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Comparative Study of Airport Layer Thickness Planning Between US Army Corp Graphical Method and Federal Aviation Administration (FAA) PCN-ACN and PCR-ACR Method

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Abstract

Airport pavement is designed following the US Corporation of Engineers method or better known as the California Bearing Ratio (CBR) method and the FAA (Federal Aviation Administration) method which issues regulations for calculating airport pavement structures, namely AC (Advisory Circular) 150_5320_6D which same as the method CBR. In 2021, the FAA issued a standard for calculating airport pavement structures, namely AC (Advisory Circular) 150_5320_6G which uses the FAARFIELD assistance program. The difference in pavement thickness is at most 7.6 cm, on the flexible pavement type base course. In the FAARFIELD Auxiliary Program, all aircraft loads are taken into account as a contributor to pavement damage indicated by the CDF value that can accommodate aircraft loads, in contrast to the graphical method where aircraft are converted to design aircraft. The thickness of the base course using the graphical method is greater than that of the FAARFIELD Assistance Program, this is because when performing calculations, the initial base course value is the minimum value based on the minimum base course table for the use of top foundation layer material (AC No.150_5320_6G). The thickness of the surface course pavement is the same according to FAA provisions for the critical thickness of the surface course which is 4 in or 102 mm.

***Keyword**: Graphic, FAARFIELD, pavement, US corporation of enginners*

Abstrak

Perkerasan bandara dirancang mengikuti metode US Corporation of Engineers atau lebih dikenal dengan California Bearing Ratio (CBR) dan metode FAA (Federal Aviation Administration) yang mengeluarkan peraturan perhitungan struktur perkerasan bandara yaitu AC (Advisory Circular) 150_5320_6D yang sama sebagai metode CBR. Pada tahun 202, FAA mengeluarkan standar perhitungan struktur perkerasan bandara yaitu AC (Advisory Circular) 150_5320_6G yang menggunakan program bantuan FAARFIELD. Perbedaan tebal perkerasan paling banyak 7,6 cm, pada lapis pondasi jenis perkerasan lentur. Dalam FAARFIELD Auxiliary Program, semua beban pesawat diperhitungkan sebagai penyumbang kerusakan perkerasan yang ditunjukkan dengan nilai CDF yang mampu menampung beban pesawat, berbeda dengan metode grafis dimana pesawat dikonversi menjadi pesawat desain. Ketebalan lapis pondasi dengan menggunakan metode grafis lebih besar dibandingkan dengan FAARFIELD Assistance Program, hal ini dikarenakan pada saat melakukan perhitungan, nilai lapis pondasi awal merupakan nilai minimal berdasarkan tabel lapis pondasi minimal untuk penggunaan lapis pondasi atas. bahan (AC No.150_5320_6G). Tebal lapis permukaan perkerasan sama menurut ketentuan FAA untuk tebal kritis, yaitu 4 in atau 102 mm.

***Kata kunci**: Grafis, FAARFIELD, perkerasan, US corporation of enginners*

Introduction

The availability of transportation facilities and infrastructure is a major requirement in supporting the regional development of an area, especially for regions that have large potential resources but are not supported by adequate infrastructure and transportation facilities (El–sayed et al., 2021), (White & Jamieson, 2024) and (Barbi et al., 2023). Air transportation is an important means of traveling to various locations, especially remote areas that are difficult to reach by land or sea transportation (Rahim et al., 2022). Air transport as one of the modes of transportation regulated in the national transportation system, has become one of the national and international regional links in the context of encouraging and accelerating national development and increasing people's welfare (Chai et al., 2022).

Air transport has a sizable role in supporting the economic activities of a region, especially the trade and tourism sectors (Karpov et al., 2023). Airports have two uses, namely air facilities and land facilities (Djonli and Sjafrudin, 2012). This planning design developed with technological advances that developed in its era. Air facilities are the most important factor in an airport because this is where the actual movement occurs or the aircraft moves (Fazal et al., 2023). This affects type of aircraft that use airport facilities, and greatly influences the type and thickness of an airport pavement (Tiwari et al., 2015).

