# Parametric Sensitivity Analysis for the FAA's Airport Pavement Thickness Design Software LEDFAA-1.3

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ABSTRACT: LEDFAA-1.3 is a computer program for airport pavement thickness design. It implements layered elastic theory based design procedures developed under the sponsorship of the Federal Aviation Administration (FAA) for new and overlay design of flexible and rigid pavements. The layered elastic procedures, as implemented in the program, are the FAA airport pavement thickness design standards referenced in Chapter 7 of Advisory Circular AC 150/5320-6D, change 3. The core of the program is Leaf, a layered elastic computational program implemented, in this case, as a Microsoft Windows™ ActiveX dynamic link library written in Visual Basic™ 6.0. Pavement thickness design needs many input parameters and different input parameters have different influences on the pavement life. Pavement life is insensitive to some parameters, a small change of the parameter has only limited effects on the pavement life; however, for other parameters, life is very sensitive to changes in their values; a small change will lead to significant change of the pavement life. Sensitivity analysis is a powerful tool to clarify, verify, quantitatively understand, and compare existing airport pavement design specifications. The results and findings of the study provide essential information in modifying and improving the existing specifications and developing new ones. Results from a parametric sensitivity analysis are presented in this paper. The findings are being used to modify and improve the existing FAA airport pavement thickness design models and in the development of the new FAA design models.

KEY WORDS: sensitivity analysis, airport, pavement, design, thickness, life.

## 1 INTRODUCTION

LEDFAA-1.3 is a computer program for airport pavement thickness design. It implements layered elastic theory based design procedures developed under the sponsorship of the Federal Aviation Administration (FAA) for new and overlay design of flexible and rigid pavements. The layered elastic procedures, as implemented in the program, are the FAA airport pavement thickness design standards referenced in Chapter 7 of Advisory Circular AC 150/5320-6D (FAA 2003). The core of the program is LEAF, a layered elastic computational program implemented, in this case, as a Microsoft Windows™ ActiveX dynamic link library written in Visual Basic™ 6.0. The remainder of the program is written in Visual Basic™ and operates under Microsoft Windows™. LEAF is loaded and executed by LEDFAA when needed and is not visible to the user.

Pavement design is a stochastic process. The thickness design and resultant pavement life can be significantly affected by the choice of the design inputs. Since it is impossible to precisely define the absolute value of the primary design variables, there is always inherent uncertainty concerning the robustness of the design. This study discusses the sensitivity of the design inputs to computed pavement thickness and resultant pavement life for existing design models for airport pavements contained in LEDFAA-1.3.

## 2 CONCEPT OF SENSITIVITY AND RELATED FORMULAE

A sensitivity study is a powerful tool to clarify, verify, quantitatively understand, and compare existing airport pavement design specifications. This tool was used in developing the computer program LEDFAA (FAA 1995). In 1995, a sensitivity study (McQueen et. al. 1995) was conducted to determine the input data for a model developed by WES, Corps of Engineers (Barker et. al. 1975, Parker et. al. 1979, and Rollings 1988) and made the design thickness comparable to those obtained by the FAA design procedure AC 150/5320-6C (FAA 1978). Two other FAA reports (Hayhoe et. al. 1994) have been drafted but not yet published. In these two reports, the concepts, derivation, and numerical results of the sensitivity for selected parameters in the FAA airport pavement design models up to 1994 were presented.

Each pavement design needs many input parameters. For a given set of structure and loading design conditions, different input parameters have different influences on the pavement life. For some parameters, pavement life is insensitive to changes in the parameters. But for other parameters; a small change can lead to a significant change in pavement life.

The sensitivity of pavement life, $L$, to any variable x is defined as

$$S_{x,L} = \frac{\partial L}{\partial x}\frac{x}{L} \qquad [1]$$

This equation is used for both hot mix asphalt (HMA) and Portland cement concrete (PCC) pavement sensitivity analysis. In some cases an analytic solution can be derived for equation 1. But, in most cases, an analytic solution is not available and numerical analysis becomes necessary to calculate the sensitivity of life to changes in $x$. In this case, the following approximate equation should be used:

$$S_{x,L} = \frac{\partial L}{\partial x}\frac{x}{L} \cong \frac{L[x+\Delta x]-L[x-\Delta x]}{2\times\Delta x}\times\frac{x}{L[x]} \qquad [2]$$

where $x$ is the value of the variable, $\Delta x$ is a small quantity that is significantly smaller than the value of $x$, and L($x+\Delta x$), $L(x,)$ and $L(x-\Delta x)$ are the values of $L$ at $x = x+\Delta x$, $x$ and $x-\Delta x$, respectively.

After values of $x$ and $\Delta x$ are selected for a parameter, $L(x+\Delta x)$, $L(x)$, and L($x-\Delta x$) can be calculated. Then the sensitivity can be calculated by substituting the results into equation 2.

