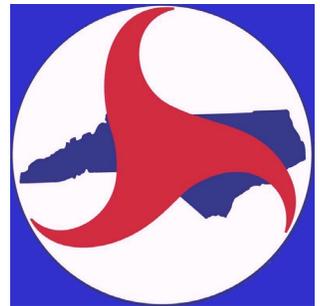

LEDGA User's Manual



**North Carolina
Division of Aviation
(NCDOA)**

Version 1.2

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INTRODUCTION

During the period of August 6, 1997 to June 30, 1999, Roy D. McQueen & Associates, Ltd. (RDM) performed the study entitled “Development of a Reliable Methodology to Determine In-Situ Pavement Strength of General Aviation Airport Pavements” under Contract No. NCSU 97-1312-01 with the Institute for Transportation Research and Education (ITRE) of the North Carolina State University (NCSU), Raleigh, NC. The basic objectives of the study were to develop standardized procedures for nondestructive testing (NDT), evaluation and design of General Aviation (GA) airport pavements in North Carolina using analytical software developed for this purpose. The resultant evaluation/design procedures and software were to permit evaluating the effects of allowing a one time or periodic overload operations on the airport pavements.

Due to the limitations of current Federal Aviation Administration (FAA) design methods for GA airport pavements – particularly the ability to handle “overload” aircraft conditions – the new design procedures for GA airport pavements and accompanying LEDGA software are based on layered elastic methods. To provide a degree of reliability, short of conducting a series of expensive full scale tests, the layered elastic subgrade strain failure criterion was based on thickness designs that comply with current FAA pavement design methods contained in FAA Advisory Circular 150/5320-6D. Therefore, it is believed that the new design methods will provide North Carolina Division of Aviation (NCDOA) with increased flexibility to handle additional design cases (e.g., overload, varying departure levels) with the same degree of reliability that exists with current FAA design methods.

LEDGA is a computer program designed for use by experienced engineers to perform structural analyses of GA. airport pavements. The design analyses that LEDGA produces are based on modifications to the Federal Aviation Administration’s (FAA) LEDFAA computer program and the results of the aforementioned study for ITRE. The LEDFAA program is described in FAA Advisory Circular (AC) 150/5320-16.

Modifications to the LEDFAA program that are incorporated in the LEDGA program include the following:

- Revised subgrade strain failure criterion;
- Elimination of rigid pavement analysis capability;
- Revised CBR-Esub transformation;
- Revised fleet mix including GA and “overload aircraft” and
- Procedures for assessing the effect of overload aircraft on GA airport pavements.

Other familiar elements of the LEDFAA program were retained for ease of use and continuity. These include:

- Design for fatigue failure expressed in terms of a cumulative damage factor (CDF) using Miner's rule;
- Similar graphical screens for the pavement structure and traffic;
- Characterization of material properties of pavement layers and subgrade in terms of the elastic modulus; and
- Same defaults for elastic modulus, Poisson's ratio and layer interface;

The LEDGA program also offers other enhancements to the evaluation and design procedures for GA airport pavements. These include the ability to:

- Vary the operational frequency of individual aircraft in the GA and overload fleet mix;
- Input back-calculated subgrade elastic modulus from nondestructive tests (NDT);
- Vary the thickness of the asphalt concrete surface layer;
- Incorporation of layered elastic design methods for the design of GA airport pavements

Documentation on the development of the revised failure criterion, computational logic and other program elements can be found in the aforementioned study for ITRE.

The LEDGA program is not intended to replace the services of professional engineers. As with any design procedure, all pavement designs must be accompanied by sound engineering design. It should also be stressed that, although layered elastic based design procedures are normally considered to be mechanistic and more rational than previous methods, a considerable amount of engineering judgement is still required. Designs produced by LEDGA should also comply with the detailed requirements of FAA AC 150/5320-6 and other applicable FAA, NCDOA and industry standards. The program does not automatically satisfy all of these requirements and the recommendations in the Advisory Circulars and other applicable standards should be followed. It is the designer's responsibility to use the program and standards in conjunction with each other.

Roy D. McQueen & Associates, Ltd. (RDM), the FAA, ITRE, and North Carolina Department of Transportation represent to the best of their knowledge that the LEDGA software does not infringe upon any copyrights, trade secrets, or patents. The software is made available on an "as is" basis. No other representation or warranty is expressed or implied. It is the user's responsibility to properly select inputs, interpret output and adhere to all applicable or governing standards.

INSTALLATION

LEDGA's setup program takes you through the installation with on screen instructions at every step.

To install LEDGA insert LEDGA Setup Disk 1 in an available diskette drive; usually **A** or **B**. Then, from the Start menu on Windows 9x select Run. At the command line type in **A:\setup.exe** (or **B:\setup.exe**) and press Enter on the keyboard.

Follow the on screen instructions until you are asked for the installation directory. The default directory is **C:\Program Files\LEDGA1.2**. If this is OK, click the setup button to begin the installation. The installation directory will be created if it does not already exist. If you want to use a different directory, type in the name with full path. The remainder of the setup is automatic. A new program group will be created called LEDGA 1.2. LEDGA is run by double clicking the LEDGA icon in the program group.

Because LEDGA makes use of the latest Windows components, the setup program will first look for these components in the Windows directory. If these components are not found, setup will install them automatically. If this is the case, the setup program will display a message indicating that you need to reboot your computer and you need to run LEDGA's setup program again.

The following files are installed by setup:

Directory LEDGA1.2 (or user determined directory)

LEDGA.EXE:	Visual Basic I/O and design program.
JuleaD32new.dll	Julea 32-bit compiled as a Windows DLL.
NCDOA.HLP:	Help file.
NCDOA.CNT	Table of contents for help file.

Directory WINDOWS

SETUP1.EXE	Setup executable.
------------	-------------------

Directory WINDOWS\SYSTEM

VB6STKIT.DLL	Setup dynamic link library.
COMCAT.DLL	Component Category Manager library
ASYCFILT.DLL	Visual Basic runtime library.
OLEPRO32.DLL	Visual Basic runtime library.
OLEAUT32.DLL	Visual Basic runtime library.
MSVBBVM60.DLL	Visual Basic virtual machine library.
MSFLXGRD.OCX	Grid (table) control library.

WHAT'S NEW IN LEDGA

LEDGA (**L**ayered **E**lastic **D**esign for **G**eneral **A**viation airport pavements) is based on the FAA's LEDFAA computer program. Although LEDGA uses the same tools used in LEDFAA, LEDGA was written specifically for General Aviation use.

LEDGA contains a new subgrade failure criterion based on field data conducted as part of the study entitled "Development of a Reliable Methodology to Determine In-Situ Pavement Strength of General Aviation Airport Pavements."

LEDGA's most important feature is the handling of heavy aircraft that are not part of a General Aviation airport's normal traffic. LEDGA allows the user to compute the damage caused by an occasional heavy load. This overload situation allows the user to estimate the remaining life in such a case.

OVERVIEW

The program consists of five main windows rigidly linked together as shown in the figure below. The essential windows for pavement design are **STARTUP**, **STRUCTURE**, and **AIRCRAFT**. The **NOTES** and **AIRCRAFT DATA** windows are for convenience in entering additional data describing the structure and traffic, and for viewing data.

Operations within a window are executed by clicking the mouse cursor on a “command button.” Command buttons are referred to by showing the button name in bold type. For example, “click the command button called Structure” is abbreviated by “click **Structure**.”

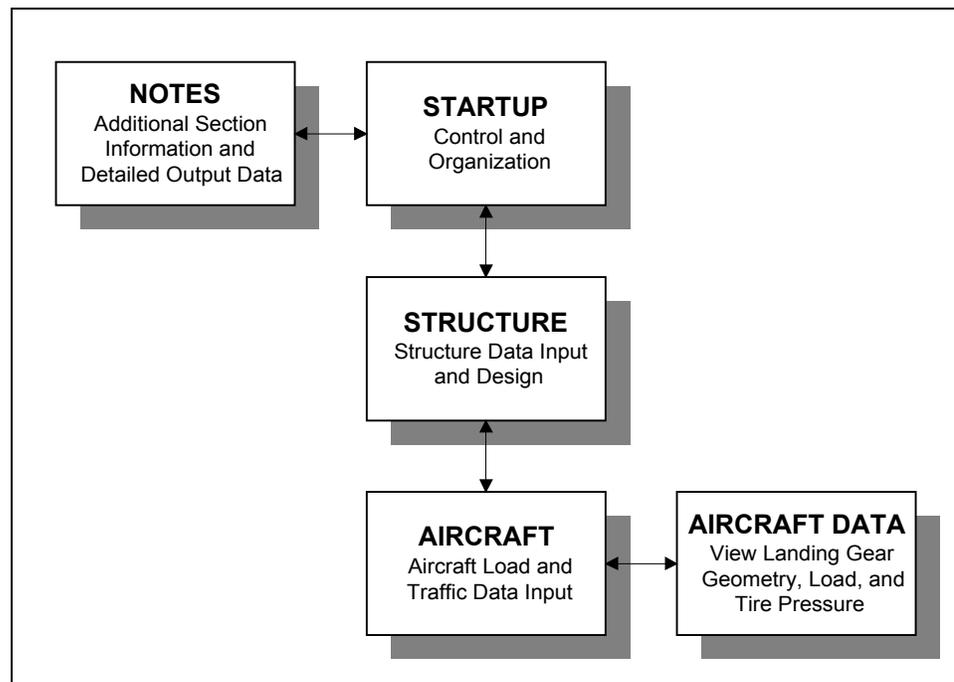


Figure 1. Program Windows and Linkage

STARTUP WINDOW

Introduction

The startup window has two functions. First is to allow selection of either the **STRUCTURE** or the **NOTES** window. Second is to organize the basic data storage units, consisting of "Sections" embedded in "Jobs." Jobs are MSDOS ASCII text files containing up to 100 sections. All Job files existing in the working directory are listed on the left of the window. A special Job file called Samples is initialized within the system and does not exist as an external file. It is always available to create new section data. This is necessary if no other Job files are present because new structures cannot be created from scratch. The Samples structures are also typical of current pavement design practice and are a convenient starting point for design. The data in the Samples sections cannot be changed and the structures cannot be "designed." The sections are provided only for starting new designs.

