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Flexible Airfield Pavement Design Using Layered Elastic Design Federal Aviation Administration (LEDFAA)

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ABSTRACT

The conventional empirical methods for structural design of flexible aircraft pavements were adapted from highway practice, then modified and extrapolated to cater for the airfield situation. The layered elastic method was introduced into design practice in the mid-1990; with the release of the computer program LEDFAA by the U.S. Federal Aviation.

ICAO's Aircraft Classification Number (ACN) indicates an aircraft's pavement damaging effect relative to other aircraft. ICAO's ACN method cannot give the design for airfield pavement. For proper design of airfield pavement design, we have to use the mechanistic approach. LEDFAA software is based on mechanistic methodology. This paper gives the idea regarding this software and gives one airfield pavement design example.

INTRODUCTION

Most current procedures for flexible airport pavement design and analysis, in particular the Federal Aviation Administration (FAA) design method and the International Civil Aviation Authority (ICAO) system for aircraft load classification, have their origins in the empirical CBR thickness method originally developed for highways. The procedures involve simplifying assumptions that were necessary for manual calculation, but which are no longer justified given the availability of desk-top computers. The major simplifications are related to the use of single layer elastic theory, the pass-to-coverage ratio to address aircraft wander, and the deflection-based Equivalent Single Wheel Load (ESWL) concept for multi wheel aircraft gear.

The empirical CBR method of pavement thickness design relates ESWL, pavement thickness and subgrade CBR. It uses single layer analysis so has no direct mechanism for crediting bound layers for their superior load spreading characteristics. Thick bound layers are increasingly used, however, and are required by airport authorities such as the FAA. Bound layers are typically accounted for within the empirical design by using layer equivalency factors based largely on elastic layer theory. The CBR method assumes a failure mode that consists of surface deformation (rutting) caused by overstressing the subgrade. Pavement failure due to fatigue cracking of the bituminous surfacing or cracking of other bound layers is not addressed by the method and must be separately considered by the designer.

Efforts by researchers have focused on the layered elastic method as that most likely to provide an adequate solution within the short time frame that is available. Elastic models with isotropic (same property values along all axes) layers have been used to compute maximum values of chosen damage indicators, most commonly subgrade strain, which are then related to pavement life (strain repetitions) by calibrating against full-scale trafficking tests. This calibration process seeks to faithfully translate the test pavement behavior to the design and analysis of new pavements. These commonly consist of materials and thicknesses that are different from the test pavements, and are trafficked by aircraft whose wheel configurations differ from those used in the tests.

LEDFAA

LEDFAA is now an FAA standard design method (FAA Advisory Circular 150/5320-16 of October 1995, which includes the LEDFAA User's Manual) and is used in parallel with FAA's traditional empirical CBR design method (FAA Advisory Circular 150/5320-6D of July 1995).

LEDFAA is not calibrated directly against the Corps data, but is conditioned by mandating certain input material properties to produce, for typical aircraft traffic mixes, similar pavement thicknesses to those obtained using the FAA conventional design method. (McQueen et al, 1997). For example, in order to better align the LEDFAA and FAA conventional thicknesses, asphalt surfacing is assigned a constant stiffness of 1380 MPa which is low for many cooler environments, especially for thick asphalt layers. FAA acknowledges that the conditioning of LEDFAA is a transitional measure to facilitate the smooth introduction of mechanistic design methods to pavement design practice. It is expected that the mandated modulus values will be modified over time towards more 'realistic' values as performance data becomes available, and as better methods are developed for determining material properties. LEDFAA produces pavements that are, on average, 3% thicker than the FAA conventional method. They are thicker for CBRs less than 5% and thinner for CBRs higher than 15% (McQueen et al, 1997).