A positive value of $S_{x,L}$ indicates that the pavement life increases when $x$ increases, and a negative value indicates that the pavement life decreases when $x$ increases. A high magnitude of $S_{x,L}$ indicates that $x$ is sensitive to $L$, no matter if it is positive or negative. The above definition of sensitivity is a non-dimensional quantity; therefore, it is independent of the unit of any variable and makes the sensitivity of different variables comparable to each other.

From equation 1, the sensitivity is not only a function of the derivative of pavement life to the variable, it is also a function of the values of pavement life and the value of the variable. That is, the sensitivity varies with different pavement structures under different aircraft even if the pavement is designed using the same failure model. The effects of response model and failure model on pavement life are discussed in detail elsewhere (Garg 2004).

## 3 FLEXIBLE PAVEMENTS

Flexible pavement thickness design in LEDFAA-1.3 is based on vertical strain at the top of the subgrade. The number of coverages to failure is related to the subgrade strain as follows:

$$C = \left(\frac{0.004}{\varepsilon_v}\right)^{8.1} \quad \text{when } C \leq 12{,}100 \qquad [3]$$

$$C = \left(\frac{0.002428}{\varepsilon_v}\right)^{14.21} \quad \text{when } C > 12{,}100 \qquad [4]$$

where $C$ is the number of coverages to failure and $\varepsilon_v$ is the vertical strain at the top of the subgrade.

Subgrade vertical strain is computed in LEDFAA using elastic layer theory and is affected by the stiffness (modulus) and thickness of layers above the subgrade as well as the applied load. Equation 2 is used to compute the sensitivity of input parameters like subgrade CBR, P-401 HMA modulus, P-401 HMA thickness, P-209 base thickness, and the gross aircraft weight. The designations P-401, P-209, and P-154 are FAA standard specifications (FAA 1989) for the asphalt concrete surface, crushed stone base, and subbase respectively. The sensitivity of pavement life to changes in these parameters was studied for three pavement structures designed using LEDFAA for three types of subgrade—low strength (CBR-3), medium strength (CBR-8), and high strength (CBR-15). The aircraft mix (anticipated at John F. Kennedy International Airport (JFK)) used for the pavement design is shown in Table 1.

Table 1. Aircraft mix used for flexible pavement design.

| No. | Aircraft | Gross Weight, tonnes (lbs) | Annual Departures | % Annual Growth |
|---|---|---|---|---|
| 1 | A300-600 | 170.505 (375,900) | 3,838 | 0 |
| 2 | A320 | 73.482 (162,000) | 15,101 | 0 |
| 3 | A330 | 229.971 (507,000) | 1,015 | 0 |
| 4 | B-757 | 122.47 (270,000) | 7,544 | 0 |
| 5 | B-737-800 | 79.016 (174,200) | 1,561 | 0 |
| 6 | B-747-200 | 377.842 (833,000) | 2,207 | 0 |
| 7 | B-747-400 | 395.986 (873,000) | 8,519 | 0 |
| 8 | B-767-200 | 151.953 (335,000) | 6,178 | 0 |
| 9 | B-767-300ER | 185.519 (409,000) | 9,635 | 0 |
| 10 | B-777-200 | 286.897 (632,500) | 3,111 | 0 |
| 11 | Concorde | 185.973 (410,000) | 406 | 0 |
| 12 | Fokker F100 | 45.359 (100,000) | 12,117 | 0 |
| 13 | DC-9-32 | 54.885 (121,000) | 569 | 0 |
| 14 | DC-9-51 | 54.885 (121,000) | 488 | 0 |
| 15 | A340-500/600 | 340.194 (750,000) | 2,441 | 0 |
| 16 | A340-500/600 Belly | 340.194 (750,000) | 2,441 | 0 |
| 17 | A380-800 | 607.814 (1340,000) | 5,475 | 0 |
| 18 | B-747-SP | 315.7 (696,000) | 3 | 0 |
| 19 | DC-8 | 162.386 (358,000) | 504 | 0 |
| 20 | MD-11 | 281.681 (621,000) | 3,315 | 0 |
| 21 | MD-11 Belly | 281.681 (621,000) | 3,315 | 0 |

Figure 1 shows the pavement designs for the three subgrade types. Table 2 and Figure 2 summarize the results from the sensitivity analyses.

