Pavement Strength Evaluation of Selected Iraqi Airports Depends on ICAO (ACN/PCN) Method

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Abstract

Runway pavements are designed to provide adequate support for loads imposed by aircraft using an airport. To fulfill this requirement, the pavement must be of such quality and thickness that it should not fail under the expected loads.

In the process of runway pavement design, the current research has been extended to evaluate the pavement sufficiency of four Iraqi airports (Baghdad International airport, Basrah International airport, Salaymaniyh International airport, and Balad Airfield) by use the (ACN / PCN) method. The investigation discusses the ability of an existing pavement to carry the different types and weights of aircraft traffic. Moreover an improvement to the existing pavement thickness to stand with the expected future load is performed.

For four studied airports, the results indicate that an improvement can be achieved by adding various thickness of asphalt concrete overlays or Portland cement concrete.

Keywords: Airport Runway, Pavement Classification Number (PCN), Aircraft Classification Number (ACN).

الخلاصة

أن أحد أهم أجزاء المطار هو المدرج أو طريق الدرج (Runway) الذي تنجز الطائرة به عمليات الإقلاع والهبوط. إن هذه الفعاليات يصاحبها العديد من التأثيرات الجانبية التي لها علاقة بالطائرة من جهة وبالمدرج من جهة أخرى كما في بقية المنشآت الخدمية.

لذلك يجب إن يكون تبليطه بنوعية جيدة وسمك كافي لكي يتحمل أوزان الطائرات المختلفة والقوى المتولدة من جراء عملية الهبوط (Impact load) بالإضافة إلى الظروف الجوية المختلفة.

يتناول هذا البحث تقييم أربع مطارات عراقية (مطار بغداد الدولي , مطار البصرة الدولي , مطار السليمانية الدولي, وقاعدة بلد الجوية) باستخدام طريقة (ACN /PCN) وذلك لمعرفة مقدار تحمل المد ارج للأنواع والأحجام المختلفة من الطائرات المدنية والعسكرية , وإضافة طبقات تبليط أضافية لتحسين قابلية تحمل المدرج.

وقد بينت عملية التقييم أن المواقع الأربعة التي تمت دراستها يمكن تطويرها بإضافة طبقات من التبليط الإسفلتي المرن أو التبليط الجاسئ وبسمك يلائم نوعية التبليط وذلك لزيادة قابلية المدرج على تحمل الأوزان المسلطة.

1. Introduction

Airport's runway is the most important part of airport who limits the other parts by its direction, length, thickness and load-carrying capacity of pavement (pavement strength) [AL-JUBORI 2001, HORONJEFF R., 1985].

Runway function is to provide aircraft pavement suitable for the unrestricted and sustained use of aircraft at maximum weights to land and take - off at an airfield. Runway must provide sufficient strength to meet the designated roles of an airport. Therefore airport pavement evaluation is necessary to asses the ability of an existing pavement to support different types, weight or volumes of aircraft traffic [ICAO, 2004].

Evaluation may also necessary to determine the condition of exiting pavement for use in the planning or design of improvements to the airport. The International Civil Aviation Organization (ICAO) requires every international airport which serves commercial airline operations to provide the Pavement Classification Number (PCN) to represent the bearing strength of the runway pavement. This PCN must be published in the airport's own Aeronautical Information Publication (AIP).

So that the International Civil Aviation Organization (ICAO) developed a standardized method of reporting airport pavement strength known as the Aircraft Classification Number / Pavement Classification Number (ACN / PCN) method. This method of reporting is based on the concept of reporting strength in terms of a standardized equivalent single wheel load [ICAO, 2004].

The purpose of this research is to evaluate the pavement strength (PCN) of selected Iraqi airports depending on ICAO (ACN / PCN) method.

2. Review of existing ACN and PCN methods

(a) Definitions of ACN and PCN

The bearing strength of pavement intended for aircraft with a mass greater than 5,700 kg shall be made available using the ACN-PCN method. ACN is defined as a number expressing the relative effect of an aircraft on a pavement for specified standard subgrade strength. PCN is defined as a number expressing the bearing strength of a pavement for unrestricted operations. Aircraft can operate in an airport unrestrictedly as long as the ACN value provided by the aircraft manufacturer is less than the PCN value of the airport.