Air-side pavement structures are different from air-side pavement structures on highway pavements or roads in general (Porot et al., 2020) The method usually used in determining the design thickness of the air-side pavement layer is the US Corporation of Engineers method or better known as the California Bearing Ratio (CBR) method and the FAA method Federal Aviation Administration) (Chai et al., 2022). FAA which was formed by United States Institutions to regulate matters relating to aviation and navigation in America (FAA Airport Engineering Division, 2021).

The FAA issued regulations for calculating airport pavement structures, namely AC (Advisory Circular) 150_5320_6D which is basically the same as the CBR method. In 2021 the FAA issued a standard for calculating airport pavement structures, namely AC (Advisory Circular) 150_5320_6G which uses the assist program FAARFIELD 2.0.7 (Federal Aviation Administration Rigid and Flexible Iterative Elastic Layer Design). The two pavement structure calculations are very different in their calculation procedures, in which the previous graphical-method procedure used aircraft operating at an airport must be converted into design aircraft (Stefanus et al., 2022). While the method with auxiliary programs for all types of aircraft operating is calculated for its effect on pavement damage to determine the thickness of the pavement that can accept a total load of aircraft movement (Sun et al., 2022). These differences became the basis for the authors to conduct this research.

The selected case study is North Kolaka Airport, based on geographical location, topography, geology, hydrology, oceanography, climatic conditions as well as socioeconomic and cultural conditions of the local community, the area of North Kolaka Regency is an area that is very profitable in various economic activities, especially in the agricultural sector in a broad sense, mining, fisheries and marine. Based on these empirical conditions, it is hoped that the region will be developed and independent through various efforts to accelerate development by placing economic development. Calculating the thickness of airport pavement today by means of graphs rounding numbers is not accurate, because when looking at the table each planner will be different in drawing the lines. Ideally the thickness planning uses a non-linear method or with auxiliary programs, one of which is FAARFIELD (Shah et al., 2023).

Method

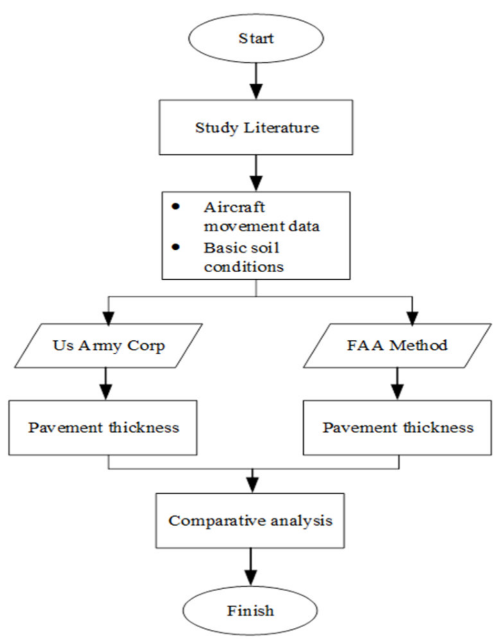


Figure 1. Flowchart of research work

To make it easier to explain the work this research, it is necessary to take steps work to be able to complete this research in accordance with applicable regulations. In this chapter will explain the steps so that it forms a framework that aims to make it easier for writers to find out research workflows. For more the details of the work steps are described in Figure 1. so that research can be carried out properly and efficient.

Results and Discussion

In the calculation of airport pavement, there are variable differences between the US Army Corp Engineers method (Graph) and the Federal Aviation Administration 150/5320_6G (Auxiliary program). Some of the differences between the two methods can be seen in Table 1.

The preparation stage is the initial stage before starting implementation of this research. Relevant data collection was carried out at the North Kolaka, Southeast Sulawesi transportation service and PT. Portal Engineering (airport planning consultant). Preparations include initial interviews with several parties to understand the environment or conditions of the airport. Sangia Nibandera Airport, North Kolaka is in the stage of increasing capacity so it is necessary to research the conditions of runway pavement because the runway is the upper component that directly receives the load from the acting forces (Istiar et al., 2017), (Prahara & Rachma, 2020) and(Fazal et al., 2023).

Pavement thickness calculation analysis.

