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Sultan Hasanuddin Airport Taxiway Rigid Pavement ACN and PCN Analysis with COMFAA 3.0 and ELMOD

Rahmat Jaya Alimin[1*], Lambang Basri Said[2], Andi Alifuddin[3]
[1] Master of Civil Engineering, Postgraduate Program, Universitas Muslim Indonesia, Makassar, 90231, Indonesia.
Correspondence Author: rahmatjayacivil@gmail.com

ABSTRACT

This research focuses on Sultan Hasanuddin Makassar International Airport, which had an average of 48,949 aircraft movements in 2019. The study utilizes COMFAA 3.0 and ELMOD software based on Heavy Weight Deflectometer (HWD) deflection bowl data. The aim of this study is to analyze the quality and load-bearing capacity of the rigid pavement structure in the taxiway area to support critical aircraft loads, specifically the B747-400ER, and to determine the Aircraft Classification Number (ACN) and Pavement Classification Number (PCN) using relevant software. The research results indicate that the rigid pavement construction in the taxiway area is capable of accommodating operating aircraft, with a 400 mm thick slab of rigid pavement and a 150 mm thick lean concrete layer. The ACN and PCN values obtained from the analysis using COMFAA 3.0 software are PCN 74 R/B/W/T with ACN 69.8, and using ELMOD software, PCN 103/R/B/W/T with ACN 70 based on the 10th percentile method of the total PCN value. In conclusion, the rigid pavement in the taxiway is capable of handling the full load of the B747-400ER aircraft as the critical aircraft, with PCN > ACN.

Keywords: PCN, ACN, Rigid Pavement, COMFAA 3.0, ELMOD.

1. INTRODUCTION

To support the smoothness, safety, and security of an airport, including its equipment and facilities, the airport must always be in good condition and ready for use [1]. In order for the taxiway pavement facility to function properly, an analysis of the Pavement Classification Number (PCN) values, especially for the taxiway facility, needs to be conducted. This effort is deemed necessary to ensure that the taxiway pavement's load-bearing capacity is able to support the aircraft that will operate on it [2]. By controlling the Aircraft Classification Number (ACN), which is a value that indicates the relative effect of an aircraft on the pavement for a specified standard sub-grade category, the service life and planned lifespan of the taxiway, apron, and runway pavements can be achieved effectively.

The evaluation program used to analyze the rigid pavement in the taxiway area is the COMFAA 3.0 and ELMOD (Evaluation of Layer Module and Overlay Design) software [3]. The ACN-PCN system is a method developed to control the aircraft load operating on the airside pavement construction of an airport. This method is only used to determine the pavement's load-bearing capacity for operational aircraft weighing a minimum of 5,700 kg (12,500 lbs). Detailed explanations of the ACN-PCN system can be found in the Aerodrome Design Manual Part 3 (1957), published by ICAO [4].

The notation for writing PCN values is as follows:

• The numerical values of pavement strength range from 1 to infinity.

• The types of pavements consist of rigid pavement with the symbol letter R and flexible pavement with the symbol letter F.

• The subgrade category is divided into four categories for both rigid and flexible pavement, namely categories A, B, C, or D.

• The wheel load pressure is divided into four categories, namely W, X, Y, or Z.

Table 1. Subgrade Bearing Capacity Categories

Categories of Subgrade Bearing Capacity for Rigid Pavement Construction

No	Category Subgrade	The value of K for the subgrade surface Pci (MN/m³)	The range of values for the subgrade surface K Pci (MN/ m³)	Code
1	High	555.6 (150)	K > 442 (>120)	A
2	Medium	294.7 (80)	221 < K < 442 (60 < K < 120)	B
3	Low	147.4 (40)	92 < K < 221 (25 < K < 60)	C
4	Ultra Low	73.7 (20)	K < 92 (≤ 25)	D

Source KP 93 Year 2015 on Guidelines for Calculating PCN of Airport Pavement Infrastructure

Aircraft Wheel Pressure Categories

No	Category	Tire Pressure (Mpa/Psi)	Code
1	High	555.6 (150)	W
2	Medium	294.7 (80)	X
3	Low	147.4 (40)	Y
4	Ultra Low	73.7 (20)	Z

Source KP 93 Year 2015 on Guidelines for Calculating PCN of Airport Pavement Infrastructure

