PERFORMANCE TRENDS IN AIRPORT RUNWAY PAVEMENTS

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ABSTRACT

Research sponsored by the FAA Office of Airport Safety and Standards (AAS) will extend the expected life of large hub runway pavements from 20 to 40 years. Research is being conducted to collect performance data at major hub airports across the U.S. that will provide performance trends of existing runways and identify factors to be considered in order to extend the pavement life expectance to the goal of 40 years. The purpose of this paper is to briefly describe the research project and to provide preliminary performance trends for 18 runway pavements studied. The pavement condition index (PCI), conducted in accordance with ASTM D5340, is a measure of overall pavement serviceability, and it can be used to track performance over time. It is generally accepted that the PCI decreases at a relatively slow rate over the first years of the pavement life, and then at some point the rate of deterioration increases. Some runways surveyed were relatively new and therefore have no performance history. However, most of the runways studied have been surveyed a number of times and some history of changes in PCI with time are available. The deterioration over time of the runways indicates the effect of maintenance that keeps serviceability at an acceptable level. The distresses found on nearly all runways studied were not load related, which implies that currently the runways are structurally sound and capable of supporting the actual (current) traffic. The predominant distresses observed on the runways studied thus far are: Low to medium severity longitudinal/transverse cracking, low severity weathering, and low severity patching (AC pavements); Low to medium spalling, low to medium longitudinal/transverse/diagonal cracking, low severity patching, and pop-outs (PCC pavements). The paper describes the data collection effort and findings thus far.

INTRODUCTION

The FAA Office of Airport Safety and Standards (AAS) has requested that methodologies be developed to extend the expected life of large hub runway construction from 20 to 40 years. Research is being conducted to collect performance data at major hub airports across the U.S. that will provide performance trends of these existing runways and identify factors to be considered in order to extend the pavement life expectance to the goal of 40 years. Table 1 shows runways selected for data collection. The purpose of this paper is to provide a discussion of the performance trends observed from pavements studied.

Table 1. Runways selected for data collection study.

Site	Surface Type	Runway
1a	New Asphalt	10R-28L
1b	Old Asphalt	10L-28R
2	Old Asphalt	4-22
3	New Concrete	9-27
4a	New Concrete	16R-34L
4b	Old Concrete	16C-34C
5	New Asphalt	5L-23R
6a	Old Asphalt	10L-28R
6b	Old Asphalt	10R-28L
7	Old Asphalt	10-28
8	Old Concrete	17R-35L

The complete results from the data collection, both historical data and current field data, are reported elsewhere as part of the research study; this paper only provides performance trends as determined from surface distress assessments.

CONSTRUCTION AND REHABILITATION HISTORY OF STUDY RUNWAYS

Construction history data were taken from various sources – original design reports, plans and specifications, quality control data, and pavement management study reports. A summary of the construction histories is shown in Table 2.

PERFORMANCE DATA REVIEW

PCI data are provided in Table 3. The PCI surveys were conducted in accordance with ASTM D5340 except that the new data collected in 2012/2013 was based on a 100 percent sampling of the runway pavements. Runway 10R-28L at Site 1a is a brand new runway with no distresses and was assigned a PCI of 100. Runway 9-27 at Site 3 was constructed in 2009 with no PCI surveys performed to date. It is assumed that the runway was in excellent condition with a PCI of 100 in 2009.

PERFORMANCE TRENDS

The PCI is a measure of pavement surface condition, and it can be used to track performance over time. It is generally accepted that the PCI decreases at a relatively slow rate over the first years of the pavement life, and then at some point the rate of deterioration increases. Most airport owners/operators have threshold values of PCI that indicate when a pavement is not providing satisfactory service and may need significant maintenance and repair effort. These threshold PCI values vary from 65 to 85 depending on various factors from funding availability to safety implications and FOD potential of the distressed runway.

PCI Indications for Runways Studied

Some runways surveyed were relatively new, such as Runway 10R-28L at Site 1a and Runway 5L-23R at Site 3, and therefore have no PCI history. Most of the other runways studied have been surveyed a number of times and some history of changes in PCI with time are available. It may be noteworthy to consider that the PCI surveys were made by different survey teams, conducted at different months of the year, and all used statistical sampling (less than 100 percent) as prescribed by ASTM D5340, except the 2012/2013 data which was based on 100 percent sampling. The following paragraphs look at the PCI indications for each runway studied thus far. For the purpose of this analysis, the assumption was made that the pavement was restored to a PCI of 100 in the year that an overlay was constructed.

The following paragraphs present and discuss the PCI trends for each of the runways studied. Some variation in PCI is expected; the ASTM D5340 states that the variability in PCI results can be ±5 points.

Runway 10R-28L at Site 1a. This AC runway was reconstructed in 2012-2013. The runway was surveyed in 2013 and was assigned a PCI of 100. This new runway will be monitored by FAA for future performance trends.

Table 2. Construction history on runways.