In calculating the pavement thickness planning, there are two methods that will be used, namely the US Army Corp Engineers (graphic) method, the classical method and the Federal Aviation Administration 150/5320_6G (Auxiliary Program) FAARFIELD. In the classical/graphical method, there are several ways to calculate using the US Army Corp Engineers (FAA), PCN and ACN methods. However, in this study the method used is the FAA method which is controlled with 2 COMFA auxiliary programs for the classic method, while FAARFIELD for the Federal Aviation Administration 150/5320_6G.

Calculation of flexible pavement using the US Army Corp Engineers method (Graph)

In pavement calculations using the graphical method, there are several things that need to be known which are the factors to be used in pavement calculations. These factors include: (1) Wheel arrangement. Each type of aircraft has a different wheel arrangement, including single wheel, dual wheel, dual tandem, and others (Yip et al., 2020), (Shah et al., 2023) and (Rezaei-Tarahomi et al., 2017); (2) MTOW (Maximum Take-off Weight). Is the maximum aircraft load at takeoff. This load includes empty operating weight, fuel, and payload (De Castro & De Oliveira, 2024), (Prahara & Rachma, 2020) and (Brill & Kawa, 2017); (3) Calculating the equivalent annual departure. It takes the movement of aircraft at Sangia Nibandera Airport, North Kolaka, the types of aircraft operating at the airport can be seen in Table 2.

Table 1. Differences in the concept of calculating the two airport pavement planning methods.

Method	Parameter		
	Total annual departures	Aircraft design	Soil condition data
US Army Corp Engineers (Grafik)	Obtained from the number of departures in the planned year and equivalent so that it can result in excess and deficiency in the number of total annual departures	What counts is the plane that has the most frequency of departures	The CBR value used is Subgrade and Subbase
Federal Aviation Administration 150/5320_6G (Software)	Traffic growth multiplied by the number of departures times the planned life of the pavement, so as not to cause shortages and excesses of the total number of annual departures	All aircraft are calculated as load contributors for each pavement layer that has CDF, so that any aircraft needs can be used	Just enter the CBR Subgrade value

Table 2. Equivalen annual departure

Step	Aircraft type	Wheel Arrangement	MTOW		Annual Departure		W1	W2	LogR1	R1
			Kg	Lb	R2'	R2				
I	ATR 42.500	Dual Wheel	18.600	41.006	730	730	44.697	9.739	3.53	3.350
	ATR 72.500	Dual Wheel	22.800	50.265	730	730	44.697	11.938	3.44	2.733
II	A320 Twin std	Dual Wheel	73.900	162.920	356	356	44.697	38.693	2.61	411
	737-800	Dual Wheel	79.243	174.699	356	356	44.697	41.491	2.58	384
III	737-900 ER	Dual Wheel	85.366	188.198	730	730	44.697	44.697	2.86	730
Total equivalent annual departure design										7.608

Table 3. PCN of the Sangia Nibandera Airport, North Kolaka

PCN	Pavement type	Subgrade category	Wheel pressure	Evaluation method
Numeric	F = Flexible	C = Low	W	T = Technical

From the table it can be seen the wheel type, maximum weight at takeoff, and annual departure for each type of aircraft. Next is to determine the Equivalent Annual Departure value by using the 737-900 ER aircraft type as the design plane that will be used to design pavement thickness; (4) Determine the design aircraft. Planned aircraft can be determined by looking at the type of aircraft in operation and the MTOW (Maximum take of Weight) and the number of departures for each type of aircraft In this planning, the heaviest and busiest operating aircraft movement data were used, namely at the time of the ultimate/third stage planning, a Boeing 737-900 ER aircraft with a dual wheel wheel configuration was selected as the design aircraft.

Determine the main landing gear load of the aircraft (W1).

