



# Pavement Performance at Southeast Airports




Prepared for

ACPA Southeast Chapter

American Concrete Pavement Association – Southeast Chapter
Lawrenceville, Georgia

# FINAL REPORT

Submitted by

**All About Pavements, Inc (API)**
*www.allaboutpavements.com*

1705 Lakeshore Drive, Mahomet, IL 61853
Phone (217) 586 2765 - Fax (217) 586 1967

**Pavement Management – Evaluation – Testing - Design**

# TABLE OF CONTENTS

# LIST OF TABLES

# LIST OF FIGURES

# LIST OF FIGURES (continued)

# CHAPTER 1

# PAVEMENT PERFORMANCE OVERVIEW

## 1.1 INTRODUCTION

Airside pavements represent a large portion of the infrastructure investment at an airport. These pavements are designed to provide adequate load-carrying capacity, good ride quality, and above all, safe operation for all aircraft. However, once pavement construction is complete, pavements immediately begin a gradual deterioration due to surface weathering, structural fatigue, poor surface and subsurface drainage, and differential movement of pavement layers. Faulty construction techniques, sub-standard materials or poor workmanship can accelerate this deterioration process. Over time, many pavements are also subjected to loads much greater than those for which they were originally designed, or experience a considerable increase in takeoff and landing frequencies, contributing to premature pavement distress.

As with any investment, airport owners and sponsors want to build pavements that will provide the intended performance throughout the design life of the newly constructed runway, taxiway, or apron. Intended performance should be based on the life cycle costs (LCC) of a specific pavement type and the rate of deterioration throughout the design life. Ideally, the owner wants to build a pavement that has the longest life that will require no maintenance or major repair work, while providing a surface that is always safe for aircraft operations. In reality, we know that pavements must be maintained, rehabilitated, and potentially reconstructed at some point in the future once construction is complete.

All About Pavements, Inc.'s (API) research effort for the Southeast Chapter of the American Concrete Pavement Association (ACPA) focuses on actual performance of airport pavements in the southeastern area of the United States. This research effort does not evaluate the LCC of each pavement type in the southeast but focuses on the development of performance models for each type of pavement that is used by airport owners in the southeast. Performance models were developed using Pavement Condition Index (PCI) data that were collected as part of statewide Airport Pavement Management Systems (APMS) that have been implemented for Florida, Georgia, and South Carolina. Reported PCI values range from 100 ("Good Rating") to 0 ("Failed" Rating) as shown in Figure 1. (ASTM D5340-04)

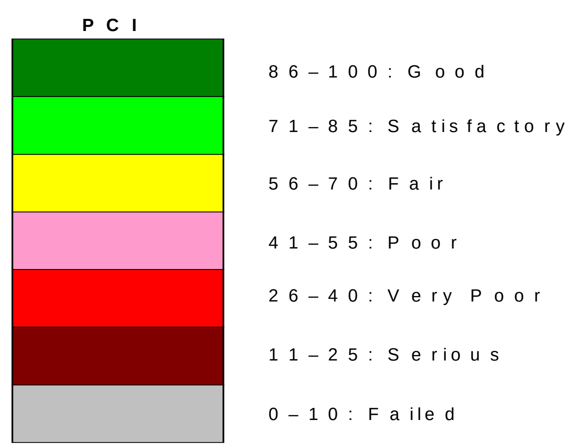


Figure 1: PCI Index Scale and Ratings.

The results of this study can be supplemented with the results from the "Life Cycle Cost Analysis for Airport Pavements" that is being conducted by Applied Research Associates, Inc. (AAPTP 06-06, 2009). The FAA, Airfield Asphalt Pavement Technology Program (AAPTP), and Innovative Pavement Research Foundation (IPRF) research programs are co-sponsors of this LCC study. The results will provide enhanced LCC analysis procedures that can be used by owners, operators, and designers to assist in the selection of a pavement type that best meets the objectives of an airport.

## 1.2 APMS OVERVIEW

The FAA recently issued updated guidance for an Airport Pavement Management System (FAA AC 150/5380-7A, 2006). This Advisory Circular "…discusses the APMS concept, its essential components, and how it can be used to make cost effective decision about pavement maintenance and rehabilitation." Also included within this AC is a list of potential benefits to be derived from the implementation of an APMS. These benefits include:

- An objective and consistent evaluation of the condition of a network of pavements;
- A systematic engineering basis for determining maintenance and rehabilitation needs;
- Identification of budget requirements necessary to maintain pavements at various levels of serviceability;
- Documentation on the present and future condition of the pavements in a network;
- Determination of life-cycle costs for various maintenance and rehabilitation (M&R) alternatives; and
- Identification of the impact on the pavement network as a result of performing major repairs.

All of these benefits lead to the implementation of an APMS that provides a systemic, consistent procedure for setting priorities and schedules, allocating resources, and budgeting for pavement maintenance and rehabilitation. As previously discussed, this research focuses on the documentation of the present and future condition of pavements in the southeast airport network of pavements. Historical conditions of airport pavements in Florida, Georgia, and South Carolina are documented with PCI distresses and analysis results that are stored in the MicroPAVER software program. MicroPAVER contains a Performance Modeling Tool (PMT) that can be used to develop performance model equations that are based on several factors including, but not limited to, pavement surface layer age, pavement type, pavement use (e.g. runway, taxiway, or apron), joint spacing, and climatic conditions.

The development of performance models is just one element of an APMS program that provides an integrated framework for comprehensive evaluation and decision making for managing airfield pavements. The essential components for a good APMS provide for an objective evaluation of the condition of existing pavements and identification of short-term and long-range rehabilitation, strengthening, and maintenance requirements, as well as costs to provide such maintenance or rehabilitation.

Historically, most organizations have made maintenance decisions based on past experience, without the benefit of documented data or analysis. This practice does not encourage a LCC analysis, nor an evaluation of the cost effectiveness of alternate scenarios, and can lead to the inefficient use of funds. With limited money to spend on new construction, reconstruction, and major M&R work, a defined procedure is necessary to help airport owners set priorities and schedules that will maximize the use of limited funds.

In examining the lifespan of a 20- or 30-year pavement, a “Good” to “Fair” condition rating may last only 12 to 15 years. After that point, the rate of deterioration of pavements accelerates sharply as the age of the pavement increases, and within five years, the pavement may deteriorate to the point of failure. In order to extend pavement life, maintenance and repairs need to be scheduled and performed before the pavement surface experiences a 40 percent drop in condition, as illustrated Figure 2. The point at which rehabilitation can be done at airports before the steep decline occurs is called the “critical PCI”, and typically occurs when the PCI is between 65 and 70. If the work is done before deterioration accelerates, the cost of rehabilitation can be reduced as shown in Figure 2 (APWA, 1983).

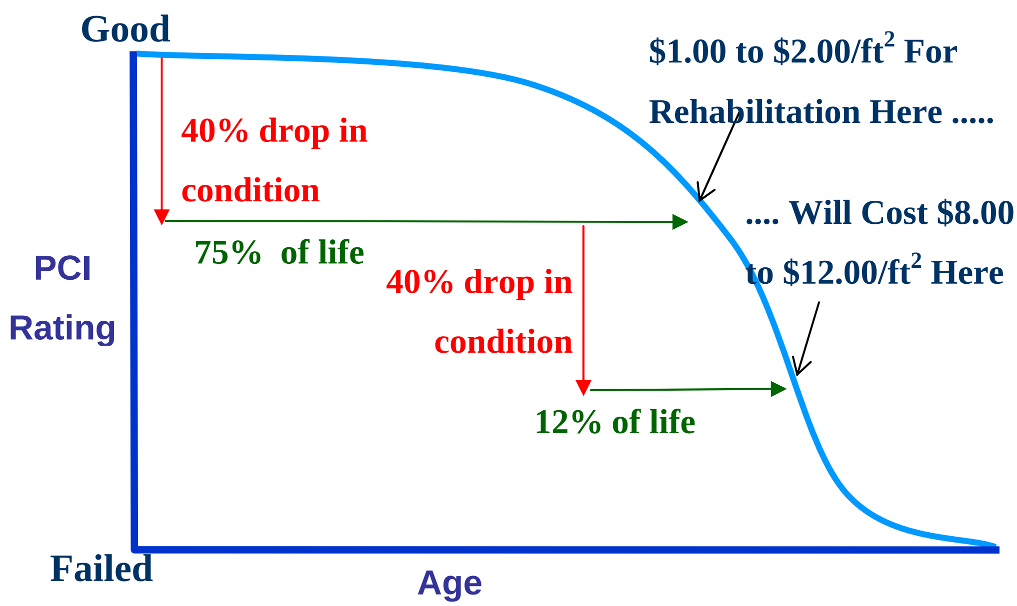


Figure 2: Illustration of a Pavement’s Life-Cycle Costs.