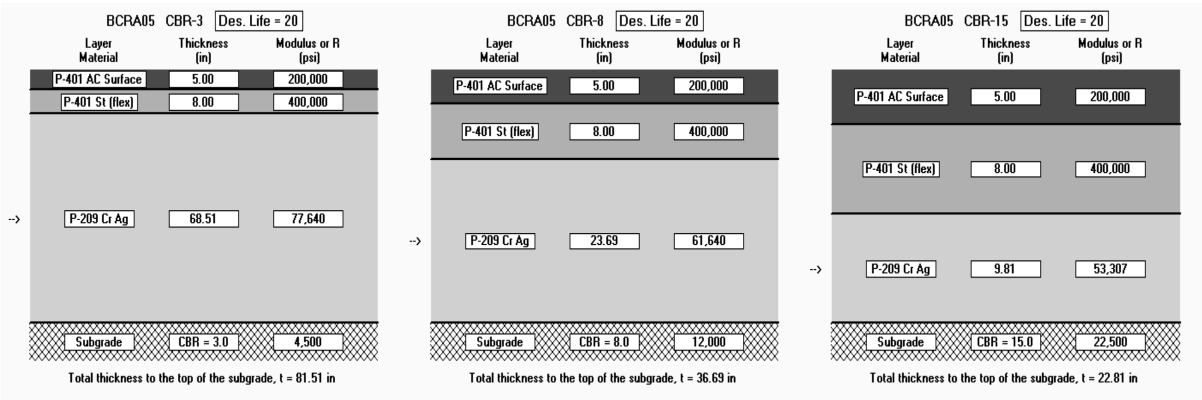


Figure 1. Flexible pavement sections used for sensitivity analyses.

Table 2. Results from sensitivity analyses for flexible pavements.

| CBR | x | Δx | x-Δx | x+Δx | L(x) | L(x+Δx) | L(x-Δx) | $S_{x,L}$ |
|---|---|---|---|---|---|---|---|---|
| *SENSITIVITY TO SUBGRADE CBR* | | | | | | | | |
| 3 | 3 | 0.3 | 2.7 | 3.3 | 20 | 52.8 | 6.9 | 11.4750 |
| 8 | 8 | 0.8 | 7.2 | 8.8 | 20 | 56.8 | 6.3 | 12.6250 |
| 15 | 15 | 1.5 | 13.5 | 16.5 | 20 | 49.9 | 7.3 | 10.6500 |
| *SENSITIVITY TO AC MODULUS (ksi)* | | | | | | | | |
| 3 | 200 | 20 | 180 | 220 | 20 | 21 | 19 | 0.5000 |
| 8 | 200 | 20 | 180 | 220 | 20 | 22.1 | 17.9 | 1.0500 |
| 15 | 200 | 20 | 180 | 220 | 20 | 24.1 | 16.4 | 1.9250 |
| *SENSITIVITY TO AC THICKNESS (inch)* | | | | | | | | |
| 3 | 5 | 0.5 | 4.5 | 5.5 | 20 | 22 | 18.2 | 0.9500 |
| 8 | 5 | 0.5 | 4.5 | 5.5 | 20 | 25.2 | 15.9 | 2.3250 |
| 15 | 5 | 0.5 | 4.5 | 5.5 | 20 | 31.5 | 12.5 | 4.7500 |
| *SENSITIVITY TO P-401 STABILIZED BASE THICKNESS (inch)* | | | | | | | | |
| 3 | 8 | 0.16 | 7.84 | 8.16 | 20 | 20.9 | 19.2 | 2.1250 |
| 8 | 8 | 0.16 | 7.84 | 8.16 | 20 | 21.8 | 18.2 | 4.5000 |
| 15 | 8 | 0.16 | 7.84 | 8.16 | 20 | 24.1 | 16.6 | 9.3750 |
| *SENSITIVITY TO P-209 THICKNESS (inch)* | | | | | | | | |
| 3 | 68.51 | 1.3702 | 67.1398 | 69.8802 | 20 | 25.4 | 15.1 | 12.8750 |
| 8 | 23.69 | 0.4738 | 23.2162 | 24.1638 | 20 | 23.9 | 16.7 | 9.0000 |
| 15 | 9.81 | 0.1962 | 9.6138 | 10.0062 | 20 | 23.1 | 17.7 | 6.7500 |
| *SENSITIVITY TO B-737 GROSS WEIGHT (lbs)* | | | | | | | | |
| 3 | 173,000 | 17300 | 155700 | 190300 | 20 | 7.5 | 88 | -20.1250 |
| 8 | 173,000 | 17300 | 155700 | 190300 | 20 | 8 | 83.8 | -18.9500 |
| 15 | 173,000 | 17300 | 155700 | 190300 | 20 | 9 | 74.9 | -16.4750 |
| *SENSITIVITY TO A-380 GROSS WEIGHT (lbs)* | | | | | | | | |
| 3 | 1,300,000 | 130000 | 1170000 | 1430000 | 20 | 6 | 83.4 | -19.3500 |
| 8 | 1,300,000 | 130000 | 1170000 | 1430000 | 20 | 5.5 | 84 | -19.6250 |
| 15 | 1,300,000 | 130000 | 1170000 | 1430000 | 20 | 6.3 | 72.5 | -16.5500 |

