

Rigid Pavement Design

FAARFIELD 1.3 Workshop

Presented to: VII ALACPA Airport Pavement Seminar & V FAA Airport Pavement Workshop

By: David R. Brill, P.E., Ph.D.

Date: December 8, 2010

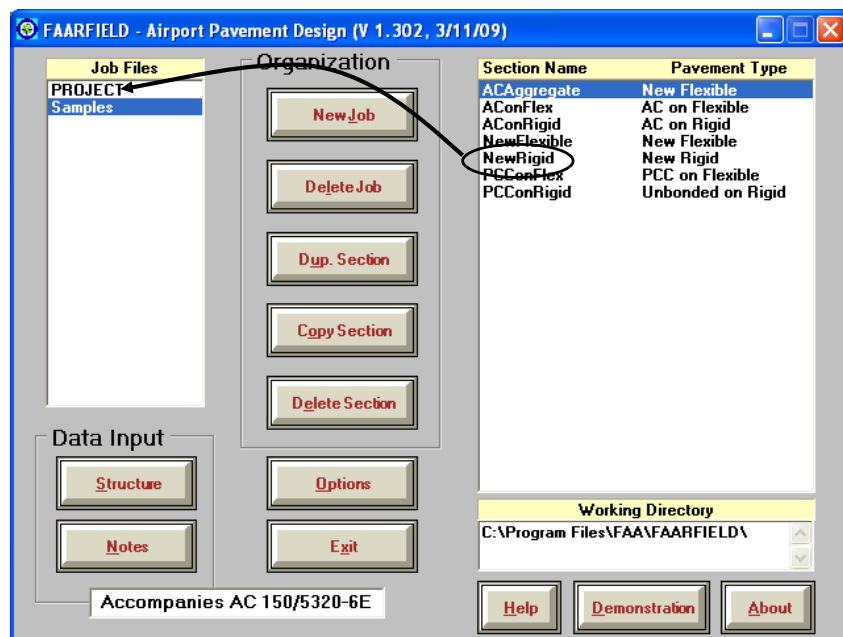


Federal Aviation Administration



New Rigid Example Set-Up

Create a new section in job PROJECT by dragging section NewRigid in Samples to PROJECT.

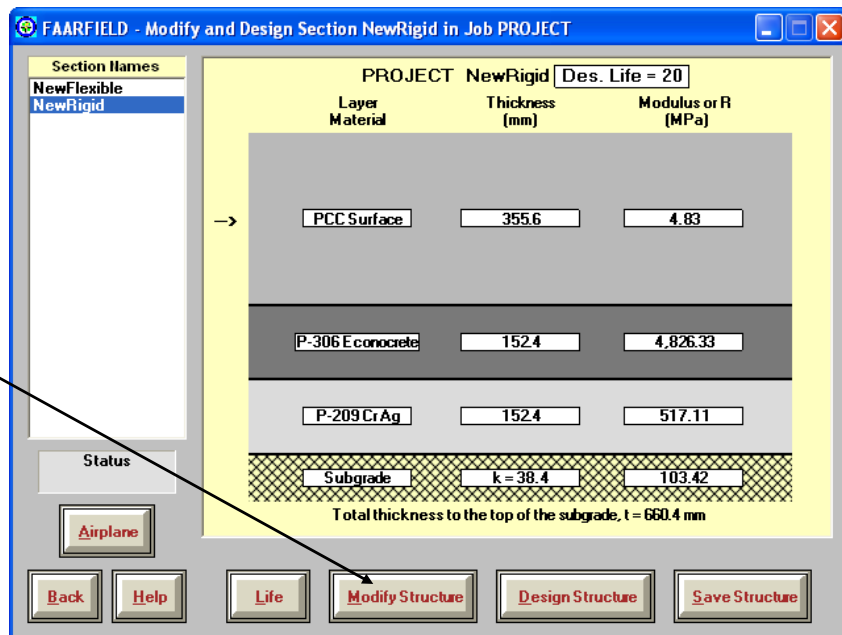


New Rigid Pavement Design Example (Metric Units)

- **Pavement Structure:**
 - PCC Slab, P-501, $R = 4.85 \text{ MN/m}^2$ (703 psi)
 - Cement-Treated Base, P-304, 150 mm (5.91 in.) thick
 - Crushed Aggregate Base, P-209, 200 mm (7.87 in.) thick
 - Subgrade $k = 28 \text{ MN/m}^3$ (103.2 pci)
- **Traffic Mix:**
 - Use traffic mix from flexible example
 - 10-Aircraft Mix includes B777, A340, A380

Change Pavement Structure

In Structure window,
click on Modify
Structure



FAARFIELD - Modify and Design Section NewRigid in Job PROJECT

Section Names
NewFlexible
NewRigid

PROJECT NewRigid Des. Life = 20

Layer Material	Thickness (mm)	Modulus or R (MPa)
PCC Surface	355.6	4.83
P-306 E concrete	152.4	4,826.33
P-209 CrAg	152.4	517.11
Subgrade	k = 38.4	103.42

Total thickness to the top of the subgrade, t = 660.4 mm

Buttons: Back, Help, Life, **Modify Structure**, Design Structure, Save Structure

Change Pavement Structure

Click R to 4.85 MN/m²

Change base layer to CTB, P-304, 150 mm

Change P-209 layer thickness to 200 mm

Change subgrade k to 28 MN/m³

Click "End Modify"

Layer Material	Thickness (mm)	Modulus or R (MPa)
PCC Surface	355.6	4.83
P-306 E concrete	152.4	4,826.33
P-209 CrAg	152.4	517.11
Subgrade	k = 38.4	103.42

Total thickness to the top of the subgrade, t = 660.4 mm



Change Pavement Structure

Click "Save Structure"

Layer Material	Thickness (mm)	Modulus or R (MPa)
PCC Surface	355.6	4.85
P-304 CTB	150.0	3,447.38
P-209 CrAg	200.0	517.11
Subgrade	k = 28.0	68.99

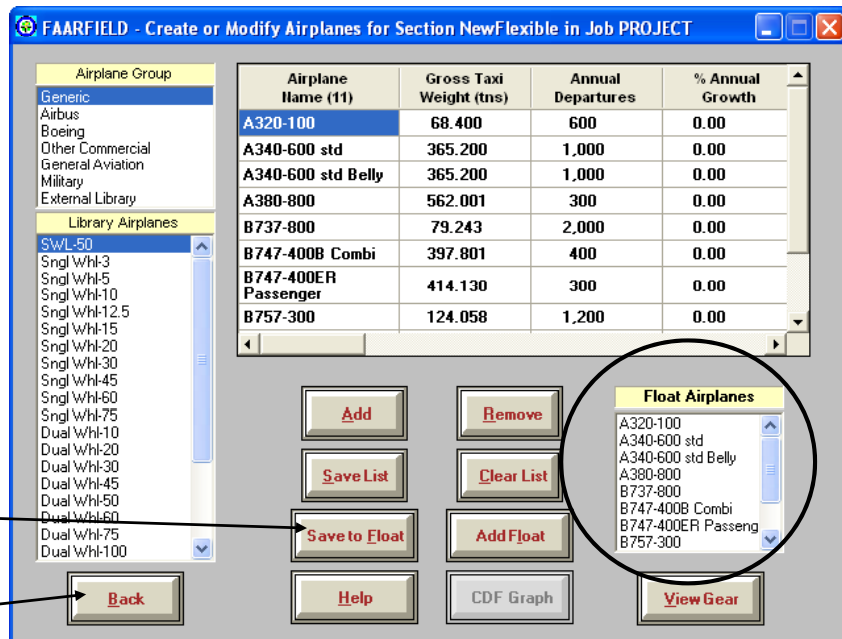
Total thickness to the top of the subgrade, t = 705.6 mm



