Thickness Analysis of Runway Pavement Construction at Zainuddin Abdul Madjid Airport to Accommodate Boeing 777-300ER

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Abstract. Lombok Island is one of destinations for travel from various regions due to construction of a racing circuit on the island. Large events such as MotoGP, GT World Challenge Asia, World Superbike, and others will often be held, so that it will increase tourists to visit Lombok Island. With this increase, it is necessary to develop facilities of Zainuddin Abdul Madjid Airport. One of them is runway pavement must have a thick layer that is able to accommodate aircraft movement activities. Zainuddin Abdul Madjid Airport is planned to be able to facilitate larger planned aircraft, that is B777-300ER. The increase in facilities needed is the extension of the runway with pavement structure which needs to be adjusted to the aircraft load that will be received by the pavement. Based on this, the runway pavement construction structure at Zainuddin Abdul Madjid Airport will be designed using FAA method with FAARFIELD software and PCN value was calculated using the COMFAA software. The data needed are annual departure, subgrade CBR, and type of pavement layer used. From the calculation results, the pavement thickness for the runway extension is Surface P-401/P-403 thickness is 100 mm thick, P-401/P-403 Stabilized thickness is 127 mm thick, and Crushed Aggregate P-209 thickness is 296mm. The PCN value for runway extension is 71/F/A/X/T.

Keywords. ACN, Airport, Pavement Thickness, PCN

1 Introduction

Lombok Island is one of the destinations for travel from various regions. This is due to the construction of a racing circuit on the island and large events such as MotoGP, GT World Challenge Asia, World Superbike, and other events will often be held, which will result in increased tourists visiting Lombok Island. With this increase, it is necessary to increase the facilities of Zainuddin Abdul Madjid Airport, both air and land facilities. Air facilities are an important factor in an airport, because in these facilities the actual movement that occurs. One of them is that the runway pavement must have a thick layer that is able to accommodate aircraft movement activities. This affects the type of aircraft that will use this airport and of course also affects the pavement construction used.

The increasing number of demand air transportation services at Zainuddin Abdul Madjijd Airport, in line with that, it is necessary to improve the airport infrastructure, one of which is thickness and the extension of the landing and take-off area of aircraft or called the runway. The design of runway pavement thickness is different from design of road pavement thickness. The road pavement thickness is calculated based on total vehicle load during design life and condition of pavement can be assessed based on the area, length, and category of each damage found on the road [1]. Zainuddin Abdul Madjid Airport is planned to be able to facilitate larger planned aircraft, namely the Boeing 777-300ER which has an ACN value of 64. The existing runway condition requires an overlay of 50.8 mm in order to facilitate the Boeing 777-300ER [2]. In addition, it is also necessary to extend the runway with an airport pavement construction structure that is suitable for the type of aircraft. The airport pavement structure needs to be adjusted to the aircraft load that will be received by the pavement. Based on data from PT Angkasa Pura I Zainuddin Abdul Madjid Airport, the runway at the airport is planned to be extended to 3,300 meters.

Based on this, the runway pavement construction structure at Zainuddin Abdul Madjid Airport will be designed using the FAA (Federal Aviation Administration) method, which is the regulatory agency related to aviation in America. FAA issued a software to calculate airport pavement structure, namely FAARFIELD (Federal Aviation Administration Rigid and Flexible Iterative Elastic Layered Design) software. The flexible pavement design in the FAARFIELD program is based on elastic analysis of each layer of the

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pavement structure [3]. Furthermore, the value of the PCN (Pavement Classification Number) of airport pavements is also calculated using COMFAA program. In calculating pavement construction structure method with FAARFIELD program and calculating PCN value using COMFAA program, it requires some data, namely annual departure data, air traffic growth data, ACN value from the planned aircraft, aircraft wheel pressure, subgrade CBR, and type data. pavement layer used. After calculating thw construction structure of runway pavement thickness and PCN value, it is hoped that Zainuddin Abdul Madjid Airport can provide air facilities on Boeing 777-300ER aircraft so that passenger accommodation to and from the island of Lombok can be fulfilled.

2 Research Methods

The first stage in this research is data collection. The data needed is data on the annual departure of Zainuddin Abdul Madjid Airport, dimensions of the existing runway, and the ACN value of the planned aircraft, aircraft wheel pressure, subgrade CBR, and data on the type of pavement used.

