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of Transportation
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Administration

Advisory Circular

Subject: AIRPORT PAVEMENT DESIGN AND EVALUATION

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1. PURPOSE. Advisory Circular (AC) 150/5320-6D, Airport Pavement Design and Evaluation, has been revised to incorporate the contents of AC 150/5320-16, Airport Pavement Design for the Boeing 777 Airplane, and to announce design software for Chapters 3 and 4.

2. PRINCIPAL CHANGES. This document makes three principal changes to AC 150/5320-6D:

a. A new Chapter 7, Layered Elastic Pavement Design, incorporates the contents of AC 150/5320-16, which is cancelled. The user's manual previously published as an appendix to 150/5320-16 is now available as a help file to the LEDFAA design program described in Chapter 7.

b. The layered elastic design method can now be used as an alternate design method to the procedures described in Chapters 3 and 4. Layered elastic design procedures were previously reserved for use only when the Boeing 777 aircraft was in the anticipated traffic mixture.

c. A new Appendix 5, Airfield Pavement Design Software, announces the availability of Microsoft Excel® spreadsheets for the design procedures described in Chapters 3 and 4. The appendix explains the purpose of the spreadsheets and describes how to access both the spreadsheets (F806faa.xls and R805faa.xls) and the associated user's manuals.

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DAVID L. BENNETT
Director of Airport Safety and Standards

FOREWORD

This AC provides guidance on the structural design and evaluation of airport pavements.

Although aircraft landing gears play a role in airport pavement design and evaluation, this AC does not dictate any facet of landing gear design. In 1958, the FAA adopted a policy of limiting maximum Federal participation in airport pavements to a pavement section designed to serve a 350,000-pound (159 000 kg) aircraft with a DC-8-50 series landing gear configuration. The intent of the policy was to ensure that future aircraft were equipped with landing gears that would not stress pavements more than the referenced 350,000-pound (159 000 kg) aircraft.

Throughout the 20th century, aircraft manufacturers accepted and followed the 1958 policy and designed aircraft landing gears that conformed to it—even though aircraft gross weights have long exceeded 350,000 pounds (159 000 kg). Despite the greater weights, manufacturers were able to conform to the policy by increasing the number and spacing of landing gear wheels. This AC does not affect the 1958 policy with regard to landing gear design.

The pavement design guidance presented in Chapter 3 is based on methods of analysis that resulted from experience and past research. The methods employed in Chapter 3 were adopted in 1978 to exploit advances in pavement technology and thus provide better performing pavements and easier-to-use design curves than were previously available. Generally speaking, the Chapter 3 guidance requires somewhat thicker pavement sections than were required prior to 1978.

Chapter 6 presents the pavement evaluation portion of this AC. It relates back to the previous FAA method of design to ensure continuity. An aircraft operator could be penalized unfairly if an existing facility was evaluated using a method different from that employed in the original design. A slight change in pavement thickness can have a dramatic effect on the payload or range of an aircraft. Since the new pavement design methodology might produce different pavement thicknesses, an evaluation of an existing pavement using the new methodology could result in incompatible results. To avoid this situation, the evaluation should be based whenever possible on the same methodology as was used for the design.

Where new aircraft have been added to the traffic mixture at an existing facility, it may not be possible to evaluate the pavement with the original design procedure. For example, when a triple dual tandem (TDT) gear aircraft is added to the traffic mixture at a facility originally designed in accordance with Chapter 3, it will be impossible to assess the impact of the new aircraft using the procedures in Chapter 3. In instances where it is not appropriate to evaluate the pavement with the original design procedure, the pavement must be evaluated with the newer design procedures.

The pavement design guidance presented in Chapter 7 implements layered elastic theory based design procedures. The FAA adopted this methodology to address the impact of new landing gear configurations such as the TDT gear, which aircraft manufacturers developed and implemented in the early 1990s. The TDT gear produces an unprecedented airport pavement loading configuration, which appears to exceed the capability of the previous methods of design. Previous methods incorporated some empiricism and have limited capacity for accommodating new gear and wheel arrangements.

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CHAPTER 3. PAVEMENT DESIGN

SECTION 1. DESIGN CONSIDERATIONS

300. SCOPE. This chapter covers pavement design for airports serving aircraft with gross weights of 30,000 pounds (13 000 kg) or more. Chapter 5 discusses the design of pavements serving lighter aircraft with gross weights under 30,000 pounds (13 000 kg).

301. DESIGN PHILOSOPHY. The Foreword of this AC describes the FAA policy of treating the design of aircraft landing gear and the design and evaluation of airport pavements as separate entities. The design of airport pavements is a complex engineering problem that involves a large number of interacting variables. The design curves presented in this chapter are based on the California Bearing Ratio (CBR) method of design for flexible pavements and a jointed edge stress analysis for rigid pavements. Other design procedures, such as those based on layered elastic analysis and those developed by the Asphalt Institute and the Portland Cement Association may be used to determine pavement thicknesses when approved by the FAA. These procedures will yield slightly different pavement thicknesses due to different basic design assumptions.

All manual and electronic pavement designs should be summarized on FAA Form 5100-1, Airport Pavement Design, which is considered part of the Engineer's Report. The Engineer's Report should be submitted for FAA review and approval along with initial plans and specifications.

Because of thickness variations, the evaluation of existing pavements should be performed using the same method employed for design. Chapter 6 describes in detail procedures to use when evaluating pavements. Details on the development of the FAA method of design are as follows:

a. Flexible Pavements. The flexible pavement design curves presented in this chapter are based on the CBR method of design. The CBR design method is basically empirical; however, a great deal of research has been done with the method, resulting in the development of reliable correlations. Gear configurations are considered using theoretical concepts as well as empirically developed data. The design curves provide the required total thickness of flexible pavement (surface, base, and subbase) needed to support a given weight of aircraft over a particular subgrade. The curves also show the required surface thickness. Minimum base course thicknesses are given in a separate table. A more detailed discussion of CBR design is presented in Appendix 2.

b. Rigid Pavements. The rigid pavement design curves in this chapter are based on the Westergaard analysis of edge loaded slabs. The edge loading analysis has been modified to simulate a jointed edge condition. Pavement stresses are higher at the jointed edge than at the slab interior. Experience shows practically all load-induced cracks develop at jointed edges and migrate toward the slab interior. Design curves are furnished for areas where traffic will travel primarily parallel or perpendicular to joints and where traffic is likely to cross joints at an acute angle. The thickness of pavement determined from the curves is for slab thickness only. Subbase thicknesses are determined separately. A more detailed discussion of the basis for rigid pavement design is presented in Appendix 2.

302. BACKGROUND. An airfield pavement and the aircraft that operate on it represent an interactive system that must be addressed in the pavement design process. Design considerations associated with both the aircraft and the pavement must be recognized in order to produce a satisfactory design. Producing a pavement that will achieve the intended design life will require careful construction control and some degree of maintenance. Pavements are designed to provide a finite life, and fatigue limits are anticipated. Poor construction and a lack of preventative maintenance will usually shorten the service life of even the best-designed pavement.

a. Variables. The determination of pavement thickness requirements is a complex engineering problem. Pavements are subject to a wide variety of loading and climatic effects. The design process involves a large number of interacting variables, which are often difficult to quantify. Despite considerable research on this subject, it has been impossible to arrive at a direct mathematical solution for thickness requirements. For this reason, pavement engineers must base pavement thickness on a theoretical analysis of load distribution through pavements and soils, the analysis of experimental pavement data, and a study of the performance of pavements under actual service conditions. The FAA developed the thickness curves presented in this chapter by correlating the data obtained from these sources. Pavements designed in accordance with these standards should have a structural life of 20 years. In addition, as long as there are no major changes in forecast traffic, the pavements should not require any major maintenance. It is likely, however, that rehabilitation of surface grades and renewal of skid-resistant properties will be needed before 20 years because of destructive climatic effects and the deteriorating effects of normal usage.

b. Structural Design. The structural design of airport pavements requires determining both the overall pavement thickness and the thickness of the component parts of the pavement. There are a number of factors that influence the thickness of pavement required to provide satisfactory service. These include the magnitude and character of the aircraft loads to be supported, the volume of traffic, the concentration of traffic in certain areas, and the quality of the subgrade soil and materials that make up the pavement structure.