Copy Airplane List

To copy the airplane list from Section NewFlexible:

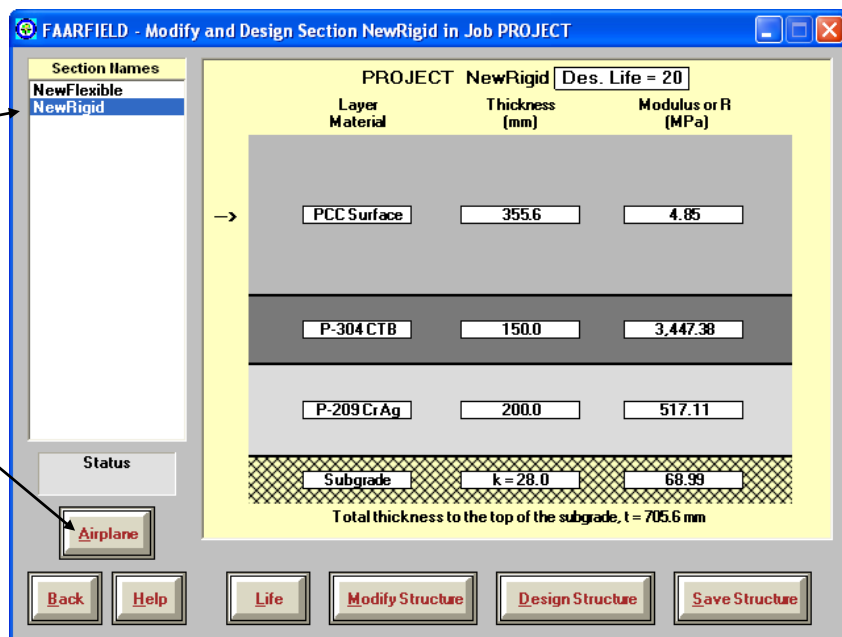
1. Open Section NewFlexible in job PROJECT.
2. Click on "Airplane" to open the Airplane window.
3. Click on "Save to Float" to copy the airplane list to Float Airplanes.
4. Click "Back"



Copy Airplane List

Click on the section name to open section "New Rigid."

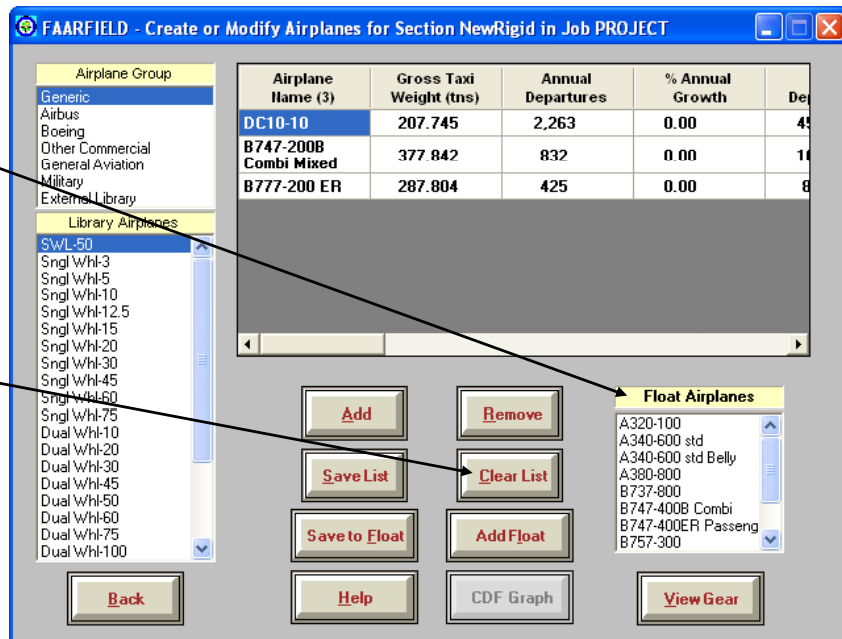
Then click on Airplane to open the Airplane window.



Copy Airplane List

The float aircraft list now appears in the window at lower right.

Click on "Clear List" to clear the sample airplanes from the design list.

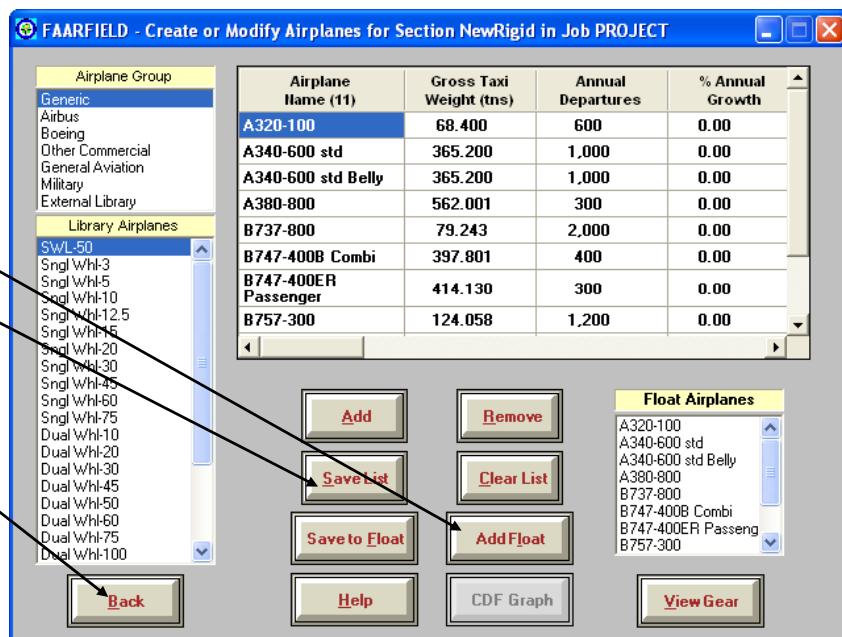


Copy Airplane List

Next, click on "Add Float" to add the float airplanes to the design list.