The first data analysis is the annual aircraft departure data which is projected during the 20-year plan life. Then the data is input into FAARFIELD software, as well as CBR data and specifications for the pavement layer to be used. From FAARFIELD software, a thickness that is in accordance with the load received by the pavement construction structure will be obtained. The CBR value is assumed to be 15% because the existing runway has a PCN code for the CBR category "A" which means the subgrade CBR > 13% [4].

Furthermore, pavement thickness was calculated based on FAA AC 150/5335-5c method to determine the evaluation thickness. The calculation method is by entering the pavement thickness, minimum thickness, and conversion factor data on the spreadsheet for the evaluation thickness calculation. From the results of the evaluated pavement thickness, it is inputted into the COMFAA software to determine the PCN value of Zainuddin Abdul Madjid Airport.

The PCN value is based on several data including the first type of pavement when using flexible pavement then using the F code if using rigid pavement using the R code. Second, the method used if the analytical method uses the “T” code and if the test is directly with an analog plane then uses the “U” code. Third, the category of subgrade bearing capacity which can be seen in the Table 1. Fourth, based on the aircraft tire pressure shown in the Table 2.

Table 1. Bearing Capacity Category of Flexible Pavement Subgrade

No.	Subgrade Category	CBR Value (%)	CBR Value Interval (%)	Code
1	High	15	CBR ≥ 13	A
2	Medium	10	8 < CBR < 13	B
3	Low	6	4 < CBR ≤ 8	C
4	Ultra Low	3	CBR ≤ 4	D

Table 2. Category Aircraft Wheel Pressure

No.	Subgrade Category	Wheel Pressure (Mpa / Psi)	Code
1	High	Unlimited	W
2	Medium	1,5 / 218	X
3	Low	1,0 / 145	Y
4	Ultra Low	0,.5 / 73	Z

2.1 Conclusions

Conclusions are drawn based on the results at the analysis stage, namely the thickness of the runway pavement construction structure and the PCN value in accordance with the Boeing 777-300ER planned aircraft. The results of this study are expected to provide air facilities, especially the runway on the Boeing 777-300ER aircraft so that passenger accommodation from and to the island of Lombok can be fulfilled.

3 Result and Discussion

3.1 Pavement Life Design

The thickness of a pavement is planned based on the ability of the pavement structure to serve a repetition load during the design life [5]. The FAA recommends a pavement structure life of 20 years [6].

3.2 Annual Departure

Aircraft movement data was obtained from PT Angkasa Pura (I) Zainuddin Abdul Madjid Airport which consisted of narrow body and wide body types. For the narrow body type, the smallest type is the ATR72 type with one aisle and MTOW < 50,000 Lb (23,000 kg), while the wide body is the A330-200 aircraft type with more than one aisle and MTOW > 50,000 Lb (23,000 kg) [7]. From the data on the movement of all aircraft at Zainuddin Abdul Madjid Airport, 12 types of aircraft have been selected with criteria that have an MTOW of > 50,000 lb (23,000 kg) which have the potential to damage the pavement. To estimate the growth rate of aircraft movement, the annual Departure data is taken for the last five years starting from 2016-2020. Annual departure and growth percentage can be seen in Table 3.

Table 3. Annual departure and growth percentage

No.	Type Aircraft	Annual Departure					Growth Percentage
		2016	2017	2018	2019	2020	
1	A319	19	7	3	26	9	3%
2	A320	2809	3386	2751	2213	1613	3%
3	ATR72	4082	4479	4802	3518	1711	3%
4	B738	3698	3344	3229	2254	1126	3%
5	B739	3428	3643	3957	3239	1713	10%
6	CRJX	641	513	482	384	200	3%
7	A333	0	7	0	9	10	3%
8	A332	0	2	0	0	6	3%
9	B735	0	0	401	411	94	3%
10	B734	2	0	0	0	5	3%
11	B733	1	0	0	1	0	3%

12	B732	2	1	5	0	1	3%

The COMFAA software cannot input growth percentage data, so it is necessary to calculate Annual Departure which is projected up to 20 years. So the data that we input is the 20 year annual departure. The increase in the capacity of the runway to meet future needs is that the runway is expected to be able to serve wide body type B777-300 ER aircraft. To fulfill these requirements, a runway loading scenario is made in the form of an annual departure from the B777-300 ER aircraft, namely the planned annual departure of the B777-300ER aircraft in the amount of 1460 times (four times a day) with a growth factor of 3%, which can be seen in Table 4.