303. AIRCRAFT CONSIDERATIONS.

a. Load. The pavement design method is based on the gross weight of the aircraft. The pavement should be designed for the maximum anticipated takeoff weight of the aircraft. The design procedure assumes 95 percent of the gross weight is carried by the main landing gears and 5 percent is carried by the nose gear. AC 150/5300-13, Airport Design, lists the weight of many civil aircraft. The FAA recommends using the maximum anticipated takeoff weight, which provides some degree of conservatism in the design. This will allow for changes in operational use and forecast traffic, which is approximate at best. The conservatism will be offset somewhat by ignoring arriving traffic.

b. Landing Gear Type and Geometry. Gear type and configuration dictate how aircraft weight is distributed to a pavement and how the pavement will respond to aircraft loadings. Because of this, separate design curves would be necessary for each type of aircraft unless some valid assumptions could be made to reduce the number of variables. However, examination of gear configuration, tire contact areas, and tire pressure in common use indicate that these factors follow a definite trend related to aircraft gross weight. Therefore, reasonable assumptions can be made, the variables reduced, and design curves constructed from the assumed data. These assumed data are as follows:

(1) Single Gear Aircraft. No special assumptions needed.

(2) Dual Gear Aircraft. A study of the spacing between dual wheels for these aircraft indicated the following design values are appropriate: a dimension of 20 inches (0.51 m) between the centerline of the tires for lighter aircraft and a dimension of 34 inches (0.86 m) between the centerline of the tires for heavier aircraft.

(3) Dual Tandem Gear Aircraft. The study indicated the following design values are appropriate: a dual wheel spacing of 20 inches (0.51m) and a tandem spacing of 45 inches (1.14 m) for lighter aircraft and a dual wheel spacing of 30 inches (0.76 m) and a tandem spacing of 55 inches (1.40 m) for heavier aircraft.

(4) Wide Body Aircraft. Aircraft such as the B-747, B-767, DC-10, and L-1011 have large spaced dual tandem gear geometries, which represent a radical departure from the geometry assumed for dual tandem aircraft described in paragraph 303b(3) above. Due to the large differences in gross weights and gear geometries, separate design curves are provided for these aircraft. The term wide body was originally applied to these aircraft because of their width compared to other contemporary aircraft.

(5) Triple Dual tandem Gear Aircraft. Aircraft such as the B-777 and A-380 have landing gears with three rows of dual wheels. Pavement design requirements for traffic mixtures containing triple dual tandem aircraft are discussed in Chapter 7.

c. Tire Pressure. Tire pressure varies between 75 and 200 psi (515 to 1 380 kPa), depending on gear configuration and gross weight. It should be noted that tire pressure asserts less influence on pavement stresses as gross weight increases, and the assumed maximum of 200 psi (1 380 kPa) may be safely exceeded if other parameters are not exceeded and a high-stability surface course is used.

d. Traffic Volume. Forecasts of annual departures by aircraft type are needed for pavement design. Information on aircraft operations is available from Airport Master Plans, Terminal Area Forecasts, the National Plan of Integrated Airport Systems, Airport Activity Statistics, and FAA Air Traffic Activity Reports. Pavement engineers should consult these publications when developing forecasts of annual departures by aircraft type.

304. DETERMINATION OF DESIGN AIRCRAFT. The forecast of annual departures by aircraft type will result in a list of several different aircraft. The required pavement thickness for each aircraft type in the forecast should be checked using the appropriate design curve and the forecast number of annual departures for that aircraft. The design aircraft is the aircraft type that produces the greatest pavement thickness. It will not necessarily be the heaviest aircraft in the forecast.

305. DETERMINATION OF EQUIVALENT ANNUAL DEPARTURES BY THE DESIGN AIRCRAFT.

a. Conversions. Since the traffic forecast is a mixture of aircraft having different landing gear types and different weights, the effects of all traffic must be accounted for in terms of the design aircraft. First, all aircraft must be converted to the same landing gear type as the design aircraft. The FAA has established factors to accomplish this conversion. These factors are constant and apply to both flexible and rigid pavements. They represent an approximation of the relative fatigue effects of different gear types. Much more precise and theoretically rigorous factors could be developed for different types and thicknesses of pavement. However, at this stage of the design process, such precision is not warranted and would be impractical for hand calculation since design changes would require numerous iterations and adjustments.

The following conversion factors should be used to convert from one landing gear type to another:

To Convert From	To	Multiply Departures By
single wheel	dual wheel	0.8
single wheel	dual tandem	0.5
dual wheel	single wheel	1.3
dual wheel	dual tandem	0.6
dual tandem	single wheel	2.0
dual tandem	dual wheel	1.7
double dual tandem	dual tandem	1.0
double dual tandem	dual wheel	1.7

After the aircraft have been grouped into the same landing gear configuration, the following formula should be used to convert to equivalent annual departures of the design aircraft:

$$\operatorname{Log} R_1 = \operatorname{Log} R_2 \times \sqrt{\frac{W_2}{W_1}}$$

where:

R_1 = equivalent annual departures by the design aircraft
R_2 = annual departures expressed in design aircraft landing gear
W_1 = wheel load of the design aircraft
W_2 = wheel load of the aircraft in question

This computation assumes that 95 percent of the gross weight of the aircraft is carried by the main landing gears. The procedure discussed above is a relative rating that compares different aircraft to a common design aircraft. Since wide body aircraft have significantly different landing gear assembly spacing than other aircraft, special considerations are needed to maintain the relative effects. This is done by treating each wide body as a 300,000-pound (136 100 kg) dual tandem aircraft when computing equivalent annual departures. Wide body aircraft should be treated this way in every instance—even when the design aircraft is a wide body. After the equivalent annual departures are determined, the design should proceed using the appropriate design curve for the design aircraft. For example, if a wide body is the design aircraft, all equivalent departures should be calculated as described above; then the design curve for the wide body should be used with the calculated equivalent annual departures.

b. Example. Assume an airport pavement is to be designed for the following forecast traffic.

Aircraft	Gear Type	Average Annual Departures	Maximum Takeoff Weight (lbs.)	Maximum Takeoff Weight (kg)
727-100	dual	3,760	160,000	72 580
727-200	dual	9,080	190,500	86 410
707-320B	dual tandem	3,050	327,000	148 330
DC-9-30	dual	5,800	108,000	49 000
CV-880	dual tandem	400	184,500	83 690
737-200	dual	2,650	115,500	52 390
L-1011-100	dual tandem	1,710	450,000	204 120
747-100	double dual tandem	85	700,000	317 520

(1) Determine Design Aircraft. A pavement thickness is determined for each aircraft in the forecast with the appropriate design curves. The pavement input data, CBR, k value, flexural strength, etc. should be the same for all aircraft. Aircraft weights and departure levels must correspond to the particular aircraft in the forecast. In this example, the 727-200 requires the greatest pavement thickness and thus is the design aircraft.

