EVOLUTION OF FEDERAL AVIATION ADMINISTRATION`S RIGID PAVEMENT DESIGN METHODS APPLIED TO BRASÍLIA INTERNATIONAL AIRPORT, BRAZIL

Bernardo Antonio Silva Ramos[1]
[1]Department of Civil Engineering, Euro-American Univesity Center, Brasília, Brazil
bernardo.ramos@unieuro.edu.br

ABSTRACT

The present study aims to showcase the evolution of the Federal Aviation Administration's (FAA) rigid pavement design method through a case study applied to Runway 11R/29L at President Juscelino Kubitschek International Airport (SBBR) located in Brasília, Federal District, Brazil. A rigid pavement project was proposed for this runway using the empirical method presented in Circular AC 150-5320-6D [4] and the mechanistic-empirical method presented in Circular AC 150/5320-6D [7]. The empirical method will be employed using the charts presented in the circular itself and the electronic spreadsheet R805FAA [5]. Meanwhile, the mechanistic-empirical method will be considered through the software FAARFIELD v.2.0.18 [8]. The thickness of the stabilized base layer was kept at 5 inches, and the thickness of the concrete slab varied between 16.7 (AC 5320-6D and FAARFIELD) and 18.4 inches (R805FAA). The pavement structures obtained clearly illustrate the advancements achieved in FAA's design methods, considering all the limitations imposed by the operational traffic mix in the empirical method.

KEYWORDS: *Airport pavement, Rigid pavement, FAA, FAARFIELD & R805FAA.*

I. INTRODUCTION

An airport pavement is a complex engineering structure. Pavement analysis and design involves the interaction of four equally important components: (i) the subgrade (naturally occurring soil); (ii) the paving materials (surface layer, base, and subbase); (iii) the characteristics of applied loads (weight, tire pressure, location, and frequency); and (iv) climate (high/low temperatures, rainfall) [7].

Airport pavements are constructed to provide adequate support for the loads imposed by aircraft using an airport and to produce a firm, stable, smooth, all-year, all-weather surface free form dust or other particles that may be blown or picked up by propeller wash or jet blast. In order to satisfactorily fulfil these requirements, the pavement must be of such quality and thickness that it will not fail under the load imposed. In addition, it must possess sufficient inherent stability to withstand, without damage, the abrasive action of traffic, adverse weather conditions and other deteriorating influences. To produce such pavement requires a coordination of many factors of design, construction, and inspection to assure the best possible combination of available materials and high standard workmanship [4].

Rigid pavements are those in which the principal load resistance is provides by the surface concrete layer. Typically, the surface course for rigid pavements is cement concrete pavement (P-501). The design curves presented in AC 150/5230-6D [4] 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. Design curves are furnished for areas where traffic will predominantly follow parallel or perpendicular to joints and for areas 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 thickness is determined separately (FAA,1995).

The mechanistic-empirical pavement design shown at AC 150/5320-6G [7] is based on both layered elastic theory and three-dimensional finite element theory. The Federal Aviation Administration (FAA) has developed the software FAA Rigid and Flexible Iterative Elastic Layer Design (FAARFIELD) to assist with pavement design. For rigid pavement design, FAARFIELD uses the horizontal stress at the bottom of the concrete panel as the predictor of the pavement structural life. The maximum horizontal stress for design is determined considering both edge and interior loading conditions. FAARFIELD provides the required thickness of the rigid pavement panel required to support a given aircraft mix for the structural design life over a given base/subbase/subgrade. FAARFIELD will check for minimum thickness of stabilizes base, base and subbase, but only analyses the rigid panel [7].

It's worth noting that the design method presented in Circular AC 150/5320-6D [4] requires the entire operational traffic mix to be represented in terms of an equivalent number of takeoffs of a design aircraft. However, the design method presented in Circular AC 150/5320-6G [7] does not utilize the concept of a design aircraft. Instead, each individual aircraft in the operational traffic mix is considered separately, and the resulting fatigue analysis for each aircraft is assessed using the Miner's Law in terms of the Cumulative Damage Factor (CDF).

This article is divided into four sections. The first section serves as an introduction to the topic addressed in the study. The second section describes how the study was conducted, including an overview of the Brasília International Airport, the materials considered in the project, and the Federal Aviation Administration's dimensioning methodologies employed. The third section presents and discusses the key findings of the study, with the aim of describing the observed patterns and, most importantly, the implications of changing the dimensioning method on the final structure of the airport pavement. The fourth section presents the conclusions drawn from the study. At the end of the paper, the bibliographic references that served as the foundation for the study's development are provided.

II. METHODOLOGY

The main objective of this study is to analyse the evolution of rigid airport pavement design methods developed by the Federal Aviation Administration (FAA). The analysis will be based on comparing pavements obtained through the application of Empirical Method described in circular AC 150/5320-6D [4] and the Mechanistic-Empirical Method presented in circular AC 150/5320-6G [7]. Pavement design using the Empirical Method [4] will be carried out using the charts provided in the circular itself and the electronic spreadsheet R805FAA [5]. On the other hand, pavement design using the Mechanistic-Empirical Method will be performed with the assistance of the software FAARFIELD in its version 2.0.18 [8].

