FAARFIELD 1.41

Updates to FAA Advisory Circular 150/5320-6

Presented to: XIII ALACPA Seminar on Airport Pavements
Panama City

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

Date: 1 December 2016

Federal Aviation Administration

Airport Technology R&D Program

- **Research conducted at the FAA William J. Hughes Technical Center, Atlantic City, NJ, USA.**

- **Sponsor: FAA Office of Airport Safety and Standards (AAS100), Washington, DC.**

- **Provide support for development of FAA pavement standards (Advisory Circulars).**

FAA Airport Pavement R&D

National Airport Pavement Test Facility (NAPTF)

Fully enclosed facility for accelerated traffic testing of airport pavements – opened 1999

National Airport Pavement Materials Research Center (NAPMRC)

Opened August 27, 2015

AC 150/5320-6F
Airport Pavement Design and Evaluation

- **Issued Nov. 10, 2016.**
  - Replaces AC 150/5320-6E.
  - Incorporates FAARFIELD 1.41 software program.
- **General reorganization of contents.**
- **Download at: https://www.faa.gov/airports/resources/recent_advisory_circulars/**

U.S. Department of Transportation
Federal Aviation Administration

Advisory Circular

Subject: Airport Pavement Design and Evaluation | **Date:** 11/10/2016 | **AC No:** 150/5320-6F
Initiated by: AAS-100 | **Change:**

1. **Purpose.**
   This advisory circular (AC) provides guidance to the public on the design and evaluation of pavements used by aircraft at civil airports. For reporting of pavement strength, see AC 150/5335-5C, *Standardized Method of Reporting Airport Pavement Strength – PCN*.

2. **Cancellation.**
   This AC cancels AC 150/5320-6E, *Airport Pavement Design and Evaluation*, dated September 30, 2009.

3. **Application.**
   The FAA recommends the guidance and standards in this AC for airport pavement design and evaluation. In general, use of this AC is not mandatory. However, use of the standards in this AC is mandatory for all projects funded under the Airport Improvement Program (AIP) or with revenue from the Passenger Facility Charge (PFC) Program.

   This AC does not apply to the design of pavements that are not used by aircraft, i.e., roadways, parking lots, and access roads.

4. **Principal Changes.**
   This AC contains the following changes:
   1. Reformatted to comply with FAA Order 1320.46, *FAA Advisory Circular System*.
   2. Revised text and design examples to incorporate changes in FAARFIELD v1.41 pavement design software. Also added general guidance on how to use FAARFIELD.
   3. Simplified and moved guidance on economic analysis to Chapter 1.

AC 150/5320-6F – Partial List of Changes - General

- Eliminated separate chapter for light-load design (intended to handle aircraft under 13,600 kg / 30,000 lbs. gross weight).
- Consolidated list of minimum thicknesses applicable for various standard layer types.
- New guidance for automated compaction criteria – replaces Table 3-4 in old AC.
- Revised shoulder design criteria.
- Updated all design examples.
- Added appendix on NDT methods for pavement evaluation.

AC 150/5320-6F –
Partial List of Changes - Flexible

- **Clarified subgrade characterization using CBR.**
- **Implemented new asphalt fatigue criteria (RDEC energy model).**
- **Reduced minimum base thickness requirements.**
  - Removed previous requirement for additional stabilized base thickness (above 125 mm / 5 inches) when P-209 subbase is used.

AC 150/5320-6F –
Partial List of Changes - Rigid

- **Modified conversion from CBR to *k*-value.**
- **Modified guidance for concrete design strength.**
- **Added detail on reinforcement at Type A1 joints (reinforced isolation joint).**
- **Added detail of transition between PCC and HMA Pavement sections.**
- **Removed CRCP design procedure (rarely used).**
- **Reduced subgrade compaction requirements for rigid pavements.**

AC 150/5320-6F Organization

- **Chapter 1: Airport Pavement Function and Purpose**
  - Pavement layers & specifications
  - Cost effectiveness analysis
- **Chapter 2: Soil Investigations**
  - Soil strength testing
  - Subgrade stabilization
- **Chapter 3: Pavement Design**
  - Flexible Pavement Design
  - Rigid Pavement Design
- **Chapter 4: Pavement Rehabilitation *(includes overlay design)***
- **Chapter 5: Pavement Structural Evaluation**
- **Chapter 6: Pavement Design for Shoulders**
- **Appendix A: Soil Characteristics (USC Classification)**
- **Appendix B: Design of Structures**
- **Appendix C: NDT Using Falling-Weight Type Devices**
- **Appendix D: Reinforced Isolation Joint**
- **Appendix E: Variable Section Runway**
- **Appendix F: Related Reading Material**

Chapter 3 – Pavement Design

1. Design Considerations
2. FAA Pavement Design
3. Flexible Pavements
4. Full Depth Asphalt Pavements
5. Rigid Pavements
6. Stabilized Base Course
7. Base/Subbase Contamination
8. Drainage Layer
9. Subgrade Compaction
10. Swelling Soils
11. Pavement Life
12. Pavement Design Using FAARFIELD
13. Flexible Pavement Design
14. Rigid Pavement Design
15. Pre-stressed, Precast, Reinforced & CRCP
16. Aggregate-Turf Pavements
17. Heliport Design
18. Passenger Loading Bridge

NOTE: No more separate chapter for light load aircraft design.

Layer Types & Allowable Modulus Values

Table 3-2. Allowable Modulus Values and Poisson's Ratios Used in FAARFIELD

Layer Type	FAA Specified Layer	Rigid Pavement psi (MPa)	Flexible Pavement psi (MPa)	Poisson's Ratio
Surface	P-501 PCC	4,000,000 (30,000)	NA	0.15
	P-401/P-403/P-601 HMA	NA	200,000 (1,380)[1]	0.35
Stabilized Base and Subbase	P-401/P-403HMA	400,000 (3,000)		0.35
	P-306 Lean Concrete	700,000 (5,000)		0.20
	P-304 cement treated base	500,000 (3,500)		0.20
	P-301 soil cement	250,000 (1,700)		0.20
	Variable stabilized rigid	250,000 to 700,000 (1,700 to 5,000)	NA	0.20
	Variable stabilized flexible	NA	150,000 to 400,000 (1,000 to 3,000)	0.35
Granular Base and Subbase	P-209 crushed aggregate	Program Defined		0.35
	P-208, aggregate	Program Defined		0.35
	P-219, Recycled concrete aggregate	Program Defined		0.35
	P-211, Lime rock	Program Defined		0.35
	P-154 uncrushed aggregate	Program Defined		0.35
Subgrade	Subgrade	1,000 to 50,000 (7 to 350)		0.35
User-defined	User-defined layer	1,000 to 4,000,000 (7 to 30,000)		0.35

Notes:
1. A fixed modulus value for hot mix surfacing is set in the program at 200,000 psi (1380 MPa). This modulus value was conservatively chosen and corresponds to a pavement temperature of approximately 90°F (32°C).

- **Similar to FAARFIELD v 1.305.**
- **"Undefined" layer replaced by "User-defined."**
- **P-306 econocrete renamed Lean Concrete.**
- **Added P-219, recycled concrete aggregate, as a standard layer type.**
- **Rubblized concrete base now handled as user-defined layer.**

Minimum Layer Thickness - Flexible

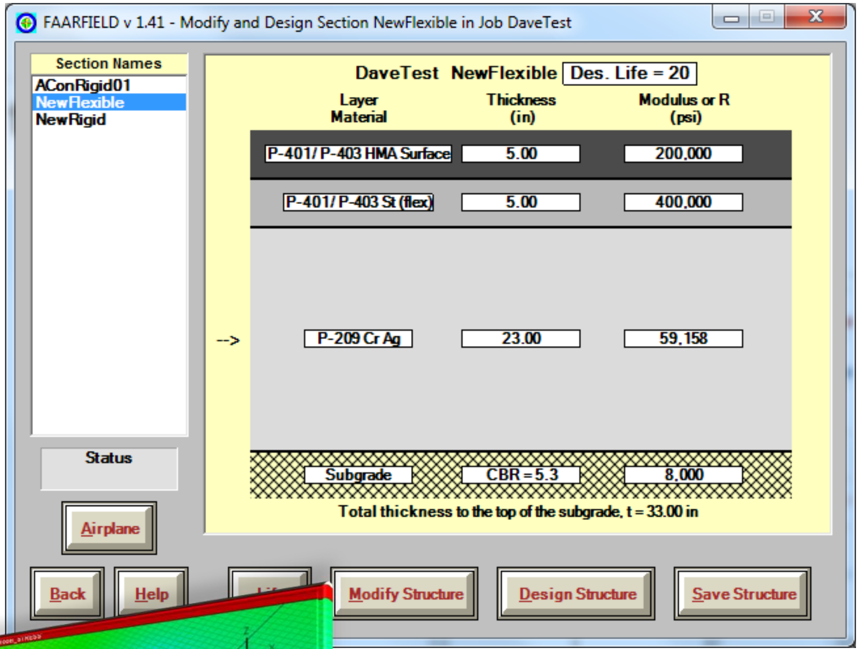
Layer Type	FAA Specification Item	Maximum Airplane Gross Weight Operating on Pavement, lbs (kg)		
		<12,500 (5 670)	< 100,000 (45 360)	≥100,000 (45 360)
HMA Surface[1, 2,3]	P-401, Hot Mix Asphalt (HMA) Pavements	3 in. (75 mm)	4 in. (100 mm)	4 in. (100 mm)
Stabilized Base	P-401 or P-403; P-304; P-306[4]	Not Required	Not Required	5 in. (125 mm)
Crushed Aggregate Base[5,6]	P-209, Crushed Aggregate Base Course	3 in. (75 mm)	6 in. (150 mm)	6 in. (150 mm)
Aggregate Base[5,7,8]	P-208,Aggregate Base Course	3 in. (75 mm)	Not Used[7]	Not Used
Subbase[5,8]	P-154, Subbase Course	4 in. (100 mm)	4 in. (100 mm) (If required)	4 in. (100 mm) (if required)

