INTRODUTION OF AIRPORT PAVEMENT EVALUATION METHOLOGY & MANAGEMENT SYSTEM OF KOREA AIRPORTS CORPORATION

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INTRODUCTION

Korea Airports Corporation (hereafter called as KAC) constructs, manages and operates 14 Airports in South Korea. 13 runways out of 21 in these 14 airports have been operated over 10years. The runway maintenance and rehabilitation cost has been drastically raised by continuously increasing defects owing to the larger aircraft, air traffic increasing and ageing. In order to secure aircraft safe during maneuvering the runway, taxiway and apron, we periodically execute the airport pavement evaluation projects every 5year. Based on the result of evaluation, we make the overall plan for the maintenance and management schedule from engineering judgments which are considered by analyzing aircraft allowable load, pavement condition, roughness, plastic deformation and so on.

Korea Airports Pavement Management System (hereafter called as KAPMS) was jointly developed by KAC and Korea Institute of Construction Technology (hereafter called as KICT) in 2002. We also established the airport pavement evaluation manual and introduced the both non-destructive bearing capacity test equipment (hereafter called as HWD) and pavement condition survey equipment. We have been promoting the R&D projects to improve the airport pavement evaluation methodology and doing solely the evaluation projects in every year.

In this paper, the main function of KAPMS will be introduced to calculate the PCI and PCN. For instance, it will be explained the process of airport pavement evaluation work of JEJU International Airport's runway and will show the results of specified section's evaluation work.

MAIN FUNCTIONS OF KAPMS

KAPMS is able to manage the airport pavement's (Runway, Taxiway, Apron) general information such as thickness, elastic modulus, and compressive strength in 14 airports. It also can graphically show the statistical air traffic data, annual maintenance work history, aircraft 's allowable load, pavement condition changing and annual budget strategy. The table 1 presents the main functions and applications of the KAPMS.

Table 1.
Main Functions of KAPMS

Main Function	Application	Contents
General Information	Facility Information	Runway, Taxiway, Apron
	General Information	Structural information
	Structure and Drawing of homogeneity Section	Homogeneity section of facilities
Analysis Information	Drawings of sample section	Drawings of Sample Section & Pavement Condition
	Structural Bearing Capacity	Current state of the structural bearing capacity
	Runway Roughness	Runway Longitudinal Evenness
	Runway Surface Friction	Current State of Runway Surface Friction
	Prediction of PCI	Predict the airport pavement condition by the maintenance cost and plan
	Analysis of Budget Strategy	Analysis the annual budget strategy

	Decision of funding	Decide the alternative funding strategy
Allowable Load	Select the detailed inspection section	Select the detailed inspection section
	Prioritize the maintenance work	Prioritize the maintenance work by budget analysis
	Economical Life	Calculate the Economical Life for every homogeneity section
	Allowable Load	Calculate the allowable load
Report	AIP Information	Show the published AIP Information
	Evaluation Report	Show the evaluation Reports
	Grooving Information	Current State of Runway Grooving
	Maintenance Method and Cost	Search the maintenance method and cost

DIVIDING THE HOMOGENITY & SAMPLE SECTION

Airport pavements are preferentially divided by the homogeneity section, which shows the same characterization area, air traffic volume. The considerations of dividing is shown below:

- Functional classification (Runway, Taxiway, Apron)

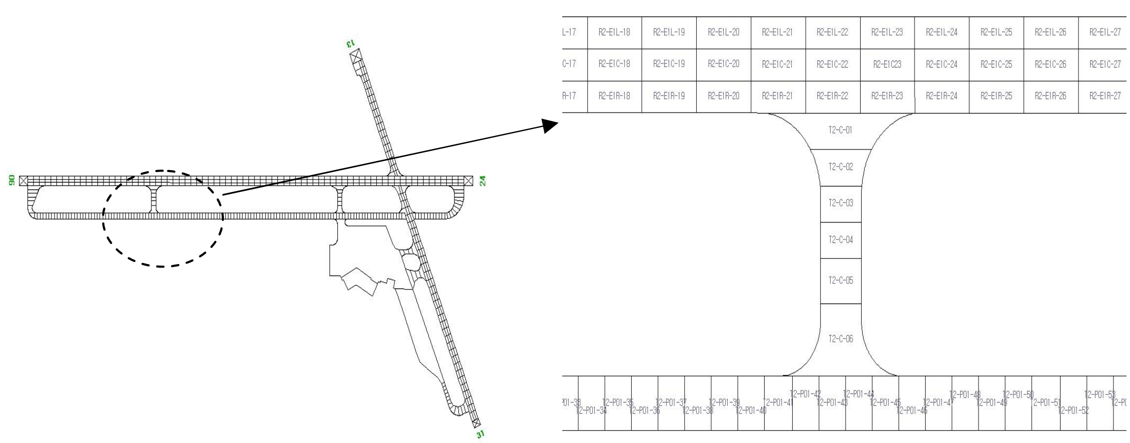
- Type of pavements (HMA, PCC, COM)