2.1 International Airport of Brasília - President Juscelino Kubitschek

For the purpose of this case study, we will propose a rigid pavement design for runway 11R/29L at the International Airport of Brasília - President Juscelino Kubitschek (SBBR), located in Brasília, Distrito Federal, Brazil.

Currently, the International Airport of Brasília has two parallel runways, both with flexible pavement, with the following dimensions: (i) Runway 11L/29R: 3,200 meters in length, 45 meters in width, and a Pavement Classification Number (PCN) of 76/F/B/X/T; and (ii) Runway 11R/29L: 3,300 meters in length, 45 meters in width, and a PCN of 68/F/B/W/T [3]. Figure 1 illustrates the layout of the runways at the International Airport of Brasília, where Simultaneous Parallel Operations have been implemented since 2015 [2].

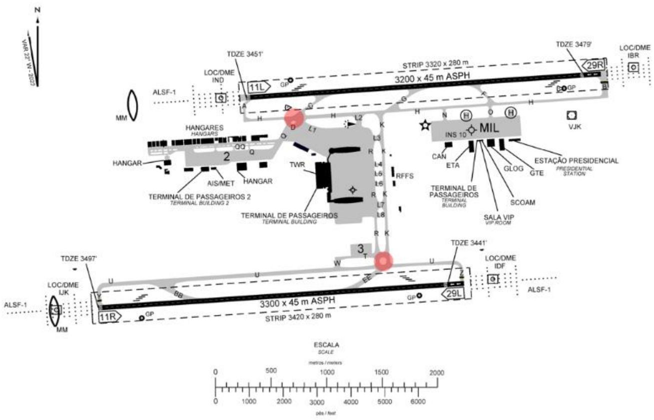

Figure 1. Aerial Chart of Brasília Airport Aerodrome [2]

The materials used in the pavement design for runway 11R/29L consist of the following layers [1]: (i) Surface layer: Hot Mix Asphalt Concrete (HMAC) with a thickness of 6.0 cm; (ii) Binder layer: HMAC with a thickness of 8.0 cm; (iii) Base layer: Granular Graded Base Course (GGBC) made of granite with a thickness of 30 cm and a California Bearing Ratio (CBR) of 80%; (iv) Sub-base layer: Granular Lateritic Gravelly Sub-base with a thickness of 38 cm and a CBR of 40%; and (iv) Subgrade reinforcement: Regularized subgrade with a CBR of 12%.

Table 1 presents the operational traffic data considered in the design of runway 11R/29L, as provided by [1].

Table 1. Operational Traffic Data Considered in the Design of Runway 11R/29L.

Aircraft	Maximum Takeoff Weight (lbs.)	Wheel Load (lbs.)	Avarege Annual Departures	Gear Type
A319-100	154.185	36.619	6.776	Dual wheel
B737-200	115.419	27.412	296	Dual wheel
B737-500	133.370	31.675	7.502	Dual wheel
A320-200	161.894	38.450	6.024	Dual wheel
B737-300	139.427	33.114	2.164	Dual wheel
B737-700	154.361	36.661	5.158	Dual wheel
B737-800	174.042	41.335	3.858	Dual wheel
A310-200	290.749	34.526	47	Dual tandem
A330-200	513.216	60.944	140	Dual tandem
B757-200	254.846	30.263	294	Dual tandem
B757-300	269.758	32.034	116	Dual tandem
B767-200ER	386.674	45.918	442	Dual tandem
B767-300ER	406.608	48.285	977	Dual tandem
MD-11	627.974	74.572	900	Dual tandem
B747-100	749.119	44.479	1.328	Double dual tandem
B777-400	874.449	51.920	203	Double dual tandem
B777-200	662.115	52.417	1.328	Triple tandem

2.2 Materials Considered in the Rigid Pavement Design

The rigid pavement surface will be composed of Portland Cement Concrete (P-501), which must have a minimum characteristic flexural strength of 4.1 MPa (600 psi). This flexural strength should vary between 4.5 MPa to 4.8 MPa (650 to 700 psi) [9]. Therefore, a characteristic flexural strength of 4.5 MPa (650 psi) has been adopted for the design. The minimum rigid surface (P-501) thickness is 6 inches [7].

Since the operational traffic includes aircraft with a weight greater than 100,000 lbs, the use of stabilized subbases is necessary [4,7]. The material chosen for the stabilized subbase in the design is the Cement Treated Base Course (P-304). To facilitate comparison between the methods, a subbase with a thickness of 5 inches has been selected. This thickness aligns with the minimum thickness of 4 inches in the CBR Method [4] and 5 inches in the Mechanistic-Empirical Method [7].

