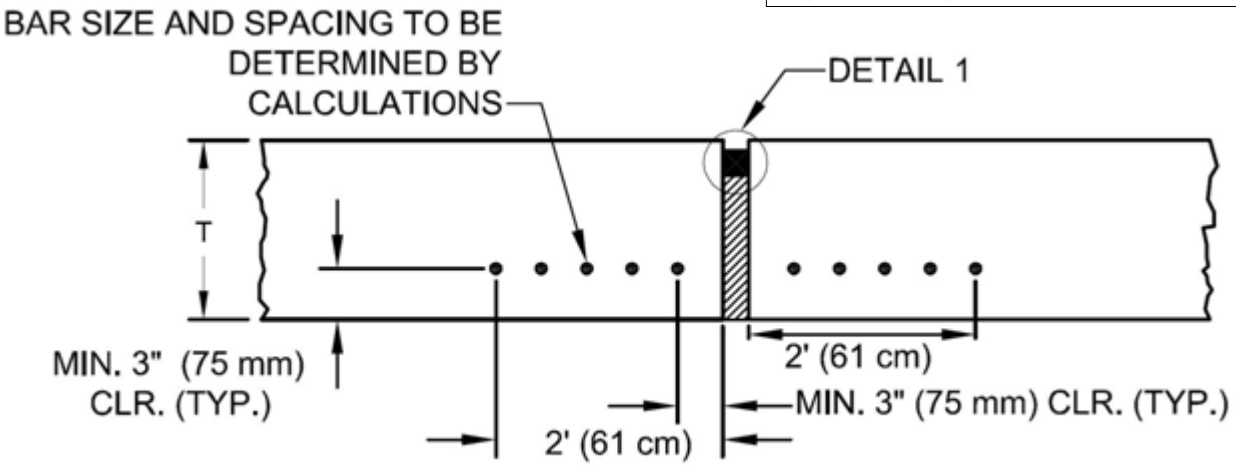
TYPE A THICKENED EDGE

Rigid Pavement Joint Types and Details

➢ Isolation Joints

- Type A-1 – Reinforced

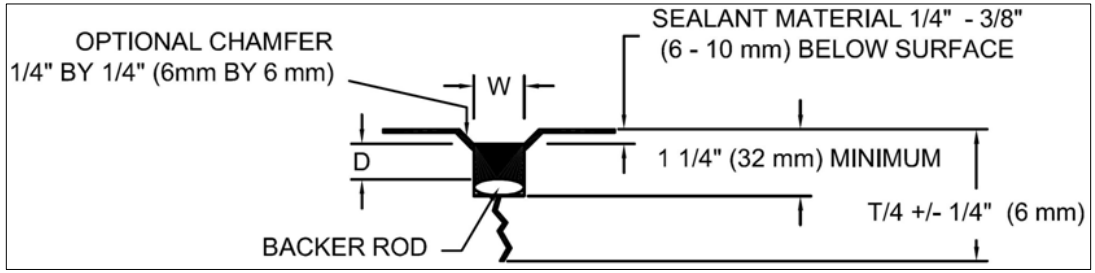


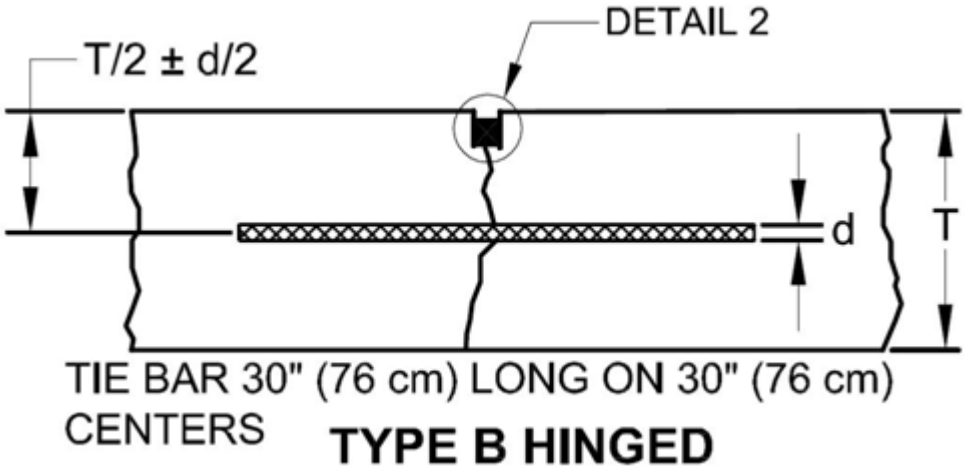


TYPE A-1 REINFORCED

Rigid Pavement Joint Types and Details

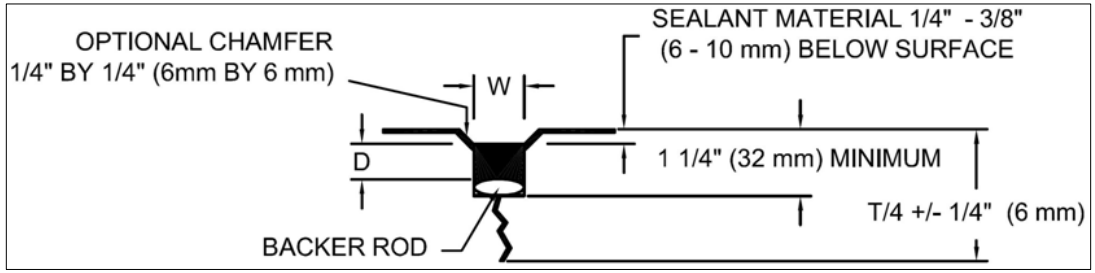
- **Contraction Joints**
  - Type B – Hinged

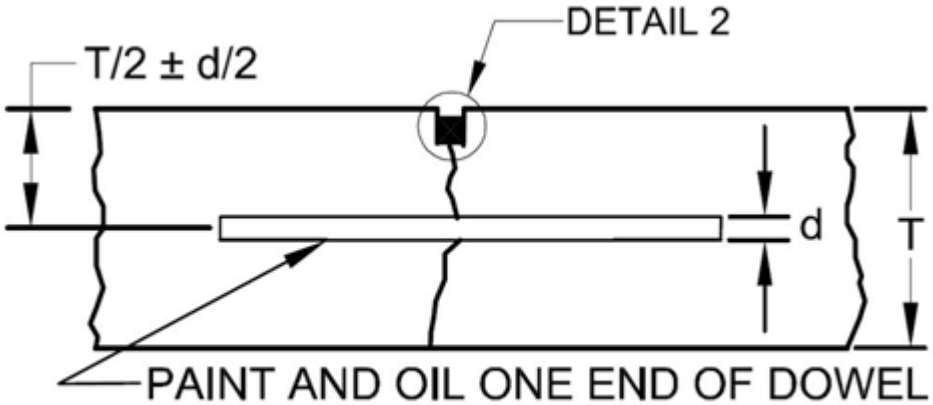




Rigid Pavement Joint Types and Details

- **Contraction Joints**
  - Type C – Doweled



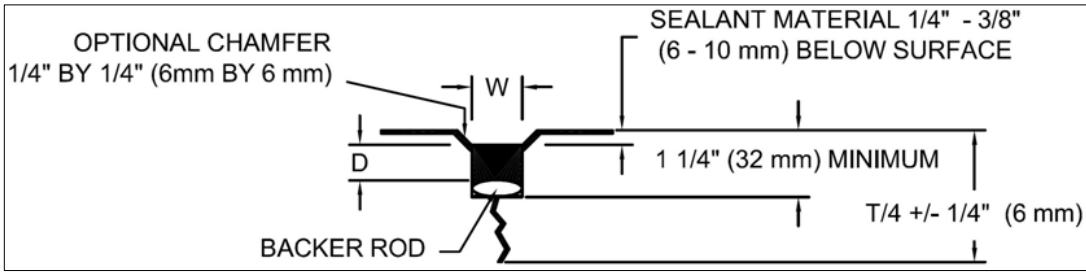


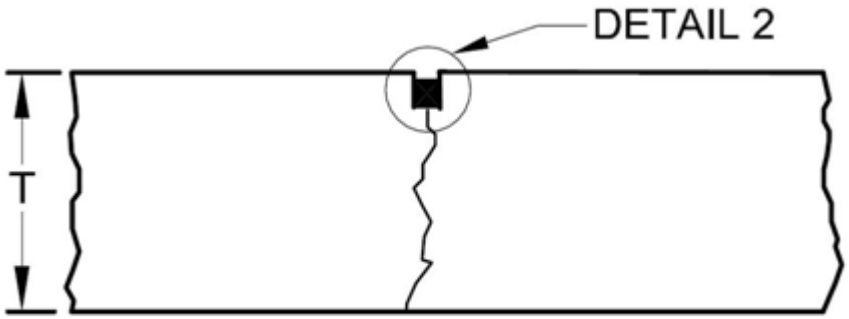
TYPE C DOWELED

Rigid Pavement Joint Types and Details

➢ Contraction Joints

- Type D – Dummy



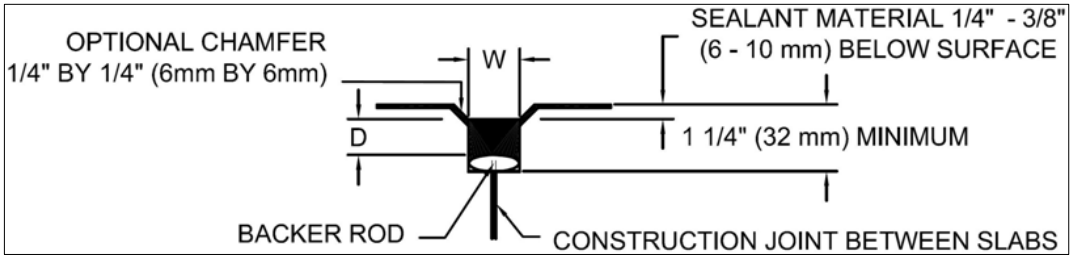


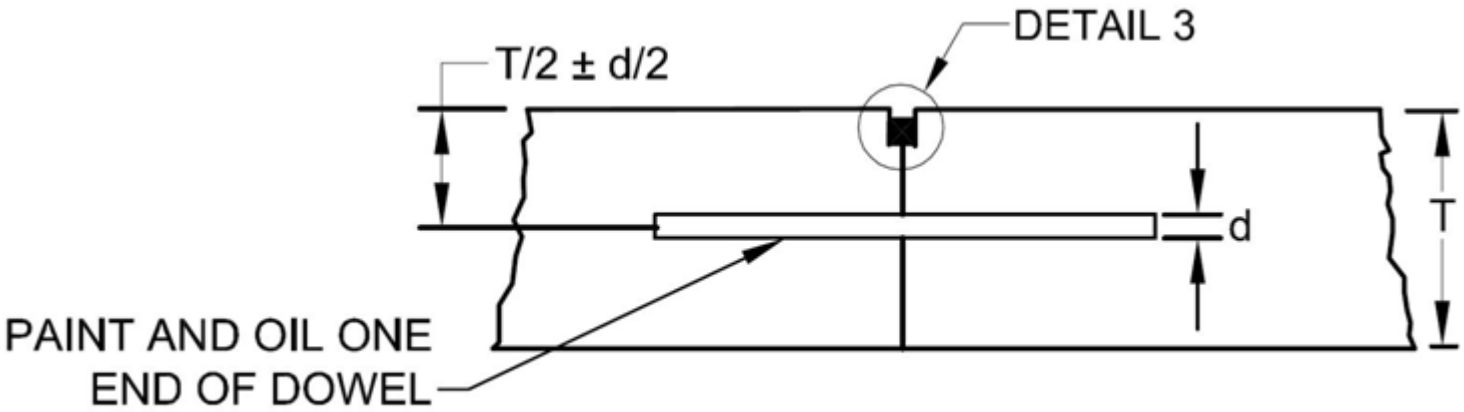
TYPE D DUMMY

Rigid Pavement Joint Types and Details

➢ Construction Joints

- Type E – Doweled

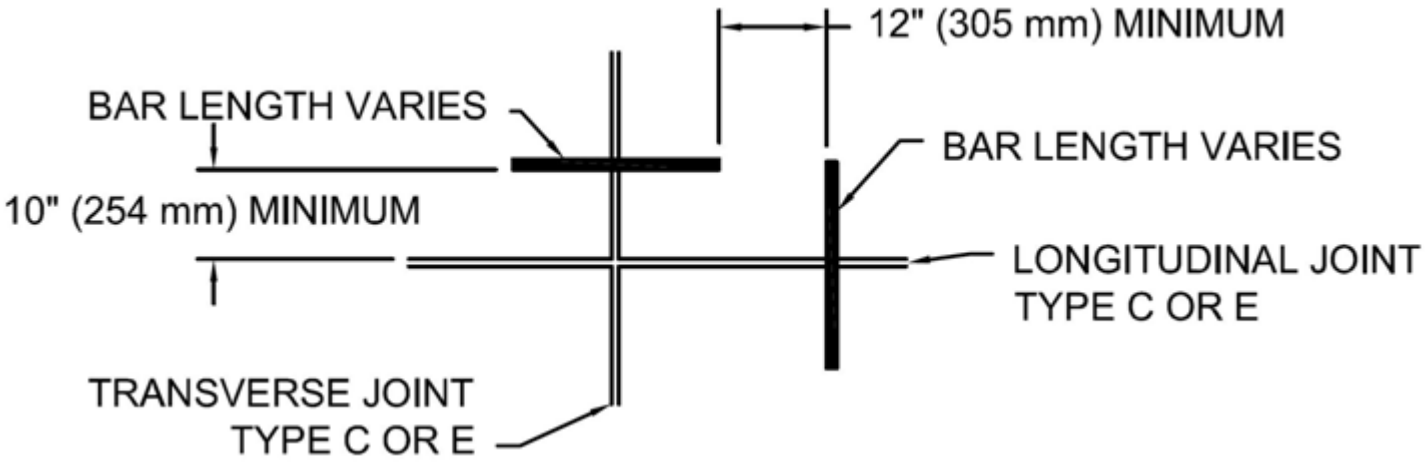




TYPE E DOWELED

Rigid Pavement Joint Types and Details

- **Dowel Bar Spacing at Slab Corner**



Chapter 5 –Pavements For Light Aircraft

Rigid Pavement – Joint Steel For Heavy Duty Pavement

Dowels

TABLE 3-17. DIMENSIONS AND SPACING OF STEEL DOWELS

Thickness of Slab	Diameter	Length	Spacing
6-7 in (152-178 mm)	¾ in[1] (20 mm)	18 in (460 mm)	12 in (305 mm)
7.5-12 in (191-305 mm)	1 in[1] (25 mm)	19 in (480 mm)	12 in (305 mm)
12.5-16 in (318-406 mm)	1 ¼ in[1] (30 mm)	20 in (510 mm)	15 in (380 mm)
16.5-20 in (419-58 mm)	1 ½ in[1] (40 mm)	20 in (510 mm)	18 in (460 m)
20.5-24 in (521-610 mm)	2 in[1] (50 mm)	24 in (610 mm)	18 in (460 mm)

[1]Dowels noted may be solid bar or high-strength pipe. High-strength pipe dowels must be plugged on each end with a tight-fitting plastic cap or mortar mix.

Rigid Pavement – Joint Steel For Heavy Duty Pavement

<u>All Tie Bars</u>

- 5/8 inch Deformed Bars (16 mm)
- 30 inch long (76 mm)
- 30 inch center (76 mm)

Rigid Pavement Joint Spacing

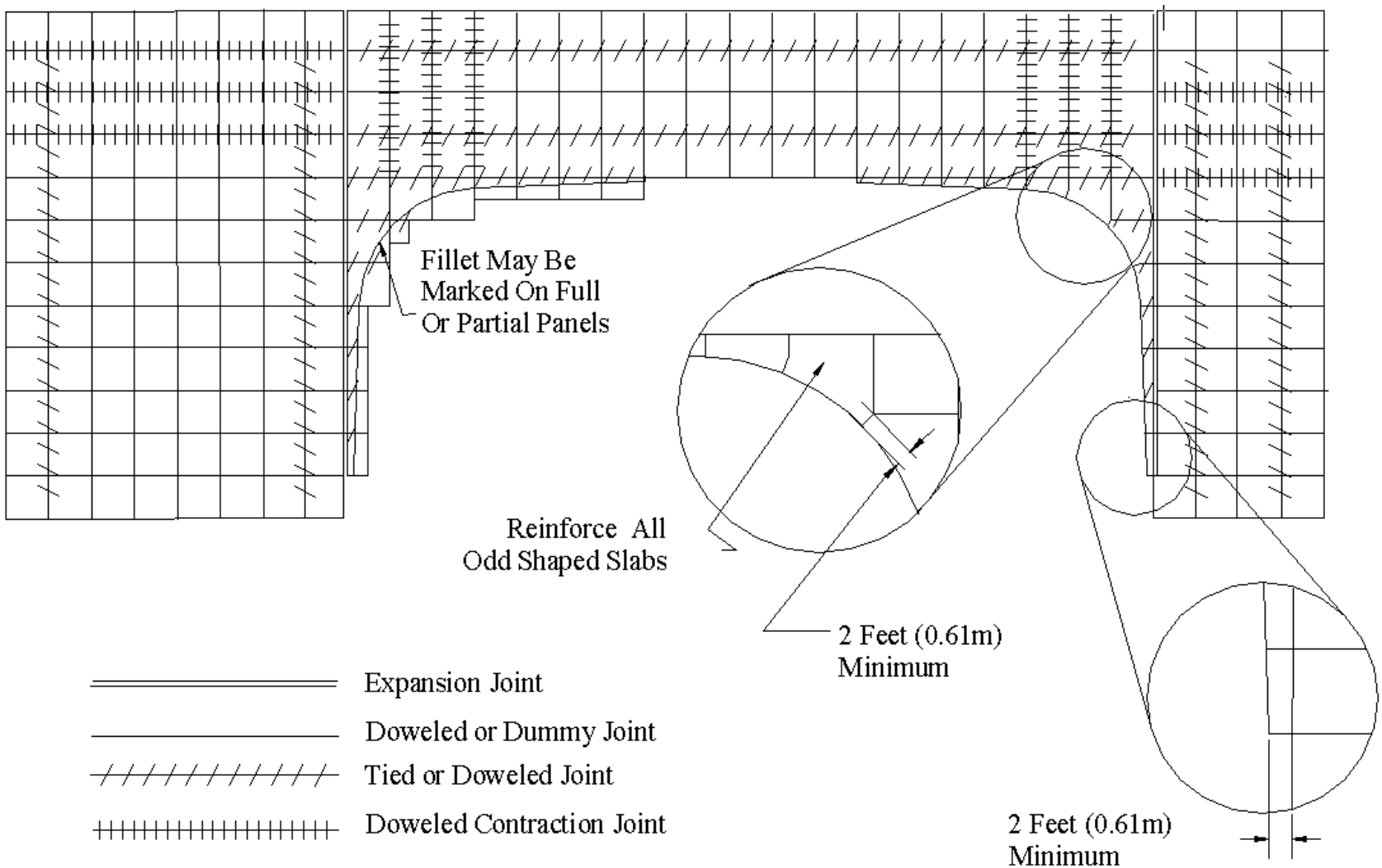
TABLE 3-16. RECOMMENDED MAXIMUM JOINT SPACINGS - RIGID PAVEMENT WITH OR WITHOUT STABILIZED SUBBASE

Part I, without Stabilized Subbase			
Slab Thickness		Joint Spacing[1]	
Inches	Millimeters	Feet	Meters
6	152	12.5	3.8
6.5-9	165-229	15	4.6
>9	>229	20	6.1

Part II, with Stabilized Subbase			
Slab Thickness		Joint Spacing[1]	
Inches	Millimeters	Feet	Meters
8–10	203-254	12.5	3.8
10.5-13	267-330	15	4.6
13.5-16	343-406	17.5[2]	5.3[2]
>16	>406	20	6.1

- **Notes:**
  1. Transverse and longitudinal joint spacing.
  2. For typical runway and taxiway geometries, the corresponding longitudinal joint spacing is 18.75 ft. (5.7 m).
  3. Joint spacings shown in this table are maximum values that may be acceptable under ideal conditions.
  4. Smaller joint spacings should be used if indicated by past experience
  5. Pavements subject to extreme seasonal temperature differentials or extreme temperature differentials during placement may require shorter joint spacings.

Rigid Pavement Joint Layout



CHAPTER 4

AIRPORT PAVEMENT OVERLAYS AND RECONSTRUCTION

Chapter 4 – Airport Pavement Overlays.

OVERLAY TYPES

- **Flexible**

  Hot Mix Asphalt over existing flexible pavement

  Hot Mix Asphalt over existing rigid pavement

- **Rigid**

  PCC over existing flexible pavement (whitetopping)

  PCC bonded to existing PCC

  PCC unbonded to existing PCC

Deleted partially bonded PCC

Chapter 4 – Airport Pavement Overlays.

Overlay design requires the FAARFIELD program

Input variables include:

- Existing pavement structure
  - Including material properties and traffic requirements
- Existing pavement condition
  - Flexible – requires engineering judgment
  - Rigid – use Structural Condition Index (SCI)

Structural Condition Index (SCI)

- Derived from the Pavement Condition Index as determined by ASTM D 5340 Airport Pavement Condition Index Surveys
- SCI is computed using only structural components from the PCI survey (6 of 15 distress types)
  - SCI will always be greater than or equal to the PCI
- SCI = 80 – FAA definition of structural failure
  - 50% of slabs with structural crack

Structural Condition Index (SCI)

TABLE 4-1. RIGID PAVEMENT DISTRESS TYPES USED TO CALCULATE THE STRUCTURAL CONDITION INDEX, (SCI)

Distress	Severity Level
Corner Break	Low, Medium, High
Longitudinal/Transverse/Diagonal Cracking	Low, Medium, High
Shattered Slab	Low, Medium, High
Shrinkage Cracks (cracking partial width of slab)*	Low
Spalling–Joint	Low, Medium, High
Spalling–Corner	Low, Medium, High

Cumulative Damage Factor Used (CDFU)

- SCI = 100 when there is no visible distress contributing to reduction in SCI (no structural distress types)
- Condition of existing pavement described by CDFU

Cumulative Damage Factor Used (CDFU)

- **CDFU defines amount of structural life used**

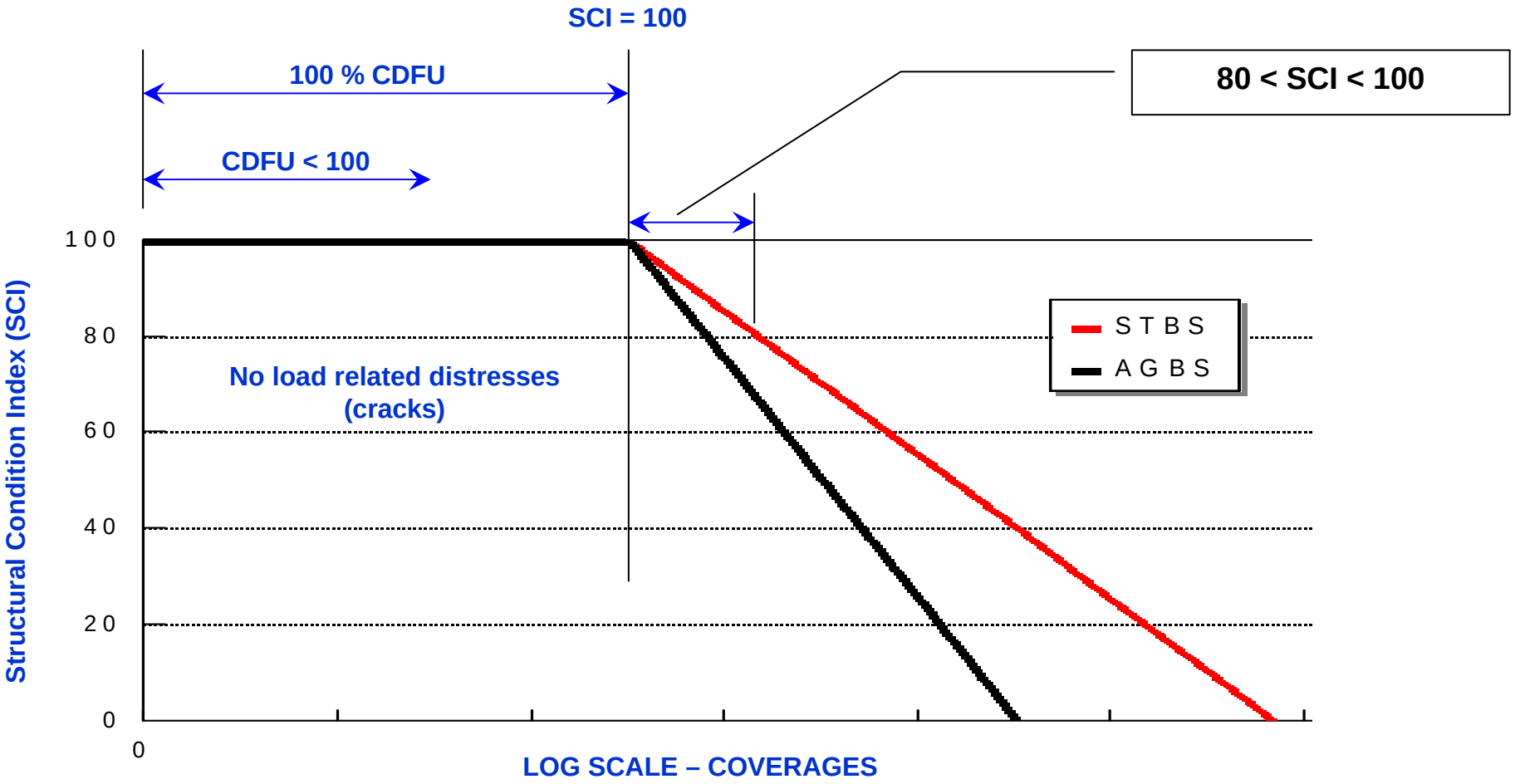
  For structures with aggregate base

$$CDFU = \frac{L_U}{0.75\,L_D} \quad \text{when } L_U < 0.75\,L_D$$
$$= \quad 1 \quad \text{when } L_U \geq 0.75\,L_D$$

LU = number of years of operation of the existing pavement until overlay
LD = design life of the existing pavement in years

- **FAARFIELD modifies this relationship for stabilized subbase to reflect improved performance**

Cumulative Damage Factor Used (CDFU)



Overlay on Rubblized Concrete Pavement

- Design process is similar to HMA over existing flexible
- Rubblized PCC layer is available in FAARFIELD
  - Recommended modulus values depend on slab thickness

Slab Thickness (inches)	Moduli (ksi)
6 to 8	100 – 135
8 – 14	135 - 235
> 14	235 - 400

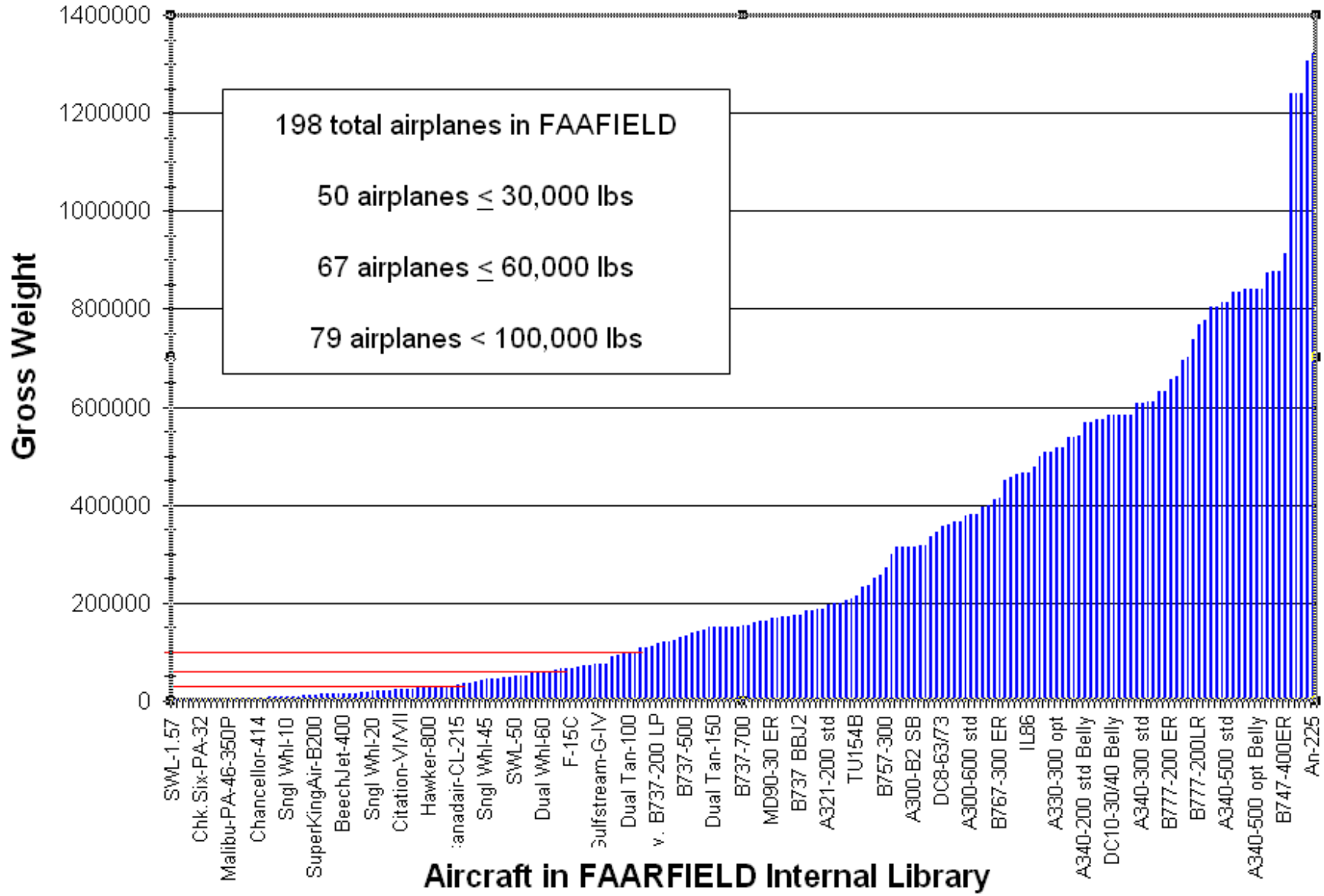
Chapter 5
Pavements for Light Aircraft

Chapter 5 –Pavements For Light Aircraft

Pavement design for airplanes weighing less than 30,000 lbs

- Flexible pavement design procedure requires FAARFIELD
- Rigid pavement design procedure – fixed thickness
- Aggregate -Turf pavement

Chapter 5 –Pavements For Light Aircraft



Chapter 5 –Pavements For Light Aircraft

Flexible Pavement -- airplanes weighing less than 30,000 lbs

- Hot Mix Asphalt surface course requirements
  - P-401 or P-403
  - State Standards permitted for < 12,500 lbs
- Minimum thickness = 2 inches over aggregate base

Chapter 5 –Pavements For Light Aircraft

Flexible Pavement -- airplanes weighing less than 30,000 lbs

Base Layer Requirements

- Minimum material requirements
  - P-208, P-209, P-210, P-211, P-212, P-213, P-301, P-304, P-306, P-401, & P-403 (some local materials)
- Design assumes minimum strength – CBR $\geq$ 80
- Minimum thickness of aggregate = 3 inches
- Aggregate layer modulus dependent on thickness
  - Modulus calculated by FAARFIELD is dependent on thickness

Chapter 5 –Pavements For Light Aircraft

Flexible Pavement -- airplanes weighing less than 30,000 lbs

Subbase Layer Requirements

- Suitable material requirements
  - P-154, P-208, P-209, P-210, P-211, P-212, P-213, P-301, P-304, P-306, P-401, & P-403 (some local materials)
- Design assumes minimum strength – CBR $\geq$ 20
- No minimum thickness
- Aggregate layer modulus dependent on thickness
  - Modulus calculated by FAARFIELD is dependent on thickness

Chapter 5 –Pavements For Light Aircraft

Flexible Pavement -- airplanes weighing less than 30,000 lbs

Subgrade Compaction Requirements

TABLE 5-1. SUBGRADE COMPACTION REQUIREMENTS FOR LIGHT LOAD FLEXIBLE PAVEMENTS

Design Aircraft Gross Weight lbs	Noncohesive Soils Depth of Compaction (in.)				Cohesive Soils Depth of Compaction (in.)			
	100%	95%	90%	85%	95%	90%	85%	80%
12,500 or less	6	6-9	9-18	18-24	4	4-8	8-12	12-15
12,501 or more	8	8-12	12-24	24-36	6	6-9	9-12	12-15

Chapter 5 –Pavements For Light Aircraft

Rigid Pavement -- airplanes weighing less than 30,000 lbs

- Portland Cement Concrete surface course requirements
  - P-501
  - State Standards permitted for < 30,000 lbs

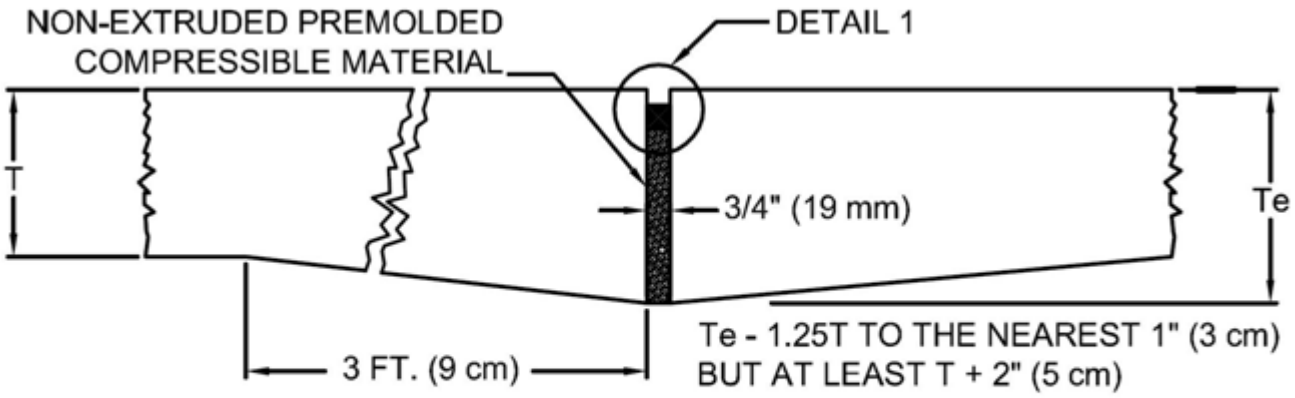
- Minimum thickness = 5 inches < 12,500 lb
  6 inches 12,501 to 30,000 lbs

- Maximum Slab Size

  12.5 x 15.0 (ft) (3.8 x 4.6 m)

Rigid Pavement -- Joints

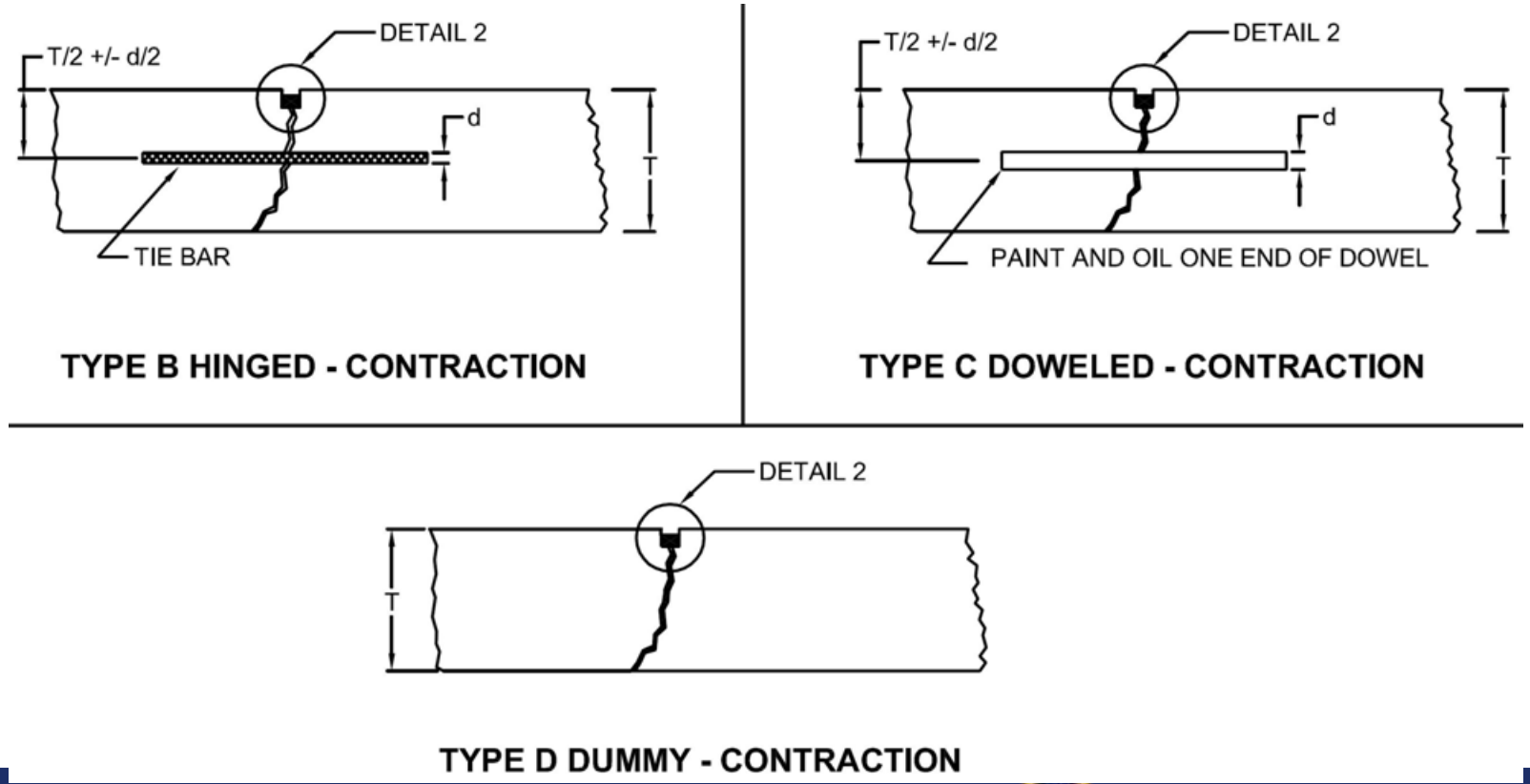
- ISOLATION JOINT



TYPE A THICKENED EDGE - ISOLATION

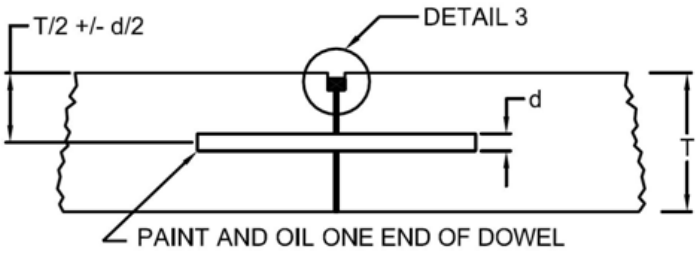
Rigid Pavement -- Joints

- CONTRACTION JOINTS

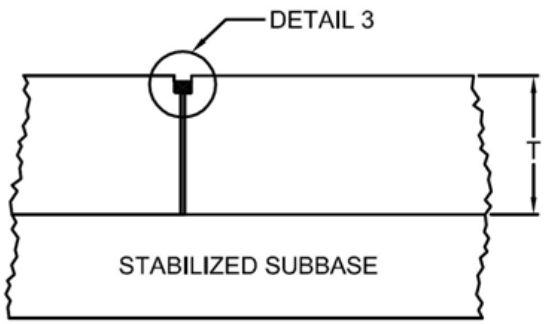


Rigid Pavement -- Joints

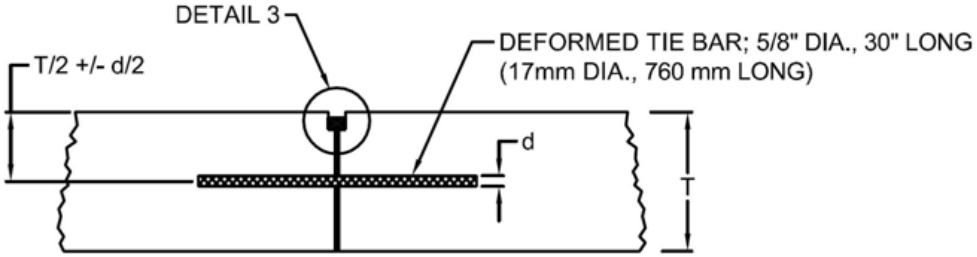
- CONSTRUCTION JOINTS



TYPE E DOWELED - CONSTRUCTION

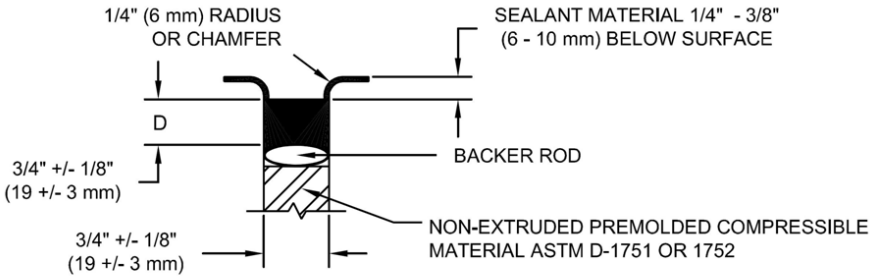


TYPE F BUTT JOINT - CONSTRUCTION

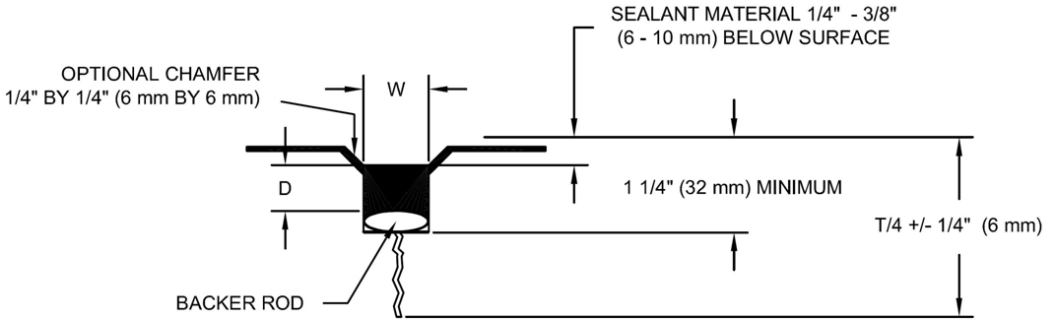


TYPE G TIED BUTT - CONSTRUCTION

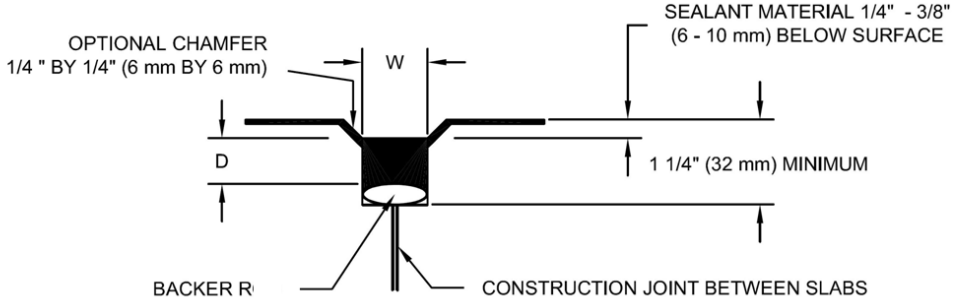
Rigid Pavement – Joint Details



DETAIL 1
ISOLATION JOINT



DETAIL 2
CONTRACTION JOINT



DETAIL 3
CONSTRUCTION JOINT

Rigid Pavement – Joint Steel For Light Duty Pavement

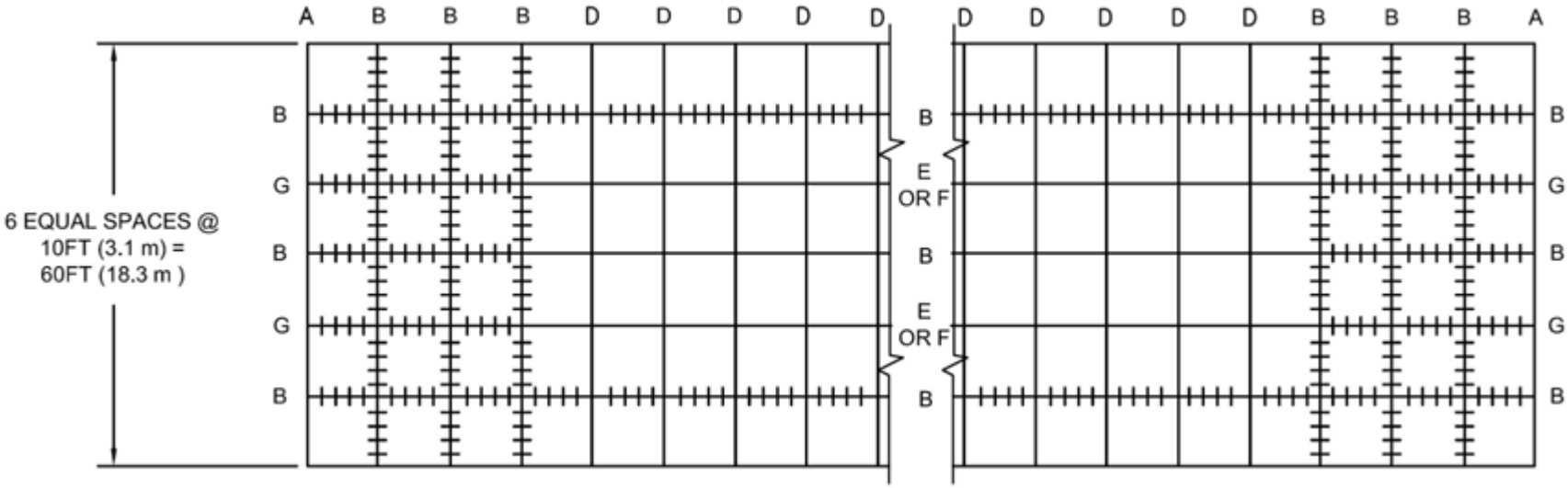
<u>All dowels</u>

- 3/4 inch diameter (19 mm)
- 18 inch Long (460 mm)
- 12 inch on center (300 mm)

<u>All Tie Bars</u>

- No. 4 Deformed Bars
- 20 inch long (510 mm)
- 36 inch center (0.9 m)

Tension-Ring Joint Pattern for 60 foot wide pavements



A: Thickened Edge

B: Hinged Contraction

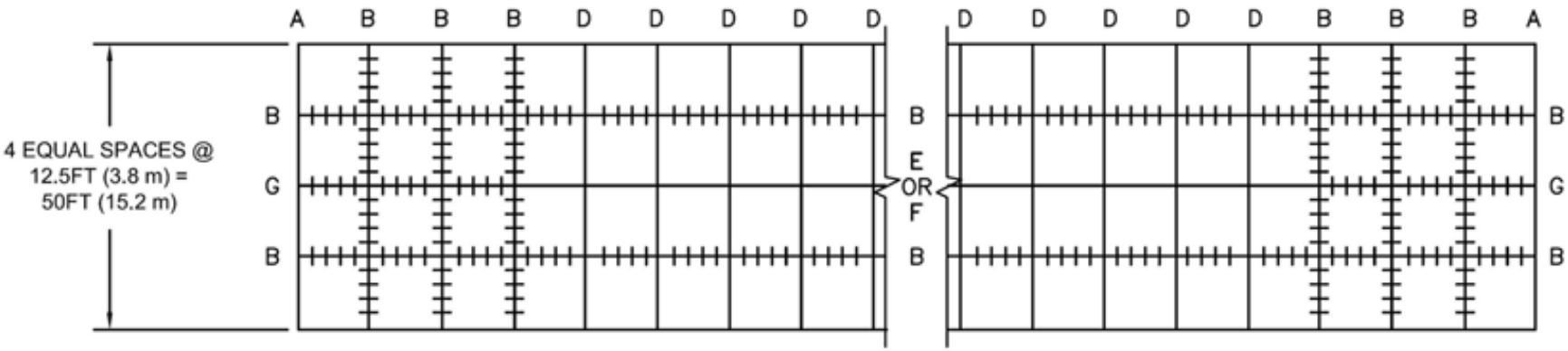
D: Dummy Contraction

D: Doweled Construction

F: Butt Construction

G: Tied Butt Construction

Tension-Ring Joint Pattern for 50 foot wide pavements



A: Thickened Edge

B: Hinged Contraction

D: Dummy Contraction

D: Doweled Construction

F: Butt Construction

G: Tied Butt Construction

Chapter 5 –Pavements For Light Aircraft

Aggregate-Turf – Non-Jet airplanes weighing less than 12,500 lbs

- Material requirements – P-217
- Procedure in 5320-6E to use FAARFIELD to determine thickness requirement of P-217 layer.