1-inch = 25.4 mm 1-lb = 0.454 kg

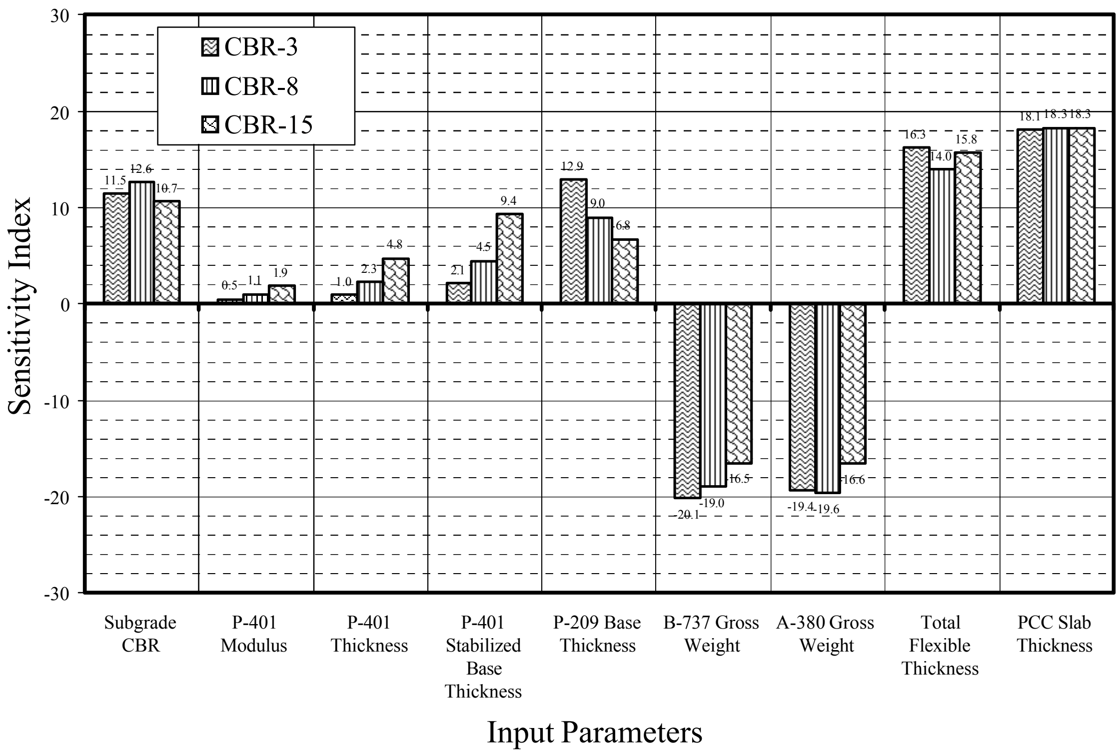


Figure 2. Summary of results from sensitivity analyses. All results are for the traffic in table 2 except those shown for the B-737 and A-380 aircraft.

3.1 Sensitivity of Pavement Life to Subgrade CBR. Subgrade CBR gave the highest sensitivity of all the material property input parameters in the design procedure. The sensitivity of pavement life to subgrade CBR is very similar at different strength subgrades.

3.2 Sensitivity of Pavement Life to HMA Modulus. Of all the parameters studied in the sensitivity analysis, HMA modulus gave the lowest sensitivity, as shown in Figure 2. The sensitivity of pavement life to HMA modulus increases with increase in subgrade strength (CBR).

3.3 Sensitivity of Pavement Life to HMA Thickness. Figure 2 shows that the sensitivity of pavement life to HMA thickness is higher than the sensitivity to HMA modulus, but comparatively lower when compared to other parameters studied. For pavements on the high-strength subgrade, the sensitivity of pavement life to HMA thickness was higher when compared to the low-strength subgrade.

3.4 Sensitivity of Pavement Life to P-401 Stabilized Base. Pavement life is more sensitive to P-401 stabilized base thickness than P-401 surface thickness and the sensitivity increases with increase in subgrade strength (CBR).

3.5 Sensitivity of Pavement Life to P-209 Base Thickness. Pavement life is more sensitive to P-209 base thickness when compared to HMA modulus and HMA thickness. Sensitivity decreases with increase in subgrade strength.

3.6 Sensitivity of Pavement Life to Aircraft Gross Weight. Two aircraft, one heavy A380 (gross weight 1,300,000 lb) and one light B-737 (gross weight 173,000 lb) were considered in the sensitivity analysis. Three pavements (one each on low-, medium-, and high-strength subgrade) were designed using LEDFAA 1.3 for each of the two aircraft, and the sensitivity of gross weight on pavement life was studied. The results are shown in Figure 2. Aircraft gross weight gave the highest sensitivity. Also, since the sensitivity is negative, it means that pavement life reduces with increase in aircraft gross weight.

