Some Issues on Surface Distress of Airport Pavements in Japan

Yoshitaka HACHIYA, Takashi WATANABE and Kentaro KITAOCHI
Service Center of Port Engineering (SCOPE), 3-3-1, Kasumigaseki, Chiyoda-ku, Tokyo, 100-0013, JAPAN

Abstract: An airport pavement management system (APMS) has been under development in Japan. In particular, a surface condition evaluation subsystem based on the method of a Pavement Rehabilitation Index (PRI) has been in use for two decades or more. This PRI method was completed in the early 1980s as a means of evaluating the surface condition of airport pavements by calculation based on objective measurements of surface conditions, as derived from the subjective opinions of pavement engineers. By comparing the calculated PRI value against appropriate criteria, the need for pavement rehabilitation work can be judged for runway, taxiway, and apron pavements.

Japan's APMS is described in outline, along with the closely related rehabilitation subsystem. The evaluation of surface conditions using the subsystem is described in detail and use of the results to judge the need for rehabilitation work is explained. In the analysis, the present conditions of airport pavements are summarized, and compared with the results of surveys conducted about 20 years ago. Further, the annual change in pavement condition of Osaka Itami Airport is analyzed.

Keywords: Airport, Surface condition, PRI, Yearly change, Rehabilitation

1 Introduction

Airport Pavements require continuous maintenance and rehabilitation works to prevent deterioration caused by repetitive aircraft loading and the action of nature. Recent introduction of larger aircraft and increased aircraft operations have accelerated the process of deterioration. However, with the limited fund for airport pavement work, there is a need to use the available funds as effectively as possible. To accomplish this, a systematic procedure for scheduling maintenance and rehabilitation works to optimize benefits to aircraft pilots, passengers, etc. and minimize costs to the agency responsible for pavement management is recognized as a useful measure. Known as a pavement management system for airports (APMS), such a system would allow administrators and engineers to allocate funds, personnel, resources, etc. most effectively.

A full APMS is a complicated undertaking and so far a full-fledged system has yet to be developed in Japan. However, some subsystems of a complete APMS, including the design, evaluation and rehabilitation subsystems, have come into practical use. Of these, the evaluation subsystem, and in particular a surface condition survey method, has been in use for two decades or more. At this point in time, it has become necessary to reevaluate the system.

The conventional method of surface condition evaluation is based on empirical and subjective judgments made by airport administrators. As a systematic alternative, a method based on a Pavement Rehabilitation Index (PRI) was developed to provide an objective evaluation of pavement surface condition, with separate criteria determined for judging the need for rehabilitation work on runway, taxiway, and apron pavements. This method has now been employed for periodic surveys of pavement condition over a period of about 25 years, as already noted. With surveys every three years, a large volume of data on pavement surfaces at various airports has now been collected. By looking at this data, it should be possible to summarize the present condition of airport pavements, evaluate changes in the pavements over time and review the current pavement management system.

This paper focuses on the pavement evaluation subsystem of Japan's APMS. First, an outline of the subsystem is given, introducing also the rehabilitation subsystem, which is a closely related part of the APMS. Then details are given of the method used to evaluate surface condition using the PRI, which forms the basis for judging the necessity of rehabilitation work. Next, experience in applying the evaluation method to airport asphalt pavements, which are selected for analysis here since their condition change more significantly over time, are described. The analysis includes a summary of the present condition of airport pavements in Japan and the findings are compared with the results of a survey conducted about 20 years ago. Further, the annual change in pavement condition at Osaka Itami Airport is analyzed. Finally, the validity of the PRI method is evaluated.

2 Evaluation and rehabilitation subsystems of APMS in Japan

Once an airport pavement has been opened to traffic, proper maintenance and rehabilitation works are essential to maintaining functionality at a satisfactory level and also to maximizing its service life. Maintenance and rehabilitation strategies were conventionally based on empirical and subjective judgments by the airport engineers. The development of a systematic method of implementing maintenance and rehabilitation works has been eagerly awaited, as it will enable airport administrators to make the best possible use of available funds.