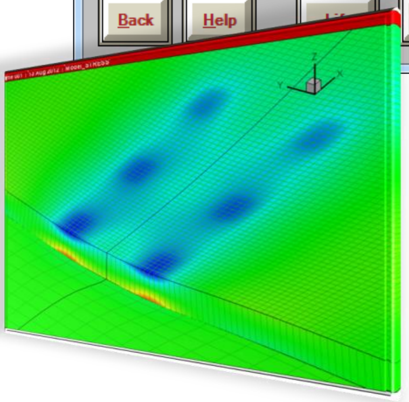
Minimum Layer Thickness - Rigid

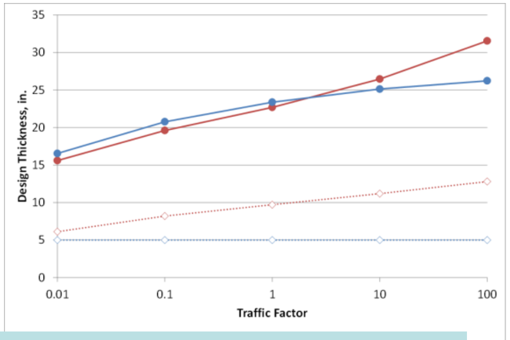
Layer Type	FAA Specification Item	Maximum Airplane Gross Weight Operating on Pavement, lbs (kg)		
		<12,500 (5,670)	< 100,000 (45,360)	≥ 100,000 (45,360)
PCC Surface	P-501, Portland Cement Concrete (PCC) Pavements	5 in. (125 mm)	6 in. (150 mm)[1]	6 in. (150 mm)[1]
Stabilized Base	P-401 or P-403; P-304; P-306	Not Required	Not Required	5 in. (125 mm)
Base	P-208, P-209, P-211, P-301	Not Required	6 in. (150 mm)[2]	6 in. (150 mm)
Subbase[3,4]	P-154, Subbase Course	4 in. (100 mm)	As needed for frost or to create working platform	As needed for frost or to create working platform

FAARFIELD 1.41

- Accompanies new AC 150/5320-6F.
- Many significant changes.
- Reduces excess design conservatism.
- New design-based compaction procedure.
- Incorporates results of full-scale tests at the National Airport Pavement Test Facility.
- Download:







http://www.airporttech.tc.faa.gov/Download/Airport-Pavement-Software-Program

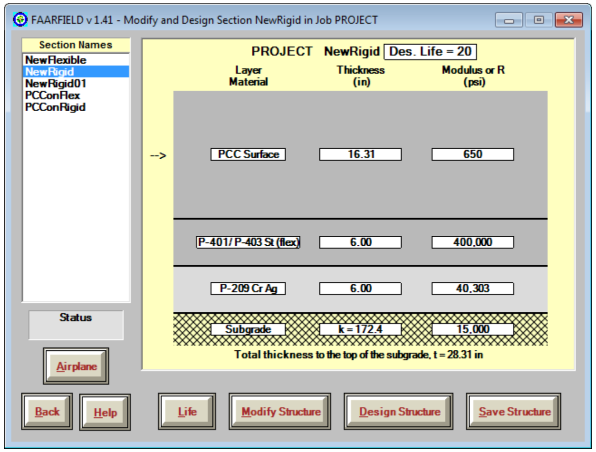
FAARFIELD – What Is It?

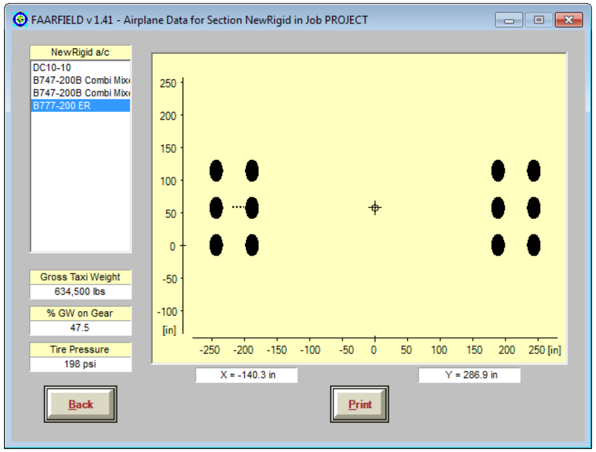
Federal
Aviation
Administration
Rigid and
Flexible
Iterative
Elastic
Layered
Design

- **FAARFIELD is the standard FAA airport pavement thickness design program.**
- **FAARFIELD design procedure for:**
  - Flexible
  - Rigid
  - Overlay
- **Current version is FAARFIELD 1.41 (posted 10 Nov 2016)**

FAARFIELD – Technical Background

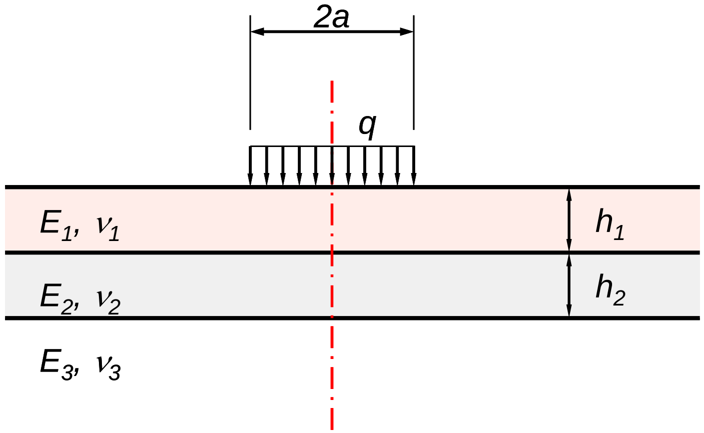
- **Computer program for Windows operating systems.**
- **Main program drives three subprograms:**
  - LEAF (layered elastic analysis).
  - NIKE3D (3D finite element analysis).
  - FAAMesh (3D mesh generation).
- **NIKE3D information:**
  - Modified for FAARFIELD by the FAA.
  - Distributed in compiled form under a software sharing agreement with Lawrence Livermore National Laboratory (LLNL).

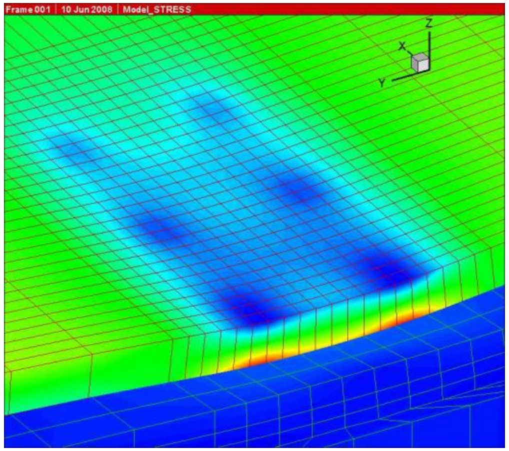




Structural Models in FAARFIELD

- **Both layered elastic (LEAF) and 3D-FEM (NIKE3D) are used in FAARFIELD.**
- **Flexible pavement design**
  - LEAF is used for all structural computations.
  - For flexible, no advantage to using 3D-FEM.
- **Rigid pavement design**
  - LEAF is used to generate a preliminary thickness.
  - Final iterations are done using a 3D finite element model (3D-FEM).