For the subgrade, a CBR value of 12% was considered, as indicated in section 2.1. Equation 1 determines the modulus k for the subgrade [7]. Therefore, a k value of 198.72 pci (pounds per square inch per inch) has been considered for the subgrade.

$$k = 28.6926 \, x \, CBR^{0,7788} \quad (1)$$

Where k is the modulus of subgrade reaction in pci; and CBR is the California bearing ration of subgrade in %.

Equation 2 determines the elastic modulus of the subgrade [7]. Thus, the subgrade modulus considered is 17,997.43 psi.

$$E = 20.15 \, x \, k^{1,284} \quad (2)$$

Where E is the elastic modulus of the subgrade in psi; and k is the modulus of subgrade reaction in pci.

These property transformations occur automatically in the R805FAA electronic spreadsheet and the software FAARFIELD v.2.0.18. A slight variation in the results of unit transformations was observed, but the author does not consider it to significantly affect the final design of the pavement structure.

III. RESULTS

3.1 Design of the Rigid Pavement Using the AC 15/5320-6D [4].

Similar to the granular subbase, the stabilized subbase has the effect of increasing the modulus of subgrade reaction. It can be said that in the design, the modulus of reaction of the system formed by the stabilized subbase and subgrade is considered. Figure 2 illustrates how the reaction coefficient at the top of the subbase is determined. From this figure, it can be determined that the modulus of reaction at the top of the subbase is approximately 280 pci.

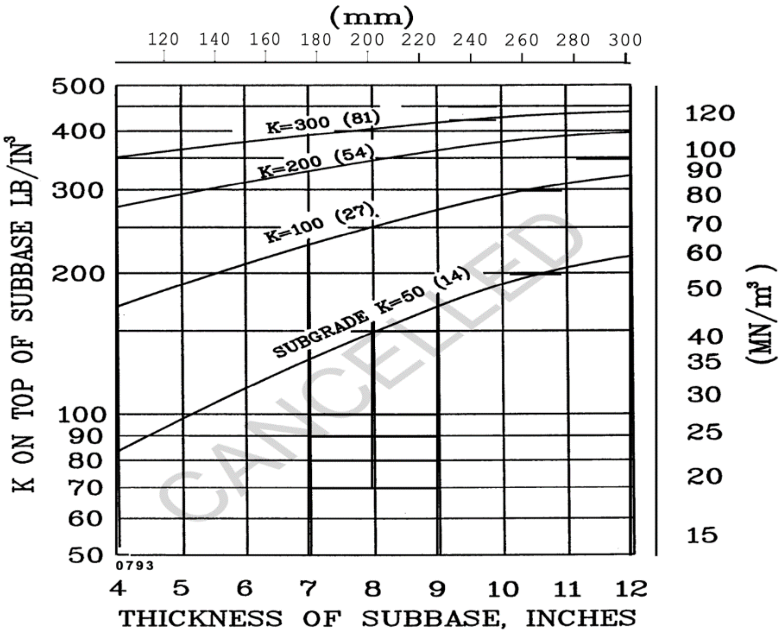

Figure 2. Effect of Stabilized Subbase on Subgrade Modulus [4]

When using the R805FAA electronic spreadsheet [5], a value of 294 pci was obtained for the coefficient of reaction at the top of the subbase. Figure 3 illustrates the input parameters in the R805FAA electronic spreadsheet. In the case of using the charts from AC 150/5320-6D [4], this variation in the results of the reaction modulus is not considered significant since, due to the operator's graphical skills and the chart's resolution, this variation may not be faithfully represented.

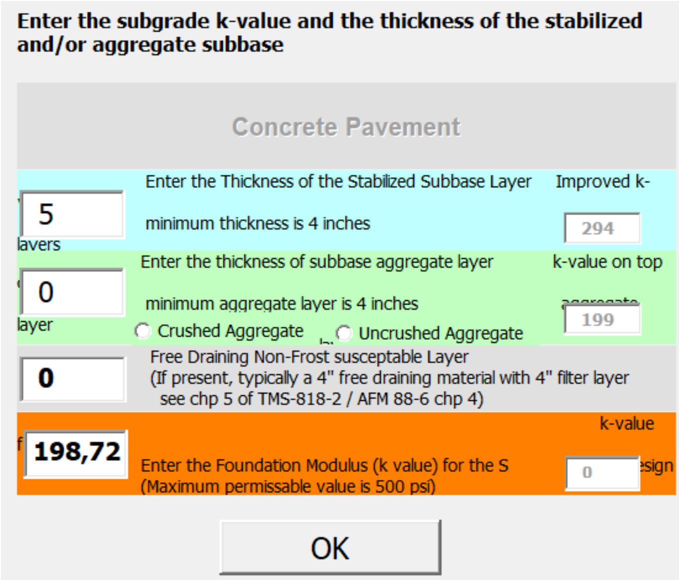

Figure 3. Input Parameters in the R805FAA Electronic Spreadsheet

Figure 4 illustrates the graph for determining the thickness of the concrete slab for a dual tandem axle. The graph is used in the following sequence: (i) draw a horizontal line from the value of the characteristic flexural strength of concrete (650 pci); (ii) intersect this line with the curve of the modulus of reaction at the top of the subbase (290 pci); (iii) from this intersection point, draw a vertical line up to the maximum takeoff weight of the aircraft; and (iv) subsequently, draw a horizontal line to intersect with the thickness of the concrete slab corresponding to the number of aircraft takeoffs considered.

