International Journal of Engineering Research Updates

Journal homepage: https://orionjournals.com/ijeru/

ISSN: 2783-0187 (Online)

(Research Article)

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Comparison analysis of flexible pavement runway layers between CBR, LCN, and FAA methods

Agus Muldyanto * and Purwanto

Civil Engineering Department, University of Semarang, Soekarno Hatta Street, Central Java 50196, Indonesia.

International Journal of Engineering Research Updates, 2023, 04(01), 010–019

Publication history: Received on 03 December 2022; revised on 19 January 2023; accepted on 21 January 2023

Article DOI: https://doi.org/10.53430/ijeru.2023.4.1.0011

Abstract

Ahmad Yani International Airport is located in Semarang City, Central Java, Indonesia. Runway length is 2650 x 45 m, located at an altitude of 3 meters above sea level and coordinates 06°58′17″S 110°22′27″E with flexible pavement. For subgrade CBR value of 3%.

The purpose of this study is to evaluate the thickness requirements of runway pavement by comparing the calculation results with three methods, namely California Bearing Ratio (CBR) by analytical method, while for the graphical method by using the Load Classification Number (LCN) and Federal Aviation Administration (FAA) methods, according to the aircraft the biggest plan at the airport is the Boeing 737-900ER aircraft type. To get results that are safe, comfortable and economical.

The basis for this calculation is subgrade soil with a CBR value of 3%. The results of the comparison of the three methods are LCN: FAA: CBR, namely 1: 1.14:1.55. From this case for the most efficient pavement thickness using the LCN method

Keywords: Runway; Flexible Pavement; CBR; LCN; FAA

1 Introduction

Ahmad Yani International Airport is located in Semarang City which is one of the major airports in Central Java Province. Ahmad Yani International Airport has a runway with a size of 2650 m x 45 m which is equipped with 2 exit taxiways and an apron with a capacity of 6 narrow body aircraft, 2 for small propeller aircraft and 2 helicopters. The largest type of aircraft currently served is the Boeing 737-900ER. To serve the type of aircraft planned, it is necessary to review the runway facilities, especially the thickness of the pavement using methods including CBR, LCN and FAA, taking into account safety, comfort and efficiency.

With the planned use of a larger type of aircraft (Boeing 737-900ER), the airport airside facilities, especially in this study, that need to be evaluated are the runway pavements which include, among others: Total aircraft traffic, Total passenger and goods traffic movements. And largest aircraft load plan (Boeing 737-900ER).

The purpose of this study was to compare the thickness of the flexible pavement runway at Ahmad Yani airport using the CBR, LCN and FAA methods.

* Corresponding author: Agus Muldyanto

2 Research Methods

The research was conducted at Ahmad Yani International Airport, Semarang. The data used in this study include: In determining pavement thickness, there are several variables or data needed, including: subgrade and subbase CBR values, maximum takeoff weight of aircraft (MTOW), number of annual departure aircraft, type of landing gear each aircraft, and airport drainage [Brian C. S., et al. 2016][1]. Then analyzed the thickness of the pavement on each method CBR, LCN, and FAA. From the results of the pavement thickness, it is then compared which result is the most efficient runway pavement thickness and which method is the easiest and fastest.

3 Results and Discussion

Soil data obtained from Ahmad Yani International Airport in Semarang has a CBR value of 3%. Maximum Takeoff Weight (MTOW) data along with the type of landing gear at Ahmad Yani International Airport Semarang can be seen in table 1.

Table 1 Data on the weight of the aircraft taking off and the type of landing gear at Ahmad Yani International Airport, Semarang

NO	JENIS PESAWAT	TIPE RODA	MTOW	
			LBS	KG
1	ATR72	Single	50,706	23,000
2	B733	Dual	139,500	63,276
3	B734	Dual	143,500	65,091
4	B735	Dual	133,500	60,555
5	B738	Dual	172,500	78,245
6	B739	Dual	187,700	85,000

Source: www.boeing.com

From the data obtained for the number of flight operations from 2013 to the first semester of 2020, this data can be seen in table 2.

From the data table above using the largest aircraft, namely the Boeing 737-900ER which has a total of 2900 flights in 2020, the data can be seen in table 2.

