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RUNWAY STRENGTH ANALYSIS USING ACR-PCR AT SULTAN MAHMUD BADARUDDIN II AIRPORT

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Abstract : Aircraft Classification Rating-Pavement Classification Rating (ACR-PCR) is a system to determine the PCR value of runway pavement strength and recommended for runway maintenance issued by International Civil Aviation Organization (ICAO) based on ICAO Advisory Circular (AC) 150/5335-5D of 2022, as a replacement for the Aircraft Classification Number - Pavement Classification Number (ACN-PCN) system that has been used since 1980. The implementation of the ACR-PCR Method is determining the strength value of runway pavement can be used as a reference in holding the load of aircraft that have a lower or the same ACR value. The ACR-PCR system was published in order to plan a more rational pavement structure strength by analyzing the response of the pavement structure to the weight of aircraft movement on the runway. The calculation was carried out using the modulus of elasticity of each layer on the runway pavement structure with a more specific type of material. Sultan Mahmud Badaruddin (SMB) II Airport is one of the airports in Indonesia that is currently in the process of transitioning using the ACN-PCN system to ACR-PCR system for runway strength reporting. Base on data of aircraft movement at SMB II airport management in 2024 and calculated by using FAARFIELD 2.1 software, PCR value for the critical runway strength of SMB II Airport was 890 F/C/X/T with a critical aircraft is Boeing B747-400.

Keywords : Runway Stregth, ACN-PCN, ACR-PCR, modulus of elasticity

Introduction

Indonesia is a country consisting of many islands, so air transportation is needed to accelerate economic growth. In this regard, the need for airports on each island is very necessary. One of the islands owned by the Indonesian state is the island of Sumatra where there is Sultan Mahmud Badarudin II (SMB II) Airport which is located in the city of Palembang, South Sumatra province. The runway of SMB II Airport is a single runway that has a length of 3000 meters and a width of 45 meters with flexible pavement. Since it was first built until now, there have been several extensions of the runway and the addition of pavement layers so that the structure of the existing layer is not homogeneous as a whole. The type of critical aircraft as the basis for planning is the Boeing 747-400 aircraft type with a large capacity. Since 2023, Airbus A330-900 have also been operating for Umrah activities. Based on data from SMB II airport management that the currently published PCN value is 80/F/C/W/T and California Bearing Rasio (CBR) is 5% with a

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total minimum thickness of the pavement layer of 40.55 inches. The runway is in accordance with applicable standards for domestic and international

The runway strenght determination system that has been established by the International Civil Aviation Organization (ICAO) since 1980 is ICAO Advisory Circular (AC) No: 150/5335-5C about the Aircraft Classification Number-Pavement Classification Number (ACN-PCN) system. ACN is a number that describes the effect caused by the pressure of an aircraft wheel on a runway pavement structure on a given ground condition while PCN is a number that shows the carrying capacity of a runway pavement on the operational load of the flight. The PCN value indicating the minimum value of runway strength must be greater than or equal to the ACN value of the critical aircraft moving on the runway. Due to the development of critical aircraft types in the world, in 2022 ICAO established a new regulation, namely ICAO AC No: 150/5335-5D concerning a runway force determination system based on the Aircraft Classification Rating-Pavement Classification Rating (ACR-PCR). The ACR-PCR System to determine the strength value of the runway is no longer only based on the California Bearing Ratio (CBR) value of the ground but also uses the modulus value of the elasticity of all types of runway structure layer materials so that the result set is the maximum value of the strength of each runway pavement layer (Wihite, 2021). The results of the determination of the ACR-PCR System can also be applied to all loads of aircraft types with various wheel configurations. To determine the value of the ACR-PCR system at each airport, it is necessary to know the existing data on the runway and critical aircraft moving on the runway in order to determine the strength of the runway (Taufiq et al., 2023).

To mechantically calculate runway strength ACR-PCR values, FAA and ICAO have provided FAA Rigid and Flexible Iterative Elastic Layered Design (FAARFIELD) and ICAO-Aircraft Classification Rating (ICAO-ACR) software. Both of these software can also be used to research and monitor runway strength (Herry et al., 2024). To calculate the change in values from ACN-PCN to ACR-PCR, it is necessary to identify existing problems so that the data needed for the convergence of PCN to PCR values is more detailed, starting from aircraft data and the structure of the runway pavement layer. Today, SMB II Airport haven't implemented the new PCR value. For this reason, the aim of this research is to be able to determine the PCR value of runway strength at SMB II airport in order to find out the type of critical aircraft and recommend in runway maintenance

