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INTEGRATING REGIONAL PAVEMENT TEMPERATURE INTO SIMPLIFIED MATERIAL CHARACTERIZATION FOR AIRPORT PAVEMENT RATING

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ABSTRACT: Indonesia currently complies with the Aircraft Classification Number – Pavement Classification Number (ACN-PCN) system for airport pavement rating. The outdated ACN-PCN system is known to be inconsistent with modern airport pavement design methods. To resolve this issue, the International Civil Aviation Organization (ICAO) introduced a new Aircraft Classification Rating – Pavement Classification Rating (ACR-PCR) system. The transition to ACR-PCR resulted in substantial expenses for the industry. The lack of an organized record of airport pavement construction posed a challenge in implementing the new system without a comprehensive yet costly pavement investigation. The objective of this study is to propose simplified and rational methods for the characterization of airport flexible pavement material that is compatible with the newly published ACR-PCR system. Implementation of the proposed method is demonstrated through an example case. This study compares the pavement rating between material characteristics proposed by the method and values obtained from the field non-destructive pavement deflection test. The proposed method integrates the Asphalt Concrete (AC) modulus prediction model based on pavement temperature observation. Analysis was performed using FAARFIELD and ICAO-ACR computer programs. The results show that the proposed method would exhibit a more conservative rating for the pavement. This method is expected to provide a practical and cost-effective solution for airports, particularly those with limited funding, in transitioning to the ICAO ACR-PCR system.

Keywords: ACN-PCN, ACR-PCR, Pavement temperature, Material characterization, Pavement rating.

1. INTRODUCTION

The Aircraft Classification Number (ACN) – Pavement Classification Number (PCN) was introduced by the International Civil Aviation Organization (ICAO) in 1981, and as a member State of ICAO, Indonesia follows this system for aerodrome pavement strength rating. The Indonesian regulators specifically refer to procedures outlined by the Federal Aviation Administration (FAA) for PCN determination using the COMFAA Program [1]. ACN represents the relative damage of aircraft upon pavement, and PCN represents the bearing capacity of pavement. Aircraft with ACN equal to or lower than reported pavement PCN is allowed to operate without restriction [1]. The default principle behind the ACN-PCN system stems from the California Bearing Ratio (CBR) method for airport pavement design developed in 1977 [2]. The system emphasizes subgrade strength, underestimating the possibility of asphalt layer concrete failure [3]. The CBR method is empirical and simple in nature and has been the basis for ACN calculations for various aircraft, as reported in each aircraft manufacturer's Airport Planning Manual documents. Several studies have demonstrated the effort to incorporate the Mechanistic-Empirical (ME) principle into the rating process using the ACN-PCN system, especially for the material characterization process described in [4,5]. The development and use of the ME principle for pavement design in Indonesia has already started [6-8]. The Indonesian Ministry of Public Works has already published an ME-based pavement design guide for highways [9]. Although not officially enforced by airport regulators, current practice for airport pavement evaluation and design in Indonesia has already adopted the ME approach using FAA procedures [10,11]. Since ACN-PCN is (by default) based on empirical principle, the progressive adoption of ME design and evaluation methods for airport pavement worldwide has led to the identification of anomalies where pavement that is designed using more sophisticated ME tools to serve design aircraft operation instead has PCN value that is lower than ACN of the aircraft [12]. To resolve these anomalies, ICAO introduced a new rating system, the Aircraft Classification Rating (ACR) – Pavement Classification Rating (PCR) system, in 2022 [13]. This new rating system uses the same mathematical basis for the calculation of aircraft relative damage upon the pavement, as used for recently adopted ME pavement design for airport airside facilities. The ACR-PCR system is expected to be fully implemented by 2024. However, several preliminary studies revealed some challenges in the application of this new system. Armenia [14] reported an absence of correlation between PCN and PCR. Somehow, there