- Pavement structural information and construction history

- Aircraft traffic characterization

Figure 1 illustrates the homogeneity and sample section of JEJU international airport runway. A sample size is about 465±186 m^2, 20±8 slab for asphalt and concrete pavement respectively. [2]

Figure 1.
JEJU INT'L Airport Sections



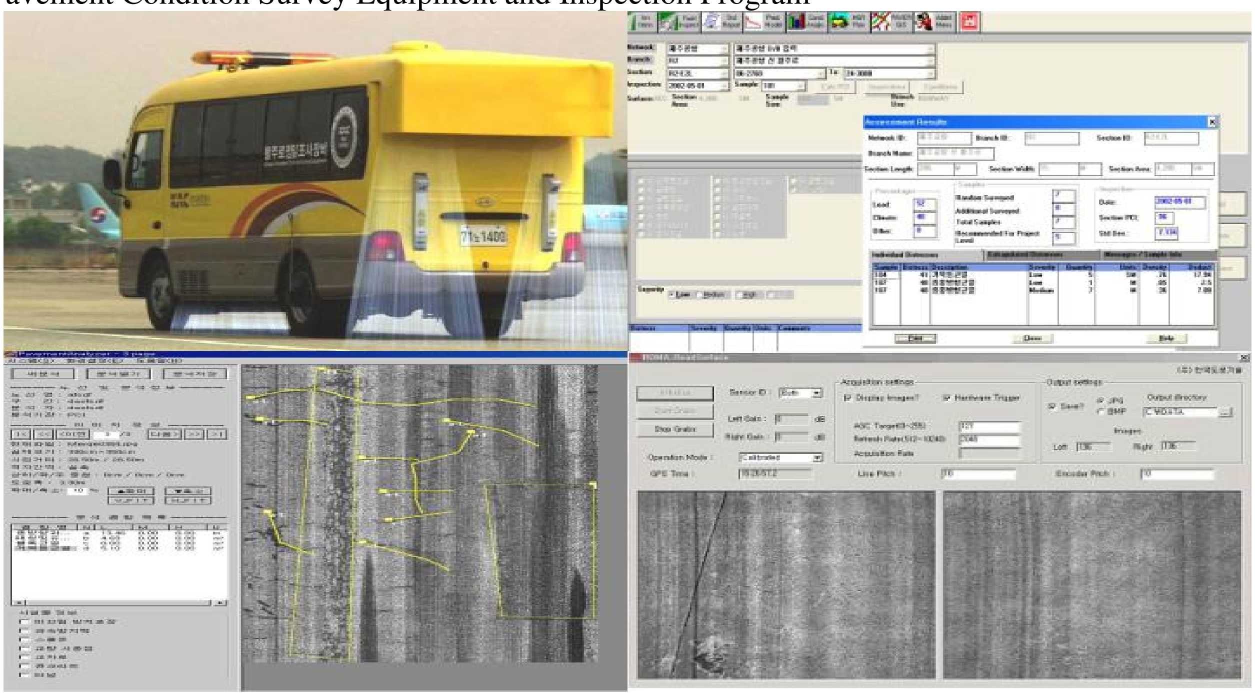
INSPECTION & EVALUATION OF PAVEMENT CONDITION

KAC introduced the non-destructive test equipment (HWD) to survey the structural bearing capacity and the pavement condition survey equipment (hereafter called as PASE) in 2008 year. In field survey, we are searching the pavement's surface defects, roughness and plastic deformation by PASE. Furthermore HWD simulates nondestructively the aircraft's load to get the elastic modulus of pavement by back-calculation

A. Pavement Surface Defects

Pavement condition index (hereafter called as PCI) is derived from the severity of pavement defects, type of faults and weighted factors (Deduct Value)[5]. The figure 2 illustrates pavement surface defects inspection and analysis program of PASE are following