(2) Group Forecast Traffic into Landing Gear of Design Aircraft. In this example, the design aircraft is equipped with a dual wheel landing gear, so all traffic must be grouped into the dual wheel configuration.

(3) Convert Aircraft to Equivalent Annual Departures of the Design Aircraft. After the aircraft mixture has been grouped into a common landing gear configuration, the equivalent annual departures of the design aircraft can be calculated.

Aircraft	Equiv. Dual Gear Departs.	Wheel Load (lbs)	Wheel Load (kg)	Wheel Load of Design Aircraft (lbs)	Wheel Load of Design Aircraft (kg)	Equiv. Annual Departures Design Aircraft
727-100	3,760	38,000	17 240	45,240	20 520	1,891
727-200	9,080	45,240	20 520	45,240	20 520	9,080
707-320B	5,185	38,830	17 610	45,240	20 520	2,764
DC-9-30	5,800	25,650	11 630	45,240	20 520	682
CV-880	680	21,910	9 940	45,240	20 520	94
737-200	2,650	27,430	12 440	45,240	20 520	463
L-1011-100	2,907	35,625[1]	16 160	45,240	20 520	1,184
747-100	145	35,625[1]	16 160	45,240	20 520	83
						Total = 16,241

[1] Wheel loads for wide body aircraft are taken as the wheel load for a 300,000-pound (136 100 kg) dual tandem aircraft for equivalent annual departure calculations.

(4) Final Result. In this example, the pavement would be designed for 16,241 annual departures of a dual wheel aircraft weighing 190,500 pounds (86 410 kg). The design, however, should provide for the heaviest aircraft in the traffic mixture, the B747-100, when considering depth of compaction, thickness of asphalt surface, drainage structures, etc.

c. Other Methods. More refined methods of considering mixed traffic are possible. These refined methods might consider variations in material properties due to climatic effects, takeoff versus landing loads, aircraft tread dimensions, etc. The FAA allows the use of these refined methods under the conditions given in paragraph 301.

306. TRAFFIC DISTRIBUTION. Research studies have shown that aircraft traffic is distributed laterally across runways and taxiways according to statistically normal (bell-shaped) distribution. FAA Report No. FAA-RD-36, Field Survey and Analysis of Aircraft Distribution on Airport Pavements, dated February 1975, contains research information on traffic distribution. The design procedures presented in this AC incorporate the statistically normal distribution in the departure levels. In addition to the lateral distribution of traffic across pavements, it also considers traffic distribution and the nature of loadings for aprons and high-speed turnoffs.

SECTION 3. RIGID PAVEMENT DESIGN

324. GENERAL. Rigid pavements for airports are composed of Portland cement concrete placed on a granular or treated subbase course that is supported on a compacted subgrade. Under certain conditions, a subbase is not required (see paragraph 326).

325. CONCRETE PAVEMENT. The concrete surface must provide a nonskid surface, prevent the infiltration of surface water into the subgrade, and provide structural support to the aircraft. The quality of the concrete, acceptance and control tests, methods of construction and handling, and quality of workmanship are covered in Item P-501, Portland Cement Concrete Pavement.

326. SUBBASE. The purpose of a subbase under a rigid pavement is to provide uniform stable support for the pavement slabs. A minimum thickness of 4 inches (100 mm) of subbase is required under all rigid pavements, except as shown in Table 3-10 below:

TABLE 3-10. CONDITIONS WHERE NO SUBBASE IS REQUIRED

Soil Classification	Good Drainage		Poor Drainage	
	No Frost	Frost	No Frost	Frost
GW	**X**	**X**	**X**	**X**
GP	**X**	**X**	**X**	
GM	**X**			
GC	**X**			
SW	**X**			

Note: X indicates conditions where no subbase is required.

327. SUBBASE QUALITY. The standard FAA subbase for rigid pavements is 4 inches (100 mm) of Item P-154, Subbase Course. In some instances, it may be desirable to use higher-quality materials or thicknesses of P-154 greater than 4 inches (100 mm). The following materials are acceptable for use as subbase under rigid pavements:

Item P-154 – Subbase Course
Item P-208 – Aggregate Base Course
Item P-209 – Crushed Aggregate Base Course
Item P-211 – Lime Rock Base Course
Item P-304 – Cement Treated Base Course
Item P-306 – Econocrete Subbase Course
Item P-401 – Plant Mix Bituminous Pavements

Materials of higher quality than P-154 and/or greater thicknesses of subbase are considered in the design process through the foundation modulus (k value). The costs of providing the additional thickness or higher-quality subbase should be weighed against the savings in concrete thickness.

328. STABILIZED SUBBASE. Stabilized subbase is required for all new rigid pavements designed to accommodate aircraft weighing 100,000 pounds (45 400 kg) or more. Stabilized subbases are as follows:

Item P-304 – Cement Treated Base Course
Item P-306 – Econocrete Subbase Course
Item P-401 – Plant Mix Bituminous Pavements

The structural benefit imparted to a pavement section by a stabilized subbase is reflected in the modulus of subgrade reaction assigned to the foundation. Exceptions to the policy of using stabilized subbase are the same as those given in paragraph 320.

329. SUBGRADE. As with a flexible pavement, the subgrade materials under a rigid pavement should be compacted to provide adequate stability and uniform support; however, the compaction requirements for rigid pavements are not as stringent as for flexible pavement because of the relatively lower subgrade stress. For cohesive soils used in fill sections, the top 6 inches (150 mm) must be compacted to 90 percent maximum density. Fill depths greater than 6 inches (150 mm) must be compacted to 90 percent maximum density or meet the requirements of Table 3-2. For cohesive soils in cut sections, the top 6 inches (150 mm) of the subgrade must be compacted to 90 percent maximum density. For noncohesive soils used in fill sections, the top 6 inches (150 mm) of fill must be compacted to 100 percent maximum density, and the remainder of the fill must be compacted to 95 percent maximum density or meet the requirements of Table 3-2. For cut sections in noncohesive soils, the top 6 inches (150 mm) of subgrade must be compacted to 100 percent maximum density and the next 18 inches (460 mm) of subgrade must be compacted to 95 percent maximum density. Swelling soils require special considerations. Paragraph 314 contains guidance on the identification and treatment of swelling soils.

a. **Contamination.** In rigid pavement systems, repeated loading might cause intermixing of soft subgrade soils and aggregate base or subbase. This mixing can create voids below the pavement in which moisture can accumulate, causing pumping to occur. Chemical and mechanical stabilization of the subbase or subgrade can effectively reduce aggregate contamination (see paragraph 207). Geotextiles have been found to be effective at providing separation between fine-grained subgrade soils and pavement aggregates (FHWA-HI-90-001 Geotextile Design and Construction Guidelines). Geotextiles should be considered for separation between fine-grained soils and overlying pavement aggregates. In this application, the geotextile is not considered to act as a structural element within the pavement. Therefore, the modulus of the base or subbase is not increased when a geotextile is used for stabilization. For separation applications, the geotextile is designed based on survivability properties. FHWA-HI-90-001 contains additional information about design and construction using separation geotextiles.