Method

The method used in this study is a quantitative method using primary and secondary data obtained from PT. Angkasa Pura II which operates SMB II Airport. The flow of the objectives of this research method can be seen in the flowchart in Figure 1. The first step is to compare the basic concepts of the two methods to determine their theoretical differences. Then, the runway strength is calculated using each method with the latest data so that it can be analyzed whether there is a correlation between the two and how their application impacts the airport, especially in determining the ACR-PCR value and critical aircraft that can use the runway at SMB II airport. The results of the ACR-PCR value calculation are compared with the ACN-PCN value that has been published by PT. Angkasa Pura as an initial reference in this study, is the purpose of this study and the analysis of the impact of its application caused by each type of aircraft on the pavement layer with different types of materials and thicknesses greatly influences the implementation of runway strength maintenance whether it is still safe for flight operations until the planned maintenance period at SMB II airport.

This research will result in the determination ACR PCR of the SMB II airport and recommendations in determining the strength of the runway in the future and the maintenance plan that needs to be carried out.

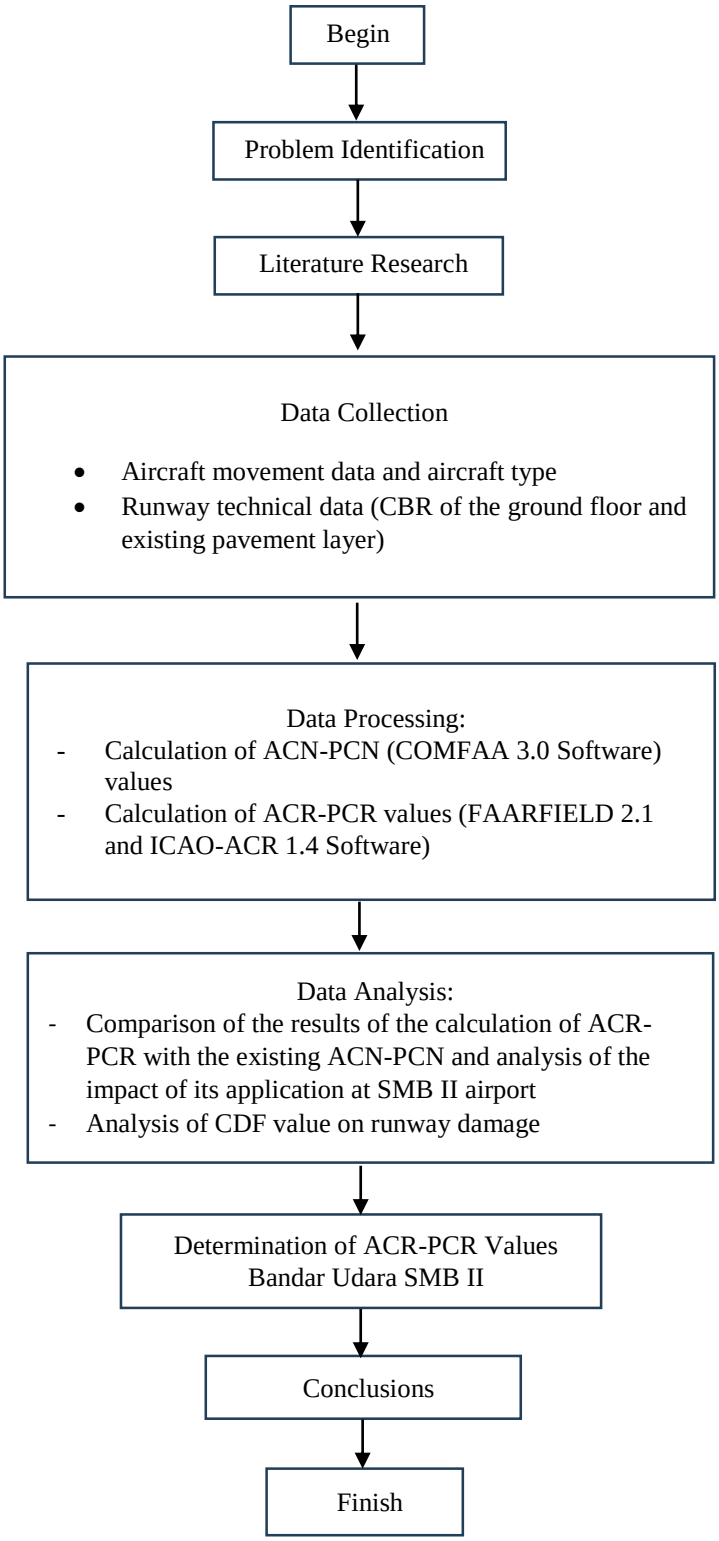

Figure 1. Research Flow Chart

ACN-PCN Method

The ACN-PCN method is a method of determining runway strength that has been used for approximately 40 years both nationally and internationally. ACN is a unique number that expresses the impact of each aircraft on various pavements *Runway* which varies according to the weight and configuration of the aircraft (e.g. tire pressure, gear geometry, etc.), the type of road pavement, and the strength of the underlying soil. The concept used is a single-wheel load of an aircraft that is considered to represent the same stress on the pavement structure. For flexible pavement types this can be obtained by equalizing the thickness obtained for 10,000 aircraft luminaire wheel coverage with the thickness obtained for DSWL (*Derived Single Wheel Load*) at standard tire pressure (181 psi/1.25 MPA). What is meant by aircraft coverage here is the trajectory required by the aircraft to apply one full load to the pavement area, while for flexible pavement thickness determination using the CBR method. ACN was then defined as two times the DSWL expressed in thousands of kilograms (Armeni & Loizos, 2023). To facilitate the ACN-PCN System, FAA developed a software called COMFAA 3.0 that calculates the value of ACN using the procedures and conditions set by ICAO (Rahmawati & Rahmawati 2021).