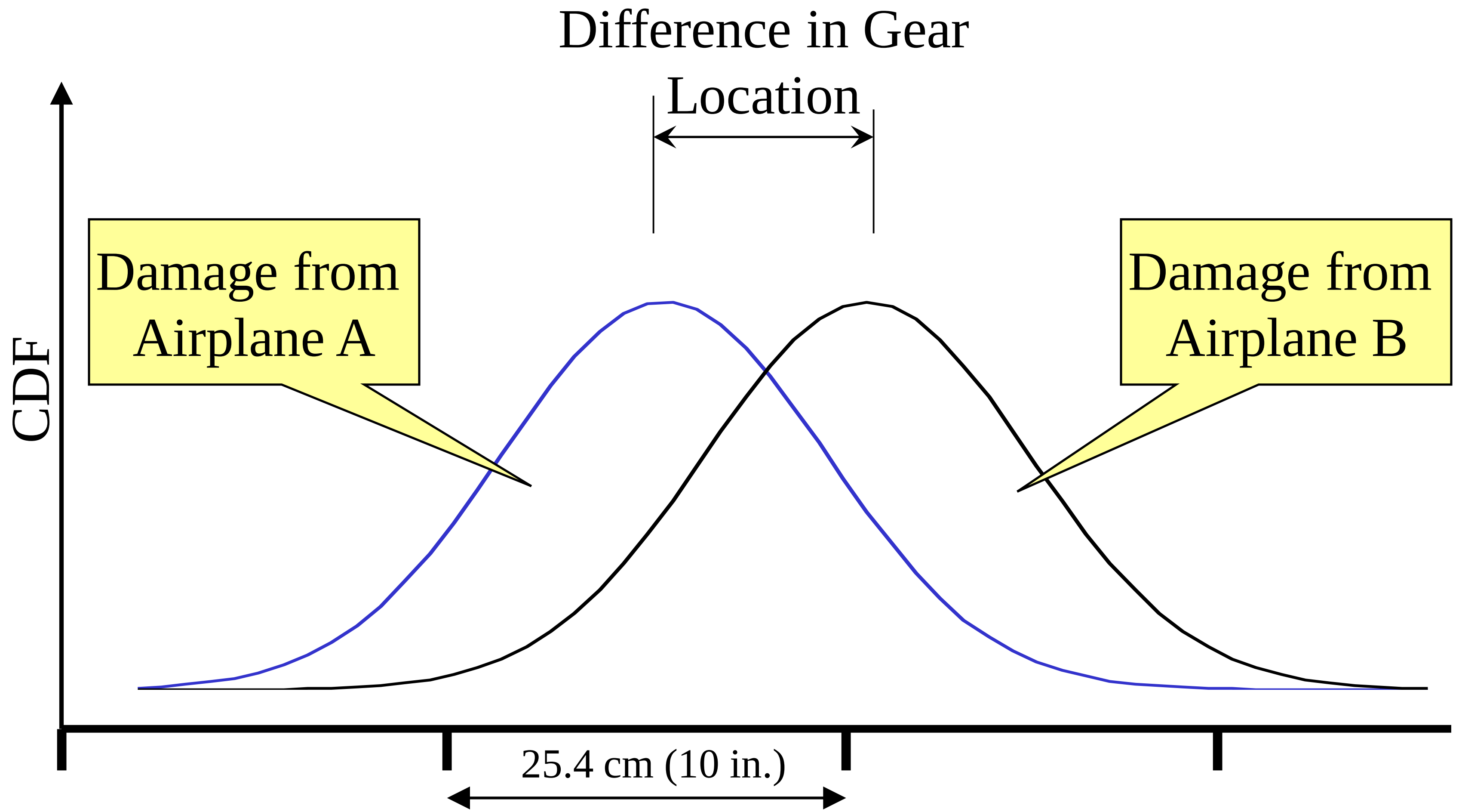




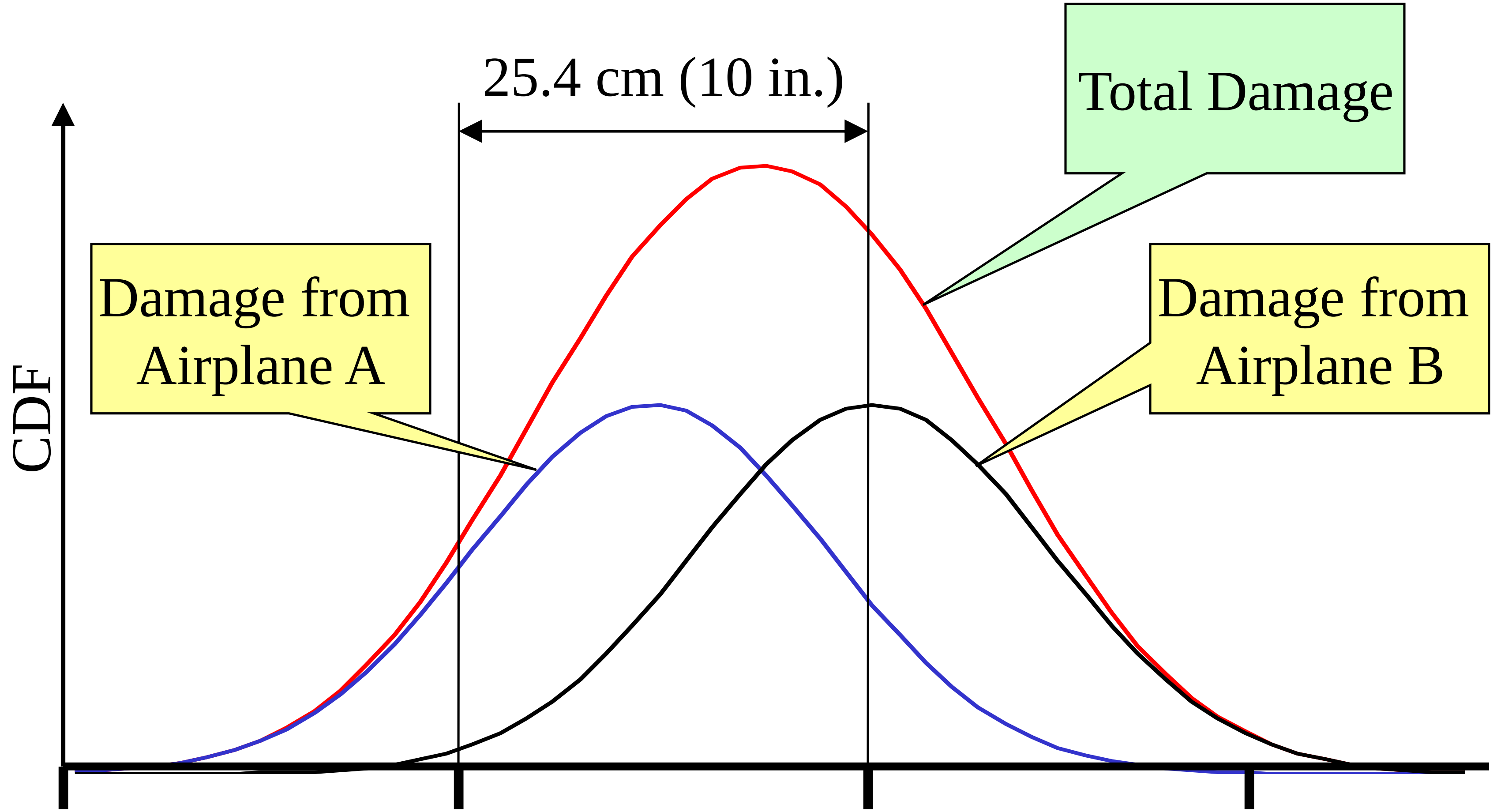
Cumulative Damage Factor (CDF)

- **Sums the damage contributed from each aircraft - not from equivalent aircraft.**
- **CDF = Σ (n_i /N_i), where:**
  - n_i = actual passes of individual aircraft *i*
  - N_i = allowable passes of individual aircraft *i*
- **When CDF = 1, design life is exhausted.**
- **In FAARFIELD:**
  - The gear location and wander are considered separately for each aircraft in the total mix.
  - CDF is calculated for each 25.4 cm (10 inch) wide strip over a total 20.83 m (820 inch) width.
  - Miner's rule to sum damage for each strip.
- **Must input the fleet mix, NOT equivalent departures of design aircraft.**

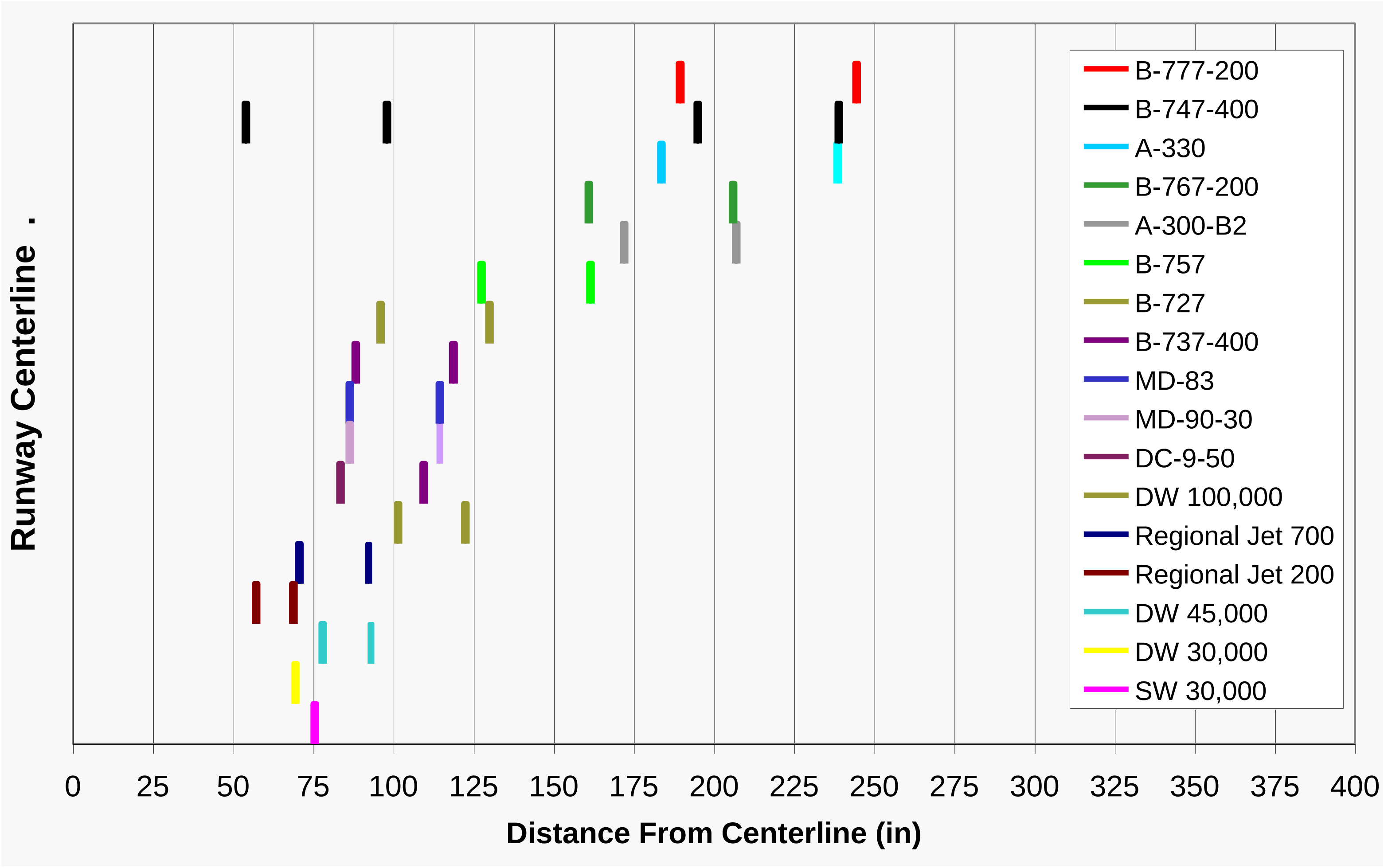
Cumulative Damage Factor (CDF)



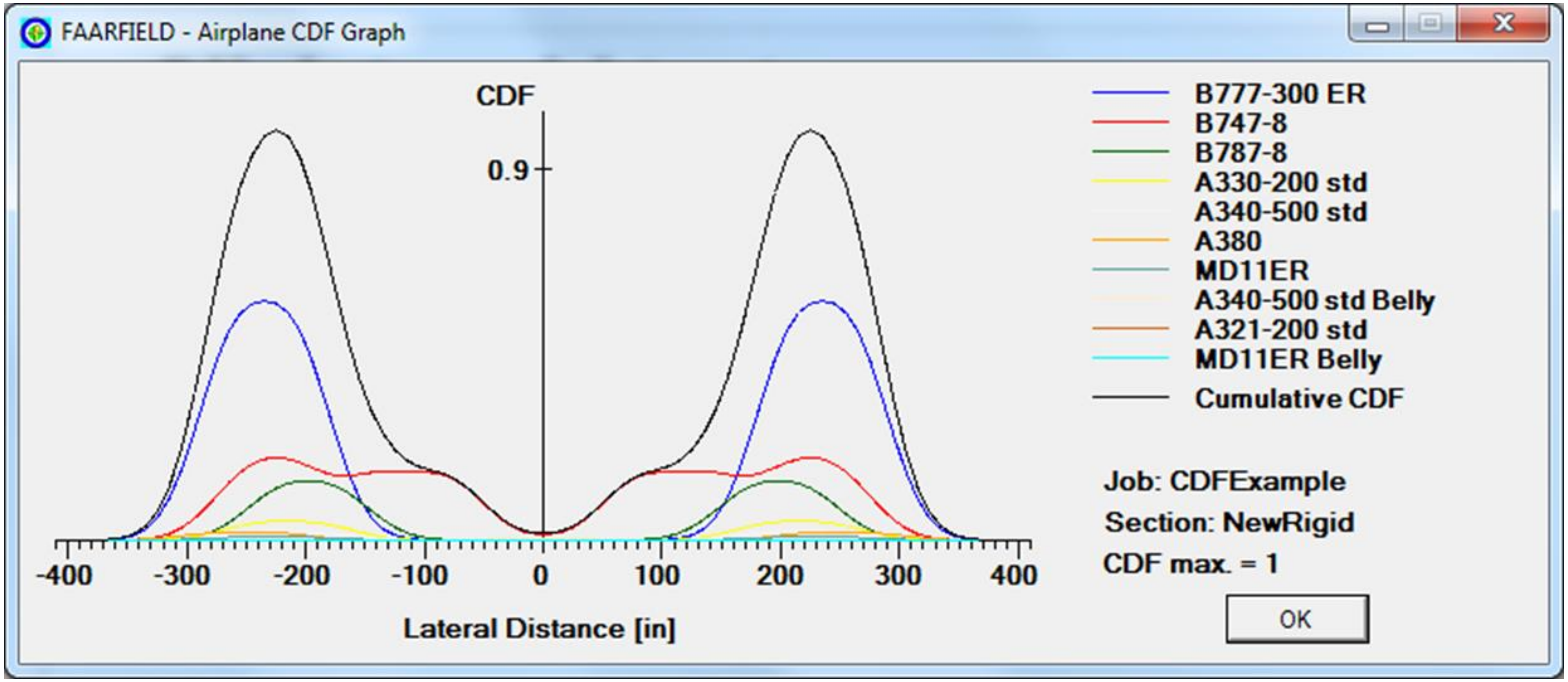
Cumulative Damage Factor (CDF)