Table 4. Annual Departure Aircraft Design

No.	Type Aircraft	Annual Departure	Growth Percentage	Annual Departure up to 20 years
1	A319	9	3%	17
2	A320	1613	3%	2914
3	ATR72	1711	3%	3091
4	B738	1126	3%	2034
5	B739	1713	10%	11525
6	CRJX	200	3%	362
7	A333	10	3%	19
8	A332	6	3%	11
9	B735	94	3%	170
10	B734	5	3%	10
11	B733	1	3%	2
12	B732	1	3%	2
13	B777-3900ER	1460	3%	2637

3.3 Pavement Layer Type

The runway pavement construction material used in this study refers to the FAA specification AC-150-5370-10H [8], the pavement structure layers are:

a. Surface uses HMA P-401/P-403
b. Stabilize using HMA P-401/P-403 Stabilized
c. Base using crushed aggregate P-209
d. Subgrade with 15% CBR based on Existing Runway data which has PCN value with code for CBR category "A" which means subgrade CBR > 13% [4].

3.4 Thickness of the Runway Pavement using FAARFIELD software

To calculate the thickness of the runway pavement structure, FAARFIELD software is used. The data needed in this program are the type of aircraft plan, annual departure, CBR subgrade, growth percentage, and the type of pavement layer planned. Based on these data, the FAARFIELD software will calculate successive iterations to determine the appropriate thickness [9]. The steps for designing the thickness of the foundation pavement using the FAARFIELD software [10], namely:

1. Input the type of pavement layer to be used
2. Input the base grade CBR value
3. Input the types of planned aircraft that are ex expected to use the runway
4. Input the annual maturity at the beginning of the planning year
5. Input traffic growth
6. Next, you will get the thickness value of each pavement layer suggested by the software.

The calculation of pavement thickness using FAARFIELD software will determine a combination of material layers and an economical thickness so that the pavement does not experience a collapse condition. Prediction of the time until when the pavement reaches failure depends on the material and the planned thickness [11]. The results of the calculation of pavement thickness using the FAARFIELD software can be seen in Figure 1.

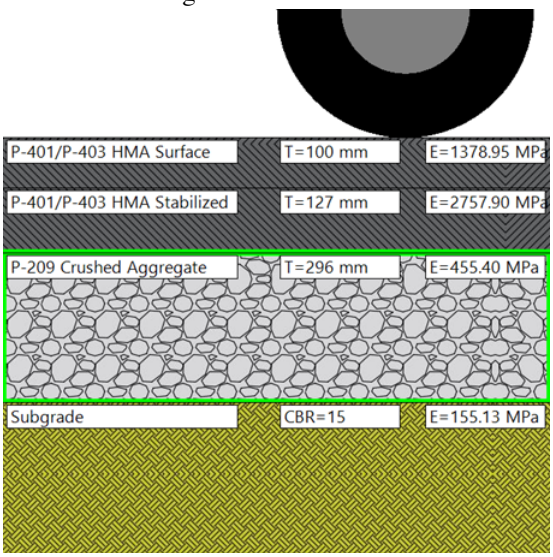

Fig. 1. Pavement thickness results based on FAARFIELD software

From the results of the FAARFIELD software calculation in the Figure 1, it is found that the thickness of the pavement above the subgrade with a CBR of 15% is Surface P-401/P-403 thickness is 100 mm thick, P-401/P-403 Stabilized thickness is 127 mm thick, and Crushed Aggregate P-209 thickness is 296mm

3.5 ACN and PCN Values using

The first stage in this research is data collection. The data needed are data on the annual departure of Zainuddin Abdul Madjid Airport, dimensions of the existing runway, and the ACN value of the planned aircraft, aircraft wheel pressure, subgrade CBR, and data on the type of pavement used.

ACN is a number that expresses the effect given by the aircraft on the pavement, while PCN is a number that expresses the strength of the pavement to accept the aircraft's load. Therefore, if an aircraft has a certain weight with ACN less than or close to the PCN value, there is no need for operational restrictions and special placements [12].

PCN value calculation using COMFAA software. However, before that, it is necessary to calculate the

evaluation thickness by entering the data of pavement thickness and conversion factor in the spreadsheet. The results of the evaluation thickness calculation can be seen in Figure 2.