The main landing gear type is crucial in calculating pavement thickness. This is due to the distribution of aircraft loads through the wheels to the pavement. The aircraft ground strength, it is assumed that 5% of the load is given to the nose gear while 95% is charged to the main gear. If there are two main gears, then each gear can withstand 47.5% of the aircraft's load. In the calculation using the formula:

$$W_1 = P \text{ x MTOW x } \frac{1}{A} \text{ x } \frac{1}{B} \quad (1)$$

Where W1 is the design load of the aircraft's landing gear load (lb), MTOW is the gross weight of the aircraft at take-off,A is the number of wheel configurations, B is the number of wheels per configuration, P is the percentage of load received by the main landing gear

In this study Boeing 737-900 ER aircraft is used with a Dual Wheel wheel configuration with an MTOW of 188,198 lb, so the main landing gear load for W1 aircraft is :

$$W_1 = P \text{ x MTOW x } \frac{1}{A} \text{ x } \frac{1}{B}$$

$$= 0{,}95 \text{ x } 188.198 \text{ x } \frac{1}{2} \text{ x } \frac{1}{2} = 44.697 \text{ lb.} \quad (2)$$

Determine the equivalent value of departure of other aircraft operating at the airport. In aircraft traffic, the pavement structure must be able to serve various types of aircraft that have different types of landing gear and vary in weight. The effect of the load caused by all types of traffic models must be converted into design aircraft, namely Boeing 737-900 ER with the equivalent annual departure from other mixed aircraft. So that it can be assumed that the calculation is useful for knowing the overall total departure of the various types of aircraft that are converted into Design aircraft. To determine W_1, the equation is used the Formula 2.

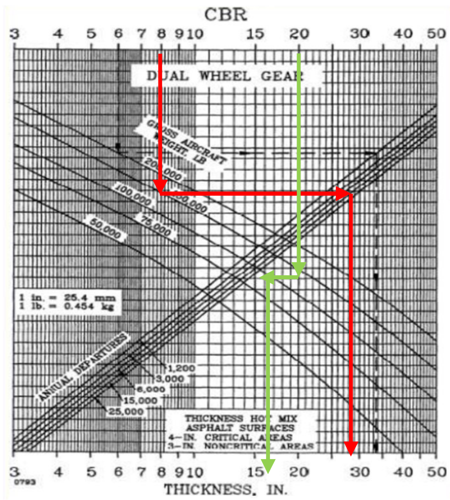
Defining the CBR control

The runway pavement is designed with several layers with several layers each layer is planned with a certain thickness and sufficient enough to ensure that the load from the aircraft can be carried by each layer of pavement (Mounier et al., 2015) and (Merhej & Feng, 2011). The strength of the pavement on the airside facility is expressed in a series of numbers and letters which is stated by the Pavement Classification Number (PCN) (Istiar & Aziz, 2021), (Wang et al., 2024) and (Nowak, 2013). PCN describes the strength of the pavement structure, the type of pavement, the subgrade strength limit, and the wheel pressure limit. Broadly speaking, PCN values are written in the following format: PCN/F/B/X/T. In this study, PCN method is used to represent the strength of the pavement structure. From the runway PCN values above, it can be seen that the subgrade category has a medium. The PCN value results of Sangia Nibandera Airport, North Kolaka can be seen in Table 3. Subgrade value which we can see from the table classification of subgrade bearing capacity categories.

The CBR Subgrade value from the analysis of the geotechnical team is as follows: The condition of the soil at the top is generally a slightly loamy sand (7.8 - 14.8%) with a blackish gray color, slightly sandy and coarse grained, loose in the range of 0 – 0.75 m, after which brownish yellow, yellowish gray, slightly whitish are found. Soil description gravel is very hard and sometimes brittle, with consistency, less consistent, SPT field and sondir test values show quite varied results with CBR correlation estimated to be the lowest 0% to the highest around 6% CBR after repairs are made so that meets the instead planning requirements of the geotechnical team is CBR> 8%.

Aircraft plan it can be seen that the wheel pressure of aircraft operating at Sangia Nibandera Airport, North Kolaka using Boeing 737-900 ER aircraft is planned to be medium wheel pressure on the pavement > 218 Psi, because the wheel pressure of Boeing 737-900 ER is 1,517 kPa at conversion 220

Psi. In determining the thickness of the pavement layer using the Dual Wheel Gear design chart, by entering the design CBR Subgrade value, Equivalent Annual Departure value, and Gross Aircraft value, which is presented in Figure 2 Subgrade CBR value is 8%, Equivalent Annual Departure 7,608 and MTOW 188,199 pounds.