Through various studies of pavements for airports, including investigations of surface condition evaluation, structural evaluation, prediction of distress and performance, and maintenance and rehabilitation strategies, the airport pavement management system for design, evaluation and rehabilitation has been developed and used for two decades or more.

Fig. 1 shows a flow chart of the evaluation and rehabilitation subsystems, in which fundamental evaluation, and maintenance and rehabilitation process consists of the following steps.

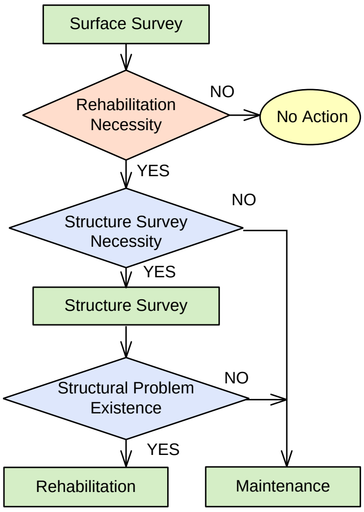


Fig. 1 Flow chart of evaluation and rehabilitation subsystems for airport pavement management in Japan.

1) Surface condition evaluation

The condition of the airport pavement surface is surveyed every three years. When the physical condition of the surface is judged to have seriously deteriorated, certain rehabilitation work may become necessary. In order to determine a suitable time for carrying out this rehabilitation work, an objective method using the already-mentioned PRI has to be applied.

2) Structural condition evaluation

If the above-mentioned PRI method indicates that certain rehabilitation work is necessary, the structural condition of the pavement has to be checked. Non-destructive testing procedures using a Falling Weight Deflectometer (FWD) are adopted for airport pavements.

3) Rehabilitation method selection

If the structural condition of a pavement is found to be unsound, rehabilitation work is necessary. However, some maintenance work may be needed even if the pavement is sound structurally.

4) Rehabilitation work design

Based on the decision made above, the procedure for the rehabilitation work should be determined. In general, there are two methods of rehabilitation, overlay and reconstruction.

3. Development of PRI system

The equations for evaluating pavement serviceability were developed by comparing the opinions of pavement engineers with objective values representing the condition of the pavement surface. In the case of asphalt pavements, 42 distressed sections (a section being 20 m wide and 30 m long) were selected and the opinions of engineers obtained for each using a questionnaire. In the case of concrete pavements, 25 sections (a section being 20 m wide and 20 m long) were selected. The results of the questionnaire were formulated using Quantification Theory. Ultimately, three indices were selected as suitable for evaluating pavement surface condition, in consideration of their ease of measurement. [1]

For asphalt pavements, they are as follows:

1) Cracking, *CR* (%): the crack ratio, defined as the cracked area divided by the area of the section and expressed as a percentage

2) Rutting, *RD* (mm): the maximum rut depth in the section

3) Roughness, *SV* (mm): the standard deviation of roughness as measured using a 3 m profilometer

For concrete pavements, they are as follows:

1) Cracking, *CR* (cm / m^2): length of cracks /area of a section,

2) Joint failure, *JC* (%): summation of the length of failed joints / total length of joints, and

3) Faulting, *SV* (mm): maximum faulting in a section.

Finally, an equation relating the engineers' opinions to these objective measures was developed for each pavement type. They take the form of polynomials in which the above three factors are explanatory variables. The explained variable in this equation was named the Pavement Rehabilitation Index (PRI). They are expressed as follows:

For asphalt pavements,

$$PRI = 10 - 0.450CR - 0.0511RD - 0.655SV \quad (1)$$

For concrete pavements,

$$PRI = 10 - 0.290CR - 0.296JC - 0.535SV \quad (2)$$

Clearly, a higher value of PRI equates to a pavement in better condition. The need for rehabilitation work in a section is judged by ranking PRI values into three categories, as follows:

1) Rank A: rehabilitation work is unnecessary

2) Rank B: rehabilitation work will be necessary in the near future

3) Rank C: rehabilitation work is necessary immediately

Tab. 1 shows the threshold values between these ranks, which differ by the type of airport facilities. This is because very strict control of the surface is necessary for a runway, while surface condition is not critical for apron pavements, where aircraft are stationary or moving only slowly.