Note: The normal Windows file dialog boxes are not supported in LEDGA. Backup to floppy disk, or other media, is therefore not possible directly from the program. This was done to simplify the user interface. But, since job files are MSDOS ASCII files, file backup and, where necessary, deletion, can be done using File Manager or from the DOS prompt. (See the Windows or DOS manual for file management procedures.) All job files have the extension .JOB.

Section data consists of pavement structure properties, aircraft names and gross loads, and annual departures and growth for each aircraft. Details of the required information are given when the data entry windows are discussed.

Jobs are listed in the list box on the left of the window. All sections in the selected job are listed in the right hand list box. Scroll bars will appear if there are too many jobs or sections to fit in the boxes. The operations associated with each of the command buttons on the **STARTUP** window are briefly described under separate headings.

Command Buttons

New Job

New jobs are created by clicking **New Job**. A dialog box will then appear requesting that a name be entered for the new job. The name can have up to 8 characters. Normal letters and numbers are allowed, together with hyphen (-) and underscore (_). Clicking **OK** or pressing Enter on the keyboard will accept the name, create the file, and close the dialog box. Clicking **Cancel** will close the dialog box without creating a new file. When first created, job files are completely empty. But new sections cannot be created from scratch. Instead, old sections are moved and renamed using **Dup. Section** or **Copy Section**.

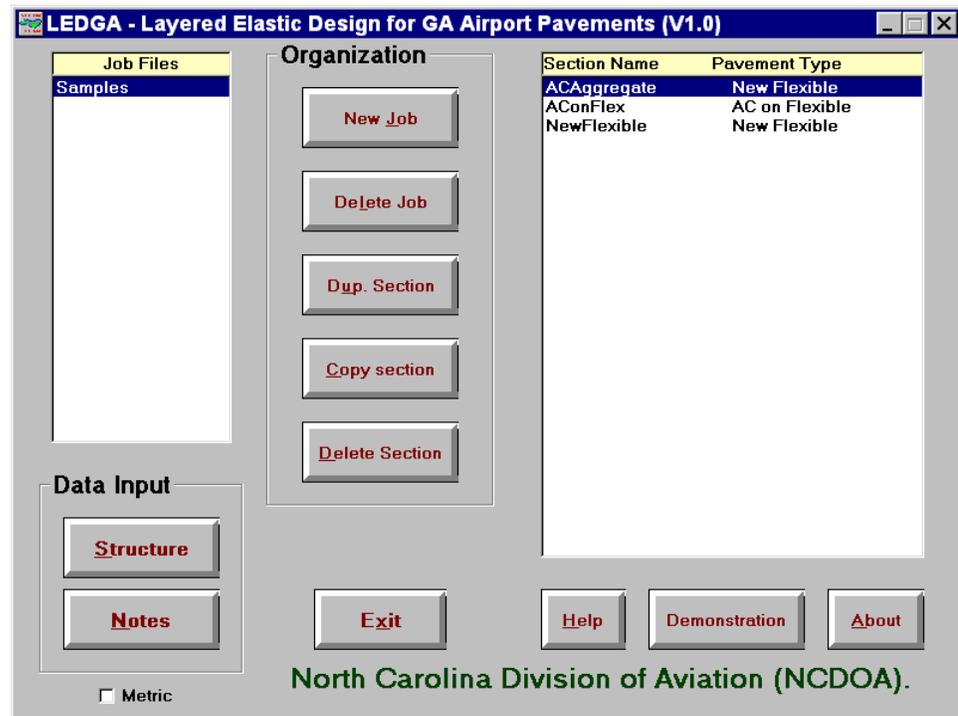


Figure 2. Startup Window

Delete Job

To delete a job file, first select the job to be deleted by clicking the job's name in the left hand list box. Then click **Delete Job**. A message box will be displayed asking if you want to continue. Click **Yes** to delete the file and close the message box. Click **No** to close the message box without deleting the job. Deleting a job will cause all of the information in a job file to be deleted from the disk. The only way to restore the information is to immediately run undelete in DOS or Windows.

Note: Whenever, as in this case, information can be destroyed by an action, a message box with a **No** or **Cancel** option is displayed to reduce the risk of accidentally destroying the information.

Copy Section

New pavement structures cannot be created from scratch in the **STRUCTURE** window. Instead, existing structures in one job are copied to another job (or duplicated and renamed within a single job as described below). The section list box shows the type of structure for each listed section so that the desired type of structure can be selected before copying without having to check the **STRUCTURE** window. Three types of structure are included:

1. New Flexible.
2. AC on Flexible (asphalt overlay on an existing flexible pavement).

3. AC on Aggregate base (asphalt overlay on crushed or uncrushed aggregate).

The sequence for copying a section is:

1. Select the job to be copied from by clicking the job name.
2. Click **Copy Section**. The caption on the button will change to **End Copy**.
3. Select the section to be copied by clicking the section name in the right hand list box.

Select the job to be copied to by clicking the job name. A dialog box will be displayed asking you to enter the name of the new section. The name can have up to 12 characters, consisting of alphanumeric, hyphen, or underscore. The old name can be kept provided it does not already exist in the job the section is being copied to.

Repeat to copy more sections or click **End Copy** to end copying.

Copying can be stopped at any time by clicking **End Copy**.

A section can also be copied by using LEDGA's drop and drag feature. To use this feature follow these steps:

1. In the Start-up screen select the Job File from the list on the left by clicking the mouse on it.
2. Next, select a Section Name/Pavement Type from the list on the right.
3. Click on the Section Name/Pavement Type selected and hold down the mouse left button. Drag the section to the list on the left. The mouse cursor will turn into a semi-transparent square.
4. Release the mouse left button.

Dup. Section

A section can be duplicated within any job and given a new name. First select the job. Then select the section and click **Dup. Section**. Enter the new name in the displayed dialog box.

Delete Section

To delete a section, first select the job. Then select the section and click **Delete Section**. The section data is completely deleted from the job file and cannot be recovered.

Help

The Help file is loaded by clicking Help in any of the windows except the **AIRCRAFT DATA** window, or by pressing the F1 key on the keyboard.

Demonstration

An interactive demonstration of the major functions in the **STARTUP**, **STRUCTURE**, and **AIRCRAFT** windows is started by clicking **Demonstration**. The demonstration can be run through all three windows in succession, or individual windows can be selected.

A time delay is inserted between each distinct operation in the demonstration so that the functions occurring can be observed. The default delay setting is 2 seconds. The delay setting can be changed any time a demonstration specific message box is displayed by clicking **Change Delay**. The demonstration can also be terminated from any of the demonstration specific message boxes by clicking **Cancel**.

Structure

Transfers control to the **STRUCTURE** window.

Notes

Transfers control to the **NOTES** window. This allows incidental section information to be entered and attached to the job file and a summary of the section data to be viewed. The **NOTES** window is described last.

Exit

Closes all files and exits to Windows.

STRUCTURE WINDOW

Introduction

The **STRUCTURE** window allows a pavement structure to be modified and “designed” to carry the load applied by the selected traffic. On the left of the window is a list of the sections in the current job. On the right of the window is a table showing the structure with all layers illustrated and the values of all changeable parameter values displayed. Clicking a new section name in the list changes the displayed structure to that of the new name.