Designation	Runway	Section Length/Width, ft	Section	Original Construction Year	Construction/Rehabilitation
1a	10R-28L	10 @ 1,000	All	2012	5.0" P-401 / 9" P-403 / 11" P-209 / 12" Stabilized Subgrade
1b	10L-28R	1,000	10N 10S 10C	1997	11" AC; 17" base course; 24" #2 stone
				2010 - 2012	2" Mill and replace patches
		6,000	20N 20S 20C	1959	4" AC surface; 5" bituminous base course;11" aggregate subbase
				1969	3" AC overlay
				1978	4.25" AC overlay
				1987	5.5" AC overlay
				1997	3" Mill and replace
				2010	2" Mill and Replace Patches
				2011	
				2012	
		1,000	30N 30S 30C	1996	11" AC; 17" base course; 12-18" stone
				2001 - 2006	Crack seal and partial depth patches
				2010 - 2012	2" Mill and replace patches
2	4-22	7,000	All	1994	14-21.5" P-401; 6" bituminous base; 6" P-154
				2000	3" AC overlay
				2009	Unknown AC overlay
3	9-27		All	2009	14" PCC; 2" AC leveling; some older AC; 20-28" Lime/Cement/Fly-ash (LCF); 30" stabilized subbase
4a	16R-34L	8,500 x 150	All	2008	17" PCC (P-501); 8" P-209; 6" P-154; 19" P-154
4b	16C-34C		All	1969	14" PCC; 6” granular base
5	5L-23R		All	2010	10" P-401; 24" P-209; 6" P-155
6a	10L-28R		All	1959	3.5-4" AC; 10" of CTB; 4" aggregate base course
				1971	4-14" AC; 8-11" CTB; 4-10" aggregate base course
				2009	4" AC overlay

Table 2. Construction history on runways (continued).

Designation	Runway	Section Length/Width, ft	Section	Year	Construction/Rehabilitation
6b	10R-28L		All	1954	3.5-4" AC; 10-12" CTB; 4" aggregate base course, or 3" AC; 15" aggregate base course
				2008	4" AC overlay
7	10-28		Original	1950	9.5-10" AC; 4" aggregate base; 15.5" aggregate subbase
				1965	1.5" AC overlay
				1973	5.5-7" AC overlay
				1987	3" AC overlay
				2011	3" AC overlay
			Extension	1993	10" AC; 15-21" aggregate base; 5.5" aggregate subbase
				2011	3" AC overlay
8	17R-35L		All	1989	17" PCC; 6" Econocrete
				2003	Joint sealant, partial depth patching, 28 slab replacements

Table 3. PCI Summary by Survey Year.

Site	1995	1998	2000	2001	2002	2003	2006	2007	2008	2009	2010	2011	2012	2013
1a													New AC	
1b				89		79	70			62			63	61
2		93		93		95	84		97		98	90	90	
3										New PCC				
4a									New PCC					99
4b	91	76	75		75		75				99			
5														93
6a							85			96			89	
6b									83	94			90	
7	76	84				73	72	58				57		93
8				97			97					96		

Runway 10L-28R at Site 1b. This AC runway is 55 years old (original construction in 1959); it was extended from both ends and received a major rehabilitation in 1997 to 1998. PCI data for the runway are plotted in Figure 1. There are no PCI data prior to 2001; it is assumed that the PCI was 100 in 1959. The runway obviously provided excellent service for over 40 years, but has shown rapid decline in the past 10 years. The runway has been maintained by annual crack sealing from 2001 to 2006 and partial depth patches from 2010 through 2012. The rate of deterioration from 1959 to 2001 was only 0.26 points per year; from 2001 to 2012 the rate increased to 2.5 PCI points per year.

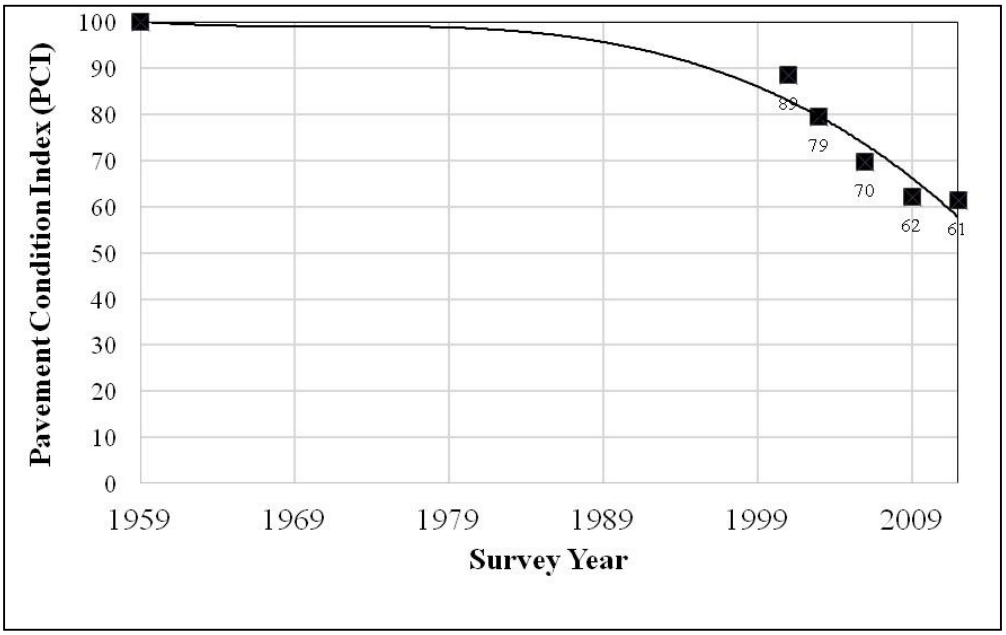

Figure 1. PCI history for Runway 10L-28R at Site 1b.