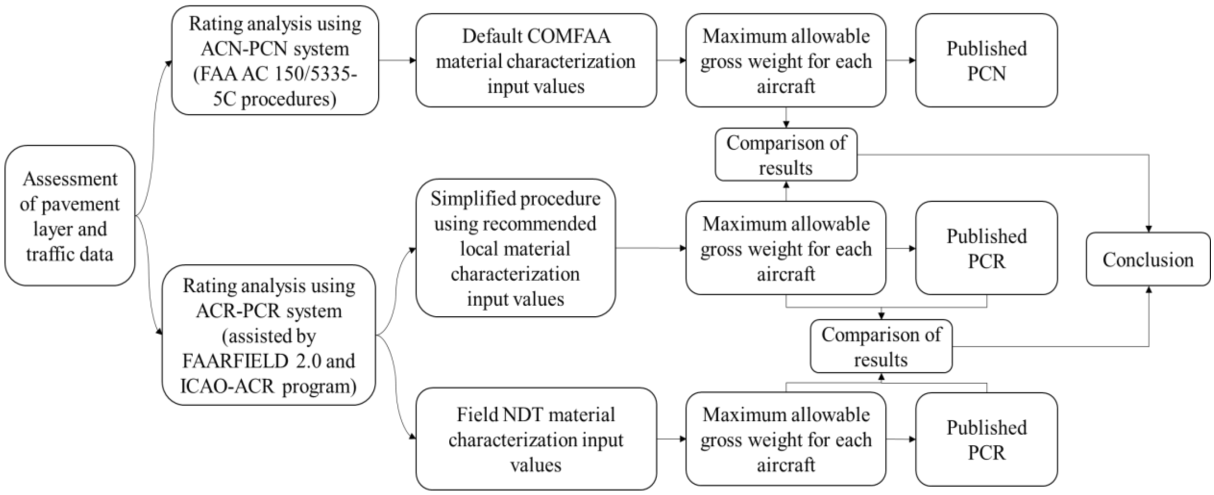


Fig. 1 Methodology followed

is a strong correlation between ACN and ACR. This indicates that PCR value cannot be directly estimated from published PCN value. It also shows that the ACR-PCR system is structured based on subgrade failure mode, whilst failure on the asphalt layer is not depicted despite its crucial role in airfield pavement performance. The report by [15] outlined several practical implications with the use of the new system: 1) airport regulator must re-publish Aeronautical Information Publication (AIP) documents containing new pavement ratings for multiple airports at the same date, which puts considerable strain on the publisher, 2) the use of new subgrade category would require airport operators to re-confirm their pavement subgrade CBR value since most airport know their PCN-based subgrade category but not the actual CBR value, 3) potential downgrade of pavement rating despite historically good performance, and 4) significant cost of transitioning to ACR-PCR system especially to perform study and analysis.

As described above, transitioning to ACR-PCR caused significant costs for the industry, particularly in developing countries such as Indonesia. The absence of a systematic inventory of airport pavement construction in the country made it challenging to apply the ME method for pavement rating without thorough pavement investigation. According to the latest data from the Ministry of Transportation, Indonesia has around 301 airports scattered throughout the archipelago. Re-publication of pavement rating using the ACR-PCR system for all Indonesian airports would require significant effort and funding. These preliminary findings indicate the need for future research to ensure a smooth transition from the ACN-PCN to the ACR-PCR system.

2. RESEARCH SIGNIFICANCE

As a member state of ICAO, Indonesia is also set to migrate from ACN-PCN to the ACR-PCR system. This paper provides a rational, simplified procedure to determine material characterization for flexible pavement strength rating using the ACR-PCR system. The procedure is primarily intended to facilitate and expedite the adoption of the new system during the transitional period, especially for airports with limited resources to conduct costly pavement structural investigations. The paper proceeds with a discussion of results between pavement rating using the proposed simplified procedure and a more sophisticated material characterization procedure based on a non-destructive field test (NDT). Although this paper presented in the context of flexible pavement in Indonesian airports, the proposed method is also principally applicable to other ICAO member states. This manuscript is an extension of [16] and presents a summary of the latest finding that incorporates regional pavement temperature data.

3. METHODOLOGY

The study introduced an alternative, simplified, and rational material characterization of flexible pavement for use in the ACR-PCR rating process. The discussion and observations included a comparison of rating results between simplified and NDT-based material characterization. Additionally, the study compared rating results between the ACN-PCN and ACR-PCR systems, focusing on the differences in the maximum allowable operational gross weight (MAGW) for each aircraft. The overall methodology followed by this paper is shown in Fig. 1. The study commences with the assessment of pavement layer and traffic data, followed by a rating analysis using two distinct rating systems. Each system generates the MAGW for every aircraft in the traffic mix, relying on various input values derived from material characterization. Subsequently, the study compares the resultant MAGW and rating values for each rating system.

3.1 ACR-PCR Rating Procedure

The current most available and ready-to-use method for pavement rating using the ACR-PCR system is provided by the FAA in AC 150/5335-5D [17]. The rating process is assisted by the FAARFIELD 2.0 computer program [18] and the ICAO-ACR computer program for the calculation of aircraft ACR at various gross weights [19]. The program automatically calculates pavement structural response and allowable gross weight for each operating aircraft and its subsequent ACR value.

The rating analysis using ACR-PCR relies on the calculation of the Cumulative Damage Factor (CDF) to quantify damage contributed by each aircraft loading. CDF is calculated using the following equation suggested by the FAA [17].

$$\mathrm{CDF} = \frac{\textit{number of load repetitions}}{\textit{number of allowable repetitions to failure}} = \frac{\textit{(annual departures)x (life in years)}}{(P/C) \times \textit{coverages to failure}} \quad (1)$$

Where P/C indicates pass to coverage ratio. The number of loading repetitions before failure is estimated using a certain transfer function that predicts the number of load repetitions to failure based on the estimated structural response. The choice of transfer function is a crucial step in the rating determination of airport pavement using the ME principle. Previous research was carried out to compare transfer functions for asphalt fatigue cracking [20]. The findings indicate that the predictive accuracy of the examined transfer function was generally modest to satisfactory. Notably, improved accuracy was observed when Field Shift Factors (FSF) were employed for calibration, underscoring the importance of tailoring transfer functions to specific sites. To simplify matters, this paper suggests adopting the transfer function recommended by the FAA to align the rating and design processes.