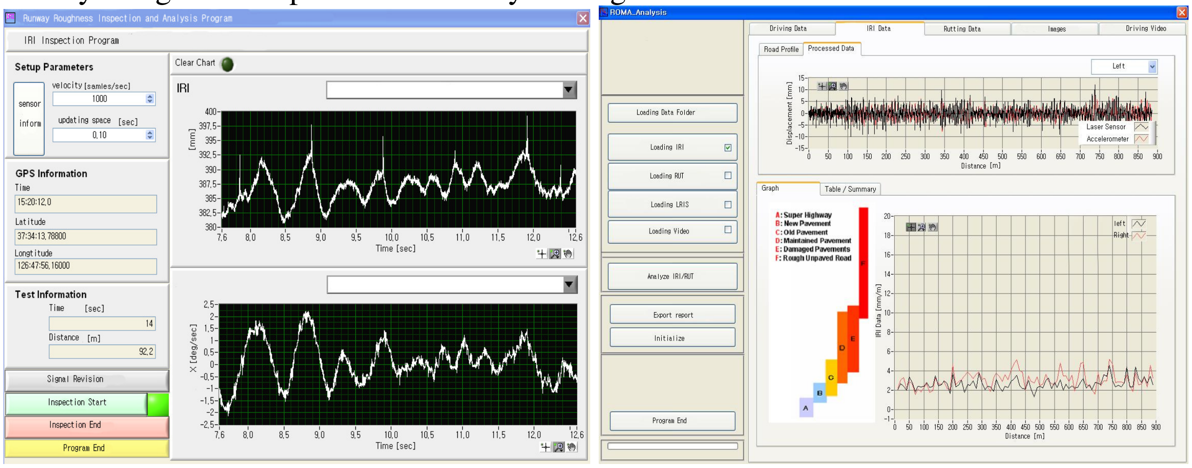
Figure 2.
Pavement Condition Survey Equipment and Inspection Program



B. Runway Roughness

We were judged the runway's longitudinal evenness by International Roughness Index (hereafter called as IRI), which originally used to know the car's comfortable riding quality on roadway. However, International Civil Aviation Organization (hereafter called as ICAO) has been established the new standard [4] to evaluate the runway roughness. In accordance with the new ICAO Annex14, KAC are trying to phase the new method of runway roughness in doing the airport pavement evaluation. In this year, we will improve and develop the data process program to accord with the new standard. The figure 3 presents the KAC's runway roughness inspection and analysis program.

Figure 3.
Runway Roughness Inspection and Analysis Program



C. Plastic Deformation (Rutting)

To grasp the pavement transverse deformation, we apply the inspection results for estimating the PCI. Rutting analysis program and severity standard will be shown in figure 4 and table 2