Line for total CBR 8% pavement thickness

Figure 2. Pavement thickness graph for Boeing 737-900 ER

The pavement thickness results are obtained from the graphic plot of Figure 2. Total pavement thickness from the graph of Figure 2 the total pavement thickness is 28 inches or 28 x 2.54 = 71.12 cm.

The thickness of the surface layer (Surface). From the graph of Figure 2**.** it is known that the thickness of the surface layer (Surface) critical area is 4 inches, while for non-critical is 3 inches. So for planning the thickness of the surface layer, a critical number is taken, namely 4 inches.

Thickness of the foundation layer (base course). Using the same graph with 20% subbase CBR, 16 inches thick is obtained. Thus, from 20% CBR, the thickness of the base layer and surface layer is 16 inches. So that the thickness of the top foundation layer is 16 inches minus 4 inches, which is 12 inches. The CBR of the top foundation is taken from the minimum thickness allowed for the top foundation layer, namely CBR 20% (FAA AC 150/5320_6D) corrected with the minimum base coursein Figure 3

Thickness of the subbase course. The total thickness of the pavement is 32 inches, so the thickness of the subbase layer is: Subbase course = total layers - base course – surface course = 28 -11- 4=13 inches.

The results of calculating the thickness of the runway flexible pavement using the US Army Corp Engineers method (Graph) are shown in Table 4 and Figure 4

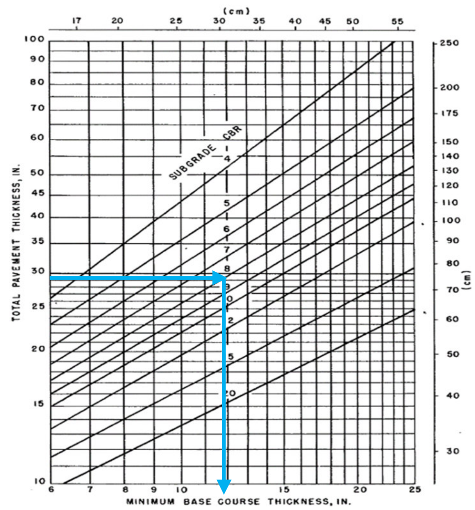


Figure 3. Thick base course graphic

Table 4 Asphalt pavement thickness

Layer	inchi	cm
Surface course (P-401/P-403 hot mix asphalt) HMA	4	10
Base course (P-304 cement treated base) CTB	11	28
Subbase course (P-208 crushed aggregate)	13	33
Total	28	71

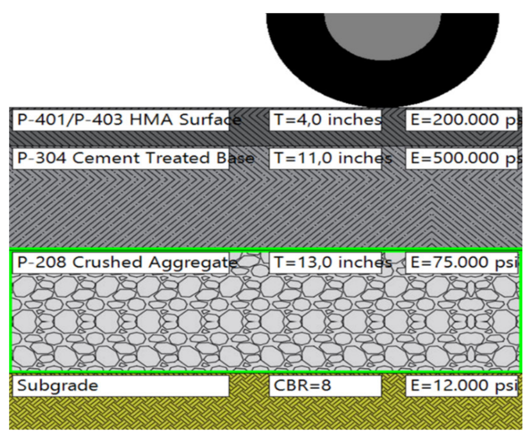


Figure 4 Asphalt pavement US Army Corp

Pavement Classification Number (PCN) analysis with COMFAA

COMFAA software tools, the PCN of the ultimate stage construction is targeted at 35 F/C/W/T. The results of the analysis of the thickness of the 34-inch pavement construction with the COMFAA 3.0

program obtained a PCN value of 49 F/C/W/T resulting from the program can be seen in Figure 5.