An APMS attempts to determine at what points on the curve a maintenance program should be implemented and at what cost. The point in the deterioration process at which an M&R program is implemented can make an enormous difference to the life of the pavement. Implementing an M&R program while the pavement is still in relatively good condition achieves almost three times the increase in life expectancy than delaying improvements for four years. However, funding availability may not always coincide with maintenance requirements, and therefore an APMS system can be a critical tool in predicting when to apply maintenance in order to maximize available funding.

# CHAPTER 2

## PERFORMANCE MODELING

Condition prediction models use the known pavement condition information as a basis to predict future deterioration trends. MicroPAVER uses a "family" model process to identify pavements with similar construction, traffic, weather, and other factors that may affect pavement life. The group of pavements assigned to a particular model is termed a *family*, and curves are generated based on the pavement's age and PCI data. These family curves are refined with each subsequent pavement inspection.

Performance modeling uses PCI results from each pavement section, or subcomponent of a runway, taxiway, or apron. A pavement branch, often referred to as pavement facility, consists of a pavement area with a distinct function (e.g. runway). Together, the pavement facilities and sections form the complete network inventory which will be managed by the airport owner.

As the smallest management unit in an APMS, it is important to carefully select the boundaries that identify the area of a pavement section. Since the objective is to identify all sections in the facilities and network that will have unique performance, each section has the same surface age (e.g. overlay age when there has been major rehabilitation work since original construction), construction surface (e.g. Asphalt Concrete {AC} or Portland Cement Concrete {PCC}), pavement cross section, aircraft fleet mix and departure routes, and other factors that may explain why performance is different throughout a runway, taxiway, or apron. It is important to note that the pavement age is always reset to zero when major rehabilitation work; such as AC overlays, millings and AC overlays, and PCC overlays; are completed on a pavement section.

The MicroPAVER condition analysis process predicts the condition of pavement sections by defining its position relative to the family prediction curve. It is assumed that the deterioration of pavements within a family is similar, and as such, the PCI can be predicted at the desired future age. The steps to PCI prediction include:

- Define the pavement family;
- Filter the data;
- Develop the family model; and
- Predict the pavement section condition.

To determine long-term M&R needs, the future condition of the pavement must be predicted. Future pavement condition is predicted using equation models that are generated from current and historical PCI data. Equation models are developed by grouping pavements based on similar performance characteristics such as construction history, surface type, traffic, rank and use. Mathematical techniques such as straight-line extrapolation and regression that include boundary and outlier filters are used to develop models that provide the best fit for the pavement condition data. Data within the MicroPAVER performance models are commonly referred to as 'Family Curves'.

For most airports, there are a minimum of four Family Curves based on the following pavement surface types and cross sections:

- AC
- AC overlaid AC (e.g. AAC)
- PCC
- AC overlaid PCC (e.g. APC)

For each of these four basic Family Curves, additional curves may be developed because other factors affect the performance of these sections. For example, AC and AAC performance may be significantly different when these pavement types are used on an apron compared to a taxiway or runway. Likewise, for state aviation offices that are responsible for the management of a network of public use General Aviation airports, these airports may be located in areas of the state that have significant differences in soil geology or climatic conditions.

This best fit curve for the family model is valid for the limits (age and condition) of the available data points. To predict future pavement condition, the curve is extrapolated by extending a tangent of the same slope as that of the curve for the last few years. Figure 3 illustrates curves that were developed for a commercial hub airport. As more PCI data are collected through future pavement inspections, these family curves can be updated to more accurately predict the future condition of each family of pavements based on performance and the amount of ongoing routine maintenance work at an airport.

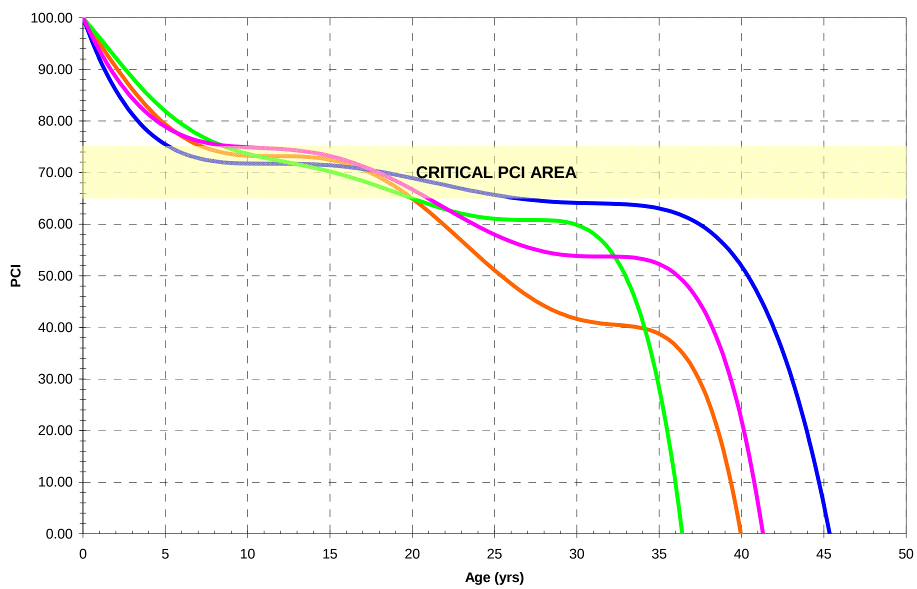


Figure 3: Illustration of Family Curves for Several Pavement Types and Maintenance Activity Levels.

# CHAPTER 3

# SOUTHEAST AIRPORT PAVEMENT INVENTORY

## 3.1 INTRODUCTION

Airside pavements from airports that are located in Georgia, Florida, and South Carolina were included in this study. The pavement inventory includes airports that were included as part of a statewide APMS. As a result, most of the airports included in this study are General Aviation (GA) and Reliever airports. No commercial hub airports were included in the study.

## 3.2 AIRSIDE INVENTORY

MicroPAVER databases from the Georgia, Florida, and South Carolina aviation offices were merged to create a SouthEast Airports (SEA) database. The State and SEA inventory are summarized in Table 1. As shown, Florida and Georgia have a similar number of total airports, but the average pavement inventory area per airport for Florida is more than double the area per airport for Georgia. The number of public use airports in South Carolina is about half of those in Georgia and Florida, but the average airport area is similar for Georgia and South Carolina.

Table 1: SEA Inventory for Georgia, Florida, and South Carolina.

| *Description* | *Georgia* | *Florida* | *South Carolina* | *Total* |
|---|---|---|---|---|
| *Total Airports* | 103 | 97 | 53 | 253 |
| *Runway Sections & (PCI*)* | 194 (81) | 929 (75) | 159 (73) | 1,282 (77) |
| *Taxiway Sections & (PCI*)* | 374 (79) | 2,747 (80) | 333 (79) | 3,454 (80) |
| *Apron Sections & (PCI*)* | 330 (76) | 1,136 (75) | 122 (75) | 1,588 (75) |
| *Helipad Sections & (PCI*)* | 4 (89) | - | 7 (88) | 11 (88) |
| *T-Hangar/Other (PCI*)* | 71 (89) | - | 53 (79) | 124 (89) |
| *Total Pavement Sections* | 973 | 4,812 | 674 | 6,459 |
| *Total Area ($Yd^2$)* | 15.5 million | 37.9 million | 6.4 million | 59.8 million |
| *Average Airport Area ($Yd^2$)* | 150,485 | 390,722 | 120,755 | 236,363 |
| *Average PCI** | 79.5 | 77.0 | 74.0 | 77.0 |

Note: * Indicates that all PCI values shown are area-weighted average PCI values.

The results in Table 1 show that there are more than twice the number of taxiways as runways or aprons in the SEA inventory and that the average taxiway condition is higher than the runways and aprons (e.g. PCI of 80 versus PCI values of 77 and 75). Often repairs to runways are delayed because of limited construction periods and repairs to aprons are delayed because these facilities have a lower funding priority for most agencies.

## 3.3 CLIMATIC CONDITIONS

Table 2 provides a summary of the range in climatic conditions that pavements are exposed to in the southeast (The Weather Channel, 2009). As the table shows, pavements at higher elevations in Georgia and South Carolina can be exposed to freeze-thaw cycles in the winter from December through February. The mean air temperature for January ranges from an average low of 32 degrees F. in Georgia and South Carlina to an average high of 76 degrees F in Florida. The average monthly rainfall is a low as 1.7 inches in Florida to as high as 8.4 inches in Florida. The amount of variability thorughout the Southeast depends on airport elevation, distance to coastal areas along the Atlantic Ocean and Gulf of Mexico, and other geograhical elements.