Runway 4-22 at Site 2. PCI data for this AC runway is shown in Figure 2. Records show that the runway was reconstructed in 1994 so it is currently 20 years of age. The runway received an AC overlay in 2009. A PCI of 100 was assumed at the rehabilitation time. The average rate of deterioration over the 20-year life ranged from 1.5 to 2.0 points per year.

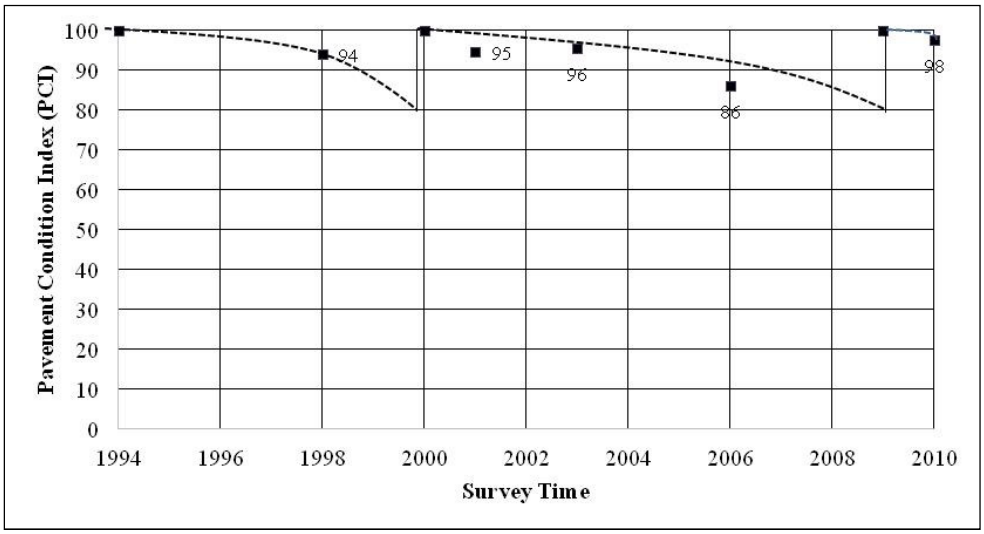

Figure 2. PCI history for Runway 4-22 at Site 2.

Runway 9-27 at Site 3. This runway was reconstructed in 2009 with new 14-inch PCC. The PCC was placed over 2 inches of AC leveling course for the middle portion of the runway, and 12 inches of AC leveling course for the runway ends. No PCI data is currently available. The runway is assumed to have an average PCI of 100 at time of construction.

Runway 16R-34L at Site 4a. The runway was constructed in 2008 with PCC. The PCI is assumed to have been 100 at the time of the construction. A 2011 survey found a PCI of 95; the 2013 survey recorded an average PCI of 98 (averages for entire runway). The pavement performance data is plotted in Figure 3. The deterioration rate between 2008 and 2013 is 0.4 PCI points per year.

Runway 16C-34C at Site 4b. PCI data for this PCC runway is shown in Figure 4; the data indicate that the airport has likely maintained the runway pavement to a PCI of 70. The average deterioration rate (from 100 PCI at original construction in 1969) is 1.2 points per year. Performance data is not available for the first 26 years of its life. Some Major M&R was performed between 2006 and 2010 that increased the PCI to 95. The average deterioration rate from 1995 to 1999 was 5 points per year; however, there was essentially no change in the PCI from 1999 to 2006. M&R applied between 2006 and 2010 increased the PCI to an average value of 95.