Tab. 1 PRI Judgment Criteria

a) Asphalt pavements

Facility	A	B	C
Runway	more than 8.0	8.0 to 3.8	less than 3.8
Taxiway	more than 6.9	6.9 to 3.0	less than 3.0
Apron	more than 5.9	5.9 to 0.0	-

b) Concrete pavements

Facility	A	B	C
Runway	more than 7.0	7.0 to 3.7	less than 3.7
Taxiway	more than 6.4	6.4 to 2.3	less than 2.3
Apron	more than 5.7	5.7 to 0	-

In addition to evaluation using PRI, it is possible to evaluate the pavement using individual item. This system is very important especially when three items which is necessary to calculate PRI cannot be measured. The threshold values shown in **Tab. 2** are introduced for this purpose.

Tab. 2 Criteria on each distress

a) Asphalt pavement

Item	Facility	A	B	C
Crack (%)	Runway	- 0.1	0.1 - 6.5	6.5-
	Taxiway	- 0.9	0.9 - 12.7	12.7
	Apron	- 1.9	1.9 - 17.0	17.0
Rut depth (mm)	Runway	- 10	10 - 38	38
	Taxiway	- 17	17 - 57	57
	Apron	- 22	22 - 70	70
Roughness (mm)	Runway	- 0.26	0.26 - 3.64	3.64
	Taxiway	- 0.91	0.91 - 6.57	6.57
	Apron	- 1.50	1.50 - 8.63	8.63

b) Concrete pavements

Item	Facility	A	B	C
Crack (%)	Runway	- 0.2	0.2 - 5.6	5.6 -
	Taxiway	- 0.6	0.6 - 7.6	7.6 -
	Apron	- 1.1	1.1 - 11.1	11.1 -
Joint failure (%)	Runway	- 0.1	0.1 - 1.3	1.3 -
	Taxiway	- 0.1	0.1 - 3.2	3.2 -
	Apron	- 0.1	0.1 - 5.7	5.7 -
Faulting (mm)	Runway	- 5	5 - 10	10 -
	Taxiway	- 5	5 - 12	12 -
	Apron	- 6	6 - 14	14 -

3. Current surface condition of airport asphalt pavements

3.1 Use of PRI

The Japanese airports at which periodic checks of pavement condition are carried out are listed in **Tab. 2**. These are airports managed by the Ministry of Land, Infrastructure and Transport and include military airbases, which fall partly under the ministry's management. [2]

Tab. 3 summarizes the latest survey results for the state of the asphalt pavement at 23 of these airports. The surveys were conducted between 1998 and 2002. Although the average value of PRI is 7.43 on the whole, the values for runways and taxiways are different, with runways averaging 7.99 and taxiways 7.12. All types of distress, including cracking, rutting, and roughness, are more severe on taxiways than on runways and this is reflected in the PRI. [3]

Tab. 3 Periodically surveyed airports

Airport type	Name
First rank	Tokyo and Osaka
Second rank	Chitose, Wakkanai, Kushiro, Hakodate, Sendai, Niigata, Yao, Hiroshima, Takamatsu, Matsuyama, Kochi, Fukuoka, Kitakyushu, Nagasaki, Kumamoto, Miyazaki, Kagoshima and Naha
Military	Sapporo, Komatsu, Miho, Tokushima and Misawa

Tab. 4 Present surface condition of airport asphalt pavements

Facility	Portion	Crack* (%)	Rut depth (mm)	Roughness (mm)	PRI
Overall	Overall	1.13	16.8	1.88	7.43
	Standard pavement**	1.26	17.1	1.91	7.32
	Thinner pavement***	0.92	16.3	1.82	7.58
Runway	Overall	0.56	14.4	1.60	7.99
	End	0.52	14.3	1.66	7.96
	Center	0.59	14.4	1.56	8.00
Taxiway	Overall	1.44	18.1	2.03	7.12
	Parallel	1.49	17.9	1.99	7.13
	Exit	1.31	18.5	2.13	7.07

* includes patching.