Figure 4.
Runway Roughness Inspection and Analysis Program

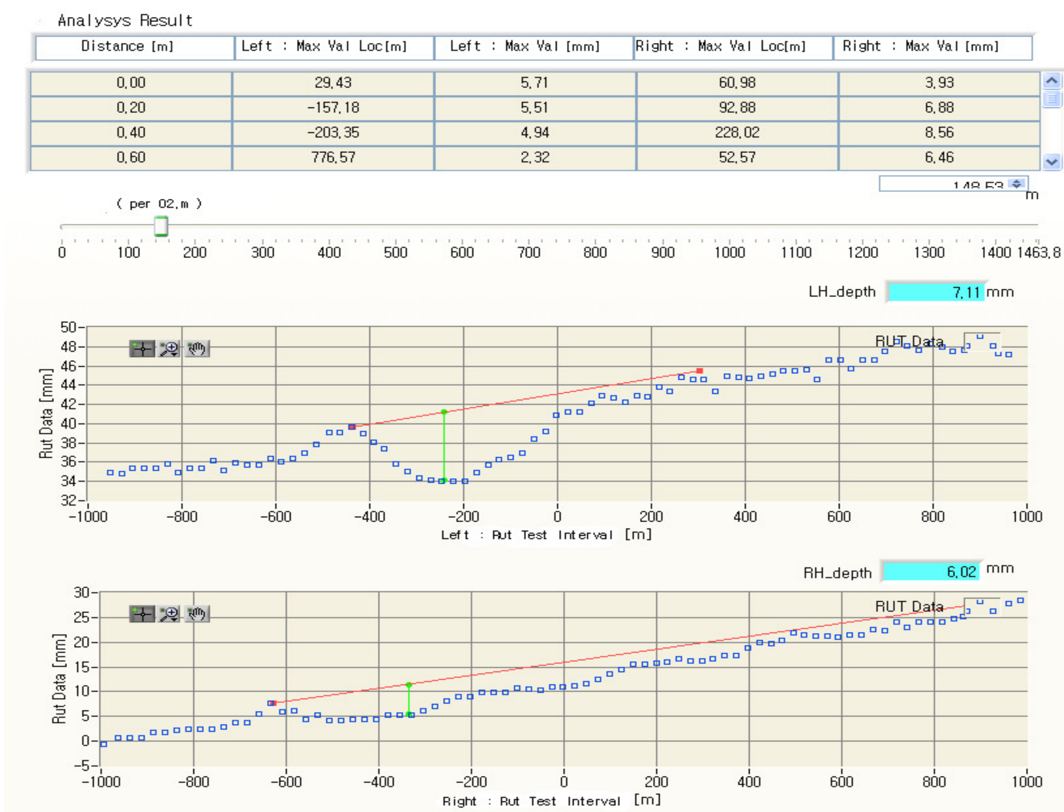


Table 2.
Severity of Rutting [5]

	Severity	Condition
Rutting	Low	Rutting Depth : 0.64cm ~ 1.27cm
	Medium	Rutting Depth : 1.27cm ~ 2.54cm
	High	Rutting Depth : Above 2.54cm

As mentioned above, we survey the pavement surface defects such as cracks, rutting and roughness to compute the specified sections PCI.

ECONOMICAL LIFE AND ALLOWABLE LOAD

A. Non Destructive Test and Back-Calculation

In order to assess the structural bearing capacity of airport pavement, the HWD stresses the critical aircraft load on the specified surface to get the deflections of pavement. These data are used to know the load transfer efficiency (hereafter called as LTE), void existence and to calculate the elastic modulus by back-calculation. The deflection data of pavement are read from the 15seismometer sensors in HWD such as figure 5

Figure 5.
Non-Destructive Test Equipment - Heavy Weight Deflectometer (HWD)

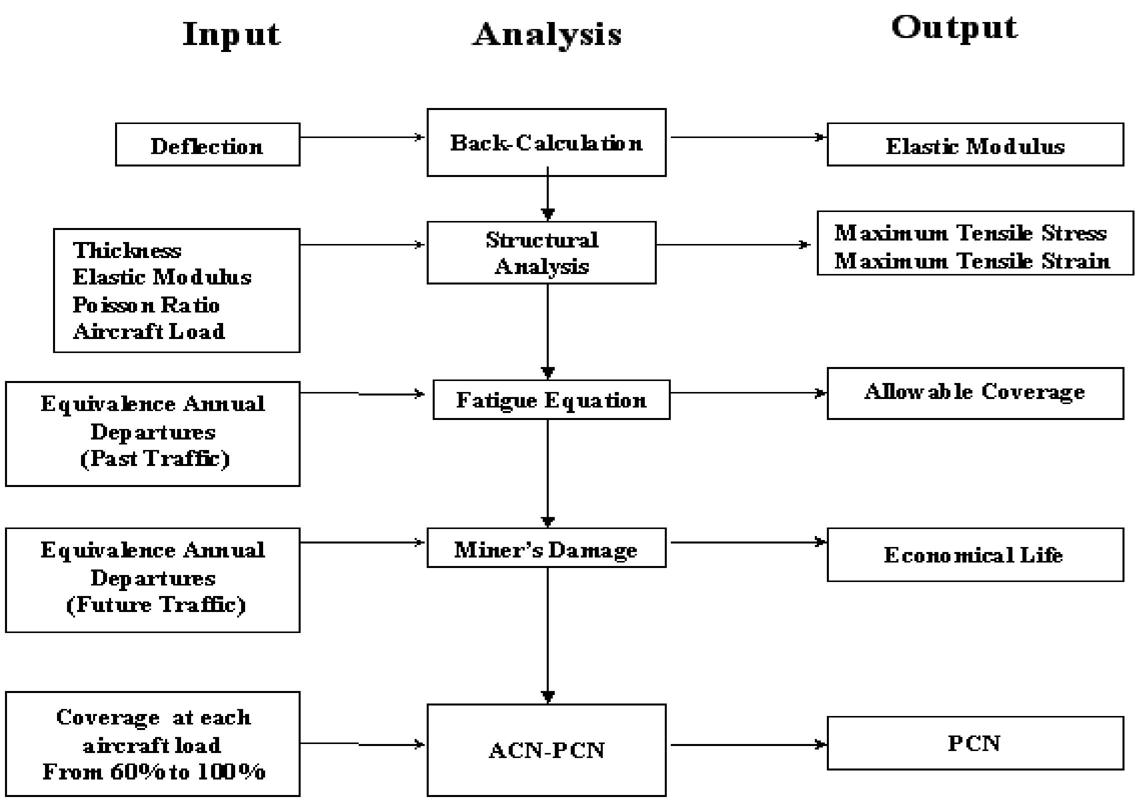
The test location of HWD is spacing each 50m along the runway center, 100m on runway right and left side. In case of concrete slab, every 5th slab for structural bearing capacity will be tested it.[2]

The above 20% slab among overall slabs will be stressed for LTE and void detection. The compressive strength test and material characteristic test will be selectively done to get the pavement physical information.