As suggested by FAA, this paper considers two types of failure: fatigue cracking of the asphalt layer and deformation of the subgrade. The transfer function for asphalt layer fatigue cracking suggested by FAA is based on the concept of Ratio of Dissipated Energy (RDEC) [21], as shown in Eq. (2).

$$\begin{aligned} \mathrm{N_f} &= 0.4801\mathrm{PV}^{-0.9007} \\ \mathrm{PV} &= 44.422{\varepsilon_h}^{5.14}\mathrm{S}^{2.993}\mathrm{VP}^{1.85}\mathrm{GP}^{-0.4061} \\ VP &= \frac{Va}{V_a+V_b} \\ \mathrm{GP} &= \frac{\mathrm{PNMS-PPCS}}{\mathrm{P200}} \end{aligned} \quad (2)$$

Where N_f = number of cycles to fatigue failure, PV = estimated value of the RDEC plateau value, dimensionless, S = HMA flexural stiffness, psi, ε_h = horizontal strain at the bottom of the asphalt layer, VP = volumetric parameter, GP = gradation parameter =. Va = air voids, Vb = asphalt content by volume, PNMS = the percent of aggregate passing the nominal maximum size sieve, PPCS = the percent of aggregate passing the primary control sieve, P200 = the percent of aggregate passing the #200 (0.075mm) sieve.

The transfer function for subgrade deformation suggested by FAA is based on Eq. (3).

$$\begin{aligned} &\mathrm{C}=\left(\frac{0.002428}{\varepsilon_z}\right)^{14.21}, \text{ when C>12100} \\ &\mathrm{C}=\left(\frac{0.004141}{\varepsilon_z}\right)^{8.1}, \text{ when C}\leq 12100 \end{aligned} \quad (3)$$

Where C = number of coverages to failure, ε_z = vertical strain at the top of the subgrade. The MAGW is calculated using the procedure described by Bazi [4] based on the Permissible Weight Multiplier (PWM) concept.

$$\begin{aligned} \mathrm{MAGW} &= \mathrm{w} \times \mathrm{PWM} \\ \mathrm{PWM} &= {\mathrm{CDF_{total}}}^{\mathrm{B}} \end{aligned} \quad (4)$$

Where w = operational weight of aircraft in analysis, CDF_{total} is the sum of damage from the loading of all traffic mix, and B = parameter from the employed damage factor. B values for eq (2) and (3) are -0.216 and -0.070 (if C>12100), and -0.123 (if C <12100), respectively. The MAGW value is then calculated using Eq.(4).

3.2 ACN-PCN System Rating Procedure

Pavement strength rating using the ACN-PCN system is conducted based on procedures outlined in FAA AC 150/5335-5C [22]. The procedure involves the assessment of traffic and conversion of pavement layer composition into standard evaluation thickness. PCN calculation is assisted using the COMFAA computer program.

4. PROPOSED SIMPLIFIED AND RATIONAL MATERIAL CHARACTERIZATION

Rational material characterization, especially modulus values, is ideally obtained through pavement investigations, which involve a series of destructive and/or non-destructive tests that require significant resources and time. To provide more simplified and rational modulus values for analysis, this paper proposes a procedure that emphasizes the selection of input values for pavement material characterization, taking into consideration local conditions. This step is crucial as it dominates the bulk of the cost for the entire pavement strength rating process.

4.1 Selection of Asphalt-Concrete (AC) Modulus Value

Various research has shown that AC modulus is known to be a function of pavement temperature [23,24]. The AC (P-401 layer) default modulus value used for analysis in the FAARFIELD 2.0 program is 1378 MPa, which corresponds to an asphalt layer temperature of 32ºC. This value clearly does not represent local conditions for most airports in Indonesia, thus potentially introducing some level of deviation when used for the rating process.

Fig. 2 shows a simplified AC modulus selection process considering local temperature conditions.

Directorate General Bina Marga, Ministry of Public Works (Indonesian road authorities), published a ME-based road pavement design manual containing recommended Weighted Mean Annual Pavement Temperature (WMAPT) for design purposes [9]. The manual suggests that for the Indonesian climate, WMAPT ranges from 38º C (mountainous areas) to 42º C (coastal areas). Table 1 shows typical modulus values for various mix types recommended by Indonesian road authorities at WMAPT 41 º C.

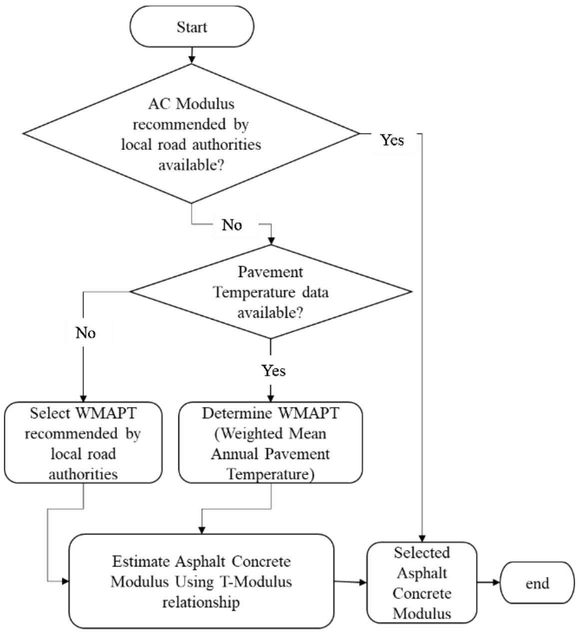


Fig. 2 Simplified AC modulus selection process

Table 2 shows the correction factor for modulus values provided in Table 1 in case another WMAPT value was considered to be used. AC modulus can also be estimated using the following Temperature-Modulus relationship proposed by Witczak [25].

$$log_{10}E = 1.53658-0.006447T-0.00007404T^2 \quad (5)$$

Where E = AC modulus (psi), T = asphalt temperature (ºF).