CHAPTER 7

PAVEMENT DESIGN FOR AIRFIELD SHOULDERS

Chapter 7 – Pavement Design For Airfield Shoulders

- **Shoulders are primarily intended to provide**
  - Protection from erosion and generation of debris from jet blast
  - Support for airplanes running off the primary pavement
  - Enhanced drainage

Chapter 7 – Pavement Design For Airfield Shoulders

Shoulder must provide sufficient support for unintentional or emergency operation of any airplane in the traffic mix.

Must also provide support for emergency and maintenance vehicle operations

Chapter 7 – Pavement Design For Airfield Shoulders

- **Minimum section provided by Chapter 7 will not perform in the same fashion as full strength pavement**
  - Expect considerable movement and possible rutting with single operations
  - Shoulder pavement should be inspected after every operation.

Shoulder Design Procedure

- Uses FAARFIELD to determine “most demanding airplane”
- Evaluate proposed shoulder section for each airplane based on 10 operations
- Does not use composite traffic mixture

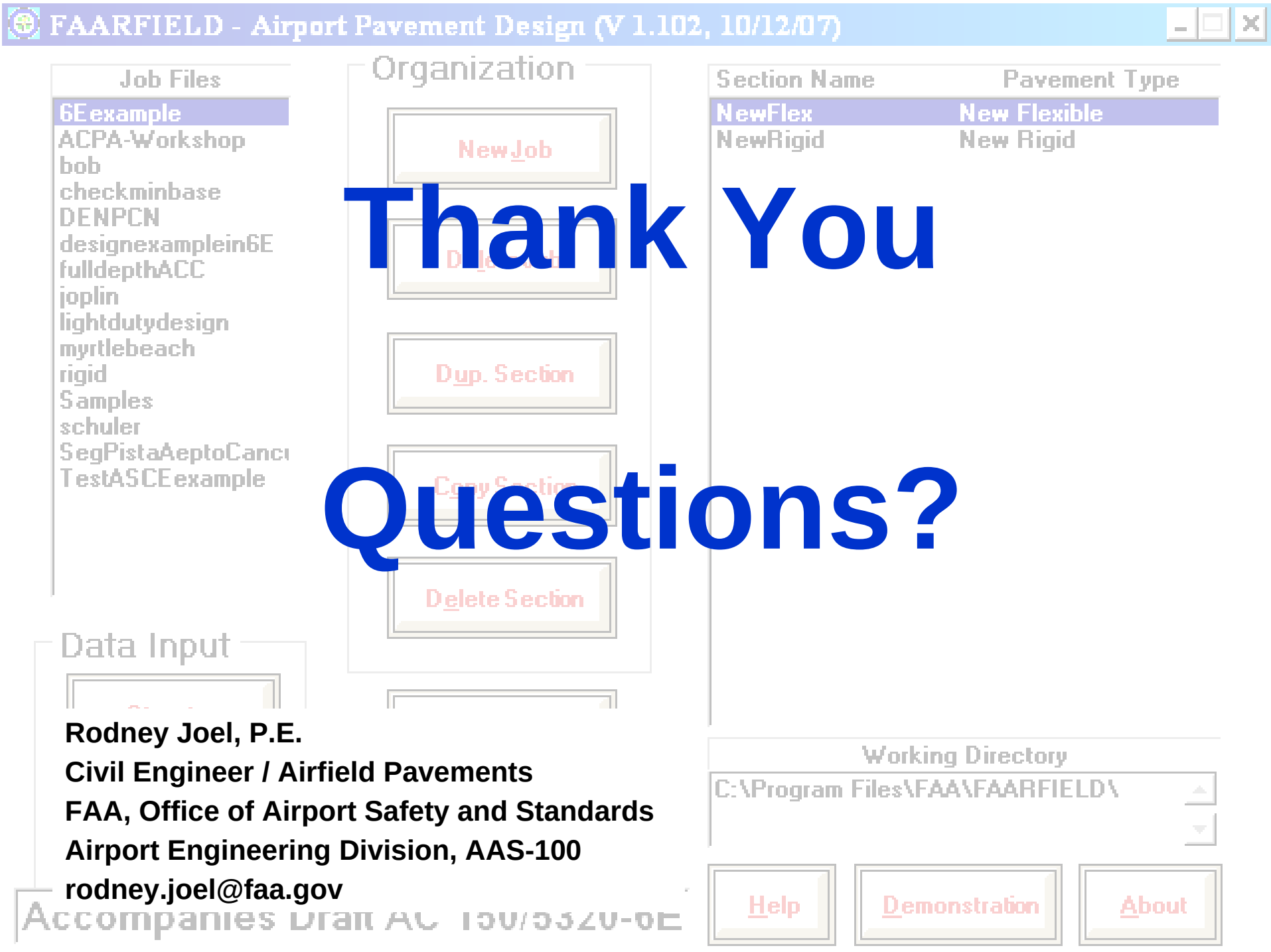
Shoulder Design Procedure – Material Requirements

- Asphalt
  - P-401/403 or similar local material specifications
  - Minimum compaction target density – 93% max theo. density
  - Minimum thickness = 3 inches
- Portland Cement Concrete
  - P-501 or similar local material specifications
  - Minimum flexural strength = 600 psi
  - Minimum thickness = 6 inches

Chapter 7 – Pavement Design For Airfield Shoulders

Shoulder Design Procedure – Material Requirements

- Base Material
  - FAA specifications or similar local material specifications
  - Expect CBR $\geq$ 80
  - Minimum thickness = 6 inches
    - May be reduced to 4 inch minimum if asphalt surface increased by 1 inch
- Subbase Material
  - FAA specifications or similar local material specifications
  - Expect CBR $\geq$ 20
  - Minimum thickness = 4 inches (practical construction limit)



Thank You

Questions?

Rodney Joel, P.E.
Civil Engineer / Airfield Pavements
FAA, Office of Airport Safety and Standards
Airport Engineering Division, AAS-100
rodney.joel@faa.gov

FAA Pavement Design

Flexible Pavement FAARFIELD Design Example

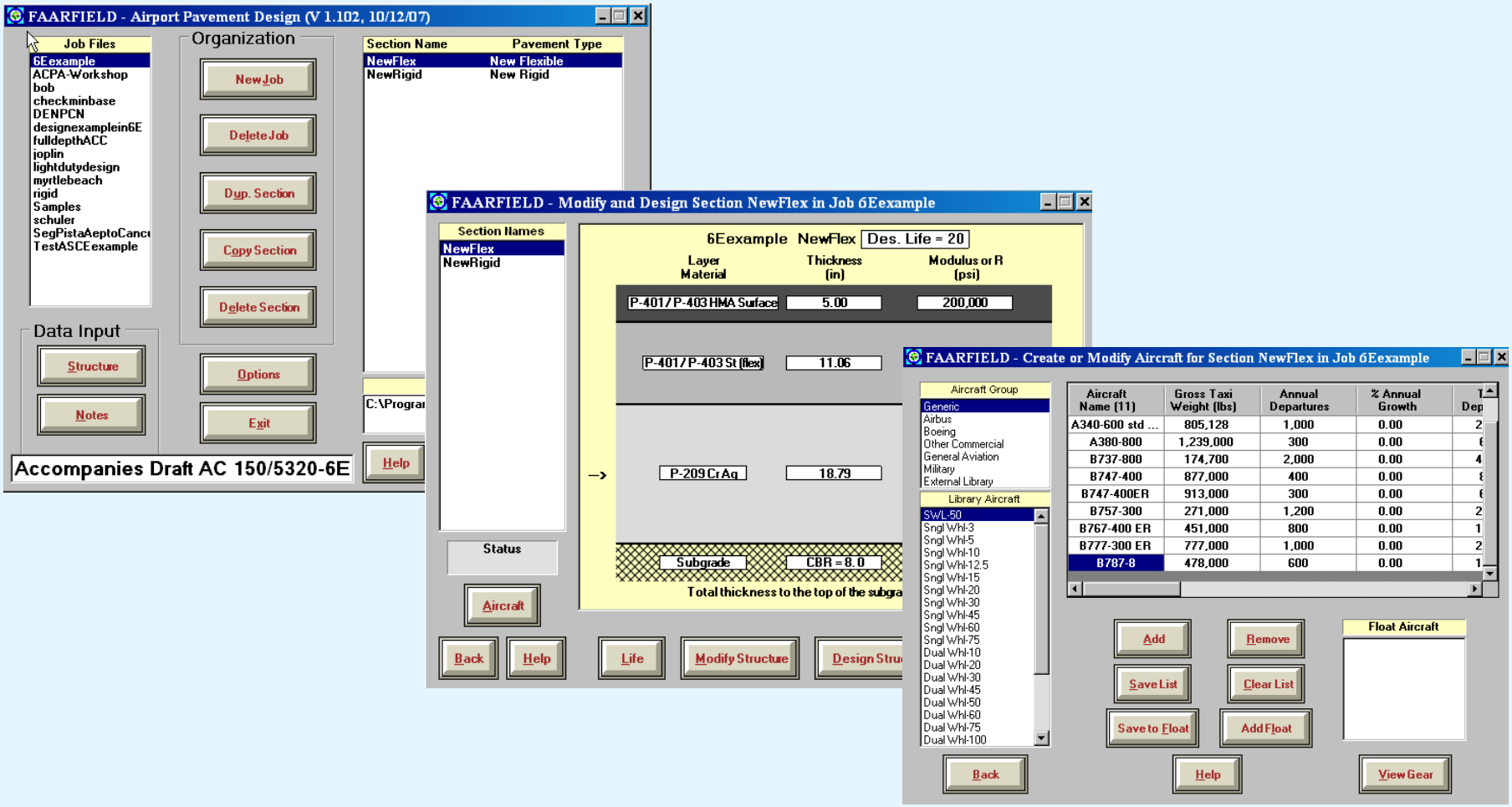
Federal Aviation Administration

Presented to: GREAT LAKES REGION AIRPORTS CONFERENCE

By: Rodney N. Joel, P.E.
Civil Engineer / Airfield Pavement
Airport Engineering Division

Date: November, 2008

FAARFIELD Flexible Pavement Design



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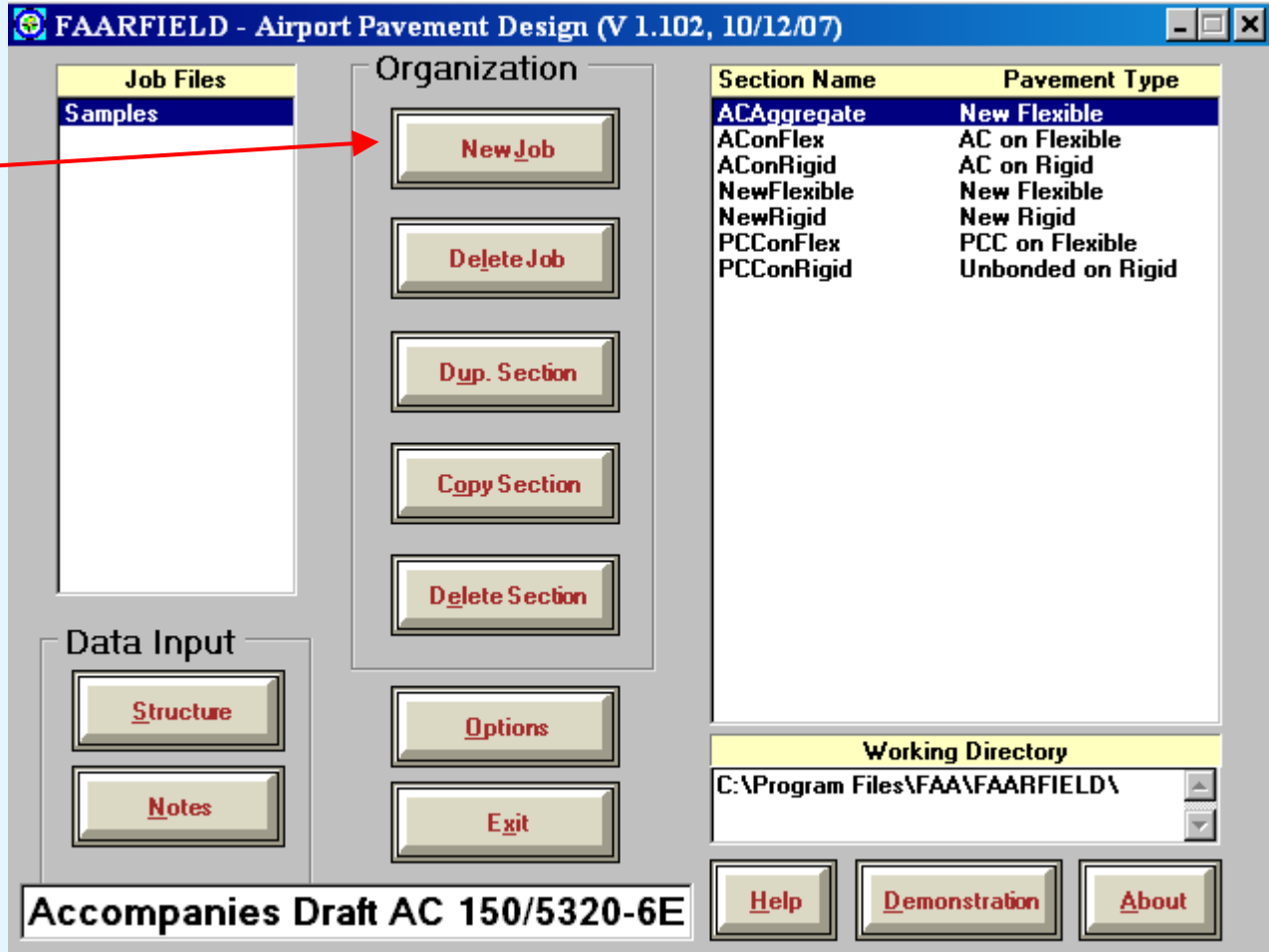
Starting Screen – No Job Files Created

Click on "New Job"



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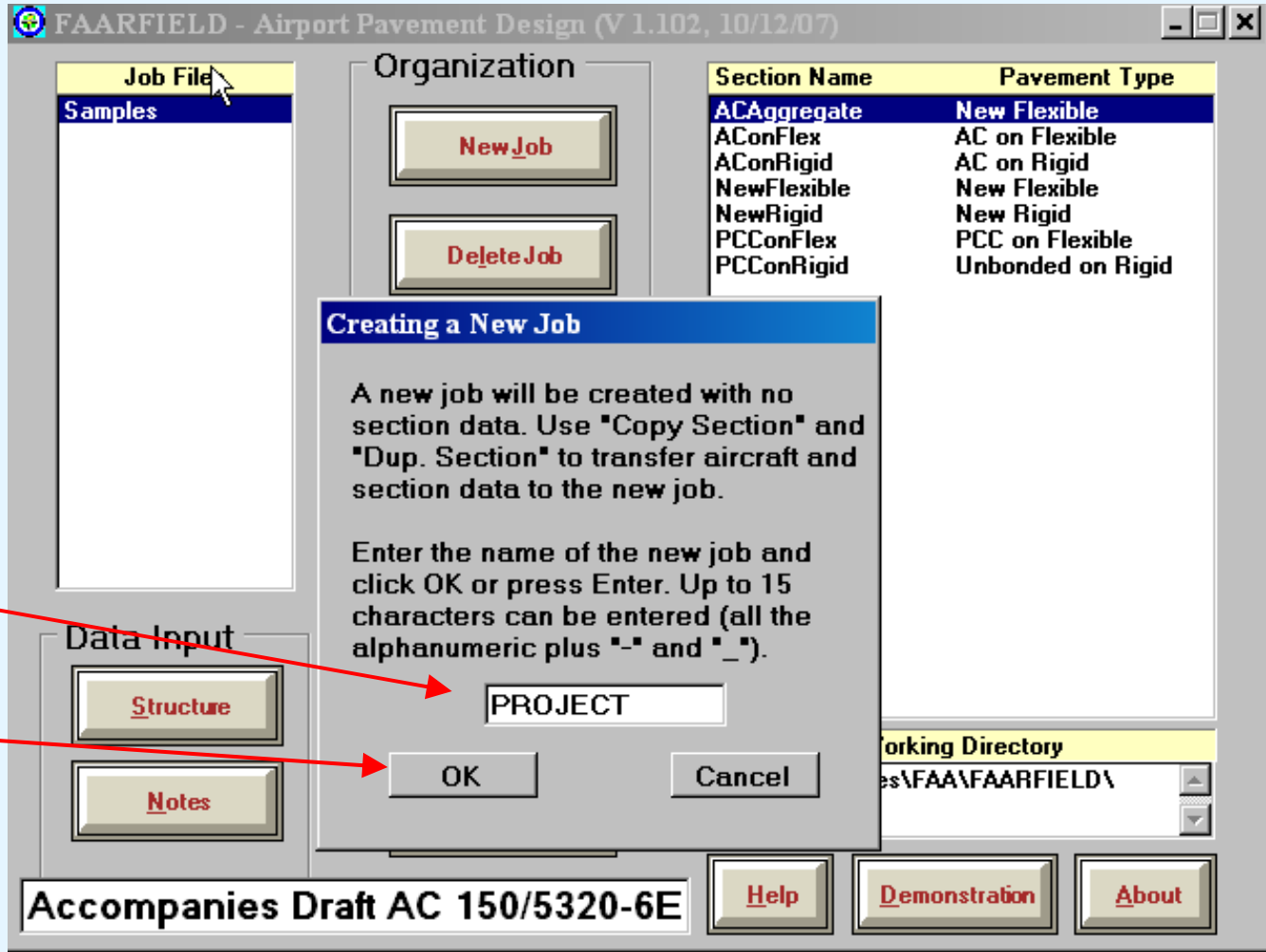
Creating / Naming a Job File



Enter Job Title

Click OK

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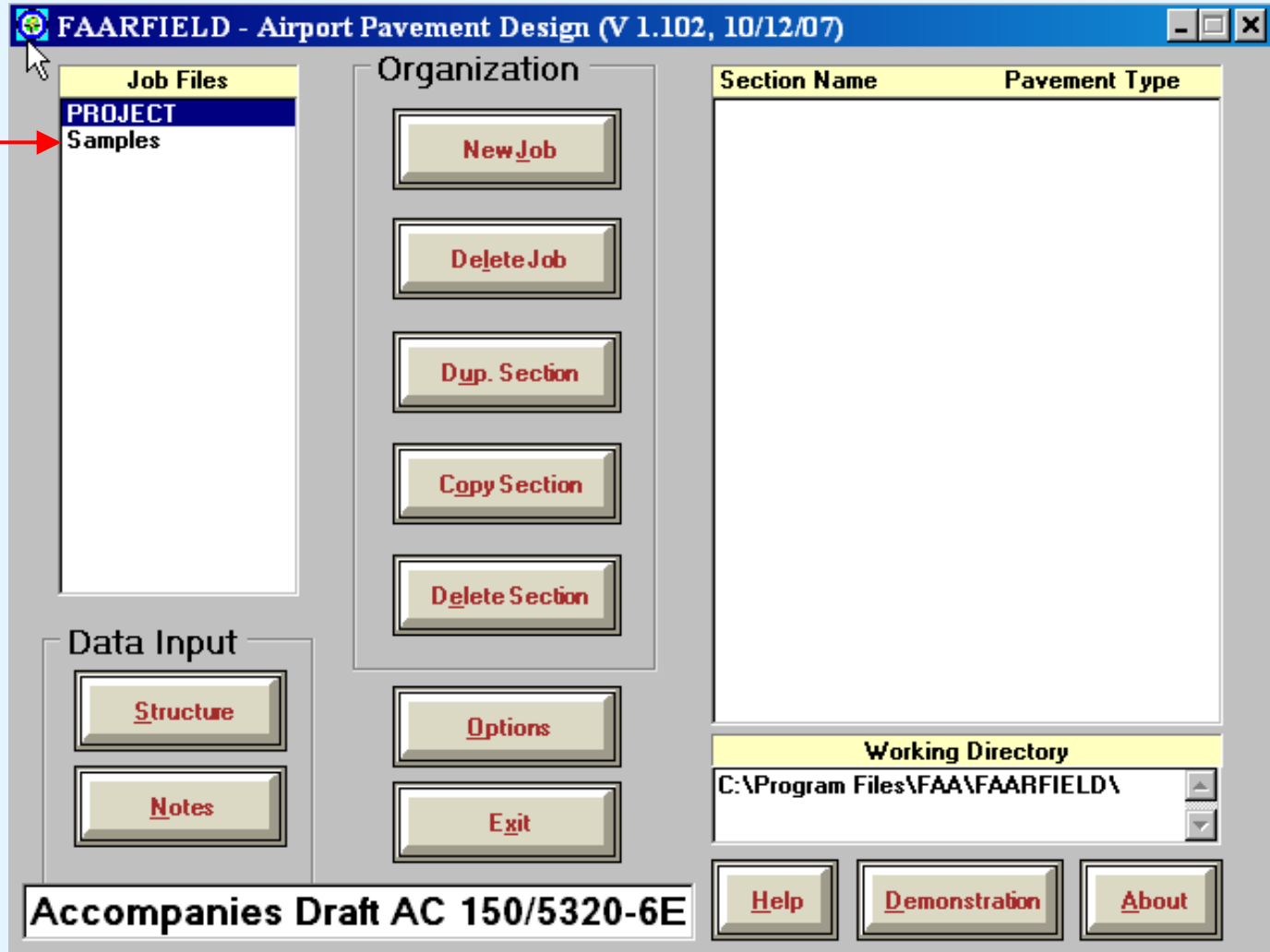
Copy Basic Section/Pavement Type from Samples

Click on “samples”



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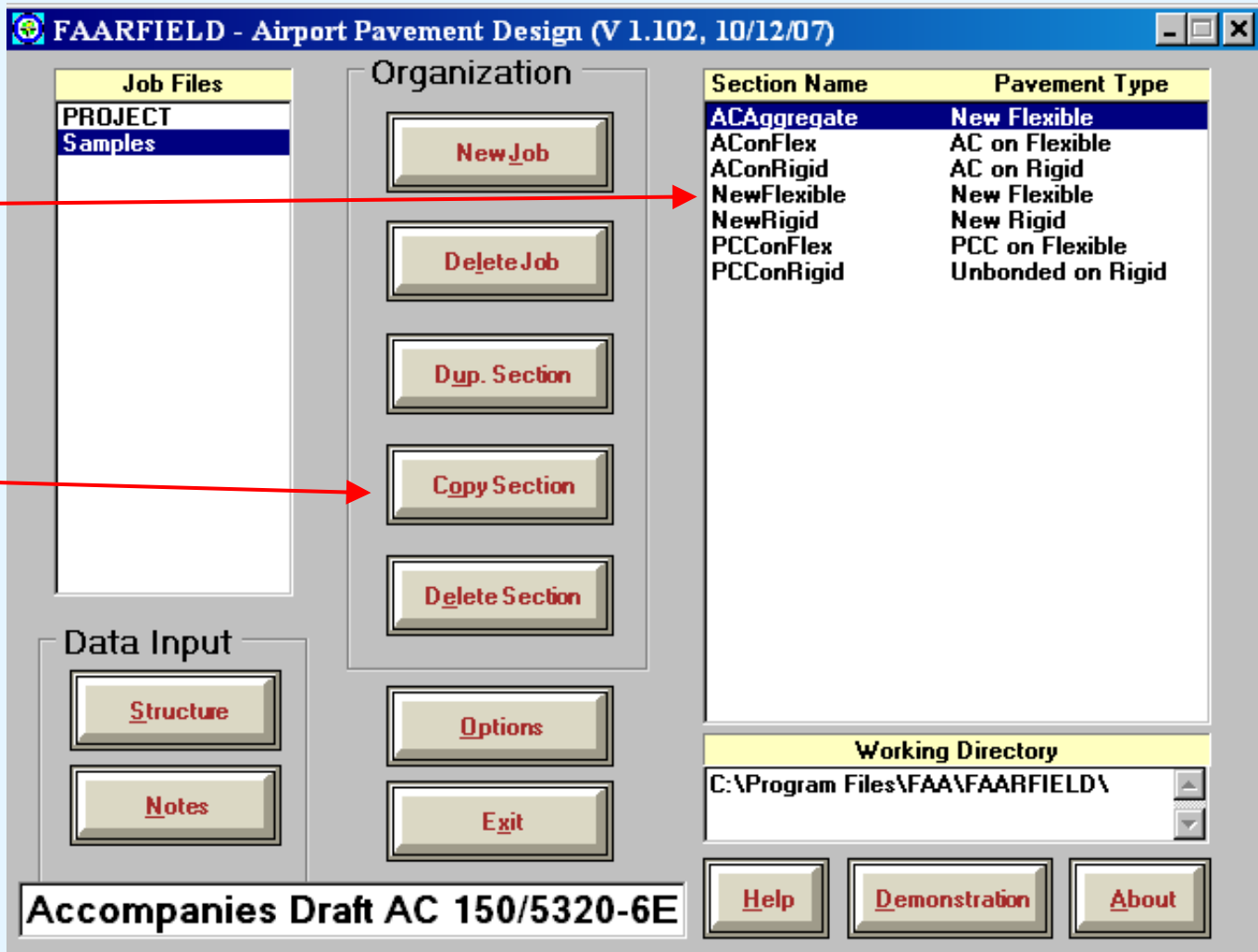
Copy Basic Section/Pavement Type from Samples

Default Basic Pavement Sections

Click on "Copy Section"



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7 Basic Starting Structures in LEDFAA

Section Name	Pavement Type
ACAggregate	New flexible on Aggregate base
AConFlex	Asphalt overlay on Flexible pavement
AConRigid	Asphalt overlay on Rigid pavement
NewFlexible	New Flexible on stabilized base
NewRigid	New Rigid on stabilized base
PCConFlex	PCC overlay on flexible
PCConRigid	Unbonded PCC on rigid

Be sure to select the pavement type that most correctly represents your pavement needs

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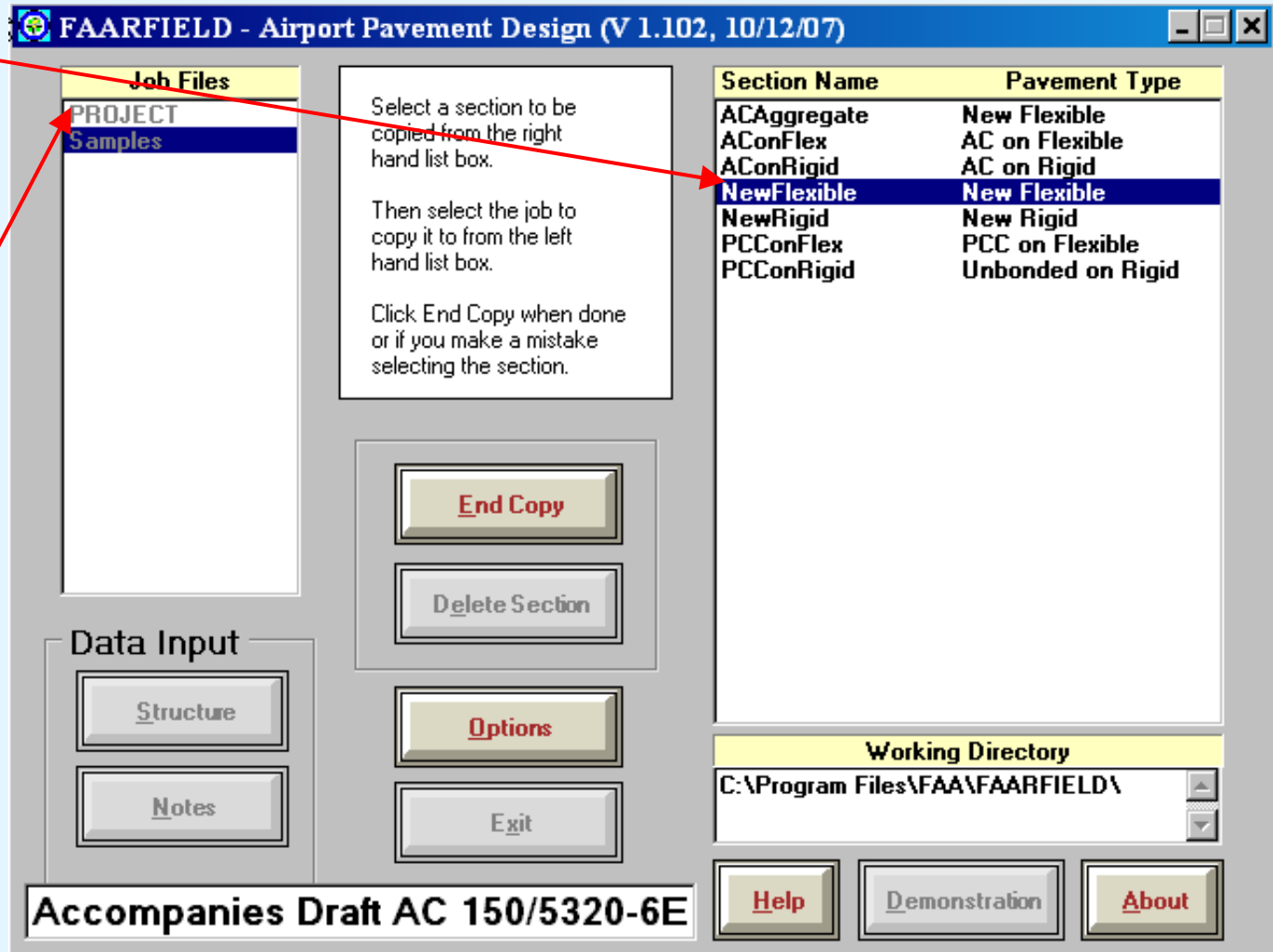
Copy a Typical Pavement Section

Click on desired pavement section

Then click on the project where the section will be saved



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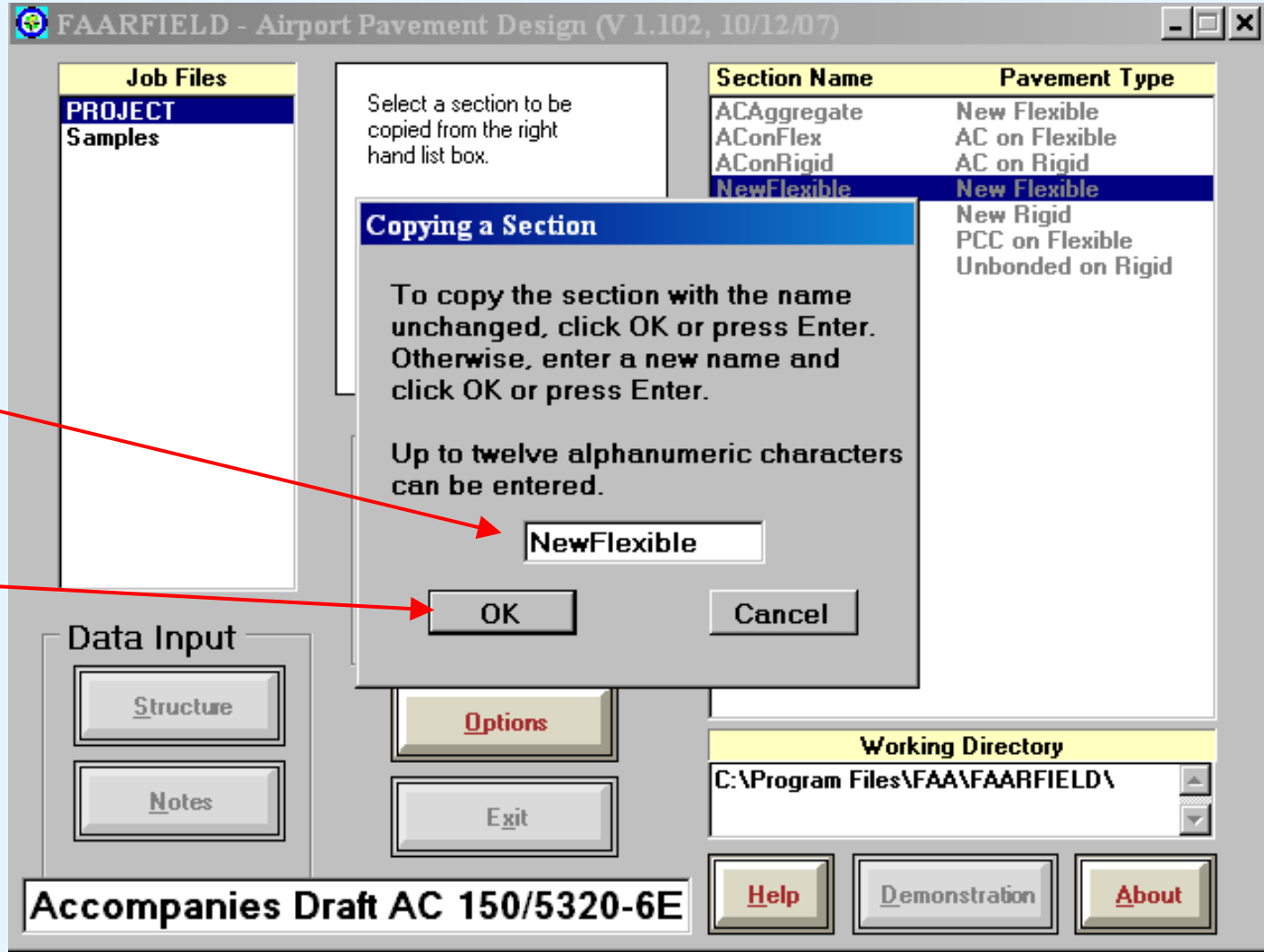
Create a New Job Title

Enter Job Title

Click OK



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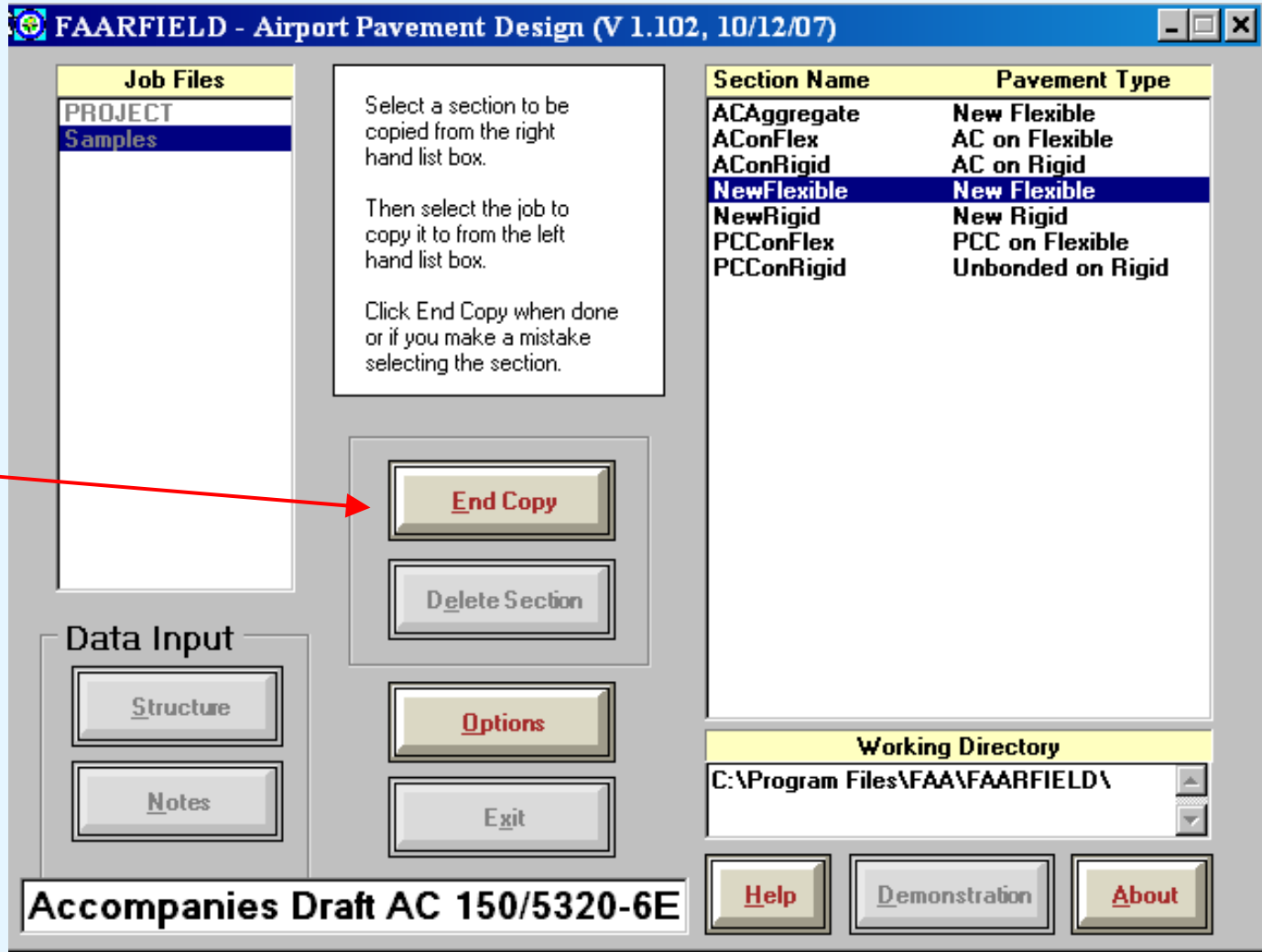
Create a New Job Title

Click “End Copy”



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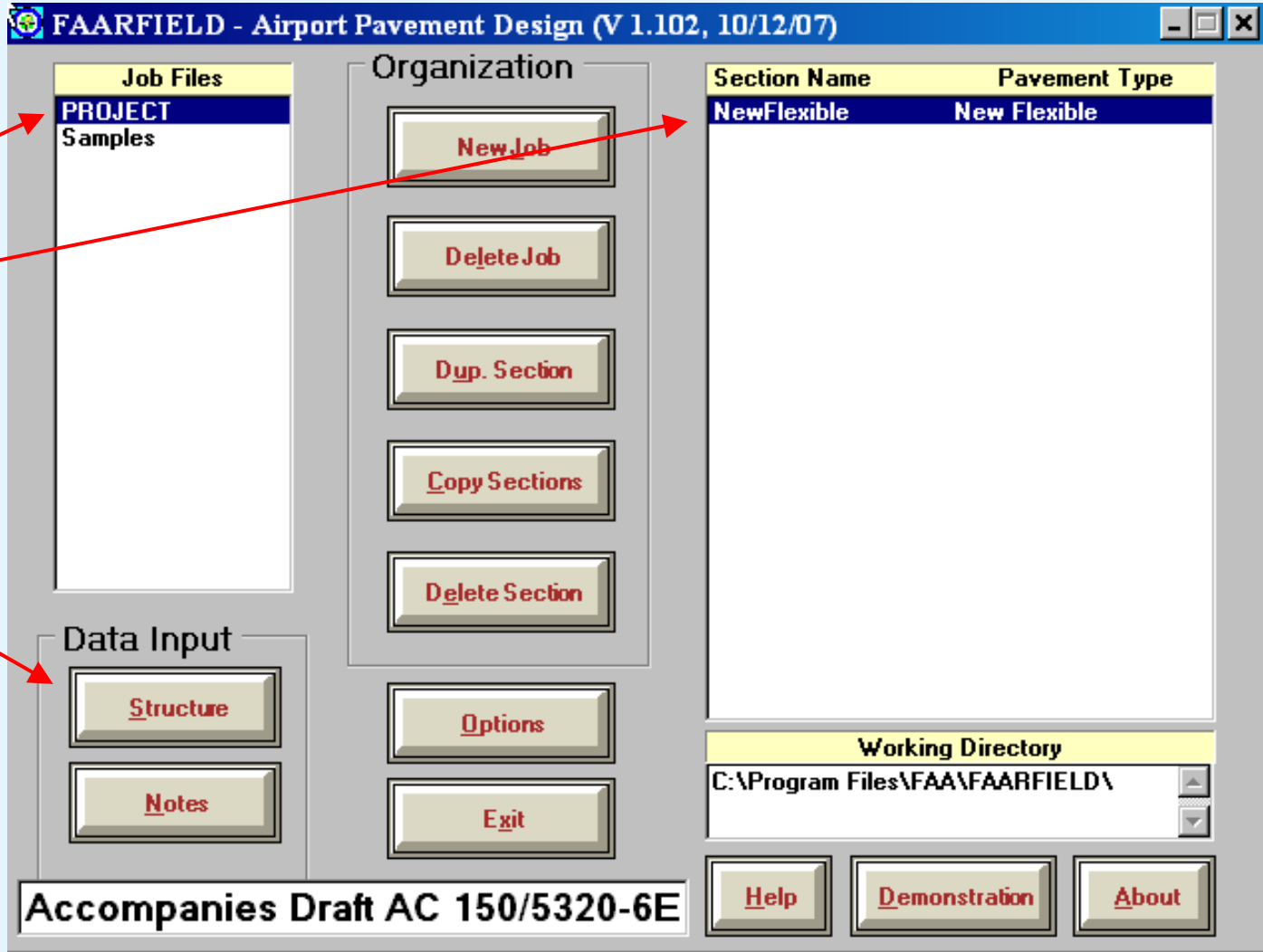
Working With a Design Structure