Table 2 Departure Movement Data for 2013-2020

NO	TIPE PSWT	2013	2014	2015	2016	2017	2018	2019	2020
1	**A320**	1407	1553	1787	3135	2982	4503	4954	5450
2	AS330	0	0	0	10	11	11	12	13
3	AS365	0	0	0	0	8	8	9	10
4	AS550	0	0	0	0	170	170	187	206
5	ATR72	1759	2408	3138	3754	3041	3548	3903	4294
6	B105	290	850	1480	476	2021	1399	1539	1693
7	B200	0	0	16	24	24	24	26	29
8	B205	338	1781	2898	2114	474	457	503	553
9	B400	0	0	0	0	4	4	4	5
10	B412	380	2018	2747	2216	3567	2651	2916	3208
11	B733	118	211	231	296	336	458	504	554

12	B734	159	401	391	403	352	276	304	334
13	B735	1677	1511	1327	1078	1098	1313	1444	1589
14	B738	3291	3730	4836	2940	5015	5511	6063	6670
15	B739	3372	3236	2715	2377	1962	2396	2636	2900
16	BK117	0	10	31	41	12	12	13	15
17	C172	1327	1473	2285	1875	319	812	893	983
18	C212	61	283	290	57	28	28	31	34
19	C402	0	11	209	0	4	4	4	5
20	CRJ1000	403	659	693	729	679	677	745	819
21	DHC6	0	0	0	224	112	112	123	136
22	E135	0	0	0	0	11	11	12	13
23	E195	0	0	0	0	281	281	309	340
24	H300	95	3075	1345	5022	848	1852	2037	2241
JUMLAH		14677	23210	26419	26771	23359	26518	29171	32094

Source: Data PT. Angkasa Pura I (Persero) Ahmad Yani Semarang – Analysis by the Author

To determine the growth rate (i) which is then projected into the planned year with equation 1 as follows

$$R_n=R_o(1+i)^n \quad \text{.....(1)}$$

Where:

Rn = data in the nth year from the last year
Ro = data in the last known year
n = the nth year from the last year
i = average growth rate

Table 3 Prediction of the Number of Departures of Planned 737-900ER Aircraft with a Design Life of 20 Years (2021-2040)

YEAR	Number of Departure Planes	YEAR	Number of Departure Planes
2021	2905	2031	2961
2022	2911	2032	2966
2023	2916	2033	2972
2024	2922	2034	2977
2025	2927	2035	2983
2026	2933	2036	2989
2027	2938	2037	2994
2028	2944	2038	3000
2029	2949	2039	3006
2030	2955	2040	3011

The heaviest aircraft with an MTOW of 85,000 Kg is the 737-900ER. Then what is used as the basis for calculating the number of predicted aircraft is 3011 in 2040, the data can be seen in table 3.

3.1 California Bearing Ratio (CBR)

The CBR method formula (Heru, 1990)[2] uses equation 2 as follows

$$T = (8{,}71.\log R + 5{,}43)\sqrt{P.\left(\frac{1}{8{,}1.CBR} - \frac{1}{450.S}\right)} \quad \text{……………. (2)}$$

Where:

T: Thickness of spot pavement (mm) above subgrade
R: Number of working ESWL (repeat load)
S: Wheel (tire) pressure in Mpa
P: ESWL (kg)

Calculation:

CBR = 3 %
R = 3011
S = 1.5 MPa
P = 85,000 Kg

Enter in the formula:

T= (8.71 Log 3011+5.43) √ (85,000 1/ (8.1 x 3)-1/ (450 x 1.5))

= 2074.784 → 2100 mm (rounded up)

2100 mm is the total thickness of crushed stone subbase

To differentiate the pavement layers, the Equivalent factor from AASHTO is used

Ratio (AC)/(CSB)= 0.017/0.0055=3

Comparison of CTB/ (CSB) = 0.0091/0.0055=1.65

For example, the thickness of the A/C is determined to be 100 mm

Is equivalent to 3 x 150 = 450 mm CSB?