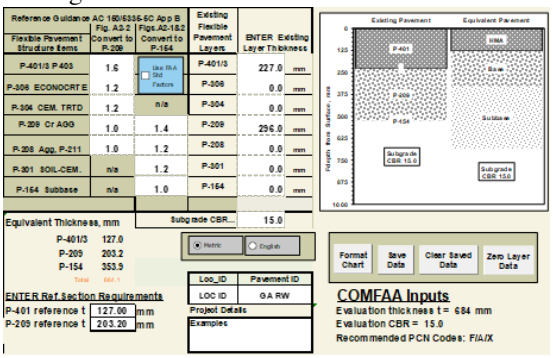

Fig. 2. Spreadsheet of Evaluation Thickness

From the calculation results obtained evaluation thickness 684mm. The value is then entered in the COMFAA software to determine the PCN value. In addition, other data that needs to be inputted are the annual departure which has been projected for 20 years and the CBR for subgrade 15%. The display of entering data in the COMFAA software can be seen in Figure 3.

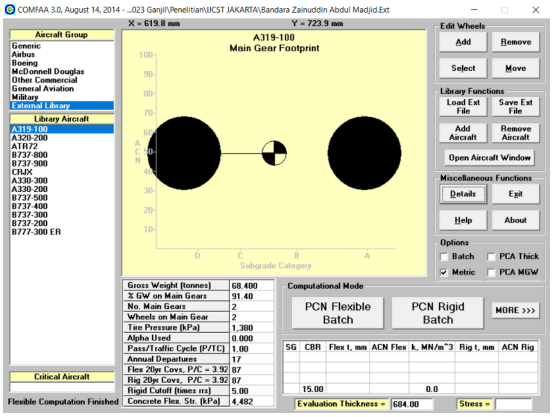

Fig. 3. Display of Entering Data in COMFAA Software

The calculation results using COMFAA software consist of three main tables. The first table shows 20 years of traffic data and the value of "6D thick" which can be seen in Figure 4. The second table shows the PCN values according to the subgrade category with a CBR value of 15%, which can be seen in Figure 5. Table three shows the ACN value of the aircraft according to the subgrade category with a CBR value of 15% which can be seen in Figure 6.

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                                    CBR = 15.00 (Subgrade Category is A(15))
          Evaluation pavement thickness = 684.0 mm
     Pass to Traffic Cycle (PtoTC) Ratio = 1.00
        Maximum number of wheels per gear = 4
     Maximum number of gears per aircraft = 2

At least one aircraft has 4 or more wheels per gear.  The FAA recommends a reference section assuming
127 mm of HMA and 203 mm of crushed aggregate for equivalent thickness calculations.

Results Table 1. Input Traffic Data
                                  Gross    Percent    Tire     Annual     20-yr      6D
 No.  Aircraft Name               Weight   Gross Wt   Press    Deps       Coverages  Thick
-----------------------------------------------------------------------------------------
  1  A319-100                    68.400    91.40     1,380      17           87     248.7
  2  A320-200                    78.400    92.80     1,440   2,914       15,709     446.4
  3  ATR72                       34.019    95.00       758   3,091       17,245     288.4
  4  B737-800                    79.243    93.56     1,413   2,034       11,435     447.7
  5  B737-900                    85.366    94.58     1,517  11,525       65,266     522.0
  6  CRJX                        45.359    95.00       965     362        2,043     301.0
  7  A330-300                   233.900    95.70     1,450      19          202     387.8
  8  A330-200                   233.900    94.76     1,420      11          118     360.3
  9  B737-500                    60.781    92.24     1,338     170          881     315.6
 10  B737-400                    68.266    93.82     1,276      10           57     239.1
 11  B737-300                    63.503    90.86     1,386       2           10     155.2
 12  B737-200                    58.332    91.92     1,255       2           10     149.2
 13  B777-300 ER                352.441    92.44     1,524   2,637       40,412     568.9
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Fig. 4. Results of the first COMFAA Software Table

The results of the first COMFAA software table in Figure 4 show the data entered, namely annual departure of 20 years, evaluation thickness, and CBR subgrade 15% with category A. In the "6D thick" section, the recommended pavement thickness using the FAA CBR method with CBR 15 % on each type of aircraft.