Table 2: Average Monthly Temperature and Rainfall Ranges by Season.

| | *State* | *Dec thru Feb* | *Mar thru May* | *Jun thru Aug* | *Sep thru Nov* |
|---|---|---|---|---|---|
| *High Temp Range( F )* | **GA[1]** | **53 — 63** | **63 — 82** | **86 — 89** | **70 — 85** |
| | **FL[2]** | **64 — 76** | **73 — 88** | **88 — 91** | **72 — 89** |
| | **SC[3]** | **52 — 62** | **62 — 84** | **86 — 92** | **62 — 85** |
| *Low Temp Range( F )* | **GA[1]** | **32 — 45** | **39 — 66** | **64 — 74** | **39 —71** |
| | **FL[2]** | **40 — 67** | **48 — 76** | **69 — 80** | **47 — 78** |
| | **SC[3]** | **32 — 41** | **40 — 63** | **65 — 73** | **39 — 68** |
| *Precip. Range ( in )* | **GA[1]** | **2.9 — 5.6** | **2.6 — 5.8** | **3.9 — 6.2** | **2.2 — 4.4** |
| | **FL[2]** | **2.0 — 4.8** | **1.7 — 5.8** | **4.8 — 8.4** | **1.7 — 6.8** |
| | **SC[3]** | **3.0 — 4.4** | **2.7 – 5.1** | **3.9 — 7.3** | **2.3 — 5.4** |

Notes: 1. Based on data for Dalton (North), Atlanta (North Central), and Brunswick (Southeast).
2. Based on data for Tallahassee (North), Orlando (Central), and Key West (South).
3. Based on data for Greenville (Northwest), Columbia (Central), and Charleston (Southeast).

In addition to the temperature and moisture variability through the southeast, there are significant differences in the geotechnical conditions within and among each of the states. Many of these areas have very good natural drainage while other geographic areas have poor natural drainage. In summary, the climatic and geotechnical variability may have a significant impact on the performance of the airside pavements.

## 3.4 PAVEMENT INVENTORY

As mentioned previously, there are four predominant types of pavement structures that have been built at airports in the southeast. The following discussion regarding the SEA inventory has been compared to Nebraska to see how this inventory compares to the inventory from a typical state in the midwest.

Figure 4 summarizes the PCC inventory that exists for these four states. Florida has the highest percentage of PCC inventory in the SEA database and the most PCC pavement. The percentages shown are based on the total pavement areas with a state. Although Georgia and South Carolina have a similar percentage of PCC pavement, Georgia has more than twice the PCC area of South Carolina. However, Florida has more than four times as much PCC pavement as Georgia.

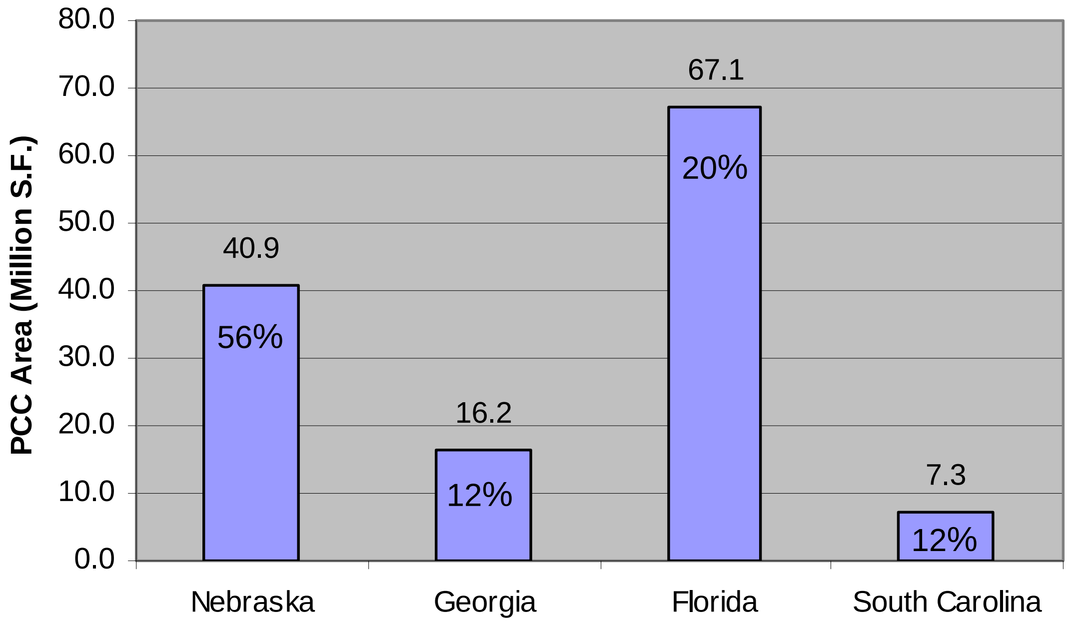


Figure 4: Amount of PCC Inventory in the SEA and Nebraska databases.

Figure 5 shows the quantity of APC pavements in the two databases. The inventory results show that South Carolina has the highest percentage of APC pavements (e.g. 4 percent). The results from the SEA database indicate that all of the states do not like to install AC overlay on existing PCC pavements. Rather than construct AC overlays, states prefer to either perform PCC restoration work (e.g. extensive patches, joint re-seal, and slab replacement) or they decide to reconstruct the PCC pavement if the repairs are too expensive or the pavement is in poor condition. This approach is in contrast to Nebraska where 27 percent of the airport pavement consists of APC.

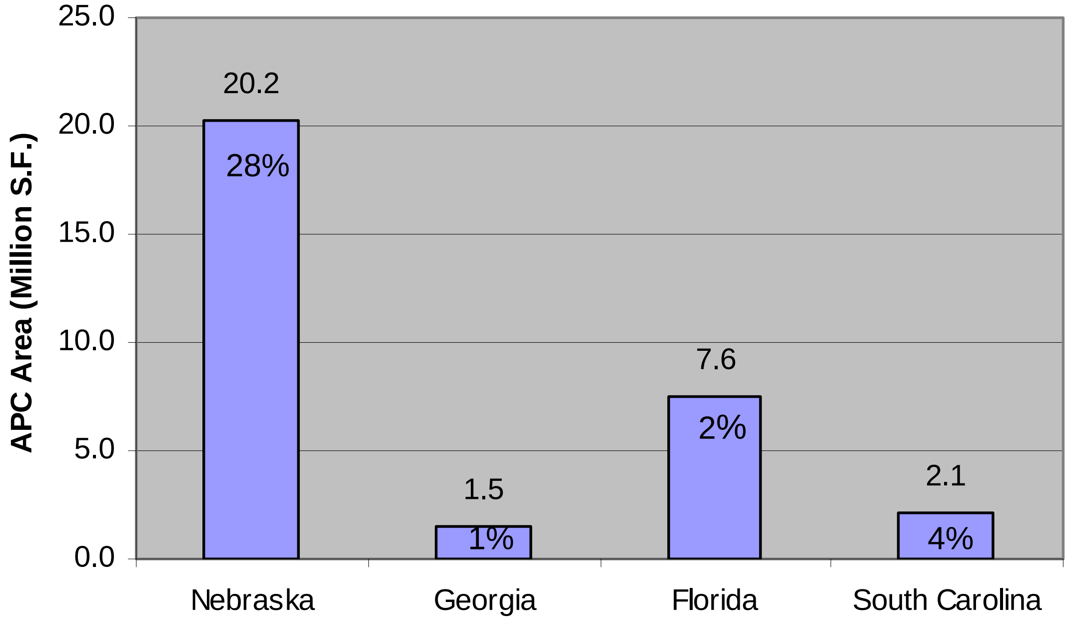


Figure 5: Amount of APC Inventory in the SEA and Nebraska databases.

Figures 6 and 7 show the amount of AC and AAC pavement area for each of the states. The results show that Florida and South Carolina have the highest percentage of AC inventory. However, 62 percent of Georgia's pavements consist of AC overlaid AC, indicating that they have a very aggressive AC overlay program throughout their state. These results indicate that either AC pavements perform better in Florida and South Carolina, or that these states prefer to have a more aggressive maintenance and repair program, thus relying less on AC overlays as a major rehabilitation strategy compared to Georgia.