3.7 Sensitivity of Pavement Life to Total Pavement Thickness. Sensitivity to total structure thickness above the top of the subgrade is shown in Figure 2 for the traffic mix of Table 1. The magnitude of sensitivity to total thickness is slightly less than for aircraft weight but of opposite sign. Therefore, changes in aircraft weight can be offset, to leave pavement life unchanged, by approximately the same proportional change in pavement thickness, except of opposite sign. Sensitivities of PCC slab thickness for a rigid pavement (discussed later) subject to the traffic mix of Table 1 are also shown in Figure 2 for comparison with the sensitivities to total thickness of the flexible pavement.

## 4 RIGID PAVEMENTS

Two types of sensitivities were studied in the sensitivity analysis for rigid pavement design. The first type considers only a failure model in which an explicit relation exists between the pavement life indicator (coverages) and the pavement failure indicator (design factor $R/\sigma$). $R$ is the flexural strength of the concrete and $\sigma$ is the working stress due to the applied load. Therefore, the closed-form solution of the sensitivity can be obtained. Since the failure models for pavement design are usually developed based on full-scale test results, the models are generally expressed as empirical equations. Therefore, the sensitivity is affected by the form of the equation being considered and the values of the parameters used in the model.

The second type of sensitivity was analyzed through the critical stress calculated using a specific response model (i.e., a mechanistic-based procedure). The sensitivity results are affected by both failure and response models. Since the critical response of a pavement is calculated with a computer program, the sensitivity is also calculated with the design program, and only numerical results are available.

4.1 Sensitivity of Design Factor R/σ. Since a closed-form equation exists between the design factor and the number of coverages, a closed-form solution of sensitivity of coverages to changes in the design factor $R/\sigma$ may be derived by using equation 1 for the design procedure in AC 150/5320-6D (edge stress computed using the Westergaard model).

$$S_{R/\sigma, COV} = \frac{Ln\ (10)}{\sqrt{1.3} \times 2 \times 0.15063} \times \sqrt{\frac{R}{\sigma}} \quad for \quad COV > 5000 \qquad [5]$$

$$S_{R/\sigma, COV} = \frac{Ln\ (10)}{\sqrt{1.3} \times 2 \times 0.07058} \times \sqrt{\frac{R}{\sigma}} \quad for \quad COV \leq 5000 \qquad [6]$$

Similarly, the closed-form solution of sensitivity based on the design procedure in LEDFAA is.

$$S_{R/\sigma, COV} = \frac{Ln\ (10)}{0.3881 + 0.000039 \times SCI} \times \frac{R}{\sigma} \qquad [7]$$

Figure 3 illustrates the relationship between sensitivity and design factor where structural condition index (SCI) has been set to a value of 80 in equation 7. SCI = 80 indicates the end of pavement structural life in the LEDFAA design procedure.

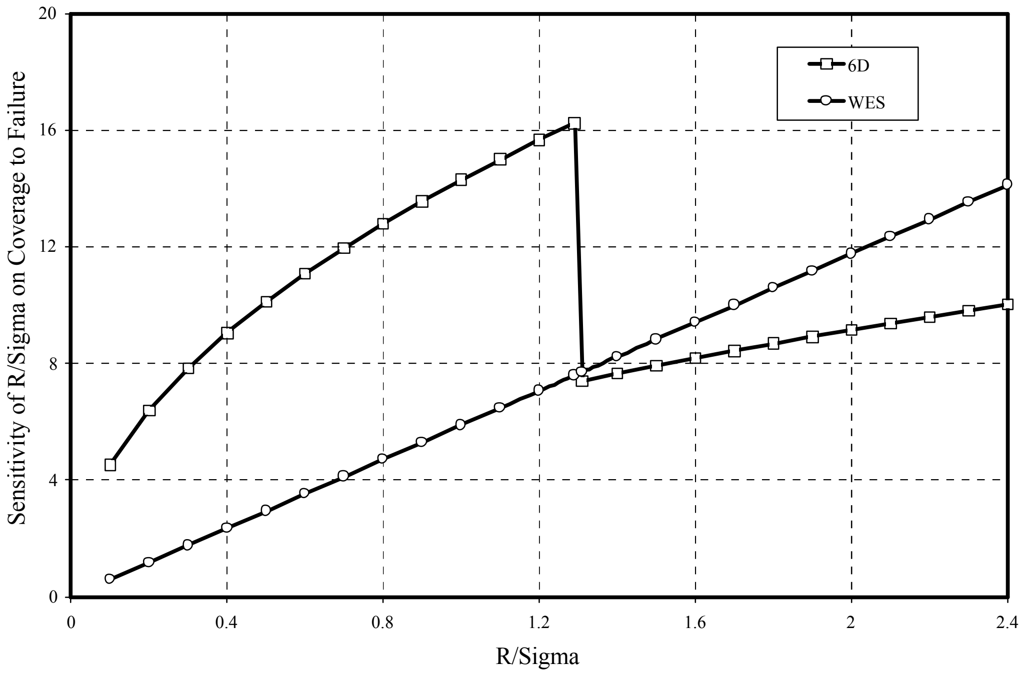


Figure 3. The sensitivities of design factor.