Table 2. Subgrade Bearing Capacity Categories for Rigid Pavement Construction

No.	Comparison ACN/PCN	Category	Informnation
1.	ACN/PCN ≤ 1,1	*Green*	The pavement is in good condition
2.	1,2<ACN/PCN≤1,4	*Yellow*	Perkerasan dalam kondisi sedang
3.	ACN/PCN>1,4	*Red*	The pavement is in fair condition
4.	ACN/PCN ≤ 1	*Green*	The pavement is in good condition and capable of serving throughout its planned lifespan
5.	1<ACN/PCN≤1,25	*Yellow*	The pavement is in fair condition, and air traffic will affect the quality of the pavement
6.	1,25<ACN/PCN≤1,5	*Yellow*	The pavement is in poor condition, and it needs to be limited to only 10 movements, with checks required after each passage

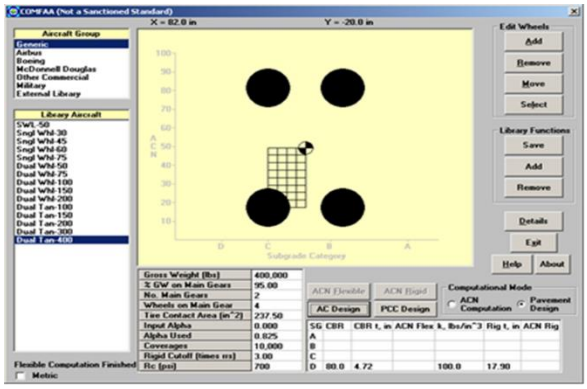
- **COMFAA 3.0 Software**

COMFAA 3.0 software operates in two calculation modes, namely ACN comparison and pavement thickness calculation [5, 6]. The ACN calculation includes the following:

• Calculating ACN for both flexible and rigid pavements.

• Calculating the thickness of flexible pavement based on ICAO procedures (CBR method) for default CBR subgrade values (15, 10, 6).

• Calculating the thickness of rigid pavement based on ICAO procedures (Portland Cement Association Method) for default K values (552, 6, 294, 147, 4, and 73.7 lb/in3 or 150, 80, 40, and 20 MN/m3). The fundamental difference between the classical PCN calculation method and the COMFAA 3.0 software is related to annual departures. In the classical method, all operating aircraft are converted into equivalent critical aircraft, while in COMFAA 3.0, all aircraft are input into the software based on annual departures and load. This is based on the fact that the damaging effect of aircraft on pavement varies depending on the characteristics of the load and aircraft traffic. COMFAA 3.0 is developed with the concept of Cumulative Damage Factor (CDF), which calculates the combined effect of multiple operating aircraft at the airport. The effect of this combined traffic is equated to the critical aircraft



Picture 1. Interface Software COMFAA 3.0

- **ELMOD Software**

ELMOD software utilizes Heavy Weight Deflectometer (HWD) testing data. The basic principle involves applying a specific weight load onto the surface of the installed pavement, with 9 Geophone sensors

positioned at distances of 0 mm, 300 mm, 600 mm, 900 mm, 1200 mm, 1500 mm, and 1800 mm from the center of the load. This process results in temporary deflection [7, 8]. The determination of PCN values using ELMOD software follows the procedure outlined in the. PCN analysis based on Heavy Weight Deflectometer (HWD) test data using ELMOD software can be performed by inputting the following parameters:

- Existing pavement layer thickness
- Air temperature and pavement temperature during testing
- Season
- Material properties

2. MATERIAL AND METHOD

Collection of secondary data serves as a reference for pavement load-bearing analysis, including:

- Planned aircraft characteristics
- Aircraft movement frequency (Annual Departure)
- ACN/PCN values specific to the airport
- Existing rigid pavement data in the taxiway area

• COMFAA 3.0 Software

The steps for calculating ACN and PCN values using COMFAA 3.0 software are as follows:

- Create a new model and go to the "Aircraft Group" section to determine and select the types of aircraft operating at the airport or research location.
- Access the "Library Aircraft" tab and cross-check the technical specifications and characteristics of the operating aircraft, such as weight, annual departures, tire pressure, and others, according to the traffic and aircraft movement data obtained from PT. Angkasa Pura
- Select the "More" button and click on the "ACN" menu.
- Calculate ACN for flexible pavement for the research object with existing flexible pavement, and calculate ACN for Rigid Pavement for the research object with existing rigid pavement.
- Click "Finish," and the ACN value for the research location will be obtained.

The steps for calculating PCN using COMFAA 3.0 software are as follows:

- Once the ACN value is obtained with the specific aircraft type and characteristics based on supporting data, input the equivalent pavement thickness obtained from calculations using a spreadsheet, as well as the subgrade strength values such as CBR for flexible pavement and K for rigid pavement.
- Then, input the concrete slab strength, both compressive strength and flexural strength.
- Click on "PCN Batch," then click "PCN batch flexible" for evaluating flexible pavement and "PCN batch rigid" for rigid pavement.
- After running the program, the PCN calculation results can be viewed by clicking on the details in the Miscellaneous Function menu.