Table 3 provides a summary of the inventory for the SEA database. For each range of age, the table provides a summary of the area weighted age and PCI. It is important to consider area weighted values in pavement management because an arithmetic average could bias the results. For example, consider a runway that has five pavement sections with four of the five sections each having an area of 50,000 $ft^2$ and the final section has an area of 300,000 $ft^2$. If the four smaller sections each have a PCI value of 80 and the large section has a value of 40, the arithmetic average PCI is 72 and the area-weighted average PCI is 56, a difference of 16 PCI points. Most experienced PCI surveyors would agree that a PCI of 56 is more representative of a runway where 60 percent of the pavement area has a PCI of 40. This same approach is appropriate when the age of pavements is considered in an APMS.

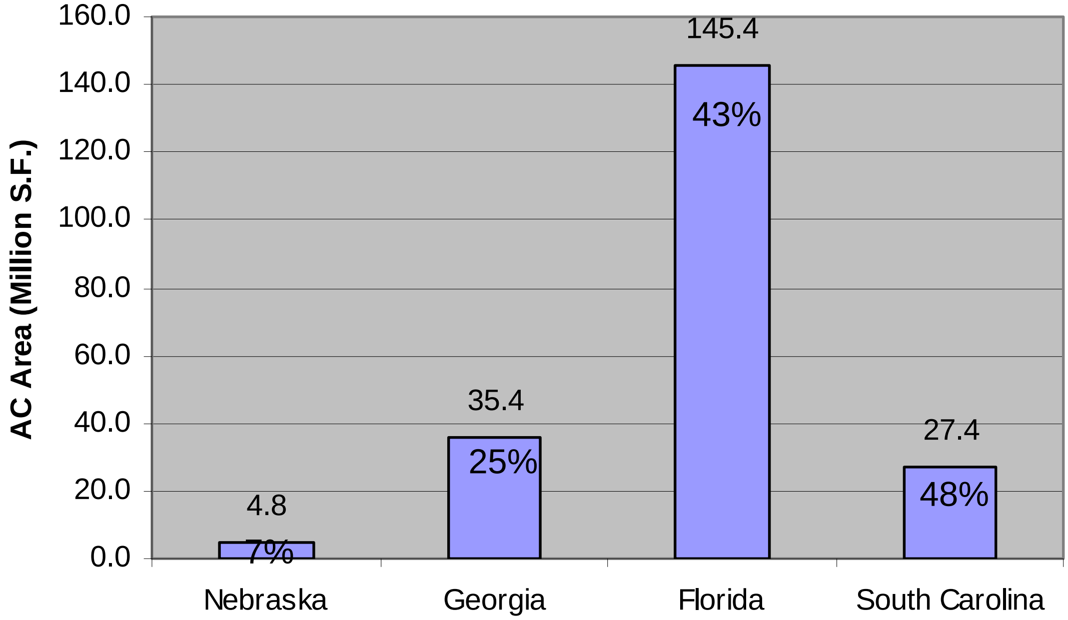


Figure 6: Amount of <u>AC</u> Inventory in the SEA and Nebraska databases.

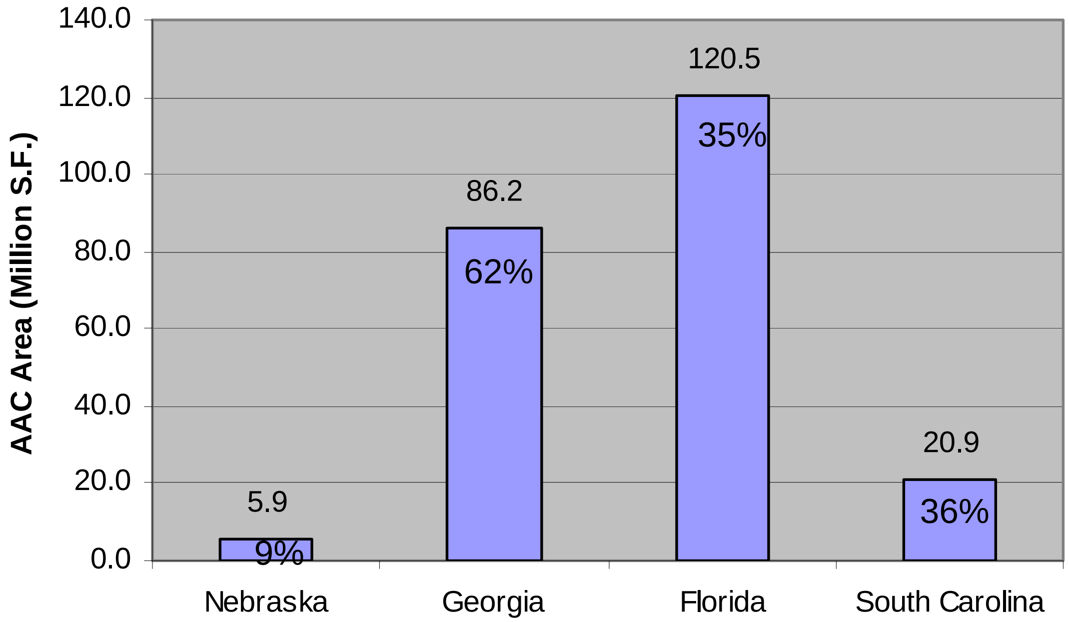


Figure 7: Amount of <u>AAC</u> Inventory in the SEA and Nebraska databases.

Table 3: SEA Pavement Inventory Age.[1]

| *Age (Years)* | *Weighted Average Age[1]* | *Weighted Average PCI* | *Number of Sections* | *Percent of Area* | *Area, Square Feet* |
|---|---|---|---|---|---|
| *0-5* | 1.8 | 96.0 | 1,731 | 27 | 142,109,123 |
| *6-10* | 7.9 | 83.4 | 1,201 | 18 | 97,344,930 |
| *11-15* | 13.0 | 77.2 | 795 | 13 | 68,122,338 |
| *16-20* | 17.6 | 69.4 | 845 | 12 | 62,776,556 |
| *21-25* | 22.4 | 62.7 | 545 | 9 | 48,641,074 |
| *26-30* | 28.1 | 66.1 | 338 | 5 | 28,381,267 |
| *31-35* | 33.2 | 57.3 | 250 | 3 | 15,177,214 |
| *36-40* | 38.0 | 68.1 | 185 | 2 | 13,280,693 |
| *41-50* | 44.9 | 68.1 | 141 | 2 | 12,777,939 |
| *> 50* | 61.0 | 54.7 | 428 | 9 | 49,480,518 |
| | | Total | 6,459 | 100% | 538,091,652 |

Note 1: Age as of the last PCI survey date.

The results in Table 3 show that 70 percent of the airport pavement area in Georgia, South Carolina, and Florida is less than 20 years old. In addition, the area-weighted PCI values are 70 or higher for the 4,572 (71 percent of all sections) that are less than 20 years old. From a pavement performance viewpoint, this means the average annual deterioration during the first 20 years of the pavements life is approximately 1.5 PCI points per year (e.g. {100 - 69.4}/20).

Figure 8 shows how the airports deteriorate over time. As this figure indicates, airports in the SEA database have almost a linear deterioration for the first 20 years followed by occasional increases in the PCI as aviation departments conduct major rehabilitation work for the next 25 to 30 years. Since Figure 8 shows the performance of all types of pavements, the next chapter introduces Performance Modeling as a tool that is used in an APMS to gain better insight in the performance of each pavement type for each type of pavement facility (e.g. runway versus apron).

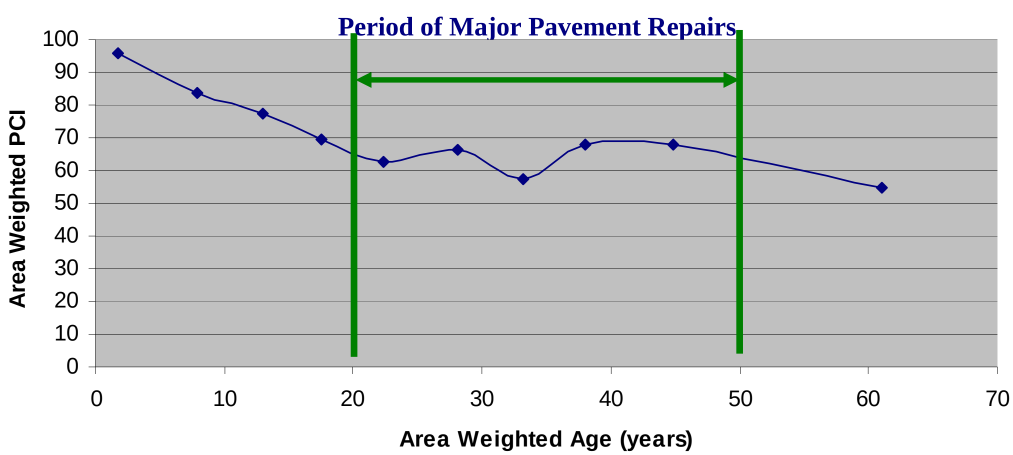


Figure 8: Pavement deterioration rates for all pavements in the SEA database.