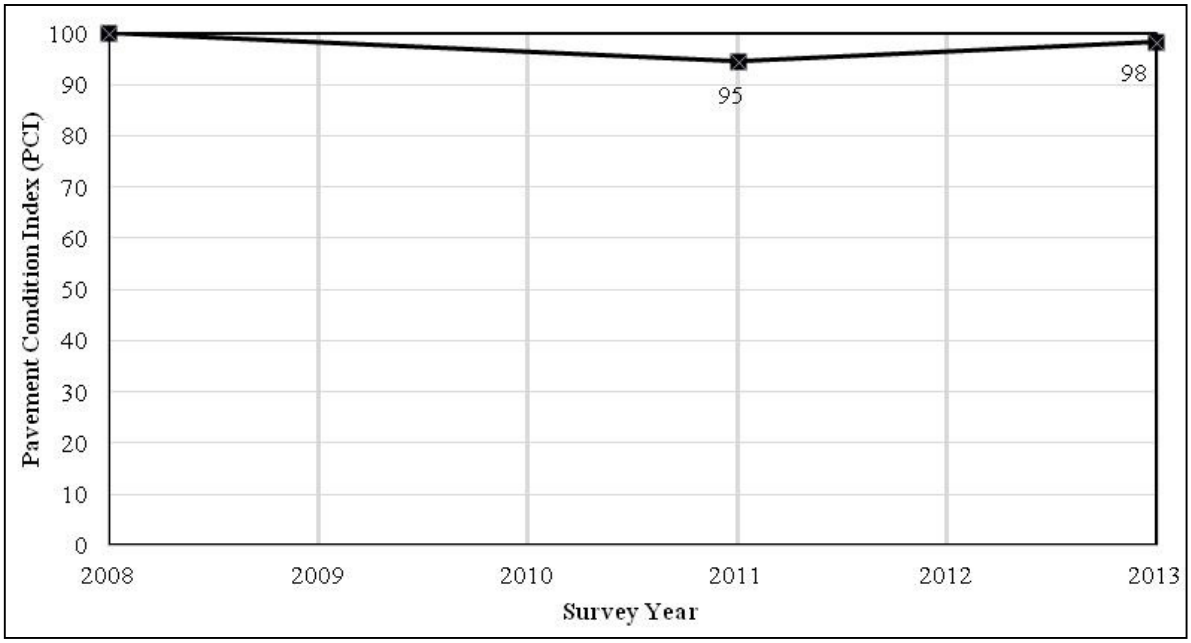

Figure 3 - PCI history for Runway 16R-34L at Site 4a.

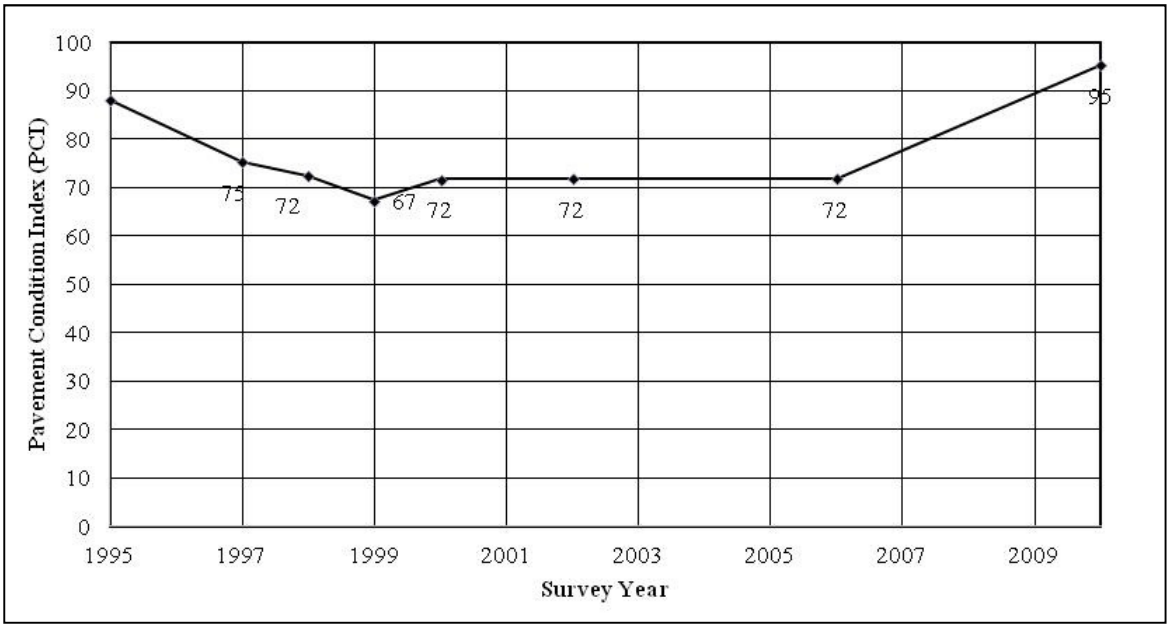

Figure 4. PCI history for Runway 16C-34C at Site 4b.

Runway 5L-23R at Site 5. This AC runway was reconstructed in 2010 and was assumed to have a PCI of 100 at the time. The 2013 survey showed an average PCI of 92.5. This gives an average deteriorated rate of 2.5 points per year.

Runway 10L-28R at Site 6a. This AC runway was constructed in 1959; major M&R, consisting of 4 inch AC overlay, was constructed in 1971 and again in 2008. PCI survey data from 2008 to 2012 is shown in Figure 5. Assuming a PCI of 100 in 1971, the rate of deterioration between 1971 and 2008 is 0.5 points per year. The rate of deterioration from the time the overlay was added in 2009 to the latest PCI survey conducted in 2012 is 2.7 points per year.

Runway 10R-28L at Site 6b. Figure 6 depicts the PCI survey results on this AC runway from 2006 to 2012. The PCI has increased between 2006 and 2009, the result of a 4.0 inch AC overlay in 2008. The PCI in 2008 is assumed 100. The average runway PCI then dropped 6 points between 2009 and 2012 resulting in a deterioration rate of 3.3 PCI points per year. This runway was originally constructed in 1954 giving it an age of 60 years. The lowest PCI level that the runway may have reached over its life is not available.