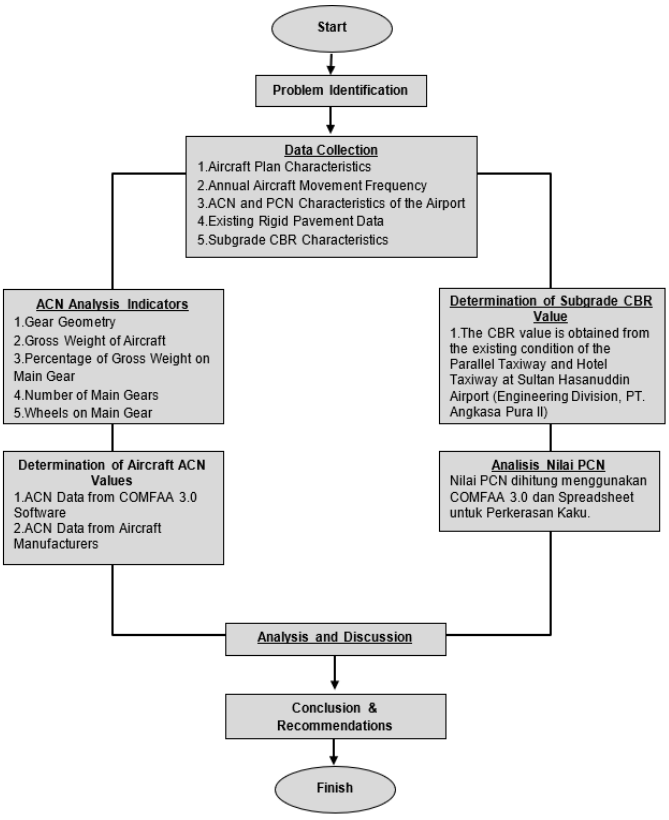
• ELMOD Software

Unlike COMFAA 3.0 software, which provides a menu for recalculating ACN values based on traffic movement (Annual Departures) according to aircraft characteristics, ELMOD can only calculate PCN values for both flexible and rigid pavements based on the elastic modulus data obtained from Heavy Weight Deflectometer tests. The steps for calculating PCN using ELMOD software are as follows:

- After conducting air traffic analysis using the classical method based on annual departures and aircraft wheel configurations and types, referring to ICAO (1983) Advisory Circular AC

150/5320-6D, the next step is to determine the critical aircraft with Maximum Take-Off Weight (MTOW) operating at the research location.

- Next, analyze the deflection data based on the results of HWD testing to obtain the Pavement Elastic Modulus value.
- Then, input the deflection data obtained from HWD testing into the ELMOD software.
- Next, fill in the thickness and type of existing pavement layers.
- Then, input the traffic data or aircraft movement information.
- Finally, click "Calculate.



Picture 2. Flowchart methodology of the study that uses COMFAA 3.0 and ELMOD software

3. RESULT AND DISCUSSION

The aircraft type with the highest CDF (Cumulative Damage Factor) value is considered the critical aircraft. Based on the data of aircraft operating at Sultan Hasanuddin International Airport in Makassar, the largest aircraft operating at the airport is the B747-400ER with a Maximum Take-Off Weight (MTOW) of 414,130 kg. According to the ELMOD-6 and COMFAA 3.0 airport pavement evaluation applications, the B747-400ER aircraft type has the following maximum ACN values:

- Subgrade category B (Medium) = 70 for rigid pavement,
- Subgrade category C (Low) = 78 for flexible pavement.

Based on secondary data obtained in the field, it is known that the Taxiway pavement at Sultan Hasanuddin International Airport in Makassar uses rigid pavement with the following thicknesses: Rigid Concrete K-500 = 40 cm and Lean Concrete = 15 cm.