Select the job and then select the section you want to analyze

Click on “Structure” To open the file



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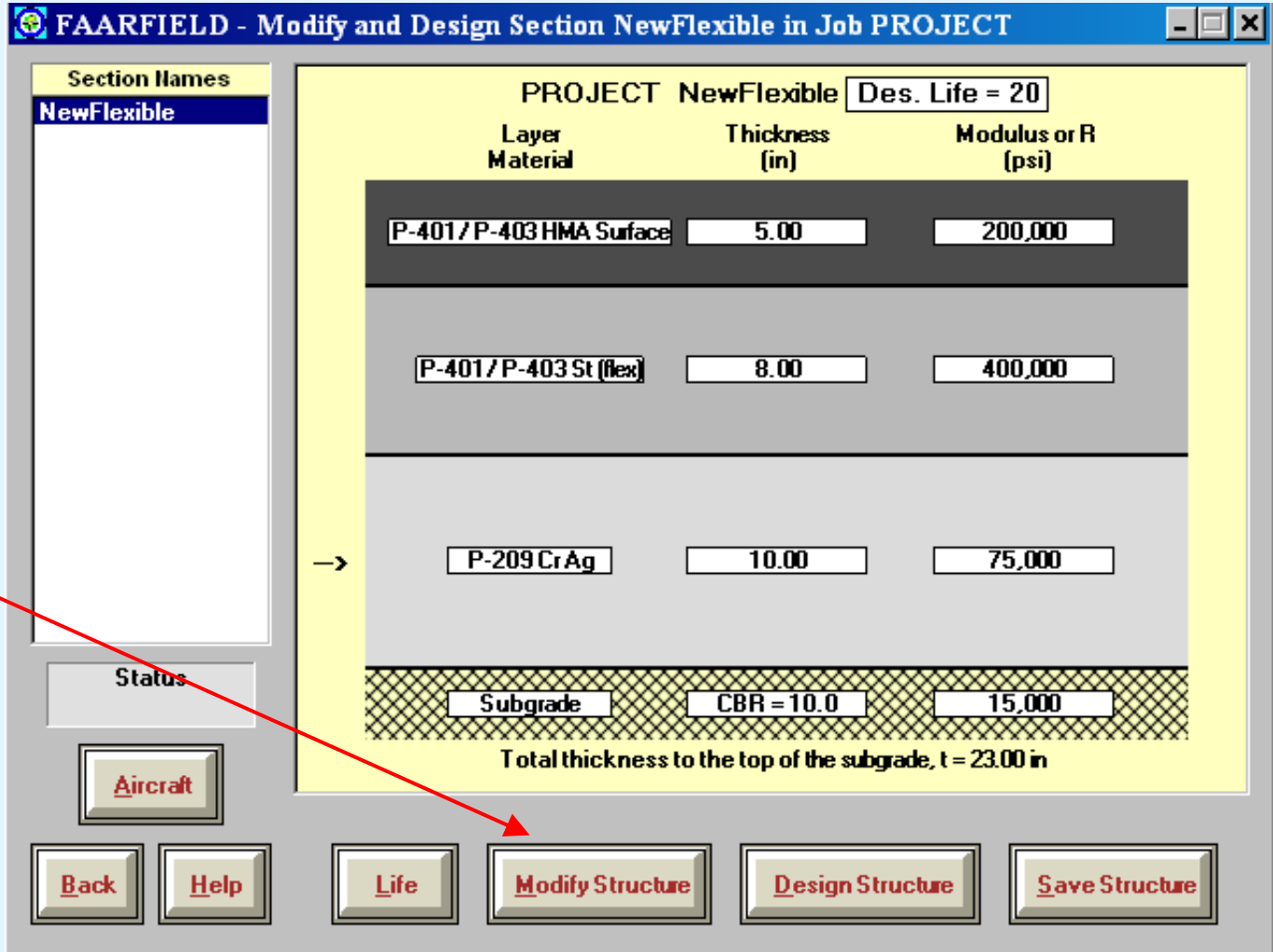
Working With a Pavement Section

The selected sample pavement will appear

The structure may be modified if desired



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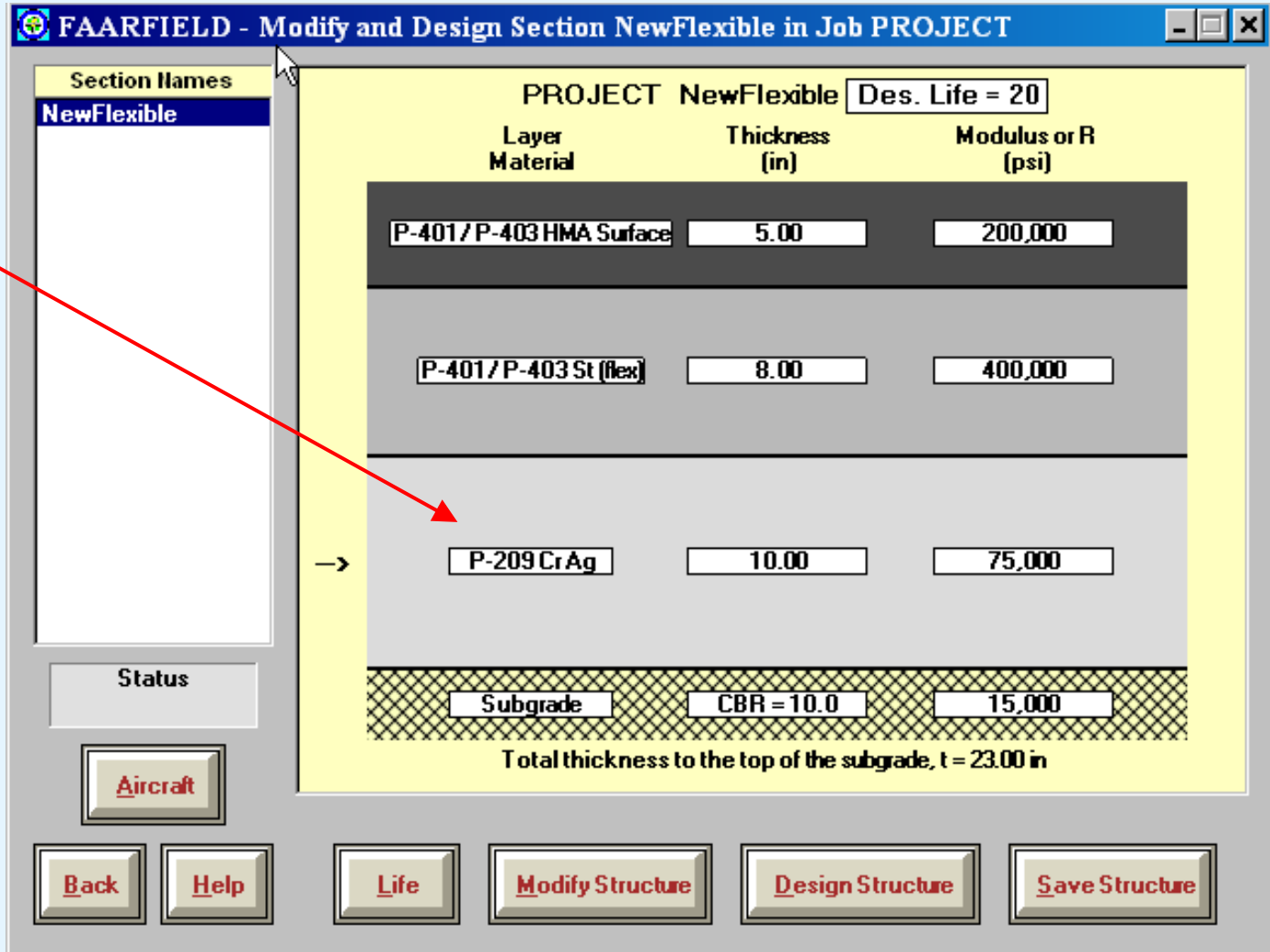
Modifying a Pavement Section

Click on the box around the layer material you want to modify



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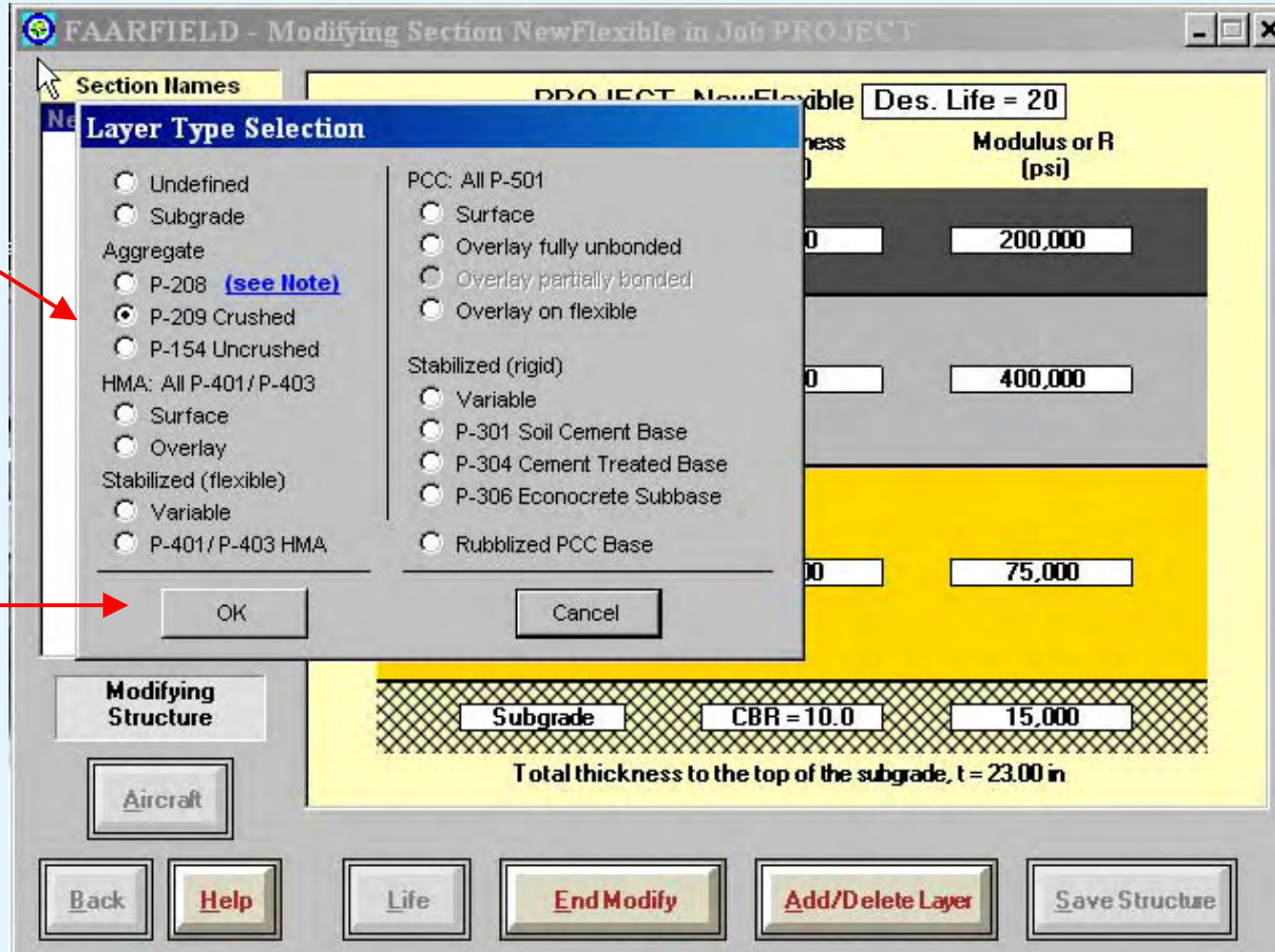
Modifying a Pavement Section

Select the layer type you want to include in your pavement section

No modification for this example

Click OK

Cancel for this example



Layer Placement Restrictions

There are restriction on placement of certain pavement layers.

e.g. You can not place an “overlay” below a “surface” course.

Other restrictions prevent or cause changes in the pavement type (flexible or rigid)

e.g. Changing a surface asphalt layer to a rigid layer will change the pavement type.

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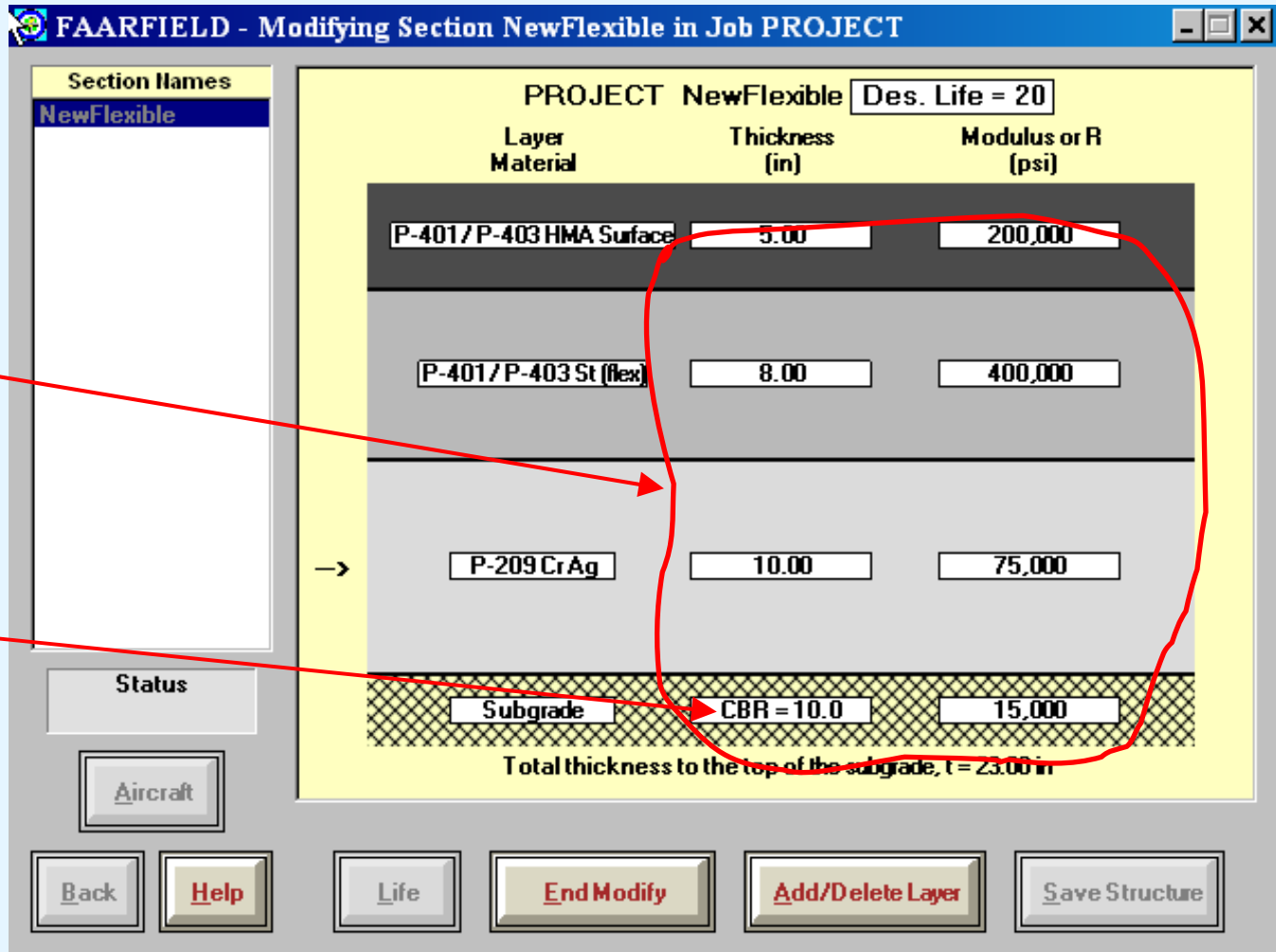
Modifying a Pavement Section

Click on a property to modify any of the layer properties

Modify the subgrade CBR for this example



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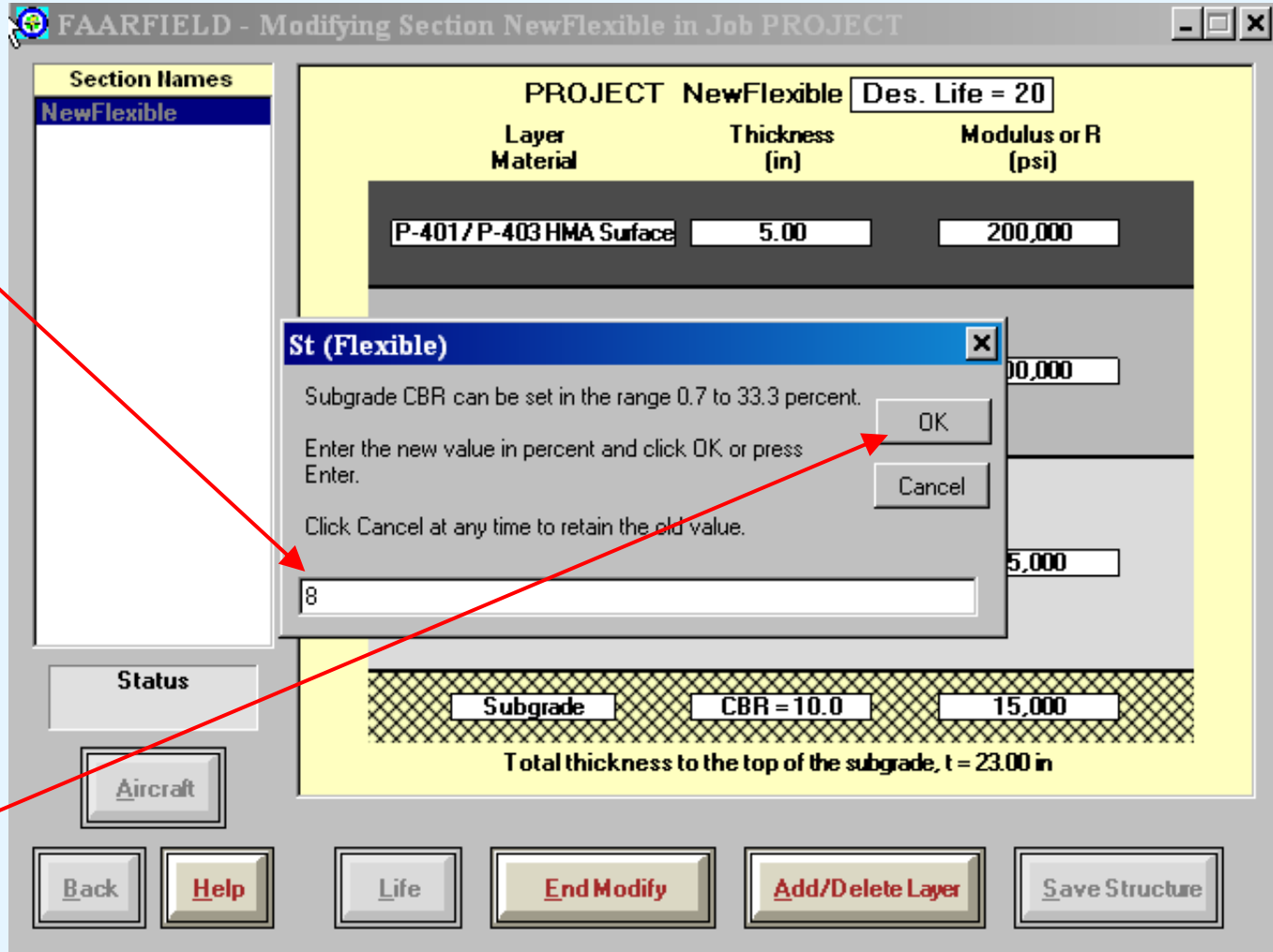
Modifying a Pavement Section

Enter the new value for the material property
***** some materials will have limits on property values***

use 8 for this example



Click OK

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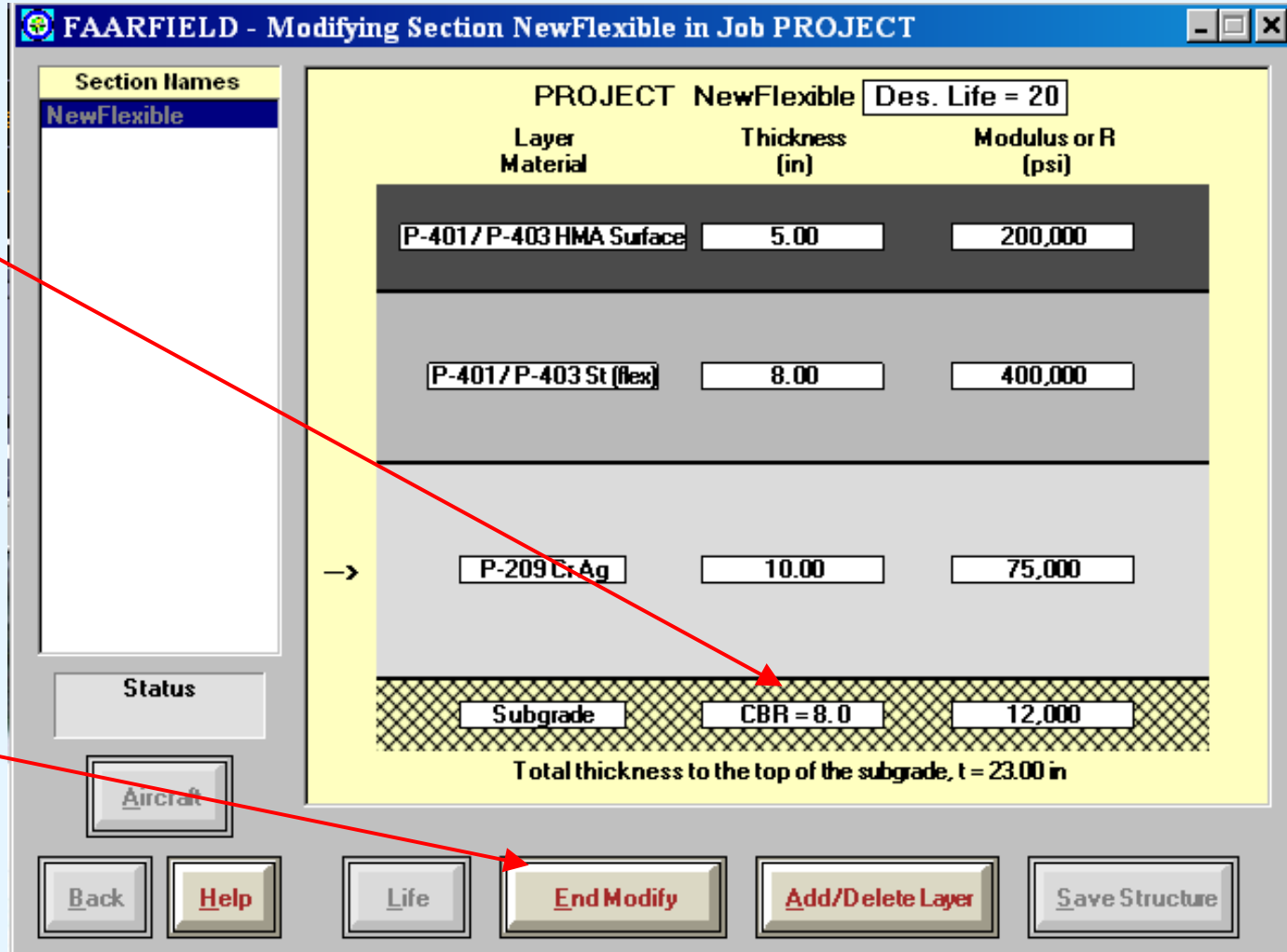
Modifying a Pavement Section

New values appear in the structure window

Click End Modify



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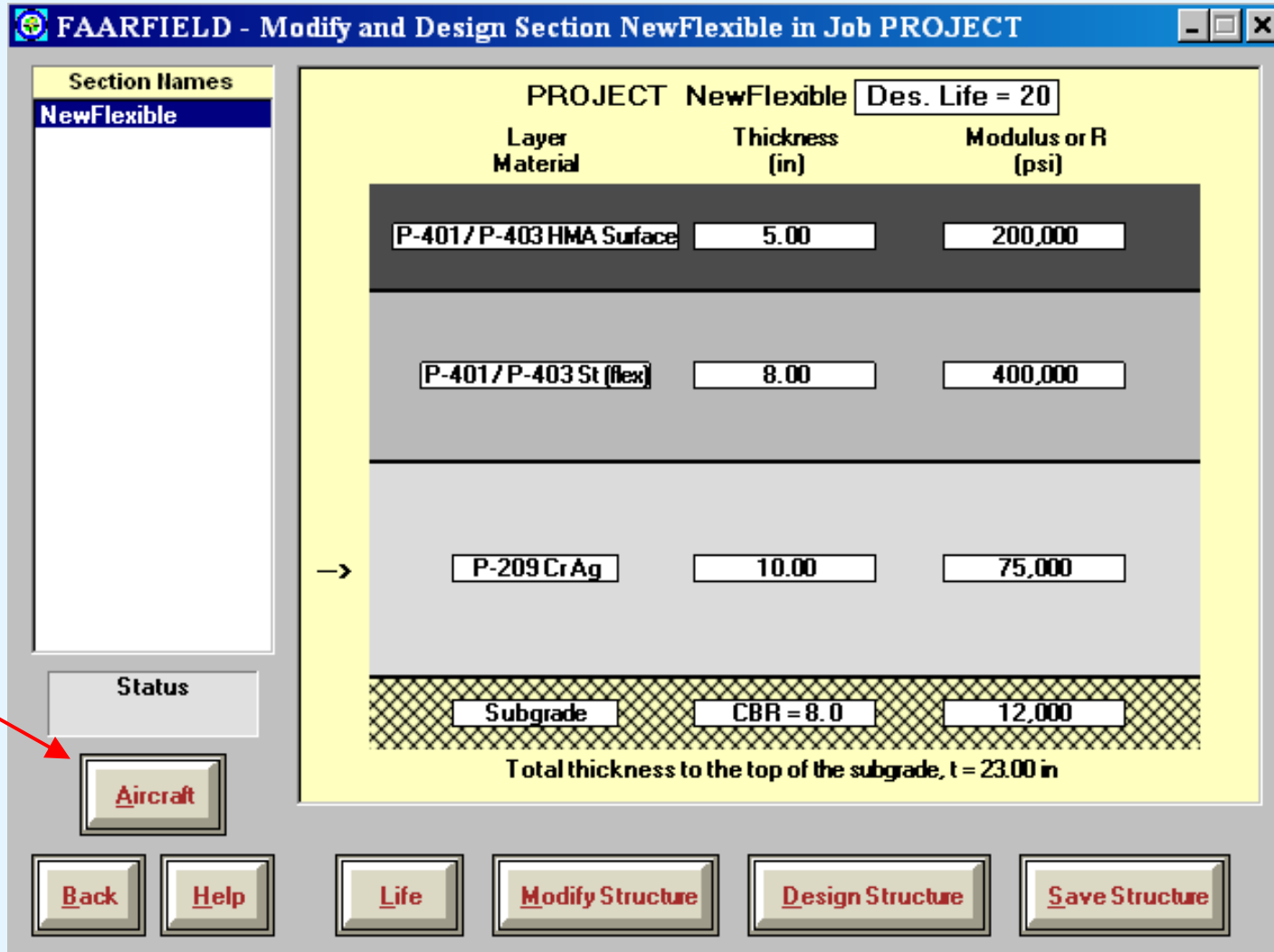
Enter Traffic Mixture

Click on "Aircraft"
To enter traffic mix



FAARFIELD Flexible Pavement Design

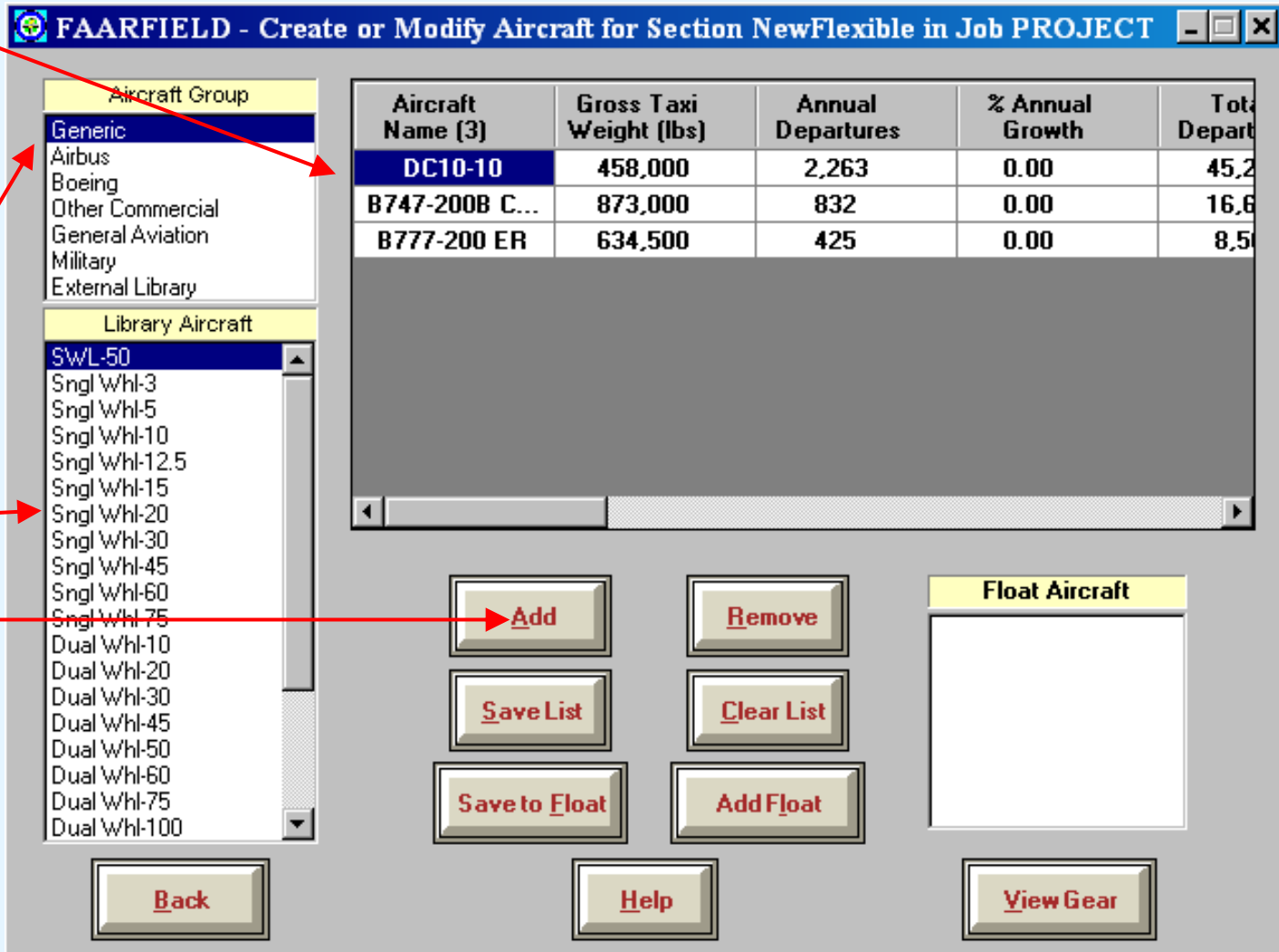
Enter Traffic Mixture

You may want to clear any existing airplanes

Click on the airplane group desired.

Then select the desired airplane and click “Add”

Repeat for complete traffic mixture



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Traffic Mix for this example

No.	Name	Gross Weight, lb	Annual Departures	Annual Growth, %
1	A320-100	150,796	600	0.00
2	A340-600 std	805,128	1,000	0.00
3	A340-600 std Belly	805,128	1,000	0.00
4	A380-800	1,239,000	300	0.00
5	B737-800	174,700	2,000	0.00
6	B747-400	877,000	400	0.00
7	B747-400ER	913,000	300	0.00
8	B757-300	271,000	1,200	0.00
9	B767-400 ER	451,000	800	0.00
10	B777-300 ER	777,000	1,000	0.00
11	B787-8	478,000	600	0.00

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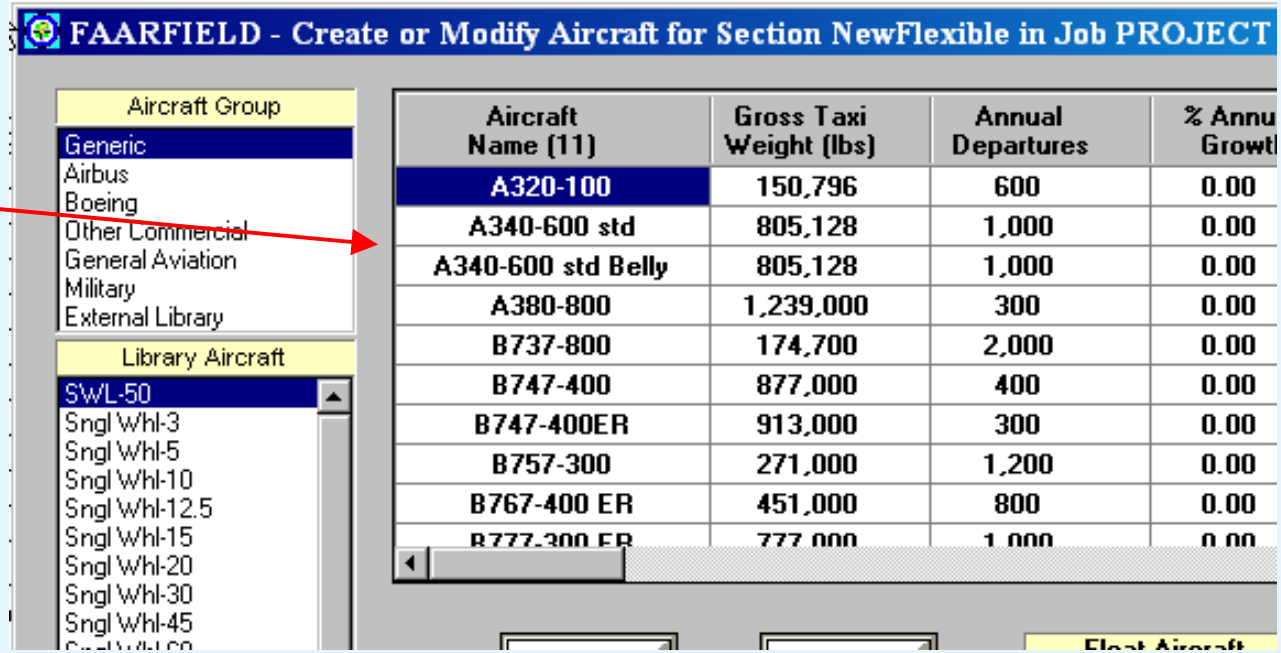
Enter Traffic Mixture

Certain airplanes may appear in the list twice. This is to address the presence of wing gears and belly gears

FAARFIELD treats these as two airplanes however the weight and departures are interlocked



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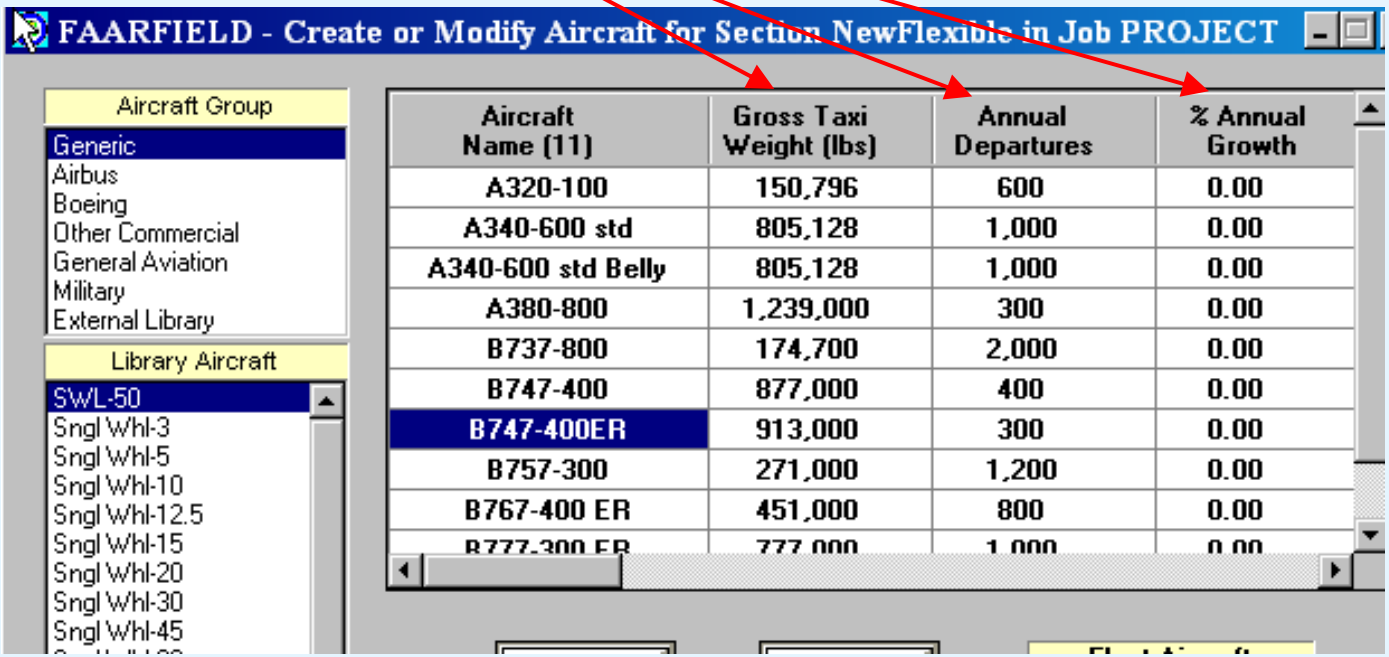
Adjusting Airplane Information

Gross Taxi Weight, Annual Departures and % Annual Growth may be modified



Aircraft Name (11)	Gross Taxi Weight (lbs)	Annual Departures	% Annual Growth
A320-100	150,796	600	0.00
A340-600 std	805,128	1,000	0.00
A340-600 std Belly	805,128	1,000	0.00
A380-800	1,239,000	300	0.00
B737-800	174,700	2,000	0.00
B747-400	877,000	400	0.00
B747-400ER	913,000	300	0.00
B757-300	271,000	1,200	0.00
B767-400 ER	451,000	800	0.00
B777-300 ER	777,000	1,000	0.00

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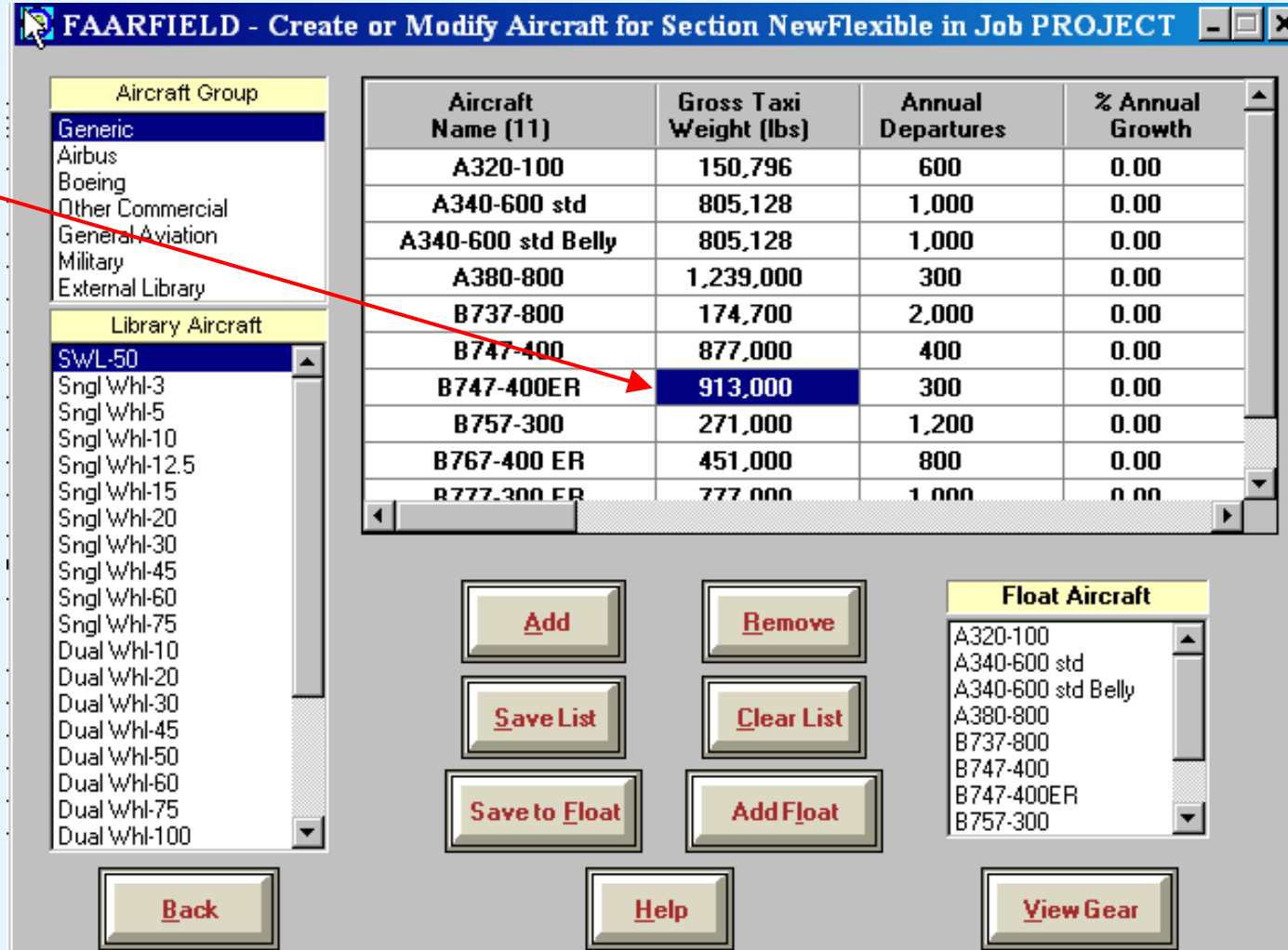
Adjusting Airplane Information – Gross Weight

Click on the airplane gross weight to change the weight



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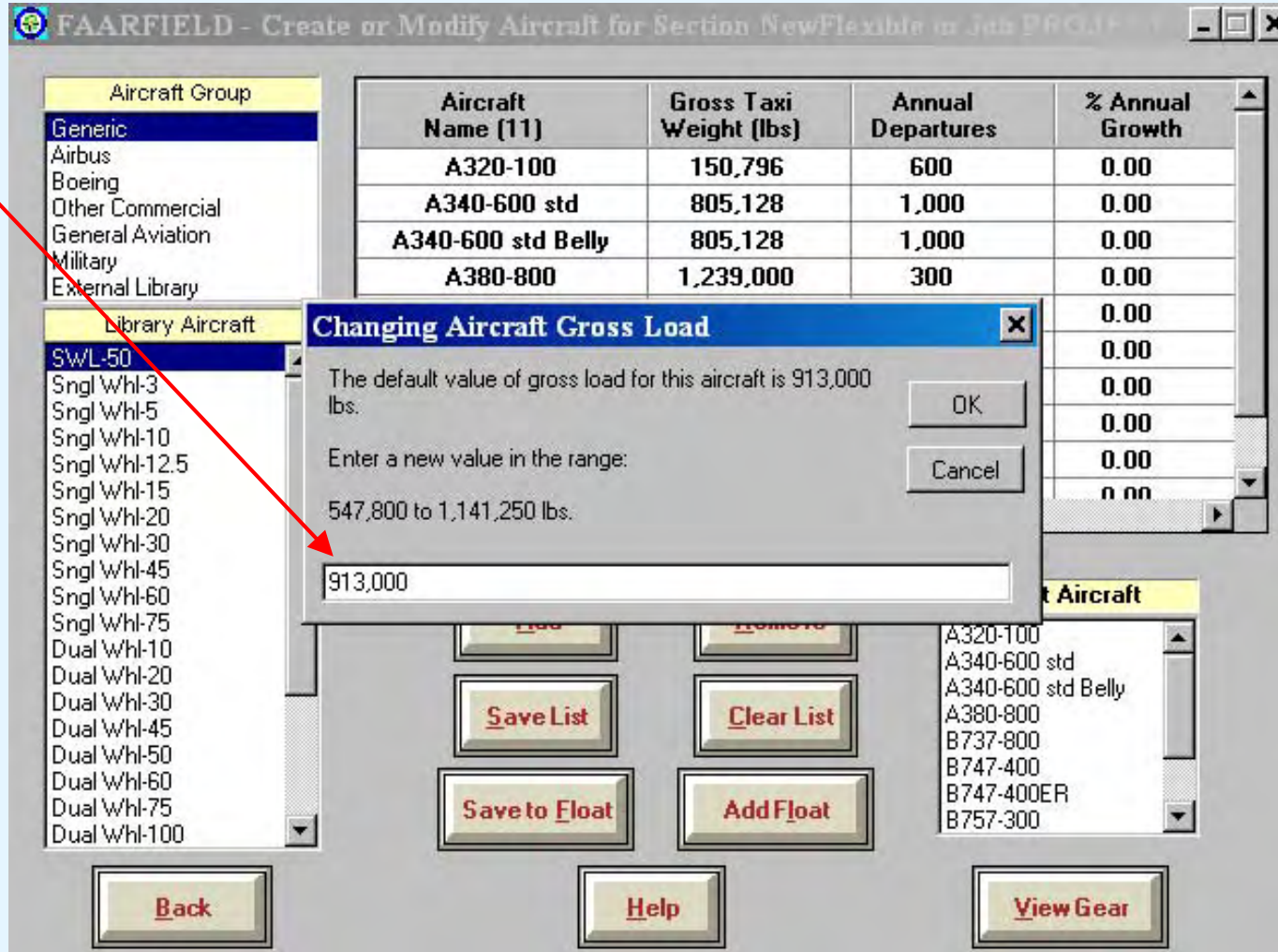
Adjusting Airplane Information – Gross Weight

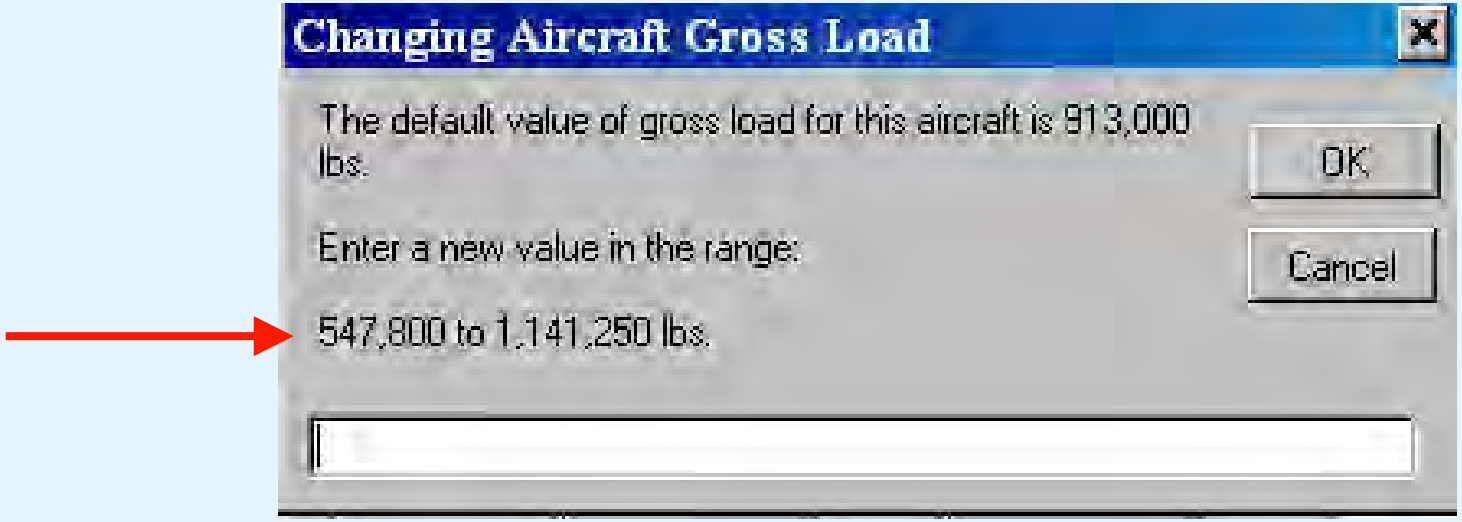
Enter the new weight and click OK



Airplane Information – Gross Weight Limitations

There are limitations on changes to airplane gross weights.