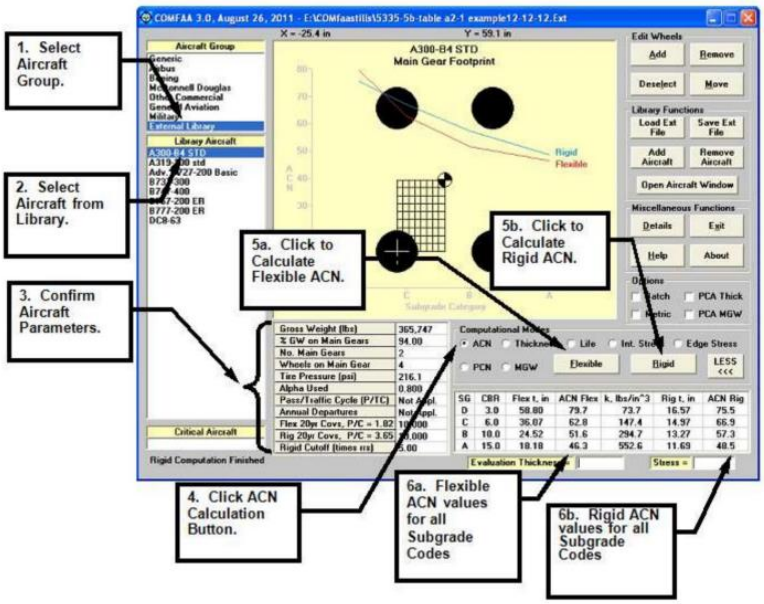

Figure 2. COMFAA 3.0 Software in ACN Mode

PCN is a numerical value that expresses the strength of a pavement to be able to withstand the weight of aircraft movement. The PCN writing format consists of five codes which are information from a pavement, namely the numerical value of the PCN, the type of pavement, the category of the base soil, the permissible tire pressure, and the method used to determine the value of the PCN. The type of pavement can be written as flexible (F) or rigid (R). Specifically, flexible pavement in the basic soil category can be seen from the CBR value of the basic soil which is categorized into four groups, namely A (High, CBR ≥ 13), B (Medium, 8<CBR<13), C (Low, 4<CBR≤8), and D (Ultra low, CBR≤4). For the permissible tire pressure, it consists of four categories namely W (Unlimited, No pressure limit), X (High, pressure limited to 1.75 MPA), Y (Medium, pressure limited to 1.25 MPA), and Z (Low, pressure limited to 0.5 MPA). When viewed from the method used in determining the value of PCN, it can be divided into two methods, namely the technical evaluation method (T) and the method using aircraft (U). For a pavement,

the PCN value can accommodate aircraft loads that have the same or lesser ACN value for unrestricted operations.

One of the procedures in determining the value of PCN developed by the FAA is a method based on the CBR method which is also implemented through COMFAA 3.0 software where data on both commercial and military aircraft and other types of aircraft can be added as needed. The mix of aircraft traffic in operation is converted into annual departures equivalent to one critical aircraft type. In this method, it is assumed that the damage that occurs on the pavement is the actual amount of load received divided by the amount of load received until the pavement construction fails/damages. By combining all aircraft impacts in the traffic mix into an equivalent critical aircraft it is possible to calculate the PCN value. The combined effects evoked by such aircraft traffic mixes were identified as cumulative damage factors or CDF (*Cumulative Damage Factor*). Where the maximum CDF value is 1 so that if it gets a value of more than 1, it is considered that the pavement structure has failed and maintenance/repair actions must be taken.