The Boeing 777-300ER has a recommended pavement thickness of 684 mm for 20 years. The pavement thickness for each type of design aircraft is close to or below the evaluation thickness. This shows that the thickness of pavement is good for the existing design aircraft traffic. This pavement thickness is expected to have a smaller value than the evaluation thickness to get better results. The value of "6D thick" has nothing to do with the calculation of the PCN value, but only for comparison of the pavement thickness calculation with the evaluation thickness.

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Results Table 2. PCN Values
                                  Critical                 Thickness    Maximum      ACN Thick at
                                  Aircraft Total           for Total    Allowable    Max. Allowable                PCN on
 No.  Aircraft Name               Equiv. Covs.             Equiv. Covs. Gross Weight Gross Weight      CDF        A(15)
-----------------------------------------------------------------------------------------------------------------------
  1  A319-100                    >5,000,000                  645.8        74.795       417.90        0.0000      38.0
  2  A320-200                    >5,000,000                  635.3        88.400       465.54        0.0000      47.1
  3  ATR72                       >5,000,000                  472.7        62.382       422.20        0.0000      38.7
  4  B737-800                    >5,000,000                  597.9        98.098       505.36        0.0000      55.5
  5  B737-900                       65,316                   522.0       130.697       611.22        0.0001      81.1
  6  CRJX                        >5,000,000                  567.7        62.193       417.70        0.0000      37.9
  7  A330-300                    >5,000,000                  647.8       253.913       548.71        0.0000      65.4
  8  A330-200                    >5,000,000                  664.7       244.118       530.44        0.0000      61.1
  9  B737-500                    >5,000,000                  632.3        68.670       410.98        0.0000      36.6
 10  B737-400                    >5,000,000                  676.6        69.454       417.30        0.0000      37.8
 11  B737-300                    >5,000,000                  644.3        69.286       411.04        0.0000      36.7
 12  B737-200                    >5,000,000                  610.7        69.231       410.60        0.0000      36.6
 13  B777-300 ER                 >5,000,000                  648.8       378.604       570.52        0.0000      70.7
                                                                                      Total CDF =   0.0001
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Fig. 5. Results of the second COMFAA Software Table

The results of the second table COMFAA software in Figure 5 show the Cumulative Damage Factor (CDF) calculation data. The CDF method is based on the Miner's Ruler principle which states the amount of life of the pavement structure used and is expressed in the form of a load repetition ratio to the permissible load removal until it fails [13]. This CDF data shows damage to the evaluation thickness of 684 mm and 6% CBR on each type of aircraft. Total CDF has a value of less than 1 (CDF < 1) means the runway pavement is very strong to accommodate aircraft traffic which is estimated to be up to 20 years [6].

Figure 5 also show the calculation of PCN values from the COMFAA software. The PCN value indicates each type of aircraft that overloaded the runway pavement more than 5,000,000 times before the pavement failed. The plan aircraft that has the most influence on pavement structural performance is the Boeing 737-900 because it has the highest annual departure value of 20 years. This can be seen in the critical aircraft total equivalent coverages that the aircraft has the smallest value. This value indicates the aircraft can only overload the runway as much as 65,316 times. So that the use of this aircraft greatly affects the quality of the pavement structure. The PCN value used is based on the Boeing 777-300ER aircraft, which is 71. The type of pavement used is flexible pavement, the code used is "F". The CBR value of subgrade is 15%, so based on the Table 1 it is included in the high category with the code "A". The largest design aircraft tire pressure based on the Boeing777-300ER plan is included in the category with the code "X" (Table 2). The calculation of the PCN value with COMFAA software uses the technical evaluation method so that the

code used is "T". Based on the calculation results, the PCN value that can be reported is 71/F/A/X/T.

Results Table 3. Flexible ACN at Indicated Gross Weight and Strength

No.	Aircraft Name	Gross Weight	% GW on Main Gear	Tire Pressure	ACN Thick	ACN on A(15)
1	A319-100	68.400	91.40	1,380	396.9	34.2
2	A320-200	78.400	92.80	1,440	434.3	41.0
3	ATR72	34.019	95.00	758	278.7	16.9
4	B737-800	79.243	93.56	1,413	444.2	42.8
5	B737-900	85.366	94.58	1,517	469.7	47.9
6	CRJX	45.359	95.00	965	339.1	25.0
7	A330-300	233.900	95.70	1,450	521.3	59.0
8	A330-200	233.900	94.76	1,420	516.3	57.9
9	B737-500	60.781	92.24	1,338	383.2	31.9
10	B737-400	68.266	93.82	1,276	412.7	37.0
11	B737-300	63.503	90.86	1,386	390.3	33.0
12	B737-200	58.332	91.92	1,255	371.5	30.0
13	B777-300 ER	352.441	92.44	1,524	541.7	63.8