The two sensitivity curves of *R*/s (calculated from equations 5, 6, and 7) are presented in Figure 3. However, they are not completely comparable. The flexural strength *R* used in the two models follows the same standard test method ASTM C 78, but the critical stress s is calculated by using two different models: plate on dense liquid foundation in AC 150/5320-6D and an elastic multiple-layer system for the LEDFAA model.

Results for the two failure models are presented in Figure 4.

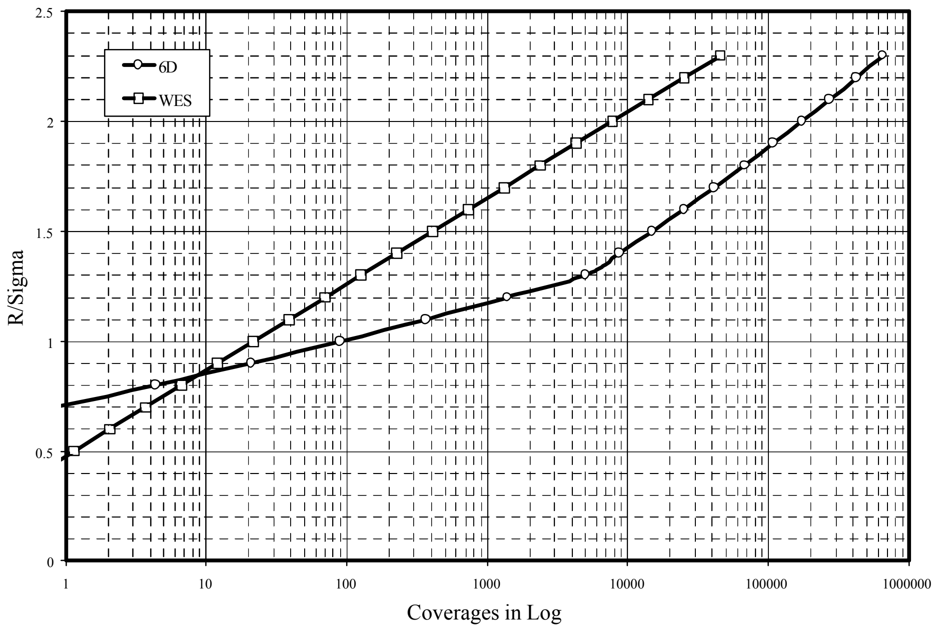


Figure 4. Failure models in AC 150/5320-6D and WES.

When the failure model of AC 150/5320-6D was developed, only four full test points were available for coverages > 5000. Unfortunately, for two of the test points the test pavement never failed. Therefore, 5000 coverages was selected as a point of intersection of two failure curves. One is for coverages lower than 5000, the other is for coverages higher than 5000. The second curve was probably selected because insufficient full-scale data were available at the time. Though two curves are used, the failure model still is a continuous function at the point coverages = 5000. However, Figure 3 shows that the sensitivity of the design factor $R/\sigma$ has a significant jump at coverages = 5000.

It can be seen in Figures 3 and 4 that the failure model and sensitivity curve in the LEDFAA design procedure, based on elastic multiple-layer theory (Parker et. al. 1979, and Rollings 1988), are continuous functions.

4.1 Sensitivity to Slab Thickness, Aircraft Gross Weight, Subgrade Strength, and Subbase Thickness. The sensitivities of the following six parameters are analyzed following equation 2: $R$ (concrete flexural strength), $H_c$ (thickness of PCC slab), $E_{subg}$ (subgrade modulus), $H_{Stab}$ (stabilized subbase layer thickness), $H_{Subb}$ (subbase thickness), and $Q_G$ (aircraft gross weight).

The analysis was conducted for PCC pavements built on two types of subgrade, with a modulus of 4500 psi, representing a very weak subgrade, and the other with a modulus of 30,000 psi, representing a very strong subgrade. The analysis was also conducted for three types of aircraft loads: a single tire with a 55,000-lb load, a B-727 aircraft with a gross weight of 200,000 lb, and a B-747 aircraft with a gross weight of 800,000 lb. Annual departures were set to 1200 for all. The LEDFAA program was used to calculate the slab thickness for 20 departure years for each aircraft. A rounded thickness value close to the required thickness was selected for the sensitivity analysis.