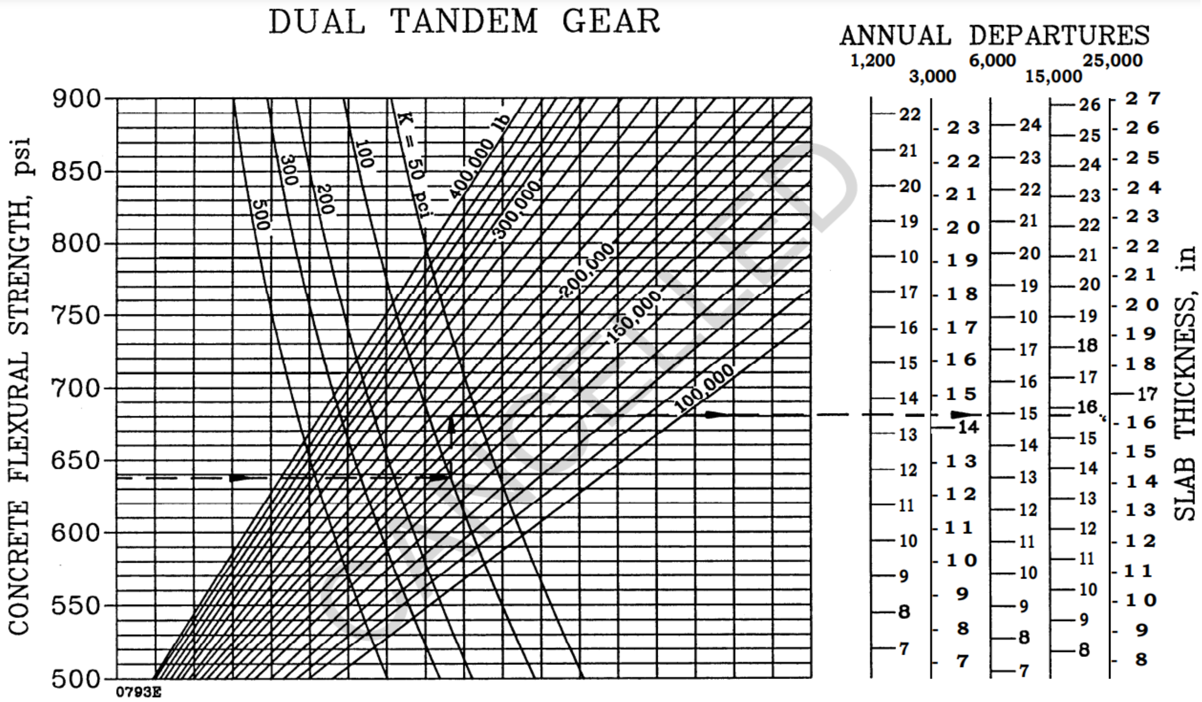

Figure 4. Graph for Determining Concrete Slab Thickness for Dual Tandem Axle

This pavement design method is based on the gross weight of the aircraft. For design purposes the pavement should be designed for the maximum anticipated takeoff 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 [4].

The forecast annual departures by aircraft type will result in a list of several different aircraft. The selection of the design aircraft should be based on the aircraft that imposes the highest pavement thickness requirement. For each aircraft type included in the forecast, it`s essential to determine the pavement thickness required by using the appropriate design curve with the forecast number of annual departures for that aircraft. The aircraft type which produces the greatest pavement thickness is the design aircraft. It is worth noting that the design aircraft may not necessarily be the heaviest among the operational traffic [4]. This is a result of stress analyses conducted using the Elastic Layered System Theory, which considers not only the properties of the constituent materials of the layers but also considers the load application points and, most importantly, the interactions between these points. In the case of Airport Pavements, these interactions can be attributed to the varying configurations of the main landing gear.

Table 2 presents the concrete slab thicknesses required for each aircraft in the operational traffic mix as obtained from the charts in AC 150/5320-6D [4] and the R805FAA electronic spreadsheet (FAA, 2002).