** includes runway ends and parallel taxiways.

*** includes runways centers and high-speed exit taxiways.

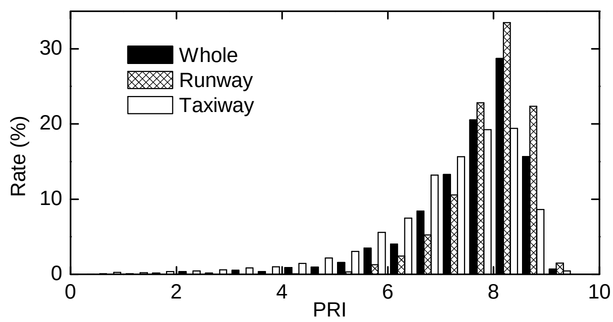
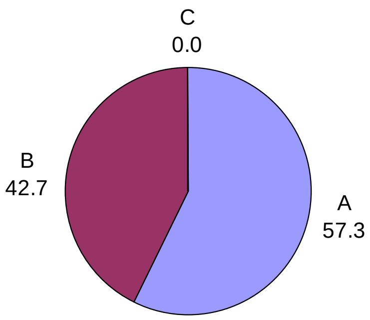


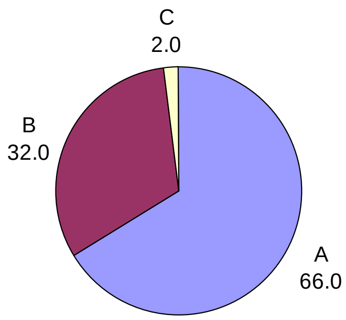
Fig. 2 PRI distribution.

The distribution of PRI values is as shown in **Fig. 2**. There is a difference of about ten percent on average between runways and taxiways, with taxiways exhibiting the smaller values of PRI.

Fig. 3 shows the need for rehabilitation work as judged from these PRI values in accordance with the criteria given in **Tab. 1**. Looking at runways, the proportion of pavements classified as A is about 60% and the remainder is B. On the other hand, about 70% of taxiway pavements are ranked as A, but there are some ranked as C. Although PRI values are smaller for taxiways than on runways, the difference in need for rehabilitation results from the different criteria used for runways and taxiways.



a) Runways



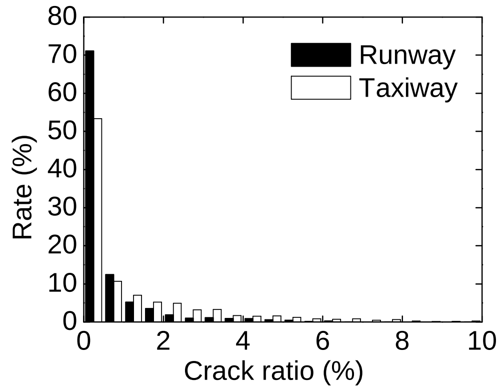
b) Taxiways

Fig. 3 Need for rehabilitation work.

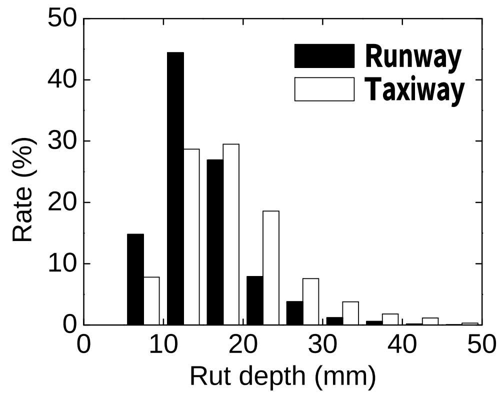
3.2 Surface Distress

Among the types of distress that appear on the pavement surface, those used as indices in composing the PRI are, as already noted, cracking, rutting and roughness. The occurrence of these types of distress is shown in **Fig. 4**.