A range is provided for each airplane which represents reasonable weights for the airplane



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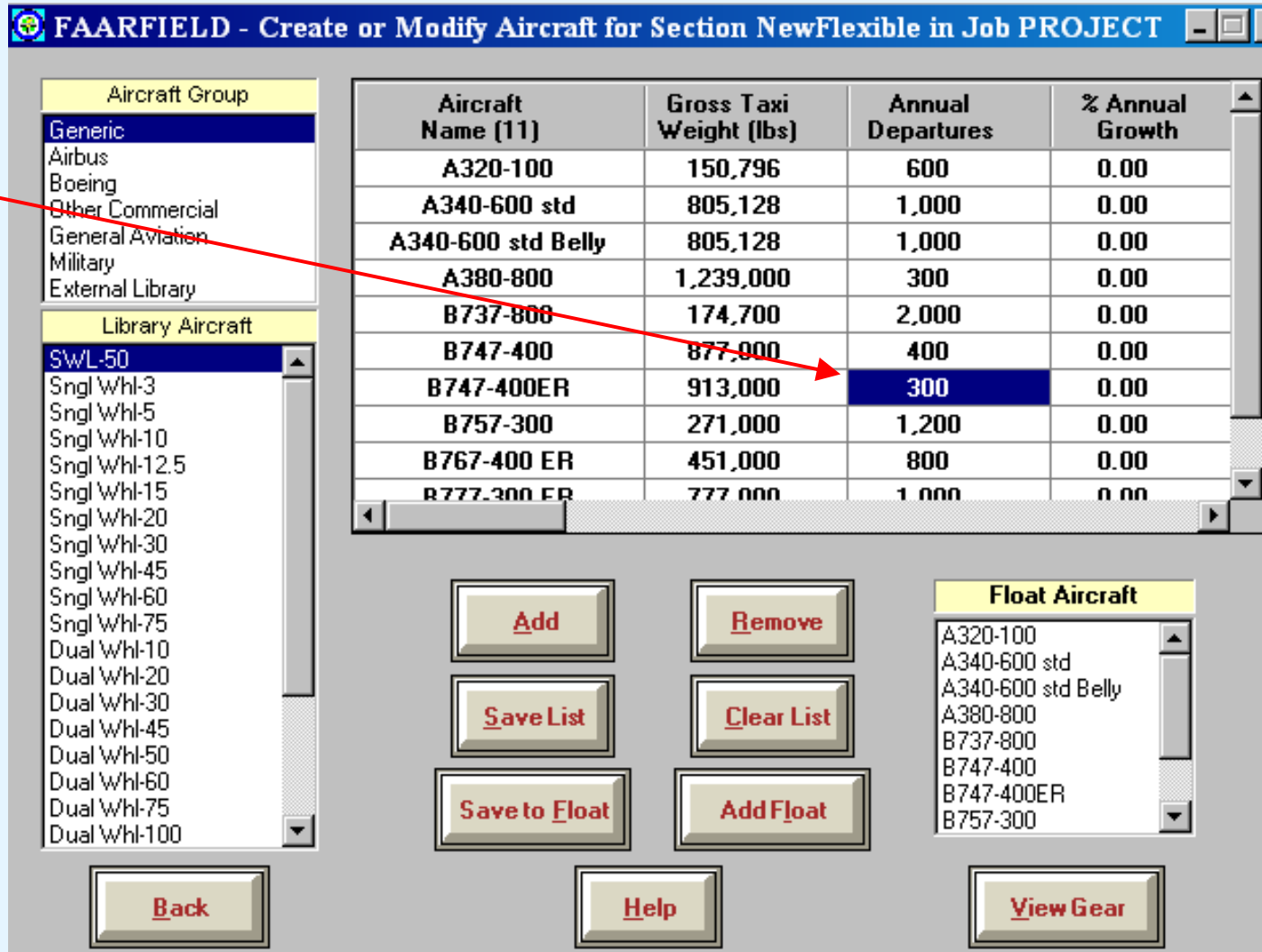
Adjusting Airplane Information – Annual Departures

Click on "Annual Departures" to change departures for an airplane



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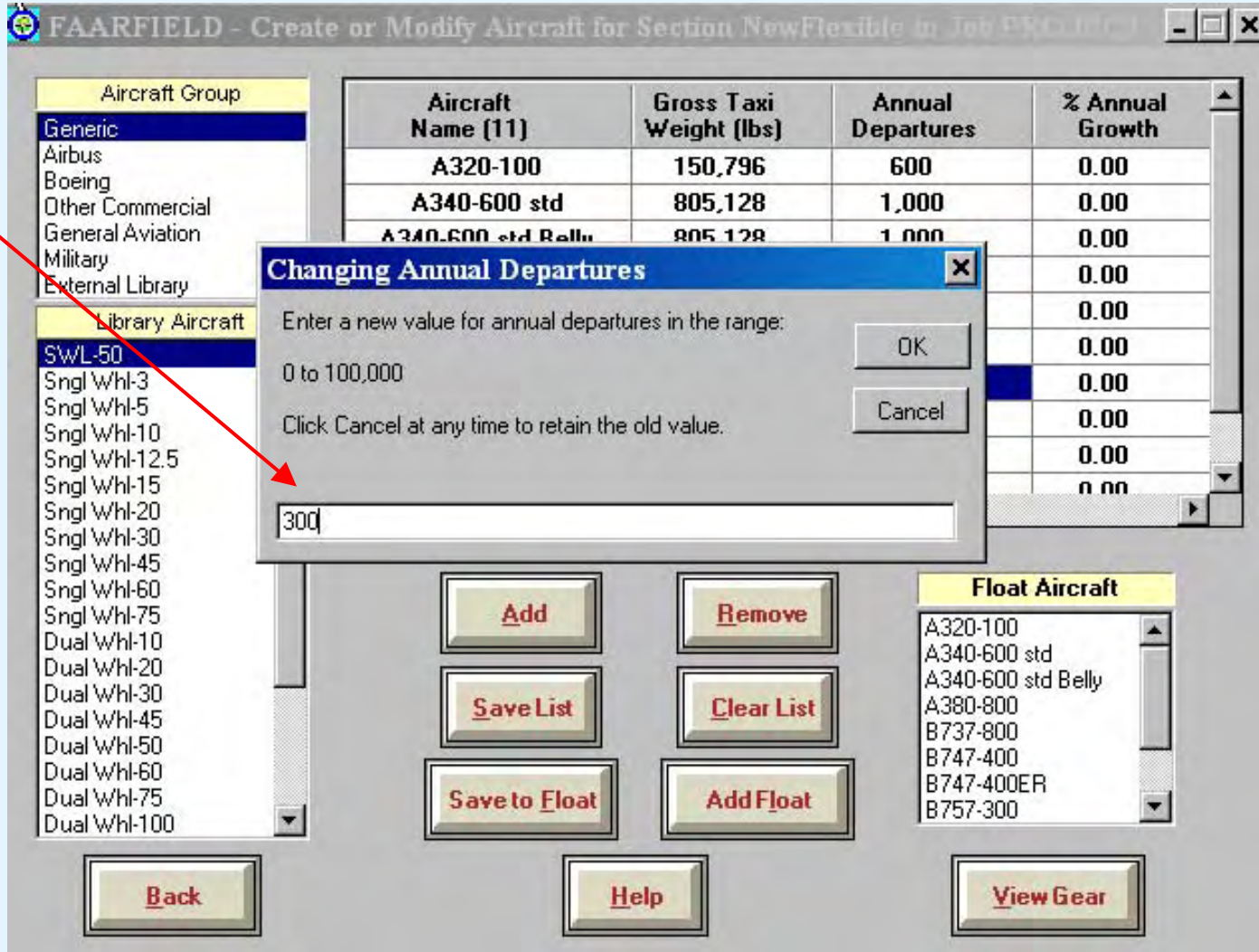
Adjusting Airplane Information – Annual Departures

Enter the annual departures of the airplane
Click OK



Annual Departures in FAARFIELD

- Annual departures has the same meaning as the previous design procedure.
- Arrivals are ignored.
- For design purposes FAARFIELD uses the total annual departures, adjusted for growth, multiplied by the total design period in years

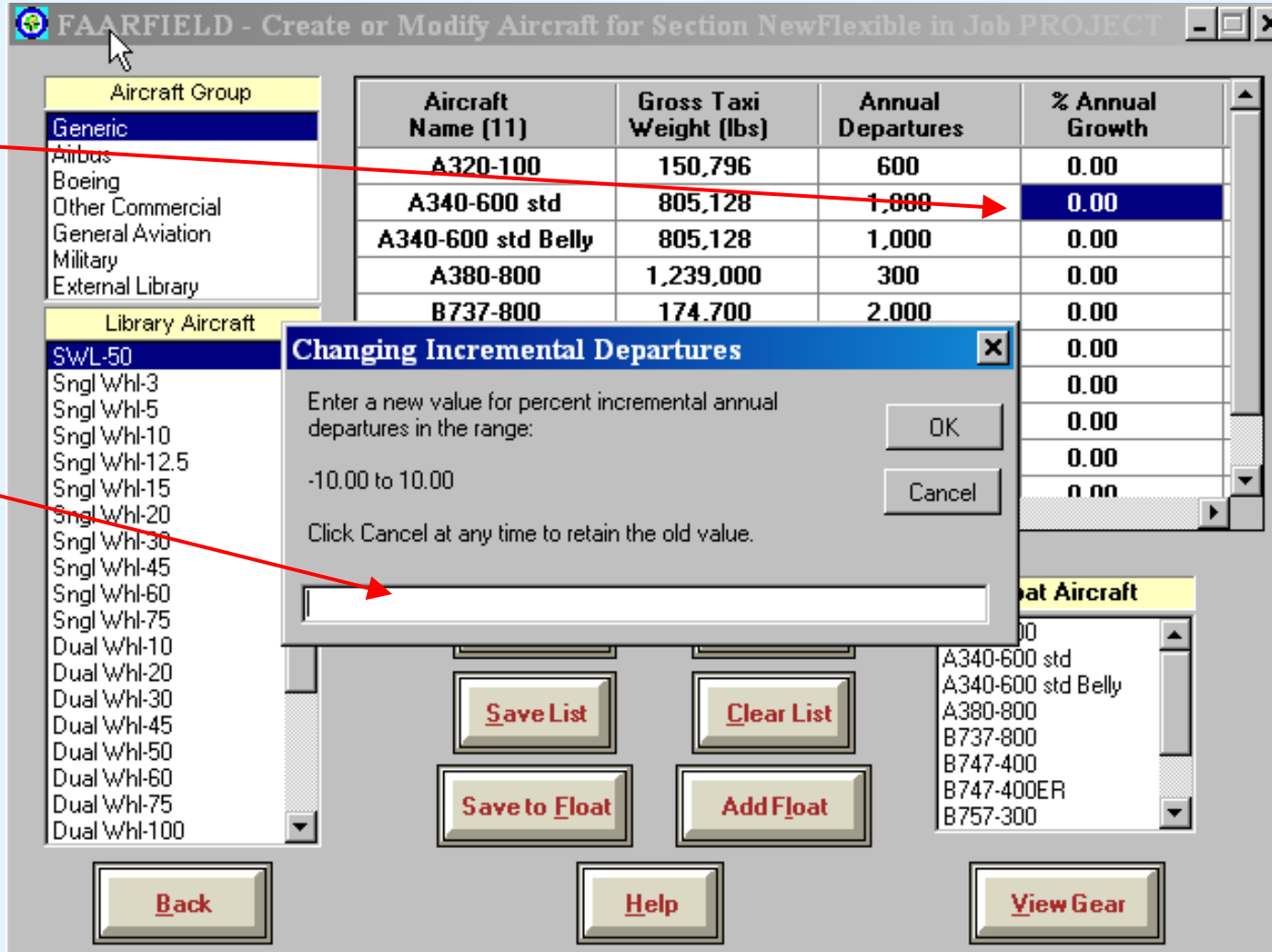
  e.g. 1200 annual departures X 20 years = 24,000 departures

FAARFIELD Flexible Pavement Design

Adjusting Airplane Information – % Annual Growth of Annual Departures

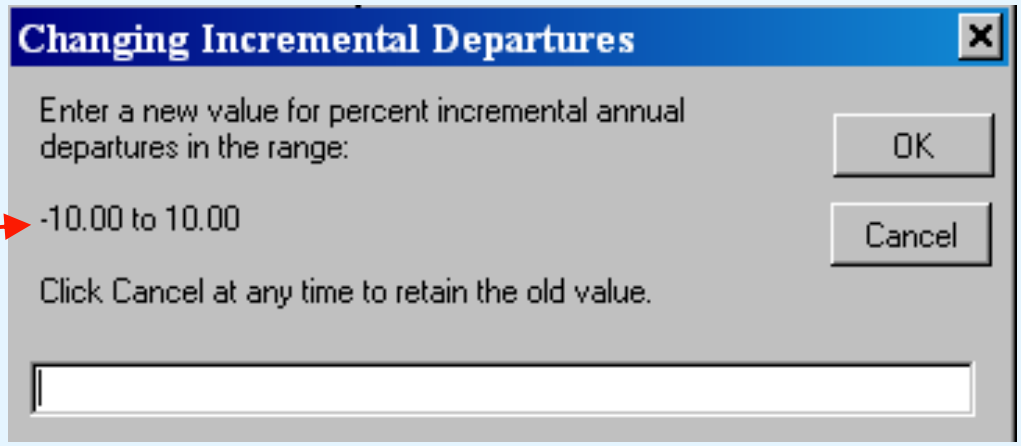
Click on the annual growth value to bring up the pop-up box.

Enter the percent annual growth and click OK



Adjusting Airplane Information – % Annual Growth of Annual Departures

Allowable range of percent annual growth is +/- 10%



You can create the same effect by modifying the annual departures such that the total annual departures results in the desired total.

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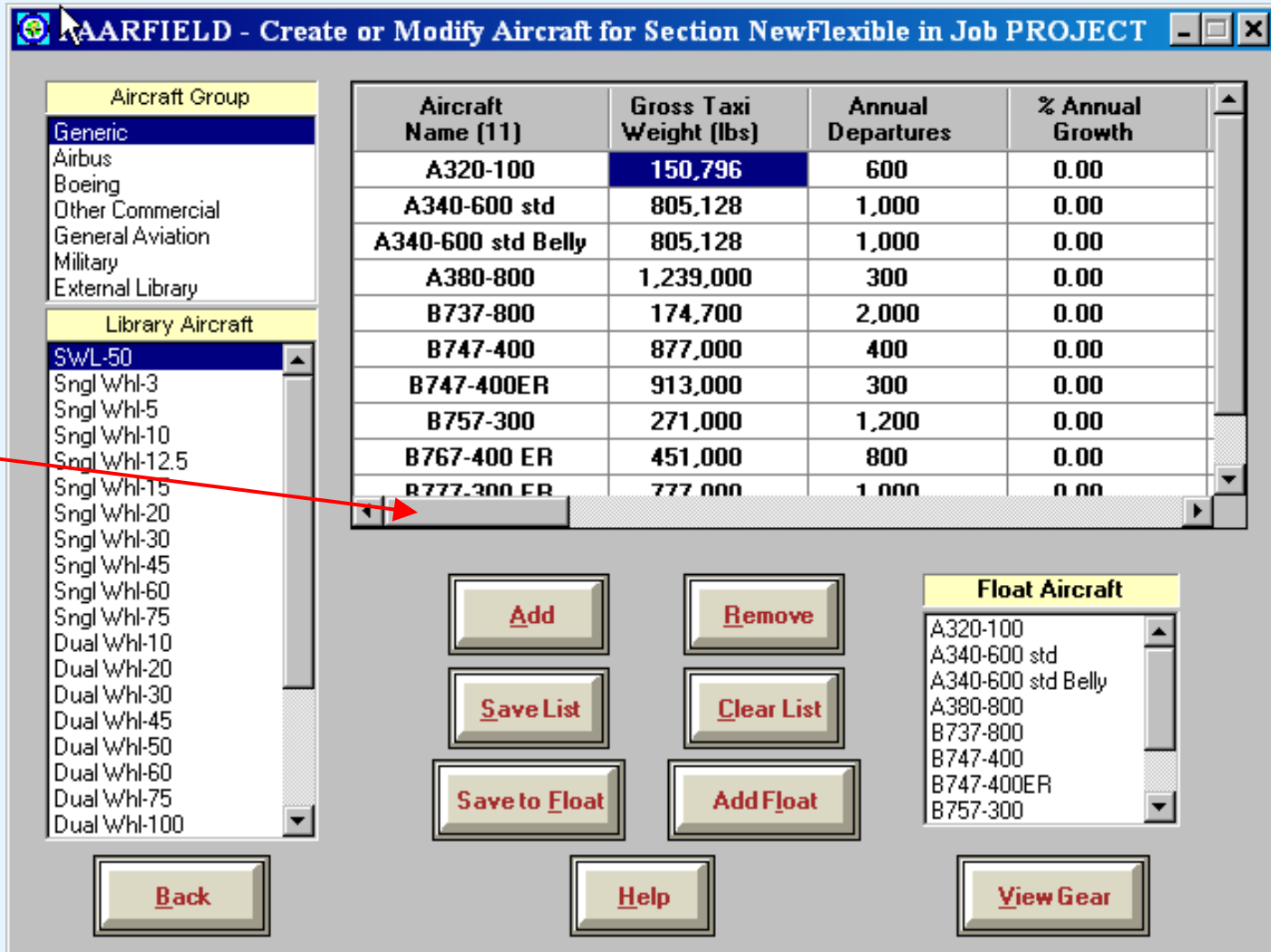
Viewing Airplane Information

Scroll over to reveal additional columns of information



FAARFIELD Flexible Pavement Design

Airplane Information

Available in FAARFIELD Aircraft Screen

Aircraft Name (11)	Gross Taxi Weight (lbs)	Annual Departures	% Annual Growth	Total Departures	CDF Contribution	CDF Max for Aircraft
A320-100	150,796	600	0.00	12,000	0.00	0.00
A340-600 std	805,128	1,000	0.00	20,000	0.00	0.00
A340-600 std Belly	805,128	1,000	0.00	20,000	0.00	0.00
A380-800	1,239,000	300	0.00	6,000	0.00	0.00
B737-800	174,700	2,000	0.00	40,000	0.00	0.00
B747-400	877,000	400	0.00	8,000	0.00	0.00
B747-400ER	913,000	300	0.00	6,000	0.00	0.00
B757-300	271,000	1,200	0.00	24,000	0.00	0.00
B767-400 ER	451,000	800	0.00	16,000	0.00	0.00

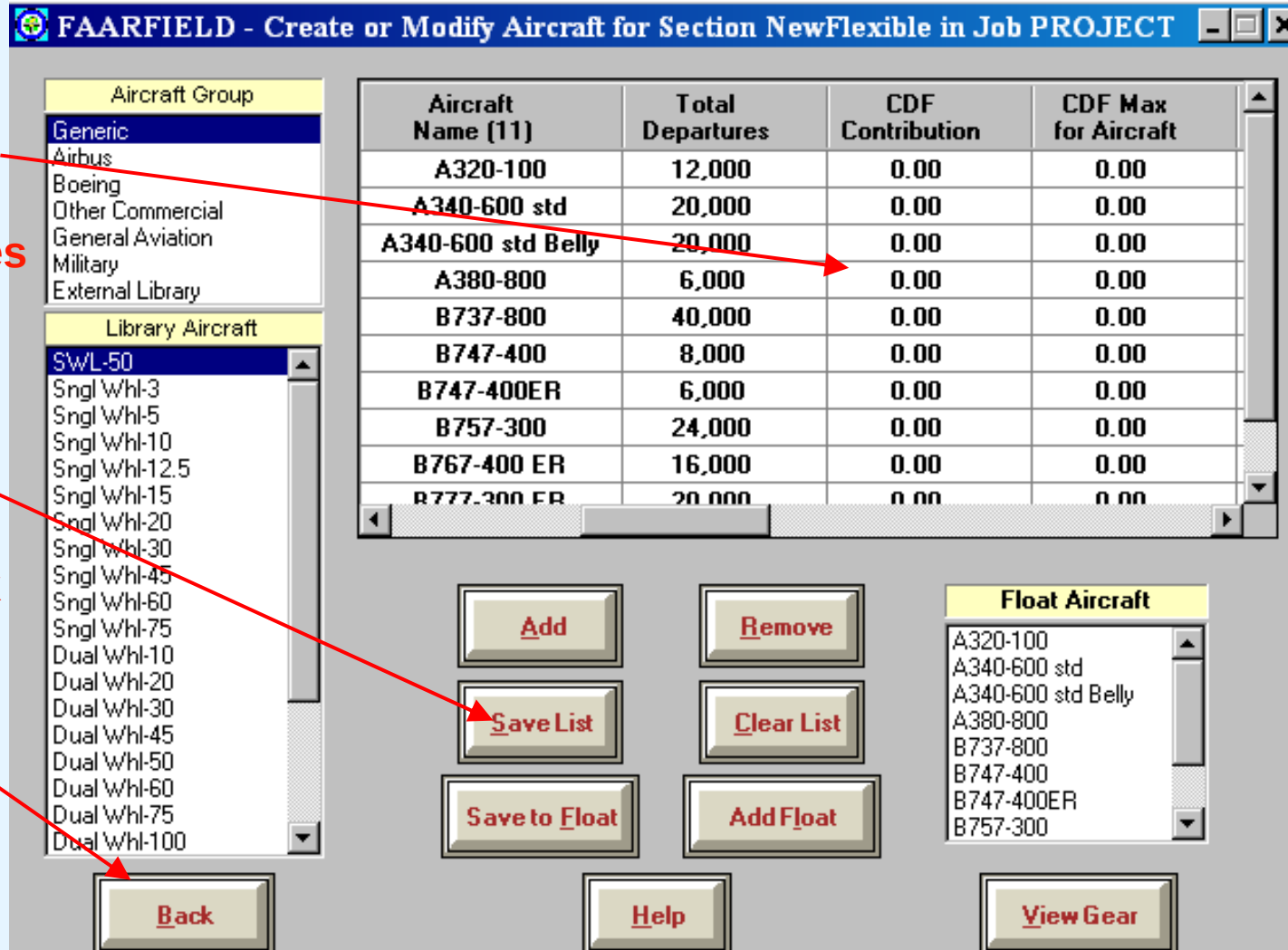
P/C Ratio	Tire Press. (psi)	Percent GW on Gear	Dual Spacing (in)	Tandem Spacing (in)	Tire Contact Width (in)	Tire Contact Length (in)
0.00	200	47.5	36.50	0.00	11.93	19.09
0.00	233	32.8	55.00	78.00	15.02	24.04
0.00	222	29.3	46.00	78.00	14.55	23.28
0.00	194	95.0	53.10	66.90	15.54	24.86
0.00	205	47.5	34.00	0.00	12.69	20.31
0.00	200	95.0	44.00	58.00	14.39	23.03
0.00	230	95.0	44.00	58.00	13.70	21.91
0.00	195	47.5	34.00	45.00	11.46	18.34
0.00	215	47.5	45.80	54.00	14.08	22.53

FAARFIELD Flexible Pavement Design

Viewing Airplane Information

CDF columns and P/C ratio will be zero when airplanes are first entered

Save the list when finished entering airplanes then click the back button

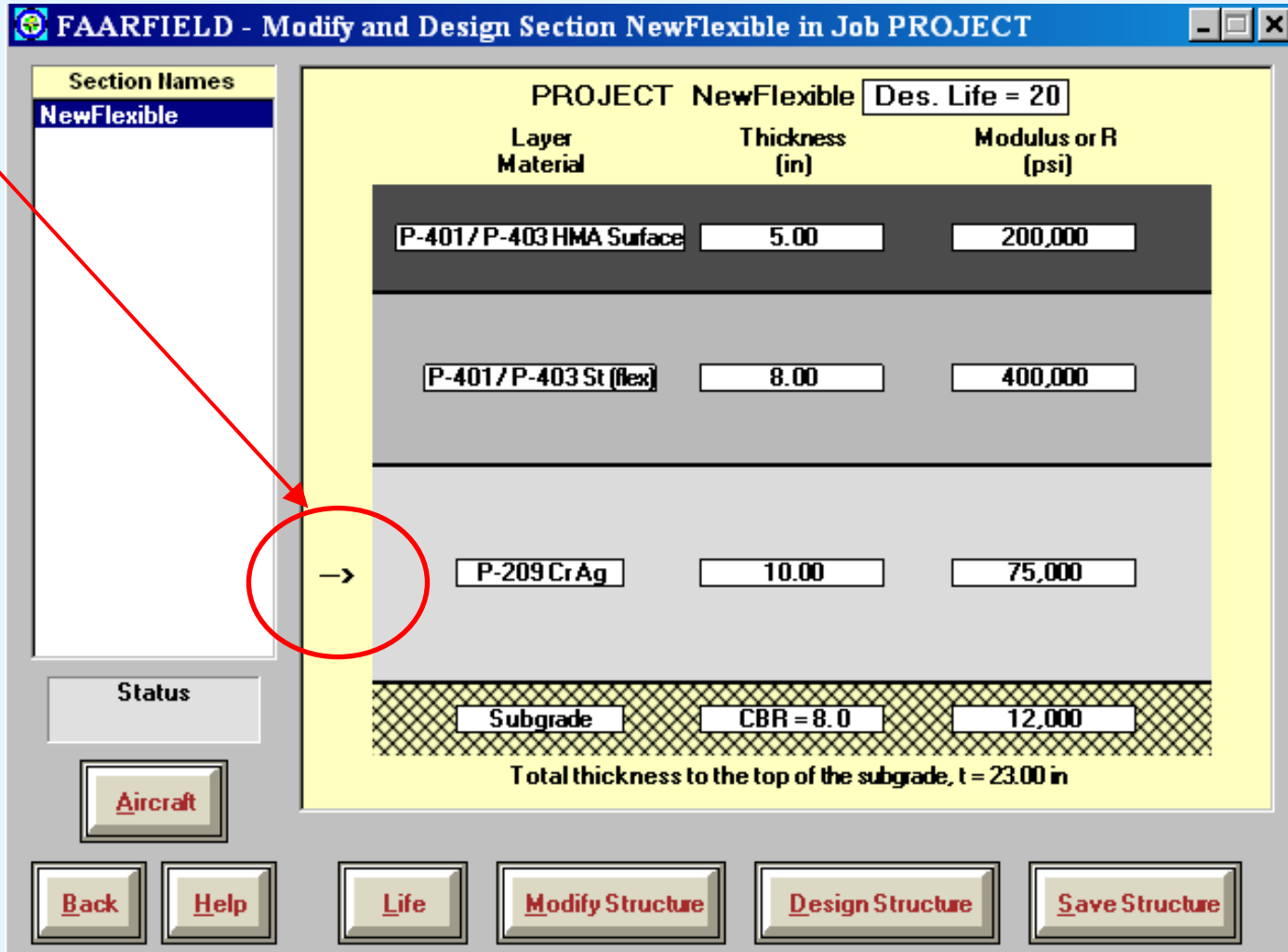


FAARFIELD Flexible Pavement Design

Performing the Pavement Design

The layer with the small arrow is the layer that will be adjusted to provide the structural design

The location of the arrow is determined by the type of pavement structure



FAARFIELD Flexible Pavement Design

Layered Adjusted During Design

PAVEMENT TYPE	LAYER ADJUSTED
ACAggregate	P-154 Subbase
AConFlex	P-401 AC Overlay
AConRigid	P-401 AC Overlay
NewFlexible	P-209 subbase
NewRigid	PCC Surface
PCConFlex	PCC Overlay on Flex
PCConRigid	PCC Overlay Unbond

For New flexible sections the arrow can be moved by double clicking next to the desired base or subbase layer during “modify design” mode.

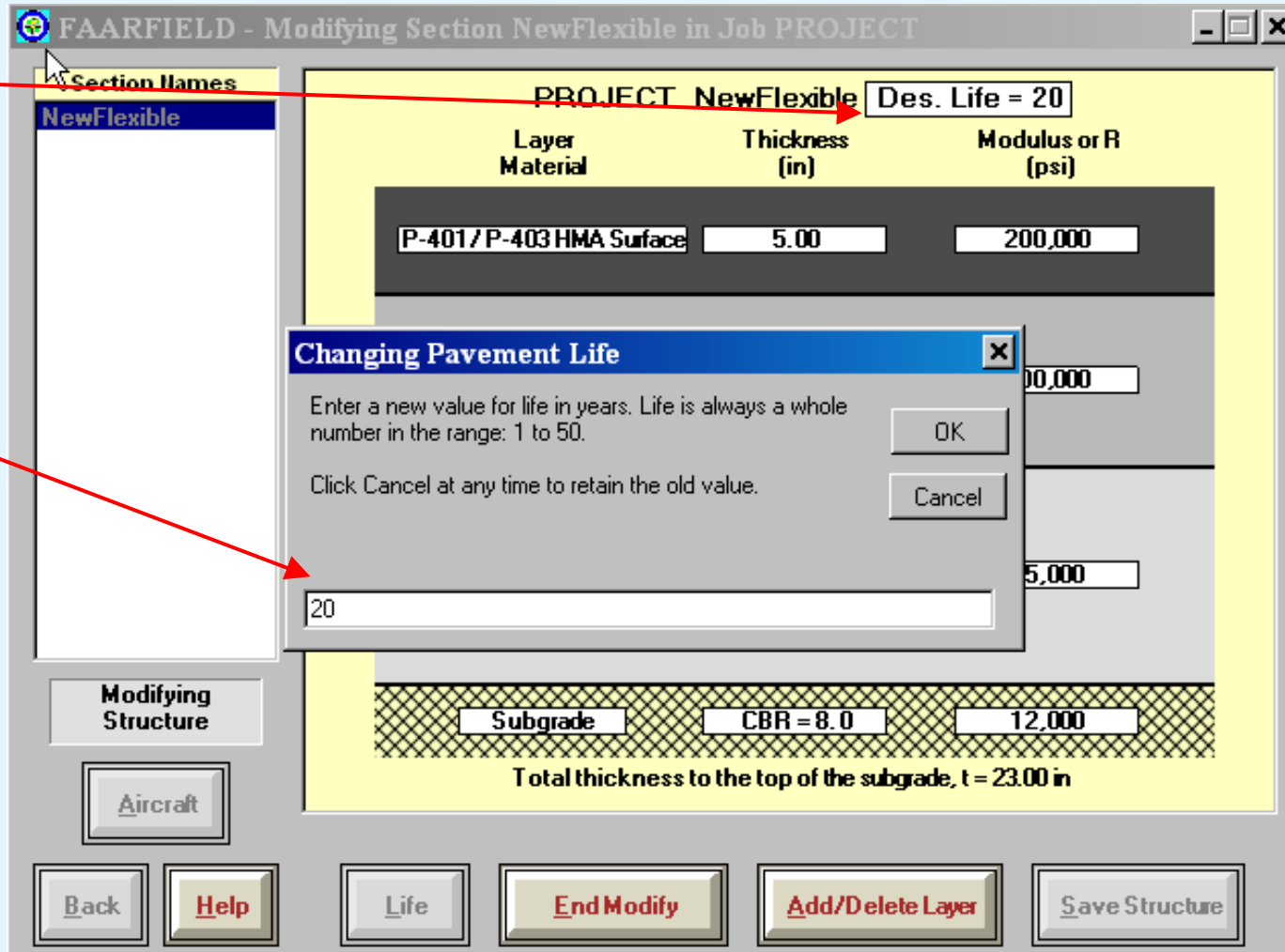
FAARFIELD Flexible Pavement Design

Design Life

Click on the "des. Life" to change number of years for the design period.

When the pop-up box appears, enter the desired number of years.

NOTE: the standard FAA design is for 20 years

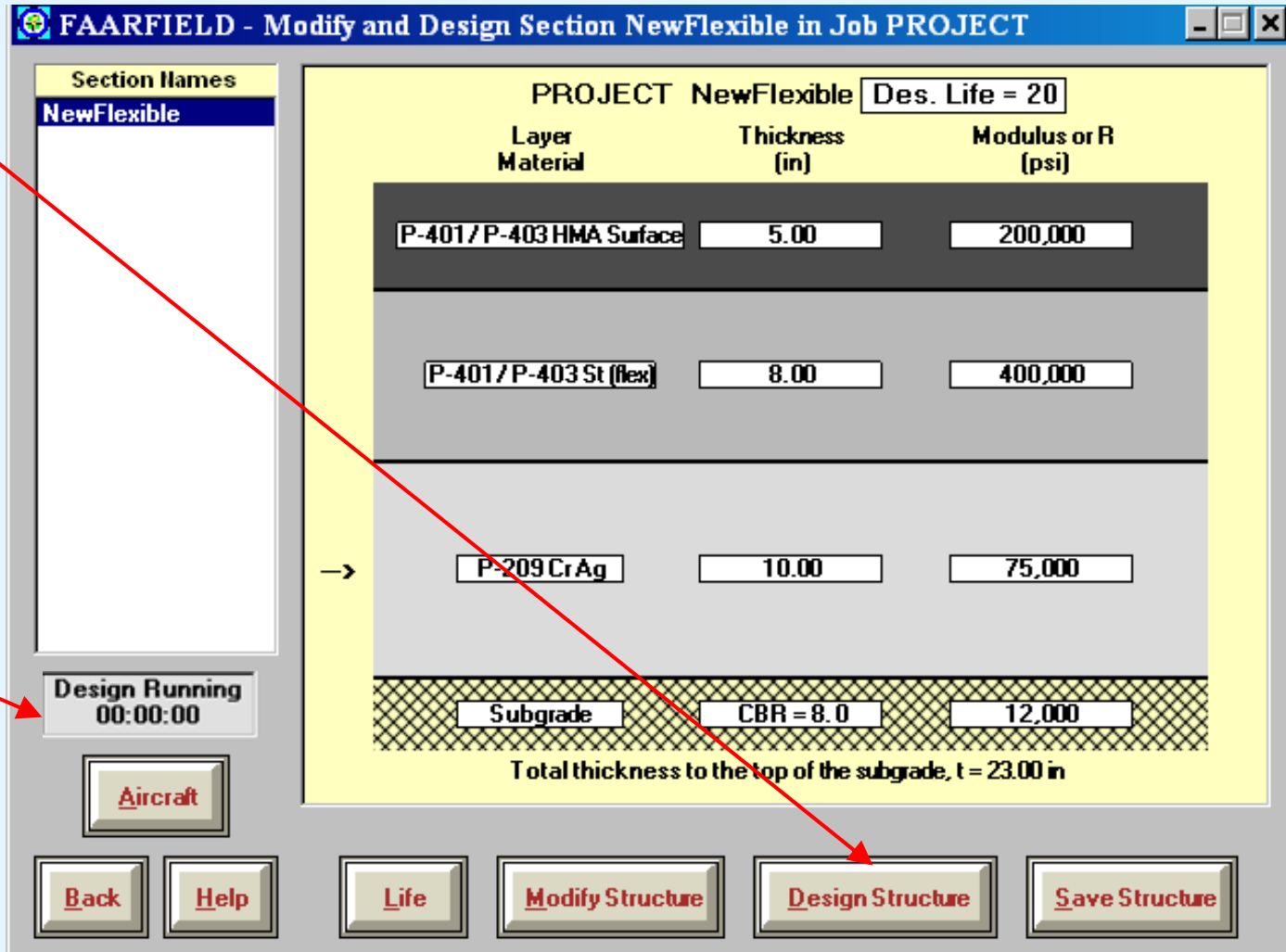


FAARFIELD Flexible Pavement Design

Performing the Pavement Design

You are now ready to design the structure.
Simply click on "Design Structure"

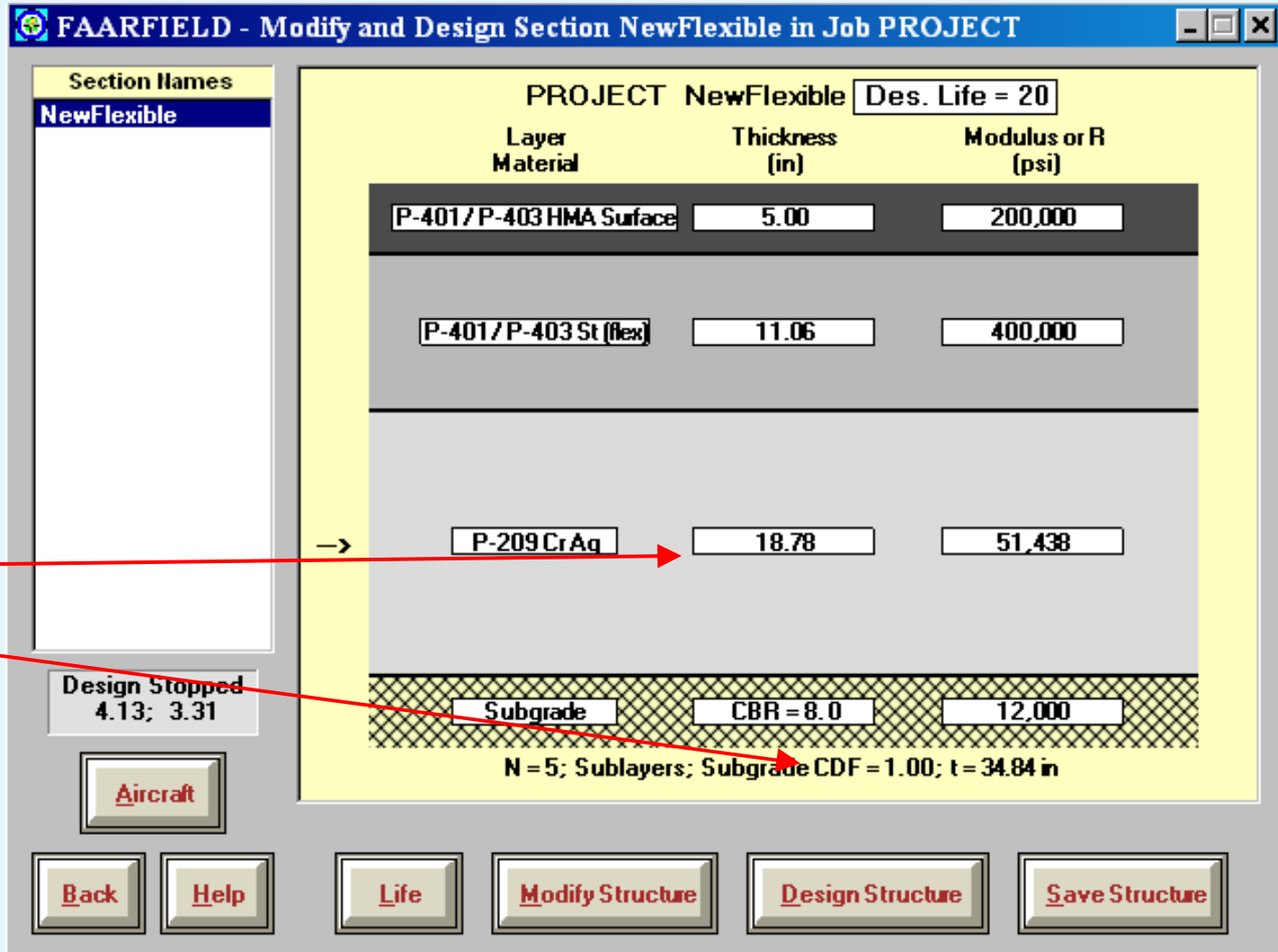
The program will keep you informed about the status of the design



FAARFIELD Flexible Pavement Design

Result of the Pavement Design

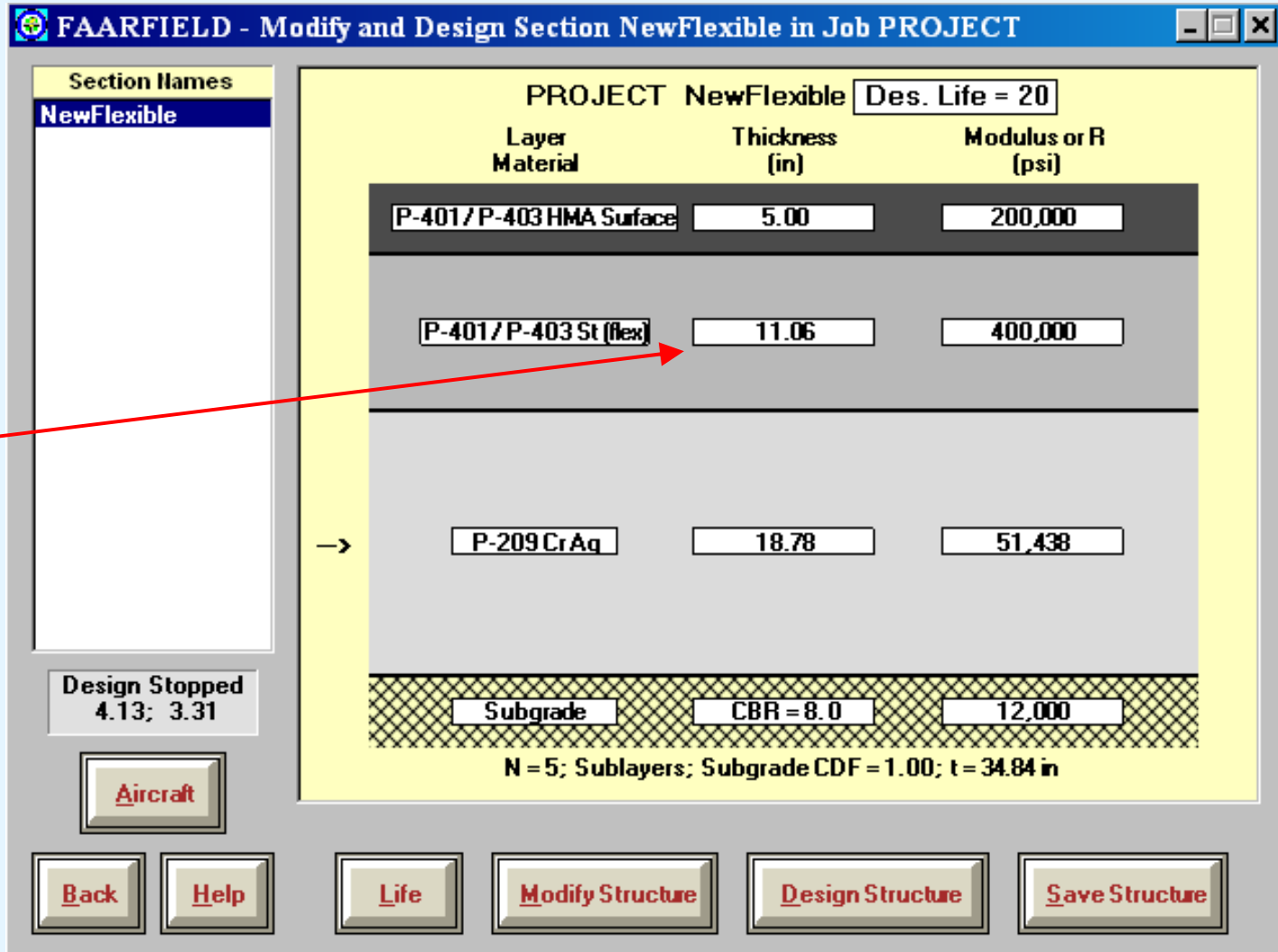
The program will adjust the design layer until a CDF of 1.0 is achieved