330. DETERMINATION OF FOUNDATION MODULUS (k VALUE) FOR RIGID PAVEMENT. In addition to the soils survey and analysis and classification of subgrade conditions, rigid pavement design also requires the determination of the foundation modulus. The k value should be assigned to the material directly beneath the concrete pavement. However, the FAA recommends that a k value be established for the subgrade and then corrected to account for the effects of the subbase.

a. **Determination of k Value for Subgrade.** The preferred method of determining the subgrade modulus is by testing a limited section of embankment that has been constructed to the required specifications. The plate bearing test procedures are given in AASHTO T 222, Nonrepetitive Static Plate Load Test of Soils and Flexible Pavement Components for Use in Evaluation and Design of Airport and Highway Pavements. If the construction and testing of a test section of embankment is impractical, the values listed in Table 2-3 may be used. The values in Table 2-3, however, are approximate, and engineering judgment should be used when selecting a design value. Fortunately, rigid pavement is not overly sensitive to k value, and an error in estimating k will not have a large impact on rigid pavement thickness.

b. **Determination of k Value for Granular Subbase.** It is usually not practical to determine a foundation modulus on top of a subbase by testing, at least in the design phase. Usually, the embankment and subbase will not be in place in time to perform any field tests, so the k value will have to be assigned without the benefit of testing. The probable increase in k value associated with various thicknesses of different subbase materials is shown in Figure 2-4. The upper graph in Figure 2-4 should be used when the subbase is composed of well-graded crushed aggregate, such as P-209. The lower graph in Figure 2-4 applies to bank-run sand and gravel, such as P-154. Both curves in Figure 2-4 apply to unstabilized granular materials. Values shown in Figure 2-4 are guides and can be tempered by local experience.

c. **Determination of k Value for Stabilized Subbase.** As with granular subbase, the effect of stabilized subbase is reflected in the foundation modulus. Figure 3-16 shows the probable increase in k value with various thicknesses of stabilized subbase located on subgrades of varying moduli. Figure 3-16 is applicable to cement stabilized (P-304), Econocrete (P-306), and bituminous stabilized (P-401) layers. Figure 3-16 assumes a stabilized layer is twice as effective as well-graded crushed aggregate in increasing the subgrade modulus. Stabilized layers of lesser quality than P-304, P-306, or P-401 should be assigned somewhat lower k values. After a k value is assigned to the stabilized subbase, the concrete slab thickness design procedure is the same as that described in paragraph 331.

CBR	3	4	5	6	7	8	9	11	13	16	20
FAA	F10	F9	F8	F7	F6	F5	F4	F3	F2	F1	Fa

SUBGRADE CLASS

FIGURE 6-1. CBR–FAA SUBGRADE CLASS COMPARISONS

(1) Subbase and Base Equivalencies. For evaluation purposes, the FAA recommends the equivalency factor ranges shown in Tables 3-6 through 3-9 for subbase and base. The actual value selected will depend on the composition, quality, and condition of the layer. If experience or physical test results show that other values are valid, they may be used in lieu of the values recommended here. Subbase or base courses should not be assigned a higher equivalency factor than any layer above it in the pavement structure. The FAA does not permit the conversion of material to a higher classification, such as subbase to base, except where excess stabilized base course (P-401 or P-304) exists immediately under a flexible surface, in which case the stabilized material may be counted as an equal thickness of surface.

(2) Surfacing. Broken hot mix asphalt surface course (shrinkage cracks due to age and weathering, without evidence of base failure) must be evaluated as an equal thickness of nonstabilized base. A hot mix asphalt surface, well maintained and with limited cracking, might justify use of an equivalency between the limits noted.

603. APPLICATION OF FLEXIBLE PAVEMENT EVALUATION PROCEDURES. After all of the evaluation parameters of the existing flexible pavement have been established using the guidance given in the above paragraphs, the evaluation process is essentially the reverse of the design procedure. The design curves presented in Chapters 3 or 5 are used to determine the load carrying capacity of the existing pavement. Required inputs are subgrade and subbase CBR values, thicknesses of surfacing, base and subbase courses, and an annual departure level. Several checks must be performed to determine the load carrying capacity of a flexible pavement. The calculation that yields the lowest allowable load will control the evaluation.

a. Total Pavement Thickness. Enter the lower abscissa of the appropriate design curve in Chapters 3 or 5 with the total pavement thickness of the existing pavement. Make a vertical projection to the annual departure level line. For light load pavements, described in Chapter 5, a single pivot line is used. At the point of intersection between the vertical projection and the departure level line, or single pivot line in the case of light load pavements, make a horizontal projection across the design curve. Enter the upper abscissa with the CBR value of the subgrade. Make a vertical projection downward until it intersects the horizontal projection made previously. The point of intersection of these two projections will be in the vicinity of the load lines on the design curves. An allowable load is read by noting where the intersection point falls in relation to the load lines.

b. Thickness of Surfacing and Base. The combined thickness of surfacing and base must also be checked to establish the load carrying capacity of an existing flexible pavement. This calculation requires the CBR of the subbase, the combined thickness of surfacing and base, and the annual departure level as inputs. The procedure is the same as that described in subparagraph a above, except that the subbase CBR and combined thickness of surfacing and base are used to enter the design curves.

c. Minimum Base Course Thickness. The thickness of the existing base course should be compared with the minimum base course thicknesses in Table 3-4 or Figure 5-2. Notice that the minimum base course thickness is 4 inches (100 mm) for heavy load pavements and 3 inches (75 mm) for light load pavements. If there is a deficiency in the thickness of the existing base course, the pavement should be closely monitored for signs of distress. The FAA recommends that overlaying the pavement to correct the deficiency be considered.

d. Minimum Surface Thickness. The thickness of the existing surface course should be compared with that shown on the appropriate design curve. If the existing surface course is thinner than that given on the design curve, the pavement should be closely observed for surface failures. The FAA recommends that correction of the deficiency in surfacing thickness be considered.

604. RIGID PAVEMENTS. Evaluation of rigid pavements requires, at a minimum, the determination of the thickness of the component layers, the flexural strength of the concrete, and the modulus of subgrade reaction.

a. Layer Thicknesses. The thickness of the component layers is sometimes available from construction records. Where information is not available or of questionable accuracy, thicknesses may be determined by borings or test pits in the pavement.

b. Concrete Flexural Strength. The flexural strength of the concrete is most accurately determined from test beams sawed from the existing pavement and tested in accordance with ASTM C 78. However, this method is often impractical, as sawed beams are expensive to obtain and costs incurred in obtaining sufficient numbers of beams to establish a representative sample are prohibitive. Construction records, if available, may be used as a source of concrete flexural strength data, but the construction data will probably have to be adjusted for age, as concrete strength increases with time.

(1) Correlations with Other Strength Tests. Correlations between concrete flexural strength and other concrete strength tests are available, but the correlations between flexural strength and other strength tests are approximate, and considerable variations are likely.

(i) Tensile Split Strength. An approximate relationship between concrete flexural strength and tensile splitting strength (ASTM C 496) exists and can be computed with the following formula:

$$R = 1.02(T) + 117$$

where:

R = flexural strength, psi
T = tensile split strength, psi
Note: For conversions in metric units, the above formula remains the same—except the 117 psi constant should be changed to 0.81 MPa.

This equation can be used with 85 percent confidence that the estimated flexural strength is at least as strong as the strength derived from the original regression analysis detailed in Concrete Strength Relationships, Miscellaneous Report Number S-74-30, published by the US Army Engineer Waterways Experiment Station, December 1974.