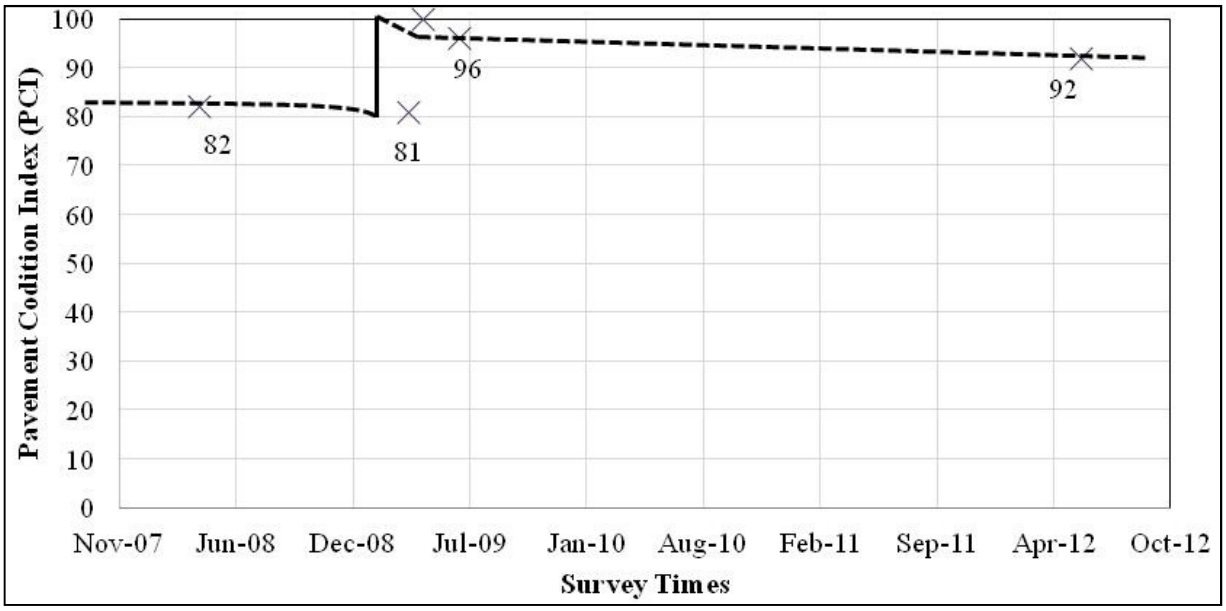

Figure 5. PCI history for Runway 10L-28R at 6a.

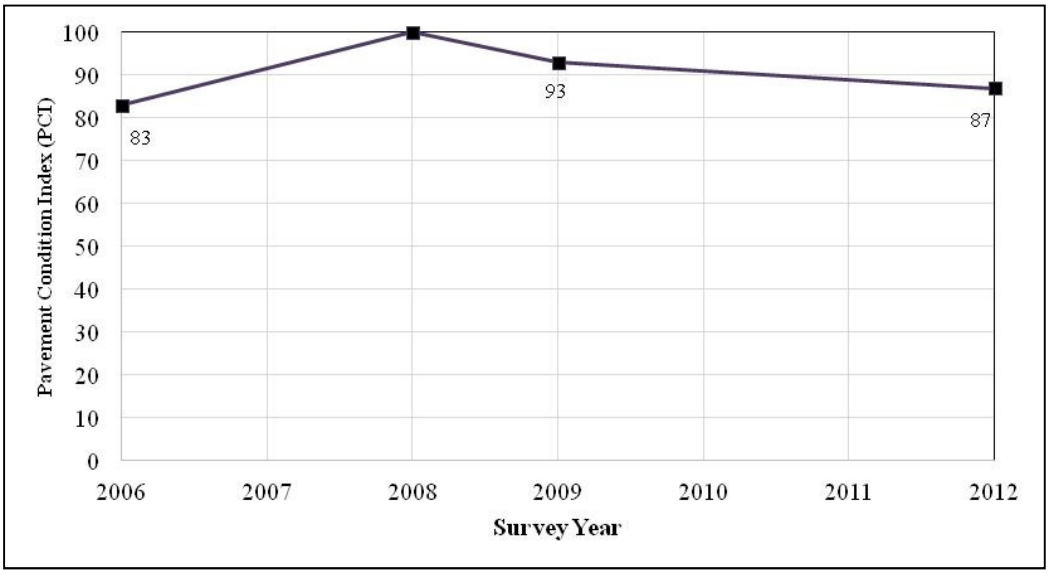

Figure 6. PCI history for Runway 10R-28L at Site 6b.

Runway 10-28 at Site 7. The AC runway was constructed in 1950; the history of the pavement in terms of maintenance and repair (M&R) during the early years is not available. PCI data is available from 1995 when the runway was 45 years old with an average PCI of 71. Figure 7 shows an increase in PCI to a value of 81 in 1998, obviously a result of some M&R. The runway received a 3 inch AC overlay in 1987 and a PCI of 100 was assumed. The deterioration after this overlay to 2006 is gradual with a rate of 1.4 PCI points per year. However, there is a significant drop in the following year's survey to a PCI of 59. The deterioration rate between subsequent overlays is 0.6 PCI points per year. The average PCI for the runway assumed 100 after the 3-inch mill and overlay in 2011 and the PCI was found to be 93 in 2013.