Table 2. Concrete Slab Thicknesses for Each Aircraft in the Operational Traffic Mix

Aircraft	Maximum Takeoff Weight (lbs.)	Wheel Load (lbs.)	Avarege Annual Departures	Gear Type	Pavement thickness (in.)	
					AC 150/5320-6D	R805FAA
A319-100	154.185	36.619	6.776	Dual wheel	14,50	14,41
B737-200	115.419	27.412	296	Dual wheel	10,90	11,02
B737-500	133.370	31.675	7.502	Dual wheel	12,50	13,07
A320-200	161.894	38.450	6.024	Dual wheel	14,60	14,81
B737-300	139.427	33.114	2.164	Dual wheel	12,60	12,50
B737-700	154.361	36.661	5.158	Dual wheel	14,20	14,19
B737-800	174.042	41.335	3.858	Dual wheel	14,90	15,16
A310-200	290.749	34.526	47	Dual tandem	13,00	11,20
A330-200	513.216	60.944	140	Dual tandem	15,30	15,29
B757-200	254.846	30.263	294	Dual tandem	11,00	10,32
B757-300	269.758	32.034	116	Dual tandem	11,00	10,52
B767-200ER	386.674	45.918	442	Dual tandem	11,90	11,55
B767-300ER	406.608	48.285	977	Dual tandem	11,90	11,84
MD-11	627.974	74.572	900	Dual tandem	15,30	16,22
B747-100	749.119	44.479	1.328	Double dual tandem	12,50	12,04
B777-400	874.449	51.920	203	Double dual tandem	*	*
B777-200	662.115	52.417	1.328	Triple tandem	*	*

It's important to note that the B777 aircraft were not considered due to the absence of specific charts in AC 150/5320-6D [4] and their inability to be included in the R805FAA electronic spreadsheet (FAA, 2002). Table 3 summarizes all the limitations and considerations made due to the constraints encountered in determining concrete slab thicknesses.

Upon analysing the concrete slab thicknesses presented in Table 3, it becomes evident that the A330-200 and MD-11 aircraft require the greatest concrete slab thickness (15.30 inches) according to the charts in AC 150/5320-6D. Conversely, the MD-11 aircraft requires the greatest concrete slab thickness

(16.22 inches) according to the R805FAA spreadsheet. Due to the limitations and considerations outlined in Table 3, the MD-11 aircraft has been selected as the design aircraft.

Since the traffic forecast is a mixture of a variety 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 [4]. Equation 3 provides conversion factors for common gear configurations that are used to convert a given gear type to that of the critical airplane. After this conversion, each airplane in the traffic mix, along with its corresponding traffic cycles, will be represented by the same gear configuration as the critical airplane [6].

$$f = 0{,}8^{(M-N)} \tag{3}$$

Where M is the number of wheels on the critical airplane's main gear and N is the number of wheels on the converted airplane's gear.

Table 3. Limitations and Considerations for Using AC 150/5320-6D Charts and R805FAA Electronic Spreadsheet

Aircraft	AC 150/5320-6D		R805FAA	
	Limitations	Considerations	Limitations	Considerations
B737-200	Minimum annual departures: 1.200	Annual departures: 1.200	-	-
A310-200	Minimum annual departures: 1.200 Maximum takeoff weight: 400.000lb.	annual departures: 1.200 Takeoff weight: 400.000lb.	-	-
A330-200	Minimum annual departures: 1.200 Maximum takeoff weight: 400.000lb.	annual departures: 1.200 Takeoff weight: 400.000lb.	Maximum takeoff weight: 450.000lb.	Takeoff weight: 450.000lb.
B757-200	Minimum annual departures: 1.200 Maximum takeoff weight: 250.000lb.	annual departures: 1.200 Takeoff weight: 250.000lb.	-	-
B757-300	Minimum annual departures: 1.200 Maximum takeoff weight: 250.000lb.	annual departures: 1.200 Takeoff weight: 250.000lb.	-	-
B767-200ER	Minimum annual departures: 1.200 Maximum takeoff weight: 325.000lb.	annual departures: 1.200 Takeoff weight: 325.000lb.	Maximum takeoff weight: 350.000lb.	Takeoff weight: 350.000lb.
B767-300ER	Minimum annual departures: 1.200 Maximum takeoff weight: 325.000lb.	annual departures: 1.200 Takeoff weight: 325.000lb.	Maximum takeoff weight: 350.000lb.	Takeoff weight: 350.000lb.
MD-11	Minimum annual departures: 1.200 Maximum takeoff weight: 400.000lb.	annual departures: 1.200 Takeoff weight: 400.000lb.	Maximum takeoff weight: 450.000lb.	Takeoff weight: 450.000lb.
B777-400	There is no specific abacus for this aircraft or landing gear.	The aircraft was not considered.	There is no option to insert this aircraft or landing gear in the spreadsheet.	The aircraft was not considered.
B777-200	There is no specific abacus for this aircraft or landing gear.	The aircraft was not considered.	There is no option to insert this aircraft or landing gear in the spreadsheet.	The aircraft was not considered.