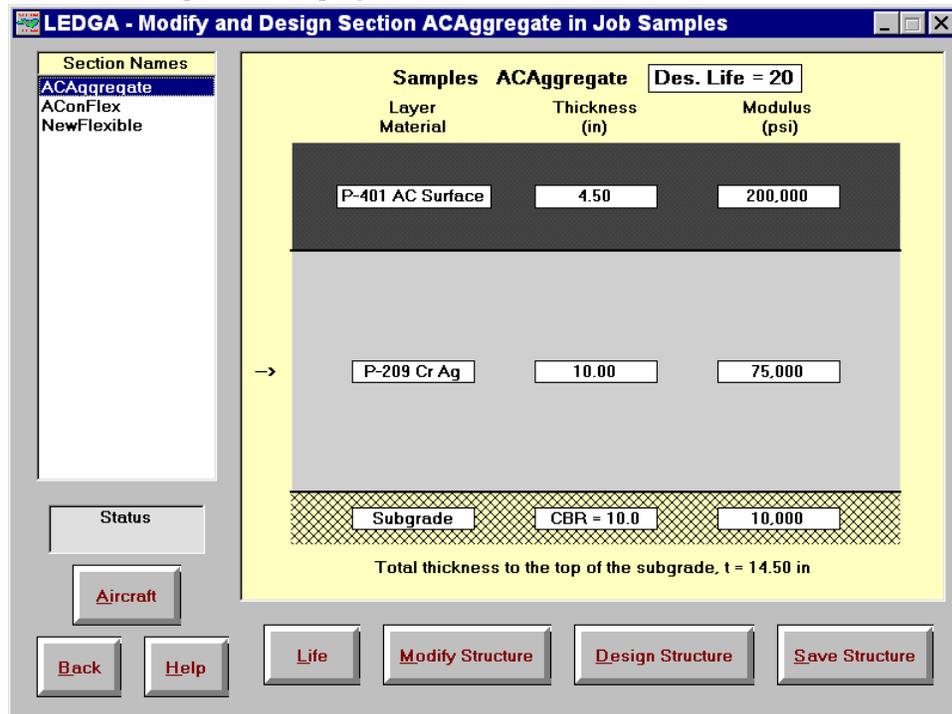


Figure 3. Structure Window

Command Buttons

Modify Structure

A structure is modified from the modify mode, generally entered by clicking **Modify Structure**. **Modify Structure** then changes to **End Modify** and **Design Structure** changes to **Add/Delete**. The only operations allowed until **End Modify** is clicked are modifications to the structure. Alternative ways of entering modify mode are double clicking a section name (also changes the displayed structure) and double clicking the picture of the structure (also starts an associated modification sequence).

Modifications that can be made to a structure are:

1. Change the composition of a layer (change layer type).
2. Change the thickness of a layer.
3. Change the modulus value of a layer (except asphalt).
4. Duplicate (add) an existing layer.
5. Delete an existing layer.
6. Change the iteration layer for flexible pavement design.

Layer types and modulus values must be selected for compatibility with the layered elastic design procedures and with FAA pavement design standards and recommendations. The purpose of this section is simply to outline the operation of the program. Detailed guidelines for selection are given in a later section. These must be read before using the program to design pavements to FAA standards. In particular, the use of an undefined layer results in a non-standard structure.

Structure properties are changed by clicking on the picture of the structure over the displayed value or setting. Instructions are then given for changing the value or setting.

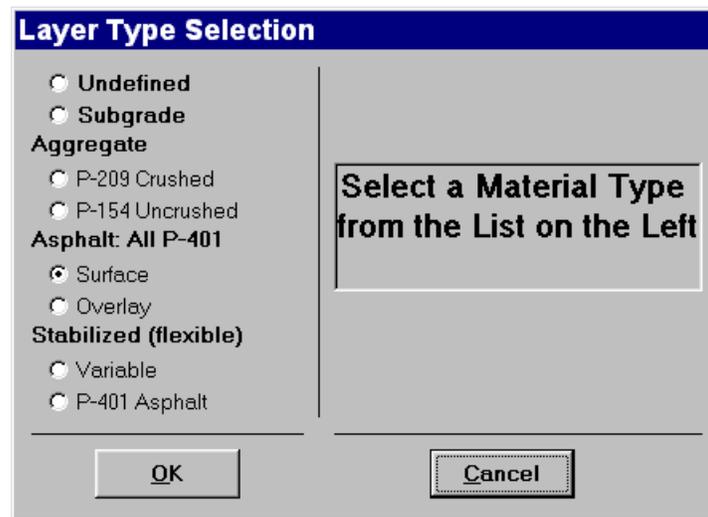


Figure 4. Layer Types

Clicking on the picture in the layer type column displays the selection box shown. To change the layer type, click the type you want to select followed by **OK**. Certain combinations of layers are not allowed in a structure (aggregate on the top, for example). However, the structure is not checked during selection and layers can be changed to anything until **End Modify** is clicked. A complete check of the structure is then made and a message displayed if the structure is not valid for design. The reason for disallowing the structure is given in the message. You cannot leave modify mode until the structure is valid for design.

When the displayed value of a layer thickness or layer modulus is clicked, an input box is displayed giving instructions on changing the value. In some cases, the modulus value cannot be changed manually and a description is given of how the program assigns the value automatically.

Note: The thickness of the bottom layer is assumed to be infinite and cannot be assigned a value. The thickness display column in the bottom layer is therefore used to display the CBR value corresponding to the modulus value of the bottom layer. The conversion factors used are given in the section Layer Types. If the value in either of the two columns is changed, the value in the other column changes automatically.

Design life, in years, is displayed at the top of the picture of the structure and can be given any value within the range 1 to 50 years. However, the standard design life is 20 years. If the design life of a section is different than 20 years the message “Non-Standard Life” is displayed. Clicking on the message displays a longer message explaining why the life is non-standard. A warning message is also printed in the **Design Info** text box in the **NOTES** window.

The small arrow in the left margin of the picture of the structure indicates the layer which will be adjusted during design (see below). The position of the arrow can only be changed when the structure is a new flexible pavement. Clicking in the margin to the left of any layer except for the top or bottom layers will select that layer as the adjustment layer for design.

Add/Delete

Layers can be added or deleted using **Add/Delete**. After clicking the button you must select a layer in the picture of the structure. A box is displayed requesting the selection of Add or Delete. Selecting Add duplicates the selected layer. The properties of the layer can then be changed as desired. Selecting Delete completely removes the selected layer from the structure.

End Modify

Terminates the modify mode. No functions other than structure modifications can be executed while the modify mode is active.

Design Structure

Clicking this button adjusts the thickness of one of the layers of the structure so that the design criteria for the particular type of structure are satisfied. The structure type is automatically determined from the top two layers and the correct design procedure executed. The layer to be adjusted is indicated by the small arrow in the left margin of the picture of the structure. Except for new flexible pavements, the layer cannot be changed. During design the layer being adjusted is highlighted by changing its display color. In some cases, if a new computed layer thickness is unreasonable (such as negative), the thickness of an adjacent layer is changed. This is only included to prevent unreasonable layer thickness and is not intended to try to optimize the design. If it occurs, the structure should be inspected and changed if necessary, followed by a redesign.

Information on the state of the design is displayed at the bottom of the picture of the structure.

Details of the design procedures executed by **Design Structure** for the different pavement structures are given in the Pavement Thickness Design section.

Interrupt Design

When a design is started by clicking **Design Structure**, **Save Structure** changes to **Interrupt Design**. Clicking this button during design stops the design calculations and leaves the thickness of the layer being adjusted at its value at the time of stopping the design. The design can be restarted with the structure as it existed at the time of interruption by clicking **Design Structure** again. Or the structure can be changed and a new design started from the changed condition. During design, the structure does not become permanent in the job until the structure is saved (see **Save Structure**).

Save Structure

The structure is saved in the current section data record by clicking **Save Structure**. This cannot be done in modify mode or during design. Saving the structure after a design has run to completion marks the section in the data record as being a completed design. Clicking **Back** without having saved the structure causes a message box to be displayed which prompts for the structure to be saved.

Modifications made to a pavement structure do not become permanent until the data is saved using **Save Structure**. You can therefore try different designs and return to the original structure by canceling the save with the following sequence: click **Back** followed by clicking **NO** in the displayed message box. This transfers control to the **STARTUP** window. Returning to the **STRUCTURE** window restores the original structure and all changes will have been lost.

Life

Computes the life of the current section in years. This function is not required for design, but is provided for convenience in computing *CDF*. If design for the section has been run to completion, the life computed using **Life** will equal the design life. *CDF* is computed for new pavement design based on the current setting of design life.

Furthermore, clicking on the **Life** button calculates the *CDF* for an overload aircraft if an overload aircraft is present in the aircraft list. For additional information on overload see the sections WHAT'S NEW IN LEDGA and the AIRCRAFT WINDOW.

Aircraft

Transfers control to the **AIRCRAFT** window.

Back

Returns control to the **STARTUP** window.

AIRCRAFT WINDOW

Introduction

The **AIRCRAFT** window allows for the creation and modification of an aircraft list for the currently selected section in the currently selected job. Other sections or jobs cannot be selected from the **AIRCRAFT** window. If you want to change to another section, return to the **STRUCTURE** window. If you want to change to another job, return to the **STARTUP** window.

Aircraft are selected from a library and placed in a list of design aircraft. Except for gross load, annual departures, percent annual growth, and overload status (defined below), all necessary aircraft information for design is stored internally as part of the library and cannot be changed. At the top left of the window is a list of library aircraft groups. Selecting one of these groups will display all of the aircraft in that group in the list box located below the aircraft group box.