LEDFAA processes traffic differently to the FAA conventional method. It retains the coverage concept but computes, for each aircraft, the number of coverages applied to each 10 inch wide strip of pavement. The lateral traffic distribution is fixed at taxiway wander and cannot be varied by the user. The total damage caused by all the aircraft expected to use the pavement is obtained by summing (using Miner's Law) the damages for the critical strip. In this way LEDFAA recognizes that the landing gears of the various aircraft in the design traffic mix track along different paths relative to pavement centreline. This contrasts with the way in which the current FAA design method combines the effects of a mix of aircraft.

The method requires that the departures of each aircraft be first converted into an equivalent number of departures of the 'Design Aircraft'. The Design Aircraft is selected from the traffic mix as the aircraft which, due to its size and number of departures, would require the thickest pavement. The departures of all the other aircraft are then converted to equivalent departures of the Design Aircraft using a prescribed approximate method. The pavement is then designed for the total equivalent departures of the Design Aircraft only, using its pass-to-coverage ratio. This procedure was devised prior to the ready availability of computers in order to reduce the computational load. The FAA method in effect sums the maximum damage caused by each aircraft even though they track along different parts of the taxiway relative to the pavement centerline. This is a conservative procedure, to a degree that depends upon the composition of each traffic mix.

A further distinction between the conventional FAA and LEDFAA's method of treating traffic is that the pass-to-coverage ratios are different. FAA's are based on the overlap of tyre contact areas at the pavement surface whereas LEDFAA considers the overlapping effects of a wider 'effective' tyre width at subgrade level and also considers depth to subgrade relative to axle spacing when deciding the number of effective strain repetitions. However, because LEDFAA computations are framed in terms of aircraft departures rather than coverages, the pass-to-coverage ratios used are not accessible to the user.

LEDFAA SOFTWARE

Design information is entered by means of two graphical screens, one for the structure and one for the traffic. Default values and ranges for the various input parameters have been set so that the designs produced by LEDFAA are compatible with designs produced by the design procedures. Here some initial information about LEDFAA is given. Figure No. 1 showing the initiation of this software, which indicate the structural graphical screen. Generate the new job and modify that structure as we required. California Bearing Ration (CBR) value of subgrade and traffic mix is necessary for airfield pavement design.

Working Directory (Click to change): C:\Program Files (x86)\Ledfaa13\

Figure No.1 LEDFAA Screenshot showing Initiation of design Software

DESIGN WITH LEDFAA SOFTWARE

CBR value of soil subgrade is taken as 8. Traffic mix also required for airfield pavement design. Table no. 1 indicates aircraft traffic details for particular airport.

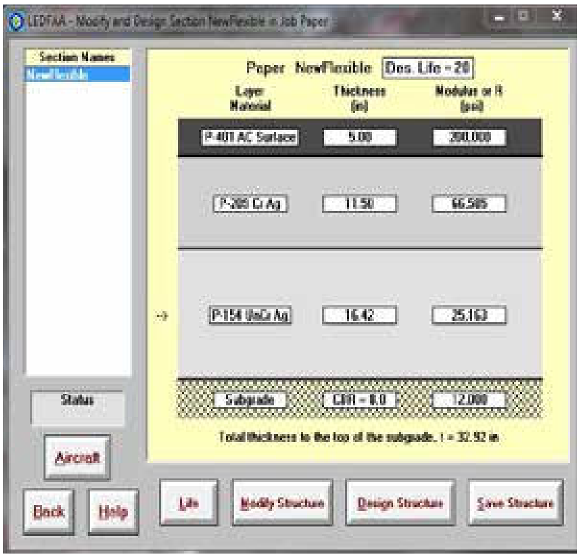
Aircraft	MSTOW (kg)	Movements
B-737-800	78,290	2000
MD-83	73,094	5000
DC-9-32	49,486	1500
A-320	68,100	4000
C-130	70,370	1000

Table No.1 Aircraft traffic mix details

After the completion of data input process, click on the "Design Structure" button. After this step we get final thickness design of airfield pavement with (Cumulative Damage Factor) CDF. The following pavement structure is used for airfield pavement design by LEDFAA summarized in Table no. 2. Figure no. 2 indicates the final airfield pavement design. It gives layer thickness of surface, base and subbase course.