For example, CTB is determined to be 300 mm thick

Is equivalent to 1.65 x 300 = 330 CSB

So the required CSB = 2100-450-495 = 1155 mm → 1200 mm

Calculation Results of Pavement Thickness CBR Method

AC thickness = 150 mm = 5.9 inch, CTB = 300mm = 11.8 inch, CSB = 1200 mm = 47.2 inch

Total thickness of seal = 65 inch

Subgrade CBR = 3 %

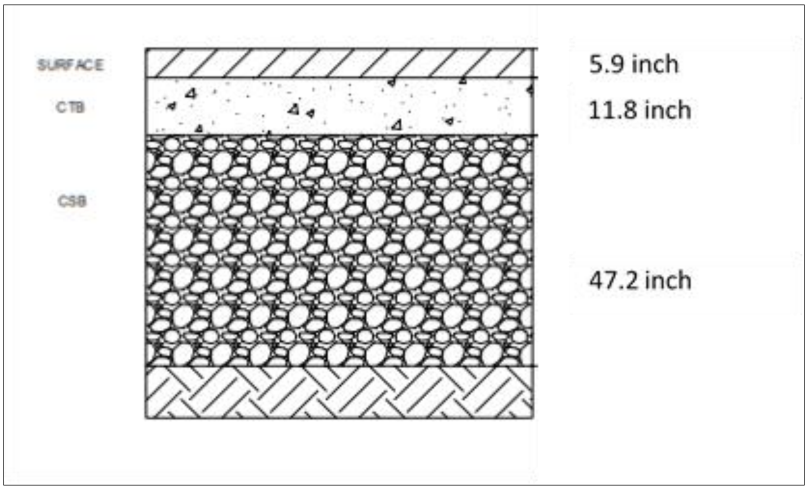


Figure 1 Pavement Thickness CBR Method

3.2 Load Classification Number (LCN)

Load Classification Number (LCN) is a pavement planning and evaluation method from England which is recognized by ICAO [4]. The bearing capacity/bearing strength of the pavement is expressed in LCN figures. Each aircraft can be expressed in LCN,. The LCN number depends on the landing gear geometry, aircraft wheel pressure, pavement thickness composition, if the airport pavement LCN number > aircraft LCN then the aircraft can land safely and securely. [Heri Basuki, 1990][2]. The LCN method also raises the ESWL value and wheel pressure of the planned aircraft to be served in order to obtain the aircraft LCN value, [Dwi A. N.H. and Suwardo, 2019][3].

$$Log\ ESWL = Log\ Pd + \frac{0.31\ Log(2xd)}{Log(2x\frac{z}{d})} \text{…………. (3)}$$

Pd = 0, 95 x 3011 = 2860.45

d = 5,72 m = 572 cm = 225,1969 inchi

z = 17,17 m = 1717 cm = 675, 9843 inchi

P = 1.5 Mpa = 217 PSI

So,

$$Log\ ESWL = Log\ 2860.45 + \frac{0.31\ Log(2x225.1969)}{Log(2x\frac{675.9843}{225.1969})}$$

$$Log\ ESWL = 4.513229$$

$$ESWL = 10^{4.513229}$$

= 32600,88 lbs

Defines Plane Area Contact Lines

Previously it was planned that the B 737-900ER aircraft would have a tire pressure of 1.5 MPa = 217 PSI

$$K = \frac{ESWL}{P} \text{………. (4)}$$

Where:

K = Contact area of the plane (lbs/psi)
ESWL = Equivalent Single Wheel Load (lbs)
P = Air Pressure on Wheels (PSI)

Then

$$K=32600.88/217 = 150.2345$$

From the results of the ESWL and K values that have been calculated above are used to determine the LCN value in figure 2.