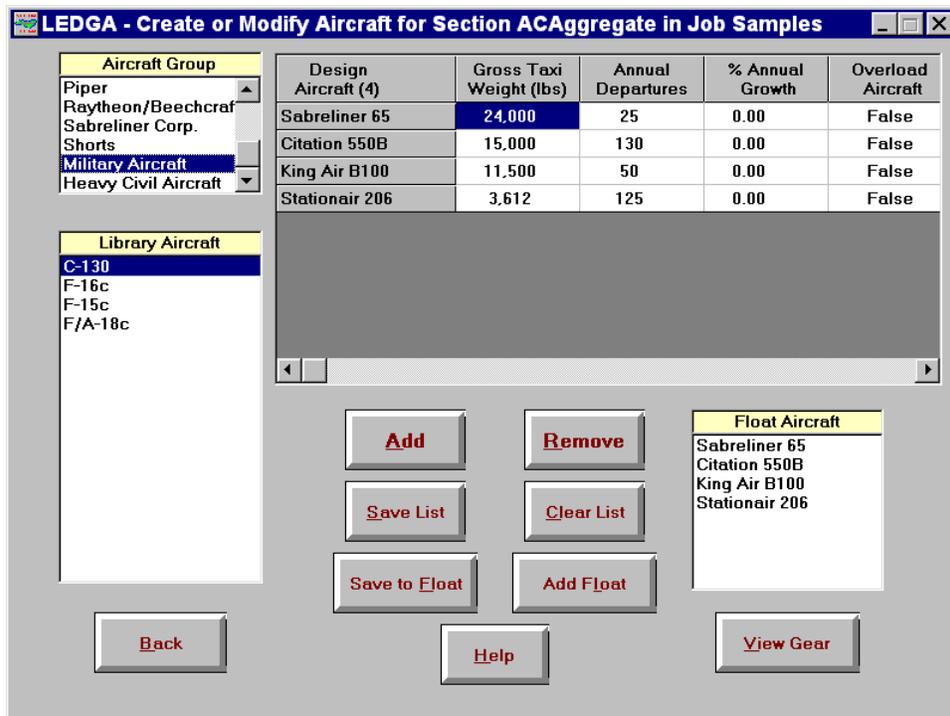


Figure 5. Aircraft Window

At the top right of the window is a table that lists the design aircraft for the currently selected section, with associated data. Aircraft are transferred from the library list to the design list by selecting an aircraft in the library list (by clicking the name once) and clicking **Add**, or by double clicking the aircraft name in the library list. Aircraft are removed from the design list by selecting

an aircraft in the design list (by clicking the name once) and clicking **Remove**, or by double clicking the aircraft name in the design list.

Values in the first four data columns of the design aircraft list table (gross load, annual departures, percent annual growth, and overload status) can be changed by clicking on the value to be changed. An input box is displayed which gives instructions and the allowed ranges for data entry. Scrolling the table columns to the left shows columns for: total lifetime departures, tire pressure, percent gross load on the design gear, dual-wheel spacing, tandem-wheel spacing, tire contact width, and tire contact length. None of these can be changed.

For an aircraft to be considered as an overload aircraft click on the column 'Overload Aircraft' to change the status of the aircraft from false to true. A message is displayed indicating that by changing the status to true the annual departures for such aircraft will be used as the total departures when computing the *CDF* for that pavement section. Also, note that only one aircraft per section can be selected as an overload.

For all aircraft in the library, the fraction of the gross load carried by the main gear has been set at 95 percent to make the LEDGA design procedures compatible with FAA standards. The tire contact lengths and widths are those used in the calculation of pass-to-coverage ratio for the aircraft. An elliptical contact patch is assumed, with its area equal to the tire load divided by the tire pressure. (In contrast, circular tire contact patches are used in JULEA because the layered elastic model is asymmetric.)

A maximum of 20 aircraft can be included in the design list.

The library list contains aircraft representative of the most common general aviation aircraft. Although any aircraft in the library can be selected as an overload aircraft, the 'Military Aircraft' and 'Heavy Civil Aircraft' libraries were added to be used as overloads. Substitutions can be made for aircraft not in the list, either by a similar aircraft or from the "Generic" group list.

Annual departures is defined as the aircraft departure rate in departures per year. The displayed value is the annual departures for the selected aircraft at the start of the pavement's design life. Percent annual growth is defined as the percent change in annual departures per year over the design life of the pavement. Negative values represent a decrease in annual departures. The total number of departures for the selected aircraft over the design life of the pavement is given by the equation:

$$N = \left(1 + \frac{b \times L}{200} \right) \times a \times L$$

where:

N = total departures

L = pavement design life

a = initial annual departures

b = percent annual growth

Large negative percent annual growth can result in negative aircraft departures before the end of the design life has been reached. The program automatically detects this condition if it occurs, and assumes zero departures for the aircraft from the time at which the departure rate becomes zero to the end of the design life.

Command Buttons

Add

An aircraft is transferred from the library list to the design list by selecting an aircraft name in the library list and clicking **Add**. The same operation can also be performed by double clicking an aircraft name in the library list.

Remove

An aircraft is removed from the design list by selecting the aircraft name and clicking **Remove**, or by double clicking the aircraft name in the design list.

Clear List

Deletes all aircraft from the design list.

Save List

Saves the data for all of the aircraft in the design list into the data record for the currently selected section in the currently selected job. All changes made to a design list must be saved, or discarded, before returning to the **STRUCTURE** window. The **Save** operation permanently changes the aircraft data stored in the section data record.

Save to Float

An independent, "floating," list of aircraft is provided to allow an existing list to be transferred easily to a different section. Clicking **Save to Float** transfers the current design list and aircraft data to the floating list, replacing the existing floating list. The new floating list will remain available until the next **Save to Float** operation or the program is terminated. The floating list is displayed in the list box at the bottom right of the window and is always empty when the program starts.

Add Float

Adds the aircraft in the floating list to the current design list up to the maximum of 20 aircraft.

View Gear

Transfers control to the **AIRCRAFT DATA** window (discussed under separate heading).

Back

Returns control to the **STRUCTURE** window. If changes have been made to the design list and the list has not been saved, a message box is displayed requesting that the changes be saved or discarded, or that the **Back** operation be canceled. Control cannot return to the **STRUCTURE** window until the changes have been saved or discarded.

NOTES WINDOW

Introduction

The **NOTES** window is provided for viewing a summary of the design information for the currently selected section and for entering and saving notes on the currently selected section, such as size, location, maintenance history, etc.

On the left of the window is a list of the sections in the currently selected job. On the right of the window is a text box which contains either the design information or the notes for the currently selected section. The design information is fixed and is taken from the section data record. The notes are entered by the user and can contain up to 30,000 characters for each section (5 to 20 pages). Text is entered and edited as it would be in the Windows Notepad text editor.

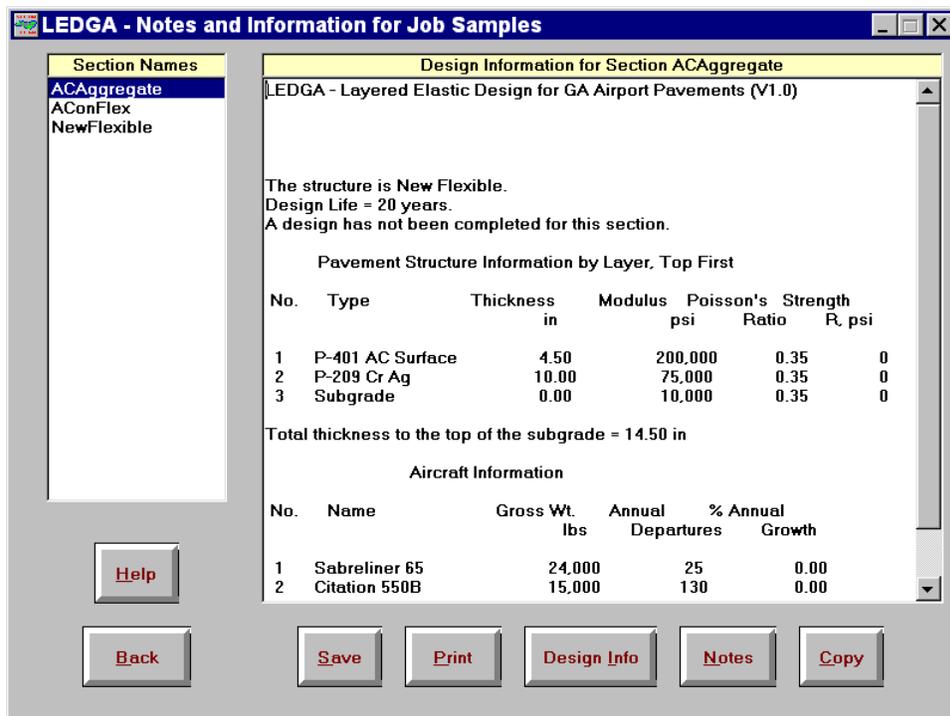


Figure 6. Notes Window

Command Buttons

Design Info

Displays in the **NOTES** window text box the design information for the currently selected section.

Notes

Displays in the **NOTES** window text box the notes for the currently selected section.

Copy

Copies the design information and the notes from the **NOTES** window to the Windows clipboard. The text can then be pasted into another application, such as a text editor or word processor.

Print

Prints the design information and the notes from the **NOTES** window to the currently selected default Windows printer.

Save

Saves the notes for the currently selected section in the .NTS file for the currently selected job. (Each .JOB file has a corresponding .NTS file. When initialized, the notes for a section contain only the section name unless the section was created using **Copy Section** in the **STARTUP** window, in which case the old notes are copied into the new section.)