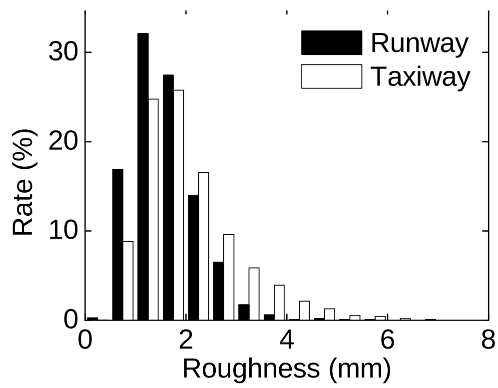
Fig. 4 a) shows the crack ratio. Although the average crack ratio is 0.52% and 1.40% on runways and taxiways, respectively, 70% of runway sections and 50% of taxiway sections have a crack ratio of 0.5% or less. Cracking of greater severity is more widespread on taxiways as compared with runways. The average rut depth is 14.4 mm and 18.1 mm on runways and taxiways, respectively, and there is a greater scatter of values and rutting of greater severity is more widespread on taxiways, as summarized in **Fig. 4 b)**. The average roughness is 1.60 mm and 2.03 mm on runways and taxiways, respectively, and there is more scatter on taxiways than on runways, as shown in **Fig. 4 c)**.



a) Cracking



b) Rutting



c) Roughness

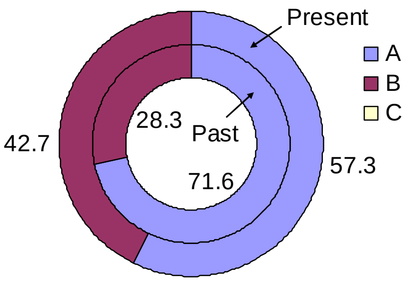
Fig. 4 Surface distress.

4. Comparison with past condition

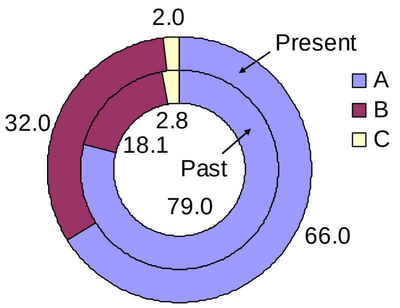
The latest survey results as presented above are compared with past results taken between 1985 and 1987 [4] in order to evaluate the validity of the current maintenance and rehabilitation system used for airport pavements.

Tab.5 compares the results of the current and past surveys, showing cracking, rutting and roughness and including the PRI calculated from these values. The broad sweep of findings from the current survey, such the generally better condition of runways than taxiways, is similar to the results given by the older data. However, it is clear that pavements are in worse state now than in the past.

Fig. 5 summarizes the need for rehabilitation work based on PRI. The proportion judged as A is ten points or more lower now than in the past survey, both for runways and taxiways, while there are more B ranks today. However, there is little difference in the proportion judged as C between the current and past surveys.



a) Runways



b) Taxiways

Fig. 5 Comparison of judged need for rehabilitation present and past

Tab. 5 Comparison of surface condition present and past

Facility	Time	Crack (%)	Rut depth (mm)	Roughness (mm)	PRI
Overall	Past	0.91	15.3	1.45	7.86
	Present	1.09	16.8	1.88	7.43
Runway	Past	0.69	12.7	1.22	8.25
	Present	0.52	14.4	1.60	7.99
Taxiway	Past	1.02	16.9	1.59	7.64
	Present	1.40	18.1	2.03	7.12

Clearly, the condition of airport pavement surfaces has worsened in the 20 years since the earlier survey, with the proportion ranked as B increasing over the years. This might suggest that the pavement management system, including the methodology used to evaluate pavements (the method and the survey interval) is barely adequate to maintain the surface in good condition.