ACR-PCR method

The ACR-PCR method has almost the same concept as ACN-PCN, where ACR is a value that expresses the influence of each aircraft on the runway pavement while PCR expresses the carrying capacity of the pavement on the weight of the aircraft. The ACR-PCR method is designed in such a way that pavements with a specific PCR value can withstand aircraft loads that have an ACR value equal to or less than the PCR value of the pavement. The ACR calculation requires detailed information about the aircraft's operational characteristics, such as the maximum rear wheel center of gravity, maximum weight, wheel configuration, number and wheelbase, and tire pressure. The single-wheel load obtained implies the same pressure on the pavement structure. This is achieved by equalizing the thickness obtained for a particular aircraft's landing wheel with the thickness obtained for a single wheel load at standard tire pressure. To standardize the ACR calculation for bending pavement, the single-wheel load obtained was calculated at a constant pressure of 218 psi (1.50 Mpa) relative to the total thickness and calculated for 36,500 aircraft runs.

In contrast to the ACN-PCN method, the calculation is based on the modulus of elasticity of each pavement layer, including the base soil. In the LEA (*Layered Elastic Analysis)* model, the base layer is subdivided into smaller sublayers and the modulus value is then set for each sublayer. The modulus value increases from the bottom up, which reflects the effect of increasing density of the aggregate material. For flexible pavement, the basic soil category can be divided into four groups based on its elastic modulus, namely A (High, E ≥150 MPa), B (Medium, E≥100<150 Mpa), C (Low, E≥60<100 Mpa), D (Ultra Low, E<60). Using the equation E(MPa) = 10 × CBR, the range of these categories can be expressed in the form of groundland CBR (Armeni, A. & Loizos, A. (2022).

In determining the current PCR value, the FAA has also issued a methodology that converts the aircraft traffic mix into aircraft equivalent to the maximum allowable gross weight to produce a total CDF equal to 1. The CDF index calculated in the form of PCR, is numerically different from the CDF index used in the PCN method which is based on the CBR method, because it presents a different theoretical background. According to the design methodology and analytical evaluation, for bending pavement, two failure modes are considered. This is combined with the corresponding critical strain: a) horizontal tensile strain at the bottom of the asphalt concrete layer and b) vertical compressive strain at the top of the subsoil (Taufiq et al., 2023). In determining PCR values, there are two ways that can be used, namely using aircraft and technical evaluation. ICAO allows member states to choose methods in PCR assessments, but the methodology used must be reported as part of the listed rankings. To facilitate the use of the ACR-

PCR system, ICAO and FAA have also developed software, ICAO-ACR 1.4, which calculates ACR values using the procedures and conditions set by ICAO and FAARFIELD 2.1 to determine PCR values which contain data on commercial aircraft and US military aircraft currently in operation.