Table 1 Typical AC modulus at WMAPT 41 º C

AC mix type	Typical modulus at WMAPT 41 º C
AC – wearing course	1100 MPa
AC – binder course	1200 MPa
AC – base course	1600 MPa
HRS – wearing course	800 MPa
HRS – binder course	900 MPa

Note: HRS = Hot Rolled Sheet

Table 2 AC modulus correction factor

WMAPT (º C)	Modulus correction factor
42	0.923
41	1.000
40	1.083
39	1.174
38	1.271

Table 3 Typical base/subbase course modulus

Material	Modulus (MPa)
Cement stabilized base course (post cracking)	500
Granular base/subbase course (based on asphalt layer thickness above granular layer)	
75 mm	350
125 mm	300
175 mm	250
200 mm	210
>250 mm	150

4.2 Study on AC Pavement Temperature in Indonesia

The asphalt layer load-bearing capacity and performance are significantly influenced by temperature [26,27]. The influence of temperature on asphalt performance is commonly attributed to the viscoelastic characteristics of the material [28]. A temperature-modulus prediction model is required to provide a rational basis for the AC modulus for the rating process. Different geographical regions exhibit different temperature variations, implying the need for locally developed prediction models. Various studies have been conducted to develop a temperature prediction model [29-31]. One specific study previously conducted in Bali, Indonesia, proposed several models to predict pavement temperature based on various climatic inputs [32]. Efforts to identify representative asphalt temperatures for Indonesian airports are currently in progress. Pavement temperature observation sensors are installed in 13 airports located at various altitudes across Indonesian main islands. Based on collected data, the maximum surface temperature of asphalt pavement varies from 35.82 °C – 66.23 °C. Subsequently, laboratory Asphalt concrete resilient modulus tests were conducted at various temperatures within the range of 15.0 °C – 55.0 °C. The sample was prepared to meet the Indonesia airport pavement specification for the wearing course using two types of binder: Pen 60/70 and PG 76 [33]. The data produce a modulus prediction model based on input temperature value for both binder types as follows:

$$E = 7E{+}06T^{-2,486} \text{ (PG 76 binder)} \quad (6)$$

$$E = 6E{+}06T^{-2,487} \text{ (Pen 60/70 binder)} \quad (7)$$

Using the produced prediction model, the AC wearing course modulus at WMAPT of 41 ⁰ C is 685 MPa and 585 MPa for PG76 and Pen 60/70 binder type, respectively. These values are significantly lower than the value presented in Table 1. In this paper, the above value is used for analysis, as presented in Table 6.

4.3 Selection of Base/Subbase Course Modulus Value

Since base/subbase course modulus are not directly affected by changes in temperature, default modulus values suggested by FAA [10] were used. Indonesian road authorities also provide typical modulus values for base/subbase courses, including cement-stabilized base courses, as shown in Table 3.

4.4 Selection of Subgrade Modulus Value

Ideally, the subgrade modulus can be estimated from the historical as-built CBR value. If the data is not available, the modulus for the subgrade layer can be approached from the previous subgrade category reported by the ACN-PCN system documented in AIP. However, there is a potential case where airport operators need to change the reported subgrade category due to the difference in the range of subgrade strength values between ACN-PCN and ACR-PCR systems, as shown in Table 4.

Table 4 Subgrade strength category between ACN-PCN vs ACR-PCR system

Subgrade category	ACN-PCN system CBR range	ACR-PCR system CBR range
A	$\geq$ 13	$\geq$ 15
B	8-12	10-14
C	5-8	6-9
D	$\leq$ 4	$\leq$ 5

For the purposes of migrating to the ACR-PCR system during the transitional period, this paper proposes CBR value as shown in Table 5 to prevent changes in the subgrade category.

Table 5 Proposed CBR value for PCR rating analysis

Subgrade category previously reported in AIP using ACN-PCN system	Proposed CBR value for use in rating analysis
A	15
B	10
C	6
D	5

Values in Table 5 are preliminary and used only when no historical subgrade strength data is available. The idea of preventing changes in the subgrade strength category is justified based on previous preliminary studies revealing how - for the same cross-section - PCR numerical value is insensitive to changes in the subgrade category [14].

5. EXAMPLE CASE: RUNWAY FLEXIBLE PAVEMENT OF LOMBOK PRAYA AIRPORT

Lombok Praya International Airport is located on Lombok Island of West Nusa Tenggara. The runway is constructed using flexible pavement with a published PCN of 64 F/A/X/T [34]. The airport was recently undergoing a significant upgrade to accommodate the prestigious Mandalika MotoGP event. The upgrade included extending the runway to serve larger aircraft and expanding the apron to increase capacity.