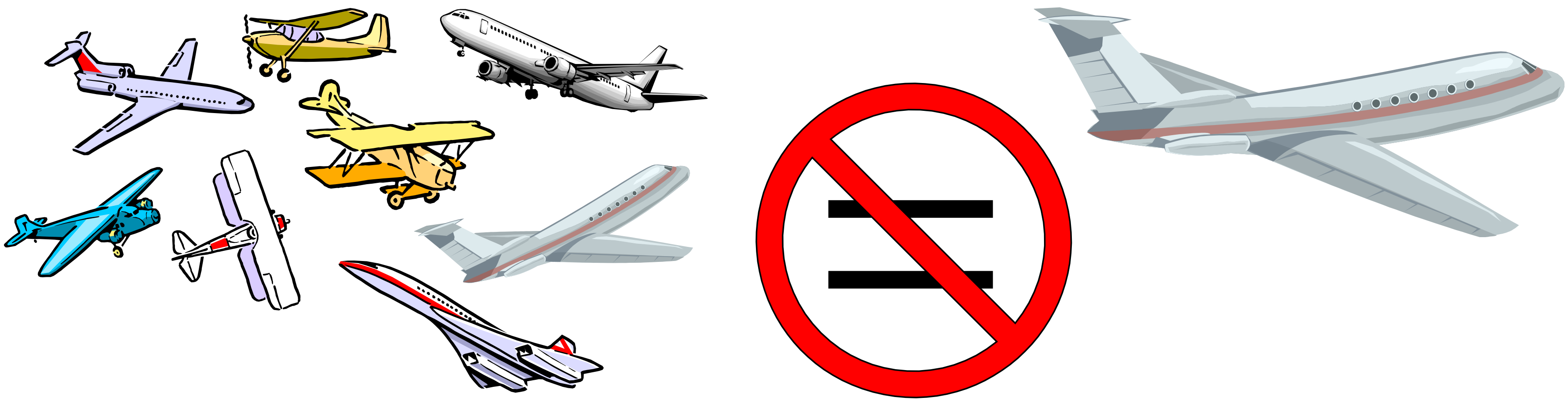
Large Airplane Traffic Mix Gear Locations



FAARFIELD – CDF Graphical Display



Remember - in FAARFIELD



Use the entire traffic mix!

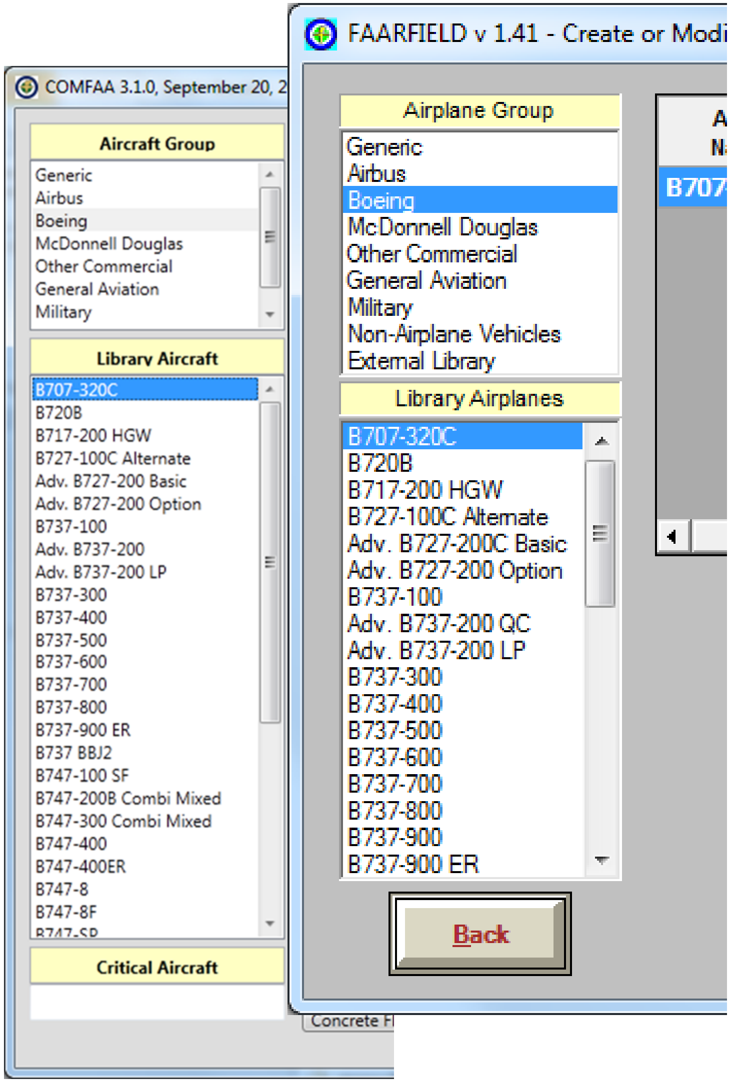
FAARFIELD 1.41 – What's New?

General Improvements:

- Updated aircraft library aligned with COMFAA 3.0.
- Added non-aircraft vehicles (trucks) to library.
- Automatically generates PDF design report.
- Automated, software-based compaction criteria.
- Support for user-defined gear configurations.
- All data files now stored in document directories.
- Minimum thickness in convenient metric units (100 mm; 125 mm)
- Updated Help file with new examples.

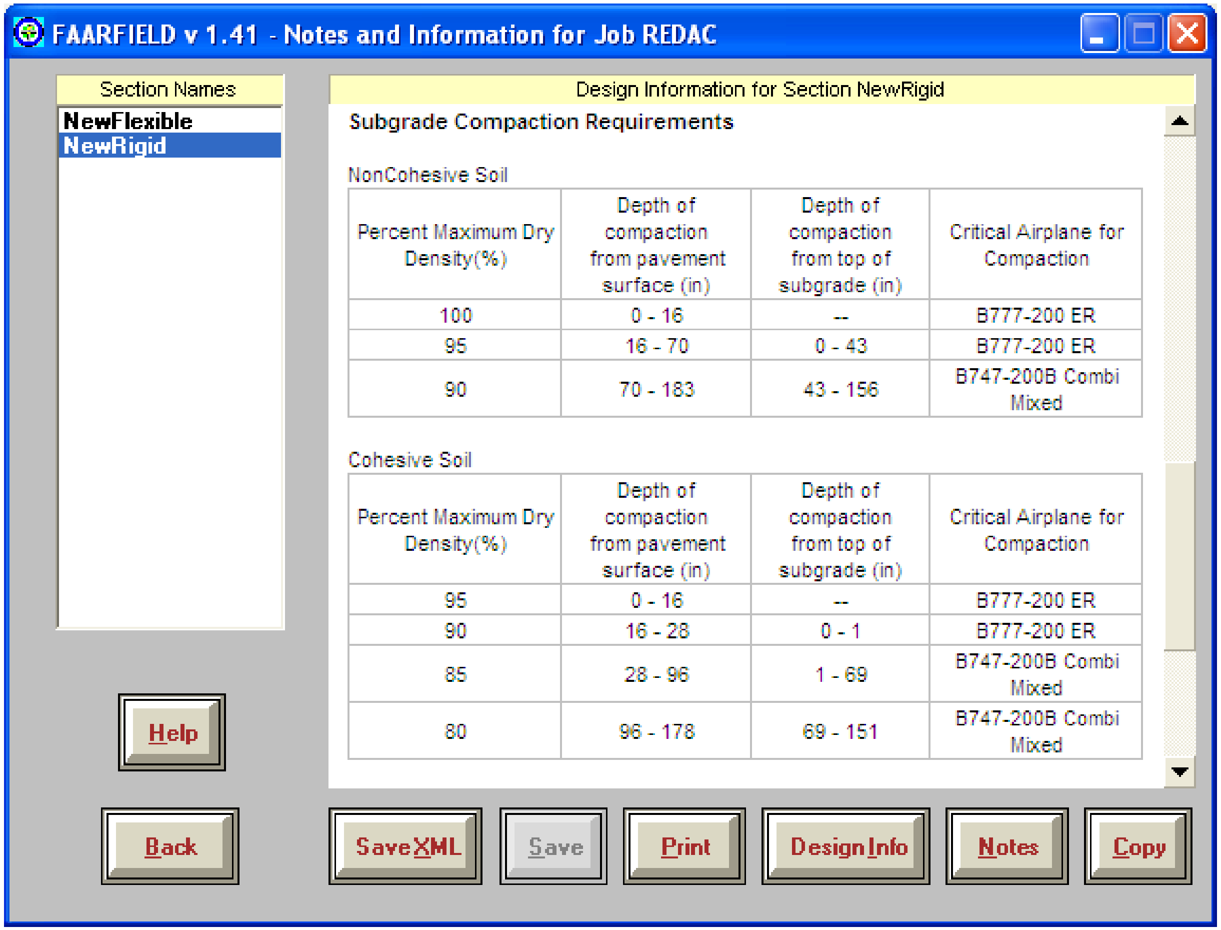
Aircraft Libraries

- **Aligned the aircraft libraries in COMFAA and FAARFIELD to the extent possible.**
- **Used the most current data from manufacturers.**
- **Includes new aircraft:**
  - A350-900/1000
  - B747-8
  - B787-9
  - Embraer Fleet



Automated Compaction Criteria

Computes compaction control points for rigid & flexible pavements.