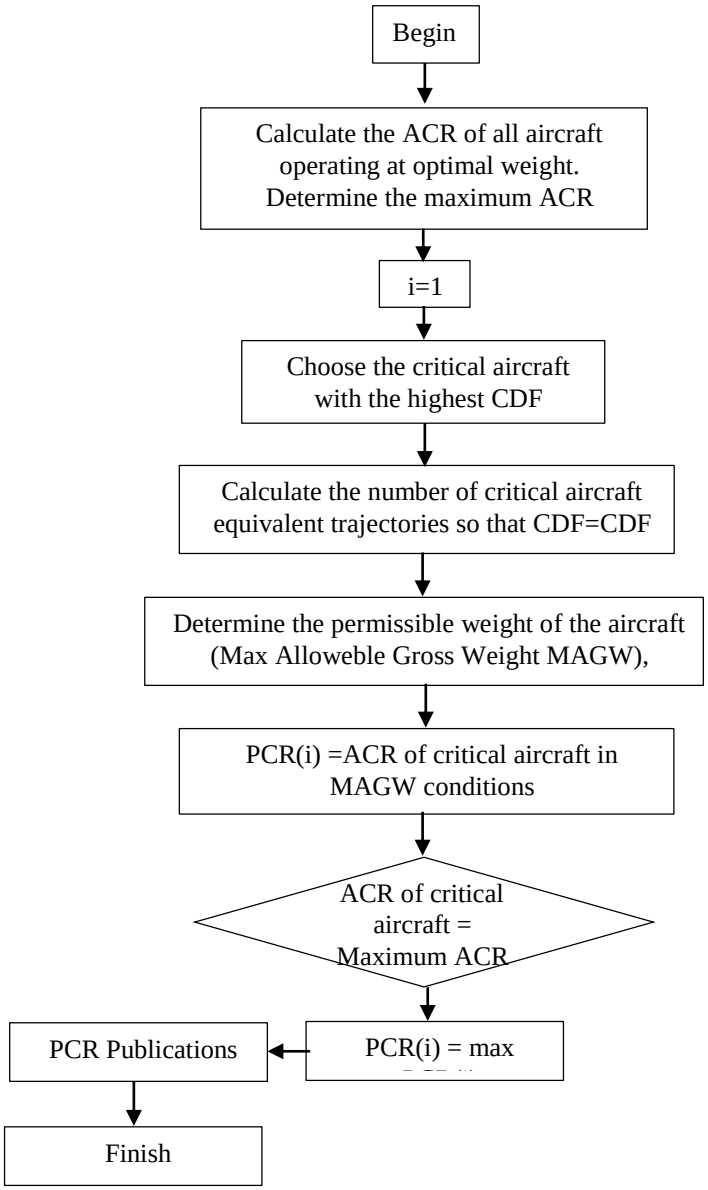

Figure 3. PCR Value Determination Flowchart (FAA AC 150/5335-5D, 2022)

Data Processing

In determining the PCN and PCR values, there are two methods allowed by ICAO, namely by using aircraft and by technical methods.

1. Determining the value of ACN/PCN

Determining the PCN value by the method of using the aircraft means that the PCN value is the most critical ACN number of all types of aircraft that operate without load restrictions. For data on aircraft movements in 2024 SMB II Airport as stated in table 1, the ACN number of Airbus 330 900 aircraft is 113.10. So for the calculation of the PCN value, it can be determined from the ACN value with rounding up, namely 113 F/C/X/U. This means that the runway has a

PCN value of 113 with flexible pavement type (F), low ground soil category (C), High (X) permissible pressure and using the aircraft use method (U).

Table 1. Aircraft Movement Data at SMB II Airport 2024

No	Aircraft Type	Annual Departures	ACN (Subgrade Category (C)
1	Airbus 320 200	6.377	44,40
2	Airbus 320 200 Neo	32	47,30
3	Airbus 330 300	107	72,60
4	Airbus 330 900	44	**113,10**
5	ATR 42 300	1	11,00
6	ATR 47 600	9	14,00
7	Boeing 737 500	82	37,40
8	Boeing 737 700	2	42,10
9	Boeing 737 800	2.031	50,30
10	Boeing 737 900 ER	590	56,00
11	Boeing 747 400	38	72,60
12	Bombardier Challanger 600	12	14,10
13	Cessna C208 Grand Caravan	130	3,30
14	Hawker Beechcraft 800XP	4	8,20
15	Learjet 35 A	10	5,00
16	Learjet 45 XR	2	6,30
	Total Departures	**9.471**	

(Source : PT. Angkasa Pura Indonesia; 2024)

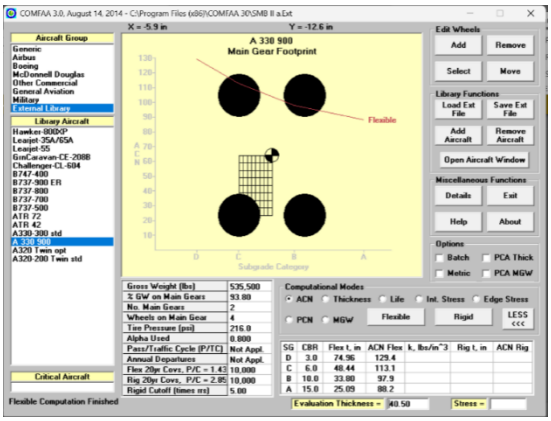

Figure 4. Calculation ACN values using COMFAA 3.0 Software

By using the same flight data and by looking at the existing condition of the pavement layer according to figure 5, PCN can be calculated technically using the COMFAA 3.0 software and the PCN value for the most critical aircraft, namely the Airbus 330 900 aircraft, is 115. This means that the PCN value is still greater than the ACN value of the critical aircraft so that it can be concluded that the most critical PCN value is 115/F/C/X/T. From the calculation results, it is also obtained that the total CDF is 0.8808 so that the pavement layer is still safe to use during the maximum expected age.