B. Structural Analysis and Allowable load

The structural analysis of pavement derives the maximum tensile stress of rigid pavement and the maximum tensile strain of flexible pavement. In KAPMS, it can carry this structural analysis with the sort of specified homogeneity sections and type of aircrafts. This result will be used to decide the aircraft allowable load & PCN. In figure 6 you can see the principal process of estimating the allowable coverage.

Figure 6.
Principal process of estimating the allowable coverage and PCN



In figure 6, the fatigue equation is applied to calculate the allowable coverage. The maximum allowable coverage will be derived from multiplying the pass to coverage (hereafter called as P/C Ratio). This maximum allowable coverage is divided by annual equivalence departures of past traffic to know the past damage and the economical life of pavement

- **Rigid Pavement**

$$\mathrm{Log(COV)} = 2.13 \times \left[\frac{M_R}{\mathrm{Stress}}\right] \quad \text{(Eq 1) [8]}$$

Where,

COV = Allowable coverage of the objected aircraft

M_R = Flexural strength of concrete pavement

Stress = Maximum tensile stress by aircraft load

- **Flexible Pavement**

$$\mathrm{Log(COV)} = -\left[5.0\ \mathrm{Log}\ H_{str} + 2.665\ \mathrm{Log}\left(\frac{E_{ac}}{14.22}\right) + 0.392\right] \quad \text{(Eq 2) [8]}$$

Where,

COV = Allowable coverage of the objected aircraft

H_{str} = Maximum horizontal tensile strain

E_{ac} = Seasonally Modified elastic modulus by season (spring, summer)

In order to evaluate the past damage of pavement, the Miner's theory is applied to calculate the past damage and economical life.

$$Miner's\ Damage = \sum \frac{n_i}{N_i} \quad \text{(Eq 3)}$$

$$R_L = X \times \left(\frac{n_1}{N_1} + \frac{n_2}{N_2} + \frac{n_3}{N_3} + \cdots\right) \quad \text{(Eq 4)}$$

Where,

R_L : Past Damage (1-Past Damage)

X : Usefulness years of Pavement (Economical Life)

n_i : i Aircraft past traffic number (Number/Year)

N_i : i Allowable coverage of objected aircraft operation

$$PCN = ACN(Max) - \frac{Max\,load - Load(\%)}{Max\,load - Min\,load} \times \{ACN(Max) - ACN(Min)\}$$ (Eq 5) [8]

Where,

Max load : maximum weight of objected Aircraft (lbs)

Min load : maximum weight of objected Aircraft (lbs)

Load(%) : allowable load(lbs)

ACN(Max) : ACN at maximum weight of objected Aircraft

ACN(Min) : ACN at minimum weight of objected Aircraft

EXAMPLE OF JEJU INTERNATIONAL AIRPORT PCI &PCN CACULATION

A. OVERVIEW

a) Airport Pavement Evaluation Period

- Field Inspection: 2009. 5. 6 ~ 5.16
- Data Analysis and Evaluation: 2009. 5.18 ~ 2009. 7.20

b) Evaluation Contents

- Pavement Surface Defects, Roughness, Rutting, PCI
- Back-calculation, Economical Life, allowable coverage, PCN

c) Subject Facilities

Table 3.
JEJU International Airport Pavement Specification

Classification (Direction)	Size
Primary Runway(06↔ 24)	3,090m×45m
Secondary Runway (13↔ 31)	2,000m×45m
Parallel Taxiway	2,000m×30m
Vertical Taxiway	200 m×30m
Apron	257,290 ㎡