The ACN-PCN method uses a code format to report the PCN. The PCN code shown in Table 1 includes: pavement type, subgrade category, allowable tire pressure, and method used to determine the PCN. There is no need to report the actual subgrade strength or the maximum tire pressure allowable. The subgrade strengths and tire pressures have been grouped into categories as indicated in Table2, and the subgrade strengths and tire pressures within the range of each category could be represented by the character of that category [ICAO, 2004].

Table (1) PCN Code Format

PCN Value	Pavement Type	Subgrade category	Allowable Tire Pressure	Method Used to Determine the PCN
A Number	R = Rigid F =Flexible	A = High B = Medium C = Low D = Ultra low	W = No limit X = To 1.5 MPa (217psi) Y = To 1.0 MPa (145psi) Z = To 0.5 MPa (73psi)	T = Technical U = Using Aircraft

Table (2) Subgrade Strength Categories

Subgrade category	Flexible Pavement		Rigid Pavement	
	Characterization	CBR range	Characterization	k-Value Range
A	CBR 15	Above 13	k = 150MN/m^3 (550 pci)	Above120MN/m^3 (442pci)
B	CBR 10	From 8 to 13	k = 80MN/m^3 (300 pci)	From 60 to 120 MN/m^3 (221 to 442pci)
C	CBR 6	From 4 to 8	k = 40MN/m^3 (150 pci)	From 25 to 60 MN/m^3 (92 to 221pci)
D	CBR 3	Below 4	k=20MN/m^3 (75pci)	Below 25 MN/m^3 (92pci)

Source [ICAO, 2004].

(b) Calculation Methods of ACN

There are a number of ways to calculate the ACN. A well known calculation method is stated in Aerodrome Design Manual Part 3. Depending on the taxiing condition of the aircraft, two masses are selected for the ACN calculation, i.e. maximum apron mass and a representative operating mass empty (OME). Both are static loads.

The ACN of an aircraft is numerically defined as two times the derived single wheel load (DSWL) expressed in 1,000 kg. The concept of a mathematically DSWL has been employed as a means to define the landing gear/pavement interaction without specifying pavement thickness. The DSWL is obtained by equating the thickness (reference thickness) given by the mathematical model for an aircraft landing gear to the thickness for a single wheel (DSWL) at a standard tire pressure of 1.25 MPa (181psi). For flexible pavements, the extended CBR design method for airfields is used to calculate the reference thickness, and the number of coverage is set at 10,000. For rigid pavements, the reference thickness is the thickness of the concrete slab which will give a maximum flexural working stress of 2.75 MPa (399 psi) by using Westergaard equation when loaded with one main gear at slab center. These calculations are derived using the program developed by Mr. R. G. Packard for rigid pavements, and by the S-77-1 method for flexible pavements [ICAO, 2004].

In addition to the method used in the Aerodrome Design Manual Part 3, the aircraft manufacturers also provide charts to obtain the ACN value solely by inputting the aircraft gross weight and subgrade category. [ICAO, 2004, CROW-report, 2004]

(c) The Calculation Methods of PCN

Table 2 illustrates two ways of obtaining the PCN, the U method and T method. Each method is described below.

1- U Method

The U method adopts the highest ACN value of the aircraft in the mixed traffic as the PCN value. Once the runway adopts this ACN value as the PCN and signs of distress operating are observed, the rating must be adjusted downward in order to 4 maintain normal airport operations. If one or more aircrafts have ACNs that exceed the lowered PCN, then the allowable gross weight for those aircrafts may need to be restricted [CROW-report, 2004].

2- T Method

The T method is based on the measurement of the response of pavement to load. Three different concepts of the T method, the ICAO method, the Boeing method, and the cumulative Damage method, in this research the ICAO method is described only.

ICAO Method [ICAO, 2004]

Theories applied to the elastic behavior of pavement indicated the proportionality between load and deflection, thus implying that deflection could indicate capacity of a pavement's capacity to support a load. The conceptual correlation between the deflection of a pavement under a wheel load and the number of repetitions of that wheel load which will result in severe deterioration of the pavement is shown in Figure 1. However, pavement bearing strength evaluations should address not merely an allowable load but a repetitions use level for that load. Normally, it is necessary to consider a mixture of loading at their respective repetitions use level. There is a strong tendency to rate pavement bearing strength in terms of some selected loading level or the allowable repetitions use level, and to rate each loading in terms of its equivalent

number of this basic loading. To do this, a relation between loading and repetitions to produce failure shown in Figure 2 should be established. Similar to Figure 1, Figure 2 is a conceptual diagram that shows the relationship between these two parameters. The linear line equations of Figures 1 and 2 should be derived based on each pavement's structural composition of the runway.