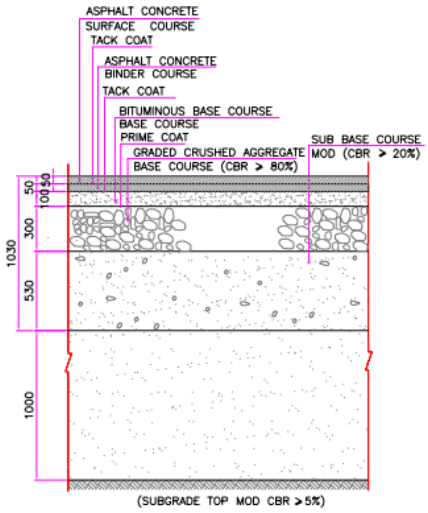

Figure 5. Cross cut of pavement layer structure

This file name = PCN Results Flexible 7-11-2025 22;19;04.txt
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Evaluation pavement type is flexible and design procedure is CBR.
Alpha Values are those approved by the ICAO in 2007.

CBR = 5.00 (Subgrade Category is C(€))
Evaluation pavement thickness = 45.64 in
Pass to Traffic Cycle (PtoTC) Ratio = 1.00
Maximum number of wheels per gear = 4
Maximum number of gears per aircraft = 4

At least one aircraft has 4 or more wheels per gear. The FAA recommends a reference section assuming 5 inches of HMA and 8 inches of crushed aggregate for equivalent thickness calculations.

Results Table 1. Input Traffic Data

No.	Aircraft Name	Gross Weight	Percent Gross Wt	Tire Press	Annual Deps	20-yr Coverages	6D Thick
1	Hawker-800XP	28,120	95.00	135.0	4	13	5.71
2	Learjet-35A/65A	18,000	95.00	171.0	10	23	5.23
3	Learjet-55	21,500	95.00	201.0	2	5	3.63
4	GrnCaravan-CE-208B	8,750	95.00	75.0	130	226	6.43
5	Challenger-CL-604	48,200	95.00	145.0	12	48	10.21
6	B747-400	877,000	93.32	200.0	38	436	33.85
7	B737-900 ER	188,200	94.58	220.0	590	3,341	35.22
8	B737-800	174,700	93.56	205.0	2,031	11,418	36.55
9	B737-700	155,000	91.70	205.0	2	10	12.30
10	B737-500	134,000	92.24	194.0	82	425	23.33
11	ATR 72	51,081	95.00	95.0	9	33	11.56
12	ATR 42	41,381	95.00	120.0	1	3	5.37
13	A330-300 std	509,047	95.74	205.9	107	1,142	37.74
14	A 330 900	535,500	93.80	216.0	44	617	44.40
15	A320 Twin opt	172,842	92.80	208.9	32	173	23.31
16	A320-200 Twin std	162,922	93.80	200.1	6,377	34,278	36.92

Figure 6. Flight Data Input Results

Results Table 2. PCN Values

No.	Aircraft Name	Critical Aircraft Total Equiv. Covs.	Thickness for Total Equiv. Covs.	Maximum Allowable Gross Weight	ACN Thick at Max. Allowable Gross Weight	CDF	PCN on C(€)
1	Hawker-800XP	>5,000,000	23.27	102,162	26.86	0.0000	34.8
2	Learjet-35A/65A	>5,000,000	18.52	100,699	26.97	0.0000	35.1
3	Learjet-55	>5,000,000	20.47	100,136	26.99	0.0000	35.1
4	GrnCaravan-CE-208B	>5,000,000	18.45	53,572	20.45	0.0000	20.1
5	Challenger-CL-604	>5,000,000	30.52	103,332	26.53	0.0000	33.9
6	B747-400	12,852	45.31	885,528	39.10	0.0299	73.7
7	B737-900 ER	341,754	45.43	189,748	34.27	0.0086	56.6
8	B737-800	1,550,318	45.47	175,866	32.43	0.0065	50.7
9	B737-700	>5,000,000	45.53	155,674	29.64	0.0000	42.4
10	B737-500	>5,000,000	45.58	134,337	27.88	0.0000	37.5
11	ATR 72	>5,000,000	45.17	52,151	20.55	0.0000	20.4
12	ATR 42	>5,000,000	41.28	50,591	20.57	0.0000	20.4
13	A330-300 std	13,418	45.31	513,938	39.07	0.0750	73.6
14	A 330 900	717	45.08	545,237	49.04	0.7577	115.9
15	A320 Twin opt	3,139,218	45.48	173,893	31.44	0.0000	47.6
16	A320-200 Twin std	>5,000,000	45.50	163,775	30.44	0.0031	44.7
					Total CDF =	0.8808	