(ii) Compressive Strength. Flexural strength can be estimated from compressive strength (ASTM C 39) using the formula below:

$$R = 9\sqrt{f_c'}$$

where:

R = flexural strength
f_c' = compressive strength

c. Modulus of Subgrade Reaction. The modulus of subgrade reaction is determined by plate bearing tests performed on the subgrade. These tests should be made in accordance with the procedures established in AASHTO T 222. An important part of the test procedure for determining the subgrade reaction modulus is the correction for soil saturation that is contained in the prescribed standard. The normal application utilizes a correction factor determined by the consolidation testing of samples at in situ and saturated moisture content. For evaluation of older pavement where evidence exists that the subgrade moisture has stabilized or varies through a limited range, the correction for saturation is not necessary. If a field plate bearing test is not practical, the modulus of subgrade reaction may be determined by nondestructive testing or estimated by using Table 2-3 in Chapter 2 of this AC. Fortunately, pavement evaluation is not too sensitive to the modulus of subgrade reaction.

(1) Adjustment for Subbase. An adjustment to the modulus of subgrade reaction will be required if a subbase exists beneath the existing pavement. The thickness of the subbase is required to calculate an adjusted k value. The subbase thickness can be determined from construction records or from borings. The guidance contained in Chapter 3, Section 3, should be used in assigning a k value to a subbase.

605. APPLICATION OF RIGID PAVEMENT EVALUATION PROCEDURES. The evaluation of rigid pavements for aircraft weighing more than 30,000 pounds (13 600 kg) requires concrete flexural strength, k value of the foundation, slab thickness, and annual departure level as inputs. The rigid pavement design curves in Chapter 3 are used to establish load carrying capacity. The design curves are entered on the left ordinate with the flexural strength of the concrete. A horizontal projection is made to the k value of the foundation. At the point of intersection of the horizontal projection and the k line, a vertical projection is made into the vicinity of the load lines. The slab thickness is entered on the appropriate departure level scale on the right side of the chart. A horizontal projection is made from the thickness scale until it intersects the previous vertical projection. The point of intersection of these projections will be in the vicinity of the load lines. The load carrying capacity is read by noting where the intersection point falls in relation to the load lines.

606. USE OF RESULTS. If the evaluation is being used for planning purposes and the existing pavement is found to be deficient in accordance with the design standards given in Chapters 3 or 5, the sponsor should be notified as to the deficiency and should consider corrective action. If the evaluation is being used as part of the design for a project to reconstruct or upgrade the facility, the procedures given in Chapters 3, 4, or 5 should be used to design the reconstruction or overlay project. In the latter case, the main concern is not the load carrying capacity, but the difference between the existing pavement structure and the section that is needed to support forecast traffic.

607. REPORTING PAVEMENT STRENGTH. The International Civil Aviation Organization (ICAO) developed a standardized method of reporting airport pavement strength known as the Aircraft Classification Number/Pavement Classification Number (ACN/PCN). This method is based on the concept of reporting strength in terms of a standardized equivalent single wheel load. This method of reporting pavement strength is discussed in FAA AC 150/5335-5, Standardized Method of Reporting Airport Pavement Strength–PCN.

608. EVALUATIONS OF EXISTING PAVEMENT WITH LAYERED ELASTIC PROCEDURES. When an existing pavement must be evaluated for use by new aircraft not covered in the nomographs provided in Chapter 3, the layered elastic design procedures described in Chapter 7 may be used. However, an evaluation with these procedures might present unique difficulties when trying to correlate results to original thickness requirements. In many cases, the original traffic mixture might not be known and only the design aircraft gross weight and annual departures be available. Since the evaluation is for current usage, the existing and forecasted traffic mixture should be used to evaluate the pavement requirements.

Existing pavements may also be evaluated for use by new aircraft with the ACN/PCN system described in AC 150/5335-5. The ACN value of new aircraft can be compared to the existing PCN value of the pavement to determine whether restricted or unrestricted operations of the new aircraft should be permitted.

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CHAPTER 7. LAYERED ELASTIC PAVEMENT DESIGN

701. PURPOSE. The design procedure presented in this chapter provides a method of design based on layered elastic analysis developed to calculate design thicknesses for airfield pavements. Layered elastic design theory was adopted to address the impact of new gear and wheel arrangements such as the triple dual tandem (TDT) main gear. The Boeing 777 and the Airbus A-380 are examples of aircraft that utilize this gear geometry. The TDT gear produces an airport pavement loading configuration that appears to exceed the capability of the previous methods of design, which incorporate some empiricism and have limited capacity for accommodating new gear and wheel arrangements. This design method is computationally intense and is thus in the form of a computer program called LEDFAA.

702. APPLICATION. The procedures and design software identified in this chapter are primarily intended to provide pavement thickness design standards for airfield pavement intended to serve aircraft traffic mixtures that include aircraft utilizing TDT or other complex main gear configurations. The pavement design procedures presented in this chapter may also be used as a design alternate for the design procedures presented in Chapters 3 and 4. In instances where newer aircraft gear configuration, tire pressures, and/or wheel loads are not appropriate for the nomographs presented in Chapters 3 and 4, the FAA recommends using the layered elastic design procedures. Pavement designs for traffic mixes that do not include aircraft with the TDT main gear must conform to the minimum pavement sections defined in Chapters 3, and 4. A companion design prepared in accordance with Chapters 3 and 4 must be submitted with the layered elastic design for FAA approval. To aid in the design review, the summary information from the design software should be printed and included with the pavement design submittal.

The LEDFAA program may not be used to compare individual aircraft pavement thickness requirements for pavement designs, in accordance with Chapters 3 and 4, to individual aircraft thickness requirements for pavement designs based on the layered elastic design methodology. The program may not be used to evaluate existing pavement structures designed in accordance with Chapters 3 and 4 against single aircraft thickness requirements using the layered elastic design methodology. Any comparison between the design methodology of LEDFAA and Chapters 3 and 4 must be performed utilizing the entire traffic mixture (see paragraph 704e).

703. BACKGROUND. The TDT main landing gear is unique in that it has six wheels arranged as three pairs of wheels in a row. When the TDT main gear assembly is analyzed using the conventional FAA design methodology, the pavement thickness requirements are considered to be unduly conservative. This is particularly noticeable for flexible pavements. In 1995, the FAA adopted a layered elastic airport pavement design methodology for the Boeing 777 to reduce some of the conservatism experienced with the methods presented in Chapters 3 and 4 and to phase in a more mechanistic approach. The U.S. Army Corps of Engineers, Waterways Experiment Station, Vicksburg, MS, originally developed the layered elastic method of design for flexible and rigid pavements and overlays of rigid pavements. Verification of the new flexible pavement design procedure was performed by full-scale pavement testing at the National Airfield Pavement Test Facility, William J. Hughes Technical Center, Atlantic City, NJ.

704. COMPUTER PROGRAM. The design method is computer-based and is called LEDFAA. The core program is LEAF, a layered elastic computational program implemented 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™.

a. Aircraft Considerations. A wide variety of aircraft with pertinent pavement design characteristics are stored in the program library. The designer has considerable latitude in selecting and adjusting aircraft parameters.

b. Metric Units. The program may be operated with U.S. customary or metric dimensions.

c. Availability. LEDFAA can be downloaded from the Office of Airport Safety and Standards website (http://www.faa.gov/arp/).

d. Related Reference Material. The internal help file for LEDFAA contains a user's manual, which provides detailed information on proper execution of the program. The manual also contains additional technical references for specific details of the LEDFAA design procedure.

e. Aircraft Traffic Mixture. LEDFAA was developed and calibrated specifically to produce pavement thickness designs consistent with previous methods based on a mixture of different aircraft rather than individual aircraft. If a single aircraft is used for design, a warning will appear in the Aircraft Window indicating a non-standard aircraft list is used in the design. This warning is intended to alert the user that the program was intended for use with a mixture of different aircraft types. Nearly any traffic mix can be developed from the aircraft in the program library. Solution times are a function of the number of aircraft in the mix. The LEDFAA design procedure deals with mixed traffic differently than did previous design methods. Determination of a design aircraft is not required to operate LEDFAA. Instead, the program calculates the damaging effects of each aircraft in the traffic mix. The damaging effects of all aircraft are summed in accordance with Miner's Law. When the cumulative damage factor (CDF) sums to a value of 1.0, the design conditions have been satisfied.