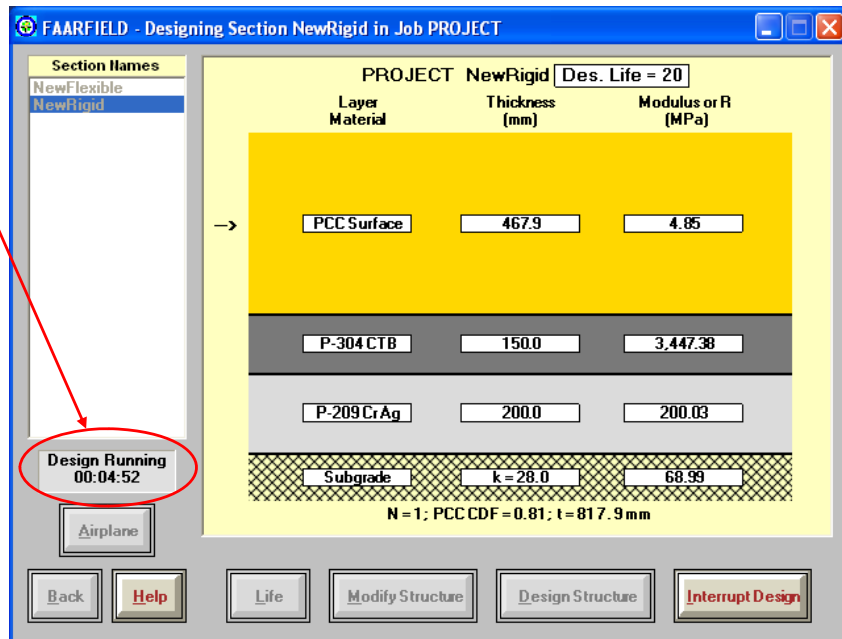
Click "Save List"

Click "Back"

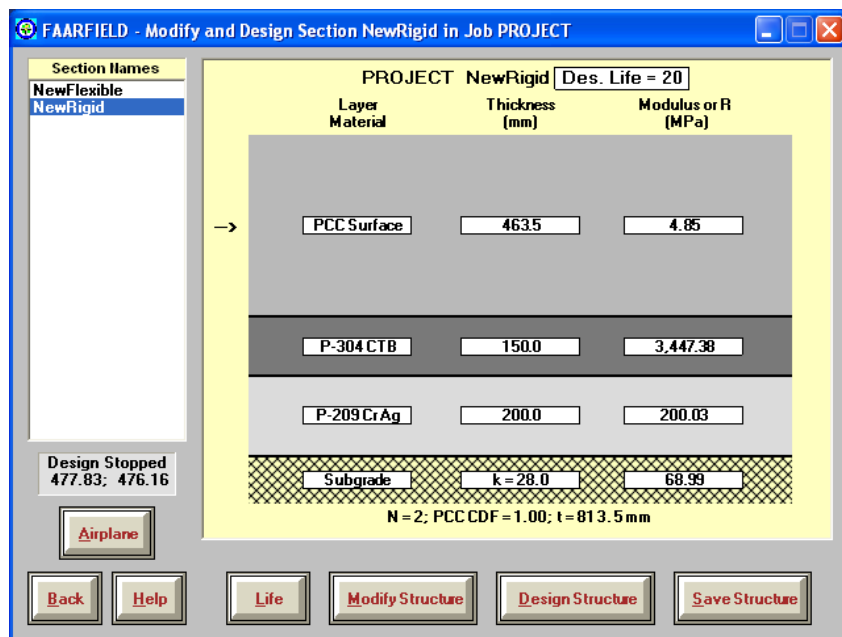


Run Design

- During the design process, the “Design Running” clock will appear.
- For rigid designs, the design will normally take a few minutes. Don’t interrupt the process.
- The screen display will change with each iteration.



New Rigid Pavement - Final Design



CDF Contribution

No.	Name	CDF Contribution	CDF Max for Aircraft	P/C Ratio
1	A320-100	0.00	0.00	3.84
2	A340-600 std	0.25	0.25	1.91
3	A340-600 std Belly	0.00	0.14	2.47
4	A380-800	0.01	0.01	3.61
5	B737-800	0.00	0.01	3.52
6	B747-400 Combi	0.02	0.02	3.46
7	B747-400 ER Passenger	0.04	0.04	3.62
8	B757-300	0.00	0.00	3.95
9	B767-400 ER	0.06	0.07	3.65
10	B777-300 ER	0.57	0.58	3.86
11	B787-8 (Preliminary)	0.04	0.05	3.78

Rigid Pavement Design
December 8, 2010



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Rigid Overlay Design

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Administration



FAARFIELD Overlay Design

- **HMA Overlays on Flexible Pavement**
 - Same as designing a new flexible pavement, except the design layer is the HMA overlay.
- **PCC Overlays on Flexible Pavement**
 - Same principle as new rigid design.
- **HMA Overlays on Rigid Pavement**
- **PCC Overlays on Rigid Pavement**
 - More complex than new rigid pavement design.
 - Both slabs (base PCC and overlay) deteriorate with applied traffic. Stresses are computed for both slabs.
 - *E*-modulus of the base slab is a function of reduced SCI.
 - Subroutines were completely rewritten for FAARFIELD.



FAARFIELD Overlay Design – PCC on Rigid Overlays

- **Fully bonded overlays**
 - Treat as a new rigid pavement design.
 - Thickness of overlay slab is $h_{overlay} = h_{design} - h_{exist}$
- **Unbonded overlay**
 - Bond breaker or leveling course is used.
- **Partially bonded overlay**
 - No longer a standard design in AC 150/5320-6E.
 - Default in FAARFIELD is off.
 - May be enabled from the Options window, but displays a “Non Standard Structure” message.



FAARFIELD Overlay Design

Required Inputs

- Existing rigid pavement condition is characterized by the Structural Condition Index (SCI).
- SCI derived from PCI as determined by ASTM D 5340 Airport Pavement Condition Index Surveys. The new AC gives guidance on SCI.
- SCI is computed using only structural components from the PCI survey.
- SCI = 80, FAA definition of structural failure (50% of slabs with structural crack)
- For existing pavements with structural damage (SCI < 100)
 - The user inputs a value of SCI for the existing pavement. The range of allowable values depends on the overlay type:
 - Rigid on Rigid Overlays: SCI 40–100
 - Flexible on Rigid Overlays: SCI 67–100 (was 50-100)
 - The Help file gives approximate formulas for relating SCI to Cr and Cb factors in earlier method.



FAARFIELD – PCC Unbonded Overlay Design Structural Condition Index (SCI)

Rigid Pavement Distress Types Used to Calculate 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

* Used only to describe a load-induced crack that extends only part of the way across a slab. The SCI does not include conventional shrinkage cracks due to curing or other non load-related problems.



Cumulative Damage Factor Used (CDFU)

- **For existing pavements where SCI=100 (no structural distress):**
 - There is no visible distress contributing to reduction in SCI (no structural distress types). However, some pavement life has been consumed by the applied traffic.
 - The amount of pavement life consumed is the percent CDF Used (%CDFU).
 - Need to estimate a value of %CDFU.
 - The Help file gives guidance on estimating %CDFU using the Life key.



Cumulative Damage Factor Used (CDFU)

- **CDFU defines the amount of structural life used.**
 - **For structures with aggregate base:**

$$\begin{aligned} CDFU &= \frac{L_U}{0.75 L_D} \quad \text{when } L_U < 0.75 L_D \\ &= 1 \quad \text{when } L_U \geq 0.75 L_D \end{aligned}$$

- L_U = number of years of operation of the existing pavement until overlay
- L_D = design life of the existing pavement in years