B. EVLUATION OF R2-E2L SECTION

a) Functional Evaluation

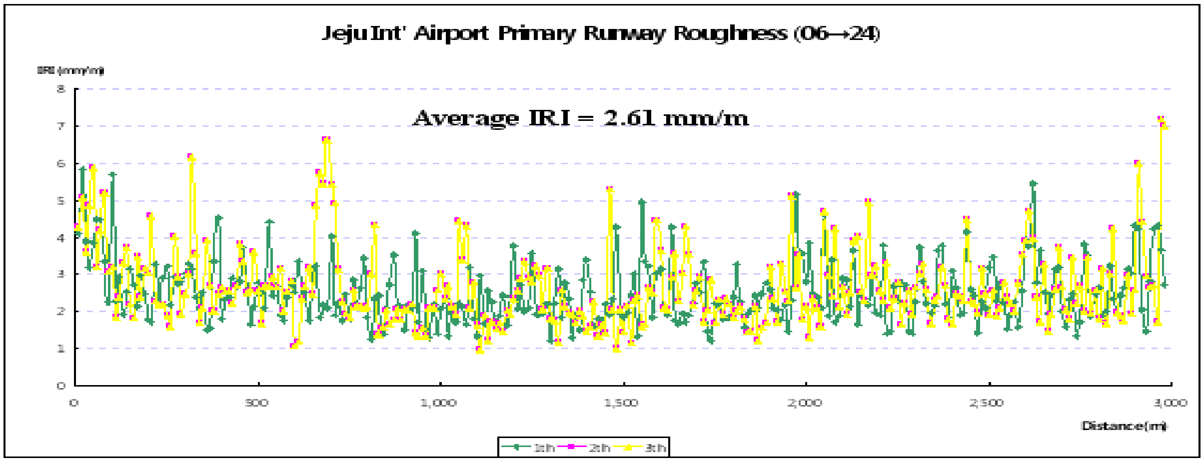
Although the R2-E2L section has the some linear cracks and alligator crack, the severity of defects is low. Likewise the overall runway longitudinal evenness (IRI) has well condition as 2.61mm/m.

Table 4.
R2-E2L Section Pavement Surface Defects & PCI

Classification	Linear Crack (m)			Alligator Crack (m^2)	Rutting (m^2)	Roughness (IRI)
Severity	Low	Medium	High	Low	Low	
Quantity	0.94	7.02	-	4.5	40	2.61mm/m Overall runway
Density	0.1	0.1	-	0.11	0.95	
Deduct Value	2.5	4.0	-	7.01	15.12	
PCI	86 (Good Condition)					

Figure 7.
Surface Defects of R2-E2L Section (Linear Cracks & Rutting)

Figure 7.
Runway Roughness (IRI)



B) Structural Evaluation

1) Physical Characterization of R2-M1C

Table 5.
Pavement Characterization of R2-M1C Section

Classification (Direction)	Section Size	Pavement Physical Characterization				
		Thickness (inch)		Elastic Modulus (psi)		Poisson Ratio
				Spring	Summer	
Primary Runway (06↔ 24) R2-M1C	650m×15m	Surface	8.1	556,138	292,704	0.35
		Base	9.6	30,000		0.35
		Subbase	22.8	15,000		0.40

2) Aircraft Specification

Table 6.
Objected Aircraft Specification

Aircraft Type	Gear Type	Maximum Take-Off Weight (lb)	Weight on Main Gear (lb)	85% of maximum weight (lb)	Wheel Load (lb)	Tire Pressure (lb/in^2)
A330-300	Dual Tandem	509,047	487,362	414,257	51,782	206
B737-400	Dual	138,500	129,941	110,450	27,612	185
B747-400	Double Dual Tandem	877,000	818,416	695,654	43,478	200

A. Maximum tensile strain and allowable coverage (COV) of R2-M1C

Table 7.
Maximum tensile strain and coverage

Aircraft Type	@ 85% of Maximum Take-Off Weight						
	Maximum Tensile Strain (10^{-6})		Allowable Coverage (COV) [a]		P/C Ratio	Maximum Allowable Coverage (Max COV) [b]	
	Spring	Summer	Spring	Summer		Spring	Summer
A330-300	181	271	751,559	99,887	1.87	1,405,416	186,789
B737-400	105	158	2,545,245	309,796	3.53	8,984,714	1,093,581
B747-400	160	238	1,482,759	191,173	1.74	2,580,001	332,675

[a] By Eq 2, [b] Max COV = COV × P/C

B. Past Damage and Economical Life of R2-M1C

Table 8.
Past Damage

Section	Max COV (Ni)			Past Traffic Number (ni)			Past Damage
	A330	B737	B747	A330	B737	B747	1- (ni / Ni) [a]
R2-M1C	186,789	1,093,581	332,675	59,858	279,691	186,789	0.791

[a] By Eq 3

Table 9.
Economical Life

Section	Prediction of Future Traffic Number for 5years						Economical Life [a] (Years)
	A330		B737		B747		
	Present	Future	Present	Future	Present	Future	
R2-M1C	6,269	31,345	151,648	758,240	13,091	65,455	41

[a] By Eq 4

C. Determination of PCN

Between 60% and 100% of the critical aircraft load are applied to estimate the maximum tensile stress and strain that are applied to get the allowable coverage by Eq 2. From the results, the graph is drawn to calculate the allowable load that means the ability of pavement. To sum up these process below,

Step 1) Change the load of critical aircraft between 60% and 100%.