Figure 7. PCN Value Calculation Results

2. Determining the ACR/PCR value

In determining the critical ACR value used as the basis for determining the PCR value in the calculation using the aircraft method, ICAO has referred to an auxiliary application in the form of ICAO-ACR 1.4 which can be easily used to determine the ACR value of each type of

aircraft operating at an airport. In the ACR-PCR system, the basic ground category for the 5% CBR value is D. From these observations, the most critical aircraft with the largest ACR value is a Boeing 747 400 with an ACR value of 832.93. If the PCR determination is made using the method of using a dining aircraft, the PCR value can be written as 832 F/C/X/U.

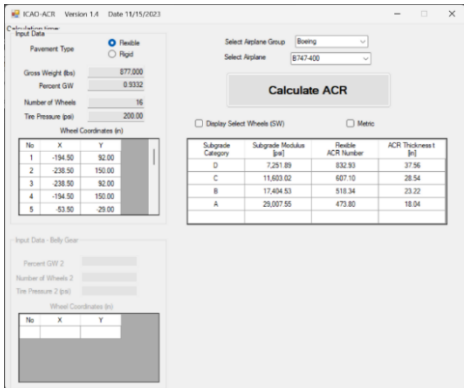

Figure 7. Calculation of ACR Values by ICAO-ACR 1.4 Software

Analysis

By using the same flight data in the calculation of the PCN value, the PCR value can be calculated using the FAARFIELD 2.1 software with data input as shown in figure 8. For the input of the pavement layer, each type of layer is identified with the appropriate modulus of elasticity value and with the existing thickness in the field. Annual growth of flights is obtained from the prediction of an increase in the next 20 years using the *Time Series Analysis* from flight data from 2021 to 2024.

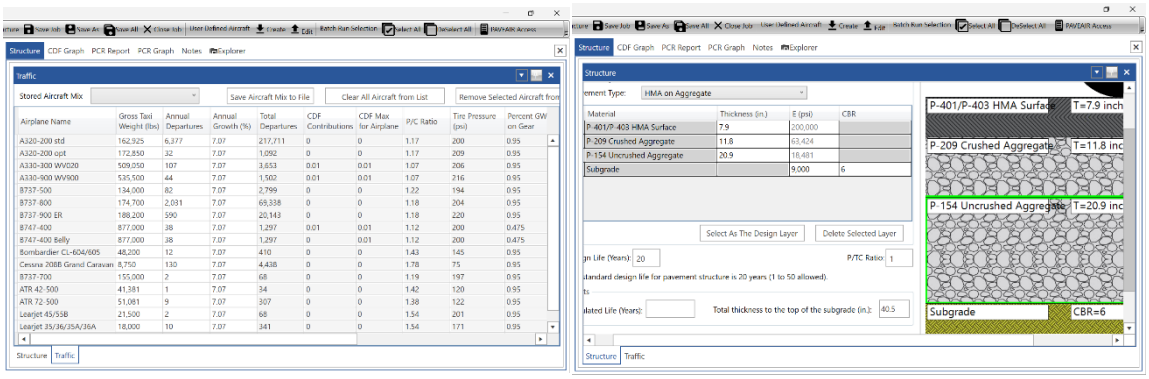

Figure 8. Data Input on FAARFIELD 2.1 Software

The PCR value obtained was 890 F/D/X/T with a critical aircraft was the Boeing 747 400 which had the largest CDF value of 0.62. This value is greater than the ACR value of the Boeing 747 400 which it is critical aircraft, so that the pavement layer is still safe for aircraft movement until next scheduled runway maintenance programs at SMB II Airport