705. PAVEMENT DESIGN CONSIDERATIONS. There are distinct differences between the design methodology presented in Chapters 3 and 4 and the methodology contained in LEDFAA. These differences, along with some common design assumptions between the two methods, are discussed below.

a. Design Life. The FAA design standard for pavements is based on a 20-year design life. The computer program is capable of considering other design life time frames, but the use of a design life other than 20 years constitutes a deviation from FAA standards.

b. Traffic Mix. As noted in paragraph 704e, traffic mix considerations are handled differently by the layered elastic design method. The procedures described in Chapters 3 and 4 require the traffic mixture to be converted into a single design aircraft and all annual departures converted to equivalent annual departures of the design aircraft. The design aircraft is determined by selecting the most damaging aircraft based on the anticipated gross weight and the number of departures for each aircraft. The layered elastic design program does not convert the traffic mixture; instead, it analyzes the damage to the pavement section for each aircraft and determines a final thickness for the total cumulative damage. LEDFAA considers the placement of each aircraft’s main gear in relationship to the pavement centerline. It also allows the pavement damage associated with a particular aircraft to be completely isolated from one or more of the other aircraft in the traffic mixture.

c. Design Reliability. The reliability of the layered elastic method of design should be approximately the same as the reliability of the CBR method of pavement design.

d. Materials. In the layered elastic design procedure, pavement materials are characterized by thickness, elastic moduli, and Poisson's ratio. Layer thicknesses can be varied, except where minimum thicknesses are required. Elastic moduli are either fixed or variable, depending on the material. The permissible range of variability for elastic moduli is fixed to ensure reasonable values. Poisson's ratio for all material is fixed. Materials are identified with their corresponding FAA specification designations; for example, crushed stone base course is identified as Item P-209. The list of materials contains an undefined layer with variable properties. If an undefined layer is used, a warning will appear in the Structure Window stating that a non-standard material has been selected and its use in the structure will require FAA approval.

e. Minimum Layer Thickness. When the layered elastic design procedure is used in lieu of the design procedures in Chapters 3 and 4, LEDFAA will not automatically establish the minimum layer thickness for each layer, as required. The user must consult paragraphs 706, 707, and 708 below to assure the minimum thickness requirements are obtained.

706. FLEXIBLE PAVEMENT DESIGN. The design process considers two modes of failure for flexible pavement: vertical strain in the subgrade and horizontal strain in the asphalt layer. Limiting vertical strain in the subgrade is intended to preclude failure by subgrade rutting. Limiting horizontal strain at the bottom of the asphalt surfacing layer guards against pavement failure initiated by cracking of the asphalt surface layer.

a. Hot Mix Asphalt Surfacing. Hot mix asphalt surfacing should meet the requirements of FAA Item P-401. A minimum thickness of 5 inches (127 mm) of hot mix surfacing is required for traffic mixes that include aircraft with the TDT gear. The minimum thickness of hot mix surfacing, as shown in Figures 3-2 through 3-15, is required for traffic mixes that do not include aircraft with the TDT gear. A fixed modulus value for hot mix surfacing is set in the program at 200,000 psi (1 380 MPa). This modulus value was chosen to produce results that closely matched thickness requirements for pavements designed with the CBR methodology.

b. Base Course. A minimum 5-inch-thick (127 mm) stabilized base course is required for pavements serving aircraft with the TDT gear. LEDFAA includes two stabilized flexible base options, designated P-401 and

Variable. The word flexible is used to indicate that these bases have a higher Poisson's ratio (0.35), act as flexible layers as opposed to rigid layers, and are not likely to crack. P-401 is the standard FAA Item P-401 bituminous base, which has a fixed modulus of 400,000 psi (2 760 MPa). The variable stabilized flexible base can be used to characterize a bound base, which does not conform to the properties of P-401. It has a variable modulus ranging from 150,000 to 400,000 psi (1 035 to 2 760 MPa). This modulus range was selected to closely duplicate results obtained from using an equivalency factor range of 1.2 to 1.6 in the CBR method of design. Stabilized (rigid) bases, P-304, and P-306 may also be used as base course; although, they are subject to cracking and can induce reflection cracking in the hot mix asphalt surfacing. Item P-301, Soil Cement Base, is not acceptable for use as a base course for these pavements.

When the layered elastic design procedure is used in lieu of the design procedures in Chapters 3 and 4, the minimum base thickness will be determined in a manner similar to the procedure described in paragraph 319b. The minimum base thickness must be determined by increasing the subgrade CBR value to 20 and removing all subbase layers. The minimum thickness required will be the greater of the resulting base thickness from the LEDFAA program or the minimum base thickness in Table 3-4.

For traffic mixtures with aircraft exceeding 100,000 lbs (45 350 kg) but not containing a TDT gear aircraft, a stabilized base course is required, as noted in paragraph 320. When using the LEDFAA design procedure, the minimum stabilized base thickness is 6 inches (150 mm).

c. **Subbase Course.** Subbases may be aggregate or bound materials. The minimum thickness of subbase for structural purposes is 3 inches (76 mm). Additional thickness might be required for practical construction limitations. Acceptable aggregate materials are P-209, Crushed Aggregate Base Course; P-208 Aggregate Base Course; or P-154, Subbase Course. Acceptable bound materials are P-401, P-304, and P-306. Use of Item P-301 is limited to locations not subject to freeze-thaw cycles. More than one layer of subbase material may be used, i.e., P-209 over a layer of P-154. Layering must be done so as not to produce a sandwich (granular layer between two bound layers) section and to assure that material quality increases toward the top of the pavement section.

For traffic mixtures with aircraft exceeding 100,000 lbs (45 350 kg), a stabilized subbase is required, as noted in paragraph 320. Acceptable materials are specified in Tables 3-6 and 3-7.

d. **Subgrade.** The subgrade is assumed to be infinite in thickness and is characterized by either a modulus or CBR value. LEDFAA converts CBR to modulus by multiplying it by 1,500. Subgrade compaction and embankment construction should be in accordance with Table 3-2.

e. **Seasonal Frost and Permafrost.** Seasonal frost and permafrost effects should be considered by applying the techniques in Chapter 2.