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



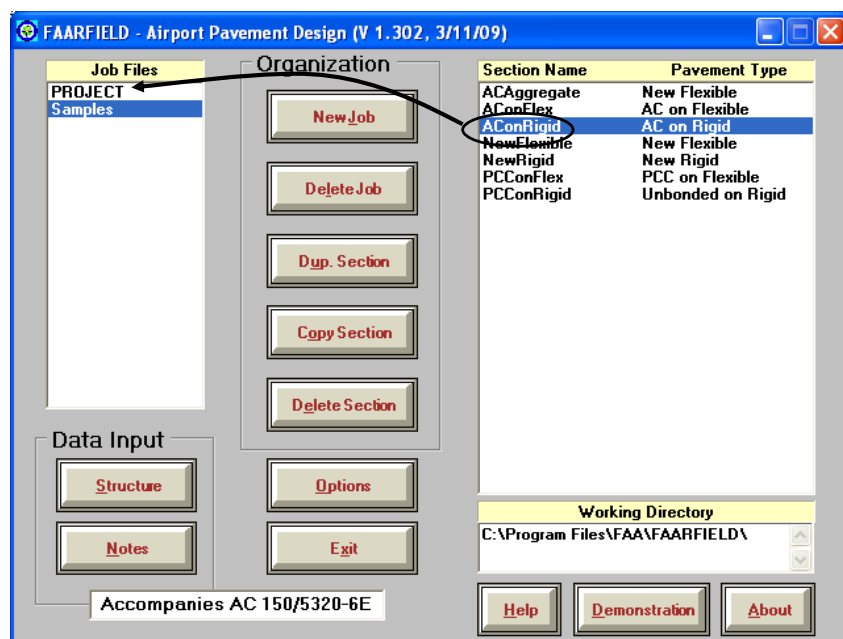
HMA on Rigid Overlay Example

- **Pavement Structure:**
 - Flexible Overlay (P-401)
 - PCC Slab (P-501), 400 mm (15.75 in.),
 $R = 4.9 \text{ MPa}$ (711 psi), $\text{SCI} = 70$
 - Cement Treated Base (P-304), 150 mm (5.91 in.)
 - Crushed Aggregate Base (P-209), 200 mm (7.87 in.)
 - Subgrade $k = 28 \text{ MN/m}^3$ (103.2 pci)
- **Traffic Mix:**
 - Use the traffic mix from the new rigid design example, but remove B777 and A380 from the mix.



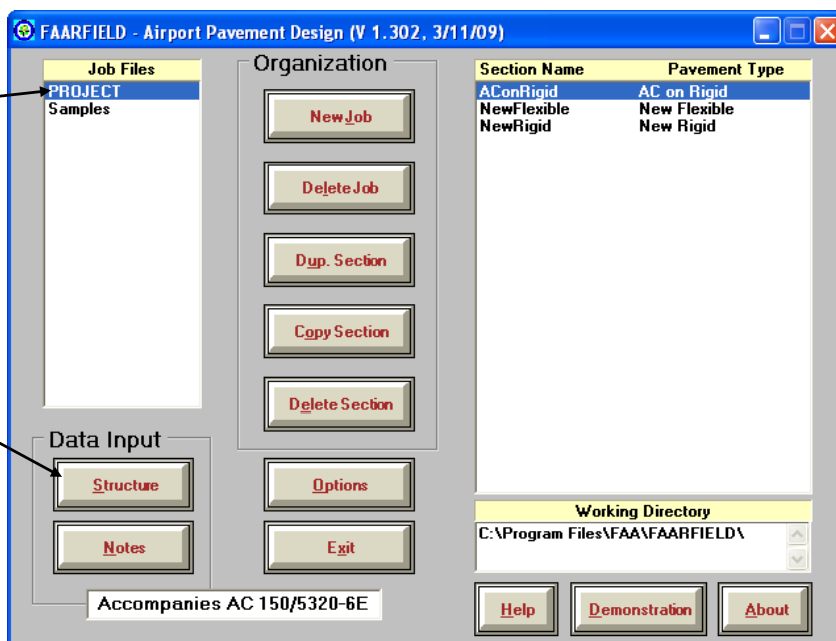
HMA on Rigid Example Set-Up

Create a new section in job PROJECT by dragging section AConRigid in Samples to PROJECT.



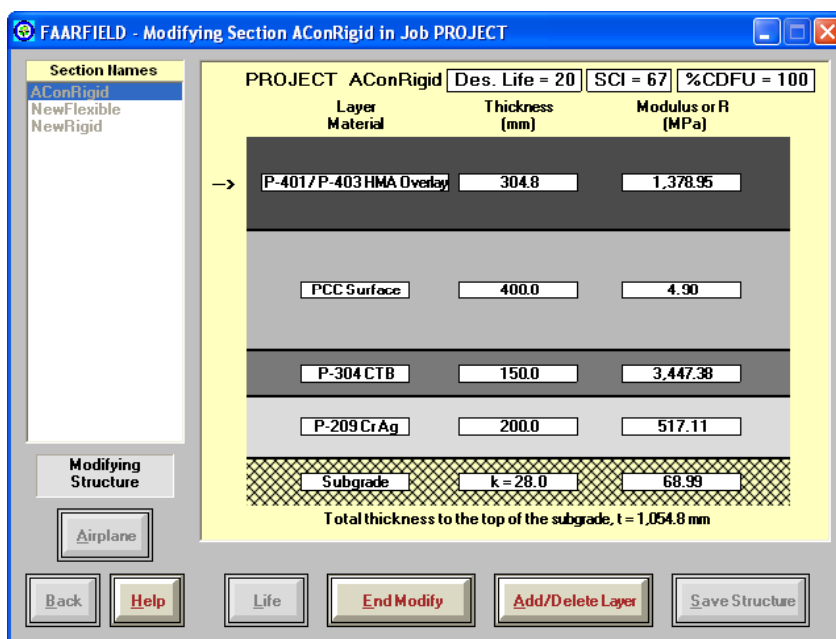
Change Pavement Structure

Double click on the job "PROJECT." (The section "AConRigid" is highlighted.) Click the "Structure" button to open the Structure window.



Change Pavement Structure

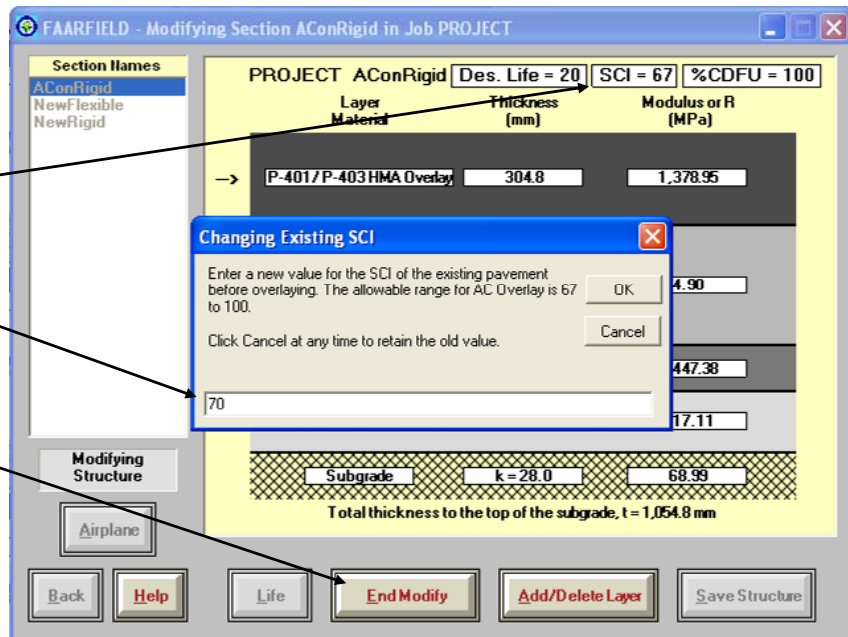
Click "Modify Structure." Make changes to the PCC, base, subbase and subgrade layer properties.