FAARFIELD Flexible Pavement Design

Result of the Pavement Design

The program has also determined the minimum base layer requirement

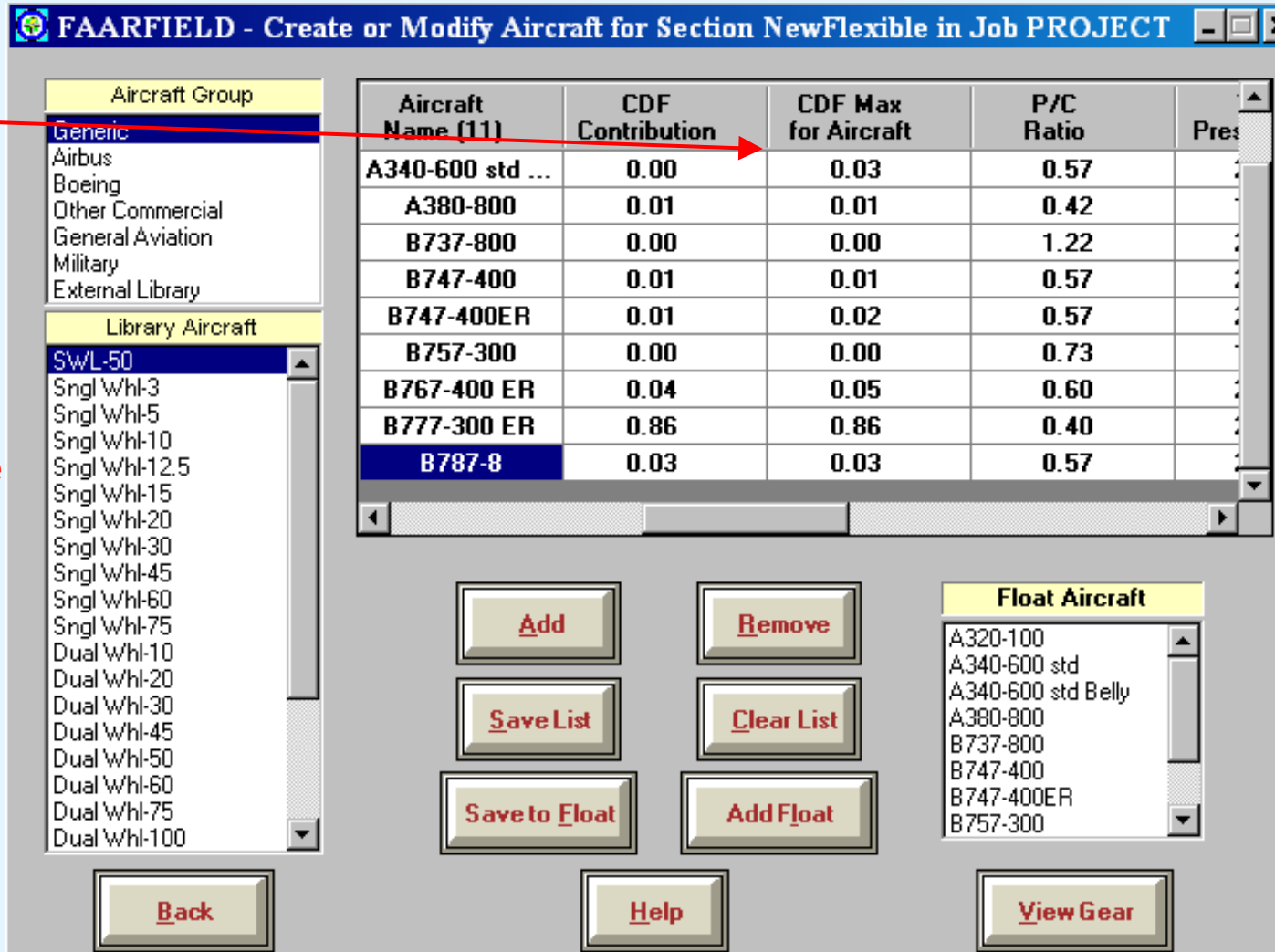


FAARFIELD Flexible Pavement Design

Reviewing Airplane Data After Completing the Design

CDF and P/C ratio information is now available

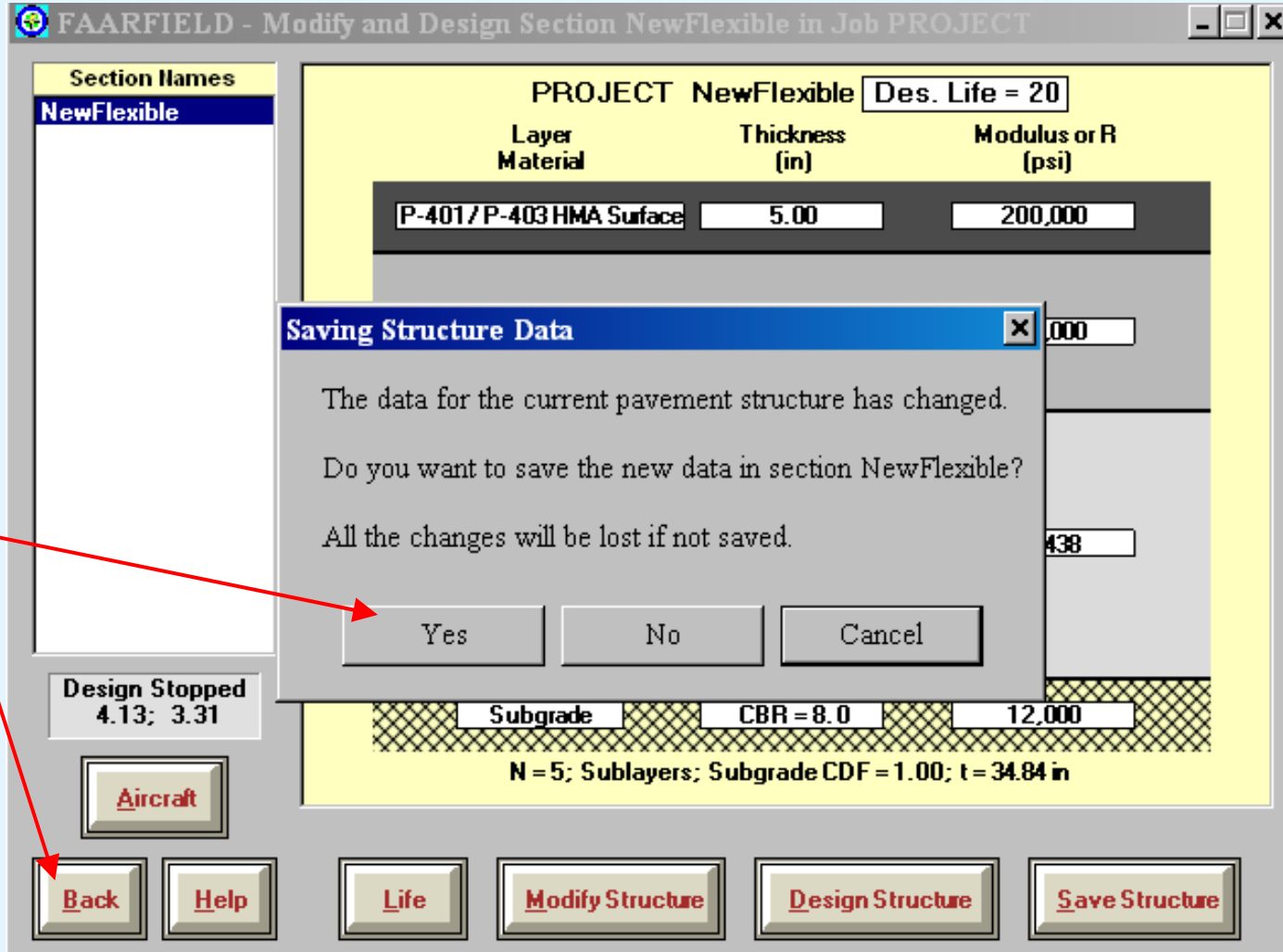
This information allows you to see which airplane have the largest impact on the pavement structure



FAARFIELD Flexible Pavement Design

Saving and Reviewing the Pavement Design Data

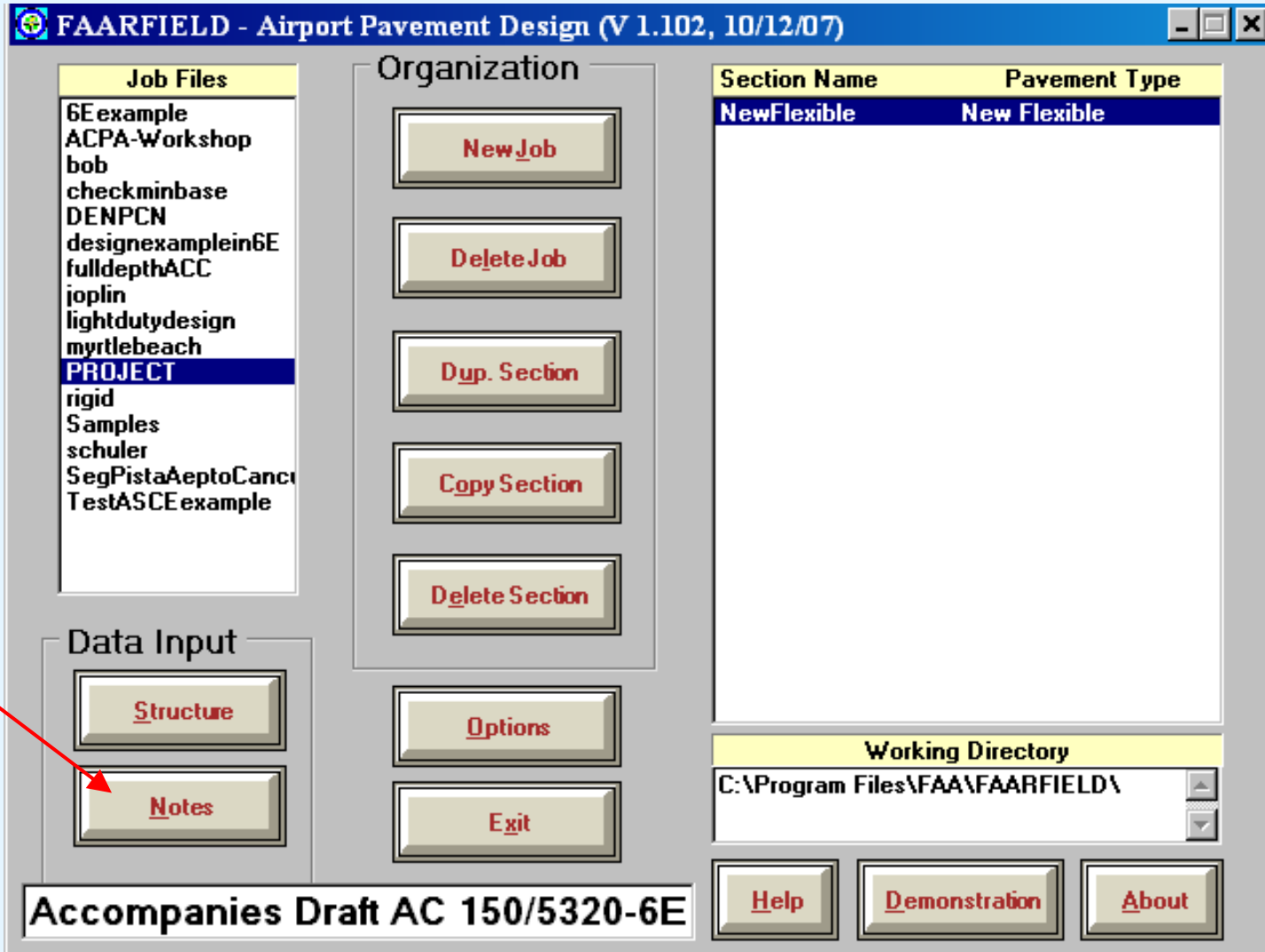
When finished with the design, click the “Back” button and select whether you want to save the data



FAARFIELD Flexible Pavement Design

Reviewing Design Information

To view a summary of the design click the “Notes” button

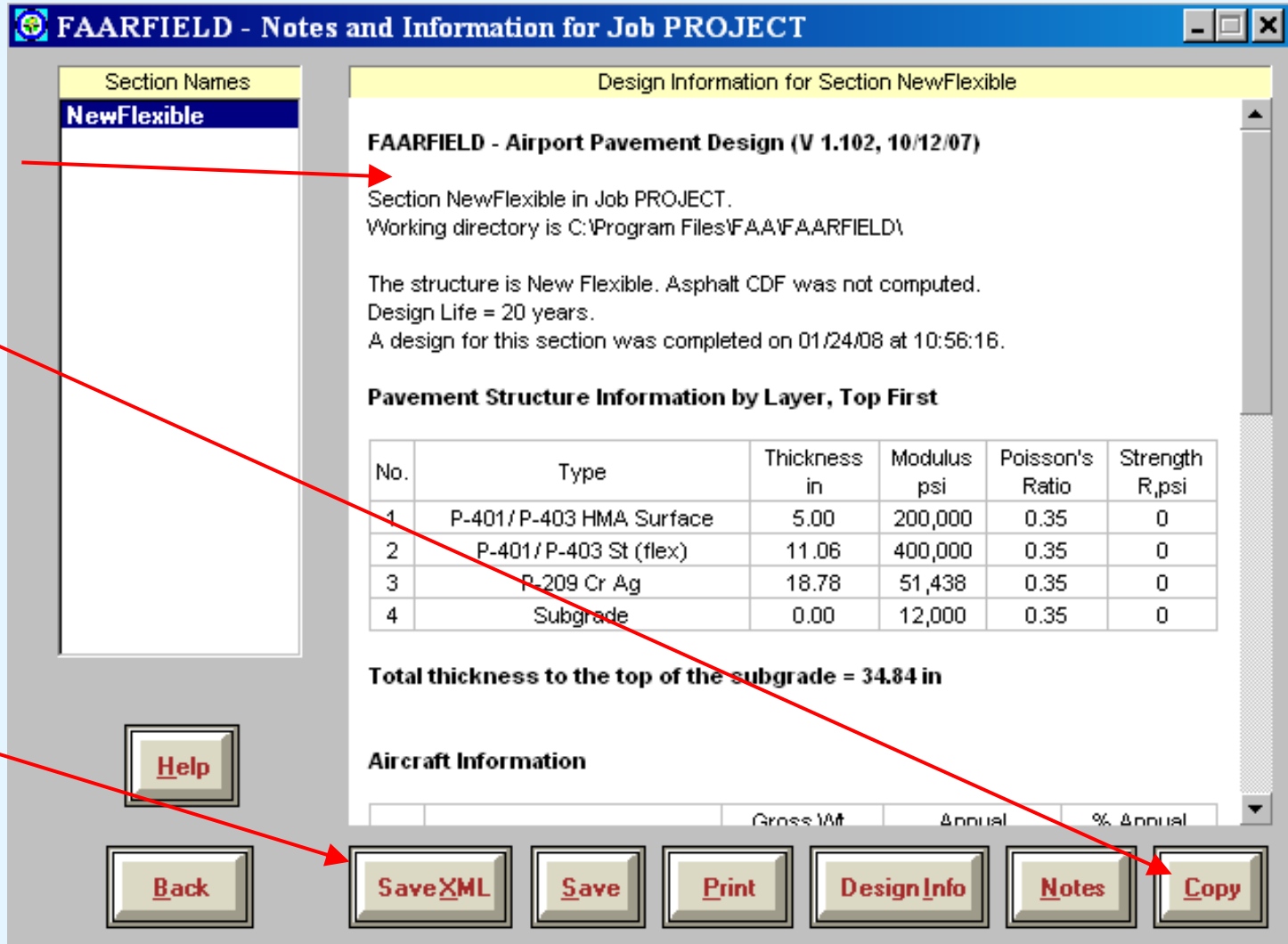


FAARFIELD Flexible Pavement Design

Reviewing Design Information

You can view the summary data or copy it to other electronic media

Data can also be exported in XML to allow automated entry into FAA Form 5100



FAARFIELD Flexible Pavement Design

Reviewing Design Information

FAARFIELD - Airport Pavement Design (V 1.102, 10/12/07)

Section NewFlexible in Job PROJECT.
Working directory is C:\Program Files\FAA\FAARFIELD\

The structure is New Flexible. Asphalt CDF was not computed.
Design Life = 20 years.
A design for this section was completed on 01/24/08 at 10:56:16.

Pavement Structure Information by Layer, Top First

No.	Type	Thickness in	Modulus psi	Poisson's Ratio	Strength R,psi
1	P-401/ P-403 HMA Surface	5.00	200,000	0.35	0
2	P-401/ P-403 St (flex)	11.06	400,000	0.35	0
3	P-209 Cr Ag	18.78	51,438	0.35	0
4	Subgrade	0.00	12,000	0.35	0

Total thickness to the top of the subgrade = 34.84 in

Aircraft Information

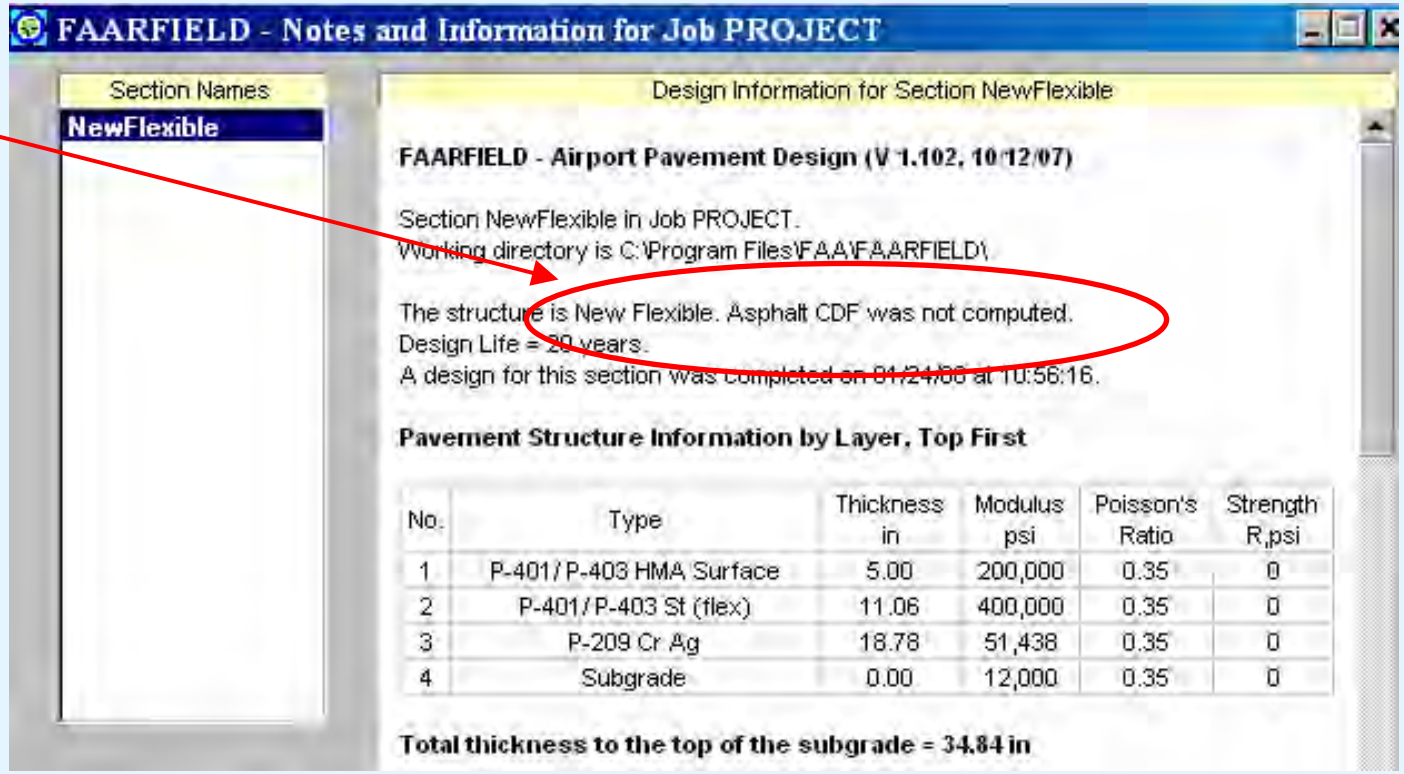
No.	Name	Gross Wt. lbs	Annual Departures	% Annual Growth	CDF Contribution	CDF Max for Aircraft	P/C Ratio
1	A320-100	150,796	600	0.00	0.00	0.00	1.21
2	A340-600 std	805,128	1,000	0.00	0.04	0.05	0.59
3	A340-600 std Belly	805,128	1,000	0.00	0.00	0.03	0.57
4	A380-800	1,239,000	300	0.00	0.01	0.01	0.42
5	B737-800	174,700	2,000	0.00	0.00	0.00	1.22
6	B747-400	877,000	400	0.00	0.01	0.01	0.57
7	B747-400ER	913,000	300	0.00	0.01	0.02	0.57
8	B757-300	271,000	1,200	0.00	0.00	0.00	0.73
9	B767-400 ER	451,000	800	0.00	0.04	0.05	0.60
10	B777-300 ER	777,000	1,000	0.00	0.86	0.86	0.40
11	B787-8	478,000	600	0.00	0.03	0.03	0.57

FAARFIELD Flexible Pavement Design

Reviewing Design Information

Notice the Statement "Asphalt CDF was not computed"

This means the design assumed the failure was in the subgrade and did not calculate the fatigue in the bottom of the asphalt layer

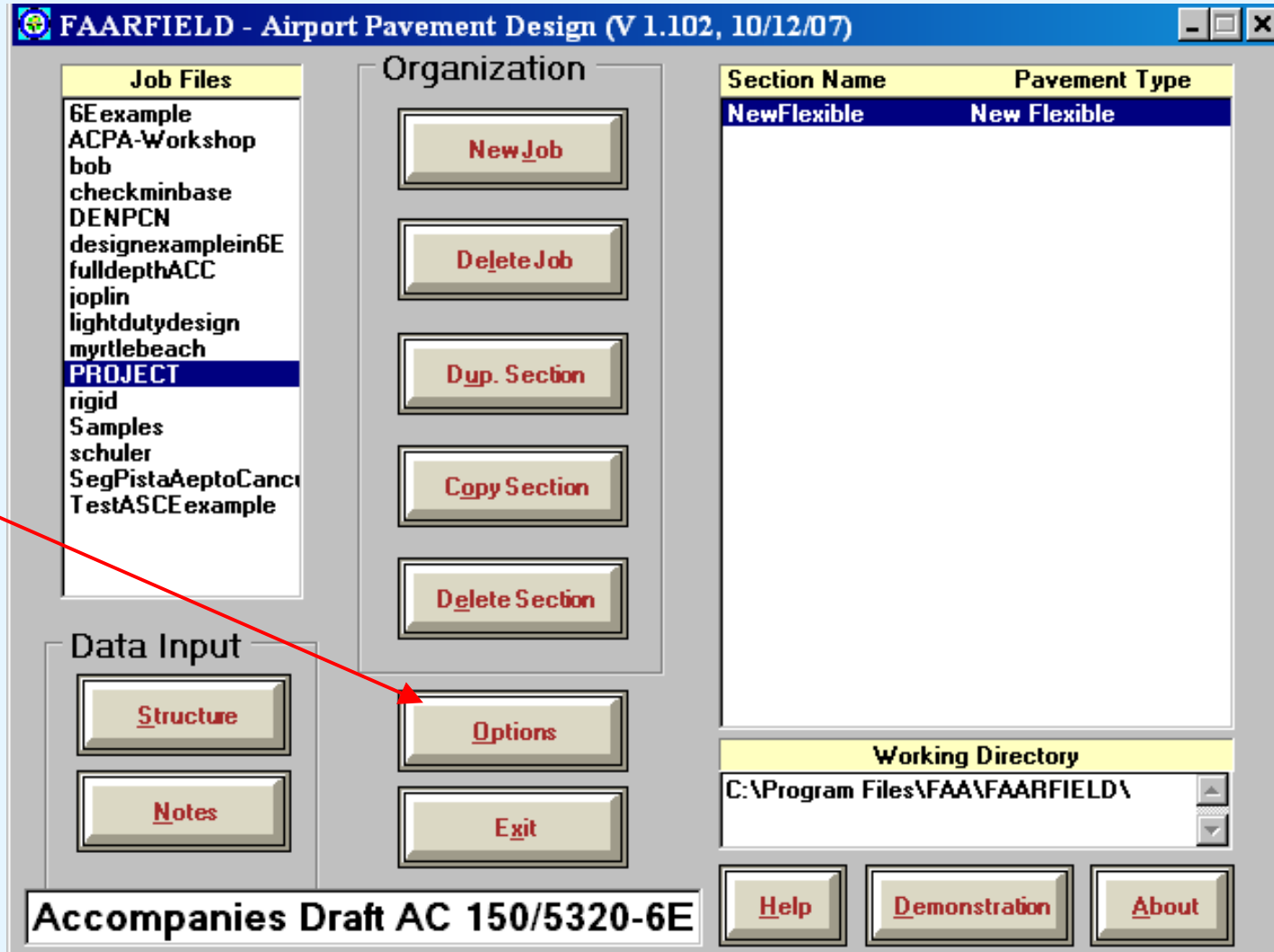


No.	Type	Thickness in	Modulus psi	Poisson's Ratio	Strength R,psi
1	P-401/P-403 HMA Surface	5.00	200,000	0.35	0
2	P-401/P-403 St (flex)	11.06	400,000	0.35	0
3	P-209 Cr Ag	18.78	51,438	0.35	0
4	Subgrade	0.00	12,000	0.35	0

FAARFIELD Flexible Pavement Design

Calculating Fatigue in the Asphalt Layer

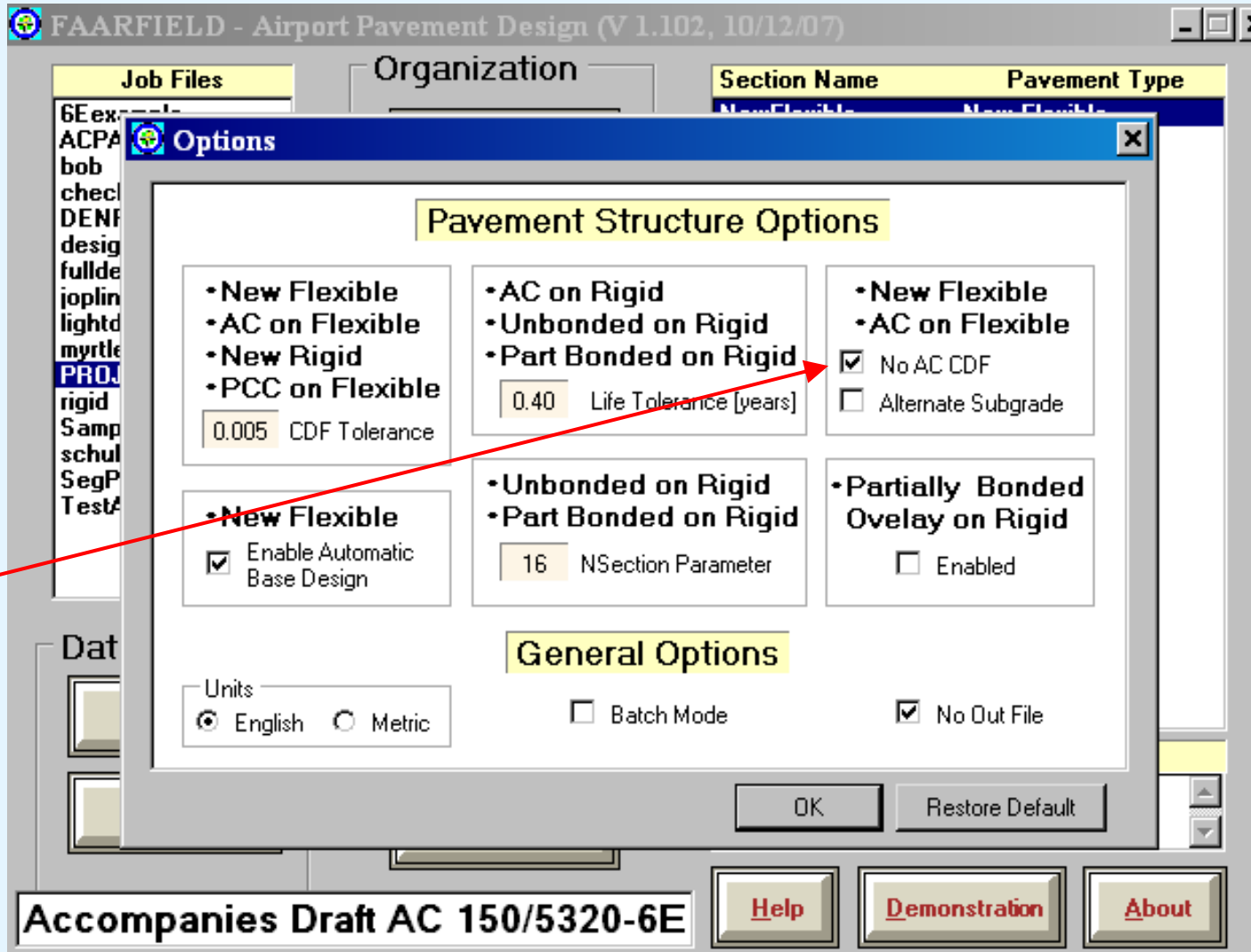
By clicking the options box the user can access the optional program features including the Asphalt layer CDF



FAARFIELD Flexible Pavement Design

Calculating Fatigue in the Asphalt Layer

If you want the program to calculate the asphalt fatigue un-check the box and re-run the design

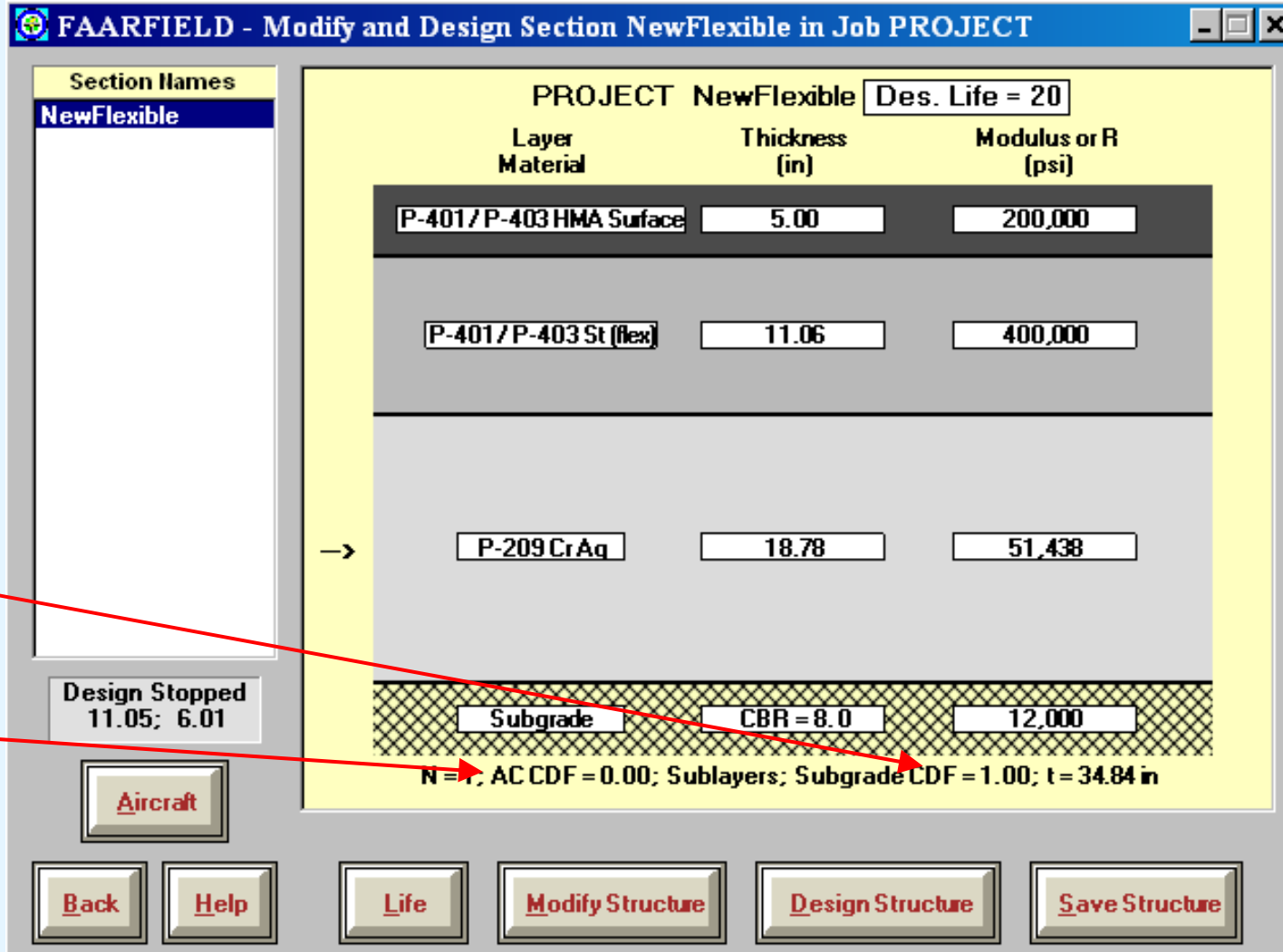


FAARFIELD Flexible Pavement Design

Calculating Fatigue in the Asphalt Layer

As this example demonstrates, the controlling feature is almost always the subgrade

i.e. subgrade CDF reaches 1.0 while the AC CDF is still 0.0



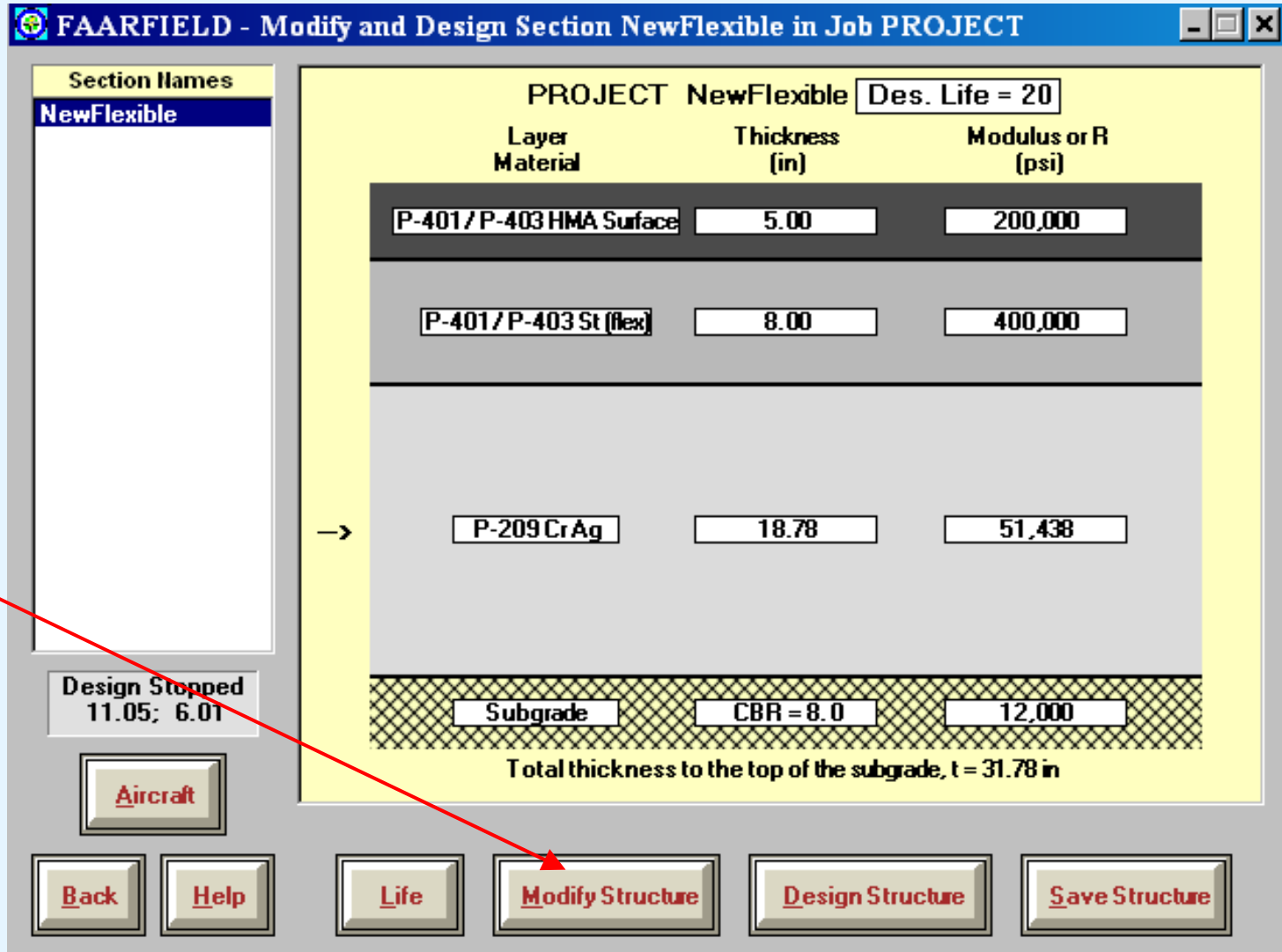
Minimum Base Course Requirements

- **FAARFIELD will automatically determine the minimum base layer requirements.**
- **Users can do this step manually if desired by deselecting this option**
  - Remove subbase layer and increase subgrade CBR to 20.
  - Re-run the design to obtain the minimum base thickness

FAARFIELD Flexible Pavement Design

Determine Minimum Base Thickness

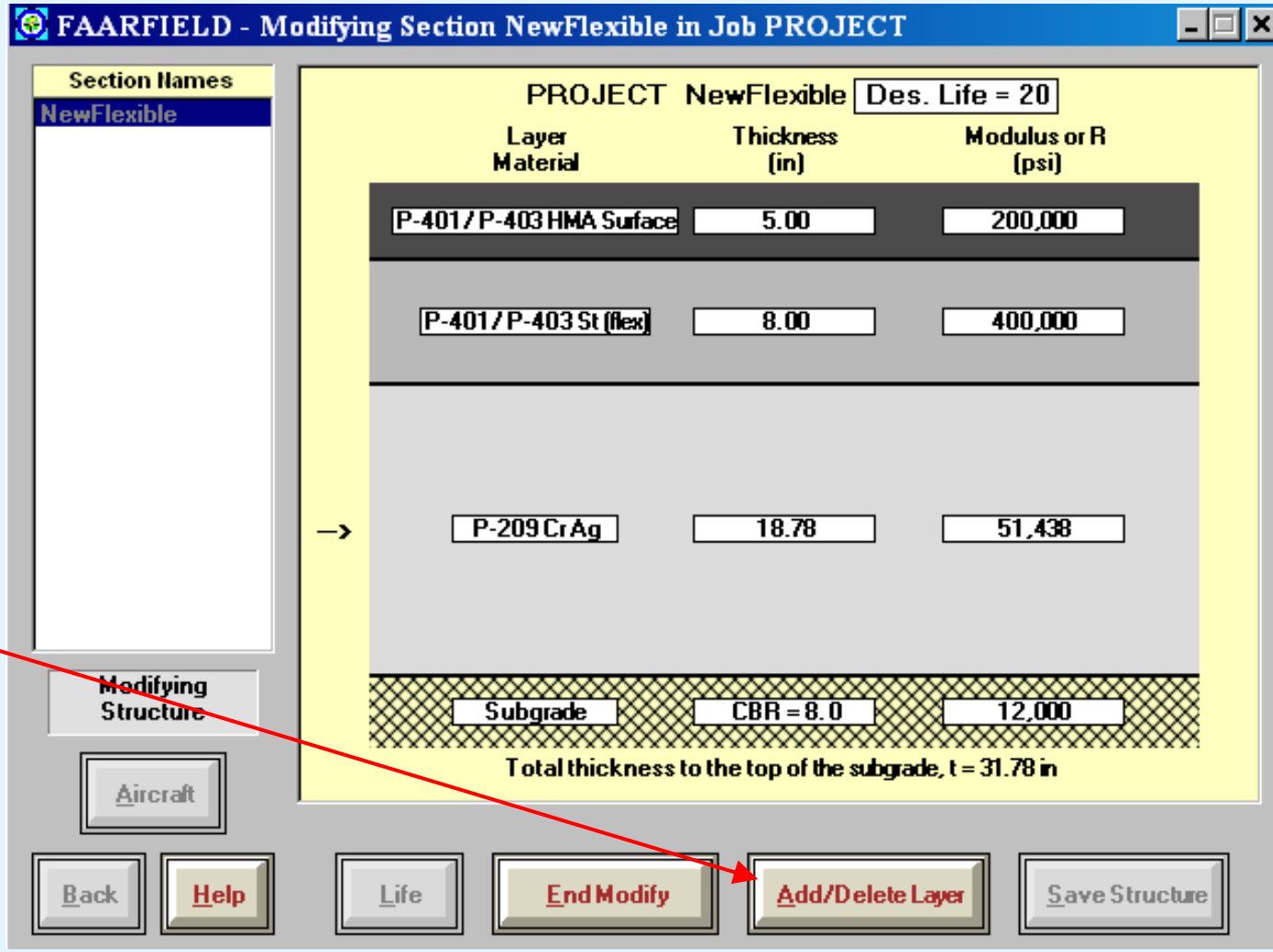
Click on “Modify Structure”



FAARFIELD Flexible Pavement Design

Determine Minimum Base Thickness

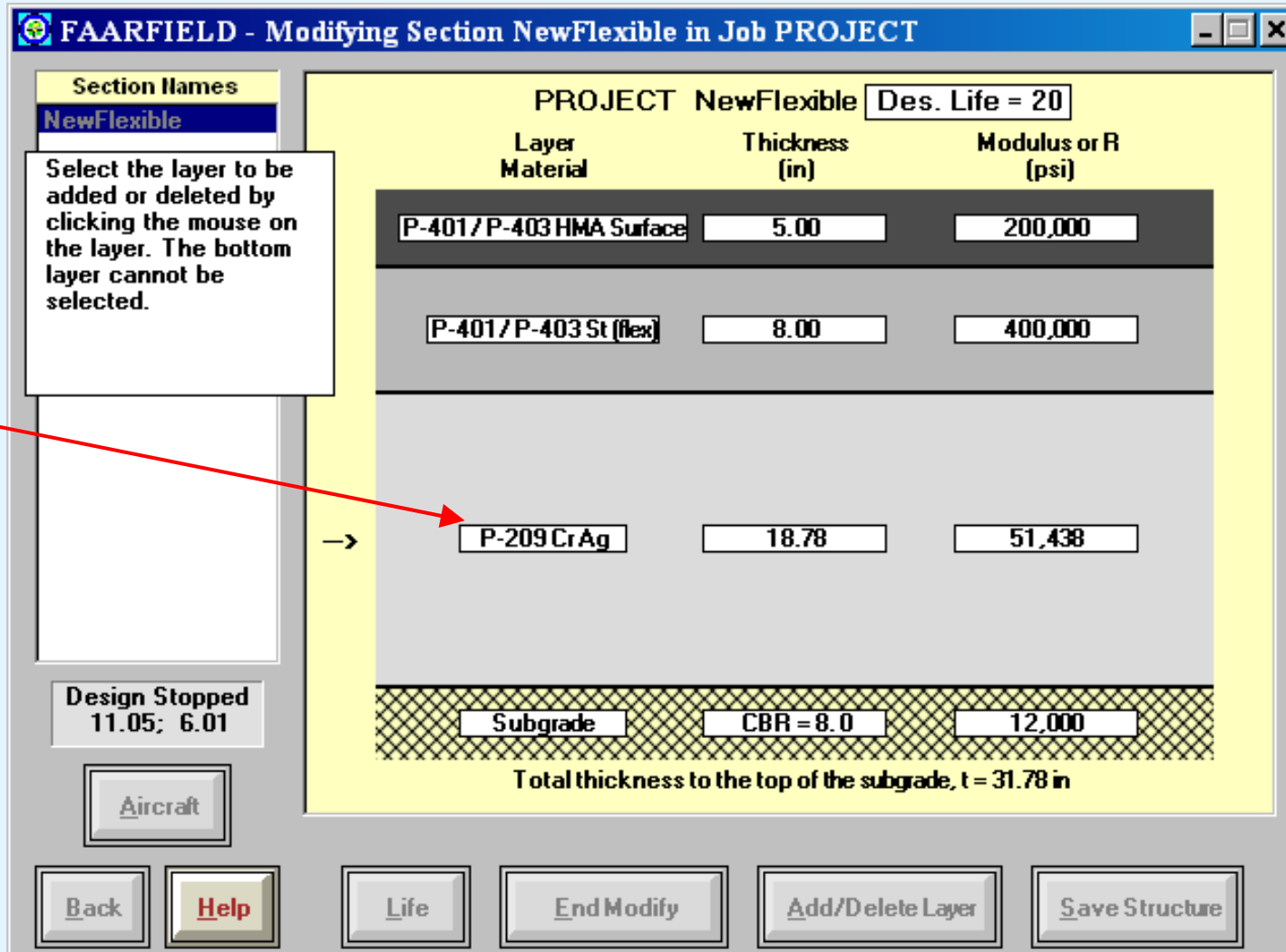
Click on
"Add/Delete Layer"