707. **RIGID PAVEMENT DESIGN.** The design process considers one mode of failure for rigid pavement, cracking of the concrete slab. Failure of subbase and subgrade layers is not considered. Limiting the horizontal stress at the bottom surface of the concrete surfacing layer guards against failure by cracking of the surface layer. LEDFAA iterates on the concrete layer thickness until the CDF reaches a value of 1.0. Once a CDF of 1.0 is achieved, the section satisfies the design conditions.

a. **Concrete Pavement Surfacing.** Concrete pavement surfacing should meet the requirements of Item P-501. The minimum concrete surfacing thickness is 6 inches (152 mm).

b. **Subbase Course.** When the layered elastic design procedure is used in lieu of the design procedures in Chapters 3 and 4, the subbase must meet the requirement of paragraphs 326, 327, and 328.

c. **Stabilized Subbase Course.** Bound materials are required for subbase under rigid pavements serving aircraft with the TDT gear. Acceptable bound materials are P-304, P-306, and P-401, variable stabilized rigid and variable stabilized flexible. The minimum thickness of subbase is 4 inches (102 mm). More than one layer of subbase may be used, i.e., P-306 over a layer of P-209. Layering must be done so as not to produce a sandwich (granular layer between two bound layers) section.

d. **Subgrade.** The subgrade is assumed to be infinite in thickness and is characterized by either a modulus or k value. The computer converts k to modulus by using the logarithmic relationship log E = 1.415 + 1.284

log k. Subgrade compaction requirements and embankment construction should be in accordance with Chapter 3 and AC 150/5370-10.

e. Seasonal Frost and Permafrost. Seasonal frost and permafrost effects should be considered by applying the techniques in Chapter 2.

f. Jointing Details. Jointing details for rigid pavements are presented in Chapter 3. The limitations on jointing of rigid pavements for wide body aircraft also apply to pavements designed to serve aircraft with the TDT gear.

708. LAYERED ELASTIC OVERLAY DESIGN. Layered system design permits a direct design approach for overlays. The overlay design method in Chapter 4 relies on an empirically based thickness deficiency approach. The layered system design calculates the thickness of overlay required to provide a 20-year life, which satisfies the layered elastic failure criteria for limiting stress or strain. The 20-year life thickness is defined as the design thickness. Dr. R. S. Rollings designed the design method for overlays of rigid pavement through an FAA-funded research effort, as listed in Appendix 4. Overlay pavements are grouped into four different types as follows:

- Hot Mix Asphalt Overlay of Existing Flexible Pavement
- Concrete Overlay of Existing Flexible Pavement
- Hot Mix Asphalt Overlay of Existing Rigid Pavement
- Concrete Overlay of Existing Rigid Pavement

a. Overlays of Existing Flexible Pavements. The design of an overlay for an existing flexible pavement is essentially the same as designing a new pavement. The existing flexible pavement is characterized by assigning the appropriate thicknesses and moduli of the existing layers. A qualified engineer should be consulted to characterize the existing pavement layers.

(1) Hot Mix Overlay of an Existing Flexible Pavement. A trial thickness of overlay is selected, and the program iterates until a CDF of 1.0 is reached. The overlay thickness required to achieve a CDF of 1.0 is the design thickness.

(2) Concrete Overlay of an Existing Flexible Pavement. The design of a concrete overlay on an existing flexible pavement is essentially the same as designing a new rigid pavement. The existing flexible pavement is characterized by assigning the appropriate thicknesses and moduli of the existing layers. A trial thickness of overlay is selected, and the program iterates until a CDF of 1.0 is reached. The overlay thickness required to achieve a CDF of 1.0 is the design thickness. The design process is relatively simple; however, the characterization of the existing pavement layers requires judgment by a qualified engineering. The program assumes the interface between the concrete overlay and the existing flexible surface is frictionless.

b. Overlays of Existing Rigid Pavements. The design of overlays for an existing rigid pavement is complex because deterioration of the underlying pavement as well as deterioration of the overlay must be considered. The condition of the existing rigid pavement prior to overlay is important and is expressed in terms of the structural condition index (SCI). The SCI is derived from the pavement condition index (PCI). (Additional guidance on deriving an SCI is provided in the LEDFAA user's manual.) The PCI is a numerical rating indicating the operational condition of an airport pavement based on visual survey. The scale ranges from a high of 100 to a low of 0, with 100 representing a pavement in excellent condition. The PCI is measured using ASTM standard test method D 5340, Standard Test Method for Airport Pavement Condition Index Survey. For rigid pavements, 15 different types of distress are considered in measuring the PCI. These distress types all reduce the PCI of a pavement, depending on their severity and relative effect on performance. Not all distress types are indicative of structural distress. Rollings has identified 6 distress types that are indicative of the structural condition of the pavement. Table 7-1 lists these 6 distress types.

TABLE 7-1. RIGID PAVEMENT DISTRESS TYPES USED TO CALCULATE THE STRUCTURAL CONDITION INDEX, SCI

Corner Break
Longitudinal/Transverse/Diagonal Cracking
Shattered Slab
Shrinkage Cracks[a] (cracking partial width of slab)
Spalling–Joint
Spalling–Corner

[a] Used only to describe a load-induced crack that extends only part of the way across a slab. The SCI does not include conventional shrinkage cracks due to curing problems.

An SCI of 80 is consistent with the current FAA definition of initial failure of a rigid pavement, i.e., 50 percent of the slabs in the traffic area exhibit initial structural cracking. The SCI allows a more precise and reproducible rating of a pavement's condition than previous FAA condition factor ratings, Cb and Cr.

(1) Hot Mix Asphalt Overlays of Existing Rigid Pavements. The design process for hot mix overlays of rigid pavements considers two conditions for the existing rigid pavement to be overlaid: a SCI of the existing pavement that is equal to or less than 100.

(i) Structural Condition Index Less Than 100. The most likely situation is one in which the existing pavement is exhibiting some structural distress, i.e., the SCI is less than 100. If the SCI is less than 100, the overlay and base pavement deteriorate at a given rate until failure is reached. LEDFAA assumes an overlay thickness and iterates on the thickness of overlay until a 20-year life is predicted. A 20-year predicted life satisfies the design requirements.

(ii) Structural Condition Index Equal to 100. An existing pavement with an SCI of 100 might require an overlay to strengthen the pavement in order to accept heavier aircraft. If the SCI of the base pavement is equal to 100, an additional input is required—the CDFU, cumulative damage factor used, which estimates the amount of pavement life used up prior to overlay. LEDFAA assumes the base pavement will deteriorate at one rate while the SCI is equal to 100 and at a different rate after the SCI drops below 100. As with an SCI less than 100, a trial overlay thickness is input, and the program iterates on that thickness until a 20-year life is predicted. The design thickness is the thickness that provides a 20-year predicted life.

(2) Concrete Overlays of Existing Concrete Pavements. The design of a concrete overlay of an existing rigid pavement is the most complex type of overlay to be designed. Deterioration of the concrete overlay and existing rigid pavement must be considered as well as the degree of bond between the overlay and existing pavement. LEDFAA considers two degrees of bond and addressed each separately for thickness design.

(i) Fully Unbonded Concrete Overlay. An unbonded concrete overlay of an existing rigid pavement is one in which steps are taken to intentionally eliminate bonding between the overlay and existing pavement. Commonly, the bond is broken by applying a thin hot mix layer to the existing rigid pavement. The interface friction coefficient between the overlay and existing pavement is set to reflect an unbonded condition. The interface coefficient is fixed and cannot be changed by the user. As with hot mix asphalt overlays, an SCI is required to describe the condition of the existing pavement. A trial overlay thickness is input, and LEDFAA iterates until a 20-year service life is predicted. The thickness that yields a 20-year service life is the design thickness.

(ii) Partially Bonded Concrete Overlay. A partially bonded overlay is one in which no particular effort is made to either eliminate or achieve bond between the concrete overlay and the existing rigid pavement. Such overlays are normally appropriate for existing rigid pavements when the SCI is 77 or greater. The interface coefficient is set to reflect a small degree of friction between the overlay and base pavement. This coefficient is fixed and cannot be changed by the user. An SCI for the existing pavement is required. A trial overlay thickness is input, and LEDFAA iterates until a 20-year service life is predicted. The thickness that yields a 20-year service life is the design thickness.