Table 6 Lombok Praya Int'l Airport runway pavement layer composition and material characteristic used for analysis

Pavement layer composition	Input 1: typical value from Eq 6, Table 3, and Table 5	Input 2: deflection data back-calculation results
Asphalt concrete 225 mm	685 MPa	1525 MPa
Asphalt treated base 100 mm	1600 MPa	2550 MPa
Granular base course 350 mm	150 MPa	474 MPa
Granular subbase course 850 mm	150 MPa	291 MPa
Subgrade	CBR 15%	CBR 9% (E = 92 MPa)

Table 7 Aircraft mix and traffic characteristics

No.	Aircraft	MTOW (kg)	Percent GW on the main gear	Tire pressure (kPa)	Annual departures	Total departures (20 years, assuming 0% growth)	Percentage
1	ATR72	22680	0.95	551.58	5748	114960	27.63%
2	B737-900 ER	85366	0.95	1516.85	4909	98180	23.60%
3	B737-800	79242	0.95	1406.53	3766	75320	18.11%
4	A320-200 opt	78400	0.95	1441	3706	74120	17.82%
5	Cessna 208B	3969	0.95	517.11	1095	21900	5.26%
6	CRJ1000	41867	0.95	1330.69	730	14600	3.51%
7	B737-500	60781	0.95	1337.58	730	14600	3.51%
8	C172	2268	1	310.26	45	900	0.22%
9	C-130	70307	0.95	723.95	26	520	0.13%
10	B737-400	68266	0.95	1275.53	12	240	0.06%
11	B777-300 ER	352441	0.95	1503.06	23	460	0.11%
12	B747-8F	449056	0.476	1523.74	10	200	0.05%

This airport was specifically selected for this study due to the availability of runway material characterization analysis from NDT deflection data tests for comparison with the values proposed in this result.

5.1 Runway Pavement Layer Composition

Runway pavement layer composition data is available from the airport operator database, as shown in Table 6. Notice that layer composition does not strictly follow pavement design requirements by FAA, where the minimum thickness of the stabilized layer is 125 mm. Here, the thickness of the stabilized layer is 100 mm.

5.2 Material Characterization Input

This paper presents the results of a rating analysis for two material characteristics input, as shown in Table 6. Input 1 is selected based on the proposed values described in this paper. Input 2 is obtained through the back-calculation of runway pavement deflection data along the runway. It is evident that the value for Input 2 is relatively higher than the proposed value, which reaffirms the significance of conducting direct pavement structural investigations. Additionally, it is noteworthy that there is a considerable disparity in the subgrade strength values. Since the current PCN-based subgrade category is “A”, the proposed value for subgrade CBR input is 15%.

5.3 Aircraft Mix and Traffic Characteristics

Aircraft mix and traffic characteristic data is provided by the airport operator. Table 7 presents the aircraft characteristics and traffic used for rating analysis. B737-900ER is the most dominant traffic operating with gross weight > 45 tons (100k lb).

5.4 ACR-PCR Rating Analysis Results

Table 8 shows the distribution of CDF value for different material characteristic inputs from Table 6. The analysis shows that cumulative damage of the asphalt layer (CDFAC) is significantly more dominant compared to damage of the subgrade layer ($CDF_{subgrade}$). For both types of material characteristic input, the CDFAC value is > 1, indicating asphalt layer failure is expected to occur within service life. Somehow, for both inputs, $CDF_{subgrade}$ is < 1, indicating subgrade structural failure is not expected within service life. As expected, the proposed material characteristic input exhibits more damage compared to input from deflection data back-calculation.

Fig. 3 illustrates a comparison of MAGW for material characteristics presented in Table 6 based on AC and subgrade failure mode. For AC failure mode, it is evident that MAGW is smaller than the operational weight at Maximum Take Off Weight (MTOW). As expected, MAGW for input 1 is less than MAGW-based input 2. For subgrade failure mode, the aircraft is still theoretically allowed to operate above operational weight at MTOW, and there is no significant disparity between MAGW input 1 and input 2.

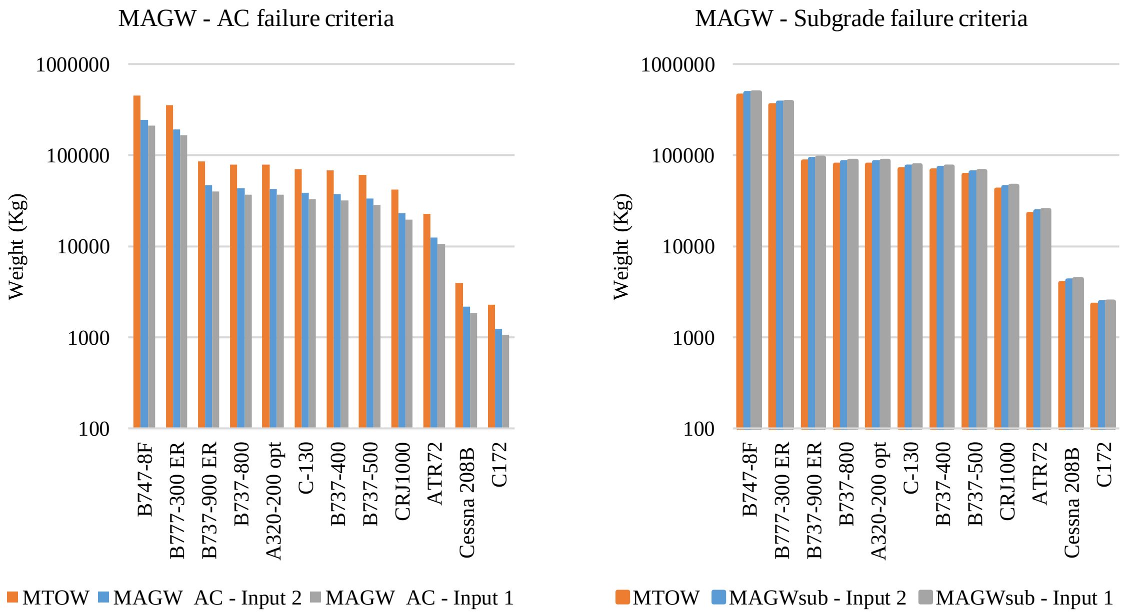
Fig. 4 illustrates a comparison between the MAGW obtained from the previous analysis using the ACR-PCR system ($MAGW_{ACR\text{-}PCR}$) and the MAGW obtained from the ACN-PCN system ($MAGW_{ACN\text{-}PCN}$).