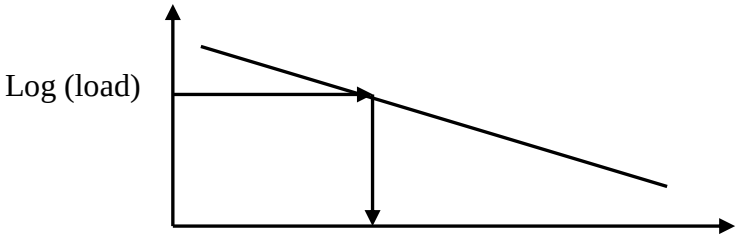

Figure (1) Relation between Deflection and Repetitions [ICAO, 2004]

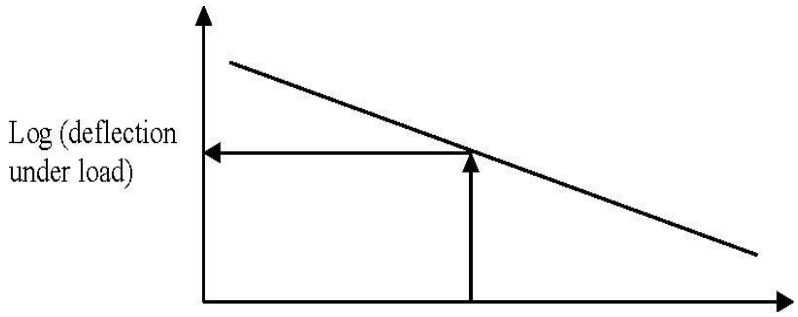

Figure (2) Relation between Load and Repetitions [ICAO, 2004]

After obtaining the above information, it is necessary to conduct deflection tests in airports to plot the relationship between the load and maximum deflection as illustrated in Figure 3. The evaluation procedure is as follows:

(1) Choose the critical aircraft and determine the equivalent repetitions of the critical aircraft from other aircraft types in the mixed traffic based on the relation given in Figure 2,

(2) Receive the deflection by inputting the cumulative equivalent repetitions to Figure1; and

(3) Input the deflection to Figure 3 to calculate the corresponding load, and then achieve the PCN value by following the ACN calculation process.

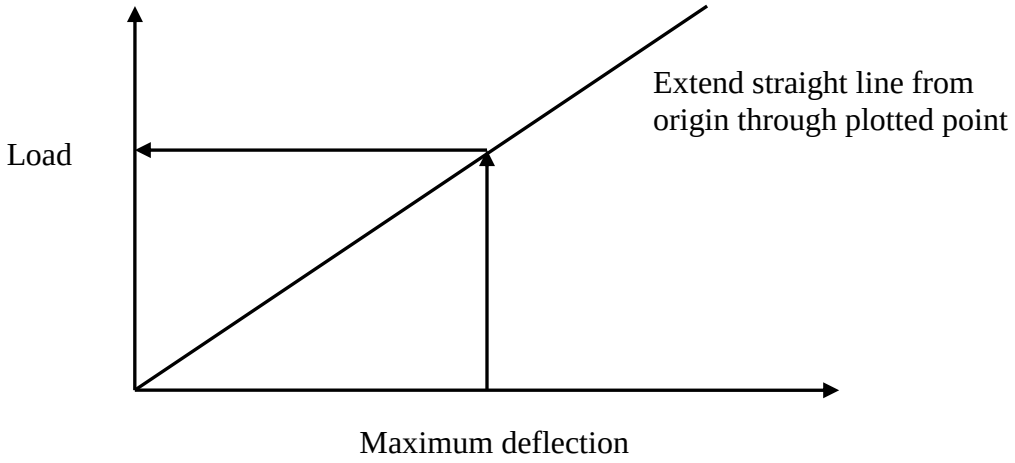

Figure (3) Relation between Load and Deflection [ICAO, 2004]

The relationships shown in Figures 1, 2 and 3 are required in order to acquire the pavement condition for each runway. In addition to laboratory tests, field tests are also necessary. Consequently, executing the process addressed by ICAO is time-consuming and labor intensive. Therefore, most airport authorities would rather adopt the U method though even the ICAO's T method has been available for years.