# CHAPTER 4

# SEA PERFORMANCE MODELS

## 4.1 INTRODUCTION

The preceding chapter focused on the inventory that exists in the SEA database and provides a summary of the condition of all pavement types. However, before owners decide on the types of new pavement that should be constructed, or the type of overlay that should be constructed when major rehabilitation work is required at a critical point in the design life, careful consideration should be given to past performance of each pavement type. While this study does not address Life Cycle Cost Analysis (LCCA) as a tool that should be considered in the selection of rehabilitation methods, the development of performance models provides owners with a tool that can be used to assist in the LCCA and make informed decisions with regard to their pavement investments.

## 4.2 CURRENT CONDITION AND AGE

Before performance models are developed, it is important to review the most recent conditions and average ages of each pavement type. This information will provide an improved understanding of the performance models that were developed during this study. While the following results are based on the most recent PCI results, it is important to realize that most pavement sections in the SEA database have been inspected multiple times and that all PCI values and inspection dates were used in the development of the performance models.

Figure 9 provides a comparison of PCC pavement condition and ages for each state in the SEA database and Nebraska. As shown, the area-weighted PCI for Nebraska is 11 points higher than the values for Georgia, Florida, and South Carolina. However, the average age of Nebraska PCC pavements is at least 14 years younger than the other states. Of interest is the fact that the PCI values for the three SEA states is the same (e.g. 80) but the average age of the PCC pavement for South Carolina is 20 to 22 years older than the PCC pavements for Georgia and Florida.

The importance of area-weighted age is illustrated in Figure 10 which summarizes the AC pavement condition and ages. While the PCI values range from a high of 85 in Nebraska to a low of 69 in South Carolina, it would be incorrect to assume that AC pavements simply have poorer performance in South Carolina. However, Figure 10 shows that the youngest AC pavements are located in Georgia and the oldest are located in South Carolina. As a result, the average deterioration rate per year for AC pavements is as approximately one PCI point year for both Nebraska and South Carolina as shown in Table 4.

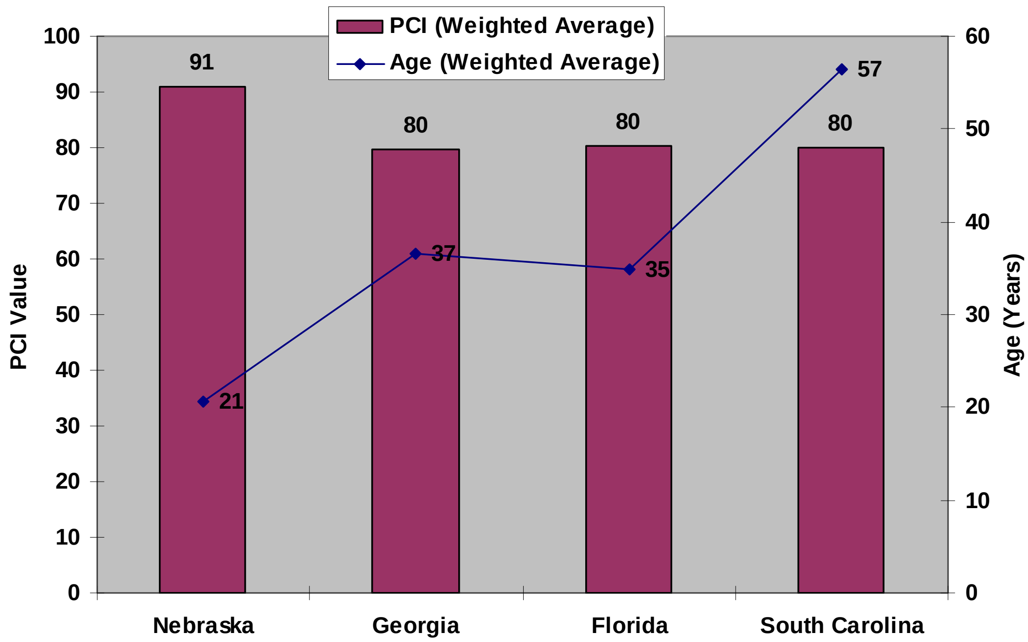


Figure 9: SEA and Nebraska Area-weighted PCI and Age values for PCC pavements.

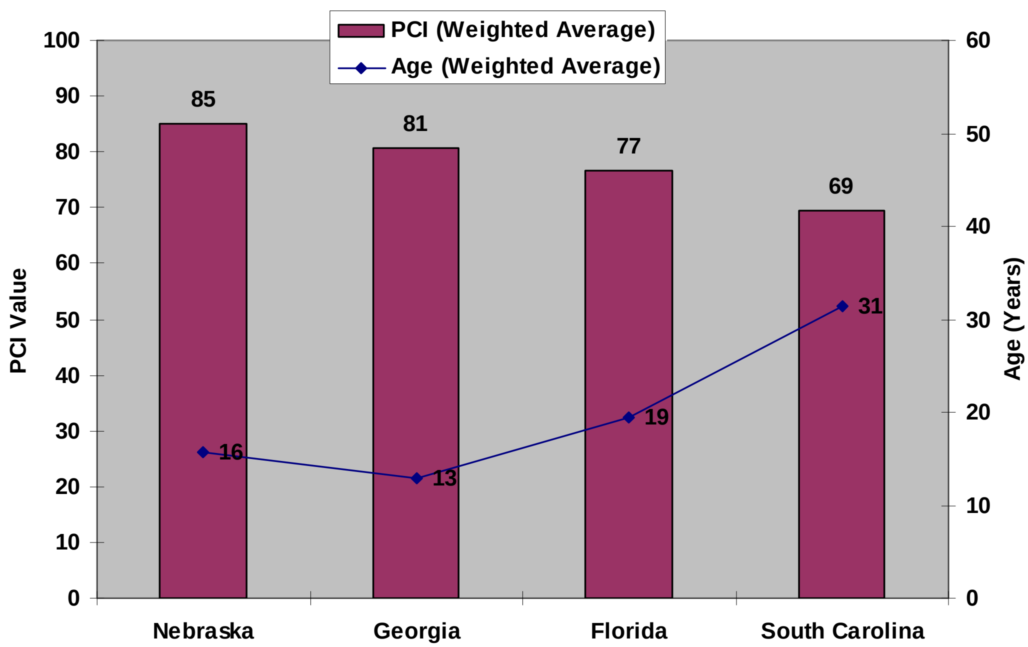


Figure 10: SEA and Nebraska Area-weighted PCI and Age values for AC pavements.

Table 4: Average Annual Deterioration Rates.[1]

| *Pavement Type* | *State* | *Weighted Average Age[1]* | *Weighted Average PCI* | *Average Annual Deterioration PCI Pts/Year* |
|---|---|---|---|---|
| *PCC* | Nebraska | 21 | 91 | 0.4 |
| | Georgia | 37 | 80 | 0.5 |
| | Florida | 36 | 80 | 0.6 |
| | S. Carolina | 57 | 80 | 0.4 |
| | | | State PCC Average | 0.5 |
| *AC* | Nebraska | 16 | 85 | 0.9 |
| | Georgia | 13 | 81 | 1.5 |
| | Florida | 19 | 77 | 1.2 |
| | S. Carolina | 31 | 69 | 1.0 |
| | | | State AC Average | 1.2 |
| *APC* | Nebraska | 16 | 83 | 1.1 |
| | Georgia | 18 | 69 | 1.7 |
| | Florida | 21 | 66 | 1.6 |
| | S. Carolina | 18 | 80 | 1.1 |
| | | | State APC Average | 1.4 |
| *AAC* | Nebraska | 22 | 74 | 1.2 |
| | Georgia | 12 | 79 | 1.8 |
| | Florida | 16 | 76 | 1.5 |
| | S. Carolina | 20 | 80 | 1.0 |
| | | | State AAC Average | 1.4 |

Note 1: Age as of the last PCI survey date.

As shown in Table 4, AC overlays on PCC and AC do not perform as well as originally constructed AC and PCC pavements. *For both AAC and APC, the average State deterioration is 1.2 to 1.4 PCI points per year which is almost one full PCI point higher than PCC pavements*. Figure 11 shows that Nebraska and South Carolina have good PCI values but the area-weighted PCI values for Georgia and Florida are just below 70. This figure indicates that on average, most AC overlays on PCC have a design life of less than 20 years, which is generally accepted as a typical life in the industry.