The results indicate that the MAGW obtained from the ACN-PCN system closely aligns with the MAGW of the ACR-PCR system, particularly when considering failure at the subgrade layer.

Table 8 Comparison of CDF values based different material characterization

Aircraft	Annual dept.	Input 1: Proposed material characterization values		Input 2: Deflection data backcalculation results	
		CDF_{AC}	$CDF_{Subgrade}$	CDF_{AC}	$CDF_{Subgrade}$
B737-900 ER	4909	15.108	0.251	7.604	0.243
A320-200 opt	3706	8.393	0.020	3.923	0.034
B737-800	3766	8.174	0.025	4.120	0.065
B737-500	730	1.122	0.001	0.459	0.001
CRJ1000	730	0.723	0.000	0.232	0.000
ATR72	5748	0.221	0.000	0.087	0.000
B777-300 ER	23	0.041	0.132	0.033	0.046
B747-8F	10	0.029	0.016	0.020	0.011
B737-400	12	0.017	<<< 0.001	0.009	<<< 0.001
C-130	26	0.004	<<< 0.001	0.002	<<< 0.001
Cessna 208B Grand Caravan EX	1095	0.001	<<< 0.001	<<< 0,001	<<< 0.001
C172	45	<<< 0.001	<<< 0.001	<<< 0.001	<<< 0.001
Total CDF		33.833	0.444	16.487	0.400

Note: CDF AC = CDF based on asphalt concrete fatigue cracking failure; CDF subgrade = CDF based on subgrade deformation failure



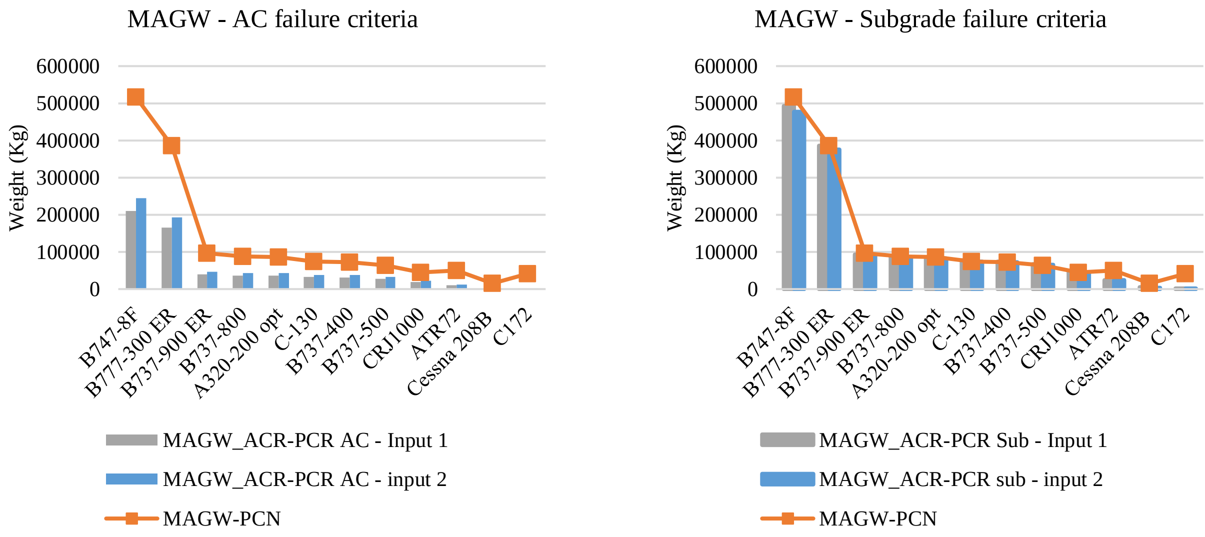
(a) (b)

Fig. 3 $MAGW_{ACR\text{-}PCR}$ based on AC (a) and subgrade (b) failure mode

Fig. 5 and Fig. 6 attempted to find the ratio between MAGW calculated based on the ACR-PCR system and ACN-PCN system. It was discovered that the ratio of MAGW between the rating systems differed based on the failure mode employed. The ratio of $MAGW_{ACR\text{-}PCR}$ to $MAGW_{ACN\text{-}PCN}$ is within the range of 0.4-0.53 and 0.93-1.06 for AC and subgrade failure modes, respectively.

Somehow, as shown in the figure, the ratio for smaller aircraft (Cessna aircraft) has different patterns and requires further analysis in the future. The ratio based on subgrade failure mode is known to be closer to 1.