AIRCRAFT DATA WINDOW

The **AIRCRAFT DATA** window primarily shows the main gear layout for the aircraft currently selected in the design list. The gear layout and the tire contact patches are drawn to scale. An image of the picture can be copied to the clipboard by clicking the right mouse button on the picture. An image of the window is printed by clicking **Print**. Gross load can also be changed by clicking the Gross Load data display box.

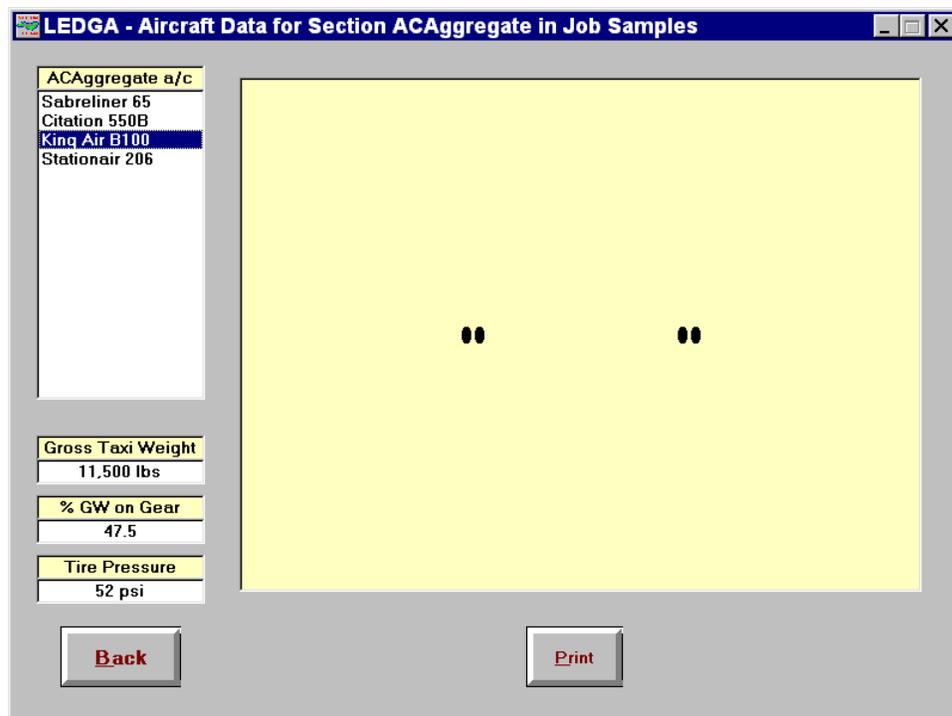


Figure 7. Aircraft Landing Gear Data

CUMULATIVE DAMAGE FACTOR

Cumulative damage factor (*CDF*) is the amount of the structural fatigue life of a pavement which has been used up. It is expressed as the ratio of applied load repetitions to allowable load repetitions to failure, or, for one aircraft and constant annual departures:

$$\begin{aligned}
 CDF &= \frac{\text{number of applied load repetitions}}{\text{number of allowable repetitions to failure}} + \frac{\text{total number of overload repetitions}}{\text{number of allowable repetitions to failure}} \\
 &= \frac{(\text{annual departures}) \times (\text{life in years})}{(\text{pass/coverage ratio}) \times (\text{coverages to failure})} + \frac{(\text{total overload departures})}{(\text{pass/coverage ratio}) \times (\text{coverages to failure})} \\
 &= \frac{\text{applied coverages}}{\text{coverages to failure}} + \frac{\text{applied overload coverages}}{\text{coverages to failure}}
 \end{aligned}$$

When $CDF = 1$, the pavement will have used up all of its fatigue life.

When $CDF < 1$, the pavement will have some life remaining, and the value of CDF will give the fraction of the life used.

When $CDF > 1$, all of the fatigue life will have been used up and the pavement will have failed.

Note: In these definitions, failure means failure in a particular structural failure mode according to the assumptions and definitions on which the design procedures are based. A value of CDF greater than one does not necessarily mean that the pavement will no longer support traffic, but that it will have failed according to the definition of failure used in the design procedure, and within the constraints of uncertainties in material property assumptions, etc. Nevertheless, the thickness design is based on the assumption that failure occurs when $CDF = 1$.

Multiple aircraft types are accounted for by using Miner's Rule instead of the "design aircraft" concept as in the current procedures, or:

$$CDF = CDF_1 + CDF_2 + \dots + CDF_N$$

Where CDF_i is the CDF for each aircraft type in the mix and N is the number of aircraft types in the mix.

Note: The same aircraft model with two different gross loads represents two different aircraft types. This is because a different pavement load will be applied by each gross load.

Each failure mode included in the design procedure will have a separate CDF . For example, in flexible pavement design, the thickness is adjusted to make the CDF for subgrade failure equal to 1. An additional computation is then made to find the CDF for asphalt surface cracking. If the asphalt CDF is less than 1, the asphalt is predicted not to fail in cracking before the subgrade fails. But if the asphalt CDF is greater than 1, the asphalt is

predicted to fail before the subgrade, and adjustments should be made to base and subbase layers so that asphalt *CDF* is less than 1 in the final design.

In the program implementation, *CDF* is calculated for each 10 inch wide strip along the pavement over a total width of 820 inches. Pass-to-coverage ratio is computed for each strip based on a normally distributed aircraft wander pattern with standard deviation of 30.5 inches (equivalent to aircraft operation on a taxiway) and used in the above equation for Miner's rule. The *CDF* for design is taken to be the maximum over all 82 strips. Even with the same gear geometry, therefore, aircraft with different main gear track widths will have different pass-to-coverage ratios in each of the 10 inch strips and may show little cumulative effect on the maximum *CDF*. Removing the aircraft with the lowest stress or strain may then have little effect on the design thickness, depending on how close the gear tracks are to each other.

LAYER TYPES

Introduction and LED References

Eight layer types are included for building pavement structures. Some of the types can be placed at any position in a structure, while others can only be placed in specified positions. The reason for specifying placement, and specifying types, is that the design procedure executed by the program is automatically determined by the layer types of the top two surface layers, and the presence of aggregate layers. Control of default parameter values is also easier when placement is controlled. Some flexibility is allowed by the inclusion of an “undefined” layer type. The only restrictions on this type are that Poisson’s ratio is fixed at 0.35 and modulus must be in the range 1,000 to 4,000,000 psi. (Default values and ranges for all layer types are displayed in the **Modify Structure** data entry dialog boxes.) However, undefined layer types do not meet FAA standards for airport pavement design.

The materials in the **Layer Type Selection** screen reference aggregate, asphalt, and stabilized pavement layers in accordance with standard FAA “P” designations. The “P” designations were retained since most airport engineers are familiar with these designations. However, on General Aviation (GA) airports, it is possible that pavement construction consists of materials conforming to North Carolina Department of Transportation (NCDOT) specifications. Since the mechanistic failure criteria is based on correspondence back to FAA design procedure for GA airports, the use of NCDOT materials in the existing structure, or for asphalt overlays, will not affect the operation of the LEDGA program or program output.

All layer types except undefined are related in some way to layer types identified or specified in AC 150/5320-6. The following includes information for making the relationship between the LEDGA and AC 150/5320-6 layer types and for selecting appropriate layer properties as input data for LEDGA.

The requirements and guidelines of AC 150/5320-6 should be followed whenever there is a discrepancy between LEDGA and the advisory circular. For example, minimum thickness should always be set according to the requirements of the circular for the particular pavement type under design and not the default minimum thickness built into LEDGA.

References for specific details of the LEDGA design procedures are:

1. Barker, W.R., and W.N. Brabston, **Development of a Structural Design Procedure for Flexible Pavements**, Report No. FAA-RD-74-199, September 1975.
2. Parker, F., Jr., W.R. Barker, R.C. Gunkel, and E.C. Odom, **Development of a Structural Design Procedure for Rigid Airport Pavements**, Report No. FAA-RD-77-81, April 1977.
3. Rollings, R.S., **Design of Overlays for Rigid Airport Pavements**, Report No. DOT/FAA/PM-87/19, April 1988.
4. Barker, W.R., and C.R. Gonzalez, **Pavement Design by Elastic Layer Theory**.

5. Roy D. McQueen & Associates, **Development of a Reliable Methodology to Determine In-situ Pavement Strength of General Aviation Airport Pavements.**

Subgrade Layers

Subgrade modulus values for flexible pavement design can be determined in a number of ways. The procedure which will be applicable in most cases is to use available CBR values and substitute in the relationship:

$$E = 1,000 \times \text{CBR psi}$$

This method will provide designs compatible with the current design procedure based on subgrade CBR. Resilient modulus and non-destructive test (NDT) data may also be used where the reliability of the measurements is felt to be high.

The equation for converting CBR to subgrade modulus is based on field test data taken at six General Aviation airports in North Carolina as part of a research project for the Institute for Transportation Research and Education (ITRE) of North Carolina State University. For a detailed explanation of the research project see the report supplied with LEDGA.

Asphalt Layers

Two types of asphalt layers are included: asphalt surface and asphalt overlay. Both have the same properties, with modulus fixed at 200,000 psi and Poisson's ratio fixed at 0.35. The asphalt overlay type can be placed over asphalt surface or aggregate material. The asphalt surface type can only be placed on the top of a structure, or under an asphalt overlay.