Secondly, after the aircraft have been grouped into the same landing gear configuration, the conversion to equivalent annual departures of the design aircraft should be determined by the Equation 4 [4].

$$Log\ R_1 = Log\ R_2\ x\ \left(\frac{W_2}{W_1}\right)^{0,5} \quad (3)$$

Where R_1 is the equivalent annual departures by the design aircraft; R_2 is the annual departures expressed in design aircraft landing gear; W_1 is the wheel load of the design aircraft; and W_2 is the wheel load of the aircraft in question.

Table 4 presents the equivalent number of takeoffs based on the design aircraft (MD-11: dual tandem landing gear and maximum takeoff weight of 627.974lb.) that will be considered in the design of the rigid pavement.

Table 4. Equivalent takeoffs for the design aircraft using AC 150/5320-6D charts and R805FAA electronic spreadsheet.

Aircraft	Wheel Load (lbs.)	Avarege Annual Departs	Conversion factor	Annual Departs Converted	Equivalent Annual Departs Design Aircraft	
					AC 150/5320-6D	R805FAA
A319-100	36.619	6.776	0,6	4337	354	972
B737-200	27.412	296	0,6	189	24	41
B737-500	31.675	7.502	0,6	4801	251	650
A320-200	38.450	6.024	0,6	3855	376	1043
B737-300	33.114	2.164	0,6	1385	124	283
B737-700	36.661	5.158	0,6	3301	293	779
B737-800	41.335	3.858	0,6	2469	336	911
A310-200	34.526	47	1,0	47	14	23
A330-200	60.944	140	1,0	140	87	140
B757-200	30.263	294	1,0	294	37	73
B757-300	32.034	116	1,0	116	23	40
B767-200ER	45.918	442	1,0	442	119	145
B767-300ER	48.285	977	1,0	977	255	277
MD-11	74.572	900	1,0	900	900	900
B747-100	44.479	1.328	2,4	3242	515	355
				TOTAL =	3.706	6.632

It`s apparent that the limitations encountered in using the charts from AC 150/5320-6D resulted in a lower number of equivalent takeoffs for the design aircraft, with 2.926 operations less than determined by the R805FAA electronic spreadsheet. After the equivalent annual departures are determined, the design should proceed using the appropriate design curve for the design aircraft.

Table 5 presents the thicknesses of the concrete pavement layers obtained using the AC 150/5320-6D charts and the R805FAA electronic spreadsheet.

Table 5. Layout of the rigid pavement designed by AC 150/5320-6D charts and R805FAA electronic spreadsheet.

Materials	Thickness requirements (in.)	
	AC 5320-6D	R805FAA
Concrete Surface (P-501)	16,7	18,4
Stabilized Subbase (P-304)	5,0	5,0
Total	21,7	23,4

It's evident that, despite the limitations and considerations applied to the operational traffic in both the charts and the electronic spreadsheet, the designed pavement thicknesses are close. Even with the operational traffic considered in the electronic spreadsheet being nearly double that of the charts, the difference in thickness was only 1.7 inches. Since the base thickness was kept constant, the variation in the rigid pavement thickness was a result of the variation in the concrete slab thickness.

3.2 Design of the Rigid Pavement Using the AC 15/5320-6G Procedure [7].

After selecting the pavement type to be designed (New Rigid) in the software FAARFIELD v.2.0.18 [8], the operational traffic mix (Table 1) was input into the program. There were no limitations in inputting the aircraft presented in the operational traffic mix. However, it's worth noting that the B777-400 aircraft was not included due to its absence in the program's library, and the program also did not provide a generic triple tandem landing gear type. Thickness designs using FAARFIELD use the entire traffic mix. FAARFIELD does not designate a design aircraft [7].

Figure 5 illustrates the thicknesses of the rigid pavement layers as well as the materials considered in the design.

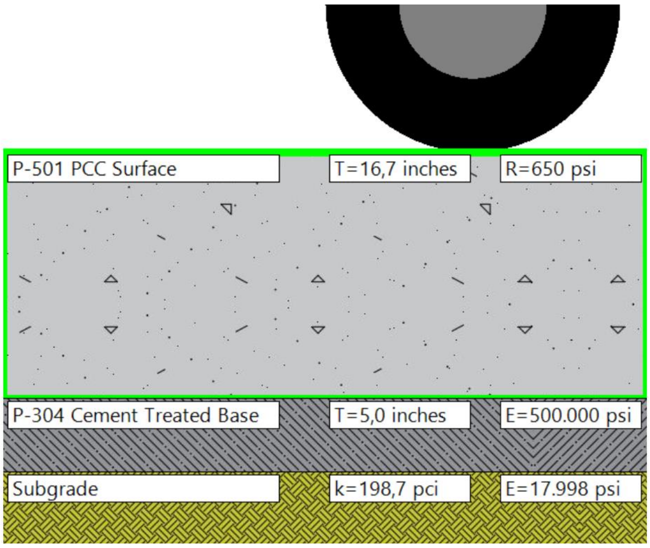

Figure 5. Layout of the rigid pavement designed by FAARFIELD v.2.0.18 [8]

Comparing the thicknesses presented in Table 5 with the thicknesses shown in Figure 5, it can be observed that the concrete slab thickness obtained by the FAARFIELD software is the same as that obtained using the charts presented in Circular AC 150/5320-6D and, consequently, approximately 1.7 inches less than the thickness obtained by the R805FAA electronic spreadsheet. This fact should be interpreted in conjunction with the limitations imposed on considering the operational traffic mix in the AC 15/5320-6D charts and R805FAA electronic spreadsheet, as presented in Table 3.