Fig. 7 and Fig. 8 show calculated ACR values using the ICAO-ACR program for inputs 1 and 2, respectively. FAA procedure [19] suggested that the max ACR be published as PCR, which, in this case, is given by a B777-300ER aircraft. As expected, the ACR value generated by proposed material characteristics is more conservative compared to ACR generated from NDT-based material characteristics.



(a) (b)

Fig. 4 MAGW$_{ACR-PCR}$ vs MAGW$_{ACN-PCN}$ for AC (a) vs subgrade (b) failure mode

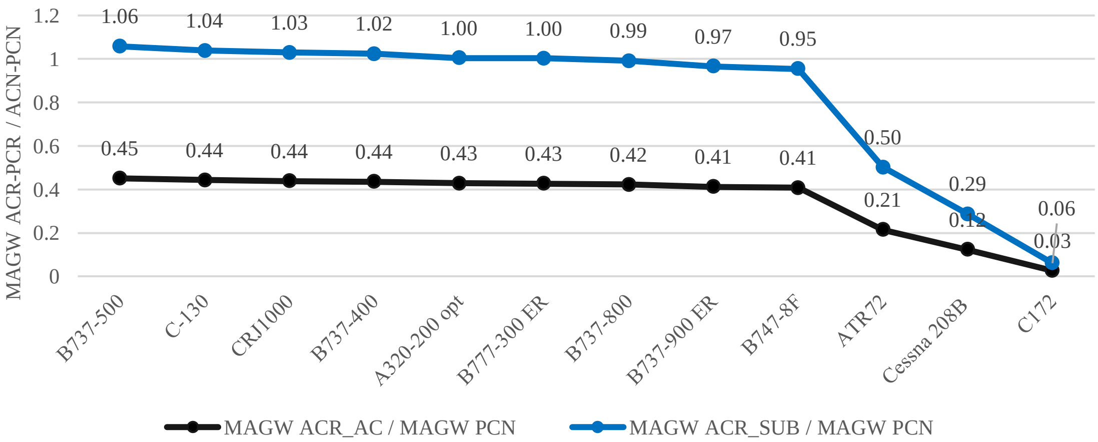


Fig. 5 Ratio of MAGW ACR-PCR vs ACN-PCN - input 1

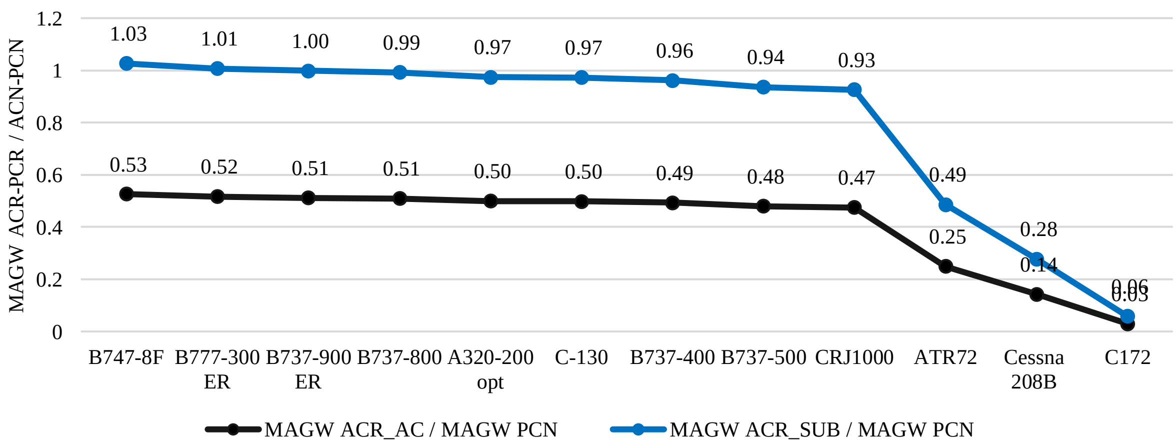


Fig. 6 Ratio of MAGW ACR-PCR vs ACN-PCN - input 2

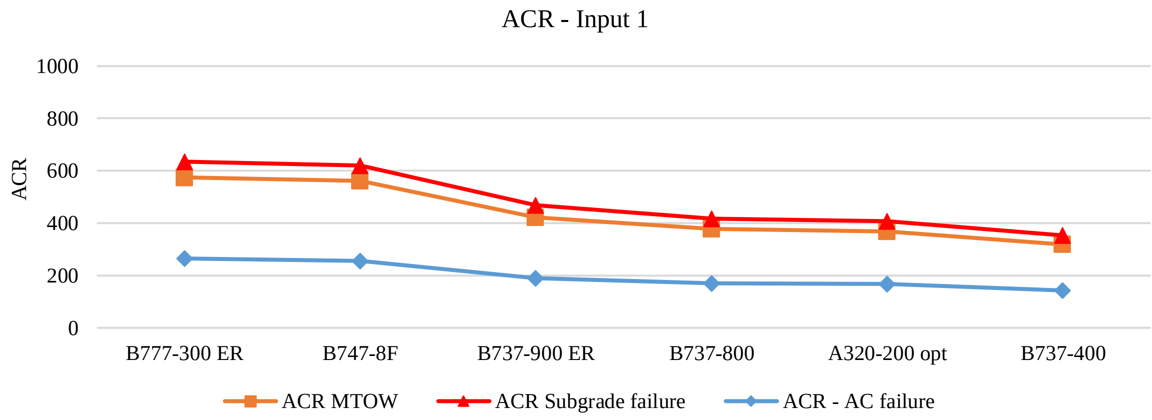


Fig. 7 Calculated ACR value at MTOW and MAGW based on failure criteria – input 1

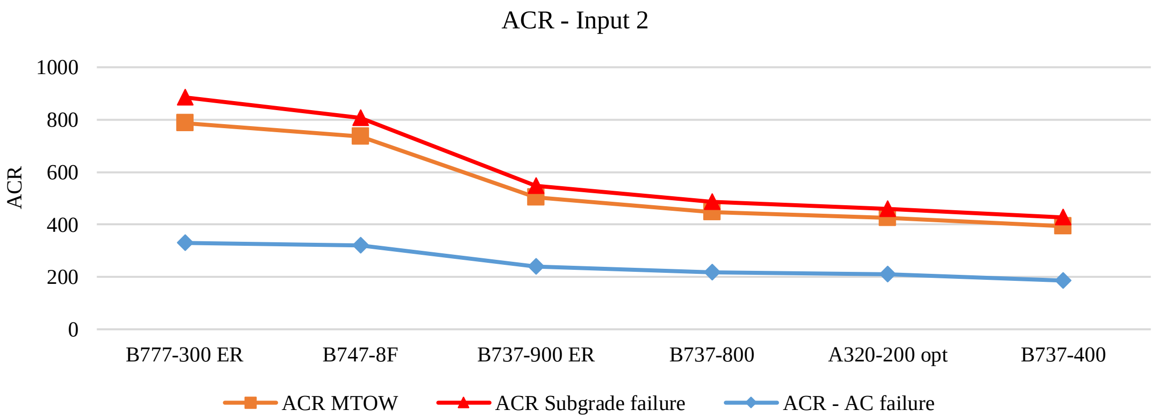


Fig. 8 Calculated ACR value at MTOW and MAGW based on failure criteria – input 2

Table 9 ACN analysis result-COMFAA

No	Aircraft	Critical aircraft total equiv. covs.	Thickness for total equiv. covs. (mm)	Maximum allowable gross weight (tons)	ACN thick at max. allowable gross weight	CDF	PCN on subgrade cat. A(15)
1	ATR72	>5,000,000	332.8	49.643	348.50	0.0000	26.4
2	B737-900ER	85,329	528.8	97.045	507.04	0.1086	55.9
3	B737-800	465,436	537.4	87.700	471.25	0.0152	48.2
4	A320 Twin opt	1,245,902	541.6	85.678	457.28	0.0053	45.4
5	C208	>5,000,000	292.9	15.186	286.52	0.0000	17.8
6	CRJ1000	>5,000,000	549.7	44.648	342.47	0.0000	25.5
7	B737-500	>5,000,000	560.7	63.047	391.65	0.0000	33.3
8	C172	>5,000,000	134.1	41.396	286.22	0.0000	17.8
9	C-130	>5,000,000	554.4	74.283	361.47	0.0000	28.3
10	B737-400	>5,000,000	548.6	73.192	431.14	0.0000	40.4
11	B777-300 ER	8,190	536.7	385.826	577.91	0.0144	72.5
12	B747-8F	5,738	523.2	516.177	592.39	0.0066	76.2
					Total CDF =	0.1502	

Table 9 shows the rating analysis result based on the ACN-PCN system from the COMFAA program. The COMFAA output table presents several results, including the MAGW and ACN of each aircraft. The B747-8F aircraft is known to have a maximum ACN of 76.2. According to procedures outlined by FAA [22], the max ACN is suggested to be published as the pavement PCN. It is known that the numerical PCN value may differ from the number published on the AIP of the airport [34]. This discrepancy is potentially a result of the airport operator's policy to limit the numerical PCN value to the ACN of critical aircraft in subgrade category A.