Aggregate Layers

Crushed Aggregate

Crushed Aggregate in LEDGA corresponds to Item P-209, Crushed Aggregate Base Course.

The modulus of crushed aggregate layers is computed automatically and cannot be changed manually.

Uncrushed Aggregate

Uncrushed Aggregate in LEDGA corresponds to Item P-154, Subbase Course.

The modulus of uncrushed aggregate layers is computed automatically and cannot be changed manually.

Modulus Values of Aggregate Layers

The modulus values of aggregate layers are calculated automatically. The WES “Modulus” procedure included with LEDNEW is followed, with sublayering performed automatically (maximum sublayer thickness are 8 inches for uncrushed aggregate and 10 inches for crushed aggregate). The modulus values of the sublayers decrease with increasing depth of a sublayer within the aggregate layer, and are also dependent on the modulus of the layer below the aggregate layer.

Aggregate layers can be placed anywhere in the pavement structure except at the top or bottom. The following additional restrictions also apply:

1. Only one crushed layer and one uncrushed layer may be present in a structure. This is for compatibility with the Modulus procedure. (Sublayering by the Modulus procedure accounts for thick layers, and multiple layers of a single aggregate type are not necessary.) The maximum number of aggregate layers which may be present in a structure is therefore two, one of each type.
2. If crushed and uncrushed layers are adjacent, the crushed layer must be above the uncrushed layer (to be compatible with the modulus procedure).

For efficiency in iterating to a valid thickness design, a two-stage process is used during design with thick aggregate layers. When *CDF* is outside the range 0.5 to 2.0, the aggregate layers are not sublayered for Julea, but are treated as a single layer with modulus equal to the average modulus of what would be the sublayers. When *CDF* is within the range 0.5 to 2.0, full sublayering is used according to the Modulus procedure. One consequence of this is that the *CDF* can increase when sublayering first occurs, apparently indicating an error in the procedure.

The modulus value displayed in the structure table for an aggregate layer is the average value of the sublayer modulus values. The only exception is for newly created layers, in which case the “defaults” of 75,000 and 40,000 are displayed for crushed and uncrushed respectively. These defaults are never used in calculations.

Sublayering by the Modulus procedure also causes a discontinuity in computed *CDF* when the number of sublayers changes as the total thickness of an aggregate layer crosses over the threshold during design. For example, if the thickness of an uncrushed aggregate layer increases from 15.99 inches to 16.01 inches the number of sublayers increases from 2 to 3, and the *CDF* may jump from a value above 1 to a value below 1. This can result in a condition in which a given combination of structure and traffic does not have a *CDF* of 1, whatever the thickness of the iteration layer may be, and the thickness of the iteration layer changes back and forth across the threshold continuously. To stop the continuous iteration, the number of sublayers in a structure is fixed when *CDF* is within the range 0.7 to 1.4. The condition can be detected by running **Design Structure** again after a design has been completed. If the second design gives a different thickness than the first, then the condition exists. A further consequence is that pavement life computed using **Life** will not agree with the design life, and sudden changes in AC layer *CDF* may occur for flexible pavements.

Stabilized Layers

Two material types of stabilized layers are included in LEDGA, defined as Variable and asphalt (P-401) materials. This classification is derived from the fact that the modulus values correspond to current procedure (AC 150/5320-6) equivalencies when comparing designs made by current and LED procedures. Variable modulus types are provided as well as fixed modulus types corresponding to standard material items. Property values are:

Type	Modulus, psi	Poisson's Ratio
Stabilized (flexible)		0.35
Variable Minimum	150,000	
Variable Maximum	400,000	
P-401 Asphalt	400,000	

Because the modulus values were determined on the basis of producing thickness designs comparable with the current design procedures, typical laboratory test data for stabilized materials should not be used in preparing input data for LEDGA designs. Instead, the material recommendations and equivalencies given in AC 150/5320-6 should be followed and related to the modulus values as follows.

For flexible pavement design, the minimum modulus value of 150,000 psi corresponds to a base course equivalency factor of 1.2, and the maximum value of 400,000 psi corresponds to a base course equivalency factor of 1.6 (paragraph 36. b. in AC 150/5320-6). The choice of base course modulus value can have a significant effect on total thickness of a flexible pavement.

When a variable modulus layer is first created, the modulus is automatically set to the minimum value.

Undefined Layer

This layer type is included to allow the use of layers not covered by the most common structural materials and to investigate the effects of using new, or otherwise nonstandard, materials. Properties of the layer type are:

minimum modulus	= 1,000 psi
maximum modulus	= 4,000,000 psi
Poisson's ratio	= 0.35 (fixed)
minimum thickness	= 2 inches

There are no restrictions on placement of the undefined layer. If an undefined layer is the topmost layer of a pavement structure, either the new flexible or an asphalt overlay pavement design procedure is automatically selected, depending on the composition of the second layer. For flexible pavements, and using the **Life** option, this allows for computing estimated asphalt *CDF* values with asphalt modulus different than the fixed value of 200,000 psi. It is **very important** to recognize that flexible pavement thickness designs made with the top layer modulus value greater than

200,000 psi will result in nonconservative designs compared with the current FAA design procedure.

The modulus value for asphalt layers as a function of temperature can be estimated using the relationship (Witczak, M.W., Report II, **Asphalt Mixture Material Characterization**, University of Maryland, May 1989):

$$\text{Log}_{10}(E) = 1.53658 - 0.006447 T - 0.00007404 T^2$$

where E = asphalt modulus with units of 10^5 psi
and T = asphalt temperature in degrees Fahrenheit.

Rearranging gives:

$$E = 10^{(6.53658 - 0.006447 T - 0.00007404 T^2)} \text{ psi}$$

The design procedures executed when an undefined layer is present in one of the top two layers of a pavement structure are summarized below.

Top Layer	Second Layer	Design Procedure
Undefined	Asphalt Surface	Asphalt Overlay on Flexible
Undefined	Any Overlay	Not valid for design
Undefined	Any except the above	New Flexible
Asphalt Surface	Undefined	New Flexible
Asphalt Overlay	Undefined	Asphalt Overlay on Flexible

If a structure contains one or more undefined layers, the message "Non-Standard Structure" is displayed. Clicking on the message displays a longer message explaining why the structure is non-standard. The long message is also displayed in the **Design Info** text box in the **NOTES** window.

PAVEMENT THICKNESS DESIGN

General Design Procedure

Thickness designs can be made for two different types of pavement structure:

1. New flexible.
2. Bituminous overlay on existing flexible.

New flexible, and bituminous overlay on flexible pavements are designed with the following general procedure:

1. Create a structure, a design aircraft list, and set the design life.
2. Click **Design Structure** in the **STRUCTURE** window. This causes the thickness of a prescribed layer to be automatically adjusted by the program until the design criteria are satisfied.
3. Inspect the structure when the design program has stopped running and, if necessary, manually adjust the thickness of other layers in the structure and click **Design Structure** again. Repeat until the thickness design is satisfactory.
4. **Click Save Structure**. This permanently saves all the information for the new structure in the job file and marks the section as being a completed design.

The automatic adjustment of the thickness of the prescribed layer in step 2 is done as follows:

1. Calculate the maximum stress or strain at a layer interface in the structure for each aircraft in the design list.
2. Calculate the allowable number of aircraft departures to failure for each aircraft based on a defined relationship between allowable departures and stress or strain.
3. Find the ratio of actual departures to allowable departures for each aircraft. This is the *CDF* for each aircraft.
4. Add the aircraft *CDFs* together to find the *CDF* for the structure.
5. Adjust the thickness of the prescribed layer until structure $CDF = 1$. (Increasing thickness decreases *CDF*.)

Design for overlays on rigid pavements is generally similar in terms of structure definition, aircraft list selection, and program execution, but the design procedures require more steps because deterioration of the existing pavement is included. More details are given below for design of each of the different types of pavement structure.

New Flexible and Bituminous Overlay on Flexible

Subgrade vertical strain and horizontal strain at the bottom of the top layer are the design criteria for both pavement types. With the fixed default asphalt modulus value of 200,000 psi, horizontal strain only becomes the dominant criterion when the structure is very deep and is heavily loaded. Under these conditions the horizontal strain also has a tendency to increase as the pavement depth increases, the opposite of the trend for subgrade strain. Overlap of the *CDFs* can therefore occur and a proper design never realized. For these reasons, and to save run time, the subgrade strain is used to iterate to a subgrade *CDF* of one. Only one evaluation depth needs to be sent to Julea and the run time is approximately halved for deep, many layered, structures (compared to computing subgrade and asphalt strain each time). When the subgrade criterion has been satisfied, a final calculation is made to find the asphalt *CDF* (again using only one evaluation depth). If the structure is saved after design without making any modifications, the section data is marked as being a completed design and the asphalt *CDF* stored in the .JOB file section data record. The value of the asphalt *CDF* can be viewed in the **Design Info** text box in the **NOTES** window. One consequence of delaying asphalt *CDF* calculation until after satisfying the subgrade criterion is that the design continues to run after the displayed (subgrade) *CDF* has reached its terminal value. A message is displayed stating that asphalt *CDF* is being computed. The value of asphalt *CDF* is displayed when the computation is complete.