5. Pavement surface distress condition at Osaka Itami Airport

The surface distress condition of airport pavements was analyzed for Osaka Itami International Airport, one of the large - sized international airports in Japan. Osaka Itami Airport was selected because its plan has not largely changed, various kinds of pavement structures have been constructed, and large-sized aircraft have been introduced. As PRI has been measured at Osaka Itami Airport for about twenty years, both the annual changes in PRI and the recovery of PRI due to rehabilitation works could be calculated with ease.

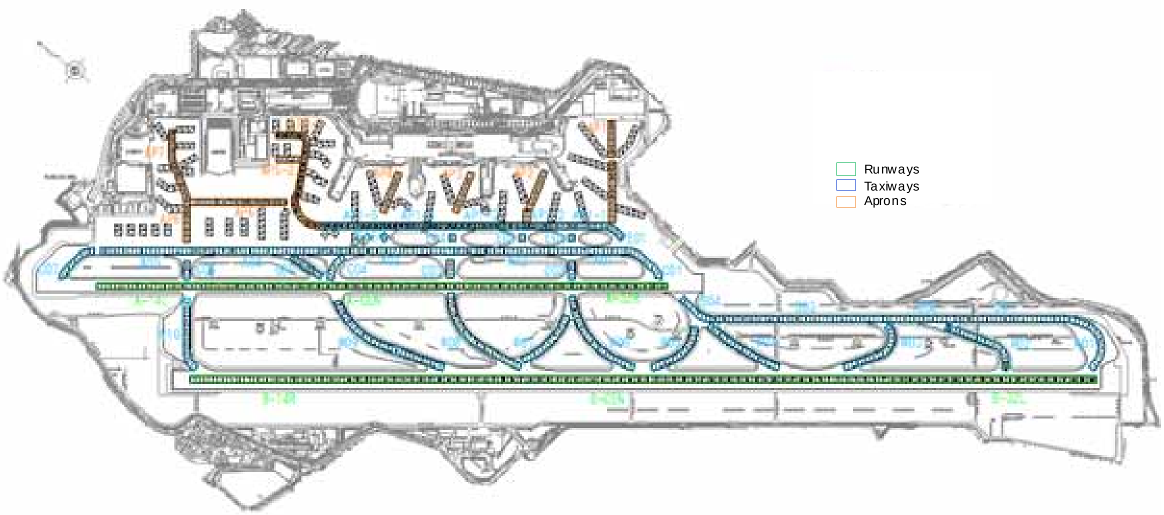


Fig. 6 Units for PRI calculation at Osaka Itami Airport

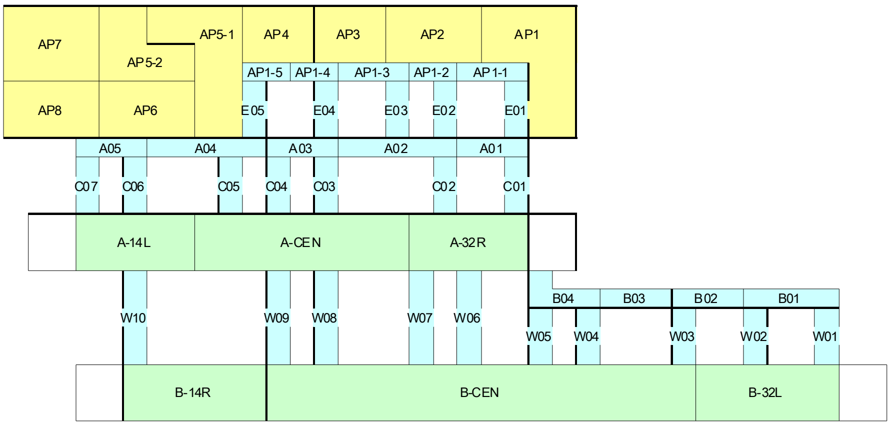


Fig. 7 Groups for PRI calculation at Osaka Itami Airport

The surface conditions of runways, taxiways and aprons were evaluated in 163, 273, 101 units, respectively as shown in **Fig. 6**. When the annual changes in PRI and the recovery of PRI due to rehabilitation works are analyzed in each unit, the results vary largely. Thus, the units are summed into several groups as shown in **Fig. 7**. The runways A and B were separated into three blocks (two end parts and one intermediate part) in each, and the aprons were divided into nine blocks in consideration of the running lines. The taxiways were divided into perpendicular taxiways, high-speed exit taxiways and the properly separated parallel taxiways.

When calculating the annual change in PRI, only the data measured in three or more times between the continuous rehabilitation works are used. For asphalt pavements, the average annual changes in PRI for runways, taxiways are 0.10 - 0.19, 0.10 - 1.15, respectively. For concrete pavements, the change in PRI of jointed concrete pavements is very small in comparison with asphalt pavements. Especially, PRI of prestressed precast concrete slab pavements scarcely changes with time.

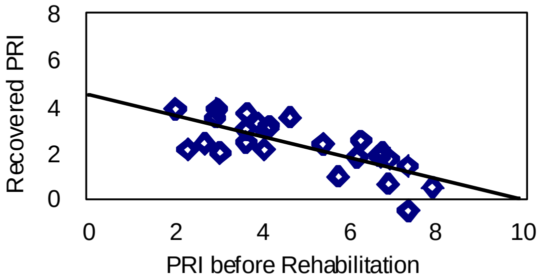


Fig. 8 An Example of recovered PRI due to rehabilitation works

PRI of the pavements is recovered by applying the rehabilitation works more or less, depending on the type of rehabilitation works. The amount of recovery in PRI is analyzed for the type of rehabilitation works of which data is five or more. The recovered amount of PRI is calculated when at least three PRI data are available either before or after rehabilitation works. The example is shown in **Fig. 8**. The recovered PRI scarcely varies in rehabilitation works conducted at this Airport.