6. CONCLUSIONS

The paper presents a simplified method for characterizing materials, which can be used in the rating process of airport flexible pavements using the newly published ACR-PCR system. As anticipated, the use of both simplified and sophisticated material characterization methods yields different published PCR values. However, the simplified method yields a more conservative rating value. The assessment of the maximum allowable gross weight for both methods also follows the same pattern. Additional data from other airports might generate rating results that are closer to each other. Additionally, the paper discusses the comparison between rating results based on two different types of failure criteria for flexible pavements: AC fatigue cracking and subgrade deformation. The analysis in this paper reveals that fatigue cracking damage to the AC layer is more dominant compared to subgrade deformation. The comparison of MAGW between the ACN-PCN and ACR-PCR systems reveals that the MAGW based on subgrade failure criteria is closer to the MAGW based on the ACN-PCN system. The ratio of $MAGW_{ACR\text{-}PCR}$ to $MAGW_{ACN\text{-}PCN}$ is within the range of 0.4-0.53 and 0.93-1.06 for AC and subgrade failure modes, respectively. The ratio based on subgrade failure mode is known to be closer to 1. However, the ratio for smaller aircraft has different patterns. This may be related to different types of main gear configuration and loading. Future analysis and studies are required. To support the full adoption of the ACR-PCR system, future research on the characteristics of local pavement material and its behavior is required, including the behavior of AC toward temperature variation. A locally developed transfer function is also required to accurately predict pavement service life.

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