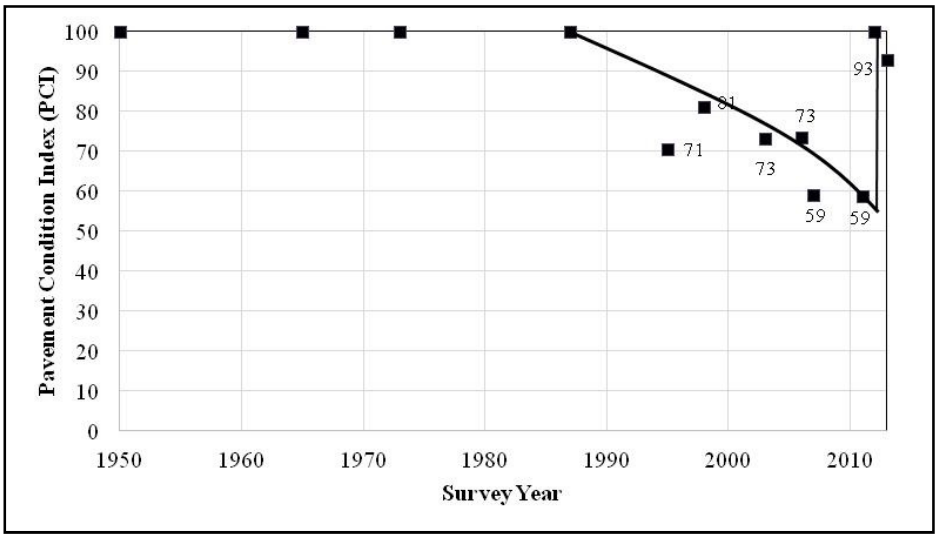

Figure 7. PCI history for Runway 10-28 at Site 7.

Runway 17R-35L at Site 8. The PCC runway, constructed in 1989, has been repaired at various times and locations and many slabs have been replaced. As shown in Figure 8, the PCI has remained fairly constant around 97. The deterioration rate between 1989 and 2011 is about 0.2 PCI points per year.

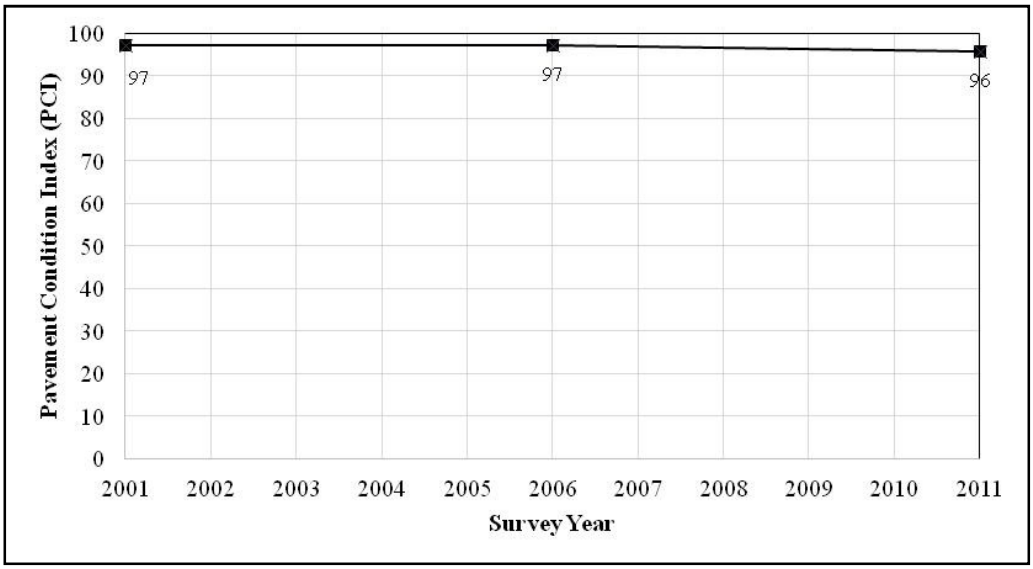

Figure 8. PCI history for Runway 17R-35L at Site 8.

CLIMATIC REGIONS FOR RUNWAYS STUDIED

The runways reported in the paper are located in the following climatic regions (in accordance with AASHTO 1995).

- Region I: Site 3, Site 8
- Region II: Site 4a, Site 4b Site 5, Site 7
- Region III: Site 1a, Site 1b, Site 2
- Region IV: Site 6a, Site 6b

Additional runway data will be collected at airports in other climatic regions. The data has not been analyzed to determine impacts of climatic conditions.

TRAFFIC DATA

The runways studied thus far are at large hub airports with significant amounts of heavy aircraft operations. These include such large aircraft as B-747, B-767, B-757, A-300, and A-340 as well as a range of medium size jet aircraft. Thus far, effects of traffic on the pavement performance have not been analyzed. As more data is collected from additional runways, the structural performance will be evaluated.

OVERALL TRENDS IN PERFORMANCE

The performance data collected on the eleven runways show insight into the overall pavement performance over time, and some conclusions can be extracted from a review of the data. Table 4 is a summary of data for the eleven runways. Figures 9 and 10 show the PCI of all runways plotted at the age of the surface at time of the survey; this includes data for all runway sections.

Based on the data collected thus far, it would appear that airports tend to manage the runway condition and maintain it at a generally satisfactory level with maintenance and repair. The lower threshold level appears to vary from runway to runway and in general range from 65 to 85. Records of maintenance activities and costs are not readily available at most airports in the study; however, reports indicate that routine M&R has been applied to most runways.

A review of Figures 9 and 10 give indications of the runway performance over time. The AC pavements in Figure 9 generally deteriorate to a PCI of 70 within approximately 12 to 15 years – requiring a new surface to reinstate them to a PCI of 100. Figure 10 shows the PCC pavement at nearly 40 years of age before a PCI of 70 is reached. There is a significant range in performance with many pavement sections showing much more rapid deterioration that others; this is likely caused by such factors as traffic loading, climatic variations and environment related distresses, subgrade conditions and support, level of maintenance, and construction quality and variability. The rate of deterioration, in general, is fairly low during the early portion of the pavement life. But increases at a rapid rate once the pavement reaches a PCI of approximately 70.