Most industry experts assume that AC overlays on PCC do not perform as well as AC overlays on existing AC pavements. However, as previously mentioned, the state average deterioration for APC and AAC is about the same (Table 4). This is also apparent when Figures 11 and 12 are compared. As was the case for APC, Figure 12 indicates that the design life of AC overlays on existing AC pavements is generally no more than 20 years.

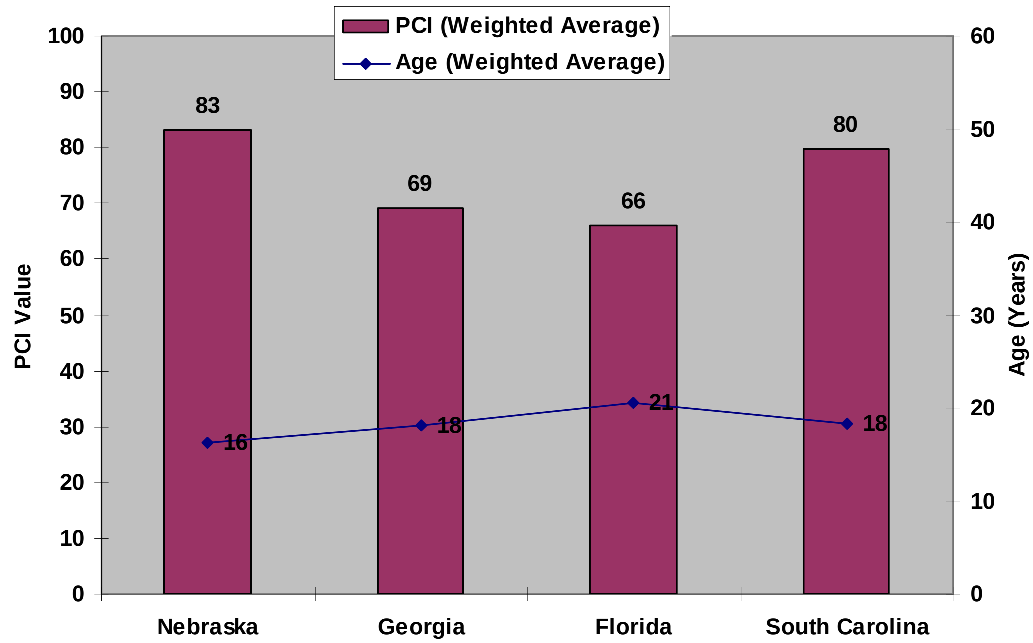


Figure 11: SEA and Nebraska Area-weighted PCI and Age values for APC pavements.

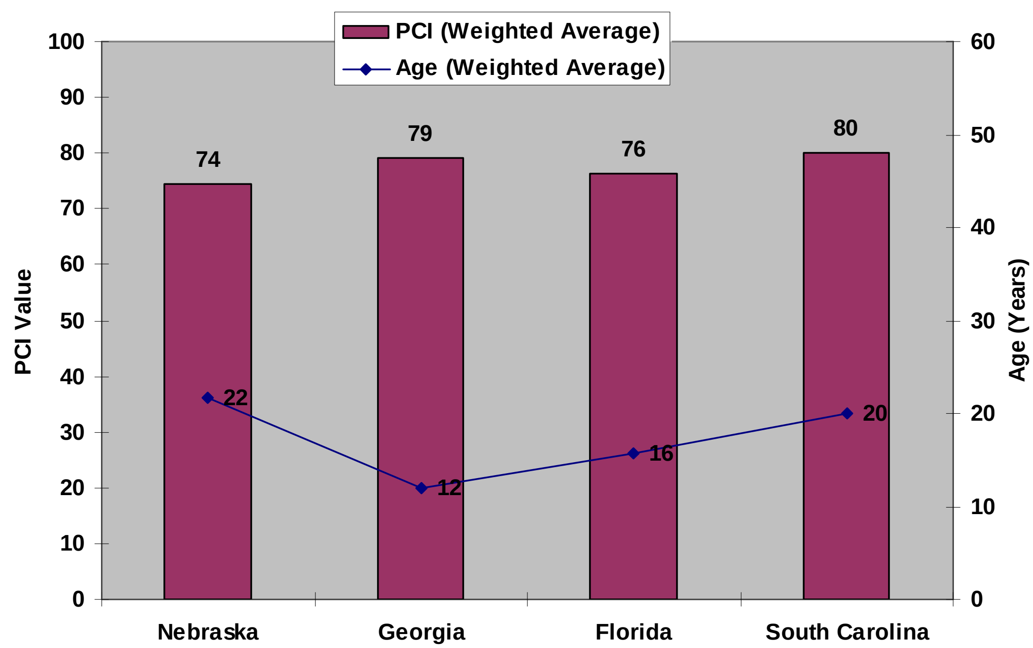


Figure 12: SEA and Nebraska Area-weighted PCI and Age values for AAC pavements.

## 4.3 PREDICTED PAVEMENT CONDITIONS

The previous section provided an overview of the age and condition of each type of pavement at the time of the last inspection. However, it is important to predict future performance of each pavement type by including all previous inspection data and the ages of each pavement section at the time of those inspections. The Performance Modeling tool in MicroPAVER was used to develop curves for each type of pavement.

Table 5 provides a general description of the seven standard ASTM ratings and the associated type of repair work that will be required in the near future. However, many agencies prefer a simplified 3-category rating system. This 3-color system includes simplified ratings of "Good", "Fair", and "Poor" as show in Table 5. Typical design lives that have been established by agencies for their pavement infrastructure include 20, 30, and 40 years. Depending on the design objective, the agency would expect the pavement to perform very well during this period so that the PCI value is 70 or higher when it is 20 or 30 years old.

Table 5: Simplified and Standard PCI Rating Scales.

| ***Simplified PCI Color Legend*** | ***ASTM PCI Color Legend*** | ***PCI Ranges*** | ***Definition*** |
|---|---|---|---|
| | | 86-100 | <u>GOOD</u>: Pavement has minor or no distresses and should require only routine maintenance. |
| | | 71-85 | <u>SATISFACTORY</u>: Pavement has scattered low-severity distresses that should require only routine maintenance. |
| | | 56-70 | <u>FAIR</u>: Pavement has a combination of generally low- and medium-severity distresses. Near-term maintenance and repair needs may range from routine to major. |
| | | 41-55 | <u>POOR</u>: Pavement has low-, medium-, and high-severity distresses that probably cause some operational problems. Near-term M&R needs range from routine to major. |
| | | 26-40 | <u>VERY POOR</u>: Pavement has predominantly medium- and high-severity distresses that cause considerable maintenance & operational problems. Near-term M&R needs will be major. |
| | | 11-25 | <u>SERIOUS</u>: Pavement has mainly high-severity distresses that cause operational restrictions; immediate repairs are needed. |
| | | 0-10 | <u>FAILED</u>: Pavement deterioration has progressed to the point that safe aircraft operations are no longer possible; complete reconstruction is required. |

Figure 13 shows the performance modeling results by pavement use for all airports in the SEA database. Simplified PCI rating scales have been placed at the 20- and 30-year age points to illustrate how PCC pavements are performing in the southeast if common design lives were used in the original construction or rehabilitation work. Although PCC aprons do not perform as well as PCC runways and taxiways, PCC aprons typically have a PCI value that is Good, or above 70 after 30 years of service.

The dark blue line represents the model for all PCC pavements in the SEA database. The blue star is the area-weighted average PCI that is plotted against the area-weighted average Age for all PCC pavements. The star's location demonstrates that PCC pavements in the SEA database are performing very well.