Change Pavement Structure

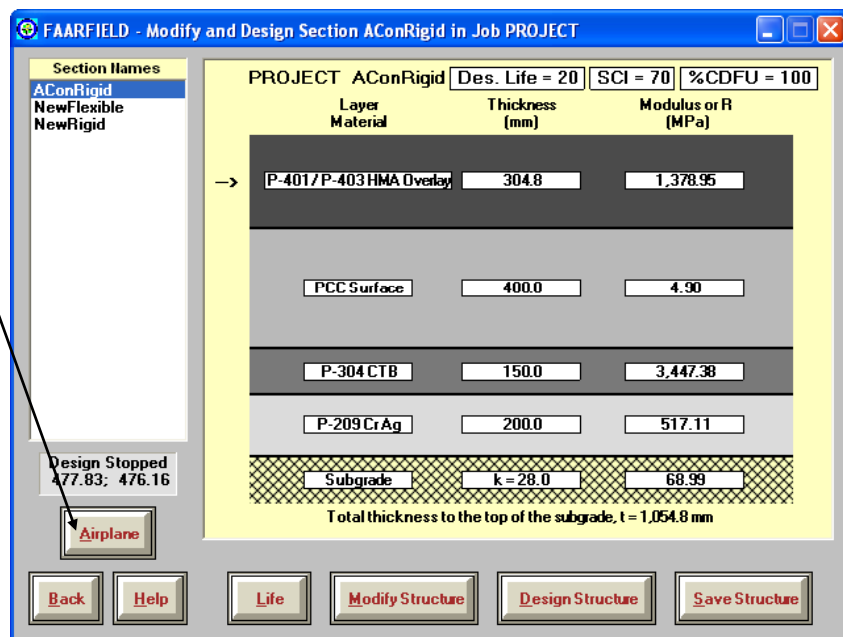
Click on the label "SCI=67" at the top of the display. In the "Changing Existing SCI" dialog box enter 70 and click OK.

Click "End Modify" then "Save Structure" to save changes.



Copy Airplane List

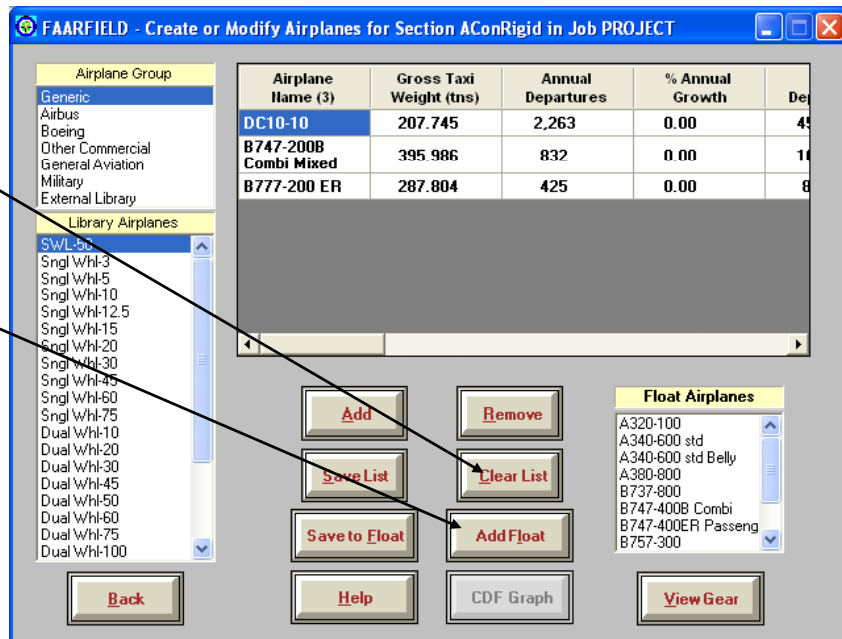
Click on Airplane



Copy Airplane List

Click "Clear List to remove the sample airplanes.

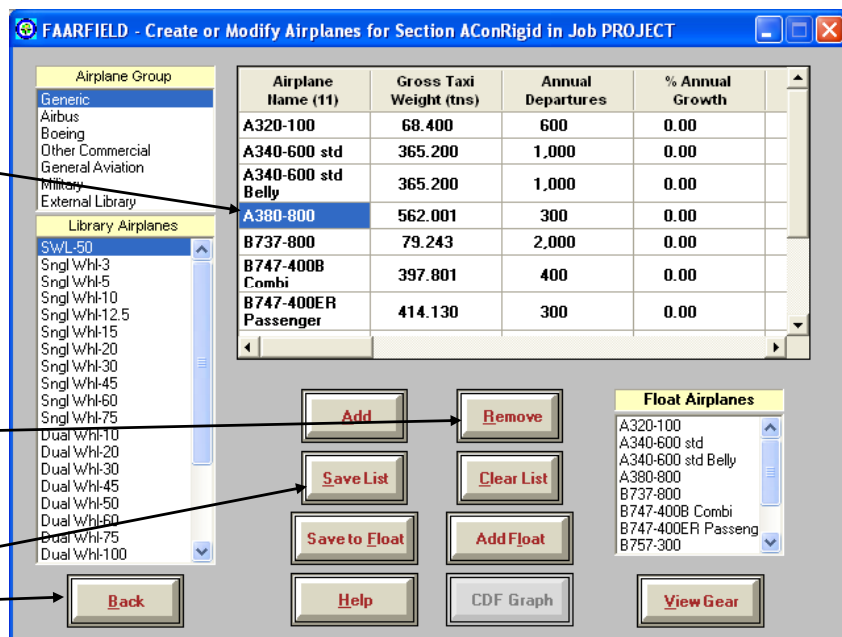
Then click "Add Float" to add the float airplanes.



Modify Airplane List

Double-click on the A380-800 and B777-300ER. This will remove those airplanes from the design list. (Alternatively, highlight the airplane and click "Remove" once.)

When done, click "Save List" then "Back."



Run Design

Click "Design Structure" to run the overlay design.

FAARFIELD - Modify and Design Section AConRigid in Job PROJECT

Section Names
AConRigid
NewFlexible
NewRigid

PROJECT AConRigid Des. Life = 20 SCI = 70 %CDFU = 100

Layer Material	Thickness (mm)	Modulus or R (MPa)
P-401/P-403 HMA Overlay	304.8	1,378.95
PCC Surface	400.0	4.90
P-304 CTB	150.0	3,447.38
P-209 CrAg	200.0	517.11
Subgrade	k = 28.0	68.99

Total thickness to the top of the subgrade, t = 1,054.8 mm

Design Stopped 477.83; 476.16

Airplane

Back Help Life Modify Structure Design Structure Save Structure



HMA on Rigid Overlay – Final Design

FAARFIELD - Modify and Design Section AConRigid in Job PROJECT

Section Names
AConRigid
NewFlexible
NewRigid

PROJECT AConRigid Des. Life = 20 SCI = 70 %CDFU = 100

Layer Material	Thickness (mm)	Modulus or R (MPa)
P-401/P-403 HMA Overlay	112.3	1,378.95
PCC Surface	400.0	4.90
P-304 CTB	150.0	3,447.38
P-209 CrAg	200.0	200.03
Subgrade	k = 28.0	68.99

N = 4; Str Life = 20.2 yrs; t = 862.3 mm

Design Stopped 1208.03;

Airplane

Back Help Life Modify Structure Design Structure Save Structure



PCC on Rigid Overlay Example

- **Existing PCC structure will receive a P-501 PCC overlay to support additional traffic.**
 - Assume R for new concrete = 4.75 MPa.
- **Existing Pavement Structure:**
 - PCC Slab, 400 mm, R = 4.90 MPa
SCI = 100. Estimate %CDFU from traffic history.
 - Cement Treated Base, P-304, 150 mm
 - Crushed Aggregate Base, P-209, 200 mm
 - Subgrade k = 28 MN/m³
- **Design Traffic Mix:**
 - Use same traffic mix as in the new rigid pavement design example.