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(d) ACN / PCN ratio method for evaluation:

The ratio of a particular Aircraft ACN to a particular pavement PCN (ACN / PCN), is indicative of the load carrying ability of that particular pavement to accommodate that particular aircraft. For a given pavement life and a number of operations for a particular aircraft, there is a relationship between the ACN /PCN ratio and the percent of pavement life used up by the applied traffic for a given ACN / PCN ratio, a relationship exists for the number of operations that will produce failure of the pavement. This relationship provides a method for evaluating allowable load depending on acceptable degree of damage to the pavement or an allowable number of operations of a particular aircraft to cause failure of a pavement.

The system works by comparing the ACN to the PCN is a representation of the allowable load for a specified number of a pavement. The ACN is a representation of the load applied by an aircraft ACN (applied load) equal to or less than the PCN (allowable load) would comply with load restrictions established based on a specified design life for the pavement facility. If however, the ACN (applied load) is greater than the PCN (allowable load), the specified design life will be shortened due to this overloading. Pavement can usually support some overload; however, pavement life is reduced.

Theoretically, if the PCN is equal to the ACN, there may be situations when it is necessary to overload a pavement; i.e the ACN is greater than the PCN, pavements can usually support some overload; however, pavement life can be reduced. If the PCN were less than the ACN, The ACN / PCN ratio would be greater than 1 and the pavement would be expected to fail before reaching the end of the analysis period. As a general rule, ACN / PCN ratios of up to 1.25. If the ACN / PCN ratio is between 1.25 and 1.50. Aircraft operations resulting in an ACN / PCN ratio over

1.50 should not be allowed except for emergencies of how to use the ACN/ PCN method [FAA, 2008].

The Summary of Section (d) represented by this four limitations:

1. ACN / PCN < 1 , the pavement should perform satisfactorily and require only routine maintenance
2. 1< ACN / PCN $\leq$ 1.25 , the pavement have minimal impact on pavement life
.
3. 1.25 < ACN / PCN $\leq$ 1.5 , aircraft operations should be limited to 10 passes and the pavement inspected after each operation.

4. ACN / PCN > 1.5, should not be allowed except for emergencies.

Although the required increase in pavement strength is presented as an overlay thickness, several other approaches could be considered. A detailed analysis will be required to select and design the most cost-effective repair or improvement alternative.

The following minimum thicknesses are recommended in:
a. 51 mm (2-in.) - thick minimum AC overlay AC pavements.
b. 102 mm (4-in.) - thick minimum AC overlay over pavements.
c. 152 mm (6-in.) - thick minimum PCC partially or no bonded overlay.
d. 51 mm (2-in.) - thick minimum PCC fully bonded overlay over PCC pavement.

These minimum overly requirements are required to control the degree of cracking which will occur in the base pavement (existing pavement) due to the application of the design traffic. If those features needing structural improvements are not upgraded in a timely manner pavement may deteriorate rapidly and result in damage to all pavement layers and increase in cost for the necessary improvements. Excessive damage may also result in lengthy closures of the pavement facility [FAA, 2004].

3. Case Study

The case study of this research includes three airports and one airfield in Iraq as discussed in the following:

3.1 Pavement Classification Number (PCN) of selected IRAQI airports

1- Case study number 1:

Baghdad International Airport (civil and military usage): The pavement information of this case is illustrated in the following table:

Table (3) Pavement Classification No.of Baghdad International Airport

Pavement of	Bearing strength (N.V)	Pavement type	Subgrade category	Maximum Tire pressure	Pavement evaluation method	PCN
Old runway	48	Rigid	Low	No pressure limit	Technical	48/R/C/W/T
New runway	62	Rigid	Low	No pressure limit	Technical	62/R/C/W/T
Taxiway S5	85	Rigid	Low	No pressure limit	Technical	85/R/C/W/T
Taxiway S1	58	Rigid	Low	No pressure limit	Technical	58/R/C/W/T
Apron	66	Rigid	Low	No pressure limit	Technical	66/R/C/W/T

Source [ICAA, 2008]

2- Case study number 2:

Basrah International Airport (civil and military usage): The pavement information of this case is illustrated in the following table:

Table (4) Pavement Classification No. of Basrah International Airport

Pavement of	Bearing strength (N.V)	Pavement type	Subgrade category	Maximum Tire pressure	Pavement evaluation method	PCN
Runway	72	Rigid	Low	No pressure limit	Technical	72/R/C/W/T
Taxiway	72	Rigid	Low	No pressure limit	Technical	72/R/C/W/T
Apron	74	Rigid	Low	No pressure limit	Technical	74/R/C/W/T

Source [ICAA, 2008]

3- Case study number 3:

Salaymaniyh International Airport (civil usage): The pavement information of this case is illustrated in the following table:

Table (5) Pavement Classification No.of Salaymaniyh International Airport

Pavement of	Bearing strength (N.V)	Pavement type	Subgrade category	Maximum Tire pressure	Pavement evaluation method	PCN
Runway	85	Rigid	Low	No pressure limit	Technical	85/R/C/W/T
Taxiway	85	Rigid	Low	No pressure limit	Technical	85/R/C/W/T
Apron	85	Rigid	Low	No pressure limit	Technical	85/R/C/W/T

Source [ICAA , 2008]

4- Case study number 4:

Balad southeast airfield (military usage): The pavement information of this case is illustrated in the following table:

Table (6) Pavement Classification No. of Balad southeast airfield.

Pavement of	Bearing strength (N.V)	Pavement type	Subgrade category	Maximum Tire pressure	Pavement evaluation method	PCN
Primary runway	45	Rigid	Medium	No pressure limit	Technical	45/R/B/W/T
Secondary runway	48	Flexible	Medium	No pressure limit	Technical	48/F/B/W/T
Taxiway D	50	Rigid	Medium	No pressure limit	Technical	50/F/B/W/T
Taxiway E	66	Rigid	Medium	No pressure limit	Technical	66/R/B/W/T

Source [ICAA, 2008]

Note:-

Where the pavement part is R (Rigid pavement) with subgrade level [C] of [Baghdad, Basrah, and Salaymaniyh airport], that need ACN (numerical value) on rigid pavement with subgrade level [C]. But the pavement part R (Rigid pavement) with subgrade level [B] of [primary runway of Balad southeast airfield] and for [secondary runway] the pavement part is F with subgrade level [B], that need ACN (N.V) on rigid and flexible pavement with subgrade level [B].

3.2 Aircraft Classification Number (ACN)

The Aircraft Classification Number (ACN) of selected civil and military aircrafts. of selected civil and military aircrafts.

1- Civil Aircrafts:

Table (7) Civil Aircraft Classification Number.

Aircraft type		Operating Wight (Ib)	Tire Pressure (psi)	ACN
Small body	B 727-200 B 727-300 A 319-100	185000 130000 150000	148 201 173	55 RC 41 RC
Medium body	B 767-300 ER DC-8-63	370000 330000	200 194	61 RC 61 RC
Large Body	MD-11 A 300-600 R B 747-400 B 777-200 B 777-200 LR	550000 378000 800000 600000 768000	206 196 200 215 218	71 RC 76 RC 67 RC 76 RC 91 RC

Source [ICAO, 2004]

2-Military aircrafts:

Table (8) Military aircraft Classification Number.

Aircraft type	Gross Wight (Ib)	RC	ACN / RB	FB
C-141	325000	59	50	50
C-130	155000	32	30	28
C-17	580000	45	42	40
C-SA	769000	40	31	36
KC-135	301600	46	38	40

Source [ICAO, 2004]

To calculate the ACN / PCN ratio that need to select the higher ACN (critical ACN) from the above tables.

a- For airport civil and military using, the higher ACN is of aircraft model 777-200 LR equal t0 91 RC.

b- For airports civil using, the higher ACN is of aircraft model 777-200 LR equal to 91 RC

c- For airports military using, the higher ACN is of aircraft model C-141 equal to [59 RC, 50 RB, 50 FB].

3.3 Calculation of ACN / PCN ratio

1- Baghdad international airport:

Table (9) Baghdad international airport (ACN/PCN) ratio.