5. Conclusions

As a step toward an APMS, subsystem for evaluating the surface condition of airport pavements has been in use in Japan for over 25 years. Using the data collected over this period, the validity of the system has been verified. In this study, the following findings on the surface condition of airport asphalt pavements in Japan have been reached:

1) The condition of runway surfaces is better than that of taxiways when quantified by crack ratio, rut depth and roughness. This results in runways having a higher PRI value.

2) The need for pavement rehabilitation work is judged at a lower value of PRI for taxiways than for runways, because taxiways play a less crucial role. However, the proportion judged as not needing rehabilitation is about 60% for both types of pavement, which means that airport pavements are, as a whole, maintained well.

3) A smaller proportion of pavements are judged as not needing rehabilitation work in the latest survey as compared with a survey carried out 20 years ago.

4) The annual rates of change in PRI and the recovery of PRI due to the rehabilitation works were quantified at Osaka Itami Airport.

Acknowledgement

The author acknowledges the Ministry of Land, Infrastructure, Transport and Tourism for its support to accomplish this study.

References

[1] Fukute, T., K.Sato, Y. Hachiya and H. Yamazaki. Evaluation of Serviceability of Airport Pavements. Technical Note of Port and Harbor Research Institute, No.414, 1982, 20p. (in Japanese).

[2] Hachiya, Y., Maekawa, R. and Su, K. Verification of Surface Condition Evaluation Subsystem for Airport

Asphalt Pavement Management in Japan, Transportation Research Board, 87th Annual Meeting, 2008.
[3] Imanishi, K., Y. Hachiya, Y. Tsubokawa and Y. Takeuchi. Study on Annual Changes in Surface Condition of Airport Pavements. 60th Annual Meeting of Japan Society of Civil Engineers, Section V, pp.287-288, 2005 (in Japanese).
[4] Hachiya,Y. Actual Surface Condition of Airport Pavements. Technical Note of Port and Harbor Research Institute, No.634, 1988, 40p. (in Japanese).