Considering that the limitations for entering aircraft into the electronic spreadsheet were fewer than those in the charts, it is evident that the pavement design method presented by FAARFIELD resulted in a reduction in the concrete slab thickness, even when considering the operational movements and weights of all aircraft in the operational traffic mix, except for the B777-400 aircraft. This fact confirms the refinement in the design routine used by the FAARFIELD computer program compared to the design concepts used in Circular AC 150/5320-6D, whether through the charts or electronic spreadsheets.

For a clear understanding of the results, it`s important to note that the FAARFIELD software comprises a comprehensive library of subprograms, including: (i) LEAF (layered elastic analysis); (ii) FAAMesh (three-dimensional mesh generation for finite element analysis); (iii) FAASR3D (finite element processing); and (iv) ICAO-ACR (ACR computation following the ICAO standard method). Specifically, for the design of rigid pavements, the FAARFIELD software employs a three-dimensional finite element model (FAARFIELD3D) to calculate stress at the edges of concrete slabs and refines the design using layered elastic analysis (LEAF) to compute internal stress [7].

The FAARFIELD program's design methodology is based on the concept of the Cumulative Damage Factor (CDF), which considers the individual contribution of each aircraft in the operational traffic to determine the total accumulated damage inflicted on the pavement over all operations of these aircraft. By using this index, although the method accounts for all aircraft within the operational traffic, it allows us to identify the one with the most significant contribution to pavement damage [7].

In simpler terms, the CDF index represents the structural fatigue value of the pavement that will be experienced during its design life based on Miner`s rule. In other words, this index expresses the relationship between the number of allowable load repetitions and the number of repetitions required to cause pavement failure [7]. It's evident that, besides changes in stress calculation methods, the concept of fatigue is introduced into the pavement design process.

Upon completing the design process, the FAARFIELD program generates a "CDF Chart" for the pavement, displaying the CDF index value and its lateral distribution range on the pavement. The design is carried out in such a way that the CDF index equals 1.0. The meanings of variations in this index can be found in the Table 6. However, it's crucial to understand that a CDF value greater than 1.0 does not imply that the pavement cannot support the operational traffic of the airport anymore. Instead, it signifies that the pavement has experienced failure according to the pavement failure concept discussed earlier [7].

Table 6. Meaning of CDF`s value [8]

CDF = 1,0	The pavement will have used all of its fatigue life.
CDF < 1,0	The pavement will have some life remaining, and the value of CDF will give the fraction of the life used.
CDF > 1,0	All of the fatigue life will have been used up and the pavement will have failed.

Figure 5 presents the calculation of the Cumulative Damage Factor (CDF) for the designed rigid pavement. It's apparent that the aircraft contributing the most to the pavement damage is the B777-200. This contribution is significantly higher than the contribution generated by the MD-11 aircraft, which was selected as the design aircraft in section 3.1.

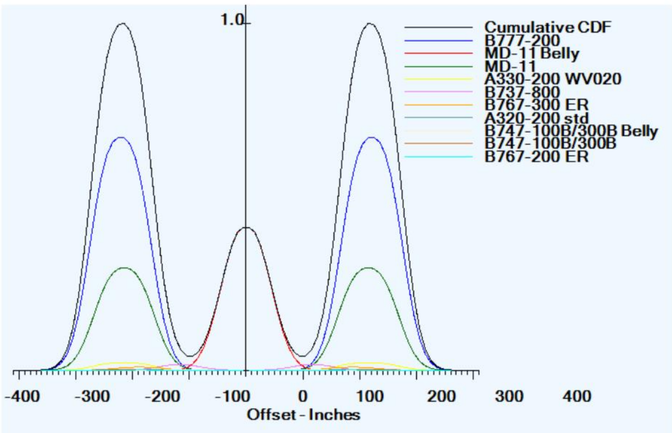

Figure 5. Graphic CDF for the rigid pavement designed by FAARFIELD v.2.0.18 [8]

IV. CONCLUSION

The present study aimed to analyse the evolution of Federal Aviation Administration (FAA) rigid airport pavement design methods applied to a case study at President Juscelino Kubitschek International Airport (SBBR) in Brasília, Federal District, Brazil. The empirical method, AC 150/5320-6D, and the mechanistic-empirical method, AC 150/5320-6G, were used for designing a rigid pavement considering the operational traffic mix for Runway 11R/29L, targeting a 20-year design period.