FAARFIELD Flexible Pavement Design

Determine Minimum Base Thickness

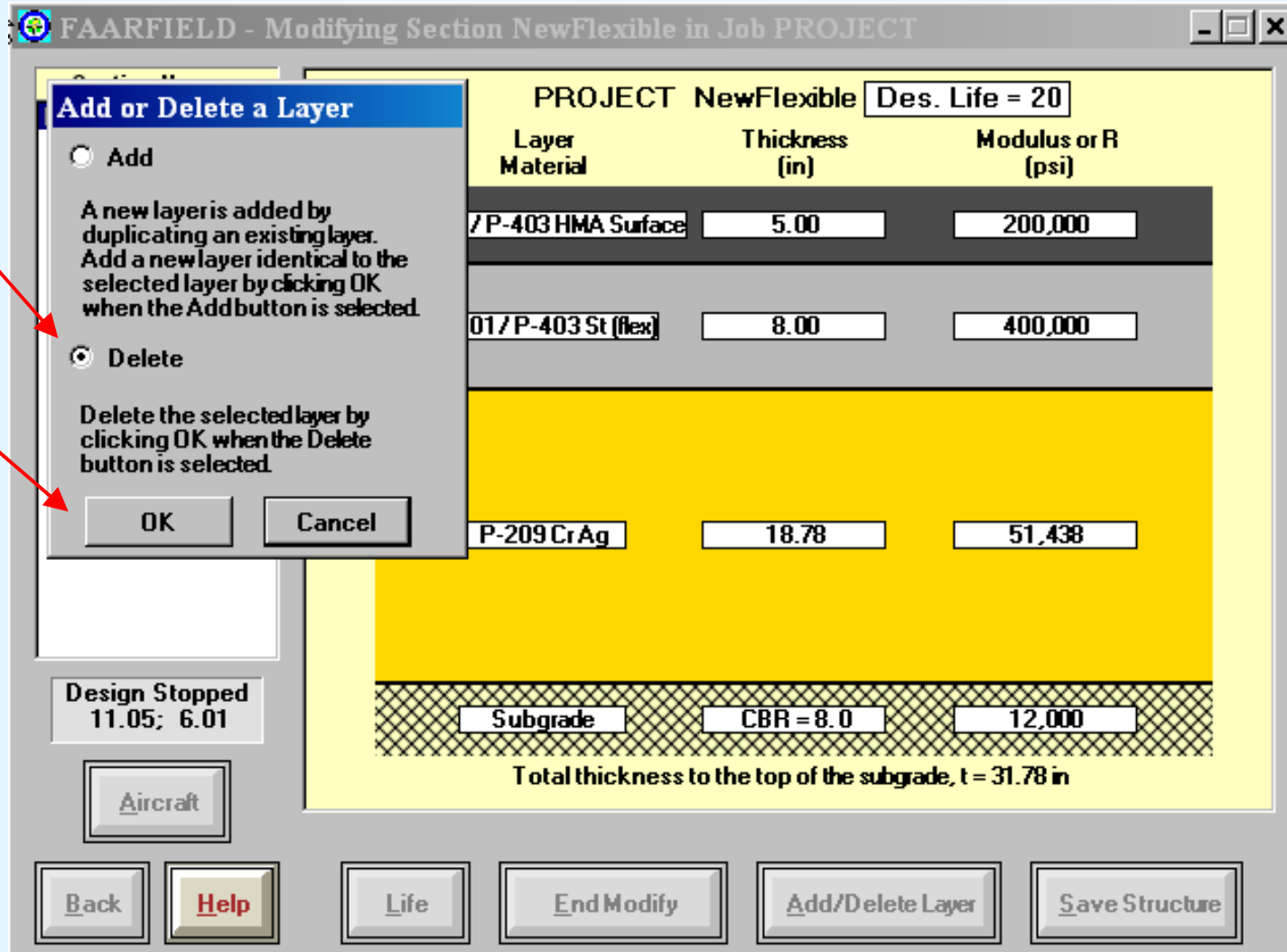
Click on the subbase layer



FAARFIELD Flexible Pavement Design

Determine Minimum Base Thickness

Check the delete option
Then click OK



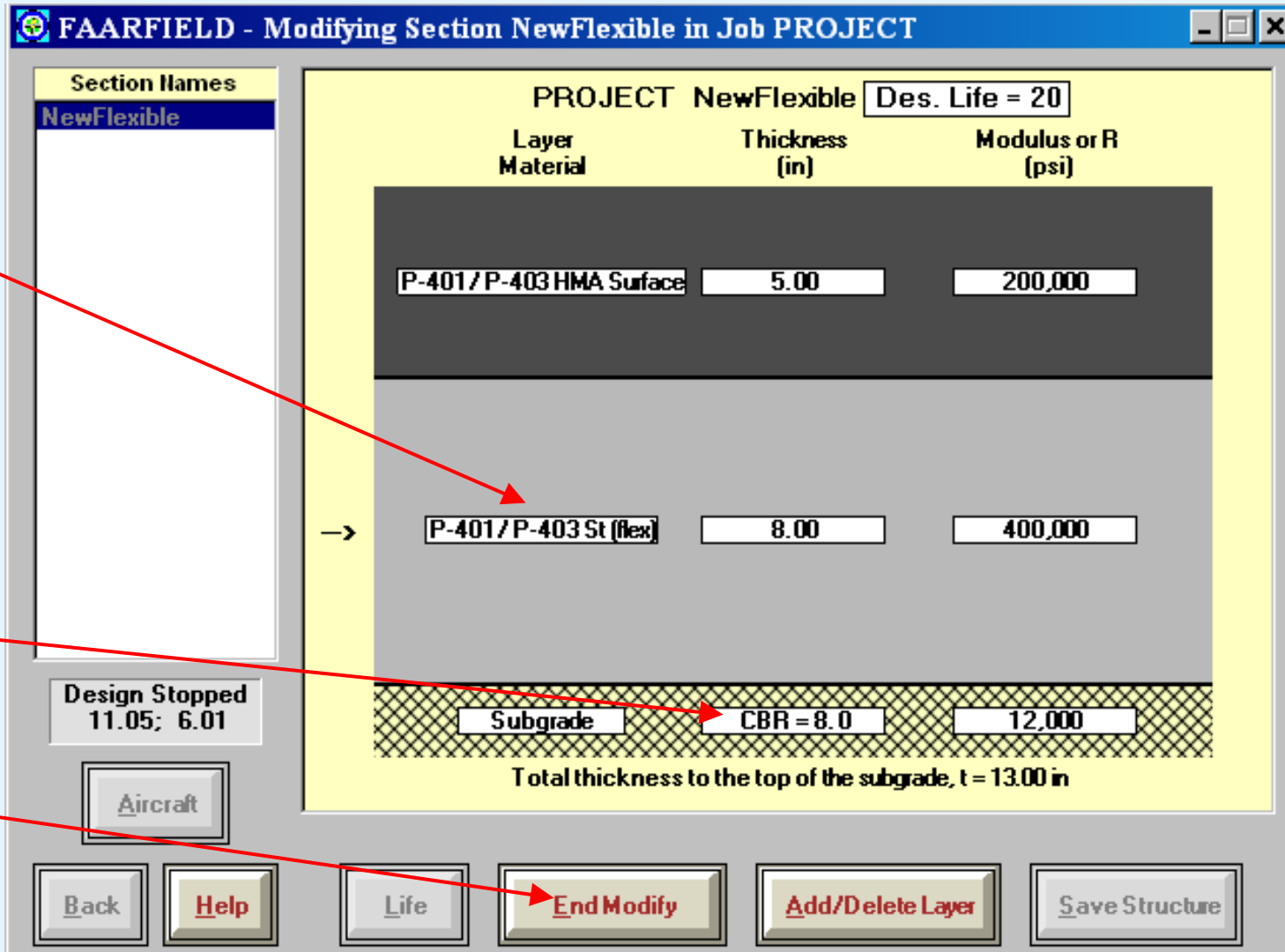
FAARFIELD Flexible Pavement Design

Determine Minimum Base Thickness

Change the P-401 Stabilized layer to P-209

Increase the subgrade CBR to 20

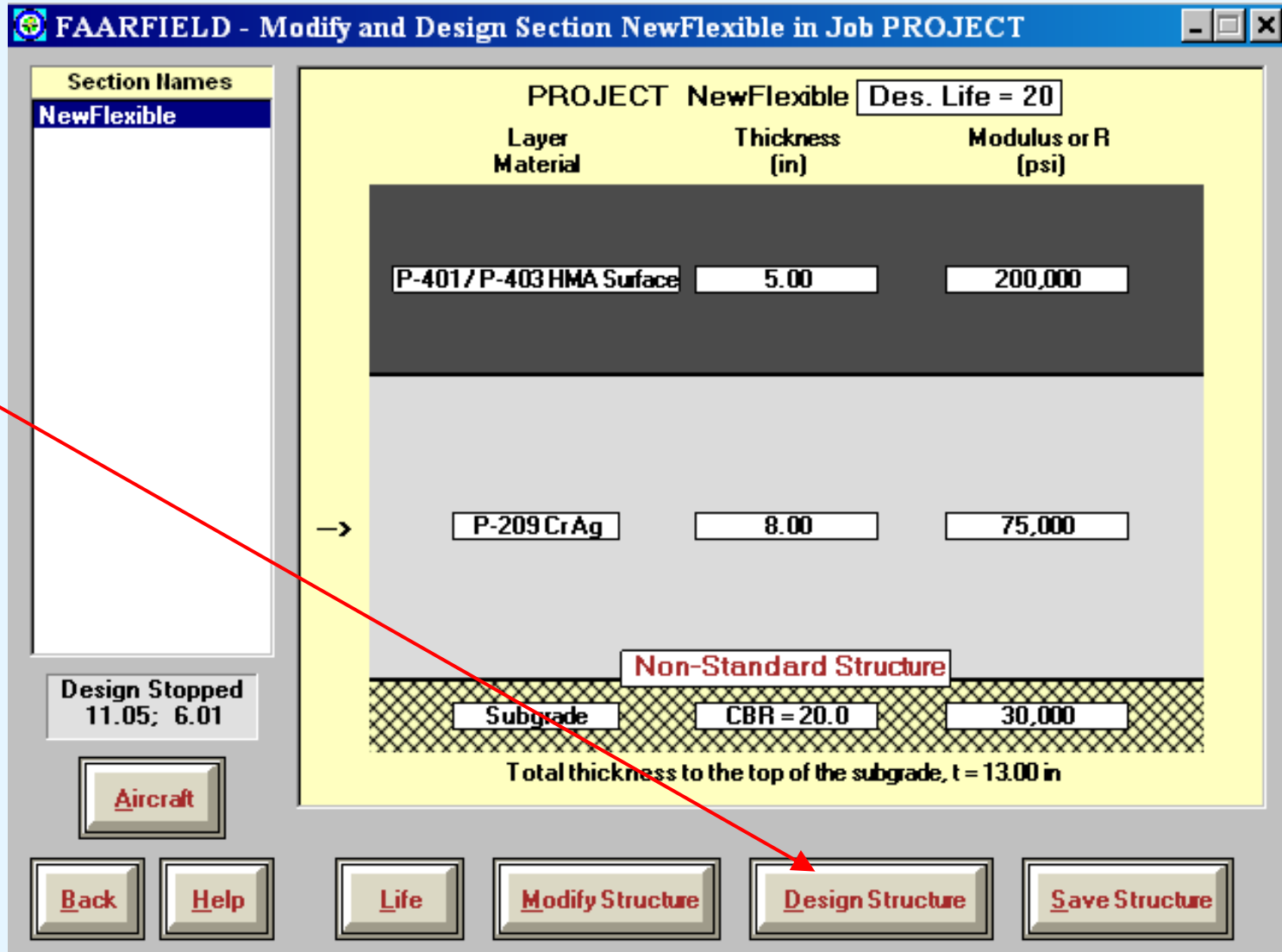
Then click "End Modify"



FAARFIELD Flexible Pavement Design

Determine Minimum Base Thickness

Click "Design Structure"

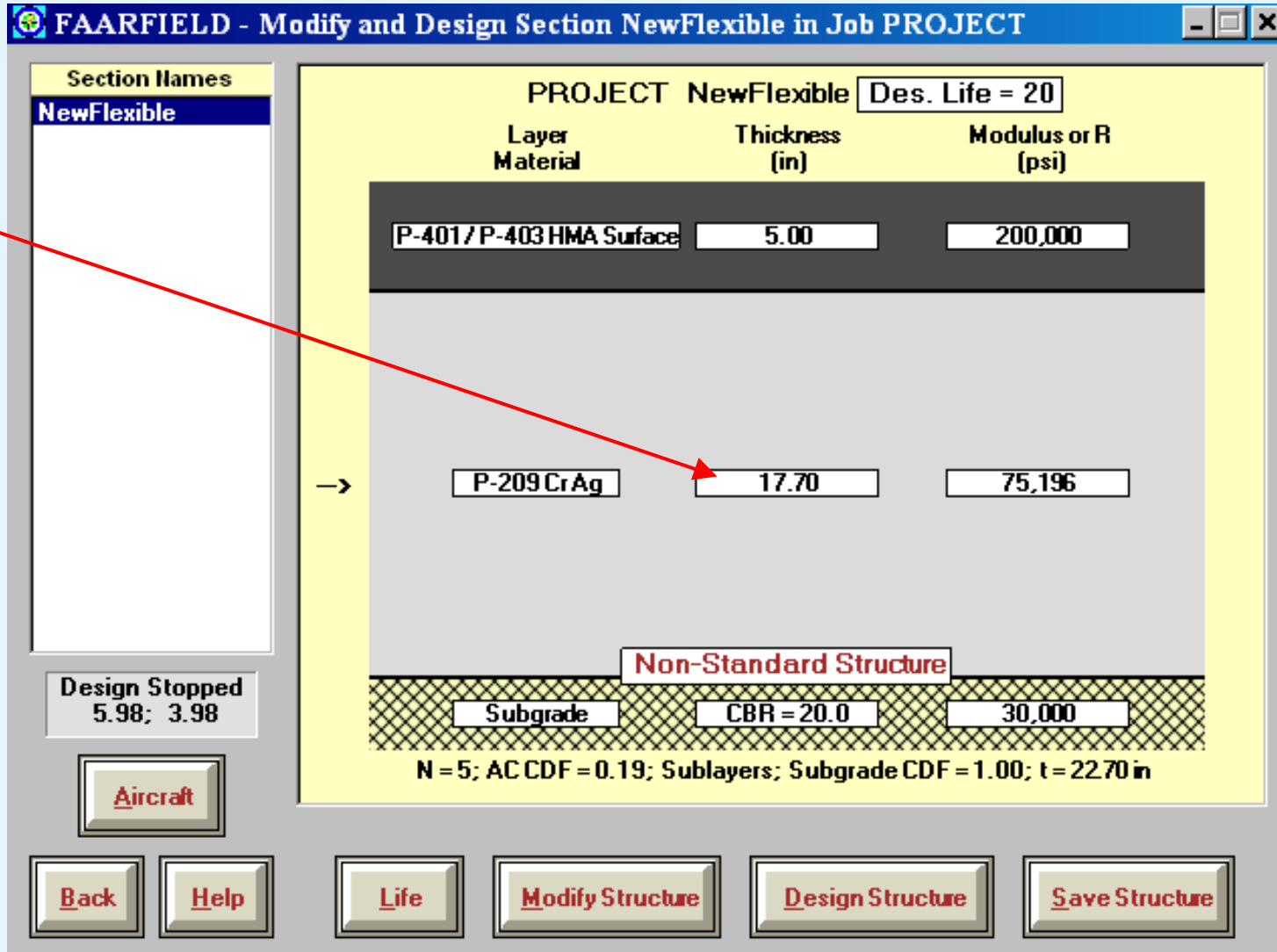


FAARFIELD Flexible Pavement Design

Determine Minimum Base Thickness

The minimum P-209 Base thickness is that necessary to protect the CBR 20 subbase material

Now convert P-209 to stabilize material



FAARFIELD Flexible Pavement Design

Determine Minimum Base Thickness

17.7 inches of P-209 is converted to Stabilized Base

For this example use P-401 as stabilized material

$T_{401Base} = T_{P209} / 1.6$ *(1.6 is provided in 5320-6E)*

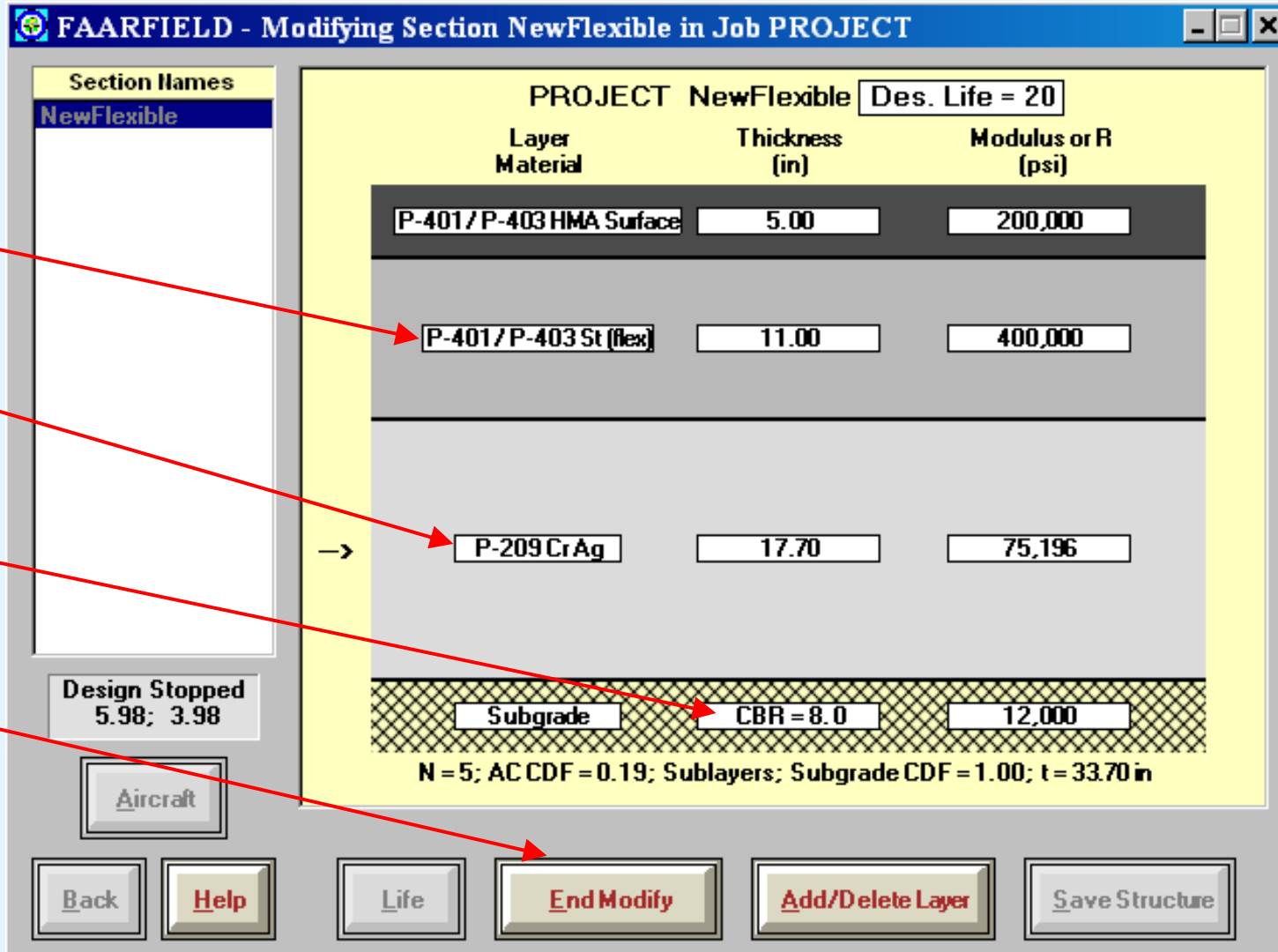
$T_{401Base} = 17.7 / 1.6 = 11.0625$ say 11.0

FAARFIELD Flexible Pavement Design

Determine Minimum Base Thickness

- Reconstruct the pavement section
- Stabilized P-401 base at 11 inches
- P-209 as the improved subbase material
- CBR returned to design value

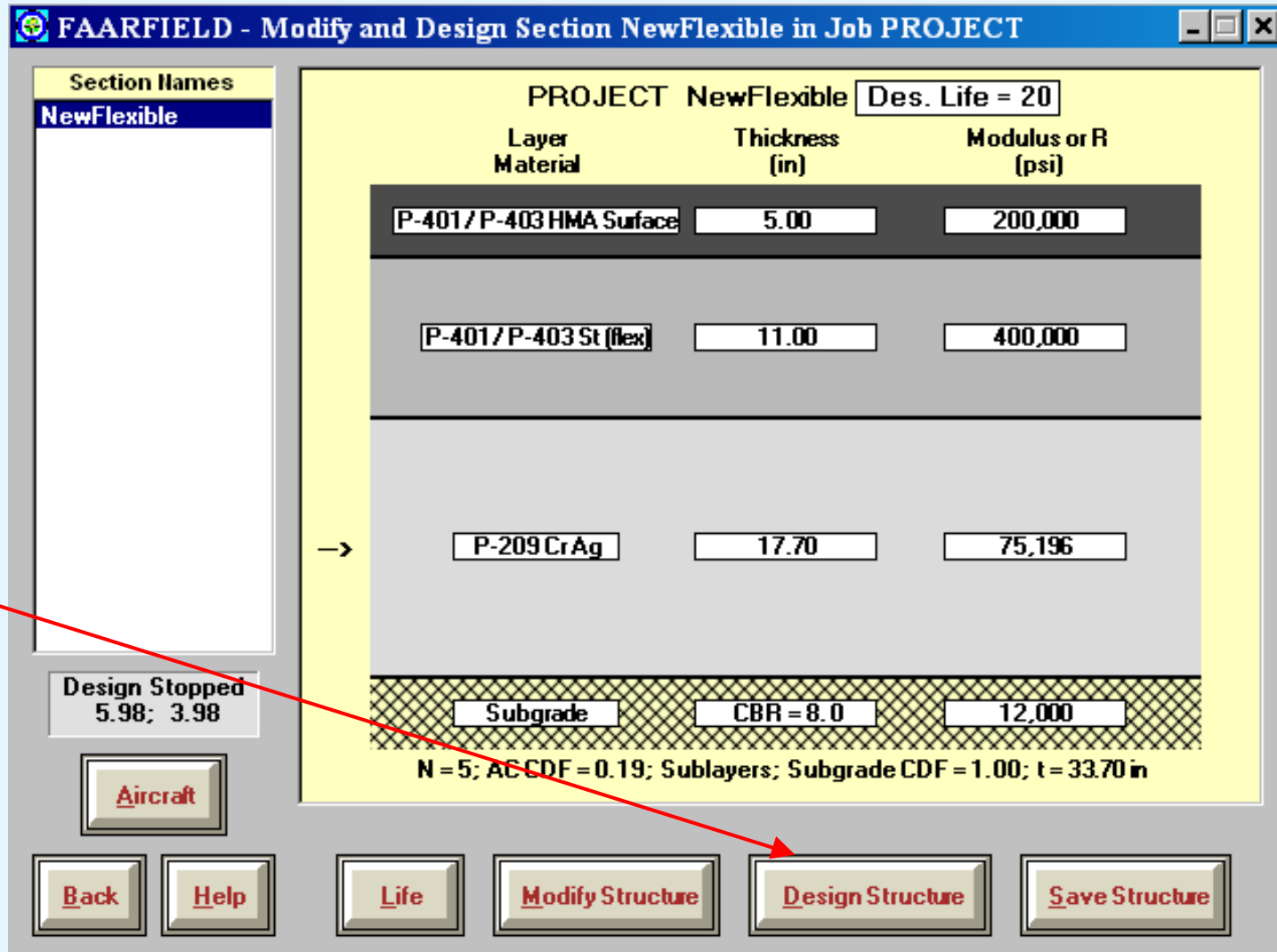
Click “End Modify”



FAARFIELD Flexible Pavement Design

Determine Minimum Base Thickness

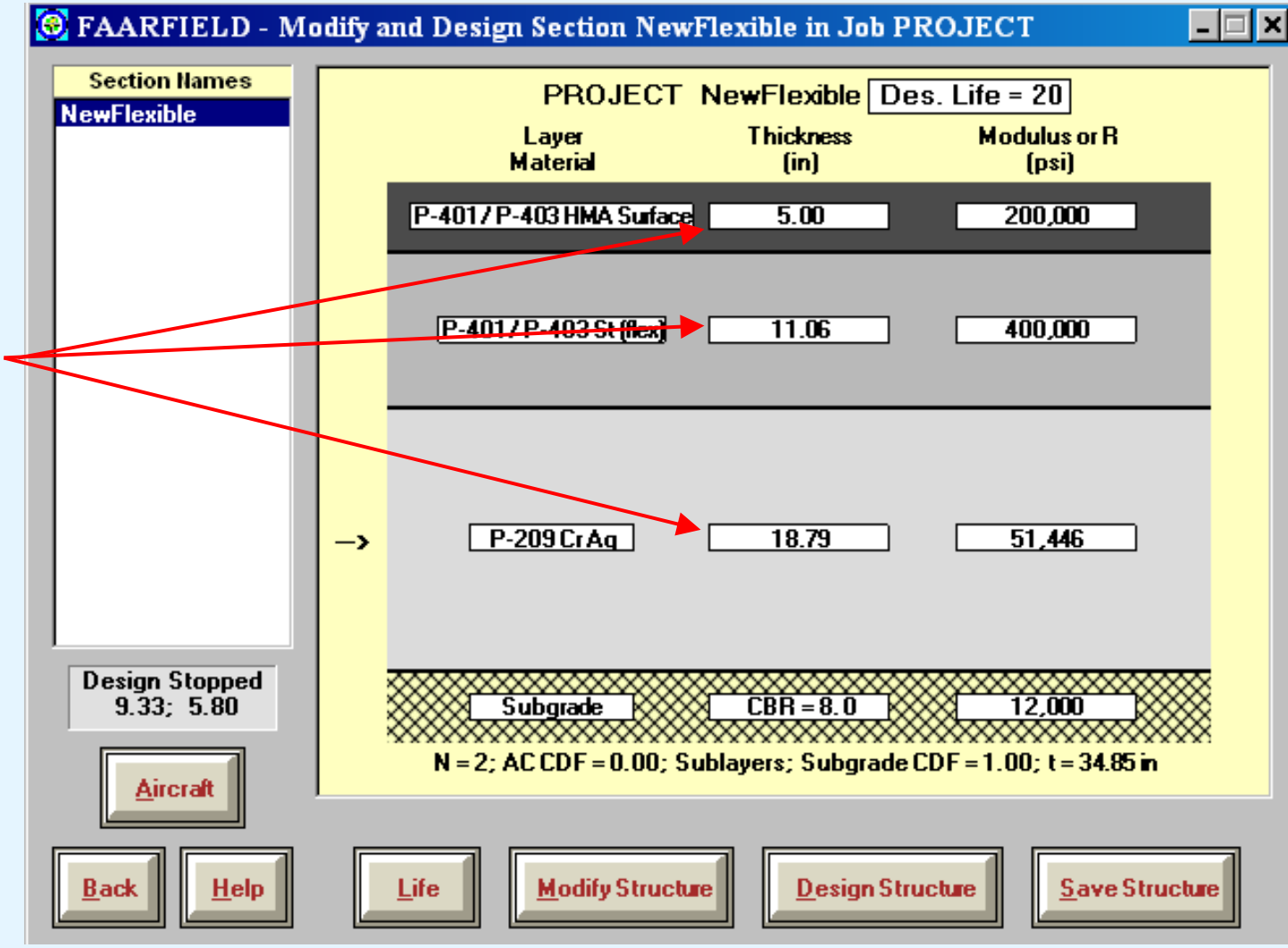
Then click “Design Structure”



FAARFIELD Flexible Pavement Design

Determine Minimum Base Thickness

The final pavement requirements are now visible



FAARFIELD - Sample HMA Overlay Design

Overlay design is very similar to new pavement design except that the design is only allowed to iterate on the overlay layer

The steps and options are similar to that of a new flexible design

FAARFIELD - Sample HMA Overlay Design

4 Basic Overlay Structures in FAARFIELD

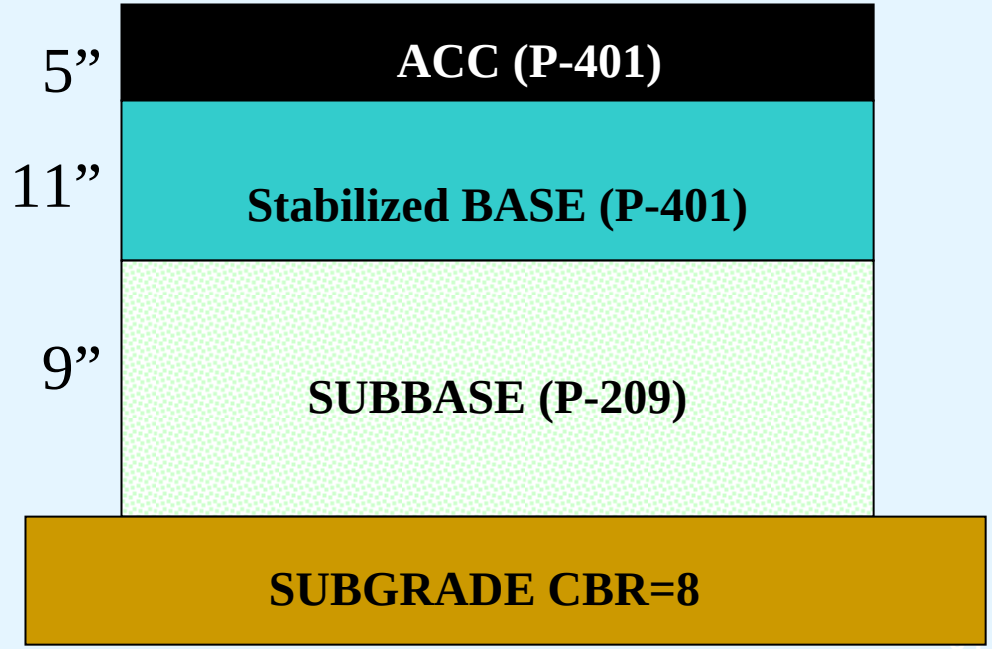
Section Name	Pavement Type
AConFlex	Asphalt overlay on Flexible pavement
AConRigid	Asphalt overlay on Rigid pavement
PCConFlex	PCC overlay on flexible
PCConRigid	Unbonded PCC on rigid

FAARFIELD - Sample HMA Overlay Design

Assume the previous design example except that the existing structure is ~10 inches deficient in the subbase layer.

AConflex
Asphalt on existing flexible pavement

Existing Pavement Section

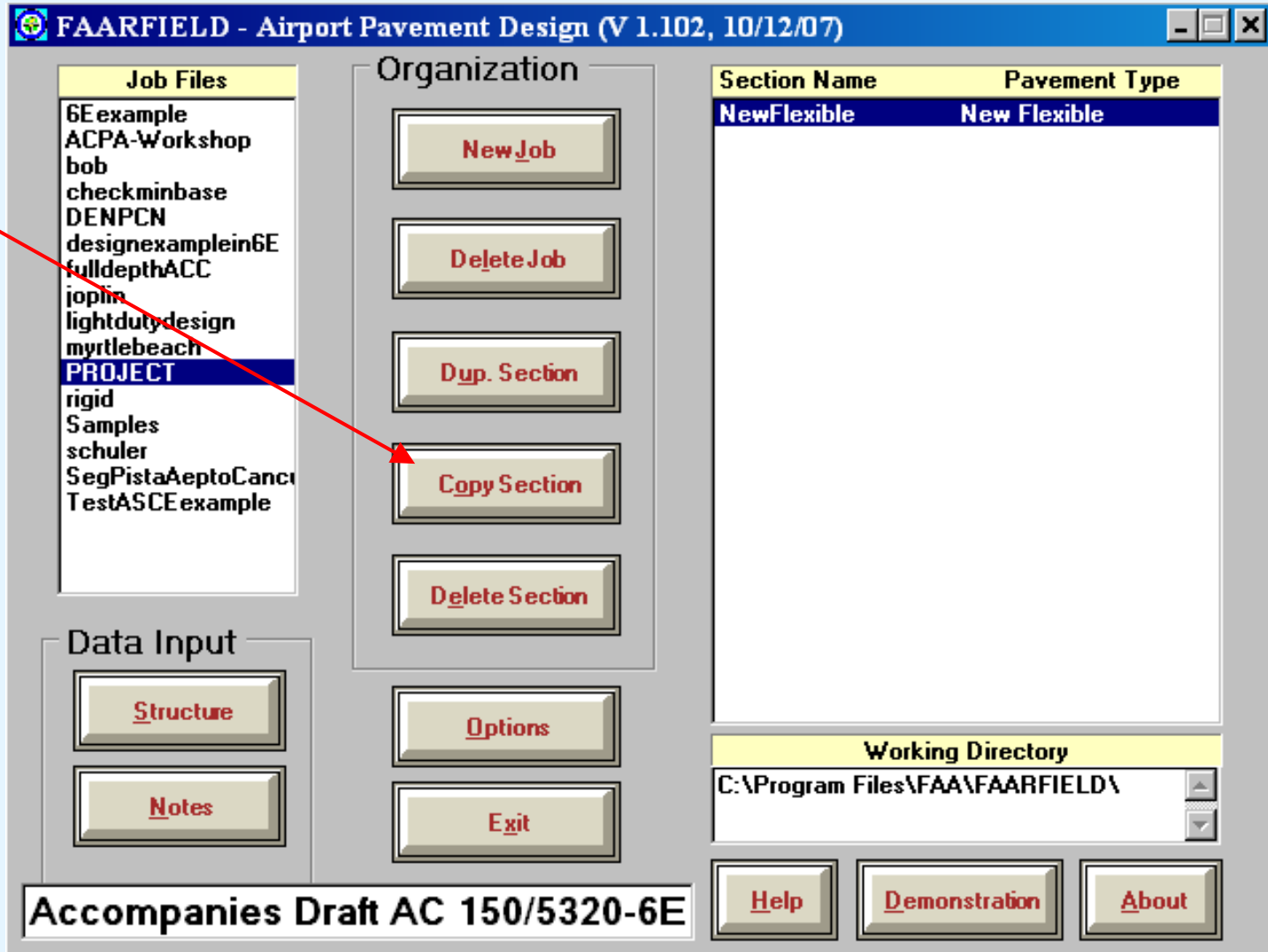


Original design required 18.8 inches of P-209

FAARFIELD - Sample HMA Overlay Design

Create Existing Pavement Section for Overlay Design

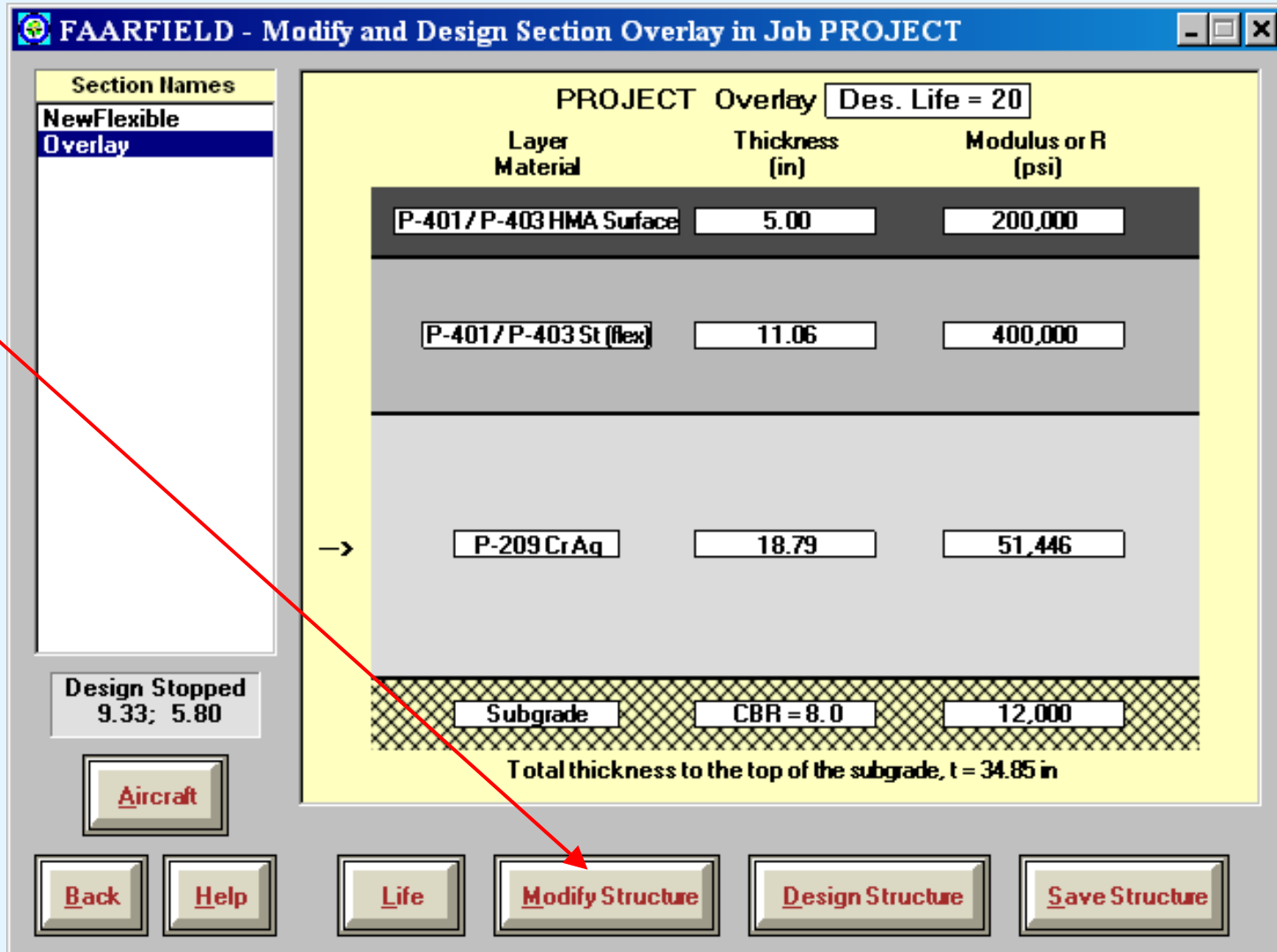
Copy the original pavement section – go to "Modify Structure"



FAARFIELD - Sample HMA Overlay Design

Create Existing Pavement Section for Overlay Design

Start with the original pavement section – go to "Modify Structure"

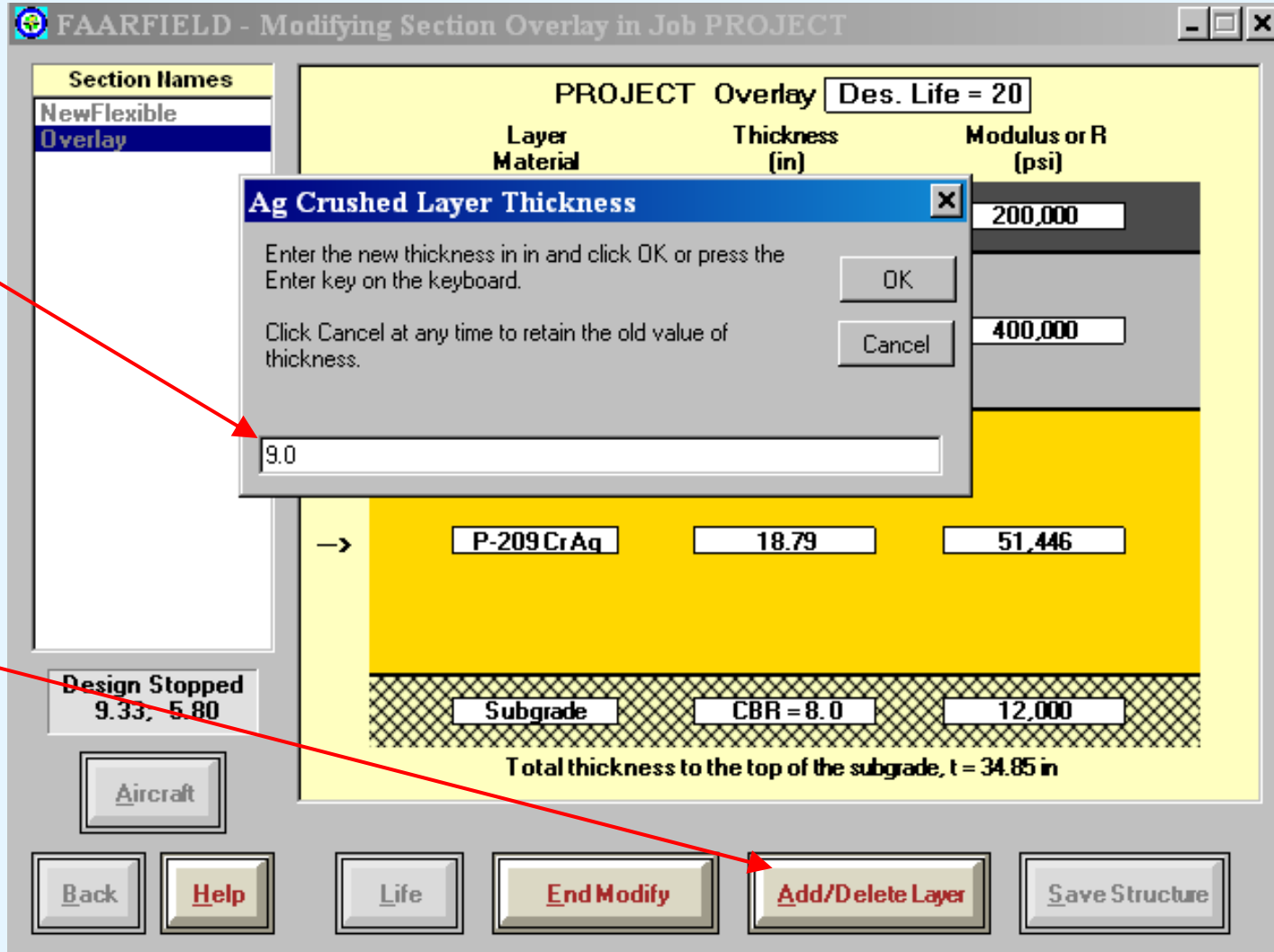


FAARFIELD - Sample HMA Overlay Design

Create Existing Pavement Section for Overlay Design

Click on the subbase thickness and enter 9.0 to establish the existing pavement structure