For new flexible design, the thickness of the layer next to the subgrade is adjusted to make the subgrade *CDF* approximately equal to one. The current error control is that the design will terminate when *CDF* is in the range 0.995 to 1.005. If the layer next to the subgrade becomes thinner than its specified minimum thickness, the thickness of the layer above is halved, or set at its minimum thickness, and the procedure continued. If the *CDF* is less than one with both of the adjusted layers at their minimum thickness, the *CDF* is displayed and the design terminated. This procedure is not intended to “optimize” a design. It is intended only to protect from inappropriate input data.

For overlay design, the thickness of the top layer is adjusted to make the subgrade strain *CDF* equal to one. The procedure is also terminated, with a message, if the top layer becomes thinner than its minimum thickness.

The failure model used to find the number of coverage to failure for a given vertical strain at the top of the subgrade is:

$$N = 10^4 \times \left(0.001347 + 0.000061 \times \log_{10} \left(\frac{E_{SUB}}{1000} \right)^{3.662532} \times \left(\frac{\epsilon_v}{1000} \right)^{9.386383} \right)$$

where:

N = number of coverage's to failure

E_{SUB} = subgrade modulus, psi

ϵ_v = vertical strain at the top of the subgrade

Subgrade modulus is included in the equation for subgrade failure and has the effect of decreasing the number of coverage's to failure, for any given strain, as the modulus value decreases. This is intended (reference 1) to simulate the effects of the increasing degree of plasticity generally encountered as soil strength decreases.

The failure model used to find the number of coverage's to failure for a given horizontal strain at the bottom of the surface asphalt layer is:

$$\log_{10}(N) = 2.68 - 5 \times \log_{10}(\epsilon_h) - 2.665 \times \log_{10}(E_A)$$

where:

N = number of coverage's to failure

E_A = asphalt modulus, psi

ϵ_h = horizontal strain at the bottom of the surface asphalt layer

Evaluation of Overload Situations

In LEDGA overload situations can be evaluated for pavements whose current CDF is less than or equal to 0.9 ($CDF \leq 0.9$). If the current CDF does not satisfy this condition, LEDGA will not allow for overload computations.

Overload situations can be evaluated by selecting an overload aircraft from the available aircraft library. To change the overload status of the aircraft, click on the Overload Aircraft column. Then, change the weight and the number of annual departures to comply with requirements. Note that the annual departures will be used as the total departures when computing CDF in overload situations.

When the **Life** button is clicked, LEDGA will process two CDF computations. One for normal GA fleet, and the second for the overload aircraft. The total CDF is then displayed. The user can then decide the pavement can handle this overload.

RUNNING THE PROGRAM

Solution Times

The execution time required to design a structure is almost completely dependent on the floating point performance of the computer when performing the layered elastic strain and stress calculations. Execution time is roughly proportional to the total number of “design” wheels for all of the aircraft in the design list, and is proportional to a small power of the number of layers in the structure. (The inner loop in JULEA consumes almost all of the solution time.) The next most important factor is disk access time, but this mainly affects the response of Windows when performing other tasks while a design is in progress and not the total solution time.

The most effective strategy for reducing solution times is to use an abbreviated aircraft list, consisting of the most damaging aircraft, to produce a first approximation to the pavement design. The full aircraft design list can then be used to finalize the design.

Thick aggregate layers increase the solution time more than would be expected because of the sublayering used to represent variation of modulus with depth.

Options

A batch option has been included in the program so that a number of time consuming designs can be executed unattended. The option is activated by double clicking anywhere on the gray background of the structure window. A check box appears which, when clicked, changes the caption of the Life button to Batch. The first section to be designed is then selected and Batch clicked. Each section in the list starting at the one selected to the last will then, in turn, be designed and the results stored in the .JOB file. The “already designed” and “saving structure” messages are suppressed. However, if any other message, such as “minimum thickness for a layer,” is displayed, the batch job will halt until the message is cleared. The results can be viewed in the **NOTES** window after the batch job has finished.

If a lengthy design computation is underway, a second instance of LEDGA can be started from Program Manager and section data edited. Design computation is only allowed from the first instance of the program because JULEA cannot be run from two programs at once. Alternatively, any other application can be run from Windows while a design is in progress. The elapsed time window will always remain on top of the desktop so that the progress of the design can be monitored.

Copying to the Clipboard

In addition to copying the design and notes information to the clipboard from the **NOTES** window, any of the program windows can be copied to the clipboard as a bitmap using the Windows Alt-PrintScreen function. The bitmap can then be pasted into another application and printed or saved. First make sure that the window to be copied is the active window by clicking the mouse within the window area. Then hold down the Alt key and press the PrintScreen key. If the window is not copied to the clipboard, check your computer documentation for the equivalent function.

The picture of the structure in the **STRUCTURE** window can also be copied to the clipboard by placing the mouse pointer within the area of the picture and clicking the right mouse button. Similarly, the picture of the gear layout in the **AIRCRAFT DATA** window can be copied by right clicking on the picture.

DATA FILES

Communication Files

Information is passed to and from JULEA in the following data files:

1. JULEA.STR
2. JULEA.LOA
3. JULEADAT.OUT
4. JULEASG.OUT
5. DAMTMP.DAT
6. DAMTMPSG.DAT

JULEA.STR and JULEA.LOA are structure and aircraft data files written by LEDGA for input to JULEA each time JULEA is executed. They are ASCII files in exactly the same format as used in the LEDNEW collection of programs. The data can be examined in a text editor if more detail is required than given in the LEDGA windows.

JULEADAT.OUT and JULEASG.OUT are ASCII files written by JULEA and have exactly the same format as used in the LEDNEW collection of programs. They contain all of the structure, aircraft, stress, and strain data read or produced by JULEA. Stresses and strains are given for each evaluation point for each aircraft in the traffic mix. Principal and octahedral stresses are included. For rigid pavements, only JULEADAT.OUT is written. For flexible pavements, JULEASG.OUT contains the data for stresses and strains computed at the top of the subgrade, and JULEADAT.OUT contains the data for stresses and strains computed at the bottom of the asphalt layer. The files are overwritten each time JULEA is executed.

DAMTMP.DAT and DAMTMPSG.DAT are written by JULEA and contain the stresses or strains used by LEDGA to compute *CDF*. For rigid pavements, DAMTMP.DAT contains the maximum principal stress at the bottom of the concrete slab for each aircraft in the mix. (These are interior stresses and are transformed to equivalent edge stresses by LEDGA before computing *CDF*. The relative magnitudes of the stresses in DAMTMP.DAT for different aircraft are therefore not a reliable indication of the relative stress levels used in the design procedure.) For flexible pavements, DAMTMPSG.DAT contains the vertical strains at the top of the subgrade and DAMTMP.DAT contains the horizontal strains at the bottom of the surface asphalt layer.

If data in any of these files needs to be stored permanently, it should be copied to a new file immediately after a design has been completed.

Storage Files

Permanent information for layered elastic design is stored in *.JOB and *.NTS files. *.JOB files contain all of the data required by LEDGA for all of the sections in one job. *.NTS files contain user entered information not needed by LEDGA but which may be useful in identifying features of the pavement sections, tracking design history, etc. Both are ASCII files and can be read by other applications if necessary.

*.JOB File Format

```

0          1          2          3          4          5          6
0123456789012345678901234567890123456789012345678901234567890
Format#
SectionName
    Date      Time          DateTime          ACCDF
Life      0.00  100.00  NL  NA
    Thick(1)  Modulus(1)   LC(1)
    Thick(2)  Modulus(2)   LC(2)
    Thick(3)  Modulus(3)   LC(3)
    Thick(I)  Modulus(I)   LC(I)
    Thick(NL) Modulus(NL)  LC(NL)
ACName(1)          GL(1)  Rps(1)  %Growth(1)
ACName(2)          GL(2)  Rps(2)  %Growth(2)
ACName(J)          GL(J)  Rps(J)  %Growth(J)
ACName(NA)         GL(NA) Rps(NA) %Growth(NA)
Blank Line (for expansion)
Blank Line (for expansion)
Next set of section data, starting with the name

```

Explanation of *.JOB File Field Names

Format# = File format identifier; Type = string; current = "Format3"
SectionName = section name; Type = string
Date = date of completed design; Type = string; Format = XX/XX/XX
Time = time of completed design; Type = string; Format = XX:XX:XX
DateTime = date and time of completed design in VB format;
 Type = double precision real
 Field Width = 20

Note: When a design has not been completed for the section,
Date = 11/01/71, Time = 00:00:00, DateTime = 26238

Name	Description	Type	Field Width
ACCDF	Asphalt Layer <i>CDF</i>	Real	12
Life	Design Life	Integer	4
NL	Number of Layers	Integer	4
NA	Number of Aircraft	Integer	4
Thick(I)	Thickness of Layer I	Real	12
Modulus(I)	Modulus of Layer I	Integer	12
LC(I)	Layer Code for Layer I	Integer	8
ACName(J)	Aircraft Name for Aircraft J	String	21
GL(J)	Gross Load for Aircraft J	Integer	9
RPS(J)	Annual Repetitions for Aircraft J	Integer	8
%Growth(J)	Percent Annual Growth for Aircraft J	Real	12