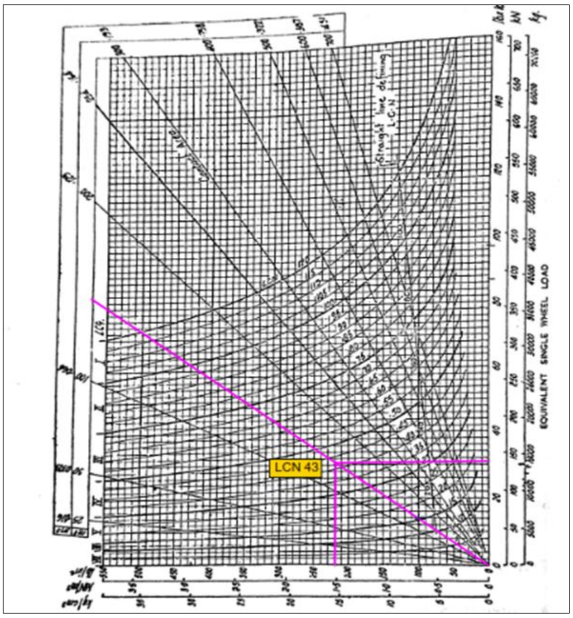


Figure 2 Load Classification Number (LCN) relationship between tire pressure load and contact area for Flexible (ICAO[4]) and rigid planning

The LCN value is 43, which can be seen in figure 2. Next, look for the thickness of the pavement using figure 3 below.

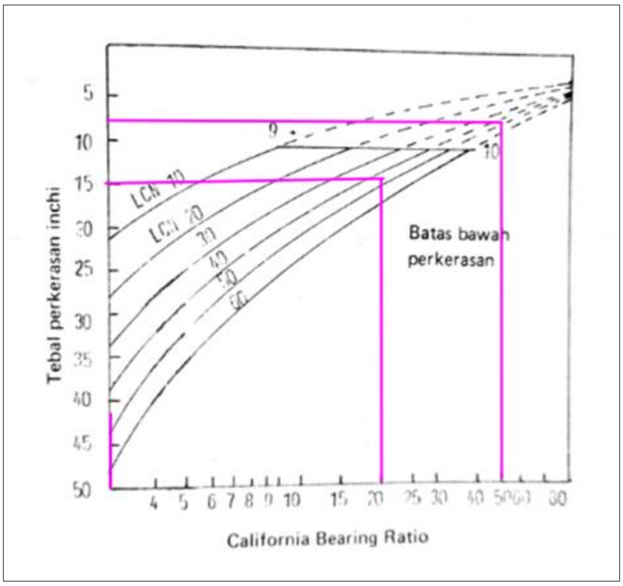


Figure 3 Design Curve of Flexible Pavement for Platform

CBR subgrade = 3, CBR subbase = 20 compared to CBR base = 50

- From figure 2, it reads LCN 43, figure 3 reads, total pavement thickness = 42 inch, subbase thickness : from LCN 43 : CBR = 20, pavement thickness = 15 inch, subbase thickness = 42-15=27 inch
- Thick base coarse , LCN 43 ; CBR 50, pavement read = 7.5 in, thick base coarse = 15 – 7.5 = 7.5 in

Calculation Results of Pavement Thickness LCN Method

Surface 7.5 inch, base coarse = 7.5 inch, subbase coarse = 27 inch and pavement thickness = 42 inch