Estimate %CDFU (Example)

- Assume the following traffic mix was applied to the existing pavement:

No.	Name	Gross Wt., Tonnes	Annual Departures
1	Adv. B727-200C Basic	78	1,200
2	B737-700	70	500
3	DC8-63/73	161	260

- Assume that at the time of the overlay the pavement will have been in operation 12 years.



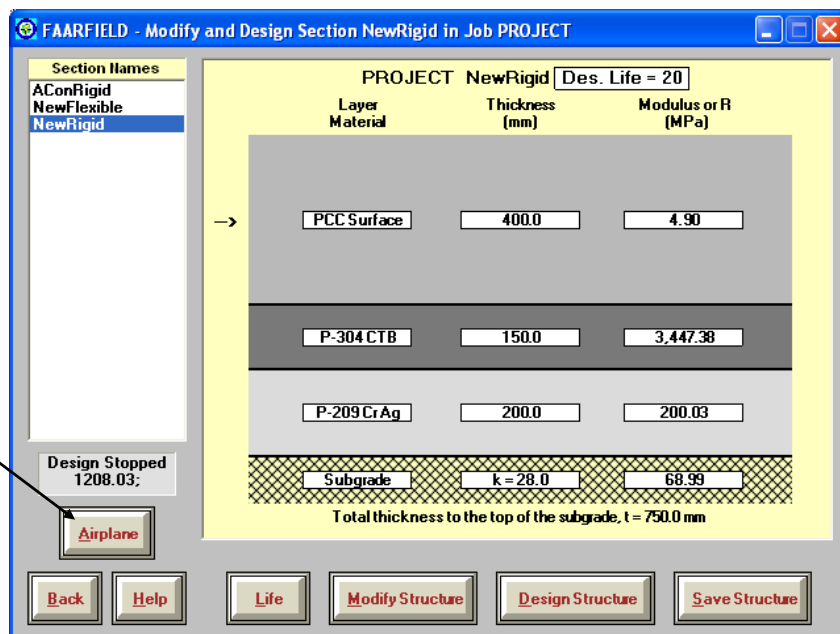
Procedure to Estimate %CDFU

- Input the original pavement structure.
- Estimate the annual traffic applied to the existing pavement up to the time of the overlay.
- Set “Design Life” to the number of years the pavement will have been in operation at the time of the overlay. Assume that at the time of the overlay the pavement will have been in operation 12 years.
- Run “Life” to obtain %CDFU.

Estimate %CDFU (Example)

In the PROJECT job, open the section NewRigid. In the Structure window, enter the existing pavement structure (no overlay).

Click *Airplane* to go to the Airplane window.



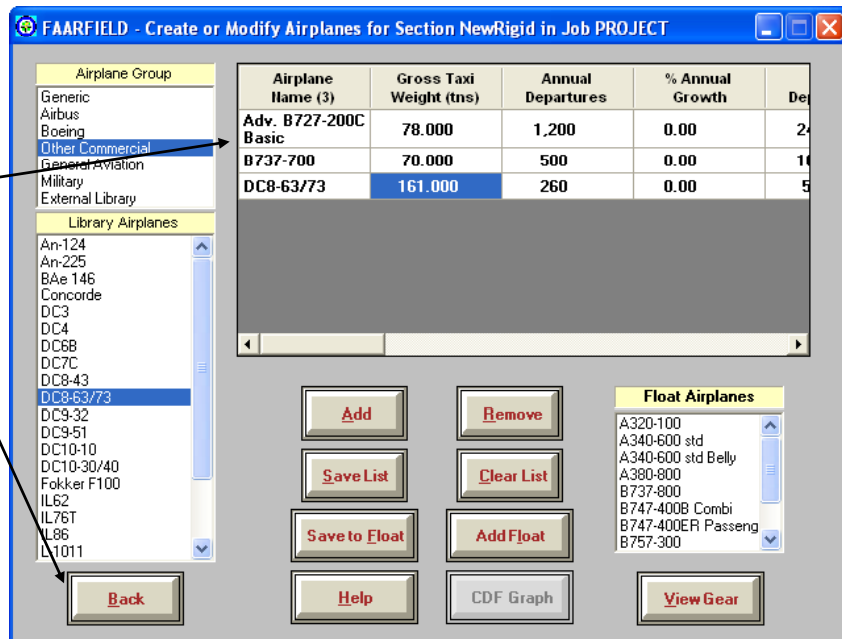
Layer Material	Thickness (mm)	Modulus or R (MPa)
PCC Surface	400.0	4.90
P-304 CTB	150.0	3,447.36
P-209 CrAg	200.0	200.03
Subgrade	k = 28.0	66.99

Total thickness to the top of the subgrade, t = 750.0 mm

Estimate %CDFU (Example)

Enter the annual traffic applied to the existing pavement structure.

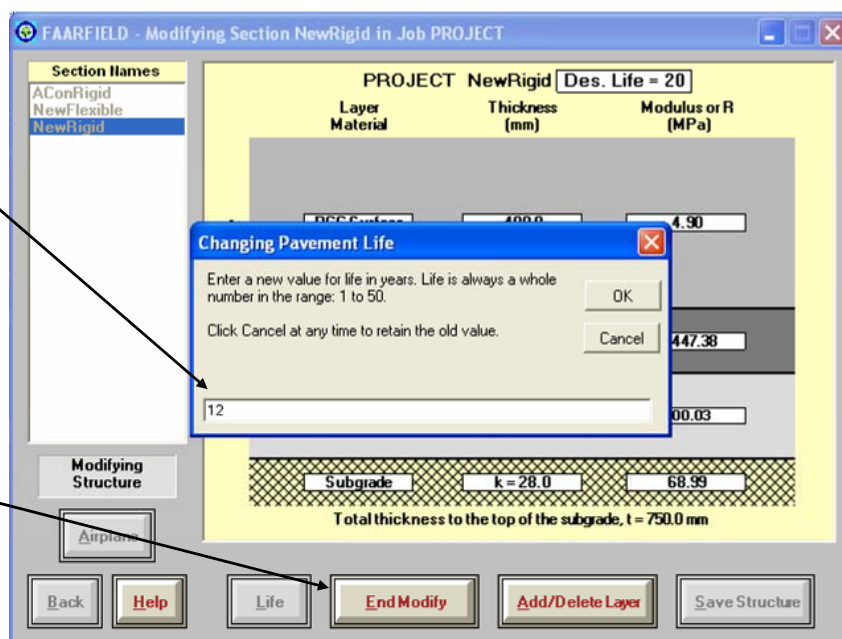
Click *Back* to return to the Structure window.



Estimate %CDFU (Example)

In the Structure window, change the design life to the number of years that the pavement will have been in service at the time of overlay (12 years in this example.)