Table 3. Domestic & International Departure Data

No.	Year	Domestic dan International
1.	2019	48.949
2.	2020	39.698
3.	2021	41.504
4.	2022	46.802

Source: Sultan Hasanuddin International Airport, Makassar, 2023

Table 4. Aircraft Characteristics and ACN Values

NO.	Aircraft Type	GEAR TYPE	JUMLAH RODA BELAKANG	Gross Weight (kg)	Tire Pressure (Mpa)	Aircraft Classification Flexible Pavements				Aircraft Classification Rigid Pavements			
						A	B	C	D	A	B	C	D
1	AIRBUS 320-100 Dual	D	4	68,400	1.4	35	37	40	46	40	42	44	46
2	200 WV 20	2D	8	230,900	1.4	57	62	72	97	53	61	73	85
3	AIRBUS 330-300 WV 20	2D	8	230,900	1.4	58	63	73	98	54	62	74	86
4	ATR-42 500	D	4	18,600	0.7	9	10	11	13	10	11	12	12
5	ATR-72 500	D	4	22,000	0.9	12	13	14	16	13	14	15	15
6	ATR72-600	D	4	22,800	0.9	12	13	15	16	14	15	15	16
7	B737-200	D	4	45,722	1.3	23	23	26	30	25	27	28	30
8	B737-300	D	4	63,503	1.4	33	35	39	43	38	40	42	44
9	B737-400	D	4	68,266	1.3	37	39	44	48	42	45	47	48
10	B737-500	D	4	60,781	1.3	32	33	37	41	37	39	40	42
11	B737-800	D	4	79,243	1.4	43	45	50	55	49	52	54	56
12	B737-900	D	4	85,366	1.5	48	51	56	61	56	58	61	63
13	B737-900ER	D	4	85,366	1.5	48	51	56	61	56	58	61	63
14	B747-400, 400ER	2D2	16	414,130	3.2	57	63	78	100	59	70	82	93
15	B777-300ER	3D	12	352,441	1.5	64	71	89	120	66	86	110	132
16	F100	D	4	19,090	2.1	19	19	18	18	21	20	20	20
17	FALCON 50	D	4	17,600	1.4	10	11	12	13	13	13	13	14
18	LAIN-LAIN	D	4	18,600	0.7	9	10	11	13	10	11	12	12
19	MD82	D	4	68,266	1.3	39	42	46	50	45	47	49	51
20	MD83	D	4	73,023	1.3	43	46	50	53	49	51	53	55

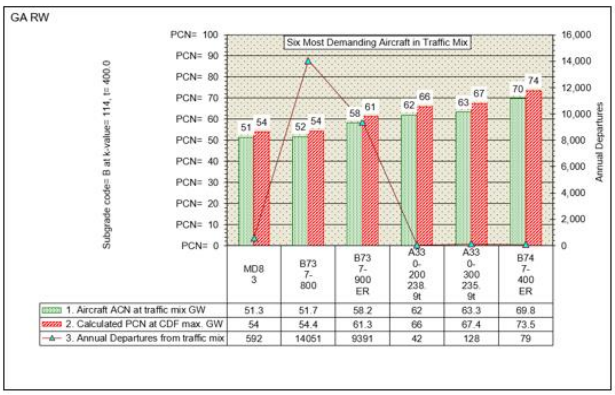
Sumber : ELMOD-6, 2023

The quality of the concrete used is K-500 or equivalent to 500 kg/cm2 / Fc' 41.5 N/mm2 and a minimum flexural strength of 50 kg/cm2 / 4933 kPa. The testing results of the subgrade soil

strength beneath the concrete slab indicate an average CBR value of 60%. To determine the modulus of subgrade reaction (k), the CBR value is converted using Figure 2.1, resulting in a value of k equal to 114 MN/m^3. According to Table 2.2, the subgrade bearing capacity under the concrete slab falls into Category B (medium) since the k value falls within the range of 60 < k < 120.

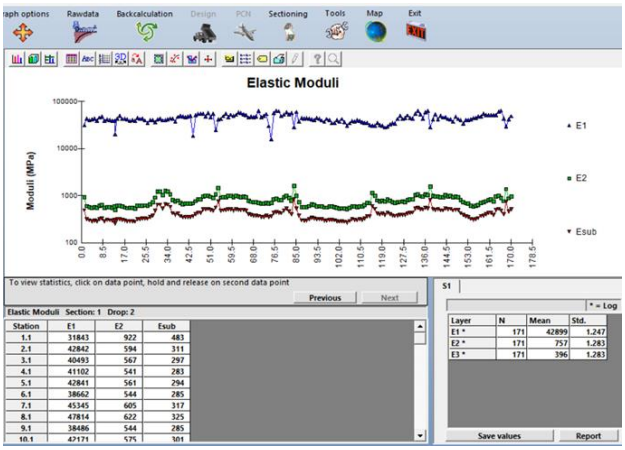
• **COMFAA 3.0 Software**

From the output analysis of COMFAA 3.0, it is determined that the Evaluation Thickness based on the existing rigid pavement slab thickness is 400 mm, with a flexural strength of 4,903 kPa as determined in the laboratory. This thickness is still higher when subjected to the CDF (Cumulative Damage Factor) of the maximum gross weight. When examining the ACN-PCN values for six types of aircraft with the highest gross weight in the output graph, the PCN values for each aircraft are still higher than their respective ACN values, as shown in Figure 4.7. The PCN value for the critical aircraft, B747-400ER, is 74, with an ACN value of 70. Therefore, the PCN code determined through the analysis using the COMFAA 3.0 application is PCN 74/R/B/W/T.