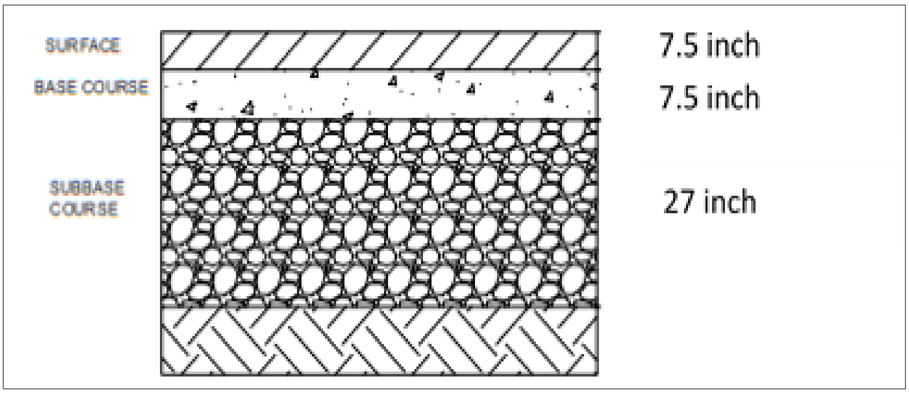
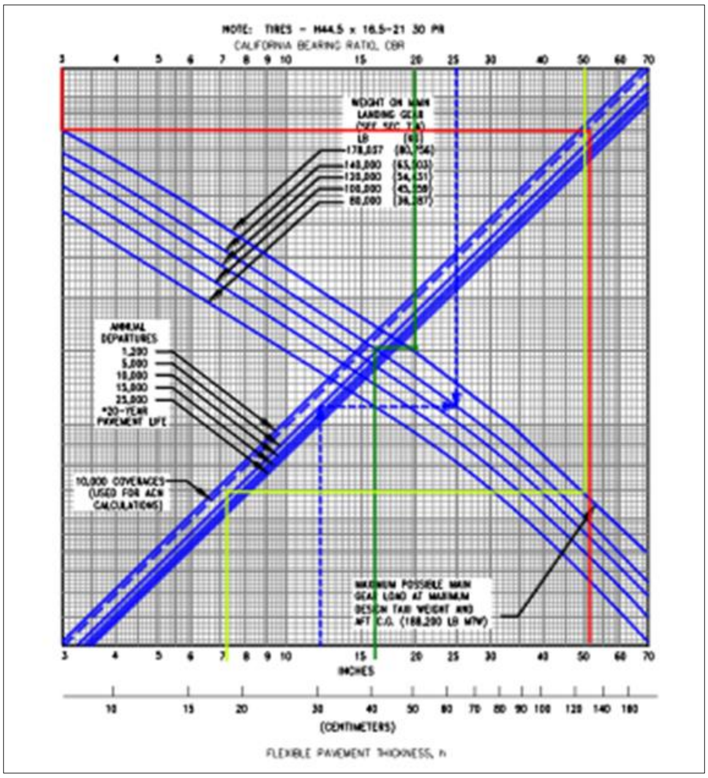


Figure 4 Pavement Thickness Result of FAA Method

3.3 Federal Aviation Administration (FAA)



Source: Airport Compatibility. 2021

Figure 5 Total Thickness Design Results of FAA Flexible Pavement with Dual Wheel Gear Main Landing Wheels

Calculation of the thickness of each pavement layer using a graph that has been prepared by the FAA. Pavement area categories include critical and non-critical areas critical areas include: taxiway, runway 300 m from the end of the threshold, apron thickness of non-critical areas is usually 0.9 times the critical thickness. A plan plane must be determined for pavement thickness calculations. Because the type of aircraft landing gear is different, it must be converted into a plan aircraft through the equivalent annual departure mixed aircraft (Risky, et al. 2019)5. To predict the next 20 years, precisely in 2040, the largest planning aircraft (Boeing 737-900ER) is used to determine the thickness of the pavement.

The parameters in determining the thickness of the pavement using the FAA method include the subgrade CBR value, the sub base CBR value and the total/planned aircraft takeoff weight. The FAA method with the following stages determines the type and characteristics of the aircraft, determines the growth of the aircraft and projected departure (annual departure),

Data on the planned 737-900ER aircraft served have dual gear landing gear, take-off weight of 187,700 lbs (85,000 Kg) Equivalent Annual Departure 3,011 of the planned aircraft, CBR Subbase = 20% and 3% Subgrade.

3.4 Calculation Stages

- The total pavement thickness, calculated using Figure 5, with a subgrade CBR value of 3% at the top abscissa follow the perpendicular line down intersect with the design aircraft weight of 187,700 lbs. From the point where the horizontal line intersects with the equivalent annual departure of 3,011, you get a total pavement thickness of 51 inches.
- Subbase thickness
- In Figure 5, from the CBR 20 point, project downwards to the bottom abscissa to obtain the thickness of the surface and base above the subbase layer with CBR 20 required 17 inches. So the thickness of the subbase is 51-17 = 34 Inch
- The surface thickness is written in Figure 5, that the surface layer pavement thickness for critical areas = 4 inches while non-critical areas are 3 inches
- The Base Coarse thickness is calculated by subtracting 17 inches – 4 = 13 inches, this result should be tested against Figure 6, compared to the required minimum course base thickness. Look at figure 6, the minimum base coarse thickness is 6 inches for the critical area. From the leftmost ordinate, take the number 51 inches, draw a horizontal line, intersect with the CBR subgrade line, take the 3% CBR subgrade number, from here drag it down to intersect with the lower abscissa, where it reads the minimum base course thickness, in this condition = 10 inches . Then the thickness of the subbase = 34 inches.