Example of a *.JOB File with 2 Sections

Format3

ACAggregate

```
05/13/99 12:00:01          26238    0.000000
  20    0.00  100.00    3    4
      4.5000      200000    1
      10.0000      75000    6
      0.0000      10000    4
Sabreliner 65          24000    25    0.000000
Citation 550B          15000    130    0.000000
King Air B100          11500    50    0.000000
Stationair 206          3612    125    0.000000
```

NewFlexible

```
05/13/99 12:00:01          26238    0.000000
  20    0.00  100.00    4    4
      2.0000      200000    1
      2.0000      400000    14
      8.0000      40000    8
      0.0000      10000    4
Citation VII          23200    10    0.000000
Learjet 35A/36A          15000    40    0.000000
DC-3                    25200    10    0.000000
Falcon 2000            35000    20    0.000000
```

Layer Codes

- 0 = Undefined
- 1 = P-401 Asphalt Surface
- 2 = Not Used
- 3 = Not Used
- 4 = Subgrade
- 5 = Not Used
- 6 = P-209 Crushed Aggregate Base Course
- 7 = Not Used
- 8 = P-154 Subbase Course (uncrushed aggregate)
- 9 = Variable Stabilized Base (flexible)
- 10 = P-401 Asphalt Overlay
- 11 = Not Used
- 12 = Not Used
- 13 = Not Used
- 14 = P-401 Stabilized Base (flexible)
- 15 = Not Used
- 16 = Not Used
- 17 = Not Used

*.NTS File Format

*.NTS files contain user entered information about sections in a job stored as strings. The format consists of a sequential list of each section name, the length of the notes string for that section, followed by the notes string. A Visual Basic routine to read the data for a specified section (ISECT) in a *.NTS file is as follows:

```
NFNo = FreeFile
Open FileName$ For Input As #NFNo

For I = 1 To ISect
    Line Input #NFNo, S$      ' Section name.
    Input #NFNo, SLen        ' Length of NotesString.
    NotesString$ = Input$(SLen, #NFNo)
    Input #NFNo, SS$         ' Get CRLF.
Next I
```

```
Close NFNo
```

All data in the notes for section ISect is left in the string NotesString\$.

OVERLOAD EXAMPLE

Introduction

The following example was intended to give the user a guideline of how an overload situation can be handled by General Aviation airport administrator. In this example, it is assumed that an external job files has not been created and the design is started from the internal Samples job. Further design examples can be found on LEDFAA's Design Examples section in the users guide.

The following traffic mix will be used in the example. The aircraft in this list were obtained from traffic information provided by NCDQA. In addition, the military aircraft C-130 will be used as the overload aircraft.

Aircraft	Gross Weight, lbs.	Annual Departures
Sabreliner 65	24,000	25
Citation 550B	15,000	130
King Air B100	11,500	50
Citation V	16,500	200
Super King Air 300	14,100	250
King Air C-90	9,710	100
Beech Jet 400A	16,300	220
C-130 (OVERLOAD)	155,000	1

Percent annual growth is assumed to be zero in all of the examples. Also, layer thickness results are all given to 1 decimal place. Rounding would be done before writing the final design specifications.

AC on Aggregate Example

On this example we will use a pavement structure similar to actual structures in General Aviation airports in North Carolina. The sample pavement structure will be the following:

Material	Thickness, (in)	Modulus (psi)
P-401 AC Surface	2.50	200,000
P-209 Cr Ag	8.00	29,146
Subgrade	CBR=10.0	10,000

When LEDGA is first started, the **STARTUP** window is displayed and, if there are no external .JOB files, a message is displayed stating that there are no job files in the working directory.

1. Clear the message by clicking **OK** and press the **New Job** command button.
2. Enter a name for the new job in the displayed dialog box and click **OK**.
3. Reselect the Samples job by clicking on its name in the left-hand list box.
4. Select the asphalt on aggregate sample section in the right hand list box by clicking on the ACAggregate section name.
5. Hold down the left mouse button and drag the ACAggregate section new to the new job name on the left list.
6. Release the left mouse button.
7. Select the new job file in the left hand list box and double click on the section name in the right hand list box (or click **Structure**) to transfer to the **STRUCTURE** window.

The asphalt on aggregate pavement structure from the Samples job will be displayed after transfer to the **STRUCTURE** window. Before we can proceed, the structure should be change to reflect our sample structure. To make the changes double click on the thickness window on the first two layer in the structure.

After this has been completed we need to modify the traffic information for our sample structure. To do this we must enter the **AIRCRAFT** window:

1. Click **Aircraft** to transfer control to the **AIRCRAFT** window.
2. Click **Clear List** and answer **Yes** in the displayed message box. All aircraft stored in the new flexible section of the Samples job will be deleted from the table of design aircraft.
3. Select one of the aircraft groups in the top left hand list box to display the aircraft contained in that group in the lower left hand Library list box.
4. Select the first aircraft in the group to be added to the table of design aircraft by clicking on its name in the library list. Transfer the aircraft to the table by clicking **Add**. (Double clicking the name will also transfer the aircraft.)
5. "Default" values of gross weight, annual departures, and percent annual growth will be displayed in the table. Any of these values can be changed within a specified range by clicking on the number in the table. An input box is displayed which also gives the default value and the range within which a new value can be entered. Enter the new value and click **OK**.
6. Select the rest of the aircraft to be added to the design aircraft table from the group one at a time and change the default data values as required. If a mistake is made and the wrong aircraft added to the table, the aircraft can be removed by selecting its name and clicking **Remove** (or by double clicking its name).

7. Repeat the process for each group until all aircraft in the traffic mix have been added to the table except for the overload aircraft; in this case the C-130 which will be enter later.
8. Click **Save List** and answer **OK** to the displayed message.
9. Click **Back** to return to the **STRUCTURE** window.

We will first calculate the CDF for normal conditions. That is, we will only use the GA fleet to accomplish to calculate the structural life of our sample pavement section. To do this, click on the **Life** button. The following screen will be displayed:

LEDGA - Modify and Design Section ACAggregate in Job ERASEME

Section Names
ACAggregate

ERASEME ACAggregate Des. Life = 20

Layer Material	Thickness (in)	Modulus (psi)
P-401 AC Surface	2.50	200,000
P-209 Cr Ag	8.00	29,146
Subgrade	CBR = 10.0	10,000

Life Stopped
-2093.06; 368.53

Aircraft

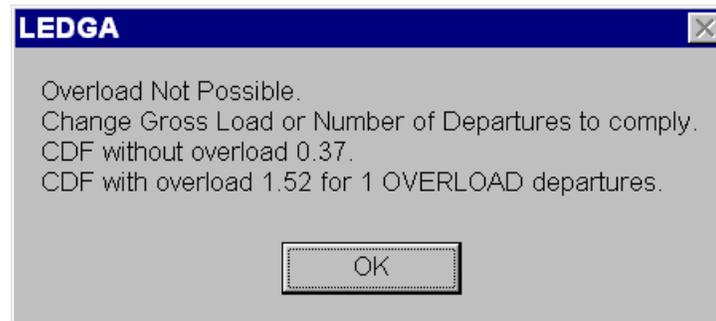
Sub CDF = 0.37; Str Life (SG) = 54.263 yrs; t = 10.50 in

Back Help Life Modify Structure Design Structure Save Structure

From this screen we can see that the current CDF is 0.37, and the structural life is 54.26 years. Since the CDF is less than 0.9 we can evaluate an overload situation. To do this follow the steps above and add a C-130 to the traffic list making sure you do the following:

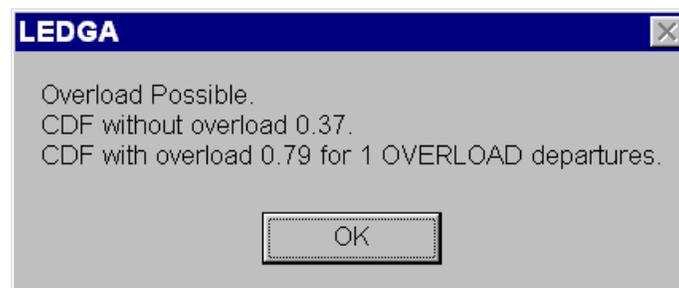
1. Change the annual departures to 1. We will evaluate the effect of one C-130 aircraft as an overload.
2. Change the value in the column Overload Aircraft to True by click on it. A message will be displayed indicating that the annual departures will be used as the total departures when computing the CDF.

- Return to the structure window and click on the **Life** button. The following message will be displayed:



This screen tells us that under the condition specify in the traffic window overload is not possible. However, we can change the gross load and/or the number of departures to see the overload can be accommodated. Do the following:

- Return to the traffic window by clicking on the **Aircraft** button.
- Click on the Gross Taxi Weight column for the C-130 and enter 130,000.
- Return to the **Structure** window by clicking the **Back** button.
- Click on the **Life** button. The following message will be displayed:



This message tell us that overload is possible under the new conditions. Note that overload is possible only for one overload aircraft as it appear in the traffic mix. Different situations can be evaluated for different pavement structures

Although our example was successful, the pavement engineer should make the decision if a CDF of 0.79, as in our example, is acceptable or not. LEDGA can only be used as a tool to aid the engineer in this final decision.