Pavement of:	Dimension	PCN	ACN	ACN/PCN	Limit
The old runway	3301m*45m	48/R/C/W/T	91/R/C	1.9	4
The new runway	4000m*60m	62/R/C/W/T	91/R/C	1.46	3
Taxiway S5	Width 32m	85/R/C/W/T	91/R/C	1.07	2-1
Taxiway S1	Width 30m	58/R/C/W/T	91/R/C	1.56	4
Apron	Delta ramp	66/R/C/W/T	91/R/C	1.37	3

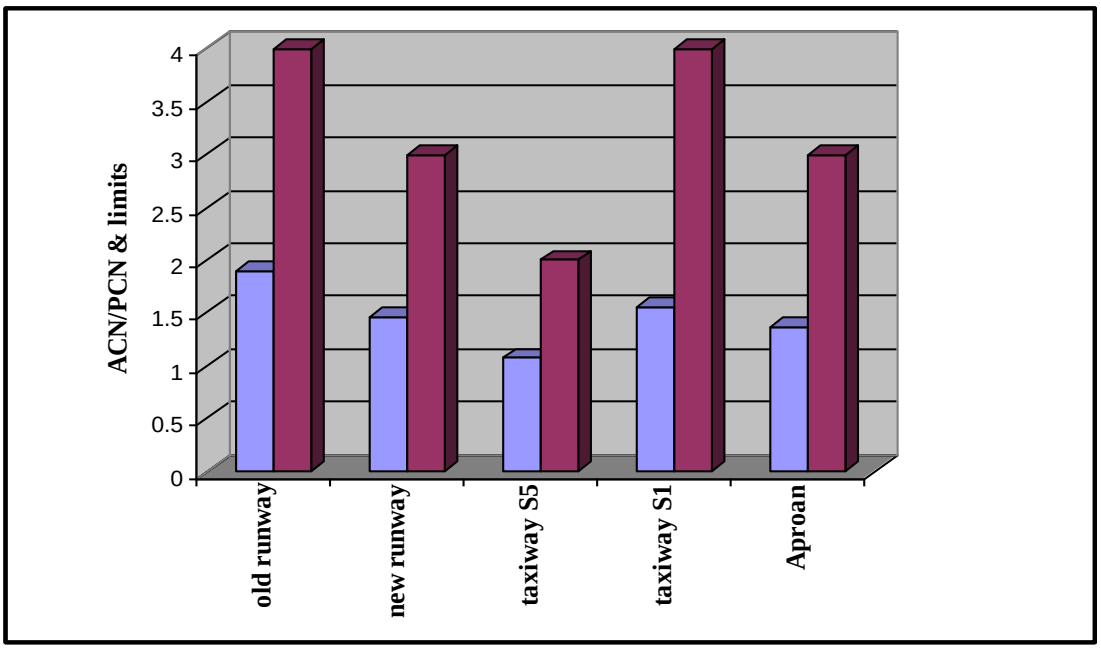

Figure (4) Baghdad international airport (ACN/PCN) ratio& limits

2- Basrah International airport:

Table (10) Basrah International airport(ACN/PCN) ratio.

Pavement of:	Dimension	PCN	ACN	ACN/PCN	Limit
The runway	4000 m*45m	72/R/C/W/T	91/R/C	1.26	3
Taxiway	-	72/R/C/W/T	91/R/C	1.26	3
Apron	-	74/R/C/W/T	91/R/C	1.23	2