SUMMARY AND PRELIMINARY CONCLUSIONS

Many factors impact pavement performance and longevity. Some of these factors are discussed below.

Structural Adequacy

The distresses found on the runways were generally not load related, which implies that currently the runways are structurally sound and capable of supporting the actual (current) traffic. Older pavements were designed using earlier design models that may not produce the same thicknesses as current FAA FARFIELD. The original design traffic most likely does not represent today's actual traffic as aircraft have changed over the years and the numbers of operations have steadily increased at most major hub airports.

Construction Materials

Subgrade soils can play a significant role in the performance of a runway pavement structure; high plastic clay subgrades can have a wide range of foundation support depending on the moisture state and the level of compaction. This report does not look specifically at subgrade types and layer materials; further analysis is needed to look at all parameters. Uniformity of

Table 4. Summary of performance trend data.

Airport	Runway	Surface Type[a]	Age from Original Construction (years)	Age of Current Surface (years)	PCI (Survey Year)	Predominant Distress Type and Severity	Avg Rate of Deterioration (PCI/years)
Site 1a	10R-28L	New Asphalt	1	1	100 (2013)	None	N/A
Site 1b	10L-28R	Old Asphalt	55	17	62 (2013)	Medium severity weathering, low and medium severity longitudinal and transverse cracking and low severity patches	0.26 for 42 years; then 2.5 for next 11 years
Site 2	4-22	Old Asphalt	20	5	98 (2010)	Low severity longitudinal and transverse cracking	1.5 to 2.0
Site 3	9-27	New Concrete	5	5	100 (2009)	None	N/A
Site 4a	16R-34L	New Concrete	6	6	98 (2013)	Pop outs	0.4
Site 4b	16C-34C	Old Concrete	45	45 (Many slabs are replaced at various years)	95 (2011)	Low and medium severity spalling-joint and spalling-corner, low severity patching, low severity joint seal damage, and low severity longitudinal, transverse, diagonal cracking	1.2 (from 1969 to 1999); 5.0 (1999 – 2006)
Site 5	5L-23R	New Asphalt	3	3	93 (2013)	Low severity weathering and low severity longitudinal and transverse cracking	2.5

[a]New pavement is defined as 3 years old or less, and old pavement is defined as more than 20 years old.

Table 4. Summary of performance trend data (continued).

Airport	Runway	Surface Type[a]	Age from Original Construction	Age (From last new surface)	PCI (Survey Year)	Predominant Distress Type and Severity	Avg Rate of Deterioration (PCI/years)
Site 6a	10L-28R	Old Asphalt	55	5 (2009) some sections have 2012 OL but most in 09	92 (2012)	Low severity longitudinal and transverse cracking, low severity patching	0.5 (1971 - 2008); 2.7 (2009 - 2012)
Site 6b	10R-28L	Old Asphalt	60	6 (2008) some sections have 2012 OL but most 08	87 (2012)	Low and medium severity longitudinal and transverse cracking, low and medium severity patching. Instances of low and medium severity depression noticed	3.3 (2009 to 2012)
Site 7	10-28	Old Asphalt	64	3 (2011) based on URS report	93 (2013)	Low severity weathering and low severity longitudinal and transverse cracking	0.6 (1987 to 2011) 3.5 (2011 to 2013)

[a]New pavement is defined as 3 years old or less, and old pavement is defined as more than 20 years old.

subgrade support is important; however, no evidence was noted that would imply a change in structure over the length of the runways. The FAA research laboratory in Atlantic City will be conducting forensic tests on core samples from both AC and PCC pavements; the results should aid in an understanding of the effect of material properties.