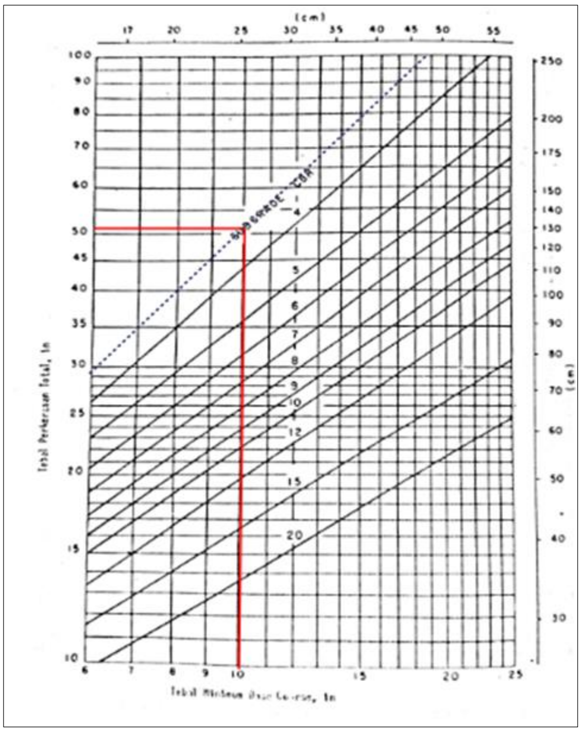


Figure 6 Is the minimum thickness of the base course required

FAA Method of Pavement Thickness Calculation Results

The calculation results are rounded up as follows:

Table 4 Analysis Results

	Layer thickness					
	Kritis		**Non Kritis**		**Pinggir**	
	In	**Cm**	**In**	**Cm**	**In**	**Cm**
Surface Aspal	4	10	3.6	10	2.8	7
Base Coarse	13	35	11.7	30	9.1	25
Subbase Coarse	31	80	27.9	70	21.7	55

Source: calculation results

Surface 4 inch, base coarse 13 inch, subbase coarse 31 inch and pavement thickness 48 inch.

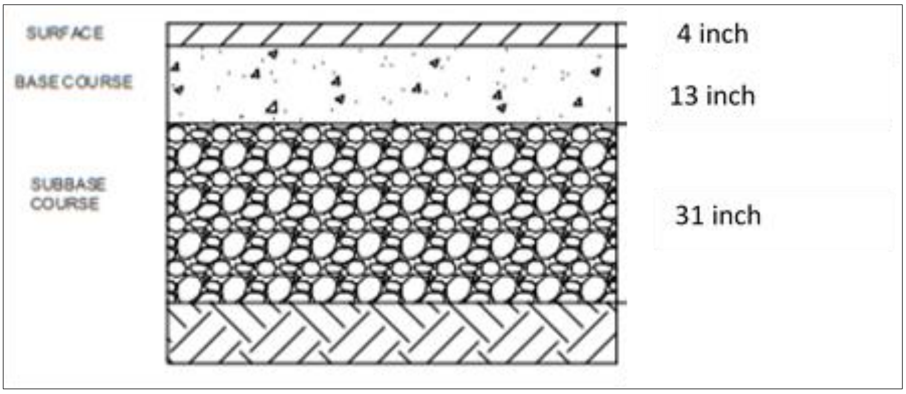


Figure 7 Pavement Thickness Result of FAA Method

4 Conclusion

- Pavement thickness with the CBR method obtained a pavement layer thickness of 65 inches, using the LCN method obtained a pavement layer thickness of 42 inches with the FAA method obtained a pavement layer thickness of 51 inches
- The results of the comparison of the three methods are LCN : FAA : CBR, namely 1 : 1.14:1.55

Compliance with ethical standards

Acknowledgments

We would like to thank the various parties involved in completing this journal, including Angkasa Pura II branch of Ahmad Yani Airport, LPPM USM and other parties that I cannot mention one by one.

Disclosure of conflict of interest

No potential conflict of interest was reported by the author

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