The empirical method is based on the Westergaard analysis for edge-loaded slabs, and the thickness of the concrete slab used as rigid surfacing is determined using charts. The subbase layer thickness is determined separately. Aircraft composing the operational traffic mix are converted, for design purposes, into a design aircraft. The design aircraft is the one requiring the thickest pavement, and subsequently, all aircraft takeoffs are converted into equivalent takeoffs of the design aircraft. This method is described in Circular AC 150/5320-6D [4] and can be implemented using the charts in the circular or through the electronic spreadsheet R805FAA [5].

It was interesting to observe that there were limitations related to weight and the number of takeoffs when considering aircraft in the operational traffic mix in both the charts and the electronic spreadsheet, as presented in Table 3. The limitations were much more numerous in the circular compared to the electronic spreadsheet. This resulted in the A330-200 and MD-11 aircraft being considered as design aircraft when using the charts and the MD-11 aircraft as the design aircraft when using the electronic spreadsheet. It's also essential to note that these limitations led to significantly different equivalent takeoffs of the design aircraft: 3,706 when using the charts and 6,632 when using the electronic spreadsheet.

As a result, a thickness of 16.7 inches was obtained through the AC 5320-6D charts and 18.4 inches through the R805FAA electronic spreadsheet. Since both design approaches follow the same design premise, the variation in thickness is justified by the limitations regarding the consideration of the aircraft in the operational traffic mix. It's important to emphasize that B777 aircraft couldn't be included in the design due to the absence of specific charts or spreadsheet entries for this aircraft or its landing gear type. The same comment applies to the electronic spreadsheets.

The mechanistic-empirical method described in Circular AC 150/5320-6G [7] is implemented through the FAARFIELD v.2.0.18 software [8]. Design through this software is conducted using finite element three-dimensional models (FAASR3D) and elastic layer analysis (LEAF). Moreover, the aircraft comprising the operational traffic mix are considered individually through the Cumulative Damage Factor (CDF). All aircraft were entered into the software without any limitations on weight or the number of takeoffs. However, the B777-400 couldn't be included due to its absence in the software's library. The design resulted in a concrete slab with a thickness of 16.7 inches, the same as the design obtained using the AC 150/5320-6D charts and 1.7 inches less than the design obtained using the R805FAA electronic spreadsheet.

The fact that the concrete slab thickness is the same in both the software and the charts illustrates the refinement of the current design method. It was possible to consider the entire operational traffic mix in the FAARFIELD software, while there were various limitations regarding aircraft weight and the number of takeoffs when using the AC 150/5320-6D charts. The 1.7-inch difference compared to the thickness obtained through the R805FAA electronic spreadsheet is quite interesting because the limitations related to weight and the number of takeoffs imposed by the spreadsheet were much fewer than the limitations imposed by the charts.

These findings support the overall objective of the study. Advancements in FAA airport pavement design methods result in pavements that are better suited to the demands imposed by traffic over the entire design life of the pavement structure.

REFERENCES

[1]. ARAÚJO, J. L. de. Características Funcionais e Mecânicas de Misturas Asfálticas para Revestimento de Pavimentos Aeroportuários. 2009. 147 p. Dissertação de Mestrado em Engenharia Civil. Universidade de Brasília. Brasília, DF, 2009.

[2]. CNT (2015). Aeroporto de Brasília será o primeiro da América do Sul a operar com duas pistas. Confederação Nacional do Transporte. Brasília, Distrito Federal.

[3]. DECEA. Carta de Aeródromo (ADC) – Brasília/Pres. Juscelino Kubitschek, INTL (SBBR). Departamento de Controle do Espaço Aéreo. Comando da Aeronáutica. Ministério da Defesa. 2022. 2p.
[4]. FAA (1995). Airport Pavement Desing and Evaluation - AC Nº 150/5320-6D. U.S. Department of Transportation, Federal Aviation Administration, Washington, D.C., USA, 165p.
[5]. FAA (2004). Rigid Pavement Design Manual – R805FAA. U. S. Department of Transportation, Federal Aviation Administration. Washington, D.C. USA.
[6]. FAA (2006). Standardized Method of Reporting Airport Pavement Strength – PCN – AC 150/5335-5A. U. S. Department of Transportation, Federal Aviation Administration. Washington, D.C., USA.
[7]. FAA (2021). Airport Pavement Desing and Evaluation - AC No. 150/5320-6G. U.S. Department of Transportation, Federal Aviation Administration, Washington, D.C., USA, 195p.
[8]. FAA (2022). Airport Pavement Desing and Evaluation - FAARFIELD 2.0.18. U.S. Department of Transportation, Federal Aviation Administration, Washington, D.C., USA.
[9]. FAA (2023). Material Characterization. U. S. Department of Transportation, Federal Aviation Administration. Washington, D.C., USA.