FAARFIELD v 1.41 - Notes and Information for Job REDAC

Section Names

NewFlexible

NewRigid

Design Information for Section NewRigid

Subgrade Compaction Requirements

NonCohesive Soil

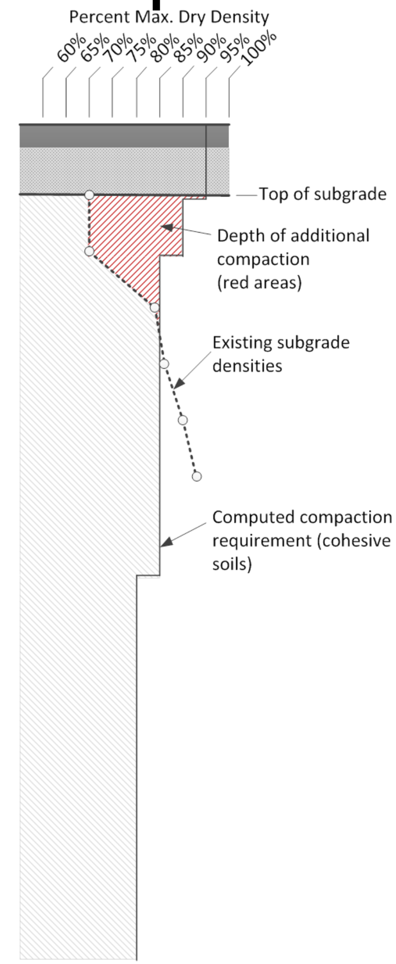
Percent Maximum Dry Density(%)	Depth of compaction from pavement surface (in)	Depth of compaction from top of subgrade (in)	Critical Airplane for Compaction
100	0 - 16	--	B777-200 ER
95	16 - 70	0 - 43	B777-200 ER
90	70 - 183	43 - 156	B747-200B Combi Mixed

Cohesive Soil

Percent Maximum Dry Density(%)	Depth of compaction from pavement surface (in)	Depth of compaction from top of subgrade (in)	Critical Airplane for Compaction
95	0 - 16	--	B777-200 ER
90	16 - 28	0 - 1	B777-200 ER
85	28 - 96	1 - 69	B747-200B Combi Mixed
80	96 - 178	69 - 151	B747-200B Combi Mixed

Help

Back | Save XML | Save | Print | Design Info | Notes | Copy



Changes in Data File Storage

- **All data files are now stored in document directories by default.**
  - Job files
  - External aircraft library files
  - Output files.
  - C:\Users\[User Name]\Documents\FAARFIELD
- **Previously, data files (including job files) were stored in the program directory.**
  - Required unrestricted read/write access for user.
  - Risk of data loss when changing/upgrading PC.

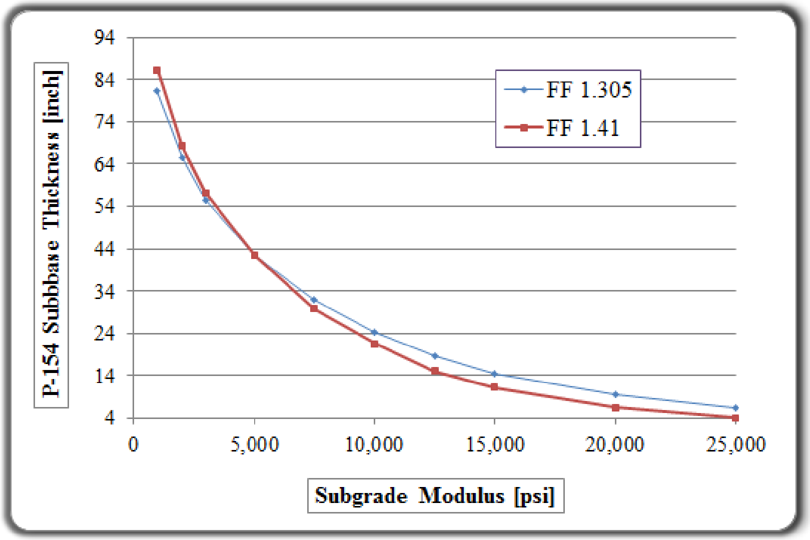
FAARFIELD 1.41 – What's New?

Flexible Designs:

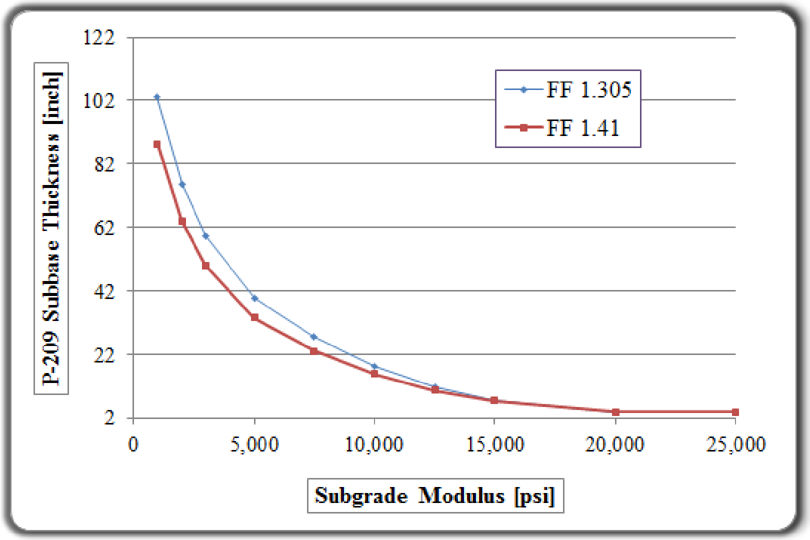
- Revised flexible failure model now includes direct evaluation of tandem gear damage.
- Advanced, energy-based asphalt fatigue models. Fatigue damage (HMA CDF) is now computed at the bottom of all asphalt layers.
- Reduced excess stabilized base thickness requirement.
- Automatic base layer thickness design feature extended to all standard flexible pavement designs.
- Improved sublayering of aggregate layers.

Flexible Pavements

- New thickness designs are generally less conservative than FAARFIELD 1.305 designs for the same inputs.
- More compatible with COMFAA 1.3 (ACN-PCN method).



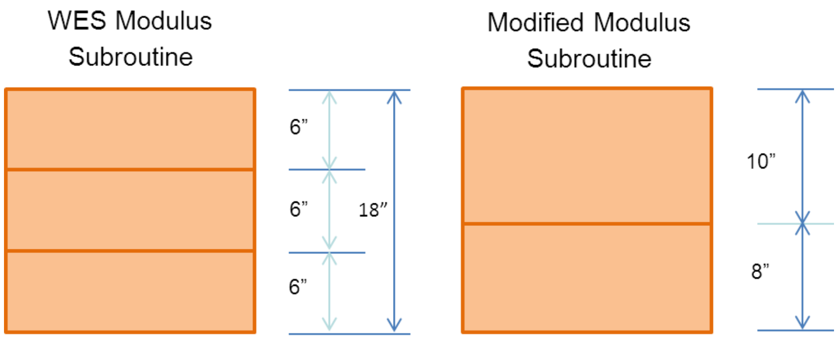
Conventional Flexible Pavement Comparison

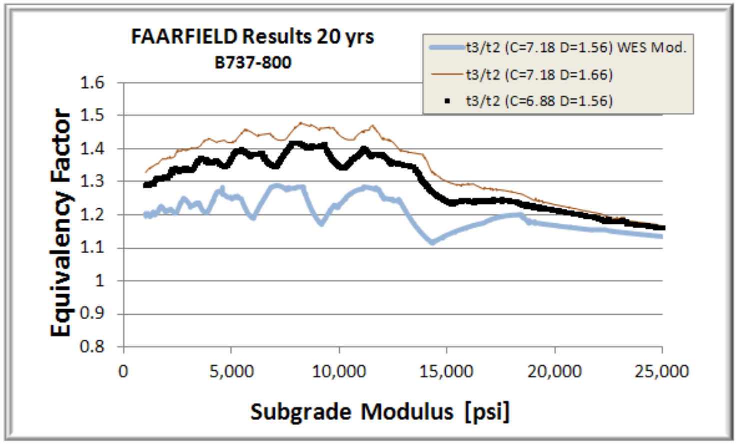


Stabilized Flexible Pavement Comparison

New Aggregate Modulus Model

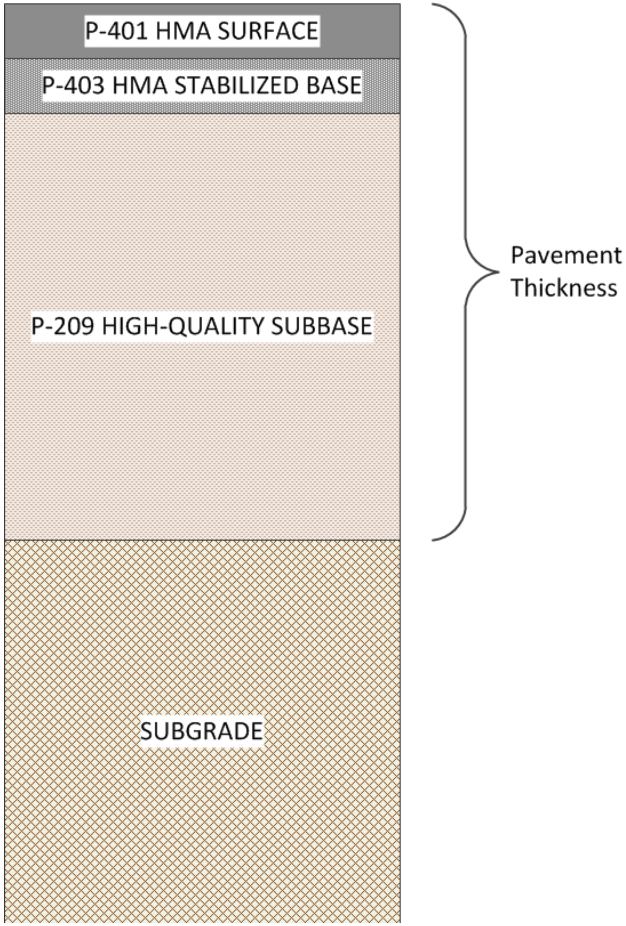
- **FAARFIELD 1.4 implements a new sublayering and modulus computation procedure for aggregate subbase (P-154 & P-209).**
- **Why?**
  - Previous procedure (WES Modulus subroutine) has gaps that can cause illogical results under some circumstances.
  - New model provides a continuous function of modulus with changes in P-154 thickness.
  - Better overall agreement with the P-209/P-154 equivalency factor used in PCN computations.