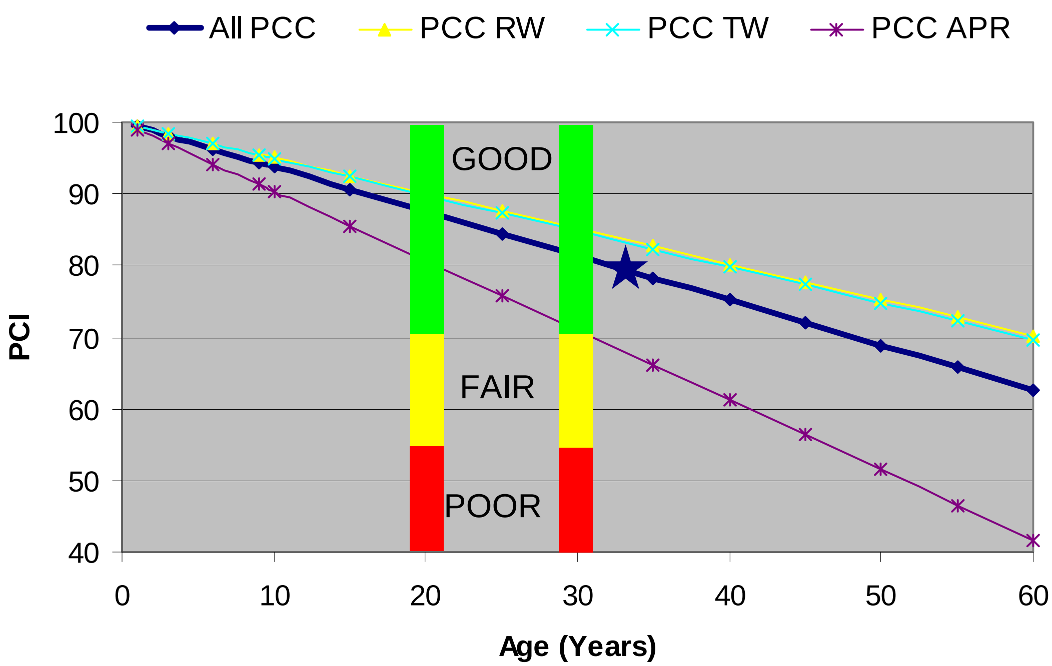


Figure 13: SEA Performance Model for PCC pavements.

For AC pavements, Figure 14 also shows the performance modeling results by pavement use for all SEA airports. As was the case for PCC, AC aprons do not perform as well as AC runways and taxiways. AC aprons typically have a PCI value that is Good, or above 70 when they are 20 years old, but the PCI value falls into the Fair category as the aprons approach 30 years of service. Although the runway and taxiway PCI values are not as low as the aprons after 30 years, they have fallen below a critical PCI value of 70.

The dark blue line for all AC pavements shows that on average, AC pavements are predicted to be at the critical point in their design life after 20 years of service. However, the blue star, which shows the actual area-weighted average PCI and Age, indicates that AC pavements provide at least 20 years of service. But the results also suggest that more frequent rehabilitation is required because the area-weighted age is 17 versus 33 years for PCC pavements.

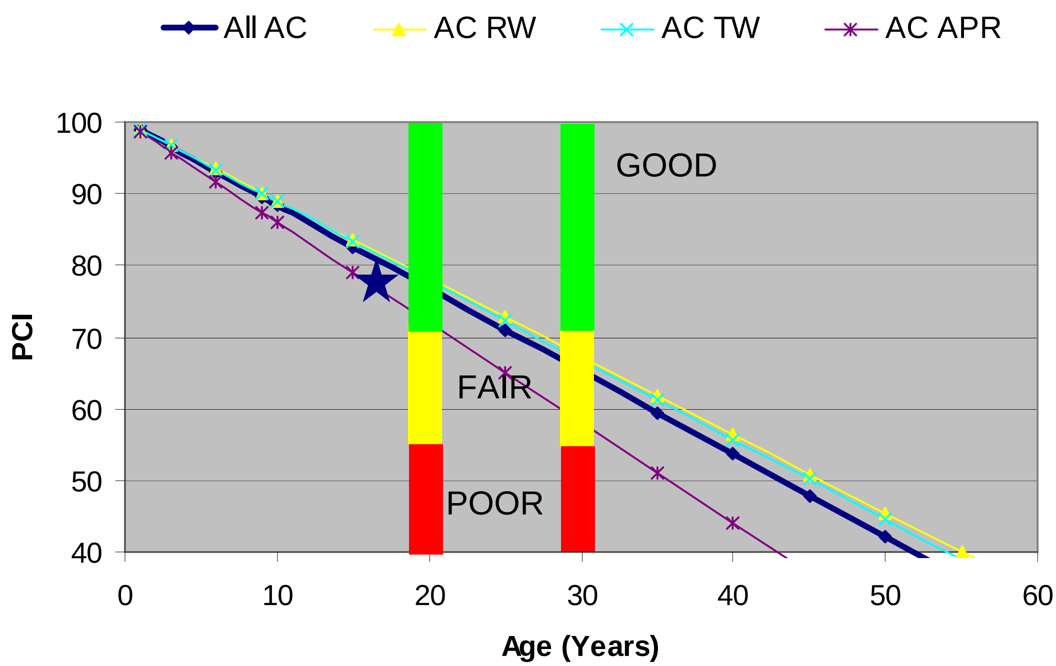


Figure 14: SEA Performance Model for AC pavements.

As the AC and PCC pavements age, a common rehabilitation alternative for these pavement types is the construction of an AC overlay. For APC pavements, the performance model in Figure 15 illustrates the challenges that must be addressed when AC overlays are constructed on jointed PCC pavements. For APC, neither aprons nor taxiways perform as well as APC runways. APC aprons and taxiways typically have a PCI value that is about 60, or Fair, when they are 20 years old. Furthermore, if no rehabilitation work occurred between 20 and 30 years of age, aprons and taxiways would have Poor surfaces with PCI values approaching 40. While AC overlays do perform better on runways, the PCI is predicted to be in the Fair to Poor category after 20 to 30 years of service, respectively.

The dark blue line for all APC pavements in the SEA database shows that on average, APC pavements are predicted to be at the critical point in their design life after 15 years of service. The blue star, which shows the actual area-weighted average PCI and Age, supports these performance models as the average age is slightly more than 15 years. Joint reflection cracking has always been a significant challenge as engineers attempt to reduce the rate of development and severity of these cracks.

For AC overlays constructed on existing AC pavements, Figure 16 shows that AAC pavements do not perform better than APC pavements in the SEA database. For AAC,

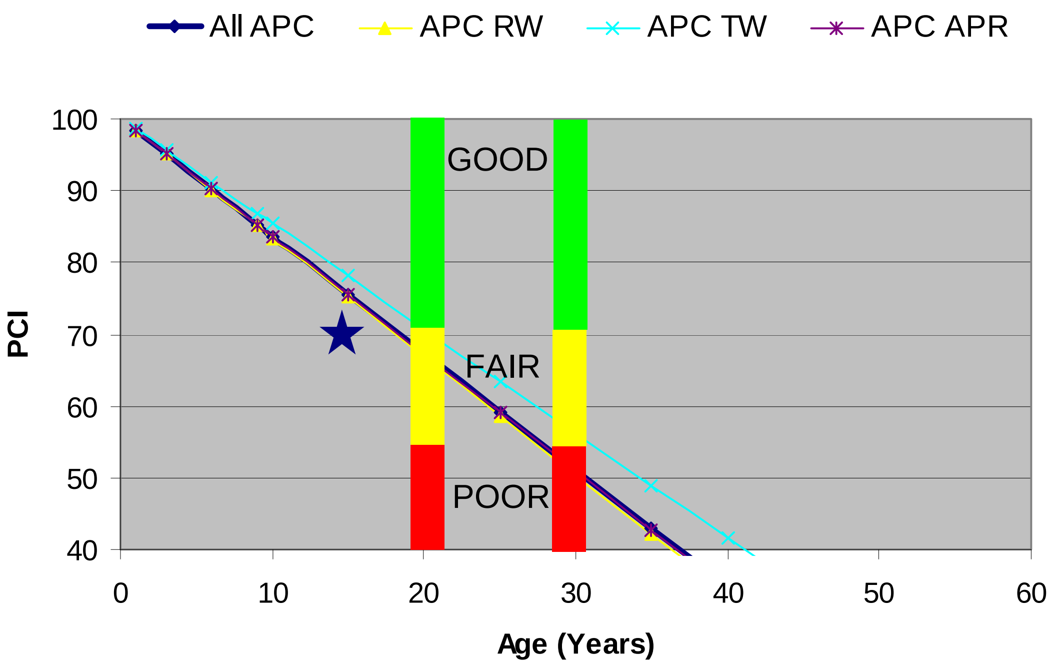


Figure 15: SEA Performance Model for APC pavements.