After a few numerical trials, it was found that pavement design life is very sensitive to concrete flexural strength, slab thickness, and aircraft gross weight; therefore, the values of $\Delta x$ were selected as 1% to 1.5% of the values of the parameters. If the same level of $\Delta x$ is used for analyzing the sensitivity of the thickness of stabilized subbase, the thickness of granular subbase, and the subgrade modulus, the difference between $L(x+\Delta x)$ and $L(x-\Delta x)$ will be too small to assure the accuracy of the calculation. Therefore, higher values are used for those three parameters. The detailed information on the input and output data is shown in Table 3 for the weak subgrade and in Table 4 for the strong subgrade.

The findings are summarized below:

- The numerical analysis of sensitivity had to be done case by case. The selected six cases covered subgrade strengths from weak to strong and covered the single, dual, and dual-tandem gears. The characteristics of each parameter's sensitivity are clearly seen in the results from the numerical analysis.
- The three parameters with the highest sensitivity (the magnitudes of the calculated sensitivity) in each group were slab thickness, flexural strength, and aircraft gross weight.
- The sensitivity of subgrade strength for the weak subgrade was higher than for the strong subgrade.
- The sensitivity of stabilized base thickness is always higher than granular base thickness. The difference between the two sensitivities for a pavement built on high-strength subgrade was more than for a pavement built on a weak subgrade.
- If the analysis is performed for the design procedure in FAA AC 150/5320-6D, then the sensitivities for R and $Q_G$ have the same magnitude but opposite signs. This is not the case for LEDFAA as shown in tables 3 and 4. The reason is that contact area is constant in FAA AC 150/5320-6D and tire pressure is constant in LEDFAA.

Table 3. Sensitivity of different parameters, Weak Subgrade $E_{subg} = 4,500$-psi.

| Single-wheel load 55,000 lb, 1200 annual passes, design PCC thickness = 14.09″ | | | | | | |
|---|---|---|---|---|---|---|
| Parameters | $x$ | $\Delta x$ | $L(x+\Delta x)$ | $L(x)$ | $L(x-\Delta x)$ | $S_{x, L}$ |
| $R$ | 700 | 7 | 19.9 | 17.7 | 15.8 | 11.6 |
| $H_c$ | 14 | 0.2 | 23.2 | 17.7 | 13.6 | 19.0 |
| $E_{subg}$ | 4,500 | 225 | 18.5 | 17.7 | 16.9 | 0.9 |
| $H_{Stab}$ | 6 | 0.5 | 18.9 | 17.7 | 16.6 | 0.8 |
| $H_{Subb}$ | 10 | 1 | 18.5 | 17.7 | 17 | 0.4 |
| $Q_G$ | 55,000 | 550 | 15.8 | 17.7 | 19.6 | -10.7 |
| B-727, 200,000 lb, 1200 annual passes, design PCC thickness = 16.46″ | | | | | | |
| Parameters | $x$ | $\Delta x$ | $L(x+\Delta x)$ | $L(x)$ | $L(x-\Delta x)$ | $S_{x, L}$ |
| $R$ | 700 | 7 | 43.6 | 38.3 | 33.6 | 13.1 |
| $H_c$ | 17 | 0.2 | 46.9 | 38.3 | 29.5 | 19.3 |
| $E_{subg}$ | 4,500 | 225 | 39.7 | 38.3 | 36 | 1.0 |
| $H_{Stab}$ | 6 | 0.5 | 41.2 | 38.3 | 35.3 | 0.9 |
| $H_{Subb}$ | 10 | 1 | 39 | 38.3 | 36.6 | 0.3 |
| $Q_G$ | 200,000 | 2,000 | 33.9 | 38.3 | 43.4 | -12.4 |
| B-747, 800,000 lb, 1200 annual passes, design PCC thickness = 15.34″ | | | | | | |
| Parameters | $x$ | $\Delta x$ | $L(x+\Delta x)$ | $L(x)$ | $L(x-\Delta x)$ | $S_{x, L}$ |
| $R$ | 700 | 7 | 16.2 | 14.4 | 12.8 | 11.8 |
| $H_c$ | 15 | 0.2 | 17.6 | 14.4 | 11.8 | 15.1 |
| $E_{subg}$ | 4,500 | 225 | 15.9 | 14.4 | 13 | 2.0 |
| $H_{Stab}$ | 6 | 0.5 | 15.3 | 14.4 | 13.6 | 0.7 |
| $H_{Subb}$ | 10 | 1 | 15.1 | 14.4 | 13.8 | 0.5 |
| $Q_G$ | 800,000 | 8,000 | 12.9 | 14.4 | 16.2 | -11.5 |