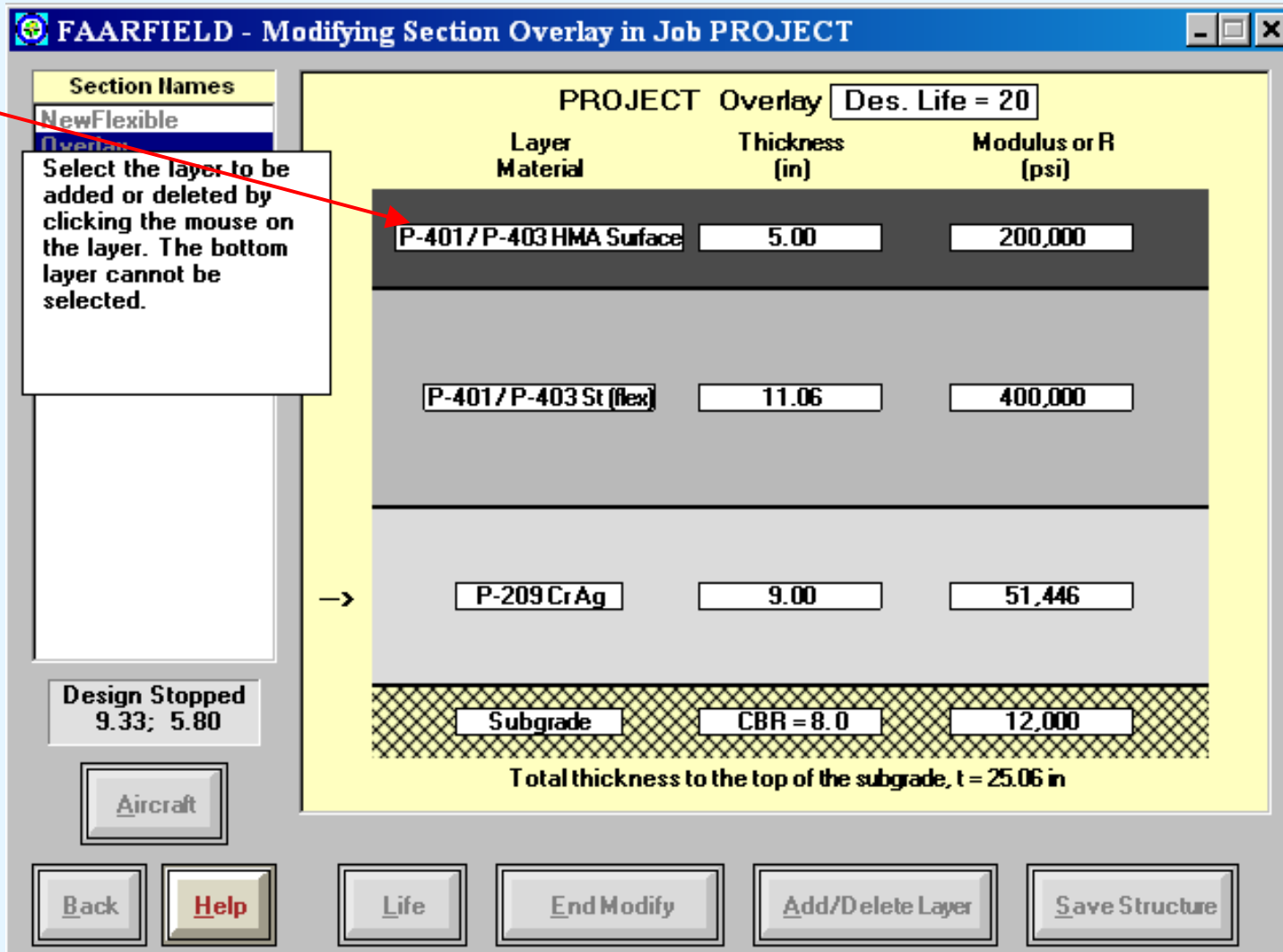
Then click on "Add/Delete Layer"



FAARFIELD - Sample HMA Overlay Design

Create Overlay Layer

Click on the P401 surface layer to add a section layer

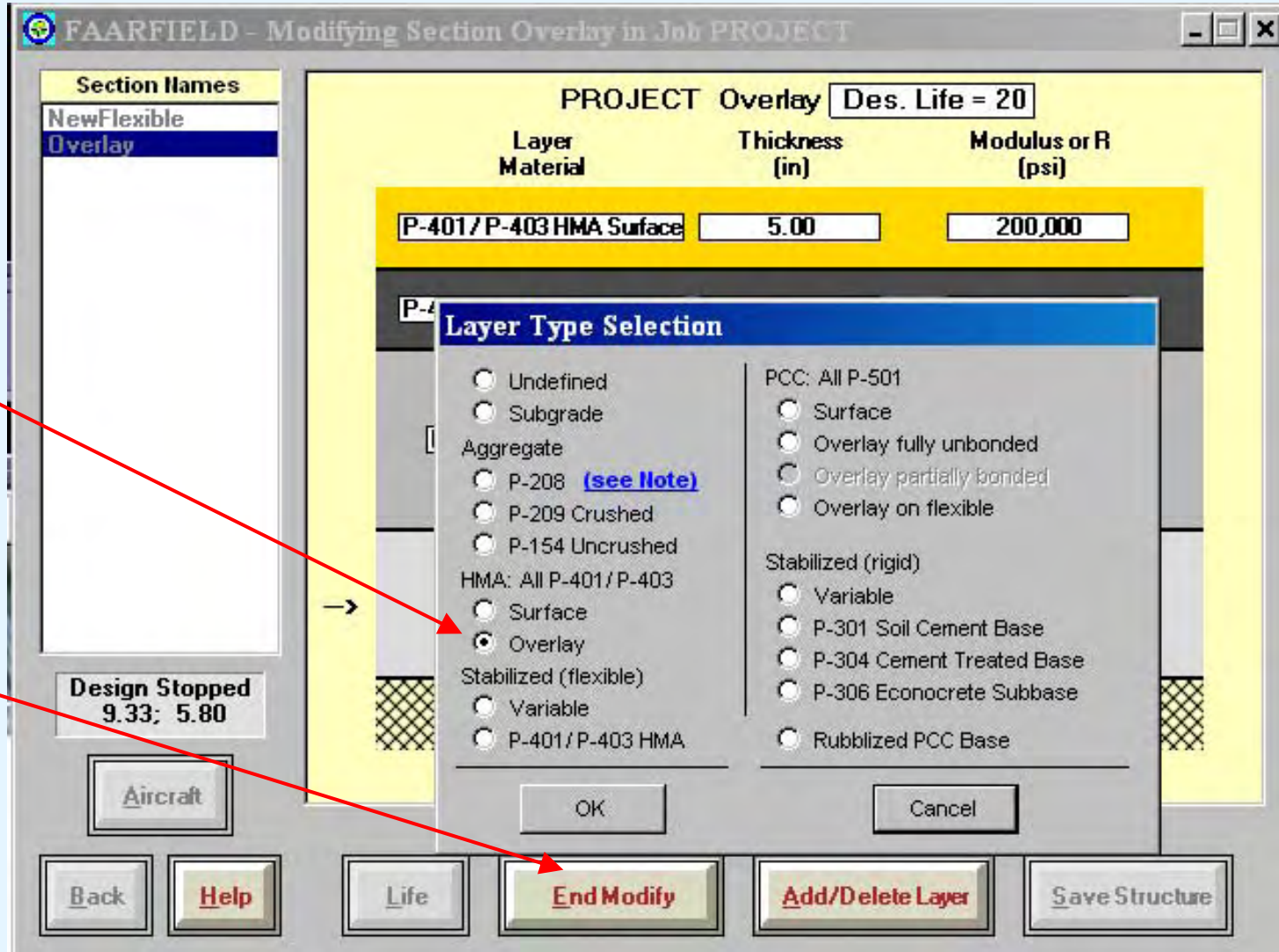


FAARFIELD - Sample HMA Overlay Design

Create Overlay Layer

Click on the top layer and change its properties to Asphalt P-401 Overlay

Then click on "End Modify" to return to design mode



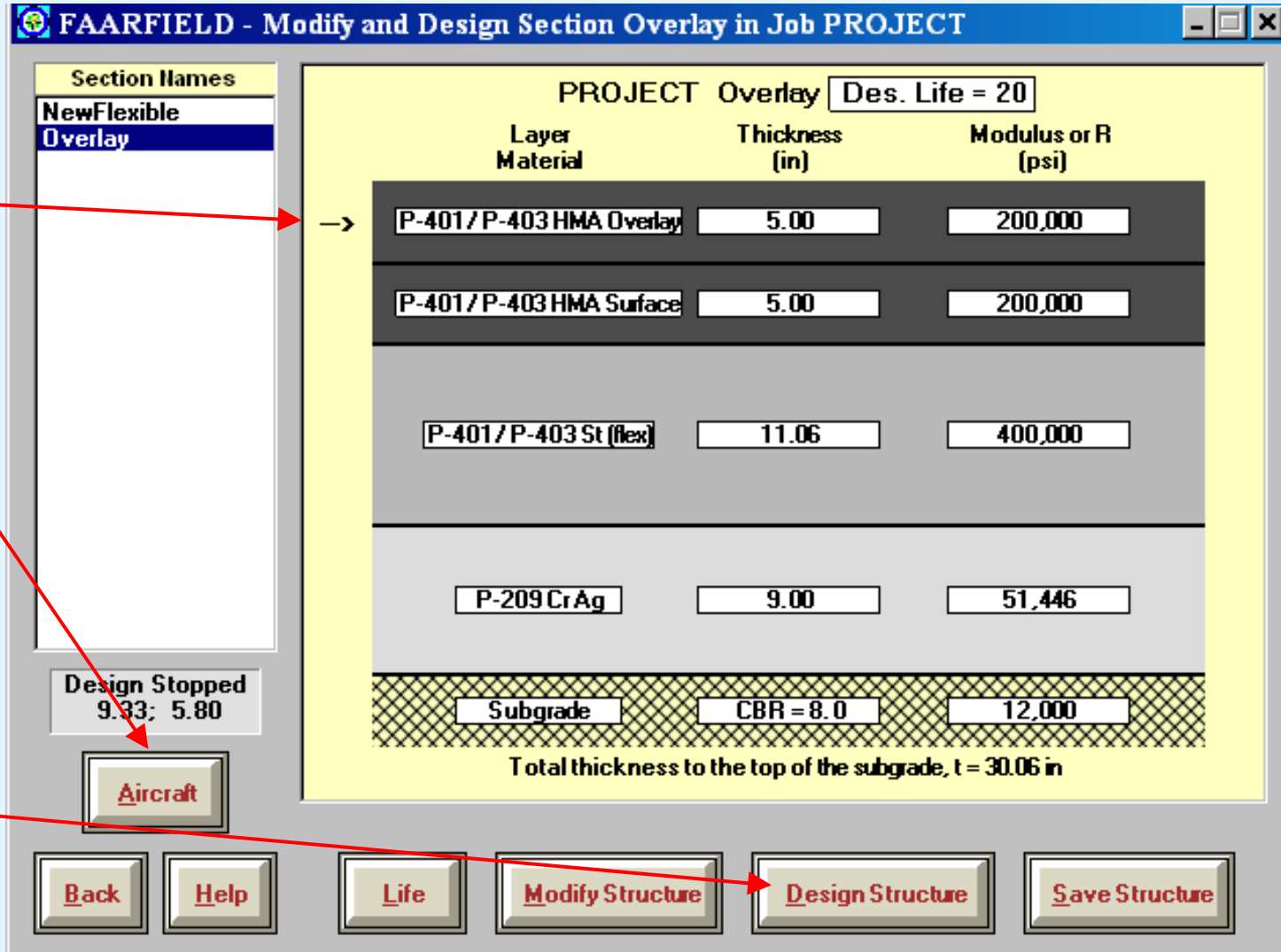
FAARFIELD - Sample HMA Overlay Design

Create Overlay Layer

Notice the arrow has relocated to the overlay layer

You may confirm or modify the airplane information

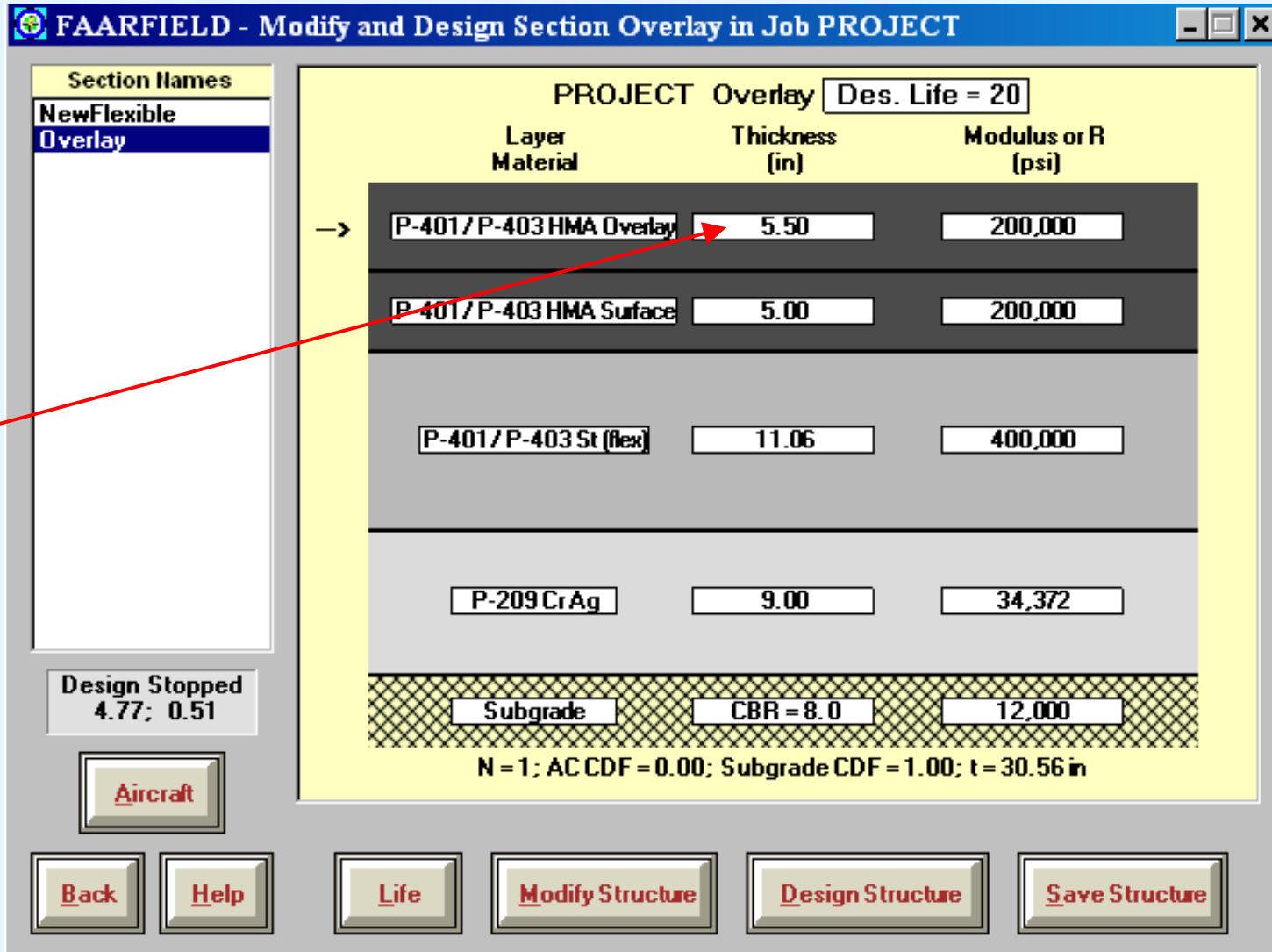
Then click "Design Structure" to complete the design



FAARFIELD - Sample HMA Overlay Design

Create Overlay Layer

The final overlay thickness is 5.5 inches



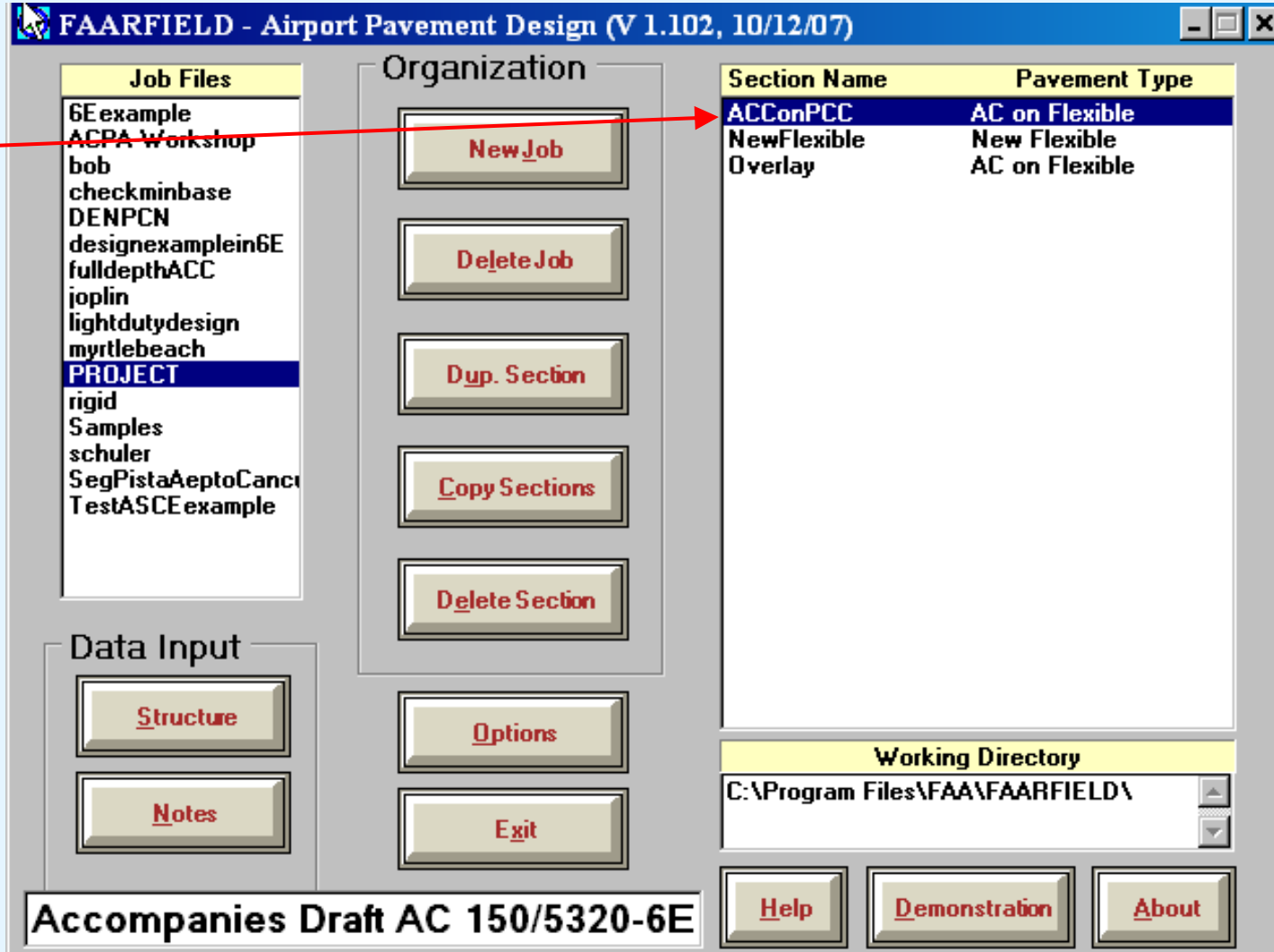
Overlay Design

Asphalt over Rigid Pavement

FAARFIELD - Sample HMA Overlay Design

Asphalt Over Rigid Pavement – Overlay Design

Create a new Section using the default samples or copying existing sections.

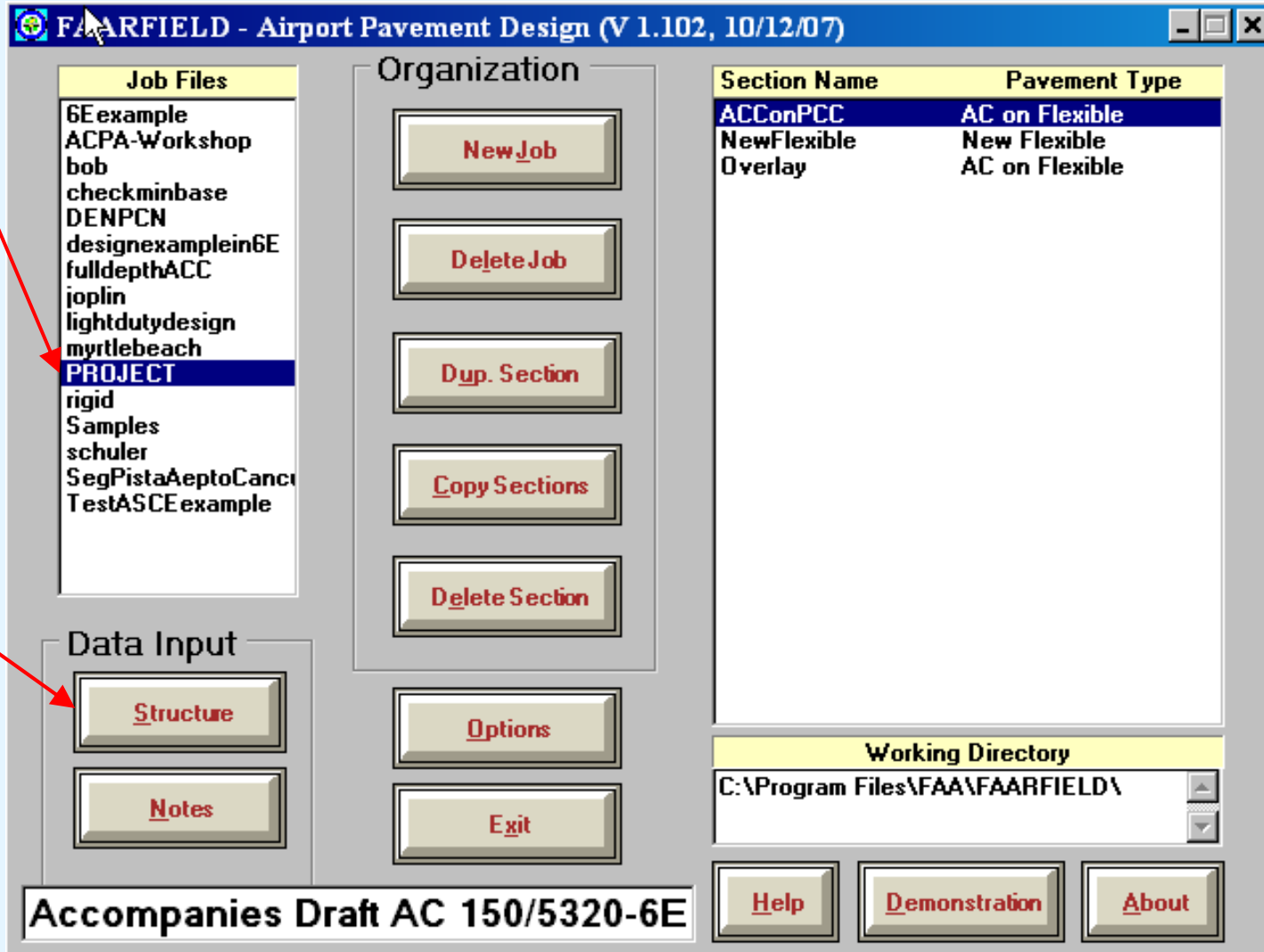


FAARFIELD - Sample HMA Overlay Design

Asphalt Over Rigid Pavement – Overlay Design

Select the Job file

Then open the structure

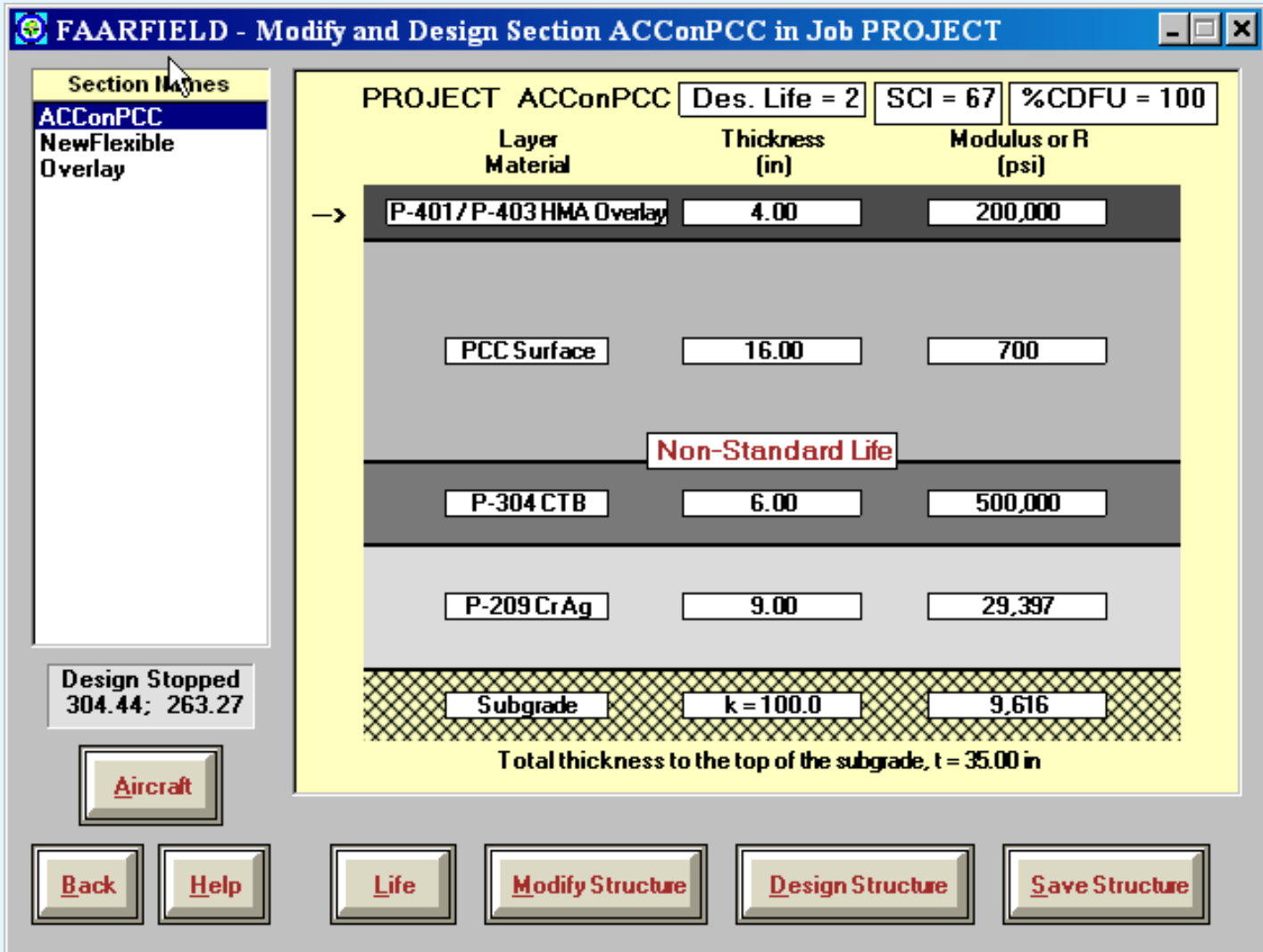


FAARFIELD - Sample HMA Overlay Design

Asphalt Over Rigid Pavement – Overlay Design

The new section may not automatically include the traffic mixture used for other sections.

You can copy the entire traffic mixture from a previous section to save time and effort.

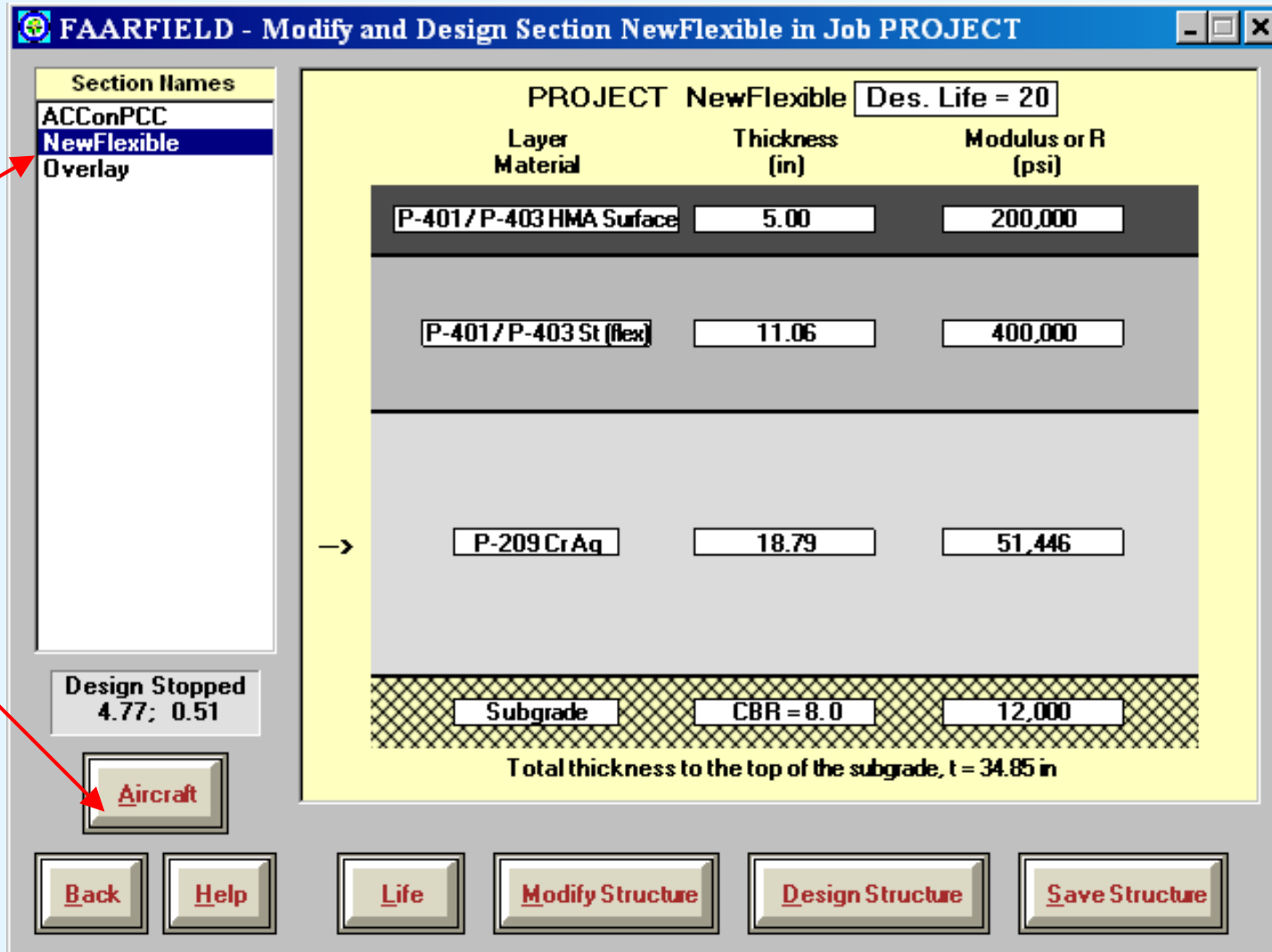


FAARFIELD - Sample HMA Overlay Design

Asphalt Over Rigid Pavement – Overlay Design

Select the section containing the traffic mixture you want to copy

Click "Aircraft"

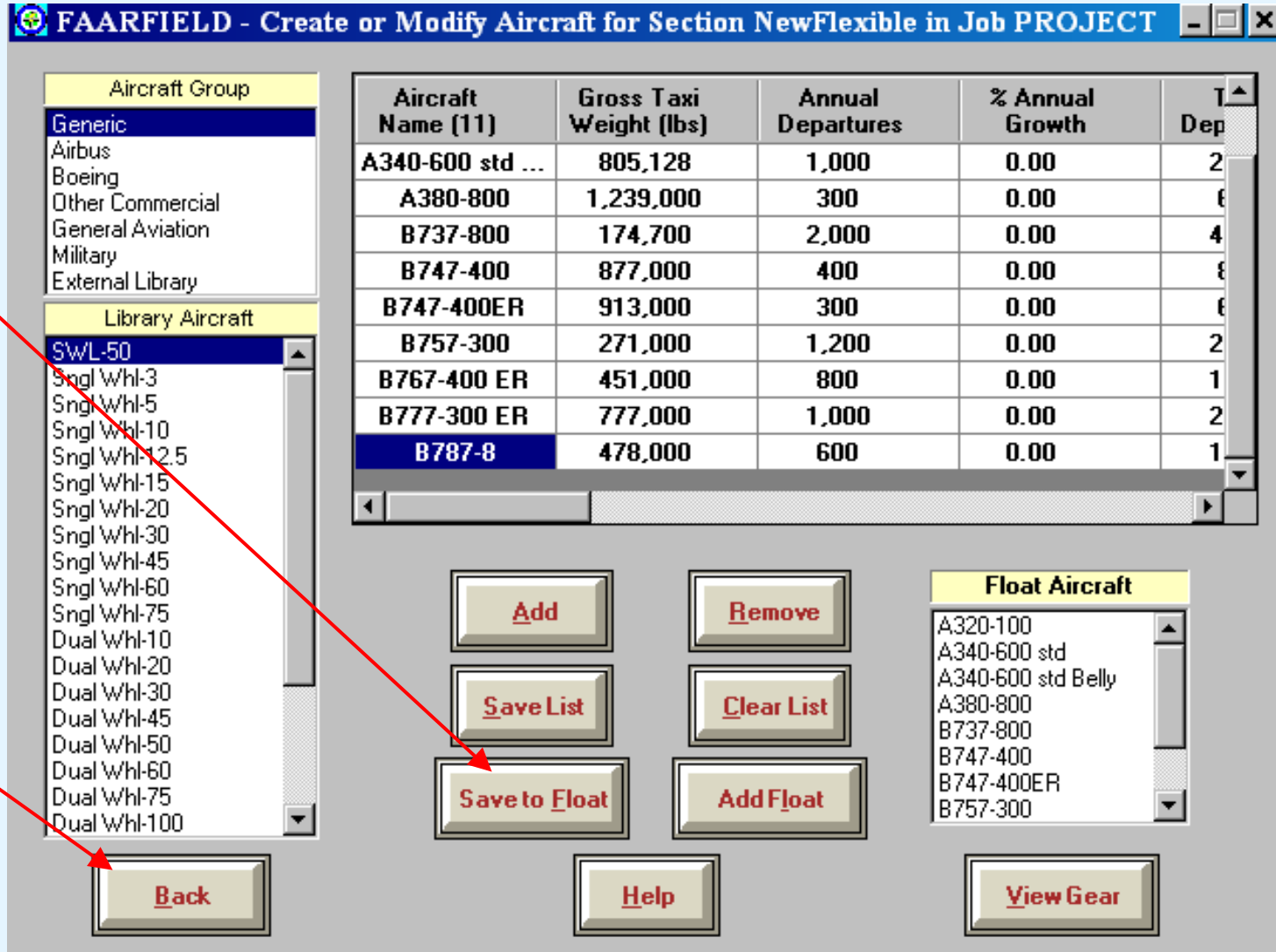


FAARFIELD - Sample HMA Overlay Design

Asphalt Over Rigid Pavement – Overlay Design

Click on “Save to Float” to copy the entire airplane list to the Float (like a clipboard)

Click “Back”

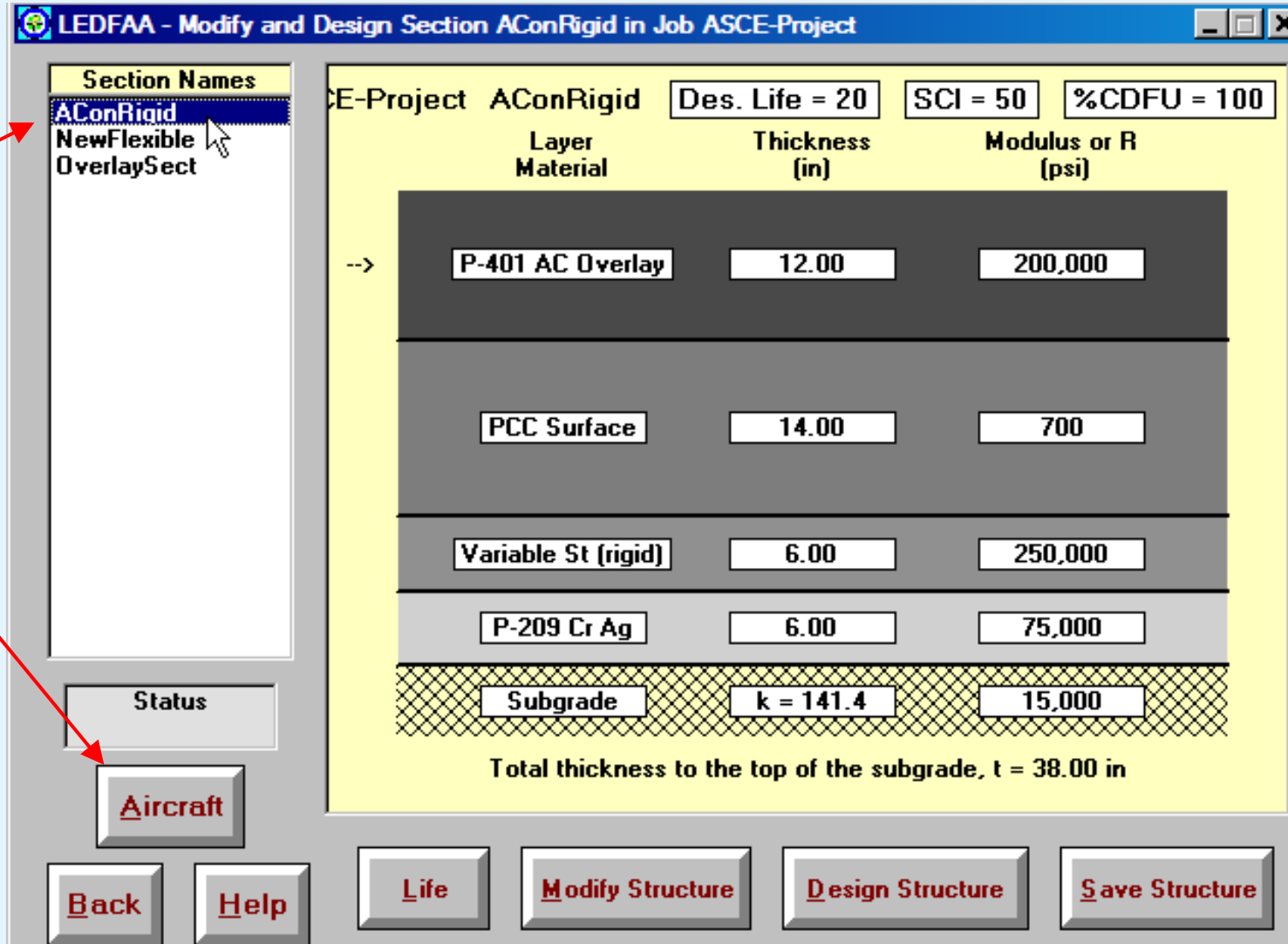


FAARFIELD - Sample HMA Overlay Design

Asphalt Over Rigid Pavement – Overlay Design

Select the new overlay section

Then click "Aircraft"

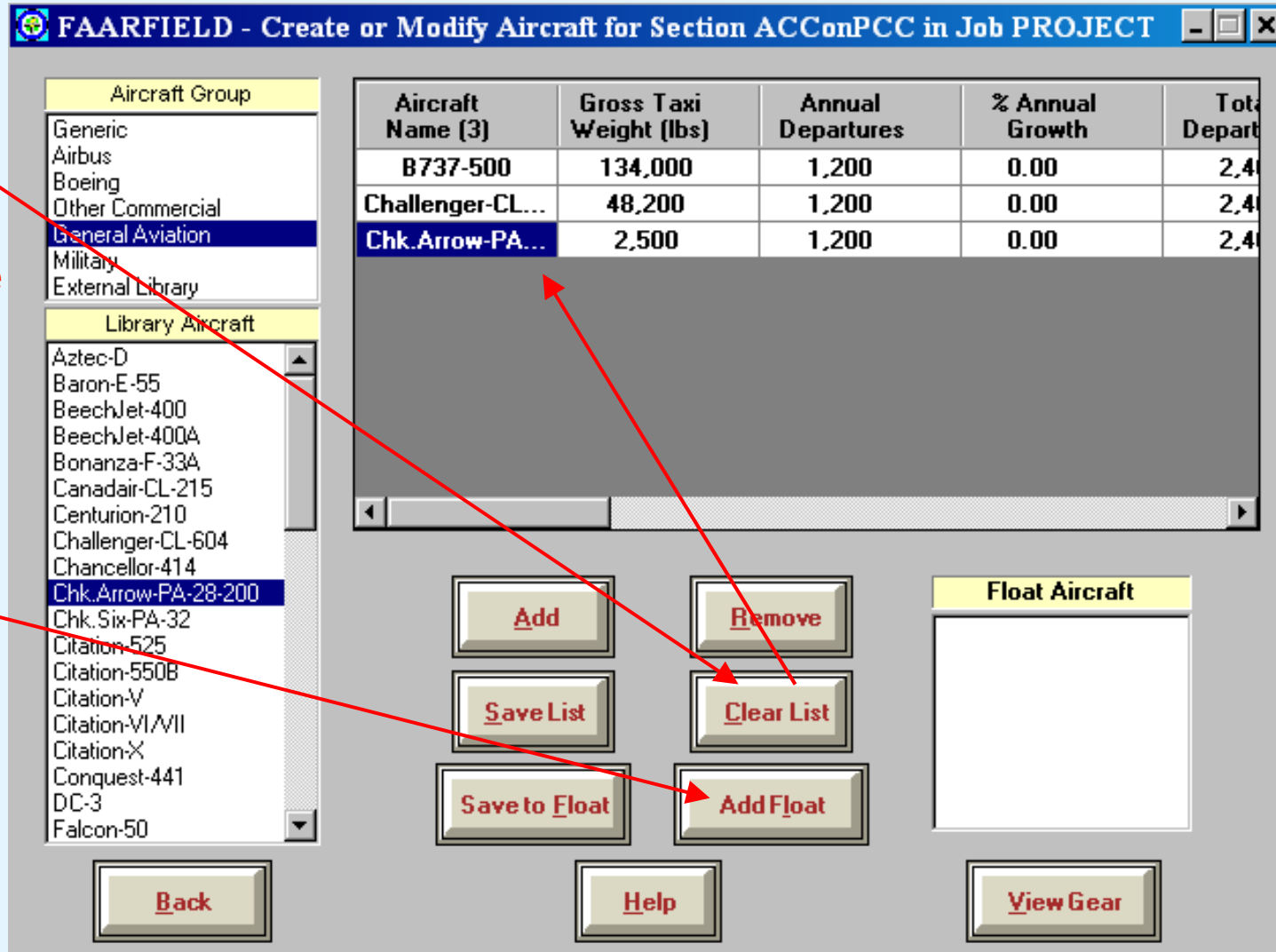


FAARFIELD - Sample HMA Overlay Design

Asphalt Over Rigid Pavement – Overlay Design

Click on "Clear List" to remove any existing airplanes from the section.