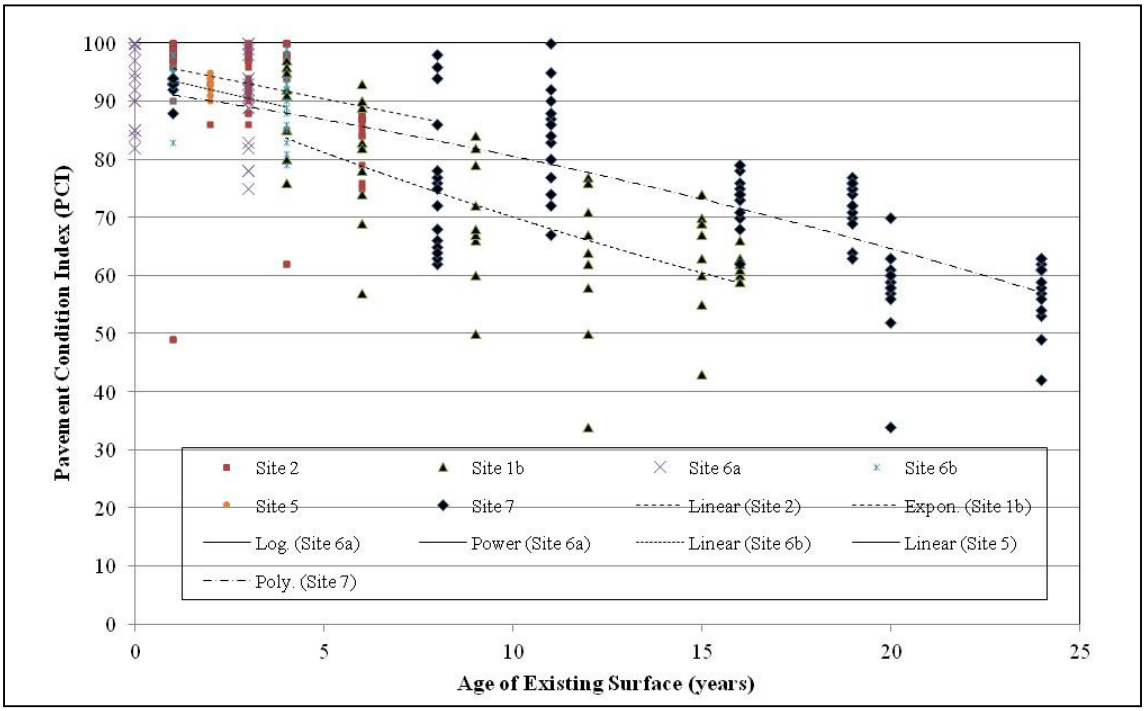

Figure 9. PCI Performance of Asphalt Concrete Runways.

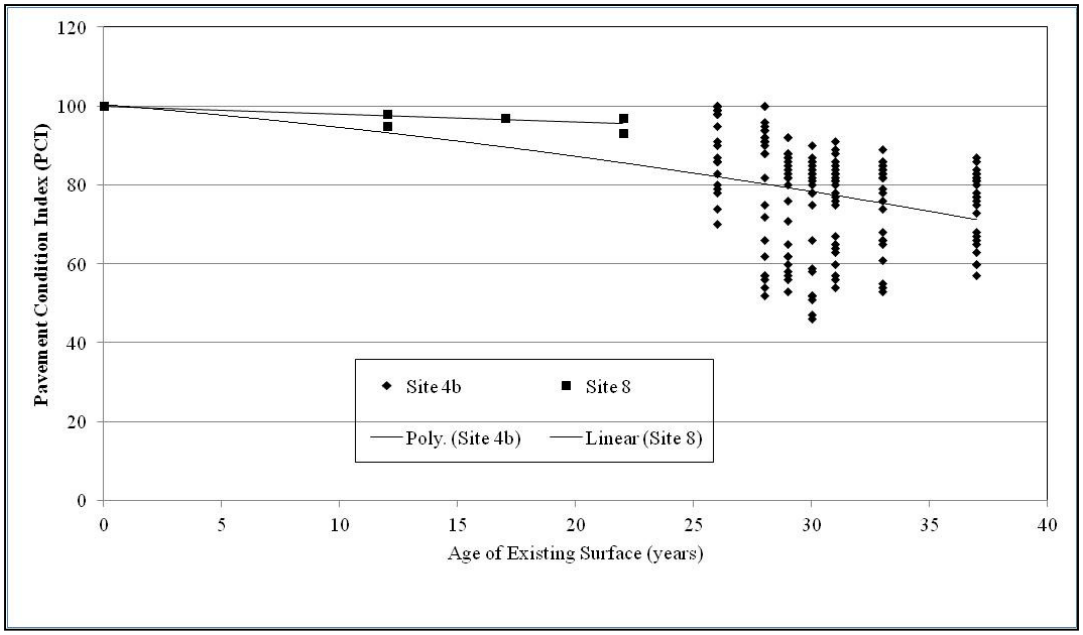

Figure 10. PCC Runway Performance.

Construction Methods and Technologies

It is generally recognized that the execution of good construction practices using most advanced methods, equipment, and technologies that ensure quality products is critical to long-life pavements. The data collected under the FAA study does not readily address construction quality or defects related thereto, but it is well understood that adherence to the construction specifications eliminates, or at least minimizes, early failures and defects related to poor construction. Updated and improved specifications, clear and concise guidance on quality achievement, and strong emphasis on construction quality will be necessary for long-life performance.

Distress Types Observed

The predominant distresses observed on the runways studied so far were:

AC Pavements:

- Low to medium severity longitudinal/transverse cracking
- Low severity weathering
- Low severity patching.

PCC Pavements:

- Low to medium spalling
- Low to medium longitudinal/transverse/diagonal cracking
- Low severity patching
- Pop-outs.

These distresses are material and environment related; not load related. There was some localized rutting in the asphalt surface layer on one end of runway at Site 7, but this is likely due to a mix/material issue.

Maintenance Treatments/Cost

It appears that the older pavements studied have been maintained to acceptable levels of serviceability. A 40-year design life may require periodic maintenance, and the frequency and intensity of the maintenance be specified as part of the design. Asphalt runways at Site 6 and Site 7 airports give indications that the rate of deterioration may be higher following a resurfacing than the rate on the original pavement. Emphasis may be needed on guidance for selection and application of maintenance treatments. The inclusion of maintenance in the design and construction costs of new airfield pavements, as part of the AIP program, could ensure

extended pavement life. The PaveAir program can be used to check the effectiveness of the M&R and to ensure that these practices are accomplished.

Climate

The impact of climate is not readily apparent from data collected. Further data collection is planned to include runways in various climatic regions as defined by he Long Term Pavement Performance (LTPP) program.

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