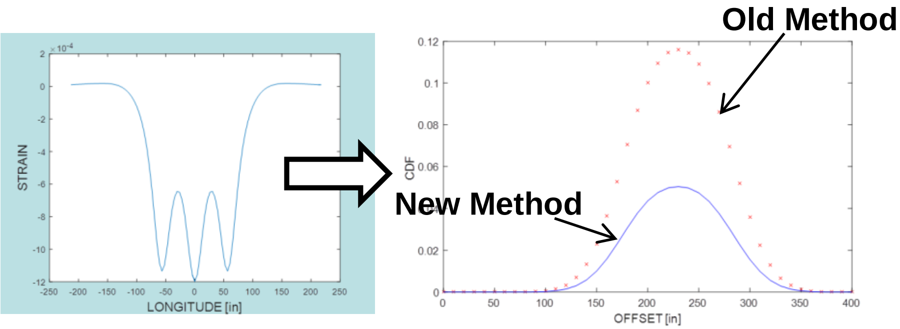


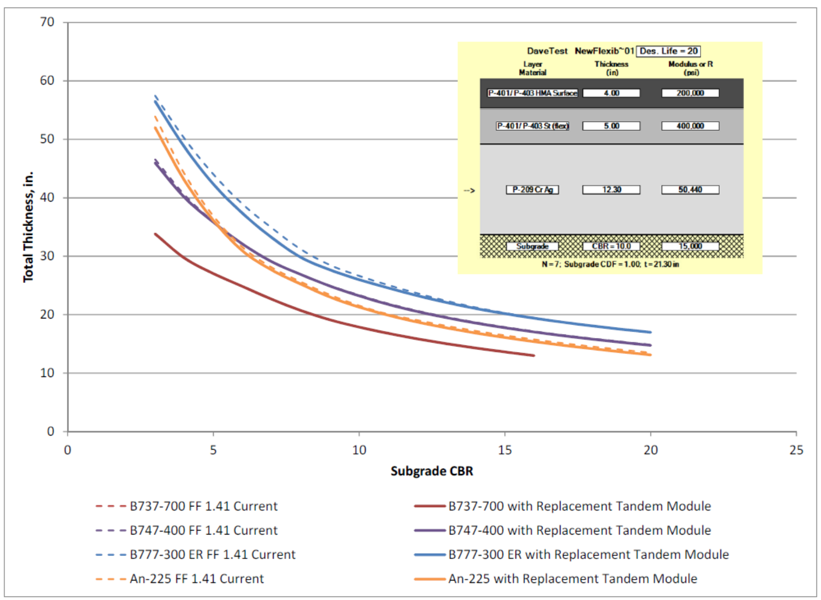
Flexible Base Thickness

- **The minimum stabilized base thickness is still 5 in.**
- **No additional stabilized base thickness requirement when improved subbase material (P-209) is used.**
- **Additional thickness requirement applies only if standard subbase (P-154) is used.**



Direct Evaluation of Tandem Gear Damage (Flexible)





- **Old method was a two-part P/C ratio consisting of a wander-related factor multiplied by a tandem factor.**
- **New method: Compute CDF for multiple wheels in tandem by numerical integration of the longitudinal strain profile.**
- **Similar to method used in Alizé-LCPC (DGAC-France).**
- **New P/C ratio relates only to wander.**

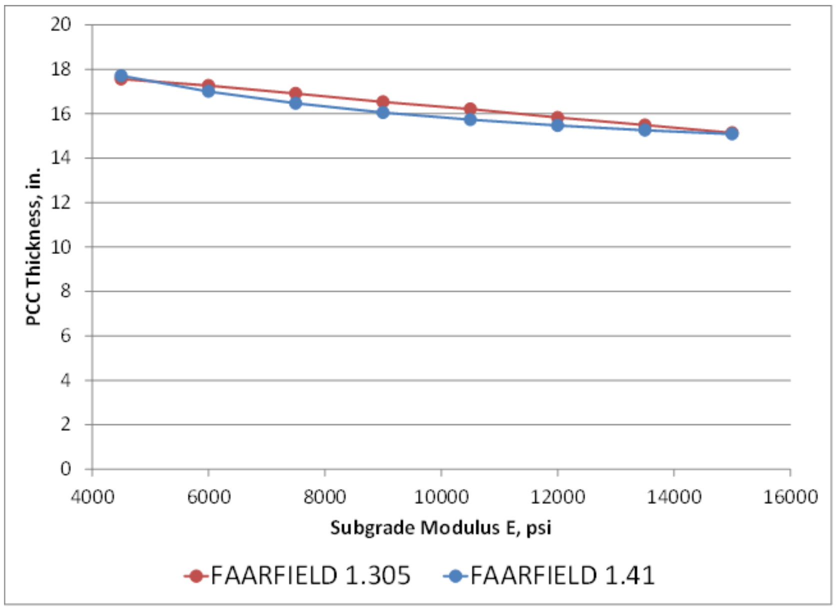
FAARFIELD 1.41 – What's New?

Rigid Designs:

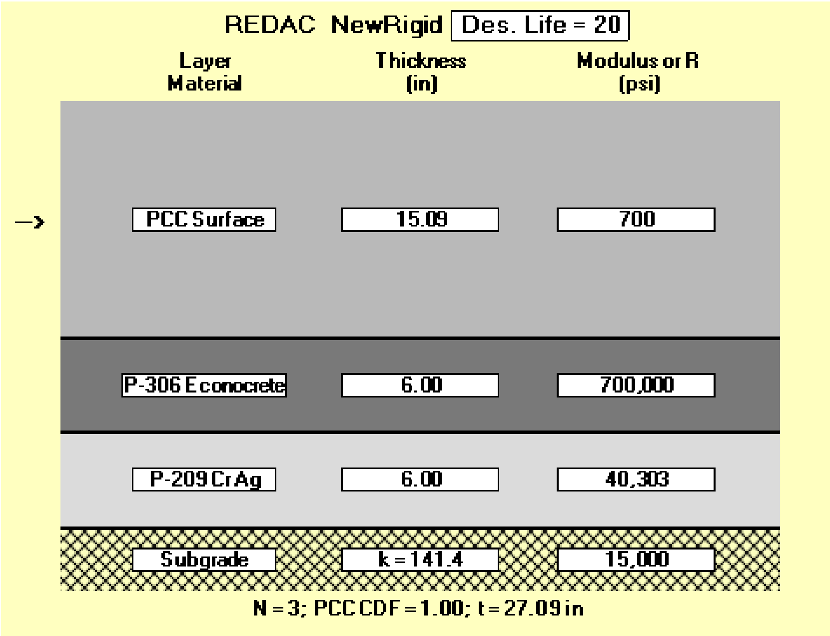
- Completely revised rigid failure model based on newest full-scale test data.
- Design stress is the larger of interior stress or 3D finite element computed edge stress (reduced by 25% for assumed load transfer).
- Completely rewritten concrete overlay design procedure.
- Improved, more accurate 3D finite element model.
- New Visual Basic.NET mesh generation procedure replaces legacy Fortran code.

Rigid Pavements

- **New thickness designs are generally less conservative than FAARFIELD 1.305 designs for the same inputs.**
- **New calibrations incorporate CC6 failure data.**



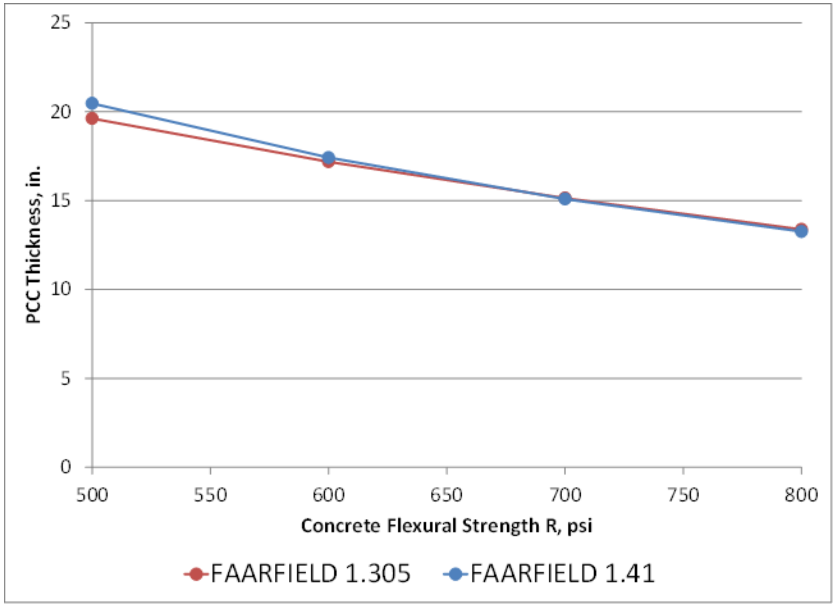
Effect of Subgrade Modulus *E*



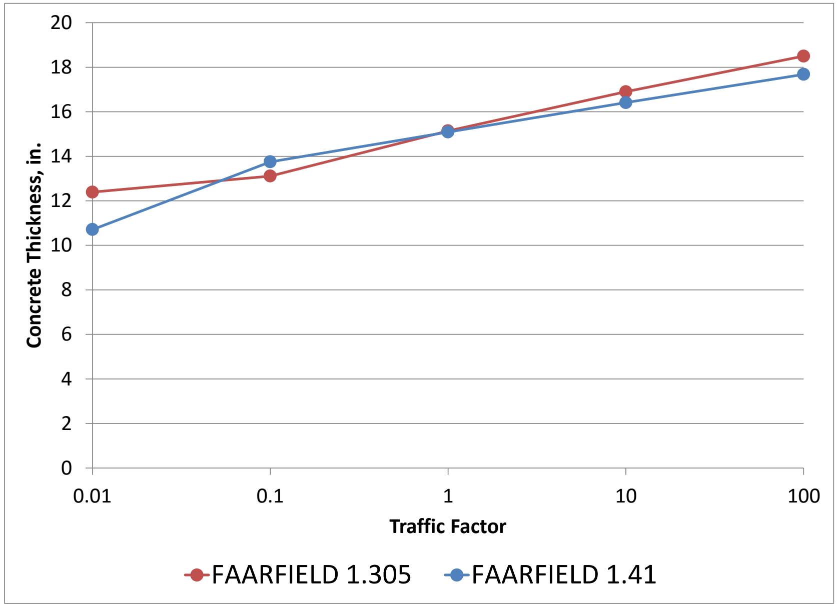
Rigid Design Example

Improved Rigid Failure Model

- **Sensitivity to factors such as concrete strength, traffic level and subgrade support is similar to current version.**