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APPENDIX 4. RELATED READING MATERIAL

1. Electronic copies of the latest versions of the following FAA publications are available on the FAA website at **http://www.faa.gov/**. Printed copies can be requested from the Department of Transportation, Subsequent Distribution Office, Ardmore East Business Center, 3341 Q 75th Ave, Landover, MD 20785. The Department of Transportation, however, will charge a fee for some of these documents. Advisory Circular 00-2, Advisory Circular Checklist, provides a list of all current ACs.

a. AC 00-2, Advisory Circular Checklist and Status of Other FAA Publications.

b. AC 150/5300-13, Airport Design.

c. AC 150/5320-5, Airport Drainage.

d. AC 150/5320-12, Measurement, Construction, and Maintenance of Skid Resistant Airport Pavement Surfaces.

e. AC 150/5300-9, Predesign, Prebid, and Preconstruction Conferences for Airport Grant Projects.

f. AC 150/5335-5, Standardized Method of Reporting Airport Pavement Strength–PCN.

g. AC 150/5370-10, Standards for Specifying Construction of Airports.

h. AC 150/5370-11, Use of Nondestructive Testing Devices in the Evaluation of Airport Pavements.

i. AC 150/5380-6, Guidelines and Procedures for Maintenance of Airport Pavements.

2. Copies of the following reports can be obtained from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161 or at **http://www.ntis.gov/**.

a. FAA-RD-73-169, Review of Soil Classification Systems Applicable to Airport Pavement Design, May 1974, by Yoder; AD-783-190.

b. FAA-RD-74-30, Design of Civil Airfield Pavement for Seasonal Frost and Permafrost Conditions, October 1974, by Berg; ADA-006-284.

c. FAA-RD-74-36, Field Survey and Analysis of Aircraft Distribution on Airport Pavements, February 1975, by Ho Sang; ADA-011-488.

d. FAA-RD-76-66, Design and Construction of Airport Pavements on Expansive Soils, June 1976, by McKeen; ADA-28-094.

e. FAA-RD-73-198-1, Design and Construction and Behavior Under Traffic of Pavement Test Sections, June 1974, by Burns, Rone, Brabston, Ulery; AD-785-024.

f. FAA-RD-74-33, III, Design Manual for Continuously Reinforced Concrete Pavements, May 1974, by Treybig, McCullough, Hudson; AD-780-512.

g. FAA-RD-75-110-II, Methodology for Determining, Isolating and Correcting Runway Roughness, June 1977, by Seeman and Nielsen; ADA-044-378.

h. FAA-RD-73-198-111, Design and Construction of MESL, December 1974, by Hammitt; AD-005-893.

i. FAA-RD-76-179, Structural Design of Pavements for Light Aircraft, December 1976, by Ladd, Parker, Pereira; ADA-04 l-300.

j. FAA-RD-74-39, Pavement Response to Aircraft Dynamic Loads, Volume II–Presentation and Analysis of Data, 1974, by Ledbetter; ADA-022-806.

k. DOT/FAA/RD-74/199, Development of a Structural Design Procedure for Flexible Airport Pavements, November 1974, by Barker and Brabston, ADA-019-205.

l. DOT/FAA/RD-77/81, Development of a Structural Design Procedure for Rigid Airport Pavements, April 1979, by Parker, Barker, Gunkel, and Odom, ADA-069-548.

m. FAA-RD-81-78, Economic Analysis of Airport Pavement Rehabilitation Alternatives, October 1981, by Epps and Wootan, ADA-112-550

n. DOT/FAA/PM-87/19, Design of Overlays for Rigid Airport Pavements, April 1988, by R. S. Rollings, ADA-194-331.

3. Copies of ASTM standards can be obtained from the ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428 or at **http://www.astm.org/**.

4. Copies of AASHTO standards can be obtained from the American Association of State Highway and Transportation Officials, 444 North Capitol Street NW, Suite 249, Washington, DC 20001 or at **http://www.transportation.org/aashto/home.nsf/FrontPage/**.

5. Copies of UFC 3-260-02, Pavement Design for Airfields, Department of the Army, Unified Facility Criteria (UFC), June, 2001 can be obtained from **http://65.204.17.188//report/doc_ufc.html**

The Unified Facility Criteria supersedes the following technical manuals previously noted in this AC:
TM5-824-2, Flexible Airfield Pavements, Department of the Army Technical Manual
TM5-824-3, Rigid Pavements for Airfields Other than Army, Departments of the Army and the Air Force,
TM5-818-2, Pavement Design for Frost Conditions, Department of the Army

6. Copies of MS-11, Full Depth Asphalt Pavements for Air Carrier Airports, January 1973; IS-154, Full Depth Asphalt Pavements for General Aviation, January 1973; and MS-10, Soils Manual, Fourth Edition (1986), can be obtained from the Asphalt Institute, Research Park Drive, PO Box 14052, Lexington, KY 40512 or at **http://www.asphaltinstitute.org/**.

7. Copies of Special Technical Publication M-5, The Estimation of Concrete Flexural Strength from Other Types of Strength Tests, DATE, by W. Charles Greer, can be obtained from MACTEC Inc., Director of Publications, 1105 Sanctuary Parkway, Suite 300 Alpharetta, Georgia. 30004.

8. Copies of FHWA-HI-90-001, Geotextile Design and Construction Guidelines, October 1989, can be obtained from the Department of Transportation, Federal Highway Administration, Turner Fairbanks Highway Research Center, 6300 Georgetown Pike, McLean, VA 22101.

APPENDIX 5. AIRFIELD PAVEMENT DESIGN SOFTWARE

1. BACKGROUND. This appendix announces software to aid with the design of airfield pavements in accordance with the methods presented in Chapters 3 and 4 of this AC. The software presented in this appendix uses Microsoft Excel® as a platform with Visual Basic® for Applications (VBA) Macros to facilitate the design process.

2. AVAILABLE SOFTWARE AND SUPPORT MATERIAL. Two programs (spreadsheets) are available to determine pavement thickness requirements in accordance with this AC. Program **F805FAA.XLS** determines pavement thickness requirements for flexible pavement sections and bituminous overlays on existing flexible pavement sections. Program **R805FAA.XLS** determines pavement thickness requirements for rigid pavement sections and bituminous or Portland cement concrete overlays on existing rigid or flexible pavement sections.

Reference manuals, which guide users through each step, are available for both programs. The manuals assume users are familiar with the design requirements of the AC.

Pavement designs developed using the Frost Design feature of the spreadsheets are consistent with the Reduced Subgrade Strength method described in Chapter 3.

The spreadsheets will produce thickness designs consistent with the nomographs provided in this AC. Small variations should be expected due to difficulties with visual interpretation of the nomographs.

3. ACCESS TO SOFTWARE. Design software and user manuals may be downloaded directly from the FAA Office of Airport Safety and Standards website (**http://www.faa.gov/arp/**). Software links are located on the "resources" and "engineering" pages of this site. Updates or additions to the design software and manuals will be posted online, as well.

4. USE OF SOFTWARE. Numerical results from the programs may be used to complete FAA Form 5100-1, Airport Pavement Design. When used to develop the pavement design, the printed results of the software should be attached to Form 5100-1. Results from the program design summary and the aircraft mixture data provide sufficient information to reproduce and review the pavement thickness design. Additional design information is required to complete Form 5100-1.