Click *End Modify*



Estimate %CDFU (Example)

Click *Life* to run Life.

The calculated %CDFU will appear on the Structure window, at the lower left of the pavement section.

%CDFU = 40.01 (Say 40%).

FAARFIELD - Modify and Design Section NewRigid in Job PROJECT

Section Names
 AConRigid
 NewFlexible
 NewRigid

PROJECT NewRigid Des. Life = 12

Layer Material	Thickness (mm)	Modulus or R (MPa)
PCC Surface	400.0	4.90
Non-Standard Life		
P-304 CTB	150.0	3,447.36
P-209 CrAg	200.0	200.03
Subgrade	k = 28.0	68.99

Life Stopped 19.09; 19.00

%CDFU = 40.01; PCC CDF = 0.25; Str Life (PCC) = 48.9 yrs; t = 750.0 mm

Buttons: Airplane, Back, Help, Life, Modify Structure, Design Structure, Save Structure



PCC on Rigid Overlay – Change Structure

In the Structure window, click *Modify Structure*.

FAARFIELD - Modify and Design Section NewRigid in Job PROJECT

Section Names
 AConRigid
 NewFlexible
 NewRigid

PROJECT NewRigid Des. Life = 12

Layer Material	Thickness (mm)	Modulus or R (MPa)
PCC Surface	400.0	4.90
Non-Standard Life		
P-304 CTB	150.0	3,447.36
P-209 CrAg	200.0	200.03
Subgrade	k = 28.0	68.99

Life Stopped 19.09; 19.00

%CDFU = 40.01; PCC CDF = 0.25; Str Life (PCC) = 48.9 yrs; t = 750.0 mm

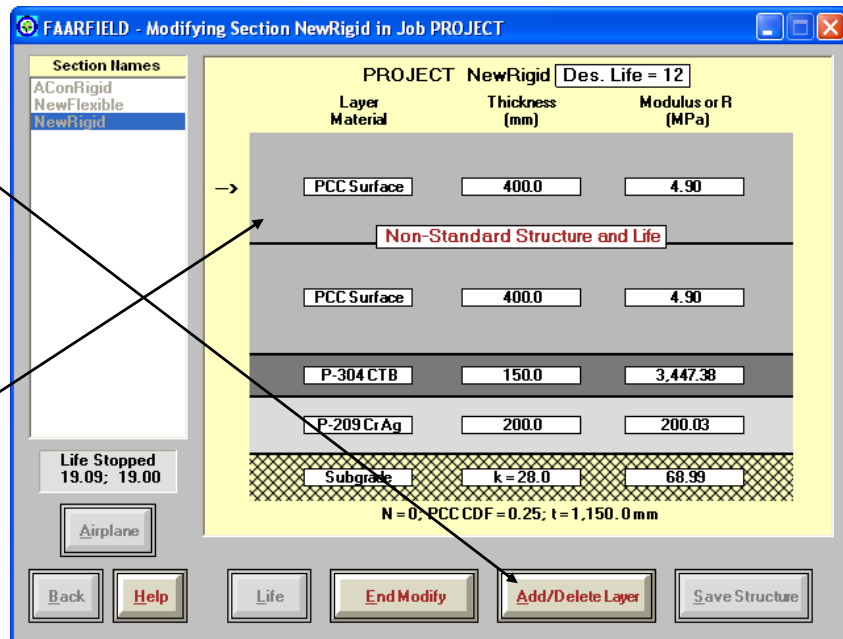
Buttons: Airplane, Back, Help, Life, Modify Structure, Design Structure, Save Structure



PCC on Rigid Overlay – Change Structure

Click **Add/Delete Layer**.

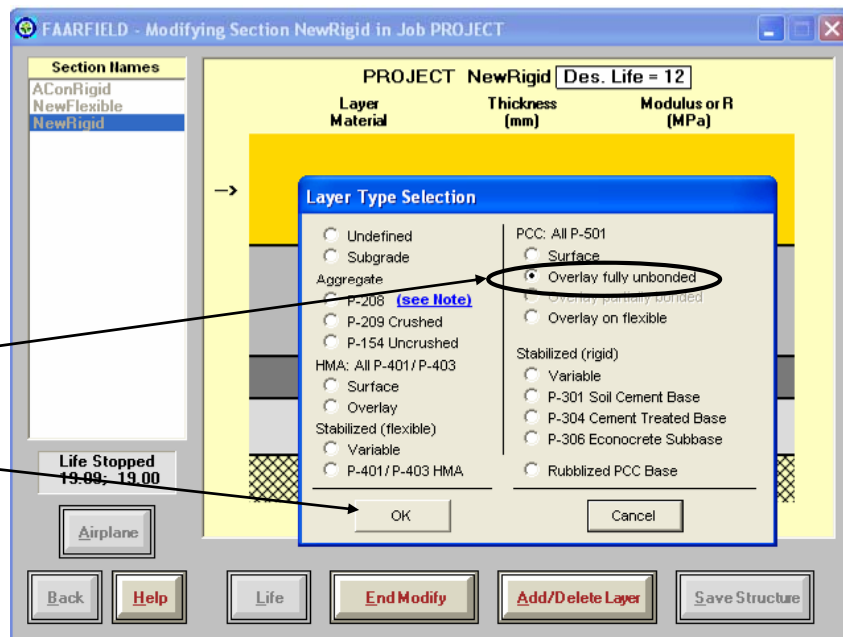
Select the PCC surface layer by clicking on it with the mouse. In the dialog box, select **Add** and click **OK**. A new PCC surface layer appears.



PCC on Rigid Overlay – Change Structure

You must change the top layer to an overlay. Click on the **Layer Material** box.

In the **Layer Type Selection** box, select **Overlay Fully Unbonded** and click **OK**.



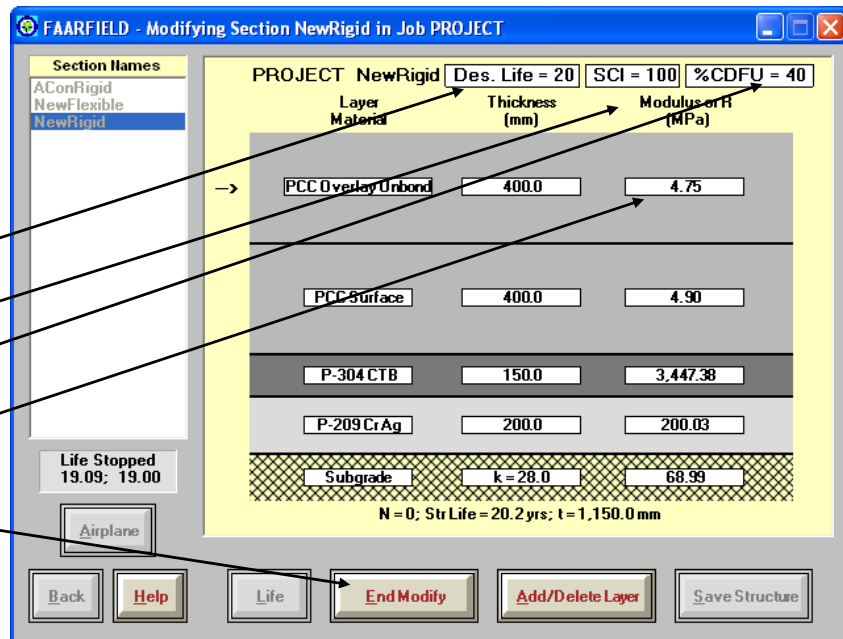
PCC on Rigid Overlay – Change Structure

In the upper right corner of the Structure window:

- Change "Design Life" to 20 years (standard).
- Change SCI to 100.
- Change %CDFU to 38.