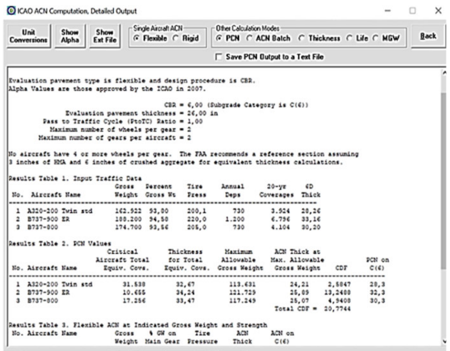


Figure 5. PCN by COMFAA

Calculation of flexible pavement method FAA AC (Advisory Circular) 150_5320_6G Assistive program FAARFIELD

Based on the calculations of the COMFAA assisted program, the PCN value is PCN 32 F/C/W/T, which means that we can know the value of the subgrade bearing capacity of the subgrade. The CBR value of the subgrade plan is 8%. Then enter data - plan aircraft data that operates and total arrivals per year can be seen in Figure 6. Enter plan material, namely:
P-401 = Hot mix asphalt
P-304 = CTB
P-208 = Crushed stone CBR 80%
Soil = CBR of at least 8%

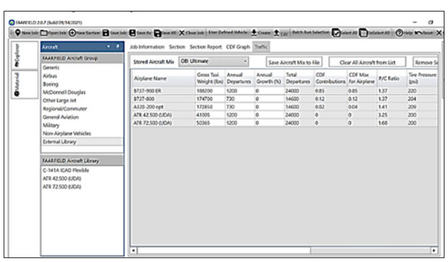


Figure 6. Ultimate aircraft design

The results of the calculation of the flexible pavement thickness of the runway using the FAA method with the auxiliary program can be seen in Table 5 and Figure 9.

Which can be seen in Figure 7. After calculating and entering the existing data, a flexible pavement thickness of 26 inches is obtained which can be seen in Figure 9. For the graph, the distance between the main landing gear of each aircraft from the line and the level of pavement damage caused by the wheels cummulative dammage factor can be seen in Figure 8.

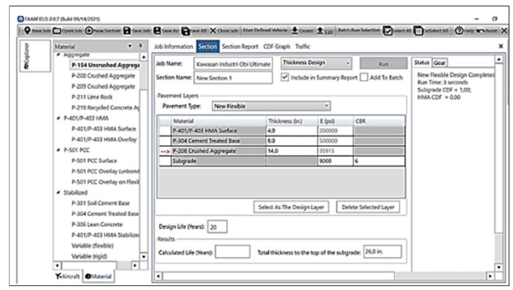


Figure 7. Ultimate pavement material design

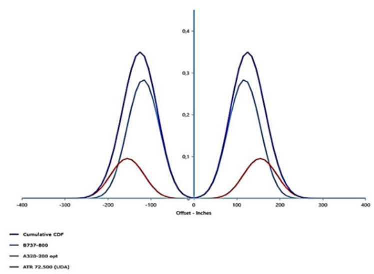


Figure 8. Cummulative dammage factor

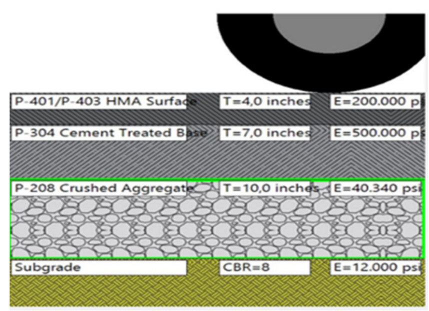


Figure 9. Flexible pavement FAARFIELD

Table 5. Total flexible pavement FAA

Layer	inchi	cm	Modulus	Poisson's ratio
Surface course (P-401/P-403 hot mix asphalt) HMA	4	10.2	200000	0.35
Base course (P-304 cement treated base) CTB	7	17.78	500000	0.2
Subbase course (P-208 crushed aggregate)	10	25.4	40340	0.45
Total	21	53.38		

Table 6. Comparation beetwen two method

No	Pavement type Flexible	The calculation report					
		US Corporation of Enginners		FAA AC (Advisory ircular) 150_5320_6G		Difference	PCN / PCR
		Graphic		FAARFIELD			COMFAA and FAARFIELD
		CBR 8%					
		ichi	cm	ichi	cm	%	
1	Surface course (P-401/P-403 hot mix asphalt) HMA	4.0	10.2	4.0	10.2	0.0%	54 F/C/W/T 490 F/C/W/T
2	Base course (P-304 cement treated base) CTB	11.0	27.9	7.0	17.78	7.5%	
3	Subbase course (P-208 crushed aggregate)	13.0	33.0	10.0	25.4	5.6%	
	Total	28.0	71.1	21.0	53.38	13.1%	