Step 2) Put Pavement's physical characteristic information such as thickness, LTE, subgrade bearing capacity (K value) in the structural analysis program to derive the maximum tensile strain (stress for rigid pavement).

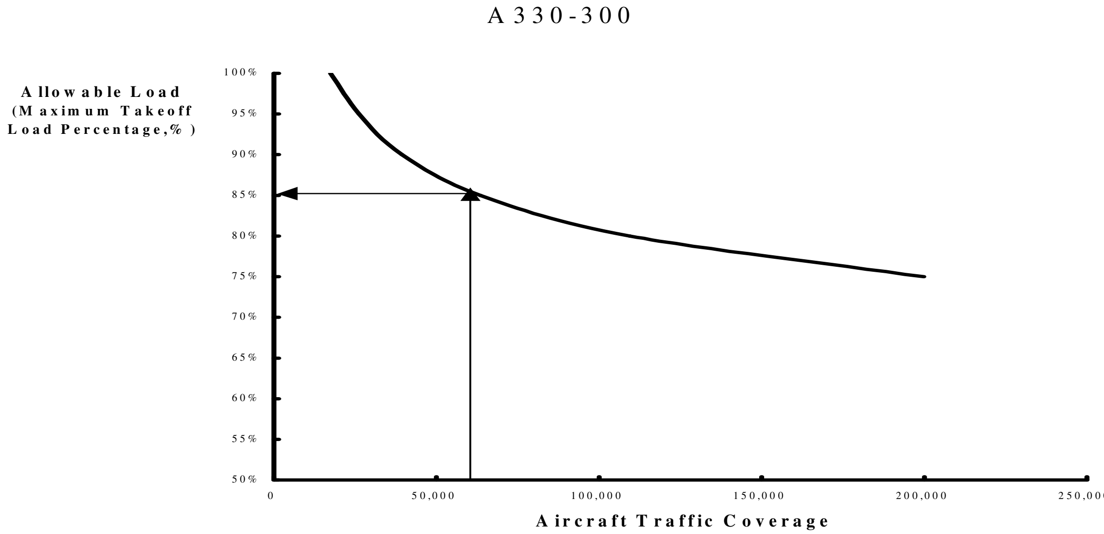
Step3) Calculate the maximum allowable coverage by the fatigue equation. (Eq 2)

Step 4) Calculate the past damage and economical life. (Eq 3&4)

Step 5) step 1 ~ step 4 will be iterated to estimate the remaining allowable coverage by aircraft load change between 60% and 100%.

Step 6) Draw the graph of the allowable load versus allowable aircraft coverage.

Figure 9.
Example of Allowable Load versus Coverage



<Example>

If we need to limit the load of A300 as 85%, how to decide the its PCN?

- Subgrade Strength: K = 250 pci
- Maximum Load: 363,800 lbs (ACN = 64)
- Minimum Load: 192,000 lbs (ACN = 64)
- 85% of A300's Weight: 309,200 lbs

$$PCN = 64 - (363{,}800-309{,}200)/(363{,}800-192{,}000) \times (64-24) \fallingdotseq 51$$

If there is no needs to limit the aircraft load that means aircraft can be operated without any load limitation, we decide the PCN by the ACN-PCN chart. For instance, the JEJU runway does not need to limit the load of all aircraft. The JEJU runway PCN is eventually decided by ACN-PCN Chart as below figure10.

Table 10.
Subgrade Strength by CBR test

Test pit	Specimen No	Interior CBR Test (%)	Grade	Applied Subgrade Grade for PCN [a]
Primary Runway of JEJU Int' Airport	1	9.5	B	B
	2	19.7	A	
	3	12.2	B	

[a] Standardized Method of Reporting Airport Pavement PCN, FAA AC150/5335-5A

- Determination of PCN

As above steps, The R2-M1C section has the 41years of economical life and PCN for A330-300 is 68/F/B/X/T with no-limitation of aircraft load. The other aircraft's PCN will be shown in table 11.