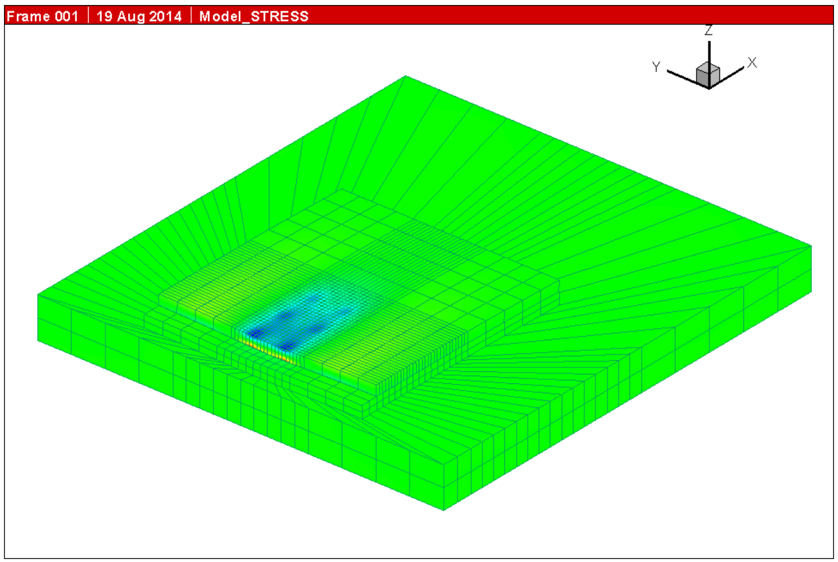
Effect of Concrete Flex Strength



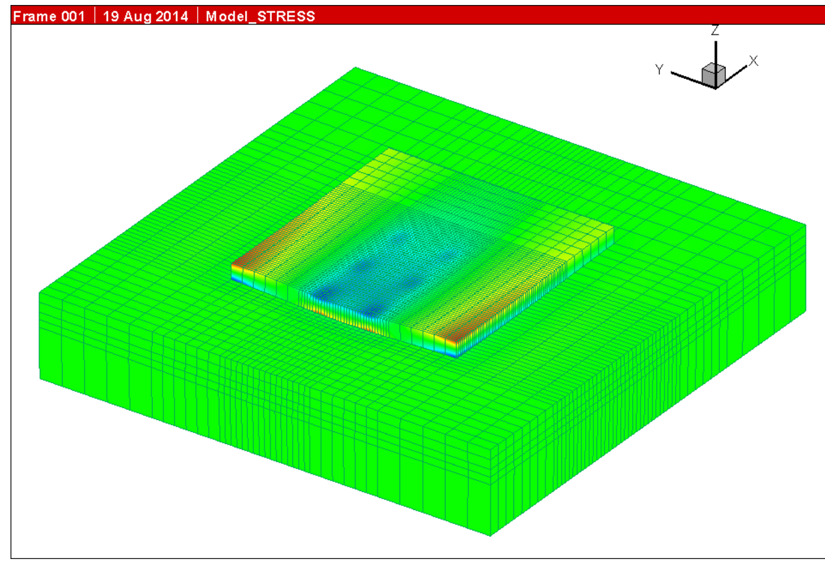
Effect of Traffic

Improved 3D Finite Element Mesh

- More accurate stress results.
- Improved infinite foundation model.
- Still one slab model with assumed 25% load transfer.



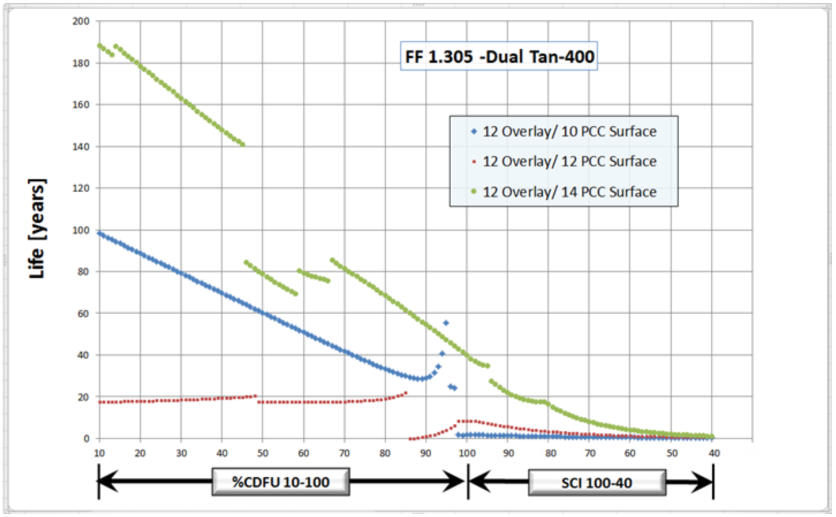
FAARFIELD 1.305



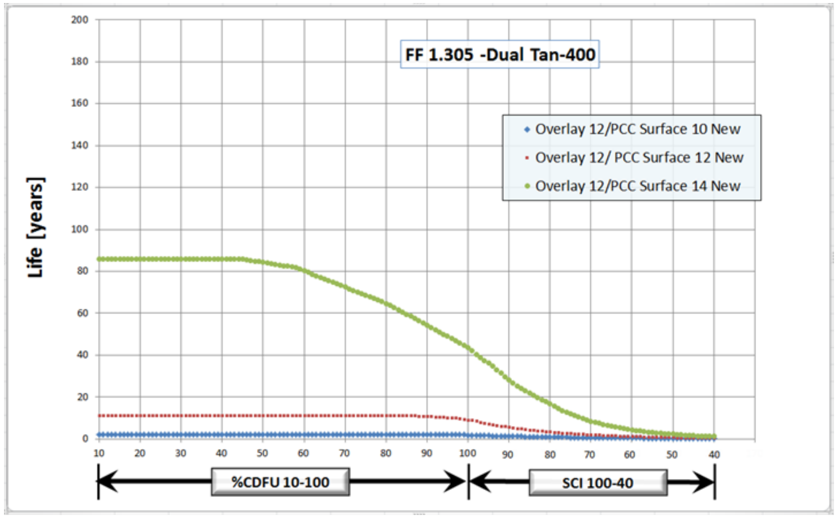
FAARFIELD 1.41

Rigid Overlay Design Procedure

- Completely rewrote overlay life program module.
- Eliminated gaps and illogical results, especially for overlays on new or undamaged PCC.



FAARFIELD 1.305



FAARFIELD 1.41

FAARFIELD 1.4 System/Software Requirements

Minimum

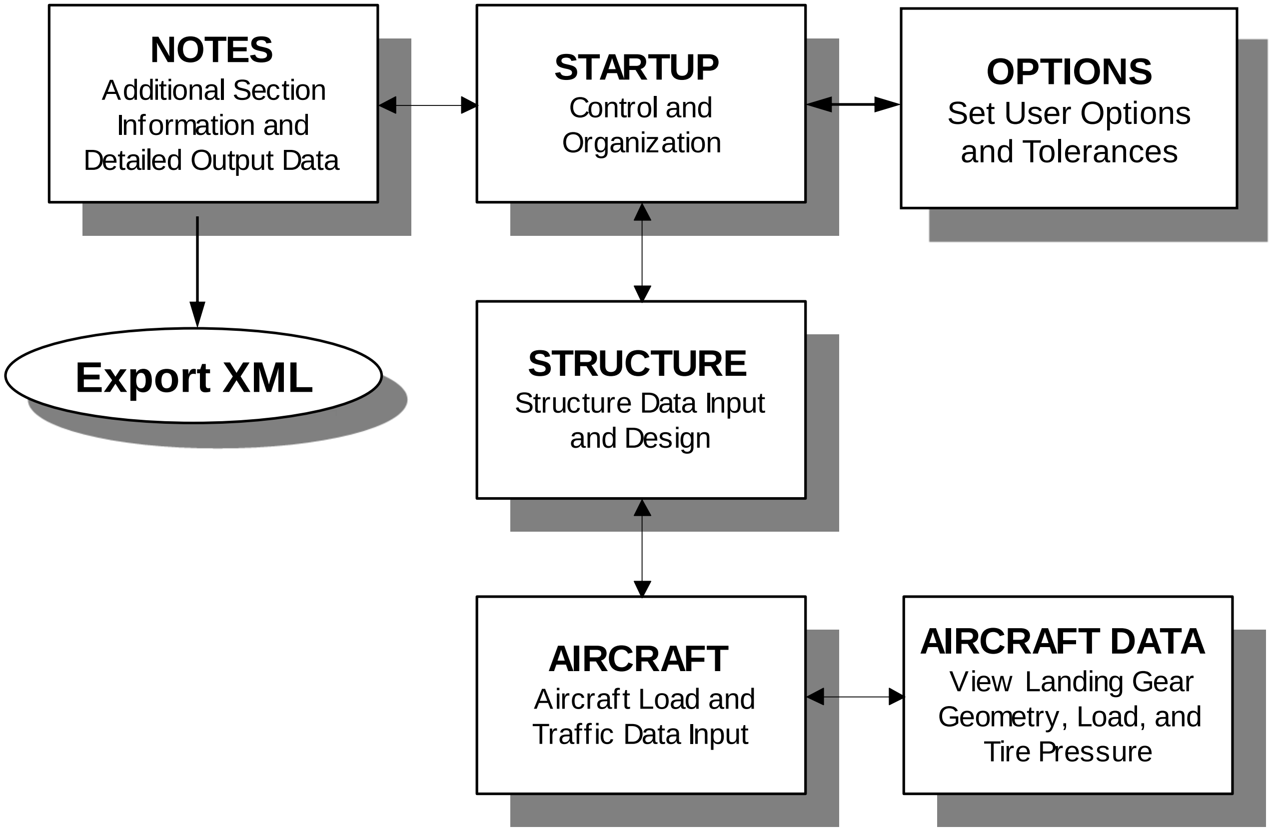
- Windows XP or higher
- 2 GHz processor
- 2 GB RAM
- 200 MB of available space on hard drive.

Recommended

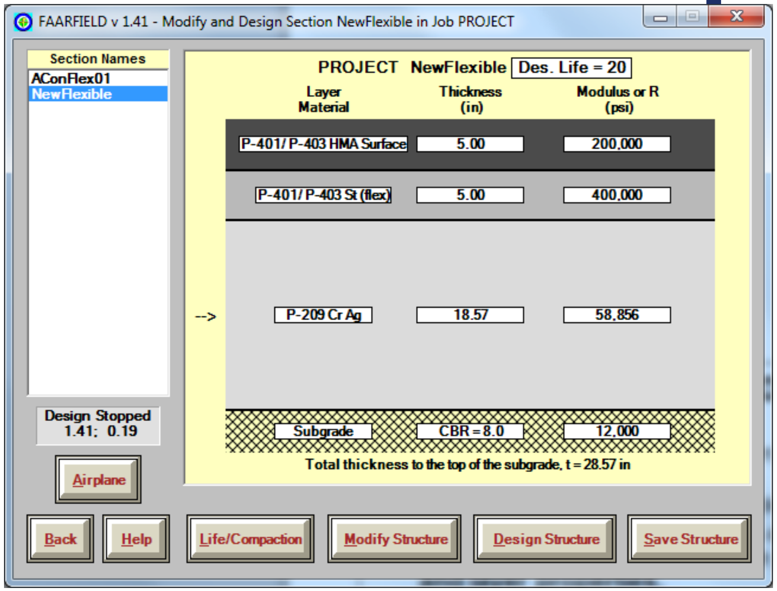
- Windows 7 or higher
- 3 GHz processor
- 4 GB RAM
- 64-bit operating system*

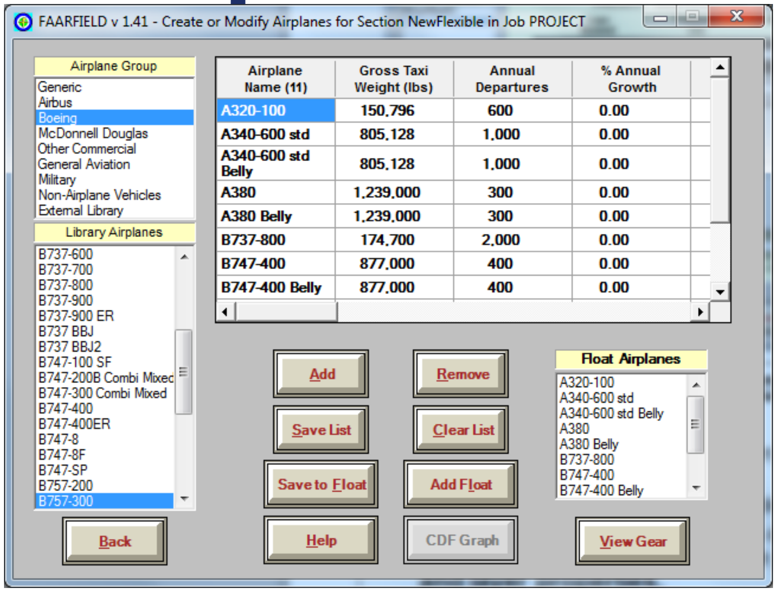
Notes:
***FAARFIELD 1.4 supports 32-bit or 64-bit Windows operating systems.**