Change *R* (overlay) to 4.75 MPa.

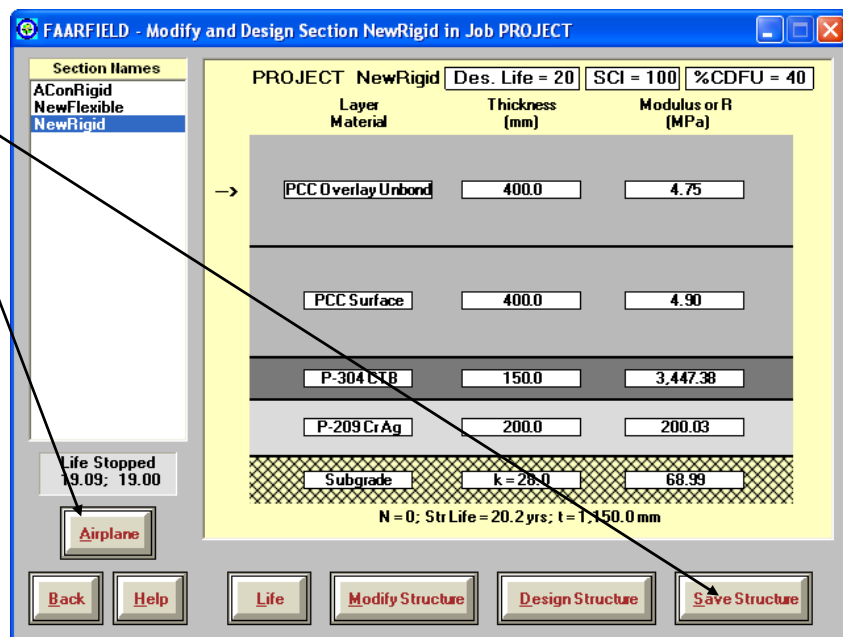
Click *End Modify*.



PCC on Rigid Overlay – Change Structure

Click *Save Structure*.

Click *Airplane* to go to the Airplane window.



PCC on Rigid Overlay – Change Airplane List

Click **Clear List** to clear all aircraft from the list.

Add the design aircraft list manually or using the **Add Float** function.

Airplane Name (3)	Gross Taxi Weight (tns)	Annual Departures	% Annual Growth	De
Adv. B727-200C Basic	78.000	1,200	0.00	2
B737-700	70.000	500	0.00	11
DC8-63/73	161.000	260	0.00	5



PCC on Rigid Overlay – Change Airplane List

Click **Save List**

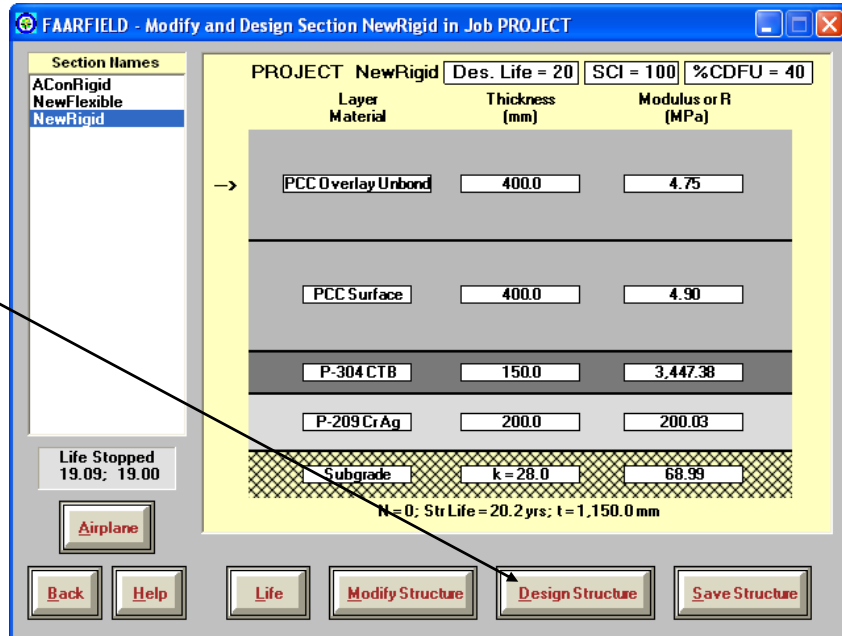
Click **Back** to return to the Structure window.

Airplane Name (11)	Gross Taxi Weight (tns)	Annual Departures	% Annual Growth
A320-100	68.400	600	0.00
A340-600 std	365.200	1,000	0.00
A340-600 std Belly	365.200	1,000	0.00
A380-800	562.001	300	0.00
B737-800	79.243	2,000	0.00
B747-400B Combi	397.801	400	0.00
B747-400ER Passenger	414.130	300	0.00

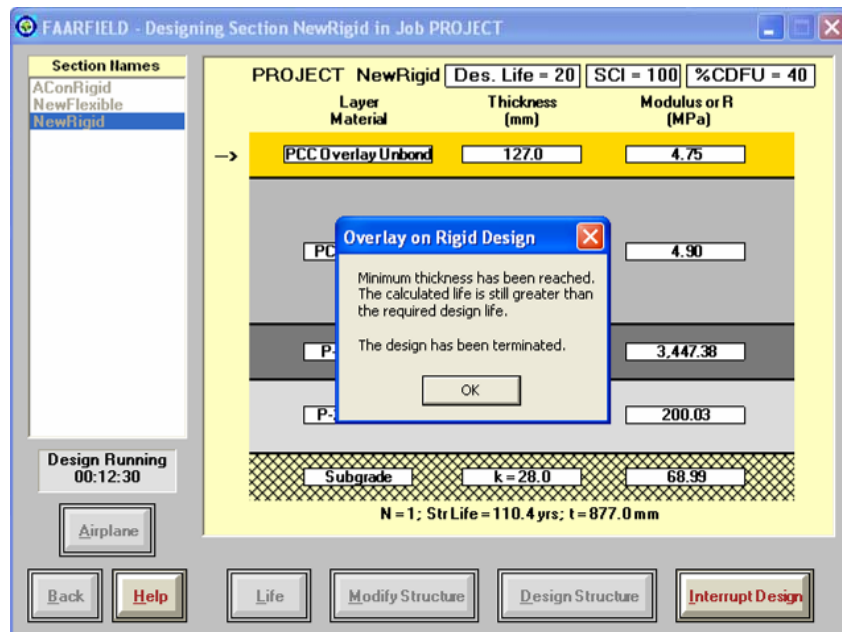


Run Overlay Design

Click *Design Structure* to run the overlay design.



Example: PCC on Rigid Overlay Final Design



Example: PCC on Rigid Overlay Final Design

Layer Material	Thickness (mm)	Modulus or R (MPa)
PCC Overlay Unbond	127.0	4.75
PCC Surface	400.0	4.90
P-304 CTB	150.0	3,447.38
P-209 CrAg	200.0	200.03
Subgrade	k = 28.0	68.99

N = 1; Str Life = 110.4 yrs; t = 877.0 mm



**Thank You
Questions?**