Figure 10.
Example of deciding the PCN of A330-300 at 85% load

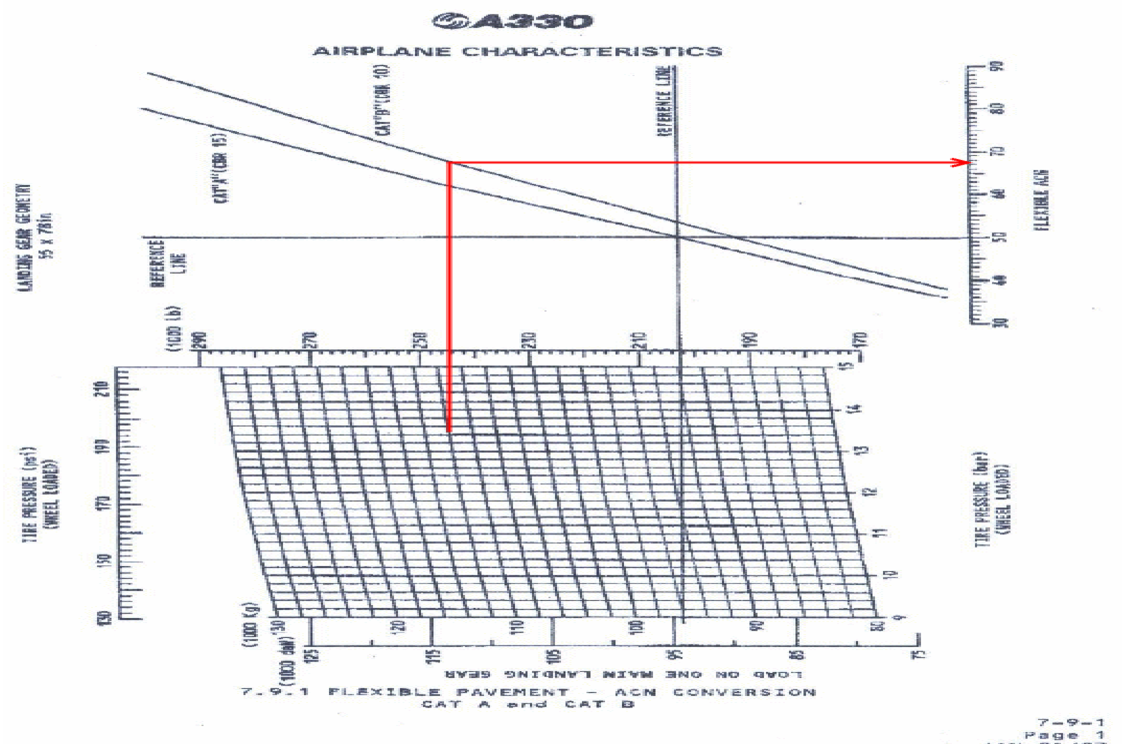


Table 11.
PCN of R2-M1C Section

Classification		B737-400		A330-300		B747-400	
JEJU INT' Airport Primary Runway	Section	PCN	Load Limit	PCN	Load Limit	PCN	Load Limit
	R2-M1C	39/F/B/XT	+ [a]	68/F/B/X/T	+	64/F/B/X/T	+

[a] Do not need to limit the aircraft operation load

CONCLUSION

A. Airport pavement evaluation in accordance with the KAPMS

There were lots of difficulties to do airport pavement evaluation work with very few specialists and test equipments in Korea until 2002. In order to solve these problems, KAC developed the KAPMS in 2002 and introduced the inspection equipments (PASE and HWD) to execute the evaluation projects. With these efforts, we solely have the ability of the airport pavement evaluation work and to promote the R&D project. Moreover, KAC is continuously trying to advance the consulting project of airport construction and operation work in overseas.

B. Developing & Improving plan of KAPMS

KAPMS has not adopted the past 7 years changed data such as new airport and extended facilities information. To improve the KAPMS, we are planning to update this data, system application and upgrade sub analysis program such as Micro-PAVER, IllI-SLAB, BISAR. These efforts will enhance the accessibility, usefulness and reliability of KAPMS. Moreover, we will develop and modify the current PASE’s Program in 2010, so as to satisfy with the runway roughness standard by ICAO.

C. Promote the R&D project

For reducing the maintenance budget and extending the life of airport pavement, KAC will continuously carry out the several R&D projects to improve the evaluation method and develop the new maintenance method for airport pavement.

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