FAARFIELD – What Is It?

FAARFIELD is the new FAA airport pavement thickness design program.

FAARFIELD superseded LEDFAA 1.3 as the standard design procedure in FAA Advisory Circular (AC) 150/5320-6E.

- Current version is 1.305 (posted 1/18/11)
# FAA Legacy Design Procedures vs. FAARFIELD

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<th>AC 150/5320-6D (Chapters 3 - 4)</th>
<th>FAARFIELD</th>
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<tbody>
<tr>
<td><strong>Traffic Model</strong></td>
<td>All traffic converted to equivalent departures of design aircraft</td>
<td>CDF (Cumulative Damage Factor) accounts for mixed traffic</td>
</tr>
</tbody>
</table>
| **Structural Response Models** | • Westergaard’s solution for rigid pavements  
• Boussinesq model used to compute ESWL for flexible | • Layered elastic analysis (LEAF) for flexible.  
• 3D finite element for rigid. |
| **Thickness Design Method**    | • CBR equation with alpha factor (flexible)  
• Apply percent of thickness to basic design for 5000 coverages (rigid) | Failure model relates coverages to structural failure to a suitable response: subgrade strain (flexible) or concrete stress (rigid). |
| **Implementation**             | Design nomographs (spreadsheet implementation also available) | Desktop computer program written in Visual Studio 2005 |
FAARFIELD 1.3

Key Differences from LEDFAA 1.3

• Rigid Pavements/Overlays
  – Slab edge stresses are now computed directly using 3D-FEM.
  – Completely revised rigid pavement failure model.
  – Rewrote and improved rigid overlay design procedures.

• Flexible Pavements/Overlays
  – Automatic base thickness design.
  – Improved pass-to-coverage ratio computation routine.
  – Supports HMA overlay design on rubblized PCC base.

• General
  – Upgrade to MS Visual Basic 2005 programming environment.
  – Aircraft library updated.
  – New function allows user to export design data to XML.
  – Improved formatting for Notes.
  – All user options collected on one “Options” screen.
FAARFIELD 1.3 New Features

• Pavement thickness is now computed for constant tire contact area.
  – Changing the airplane gross weight causes the tire pressure to be adjusted to maintain the contact area.

• External aircraft library in XML format.

• Displays CDF values graphically.

• Enhanced Airplane Data window now displays gear coordinates.

• Support for PCC over rubblized base.
FAARFIELD Version 1.305

- Upgrade was posted January 2011.
- Compatible with Windows 7.0 and the 32- and 64-bit versions of Windows Vista.
  - Previous versions of FAARFIELD (up to 1.302) were not compatible with 64-bit operating systems.
  - Link to previous version (1.302) is still maintained.
- Design outputs from FAARFIELD were not affected by this version upgrade.
FAARFIELD – Technical Background

- Computer program for desktop PCs.
- Program preserves the “look and feel” of LEDFAA 1.3.
- Major changes are internal.
- Main program drives three subprograms:
  - LEAF (layered elastic analysis)
  - NIKE3D (3D finite element analysis)
  - INGRID (3D mesh generation)
- NIKE3D and INGRID 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).
What is 3D Finite Element?

• **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 not:**
  – A design method or procedure.
  – An exact mathematical solution.
  – Always preferable to other analysis models.

Types of 3D Elements:
- Linear (8-Node) Brick
- Quadratic (20-Node) Brick
- Nonconforming (Incompatible Modes)
- Axial (1-D)
- Infinite Element
- Focal Point
Why 3D Finite Element?

• For rigid pavements, we desire a method that gives a direct edge stress solution for a layered structural system.

• Layered elastic analysis programs such as LEAF always assume continuous, uniform layers with no interruptions (e.g., no joints).
  – LEAF cannot model jointed rigid pavements accurately.
  – LEDFAA 1.3 compensates for this with the “equivalent edge stress” approach, but this is theoretically unsatisfactory and is not extendable to new aircraft types.

• 3D-FEM provides a practical solution.
  – Suitable for modeling complex landing gear configurations explicitly.
  – Recent advances in computing power allow implementation in routine design programs.
Summary of Advantages and Disadvantages of 3D-FEM

- **Advantages**
  - Properly models rigid pavement features including 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**
  - May require long computation times.
  - Pre-processing and post-processing requirements.
  - Solution may be mesh-dependent.
    - In theory, the solution can always be improved by refining the 3D mesh.
    - Improvement comes at the expense of time.
3D-FEM Stress Response

Stress $\sigma_{yy}$ Contours Displayed Using NikePlot

- 3D-FEM responses are not visible to the user during design.
Cumulative Damage Factor (CDF)

- Sums the damage contributed from each aircraft - not from equivalent aircraft.
- \( \text{CDF} = \sum \left( \frac{n_i}{N_i} \right) \), where:
  - \( n_i \) = actual passes of individual aircraft \( i \)
  - \( N_i \) = allowable passes of individual aircraft \( i \)
- When \( \text{CDF} = 1 \), design life is exhausted.
- In FAARFIELD (and LEDFAA 1.3):
  - The gear location and wander are considered separately for each aircraft in the total mix.
  - CDF is calculated for each \( 25.4 \text{ cm} \) (10 inch) wide strip over a total \( 20.83 \text{ m} \) (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)

Difference in Gear Location

Damage from Airplane A

Damage from Airplane B

25.4 cm (10 in.)
Cumulative Damage Factor (CDF)

25.4 cm (10 in.)

Damage from Airplane A

Total Damage

Damage from Airplane B
Large Airplane Traffic Mix Gear Locations
FAARFIELD – CDF Graphical Display
Remember - in FAARFIELD

Use the entire traffic mix!
Installing and Running FAARFIELD

• Download files from FAA Airport Technology R&D Branch Downloads page: http://www.airporttech.tc.faa.gov/naptf/download/index1.asp or unpack the FAARFIELD 1.305 installation files from the thumb drive you received at registration.