Table 4. Sensitivity of different parameters, Strong Subgrade $E_{subg} = 30,000$-psi.

| Single-wheel load 55,000 lb, 1200 annual passes, design PCC thickness = 13.48″ | | | | | | |
|---|---|---|---|---|---|---|
| Parameters | $x$ | $\Delta x$ | $L(x+\Delta x)$ | $L(x)$ | $L(x-\Delta x)$ | $S_{x, L}$ |
| $R$ | 700 | 7 | 12.4 | 11.1 | 10 | 10.8 |
| $H_c$ | 13 | 0.2 | 14.2 | 11.1 | 8.7 | 16.1 |
| $E_{subg}$ | 3,0000 | 6,000 | 11.3 | 11.1 | 11 | 0.1 |
| $H_{Stab}$ | 6 | 0.5 | 11.7 | 11.1 | 10.6 | 0.6 |
| $H_{Subb}$ | 10 | 1 | 11.2 | 11.1 | 11 | 0.1 |
| $Q_G$ | 55,000 | 550 | 10.2 | 11.1 | 12.1 | -8.6 |
| B-727, 200,000 lb, 1200 annual passes, design PCC thickness = 15.36″ | | | | | | |
| Parameters | $x$ | $\Delta x$ | $L(x+\Delta x)$ | $L(x)$ | $L(x-\Delta x)$ | $S_{x, L}$ |
| $R$ | 700 | 7 | 15.4 | 13.7 | 12.2 | 11.7 |
| $H_c$ | 15 | 0.2 | 16.9 | 13.7 | 11.2 | 15.6 |
| $E_{subg}$ | 3,0000 | 3,000 | 14 | 13.7 | 13.5 | 0.2 |
| $H_{Stab}$ | 6 | 0.5 | 14.3 | 13.7 | 13.2 | 0.5 |
| $H_{Subb}$ | 10 | 1 | 13.9 | 13.7 | 13.6 | 0.1 |
| $Q_G$ | 200,000 | 2,000 | 12.4 | 13.7 | 15.3 | -10.6 |
| B-747, 800,000 lb, 1200 annual passes, design PCC thickness = 12.67″ | | | | | | |
| Parameters | $x$ | $\Delta x$ | $L(x+\Delta x)$ | $L(x)$ | $L(x-\Delta x)$ | $S_{x, L}$ |
| $R$ | 700 | 7 | 31.6 | 28 | 24.9 | 12.0 |
| $H_c$ | 13 | 0.2 | 34.3 | 28 | 22.9 | 13.2 |
| $E_{subg}$ | 30,000 | 3,000 | 29.5 | 28 | 26.5 | 0.5 |
| $H_{Stab}$ | 6 | 0.5 | 29.6 | 28 | 26.7 | 0.6 |
| $H_{Subb}$ | 10 | 1 | 28.4 | 28 | 27.6 | 0.1 |
| $Q_G$ | 800,000 | 8,000 | 25.3 | 28 | 31.1 | -10.4 |

## 5 SUMMARY/CONCLUSIONS

Designing the thickness of a pavement needs many input parameters and different input parameters have different influences on pavement life. Pavement life is insensitive to some parameters, i.e., a small change in the parameter has only limited effects on pavement life. However, for other parameters, pavement life is very sensitive to changes in their values, i.e., a small change will lead to a significant change in pavement life. The following can be summarized from the results of the parametric sensitivity analysis that was presented in this paper.

For flexible pavements, pavement life is most sensitive to aircraft gross weight, subgrade strength, and total pavement thickness. Pavement life is more sensitive to P-209 crushed stone base thickness when compared to HMA modulus and HMA thickness. For rigid pavements, pavement life is most sensitive to slab thickness, flexural strength of the concrete, and aircraft gross weight. For the LEDFAA design procedures, the largest sensitivities have magnitudes in the range 15 to 20. This means that for a change of, say, one percent in the value of the parameter of interest, pavement design life will change in the range 15 to 20 percent.

To compare the sensitivities to thickness and stiffness effects between flexible and rigid pavements, the two pavement types (rigid and flexible) were evaluated using a traffic mix representative of operations at a major international airport. The results show that the sensitivity of life to slab thickness in a rigid pavement is about the same as the sensitivity of life to total pavement thickness in a flexible pavement. On the other hand, a slight increase in thickness and flexural strength of the concrete slab in a rigid pavement has a much larger effect on pavement life compared to similar changes in the HMA thickness and stiffness in a flexible pavement.

The methodology for calculating sensitivities provides a convenient means of comparing different design procedures, such as those in AC 150/5320-6D and LEDFAA, on a consistent basis.

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