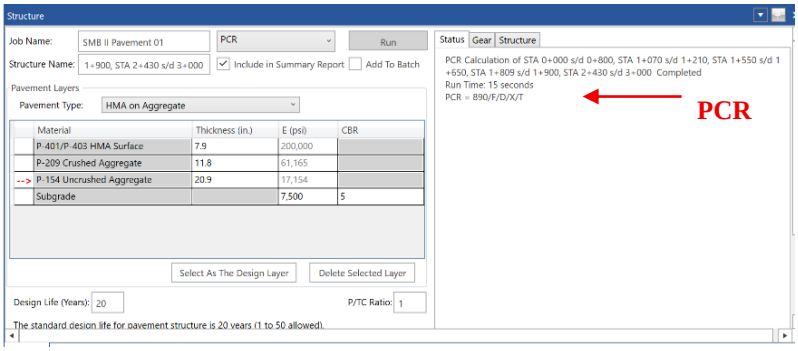

Figure 9. Calculation PCR Values Results Report

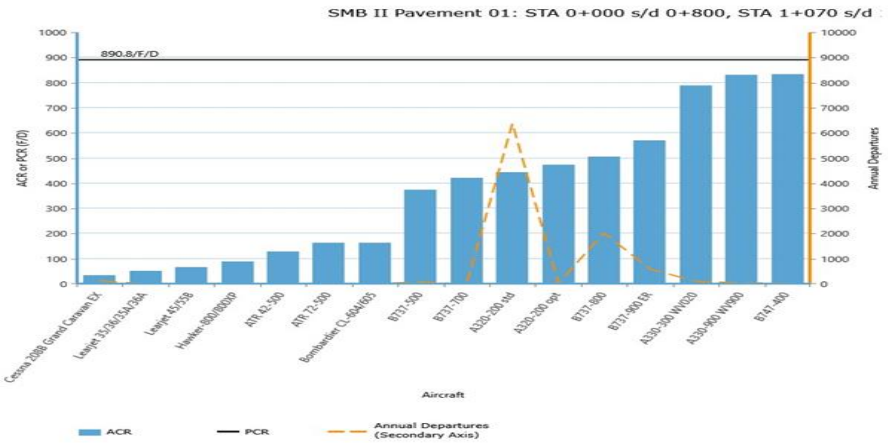

Figure 10. Comparison Chart of PCR and ACR Values

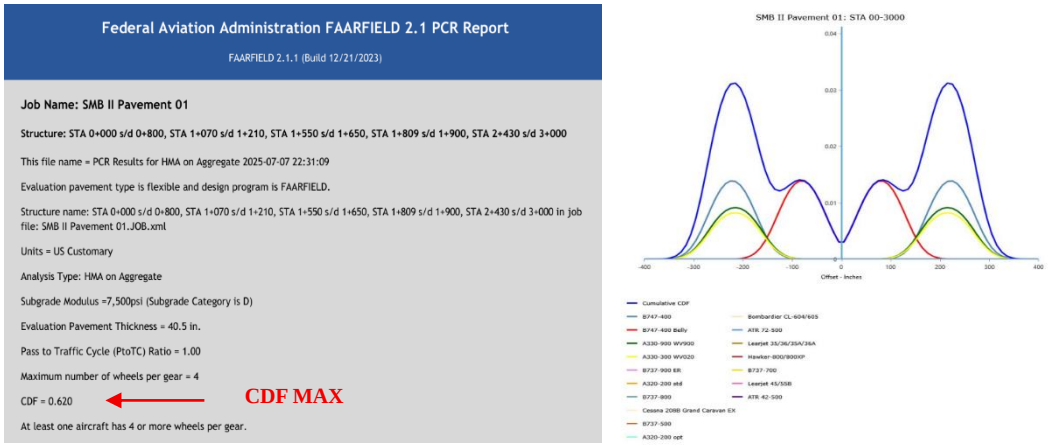

Figure 11. CDF Value Graph

Conclusion

Based on data from SMB II airport management that the currently published PCN value is 80/F/C/W/T with a critical Boeing B747-400 aircraft. From the calculation results using 2024 data, the PCN value of the SMB II airport runway pavement is 115 F/C/X/T with a total CDF of 0.76 which is mostly produced by the critical Airbus A330-900 aircraft. While for the PCR value after calculation is 890 F/C/X/T with a total CDF of 0.62 with a critical Boeing B747-400 aircraft. The type of critical aircraft that contributes the most damage between the PCN and PCR methods there is a difference this is caused by differences in calculation methods. The variable that distinguishes the two methods is in determining the strength of the layer. The PCN method is only based on the CBR of the subgrade and the pavement layer has not been detailed in detail as a part that can also provide a response to the load caused by the combination of the number of aircraft movements on the runway. Meanwhile, the PCR method is based on layered elastic analysis (LEA), which more closely represents actual conditions. The impact of each aircraft type on the pavement layer, with its varying material and thickness, significantly impacts runway strength maintenance. Based on the PCR calculation results above, the runway pavement layer at SMB II Airport remains safe for flight operations until the planned maintenance period. The pavement structure data used in the analysis represents initial planning data, as the pavement condition will change due to repeated loads, weather, and other influencing factors. Therefore, a more in-depth examination of the runway strength is required. This examination can be performed using a Heavy

Weight Deflectometer (HWD), which can more accurately analyze the elastic modulus of the layer to determine the timing of the next maintenance period.

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