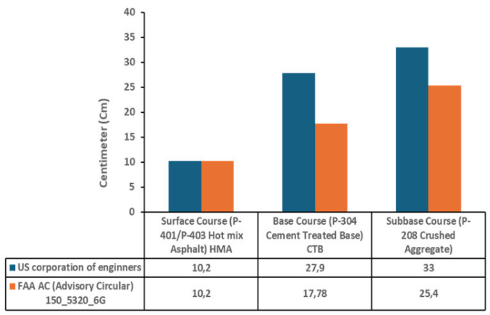


Figure 10. Comparation Beetwen Two Method

From the results of the two methods of planning the calculation of airport pavement thickness, namely the US Corporation of Engineers (Graphic) method and FAA AC (Advisory Circular) 150_5320_6G (FAARFILED), several differences can be seen which can be seen in Table 6 and Figure 10.

Calculation analysis

The difference in graphical calculations with the FAARFIELD auxiliary program for flexible pavements is 17.72 cm or 13.1 %, so that the graphical calculation results are thicker compared to the FAARFIELD auxiliary program method. The results obtained from each method have differences in each layer, this is caused by several factors, namely:

In the FAARFIELD assisted program method, all aircraft loads are taken into account as a contributor to pavement damage indicated by the CDF value, in contrast to the graphical method where the aircraft are converted to design aircraft. From the results of calculations using the FAARFILED auxiliary program, the CDF value is 1, which means that the pavement is able to accommodate the maximum aircraft load (Boeing 737-800 and Boeing 737-900 ER) up to the 20 years plan.

The surface course values for the two pavement thicknesses are different because the graphic method that uses a graph depends on the dual wheel gear type design plane, so the critical thickness is taken as shown on the graph. The thickness of the base course using the graphical method is thicker than using the FAARFIELD software, this is because when performing calculations, input the initial value of the base course pavement thickness which is the minimum value based on the minimum base course table for using subbase layers (AC No. 150_5320_6G). Graphical calculations have the disadvantage of accuracy in drawing lines for the values of each parameter to be plotted onto a graph, so that the results obtained can be larger or smaller.

Conclusion

The variables that affect the dissimilarity in the two methods are the determination of the type of design aircraft, the method used, and the design age. The results of planning the thickness of the flexible pavement layer using the US Army Corps Engineer method (graph) is 711 mm with details of the surface course (P-401/P-403 hot mix asphalt) is 102 mm, base course (P-304 cement treated base) is 279 mm, subbase course (P-208 crushed aggregate) is 330 mm with a PCN value of 32 F/C/W/T. The results of planning the thickness of the flexible pavement layer using the Federal Aviation Administration (FAA) method with the FAARFIELD program is 538 mm with details of the surface course (P-401/P-403 hot mix asphalt) is 102 mm, base course (P-304 cement treated base) is 178 mm, subbase course (P-208 crushed aggregate) is 254 mm with a PCN value of 49 F/C/W/T. The difference in pavement thickness is at most 17.72 cm, on the base course layer of the flexible pavement type.

In the FAARFIELD Auxiliary Program, all aircraft loads are taken into account as a contributor to pavement damage indicated by the CDF value that can accommodate aircraft loads, in contrast to the graphical method where aircraft are converted to design aircraft. The thickness of the base course using the graphical method is greater than that of the FAARFIELD Assistance Program, this is because when performing calculations, the initial base course value is the minimum value based on the minimum base course table for the use of top foundation layer material (AC No.150_5320_6G). The thickness of the surface course pavement is the same according to FAA provisions for the critical thickness of the surface course which is 102 mm.

Suggestion

In terms of accuracy, it is better to choose to use the FAARFIELD Auxiliary Program, because the method of calculation with the FAARFIELD auxiliary program, all aircraft loads are taken into account as a contributor to pavement damage indicated by the CDF value, unlike the graphical method where the aircraft are converted to plan planes. From the results of calculations using the FAARFILED auxiliary program, the CDF value is 1, which means that the pavement is able to accommodate the maximum aircraft load (Boeing 737-800 and Boeing 737-900 ER) up to the 20 years plan.

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