Then click on "Add Float" to add the Float list to the section

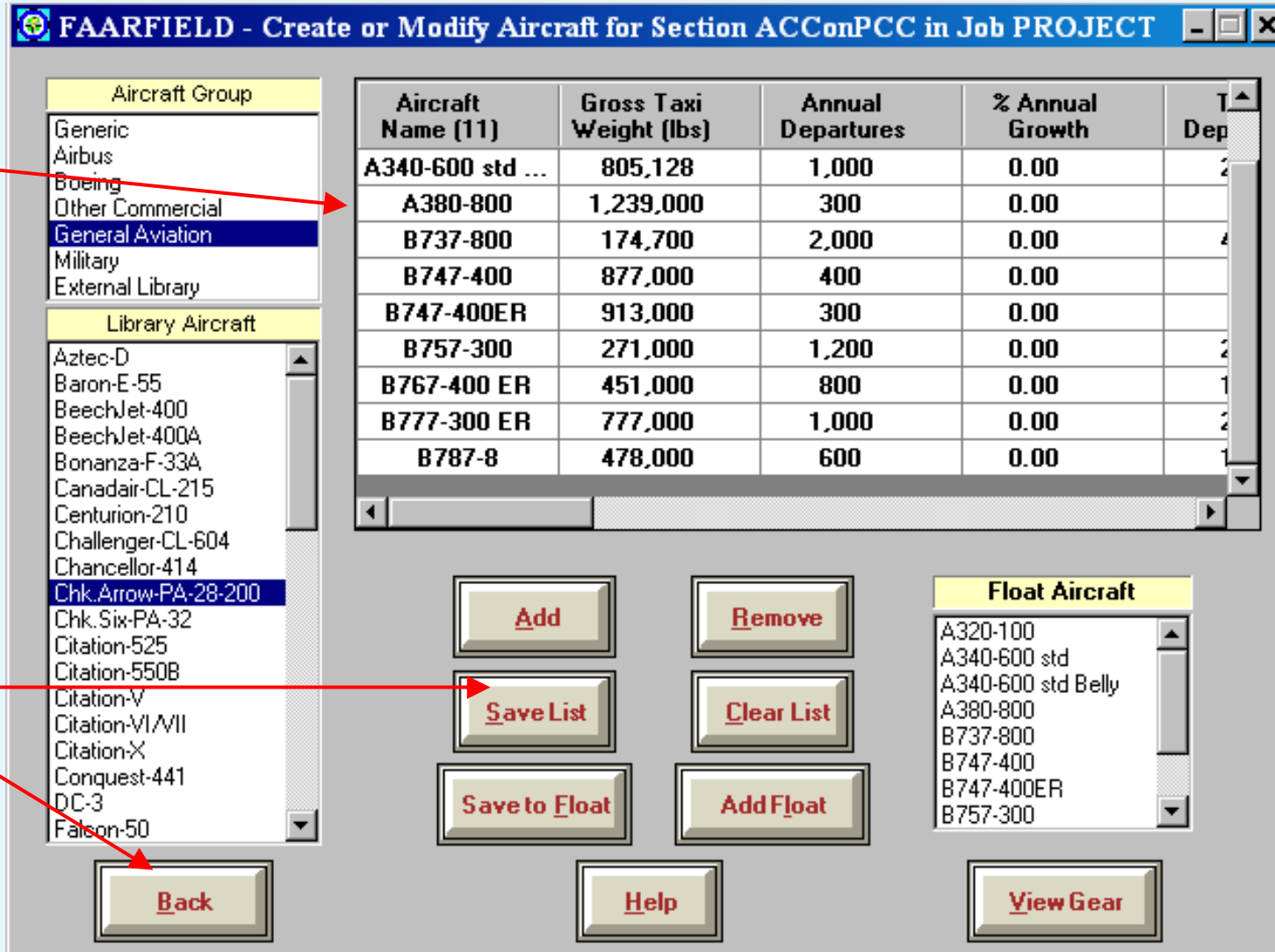


FAARFIELD - Sample HMA Overlay Design

Asphalt Over Rigid Pavement – Overlay Design

The updated list is now visible. You can modify the list if necessary

Once you are satisfied with the airplane list click "Save List" and "Back"

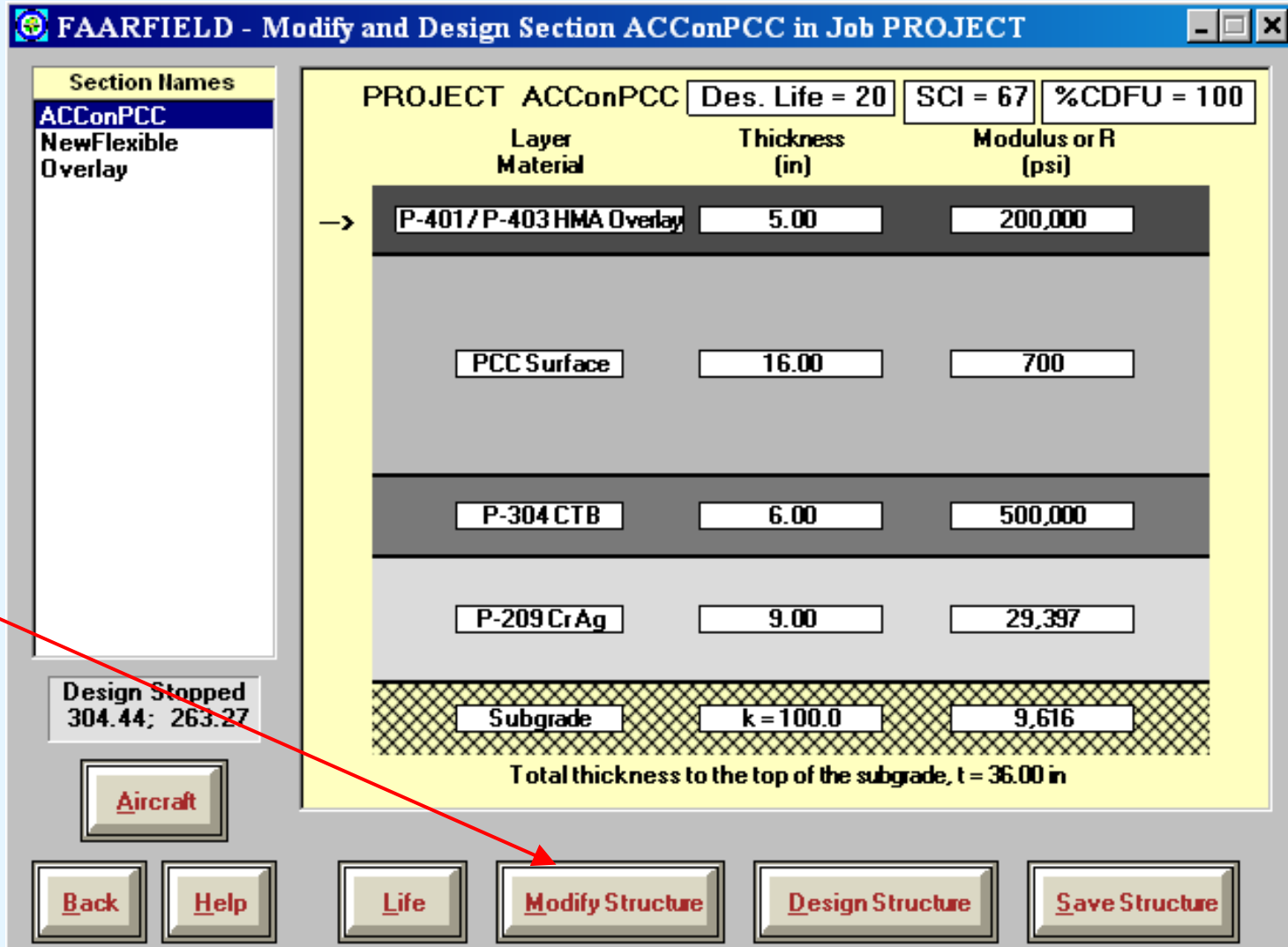


FAARFIELD - Sample HMA Overlay Design

Asphalt Over Rigid Pavement – Overlay Design

You may need to modify the sample section to accurately mimic your existing pavement section

Using the same procedures as before to modify the section



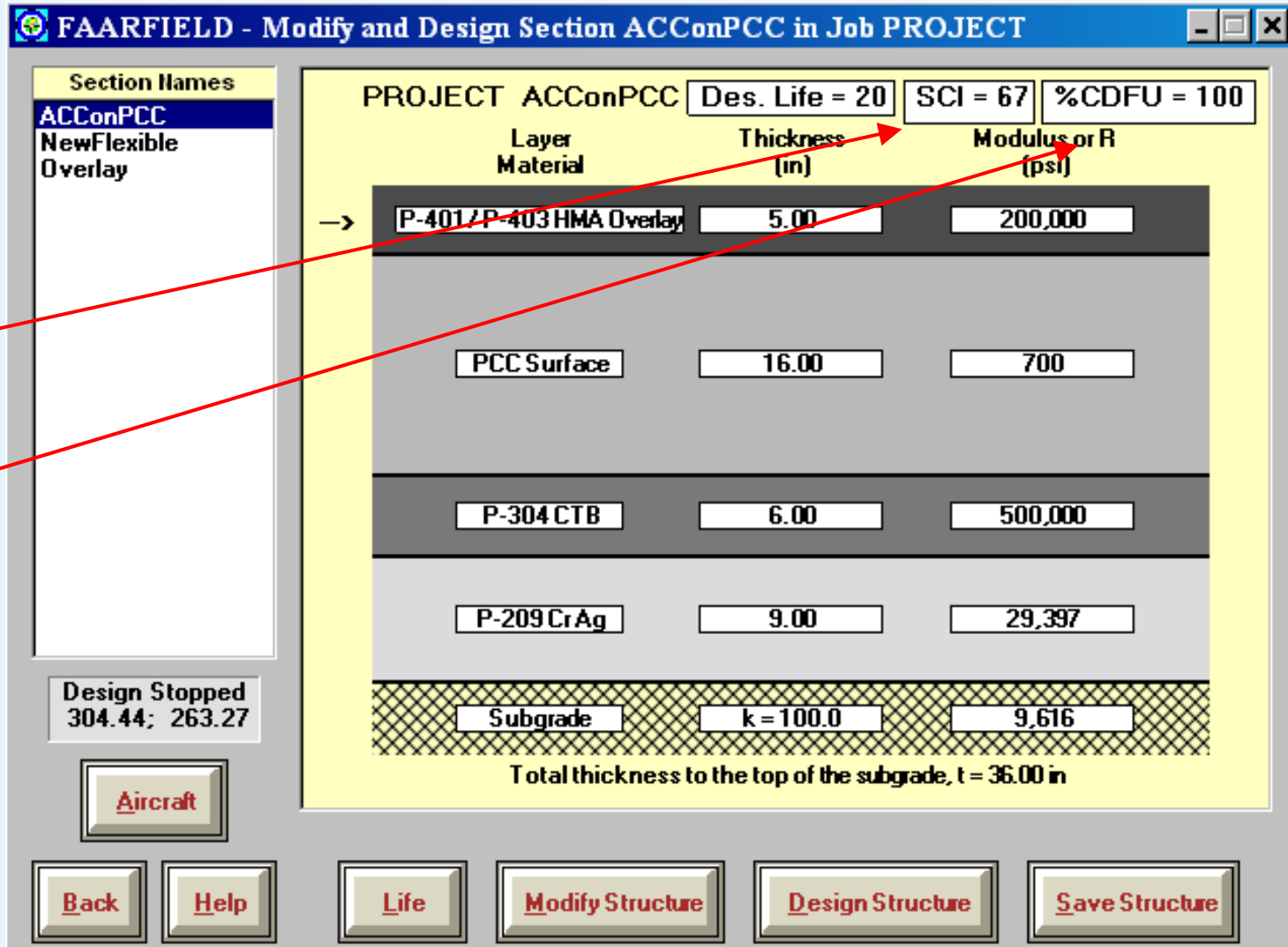
FAARFIELD - Sample HMA Overlay Design

Asphalt Over Rigid Pavement – Overlay Design

You will notice two new variables in the design window

SCI

%CDFU



FAARFIELD - Sample HMA Overlay Design

Asphalt Over Rigid Pavement – Overlay Design

SCI – Structural Condition Index

A measure of the structure condition of the existing pavement structure.

Summation of structural components from PCI Distress Survey

SCI range 0 (complete failure) – 100 (no distress)

FAARFIELD - Sample HMA Overlay Design

Asphalt Over Rigid Pavement – Overlay Design

CDFU = Cumulative Damage Factor Used

When SCI = 100, you must identify the percentage of pavement life that has already been consumed i.e. CDFU

$$CDFU = \frac{L_U}{0.75\,L_D} \quad \text{when } L_U < 0.75\,L_D$$
$$= 1 \quad \text{when } L_U \geq 0.75\,L_D$$

LU = number of years of operation of the existing pavement until overlay

LD = design life of the existing pavement in years

To calculate CDFU – create original structure, create traffic applied to this point, use "Life" button

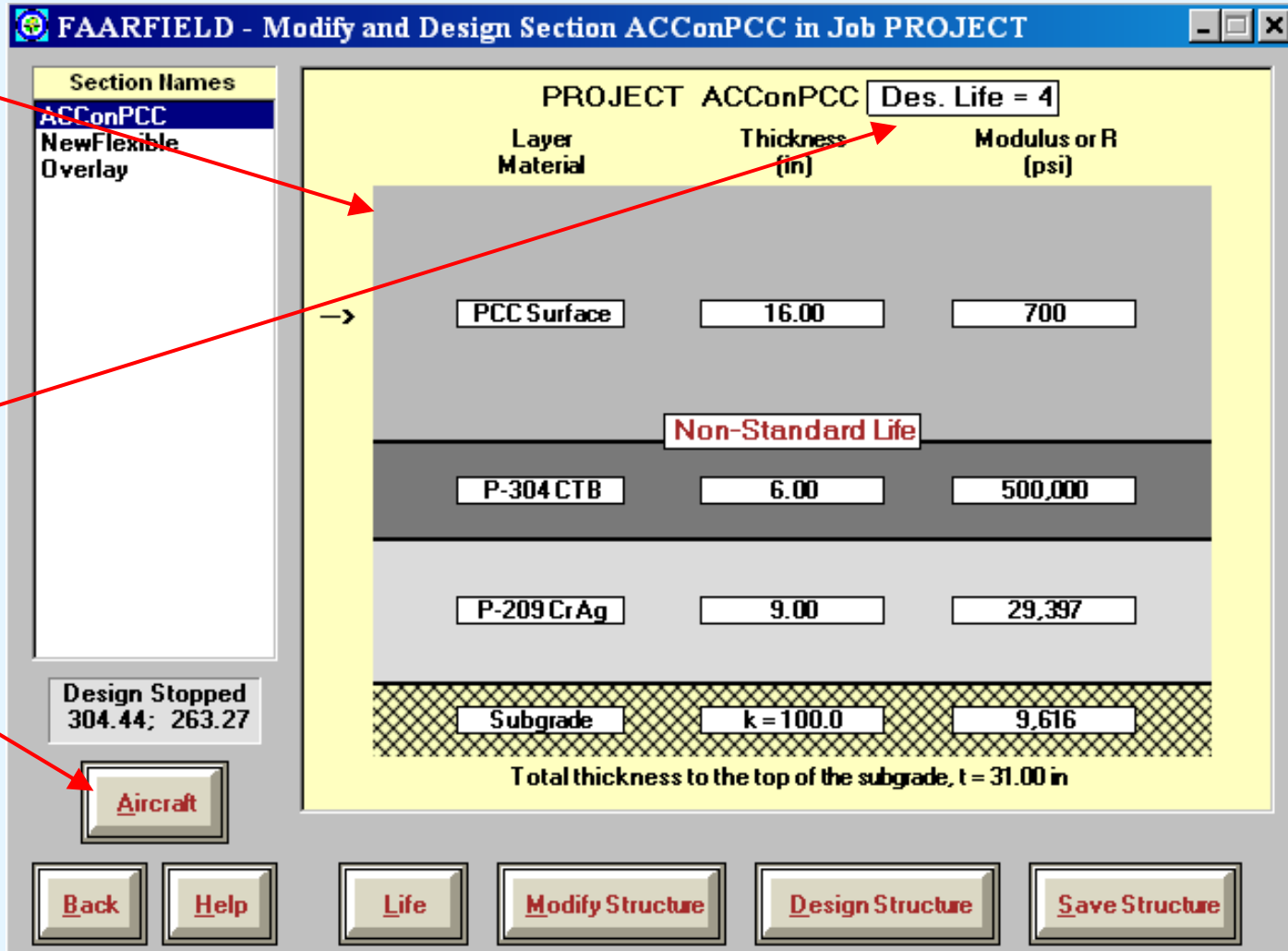
FAARFIELD - Sample HMA Overlay Design

Asphalt Over Rigid Pavement – Overlay Design Calculate CDFU

Overlay removed to create original structure

Design Life changed to 4 years to estimate in-service life.

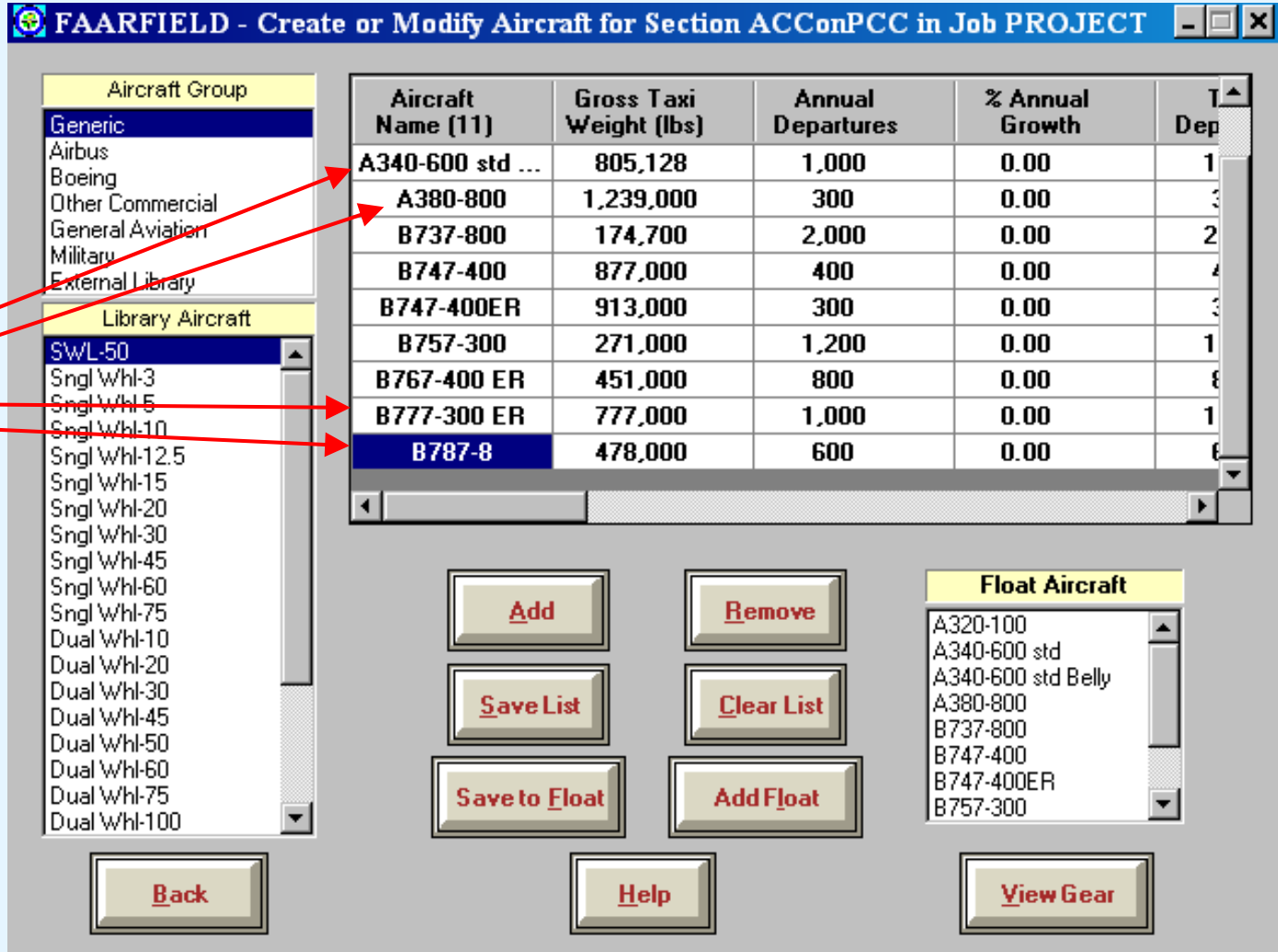
Click on "Aircraft" to enter historic traffic mixture



FAARFIELD - Sample HMA Overlay Design

Asphalt Over Rigid Pavement – Overlay Design Calculate CDFU

For this example assume the B777, B787, A340 and A380 are not in the historic traffic mix, Remove these airplanes.

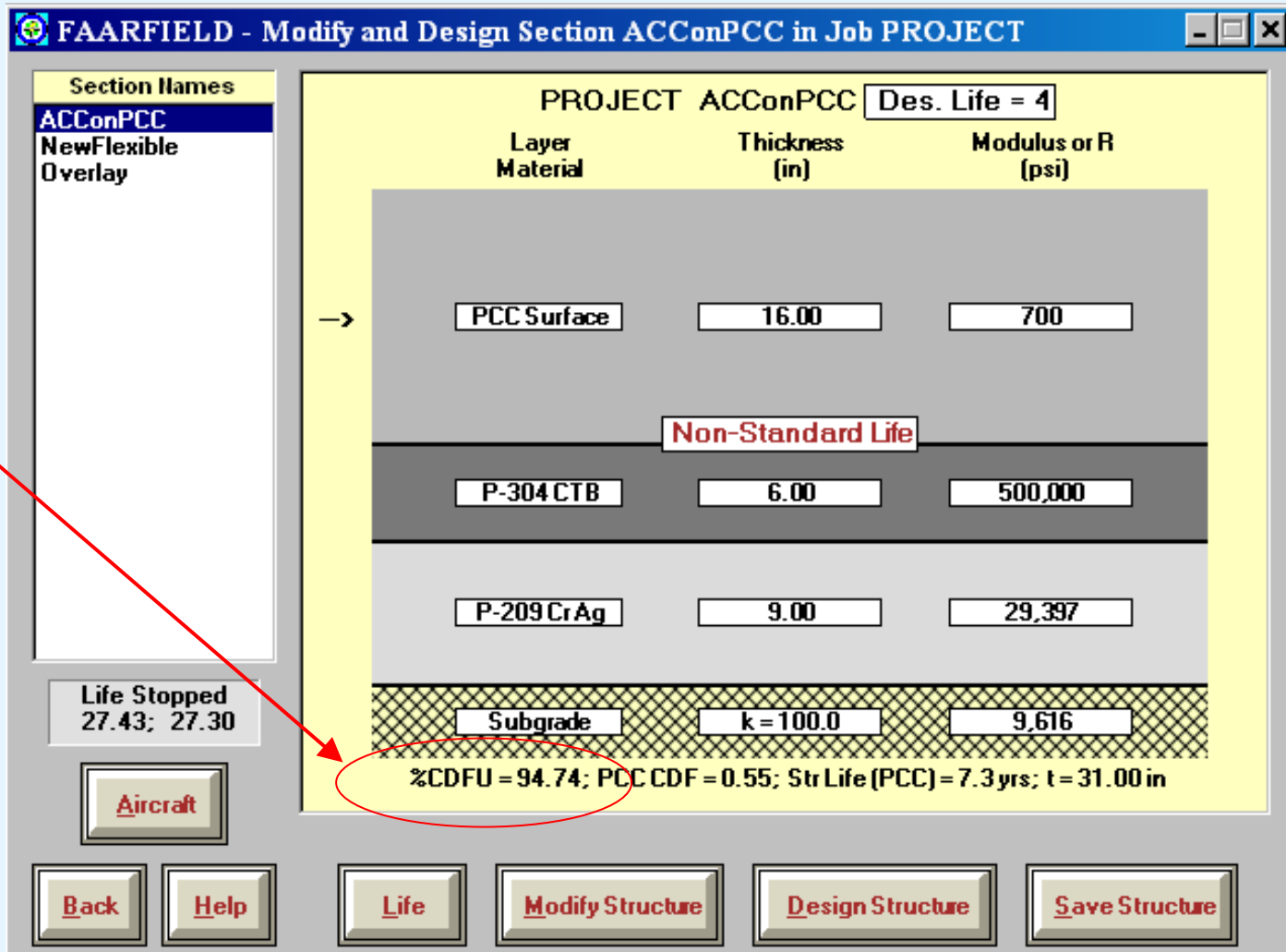


FAARFIELD - Sample HMA Overlay Design

Asphalt Over Rigid Pavement – Overlay Design Calculate CDFU

Click the "Life" button and the %CDFU for this pavement structure and the historic traffic will be displayed

%CDFU =94.7% indicates that the pavement life is mostly consumed. Enter this value for CDFU before design



FAARFIELD - Sample HMA Overlay Design

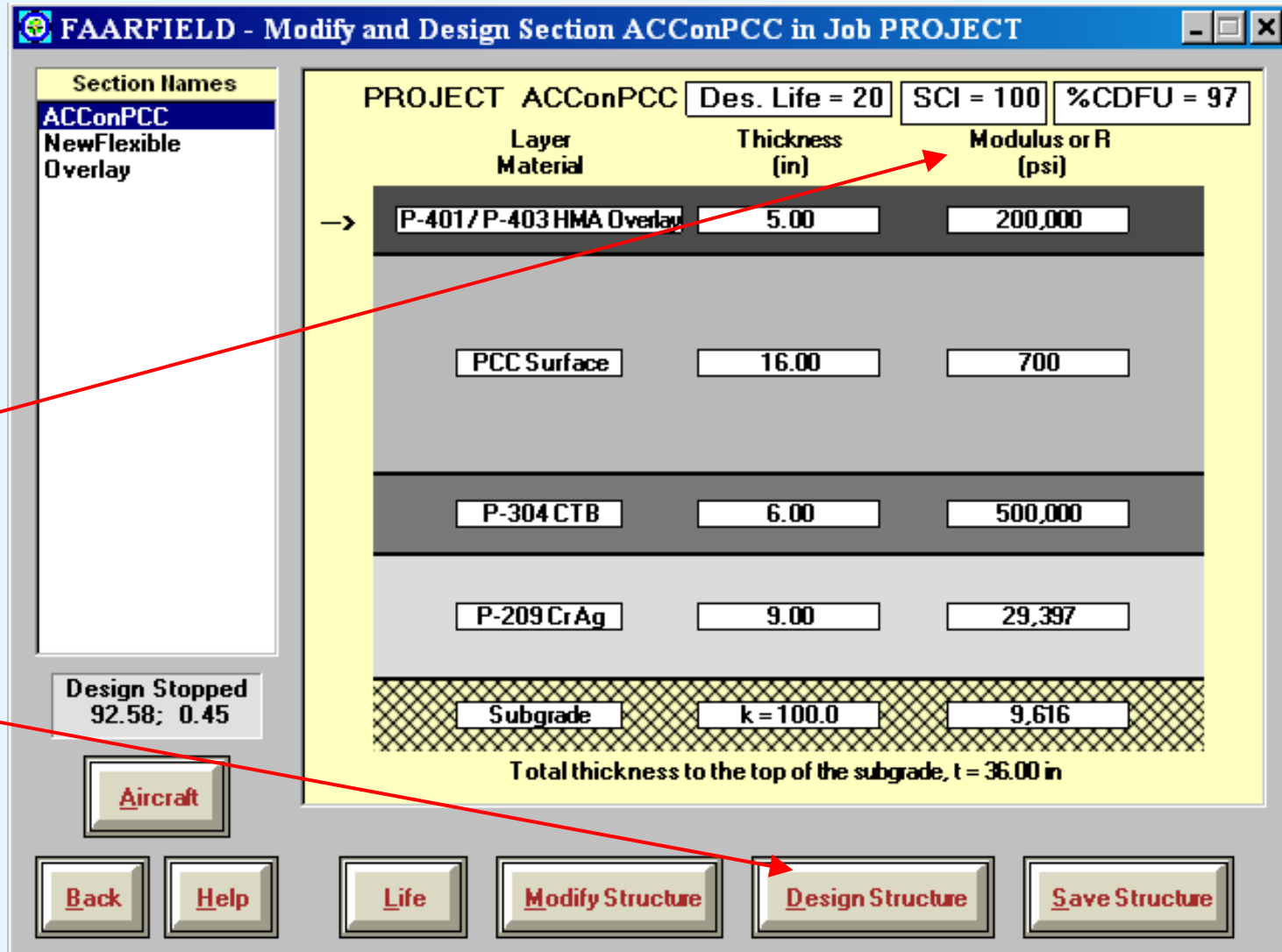
Asphalt Over Rigid Pavement – Overlay Design

Return to original overlay section

Restore original traffic mixture

Adjust SCI and %CDFU

Click on "Design Structure" to complete the overlay design

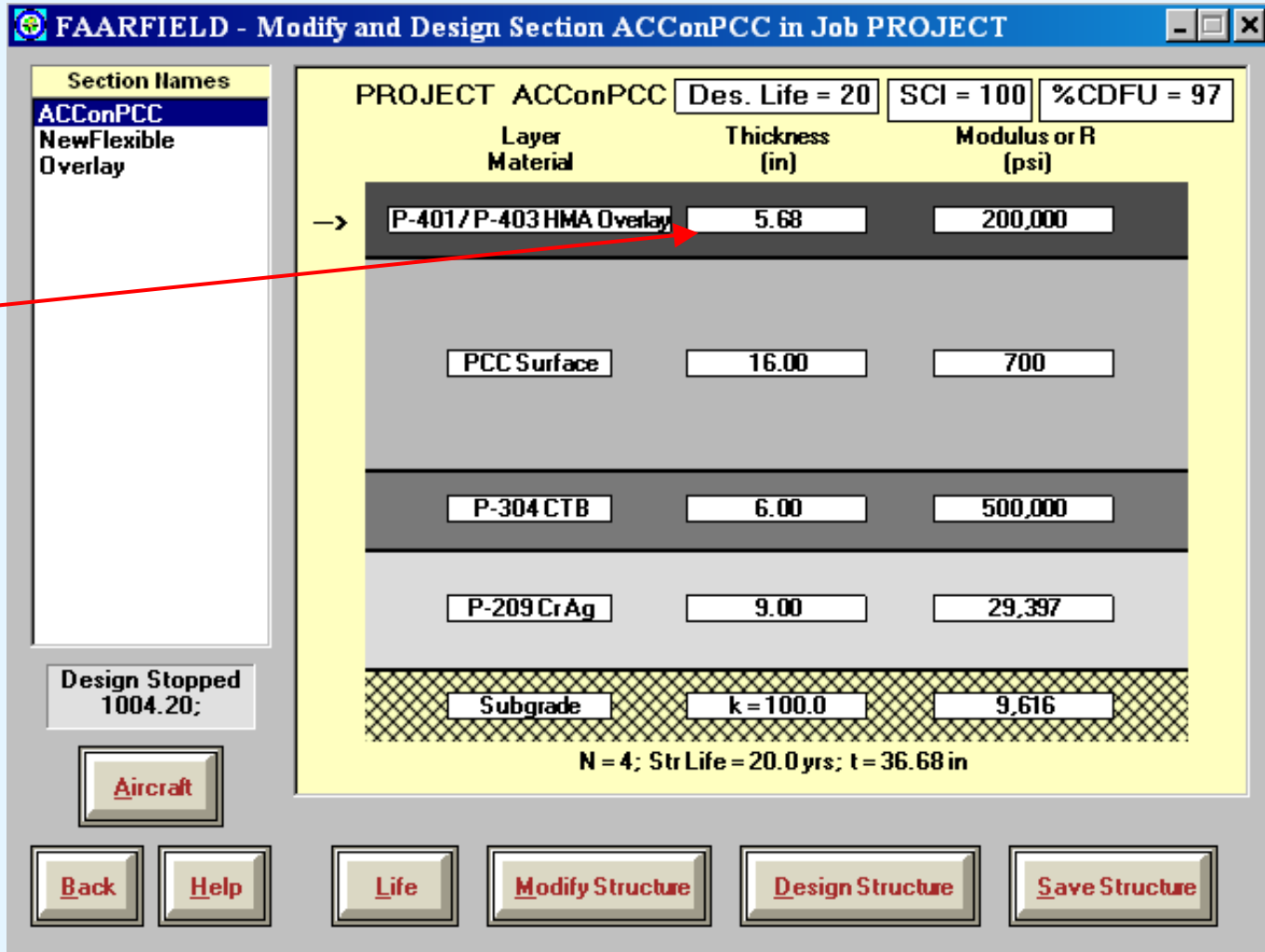


FAARFIELD - Sample HMA Overlay Design

Asphalt Over Rigid Pavement – Overlay Design

Final Pavement Section

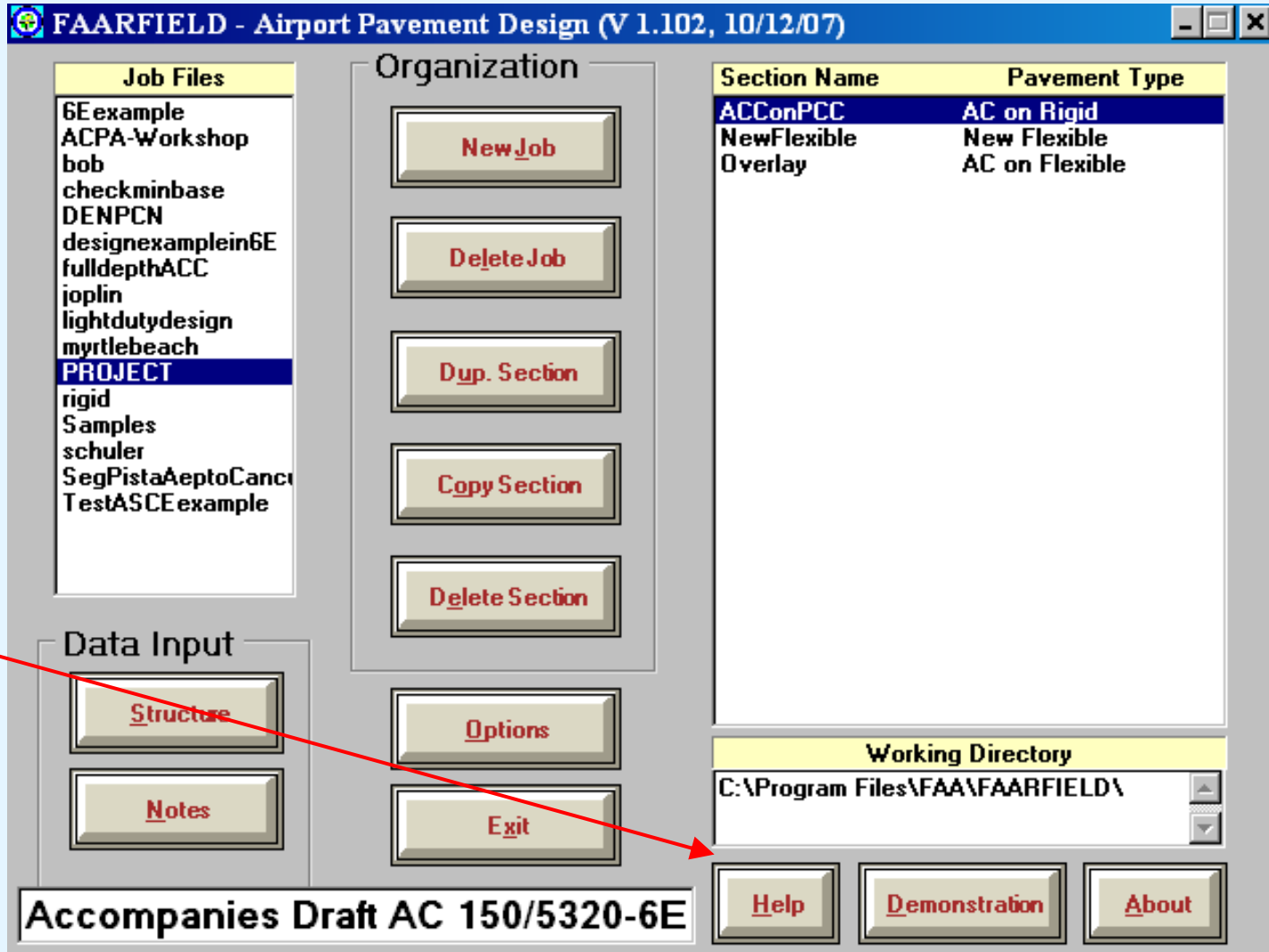
Requires ~6.0 inch overlay thickness



FAARFIELD - Help Manual

Interactive User's Manual / Help File

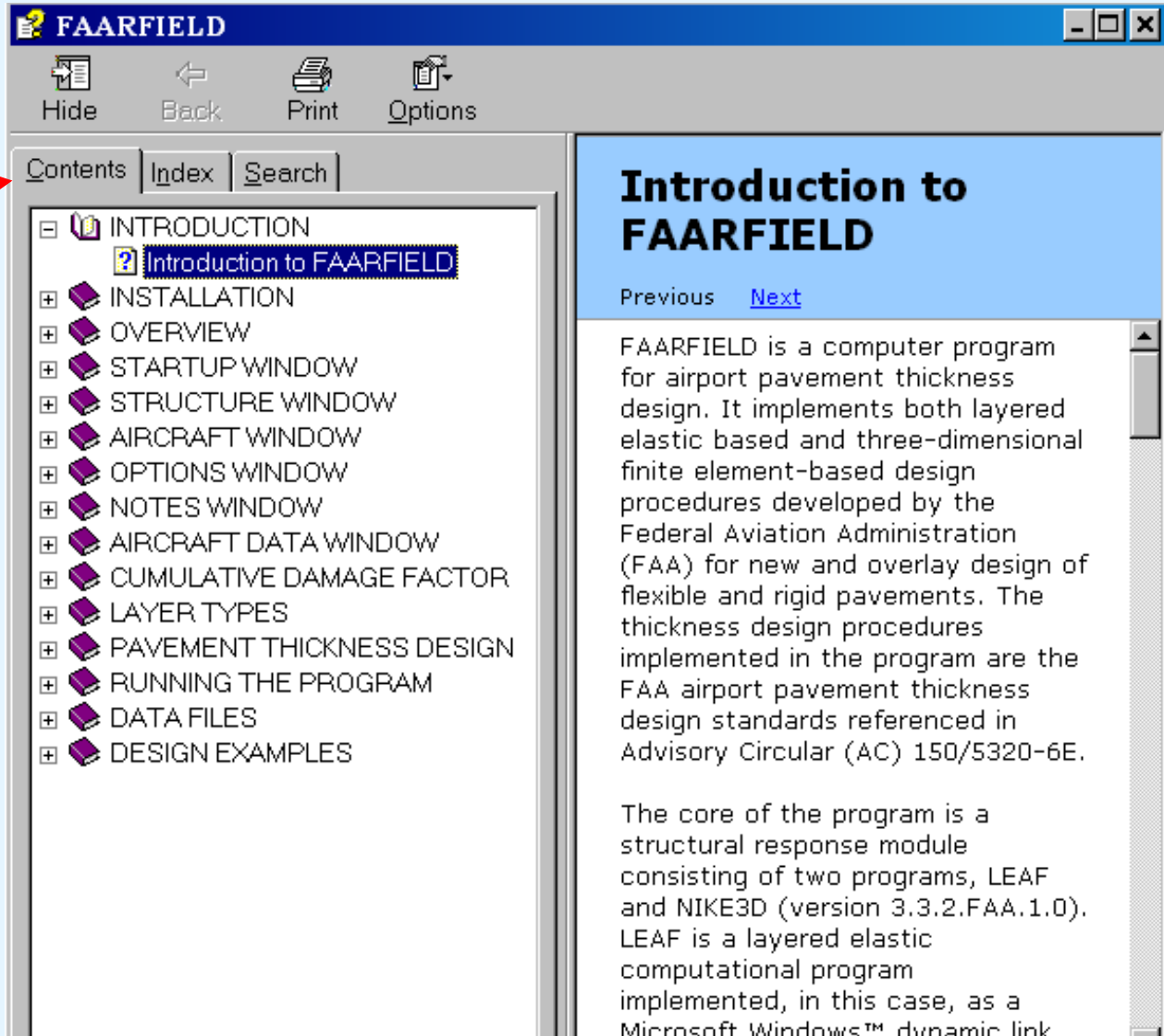
For assistance with the program click the Help key



FAARFIELD - Help Manual

Interactive User's Manual / Help File

Search by Contents/chapters, Index, or word search

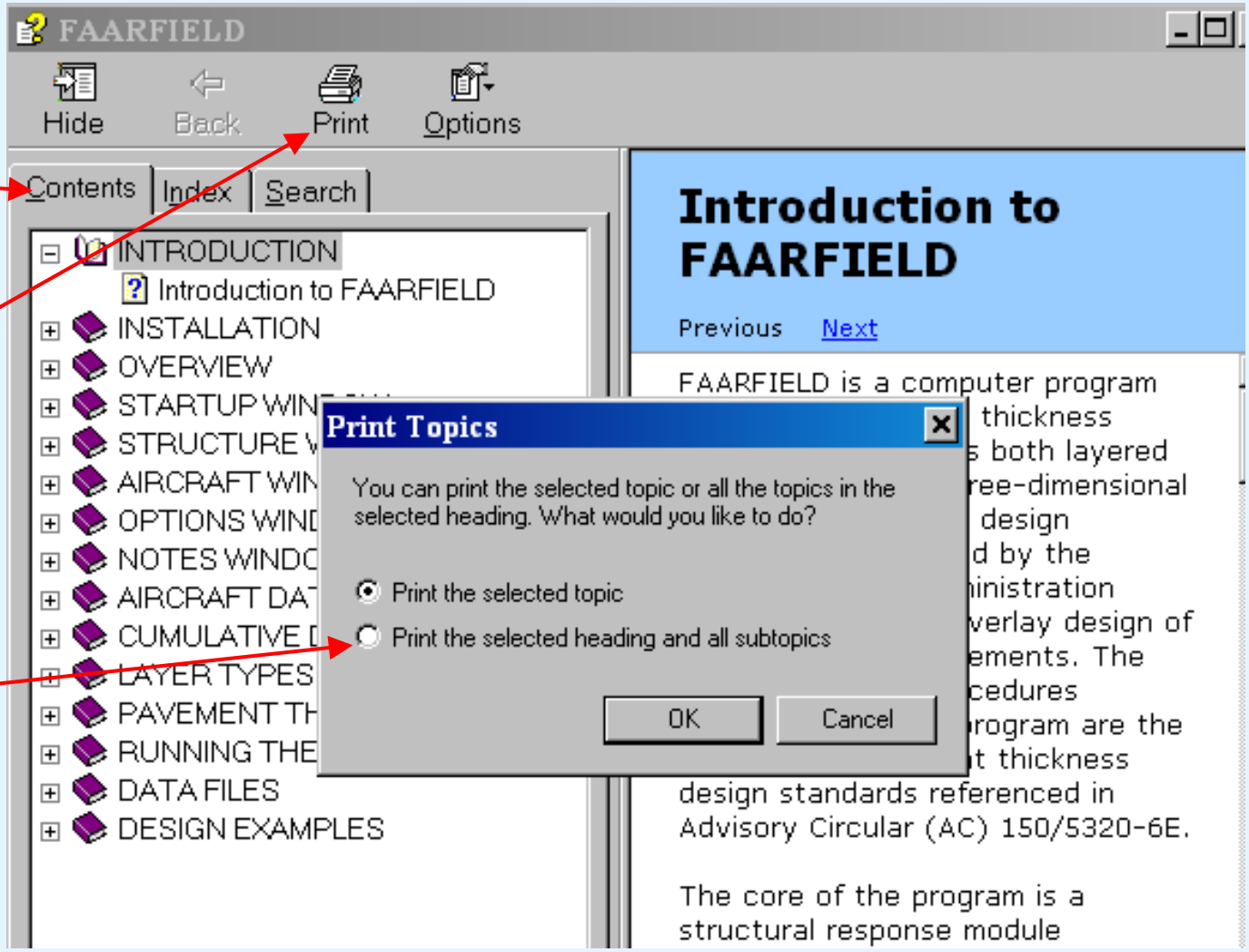


FAARFIELD - Help Manual

Printing Help Manuals

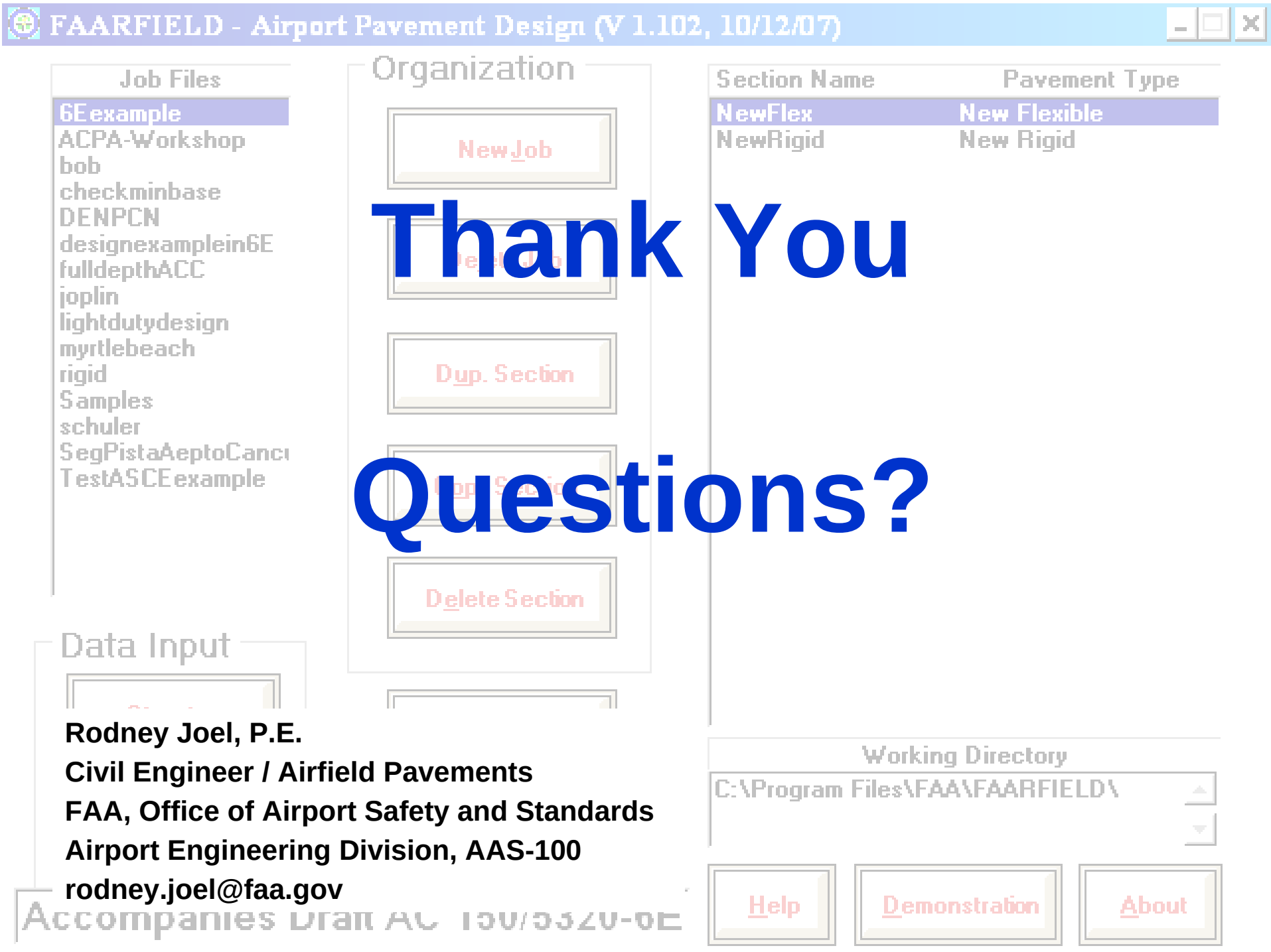
To print the manual move to the "Contents" tab and click Print

Select "Print the selected heading and all subtopic" Do this for each heading



Software Available at:

http://www.faa.gov/airports_airtraffic/airports/construction/design_software/



Thank You

Questions?

Rodney Joel, P.E.
Civil Engineer / Airfield Pavements
FAA, Office of Airport Safety and Standards
Airport Engineering Division, AAS-100
rodney.joel@faa.gov