Material	Thickness
Asphaltic concrete (P-401)	127
Base course (crushed rock, P209)	292
Subbase (uncrushed gravel, P154)	417
Subgrade: E (MPa) = 10.0 x CBR	

Table No. 2 Material selection details



Paper NewFlexible Des. Life = 20

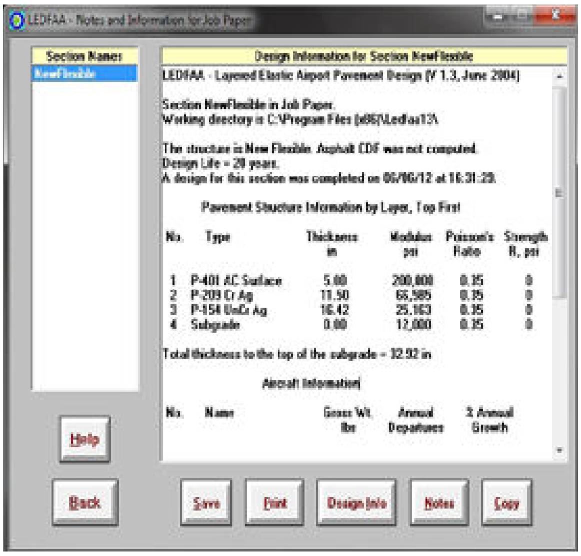
Layer Material	Thickness (in)	Modulus or R (psi)
P-401 AC Surface	5.00	200,000
P-209 Cr Ag	11.50	66,585
P-154 UnCr Ag	16.42	25,163
Subgrade	CBR = 8.0	12,000

Total thickness to the top of the subgrade, t = 32.92 in

Figure No. 2 LEDFAA screenshot showing final thickness design

The pavement consisted of a 127 mm asphalt surface course over a 292 mm crushed rock base course over 417 mm uncrushed gravel subbase. Realistic modulus and Poisson's ratios were assigned to the pavement materials and subgrade.

Figure 3 indicates notes and information of job. All information like thickness design, traffic, Cumulative damage factor (CDF), Poisson's ratio, modulus are included in this note.



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Design Information for Section NewFlexible
LEDFAA - Layered Elastic Airport Pavement Design (V 1.3, June 2004)

Section NewFlexible in Job Paper.
Working directory is C:\Program Files (x86)\Ledfaa13\

The structure is New Flexible. Asphalt CDF was not computed.
Design Life = 20 years.
A design for this section was completed on 06/06/12 at 16:31:29.

        Pavement Structure Information by Layer, Top First

 No.   Type                 Thickness   Modulus   Poisson's   Strength
                               in         psi       Ratio      R, psi

  1   P-401 AC Surface        5.00      200,000     0.35         0
  2   P-209 Cr Ag            11.50       66,585     0.35         0
  3   P-154 UnCr Ag          16.42       25,163     0.35         0
  4   Subgrade                0.00       12,000     0.35         0

Total thickness to the top of the subgrade = 32.92 in

               Aircraft Information

 No.   Name                 Gross Wt.    Annual     % Annual
                               lbs      Departures   Growth
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Figure No. 3 LEDFAA screenshot of Notes and information for job

CONCLUSION

LEDFAA functions as an FAA design standard intended for use in parallel with FAA's conventional empirical design method. To facilitate the introduction of the new 'mechanistic' methodology into design practice LEDFAA was conditioned to produce similar pavement thicknesses to the older method by mandating the properties assigned to materials.

The ICAO ACN rating system uses the conventional empirical design method and predicts damage by the B777 and NLAs that appears to be unrealistically high for low strength subgrades relative to that caused by the B747. This situation is not resolved, however, by the introduction of ‘mechanistic’ methods based on layered elastic analysis.

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