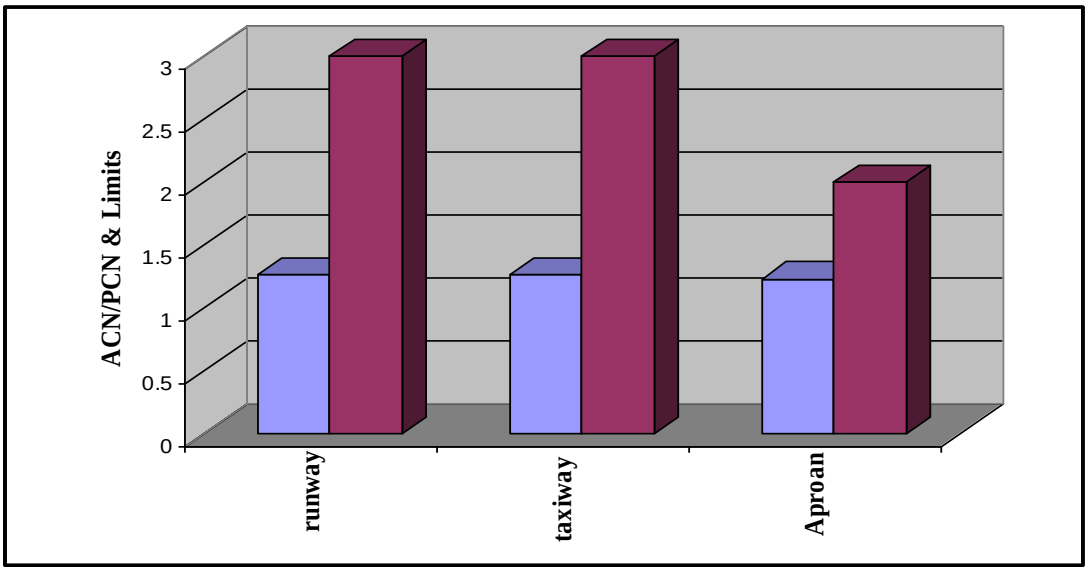

Figure (5) Basrah international airport (ACN/PCN) ratio& limits

3- Salaymaniyh International airport:

Table (11) Salaymaniyh International airport (ACN/PCN) ratio.

Pavement of:	Dimension	PCN	ACN	ACN/PCN	Limit
The runway	3500 m*45m	85/R/C/W/T	91/R/C	1.07	2-1
The Taxiway	3500m*30m	85/R/C/W/T	91/R/C	1.07	2-1
Apron	-	85/R/C/W/T	91/R/C	1.07	2-1

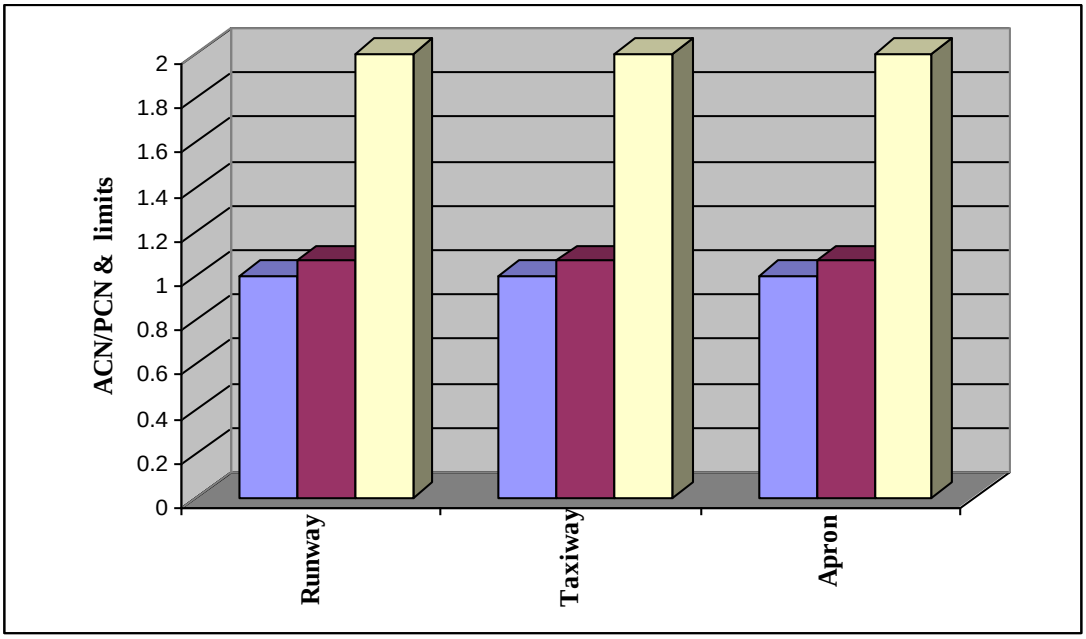

Figure (6) Salaymaniyh international airport (ACN/PCN) ratio& limits

4- Balad southeast airfield :

Table (12) Balad southeast airfield (ACN/PCN) ratio.