Picture 3. COMFAA 3.0 Output Graph ACN-PCN Comparison

• **ELMOD Software**

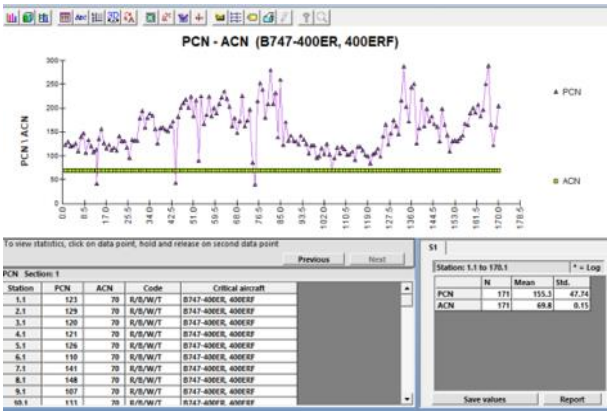


Picture 4. HWD Test Modulus Elasticity Output Graph

From the analysis of deflection data obtained from the HWD device, by inputting the thickness and material type of each pavement layer, values of E (modulus of elasticity) are obtained for each pavement layer. E1 represents the modulus of elasticity for the slab, E2 for the Lean Concrete (LC), and E3 represents the modulus of elasticity for the subgrade [10].

Elastic Modulus (MPa)		
E1	**E2**	**E3**
42899	757	395

Source: Analysis 2023



Picture 5. Graph of ACN-PCN Comparison Output from ELMOD Software

Table 5. Summary of ACN-PCN Analysis Results

Description PCN	PCN	ACN Max	Kode
Maximum	289	70	R/B/W/T
Mean	155	70	R/B/W/T
Percentile 10%	**103**	**70**	**R/B/W/T**
Percentile 20%	116	70	R/B/W/T

Source: Analysis 2023

PCN Analysis using the 10th percentile assumption means taking the lowest 10 percent of all PCN values obtained. From the analysis, the PCN value for the Parallel Taxiway and Hotel is determined to be 103 for rigid pavement construction with a subgrade category of B (medium). This PCN value indicates that the existing pavement is capable of accommodating the operations of the critical aircraft B747-400ER at full capacity, as it exceeds the ACN value of 70 for the aircraft. The recapitulation of PCN values for the Taxiway shows that the 10th percentile PCN value is the smallest PCN value among all tested taxiways [11]. If the obtained PCN value is smaller than its maximum ACN value, a tolerance of 5% is given for rigid pavement, which is 5% x 70 = 3.5 or a PCN value of 66.5.

4. CONCLUSION

Based on the results and discussions, the following conclusions can be drawn:

- The maximum ACN value for the B747-400ER aircraft, considered as a critical aircraft operating at Sultan Hasanuddin Makassar Airport in the taxiway area with rigid pavement construction, is 69.8 based on COMFAA 3.0 software using subgrade modulus reaction category B (medium). Meanwhile, the maximum ACN value for the B747-400ER aircraft based on ELMOD software using subgrade modulus reaction category B (medium) is 70.
- The PCN values for the rigid pavement with the B747-400ER aircraft obtained from the analysis using the software are as follows:
  - The PCN value using COMFAA 3.0 software is PCN 74 R/B/W/T.
  - The PCN value using ELMOD software with a 10% percentile is PCN 103 R/B/W/T, which indicates excellent conditions as the PCN value exceeds the maximum ACN value.

From the analysis using both software, it was found that the PCN values exceed the maximum ACN values in both cases. The obtained PCN values indicate that the pavement in that area is capable of accommodating the operations of critical B747-400ER aircraft at full capacity.

Therefore, based on the recapitulation of the ACN-PCN analysis using COMFAA 3.0 and ELMOD software, it can be concluded that the pavement condition in that area is in good condition and has a long planned service life.

Table 6. Summary of ACN-PCN Analysis Results using COMFAA 3.0 & ELMOD Software

Software	Fasilitas	Konstruksi	Metode	PCN	ACN Maks	Kode
COMFAA 3.0	Taxiway	Rigid Pavement	Analitis	74	69.8	R/B/W/T
ELMOD	Taxiway	Rigid Pavement	Analitis	103	70	R/B/W/T

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