Fig. 6. Results of the first COMFAA Software Table

Figure 6 shows the ACN of each type of aircraft which is an ICAO standard of each type of aircraft design from the value of gross weight, percent gross weight on the main gear, and tire pressure entered. The largest ACN value is on the Boeing 777-300ER aircraft with a value of 63,8. Based on the calculation results of the COMFAA software that ACN of each type of aircraft shows a value that is smaller than the PCN, it can be concluded that the runway pavement is safe for planned aircraft traffic for 20 years.

3.6 PCN and ACN Curve

PCN and ACN curve data obtained from the calculation of the COMFAA program, then the data is entered into a spreadsheet that was previously used for evaluation thickness calculations and will produce two curves. The first curve shows the recommended pavement thickness as shown in Figure 7. The second curve shows the comparison of PCN and ACN which can be seen in Figure 8. The PCN and ACN curves only include the 6 largest planes that affect the pavement structure.

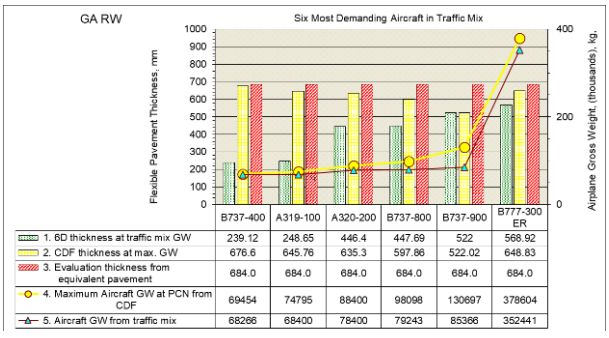

Fig. 7. COMFAA Software Pavement Thickness Comparison

From the curve of pavement thickness and the maximum recommended plane weight in Figure 7 it can be seen that the pavement thickness for the CDF value (yellow curve) is smaller than the evaluated pavement thickness (red curve). Likewise with the "6D thick" pavement thickness which indicates that the PCN value obtained is greater than the aircraft ACN value so that the pavement is very safe for aircraft operations. The design aircraft weight for the analyzed traffic (triangle symbol) can still overload the evaluation thickness pavement because it has a weight that does not exceed the maximum recommended aircraft weight for pavement based on the CDF value (circle symbol).

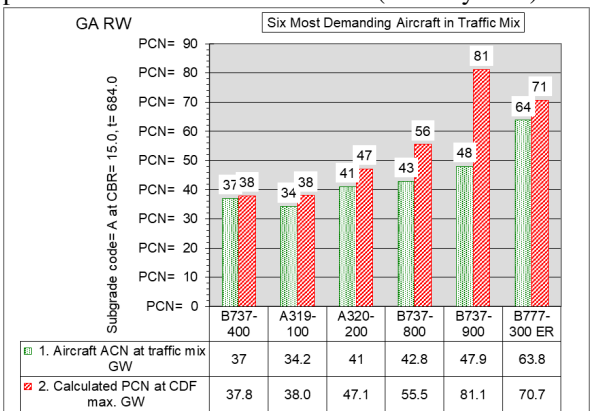

Fig. 8. COMFAA Software Pavement Thickness Comparison

From the curve in Figure 8 shows the comparison of the PCN value and the ACN value. It can be seen that the existing PCN (red curve) has a greater value than the ACN of the design aircraft (green curve). This shows that the existing pavement is very safe for aircraft operations.

4 Conclusions

Based on the results of the analysis of the FAA method using FAARFIELD software, it was found that the thickness of the new runway extension structure on the CBR subgrade 15% to accommodate the Boeing 777-300ER at Zainuddin Abdul Madjid Airport, namely Surface P-401/P-403 thickness is 100 mm thick, P-401/P-403 Stabilized thickness is 127 mm thick, and Crushed Aggregate P-209 thickness is 296mm. In addition, the PCN value obtained from the COMFAA software is 71/F/A/X/T. The PCN value exceeds the planned aircraft ACN, so it can be concluded that the new pavement thickness is safe for aircraft operations for 20 years.

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