Running FAARFIELD:
Program Windows and Linkage



FAARFIELD Input Requirements





Structure Window

- **For each structural layer:**
  - Material type (FAA specification)
  - Layer Thickness
  - Modulus or R-value (if applicable)
- **There are built-in restrictions on the layer types, including relative position and layer properties.**
- **For subgrade, can enter CBR or k and FAARFIELD will convert to E.**

Aircraft Window

- **Select airplane from library.**
- **For each airplane in the mix:**
  - Aircraft Name
  - Gross Taxi Weight
  - Annual departures and percent annual growth if applicable
- **Enter data for all airplanes in the mix.**

FAARFIELD External Airplane Library

- FAARFIELD includes >190 airplanes in the internal library.
- FAARFIELD allows users to define additional airplanes in the external library.
- Add or modify external library airplanes by editing the file: FAAairplaneLibrary.xml
- XML (Extensible Markup Language) format.
- Edit the file using Microsoft Word or other XML editor.

Example Airplane Info in XML File


```
- <AirplaneInfo>
    <Name>B777-300ER Example</Name>
    <GrossWt>777000</GrossWt>
    <MGpcnt>0.475</MGpcnt>
    <CP>221</CP>
    <Gear>N</Gear>
    <IGear>3</IGear>
    <TT>55.00</TT>
    <TS>404.50</TS>
    <TG>0.00</TG>
    <B>57.60</B>
    <NTires>6</NTires>
  - <Wheel_Coordinates>
      <TX>-27.50</TX>
      <TY>-57.60</TY>
      <TX>27.50</TX>
      <TY>-57.60</TY>
      <TX>-27.50</TX>
      <TY>0.00</TY>
      <TX>27.50</TX>
      <TY>0.00</TY>
      <TX>-27.50</TX>
      <TY>57.60</TY>
      <TX>27.50</TX>
      <TY>57.60</TY>
    </Wheel_Coordinates>
    <NEVPTS>6</NEVPTS>
  - <Evaluation_Points>
      <EVPTX>27.5</EVPTX>
      <EVPTY>0.00</EVPTY>
      <EVPTX>22.00</EVPTX>
      <EVPTY>0.00</EVPTY>
      <EVPTX>16.50</EVPTX>
      <EVPTY>0.00</EVPTY>
      <EVPTX>11.00</EVPTX>
      <EVPTY>0.00</EVPTY>
      <EVPTX>5.50</EVPTX>
      <EVPTY>0.00</EVPTY>
      <EVPTX>0.00</EVPTX>
      <EVPTY>0.00</EVPTY>
    </Evaluation_Points>
  </AirplaneInfo>
```


- **GrossWt = weight of airplane, lbs.**
- **MGpcnt = % of GrossWt on 1 main gear**
- **CP = tire contact pressure, psi**
- **Gear = gear designation letter code**
- **IGear = gear ID no. (see next slide)**
- **TT, TS, TG, B = gear parameters (see Help File)**
- **NTires = no. of tires in 1 gear**
  - TX, TY: Enter 1 pair of coordinates for each tire (1 through NTires), in.
- **NEVPTS = no. of evaluation points for LEAF**
  - EVPTX, EVPTY: Enter 1 pair of x,y coordinates for each evaluation point (1 through NEVPTS), in.
- Note: You have to enter the data in U.S. units (inches, psi).

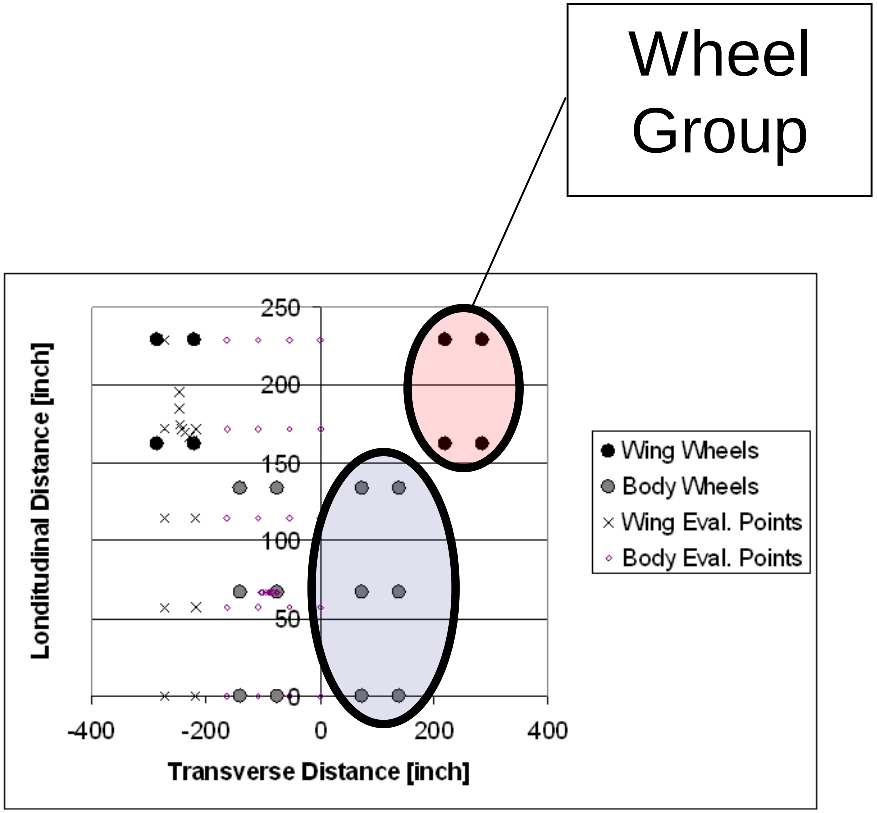
Codes for Various Gear Types

Gear Type	Example	Code	ID No.
S	DC3	B	2
D	B737	D	3
2D	B767	F	3
3D	B777	N	3
User-Defined*	A380 (20 wheels)	X	13

*See help file for information on user-defined gear geometries.

User-Defined Gear Geometries

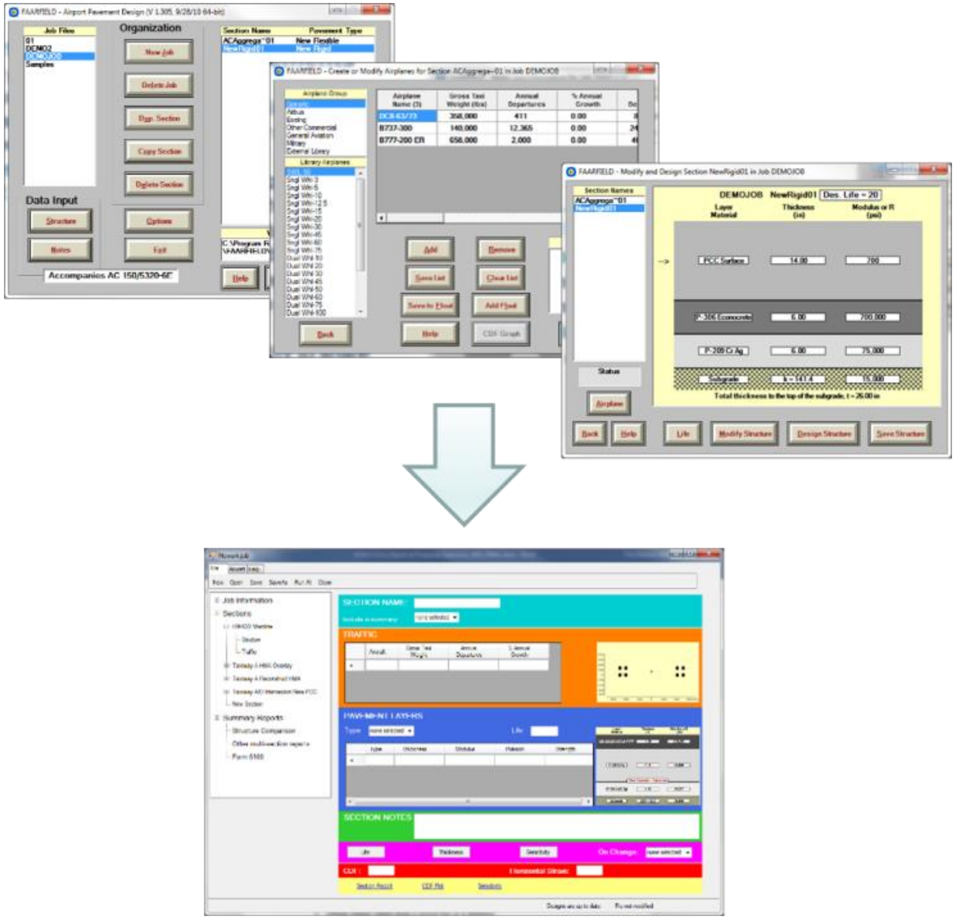
- **A new feature allows users to specify arbitrary gear geometries in the external library.**
  - Coded as “X” in the external library.
  - Allows multiple wheel groups to be defined.
- **Uses rewritten internal pass/coverage computation routine.**
- **New user guidance for the external library – see FAARFIELD Help File.**



In this example, the externally defined A380 main gear gives the identical result as the internally stored airplane.

Further Improvements

- **Modernize the FAARFIELD graphical user interface (GUI).**
  - Job and section entry.
  - Improved start-up screen.
  - Improved screen re-sizing and appearance.
  - Improved flow between screens.
- **Rationalize data file structure.**



Thank You! ¡Gracias!

http://www.airporttech.tc.faa.gov/

david.brill@faa.gov

Acknowledgments:

FAA Airport Technology R&D Branch:
Dr. Michel Hovan, Branch Manager;
Jeff Gagnon, Airport Pavement Section Manager;
Dr. Navneet Garg; Al Larkin; Murphy Flynn; Ryan Rutter; Quinn Jia, Wilfredo Villafane

FAA Airport Engineering Division:
Doug Johnson; Greg Cline

SRA International:
Michael Collins; Dr. Izydor Kawa; Dr. Qiang Wang; Dr. Yuanguo Chen; Dr. Kairat Tuleubekov; Shawn Hershman; Jeff Stein

Gemini:
Dr. Hao Yin