Pavement of:	Dimension	PCN	ACN	ACN/PCN	Limit
The primary runway	3502 m*60m	45/R/B/W/T	50/R/B	1.1	2
The secondary runway	3493m*45.5m	48/F/B/W/T	50/F/B	1.04	2-1
Taxiway D	-	50/F/B/W/T	50/F/B	1.0	1
Taxiway E	-	66/R/B/W/T	50/R/B	0.75	1

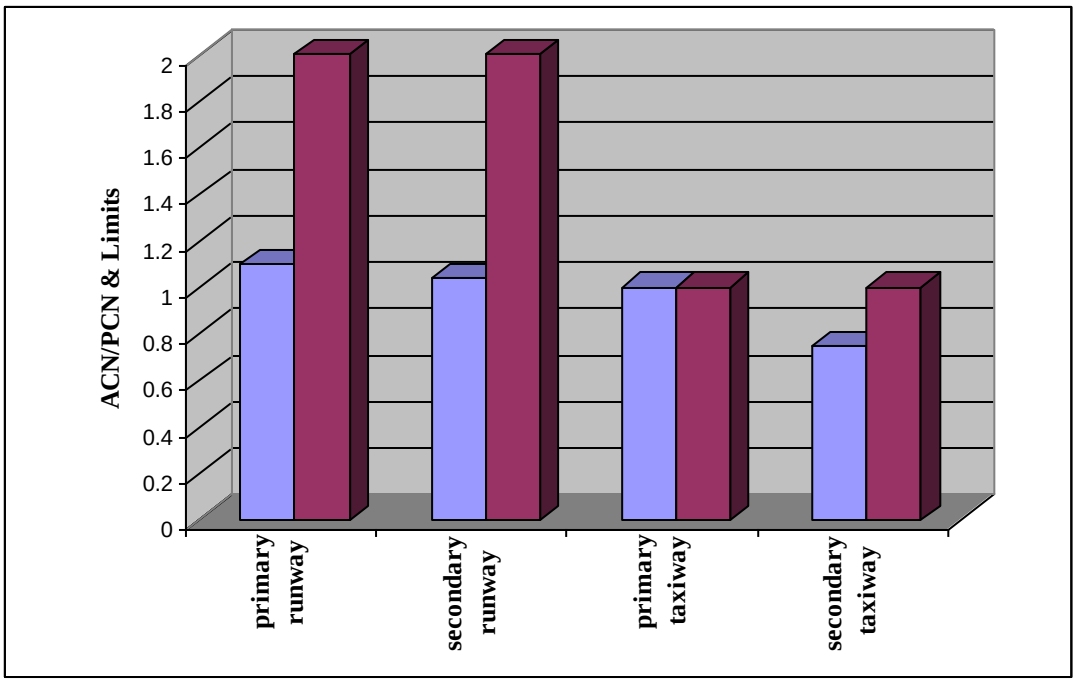

Figure (7) Balad southeast airfield (ACN/PCN) ratio& limits

4. Conclusions and Recommendations

1- Baghdad International Airport.

From the study case depending on ICAO (ACN / PCN) evaluation method the PCN (pavement strength) number of

A. The old runway is not adequate to accommodate every type of aircraft except the small body aircraft [B 737-300 , A 319-100]: because the ACN / PCN ratio of the critical airplane model B 777-200 LR equal to 1.9 which is more than 1 , therefore this runway should be reconstructed to increase the pavement strength (PCN).

B. The new runway is adequate to accommodate small and medium aircraft only,

because the ACN / PCN ratio of the critical airplane model B 777-200 LR equal to 1.4 ; therefore this runway need an overlay design to increase the pavement strength (PCN).

C. The Taxiway S5 is adequate to accommodate every type of Aircraft because the ACN / PCN ratio of the critical airplane model B 777-200 LR equal to 1.07, but need a thin overlay.

D. The taxiway S1 is not adequate to accommodate every type of aircraft because the ACN / PCN ratio equal to 1.56; therefore this taxiway should be reconstructed.

2- Basrah International Airport

The runway and apron pavement is not adequate to accommodate the large body aircraft because the ACN/PCN ration equal to (1.26), therefore the runway needs an overlay.

3- Sulaymaniya International Airport

The runway, taxiway and apron pavement can adequate all types of aircrafts because the ACN/PCN ration equal to (1.07).

4- Balad Southeast Airfield

A- The primary runway need and overlay design to accommodate the military critical airplane C-141.

B- The secondary runway can accommodate all types of military aircrafts because the ACN/PCN ration equal to (1.04).

C- Taxiway D and E can accommodate all types of military aircrafts.

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