• Run setup.exe

• Follow the instructions in the setup wizard.
FAARFIELD Installation Procedure

1. Welcome to the FAARFIELD Setup Wizard

2. Select Installation Folder

3. Confirm Installation

4. Installation Complete

Please use Windows Update to check for any critical updates to the .NET Framework.
FAARFIELD System/Software Requirements

**Minimum**
- Windows 2000
- 600 MHz Pentium III processor
- 256 MB memory
- 200 MB of available space on hard drive.
- Users of older operating systems may require a one-time installation of the .NET Framework (free download from Microsoft).

**Recommended**
- Windows 7, Vista, XP or higher.*
- 2 GHz Pentium IV processor
- 512 MB memory
- Users of older operating systems may require a one-time installation of the .NET Framework (free download from Microsoft).

*Note: FAARFIELD 1.305 supports 64-bit operating systems. Users of Windows 7.0 and Vista 64-bit versions must install FAARFIELD version 1.305.*
Running FAARFIELD: Program Windows and Linkage

- Export XML
- STARTUP Control and Organization
- NOTES Additional Section Information and Detailed Output Data
- OPTIONS Set User Options and Tolerances
- STRUCTURE Structure Data Input and Design
- AIRCRAFT Aircraft Load and Traffic Data Input
- AIRCRAFT DATA View Landing Gear Geometry, Load, and Tire Pressure
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 Files

### New Flexible Pavements
- **LeafSG.out** – Subgrade layer responses for flexible pavement.
- **LeafAC.out** – HMA surface layer responses for a flexible pavement.

### Flexible Overlays on Flexible Pavements
- **LeafAC.out** – HMA surface layer responses for a flexible pavement.

### Common Files
- **Storage files:**
  - *.JOB.xml – job files (XML format) contain data required by FAARFIELD for all the sections in one job.
  - *.DES.xml – design information files generated by “Save XML” command.
  - *.nts – notes files (contain user entered information)
- **Help file:** faarfield.chm.
- **External airplane file:** FAAAirplaneLibrary.xml

### New Rigid Pavements, Rigid Overlays on Rigid Pavement, Flex Overlays on Rigid Pavement
- **NikePCC.out** – Stresses at the bottom of PCC layer.
- **Nike3d.txt** – 3D finite element summary output file.
- **n3dhsp** – 3D finite element detailed output file.

### Legacy Files
- **Leaf.loa and Leaf.str** – Load and structure definition files compatible with programs LEDNEW and Juleaww.exe
FAARFIELD Job Files (JOB.xml)

• Job files in FAARFIELD 1.3 are in XML format. This is a different format than previous job files in LEDFAA.

• FAARFIELD looks for old job files in the working directory and automatically converts them to the new XML format.
  – After reading, the old job files are moved to a subdirectory of the working directory called `old_job_files`.
  – All subsequent changes are written to the JOB.xml files only. The old job files are not changed.
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

- 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 file ExtFile.doc)
- TT, TS, TG, B = gear parameters (see file LEDGear.doc)
- 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 Common Gear Types

<table>
<thead>
<tr>
<th>Gear Type</th>
<th>Example</th>
<th>Letter Code</th>
<th>ID No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>S</td>
<td>DC3</td>
<td>B</td>
<td>2</td>
</tr>
<tr>
<td>D</td>
<td>B737</td>
<td>D</td>
<td>3</td>
</tr>
<tr>
<td>2D</td>
<td>B767</td>
<td>F</td>
<td>3</td>
</tr>
<tr>
<td>2D/2D2</td>
<td>B747</td>
<td>J</td>
<td>4</td>
</tr>
<tr>
<td>3D</td>
<td>B777</td>
<td>N</td>
<td>3</td>
</tr>
</tbody>
</table>

- Note: Currently only common gear types conforming to one of the letter codes can be entered in the external library. Future versions will allow complex gear geometries (e.g., A380). This feature is in development.
Example of Gear from External File
- <AirplaneInfo>
  <Name>B777-300ER Example</Name>
  <GrossWt>777000</GrossWt>
  <MGpctn>0.475</MGpctn>
  <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>
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  <TY>-57.60</TY>
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  <TY>-57.60</TY>
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  <TX>27.50</TX>
  <TY>-57.60</TY>
  <TX>-27.50</TX>
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  <TY>-57.60</TY>
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  <EVPTX>27.5</EVPTX>
  <EVPTY>0.00</EVPTY>
  <EVPTX>22.00</EVPTX>
  <EVPTY>0.00</EVPTY>
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  <EVPTY>0.00</EVPTY>
  <EVPTX>16.50</EVPTX>
  <EVPTY>0.00</EVPTY>
  <EVPTX>5.50</EVPTX>
  <EVPTY>0.00</EVPTY>
  <EVPTX>0.00</EVPTY>
  <EVPTY>0.00</EVPTY>
- </Evaluation_Points>
</AirplaneInfo>

**Example Airplane Info in XML File**

![Diagram showing airplane data](image)

- Gross Taxi Weight: 777,000 lbs
- % G on Gear: 47.5
- Tire Pressure: 221 psi

**Legend:**
- TT
- TS
- B

**Annotations:**
- X = -238.9 in
- Y = 291.6 in
FAARFIELD External Airplane Library
Related Materials and Resources

• XML Standard: http://www.w3.org/XML/
• FAA Airport Technology R&D web page:
  – www.airporttechnology.tc.faa.gov
  – Click on Downloads, then Pavement, then Software.
  – Link to “Format for External Data File” (under BAKFAA) – contains additional documentation.
Thank You. Questions?

Gracias. ¿Preguntas?