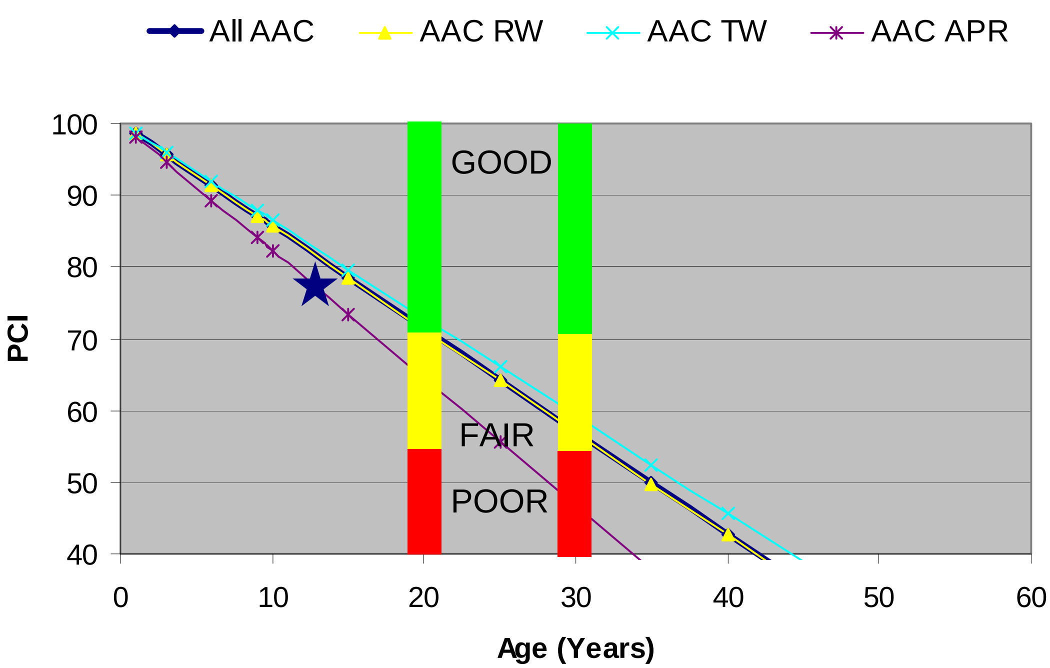


Figure 16: SEA Performance Model for AAC pavements.

aprons do not perform as well as AAC taxiways and runways. AAC aprons typically have a PCI value that is about 60 (e.g. same as APC aprons), or Fair, when they are 20 years old. As was the case for APC pavements, if no rehabilitation work occurred between 20 and 30 years of age, all AAC pavements would have Poor surfaces with PCI values approaching 40. While AC overlays do perform better on runways, the PCI is predicted to be in the Fair to Poor category after 20 to 30 years of service, respectively.

The dark blue line for all AAC pavements in Figure 16 shows that on average, AAC pavements are predicted to be at the critical point in their design life after 18 years of service. The AAC blue star, which shows the average PCI and Age, occurs at 12 years with a PCI value of 77, compared to the APC blue star located in the chart at 15 years and a PCI of 69.

Figure 17 shows the MicroPAVER performance models for all pavement sections within each pavement type in the SEA database. The results clearly show that AC and PCC pavements are performing much better than AAC and APC. However, as was mentioned earlier in this study, a LCCA would incorporate performance results during planning and design by also considering construction and other tangible costs, including user costs. For example, it is generally less expensive to construct an AC overlay than it is to construct a new AC or PCC pavement, but improved performance will offset higher initial construction costs. Without a doubt, it is clear that PCC pavements are outperforming all other types of pavements, as illustrated in the performance models and the actual area-weighted PCI and Age values from the most recent inspection.

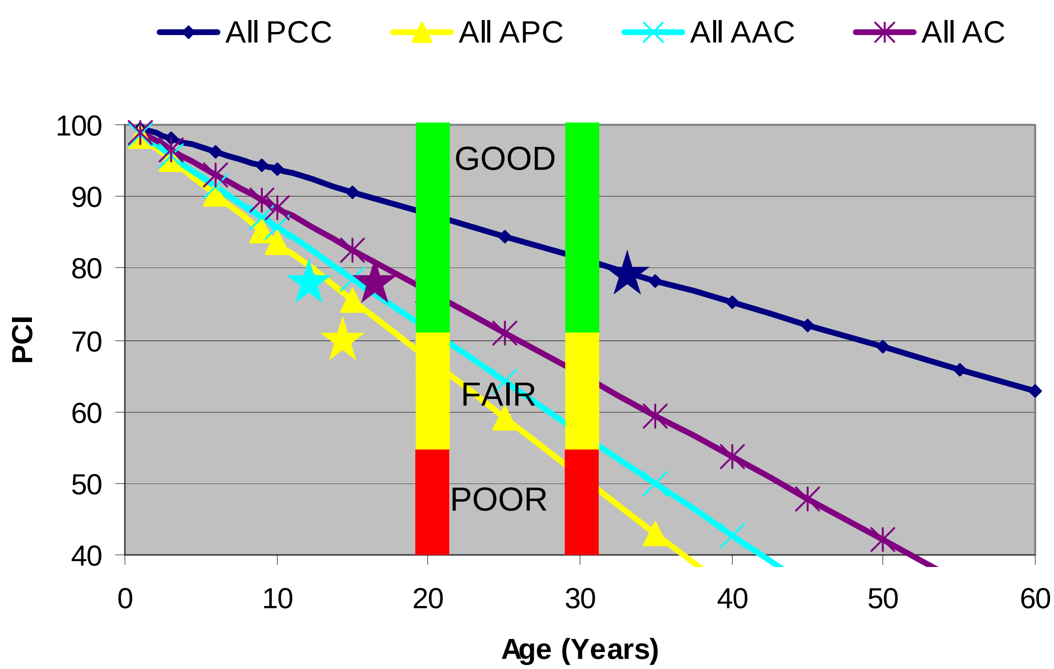


Figure 17: Summary of SEA Performance Models for AC, PCC, AAC, and PCC.

It is important to note that MicroPAVER automatically chooses the order of the regression equation that provides the best fit for each pavement family. However, for the modeling analysis of the SEA database pavements, there was very little difference in the results (e.g. coefficient of correlation and $R^2$) that were obtained using a linear regression versus a higher order regression that is selected by MicroPAVER. To provide an easier method of understanding the differences between the performances of pavement families, the linear models were presented in the previous figures. Statistical results from the linear regression are summarized in Table 6.

Table 6: Performance Model Statistical Summary.

| *Pavement Type* | *Use* | *Linear Deterioration Rate (PCI/yr)* | *Coeff. Of Correlation* | *$R^2$* | *St.Dev. Of Error* | *Abs. Mean of Error* | *Arith. Mean of Error* |
|---|---|---|---|---|---|---|---|
| *PCC* | All | -0.6195 | 0.632 | 0.400 | 17.202 | 12.713 | 0.840 |
| | Runway | -0.4957 | 0.544 | 0.296 | 16.518 | 13.258 | 0.310 |
| | Taxiway | -0.5047 | 0.739 | 0.546 | 10.688 | 7.696 | 0.714 |
| | Apron | -0.9713 | 0.677 | 0.458 | 22.677 | 17.622 | -0.296 |
| *AC* | All | -1.1580 | 0.696 | 0.484 | 15.429 | 12.044 | -1.962 |
| | Runway | -1.0913 | 0.754 | 0.568 | 16.021 | 12.627 | -1.827 |
| | Taxiway | -1.1081 | 0.688 | 0.474 | 15.005 | 11.701 | -1.745 |
| | Apron | -1.3995 | 0.665 | 0.443 | 15.649 | 12.169 | -1.890 |
| *APC* | All | -1.6332 | 0.488 | 0.239 | 19.733 | 15.833 | -4.433 |
| | Runway | -1.6560 | 0.466 | 0.199 | 18.006 | 12.909 | -3.147 |
| | Taxiway | -1.4599 | 0.540 | 0.292 | 16.466 | 13.911 | -3.088 |
| | Apron | -1.6353 | 0.493 | 0.243 | 22.275 | 18.558 | -6.389 |
| *AAC* | All | -1.4318 | 0.567 | 0.321 | 14.716 | 11.410 | -1.748 |
| | Runway | -1.4353 | 0.545 | 0.297 | 15.022 | 11.755 | -2.353 |
| | Taxiway | -1.3577 | 0.543 | 0.295 | 14.742 | 11.484 | -1.424 |
| | Apron | -1.7756 | 0.754 | 0.568 | 12.591 | 9.508 | -1.151 |

The results in Table 6 show that the coefficient of correlation is best for AC and PCC pavements with values of 0.696 and 0.632, respectively. The coefficient of correlation is not as good for APC and AAC pavements. For these AC overlaid pavements, the poorer correlation may be attributed to the methods of treatment of AC and PCC distresses (e.g. linear cracks, alligator cracking, PCC spalls, and poor patches) prior to the construction of AC overlays.

In addition to existing distresses, the amount of vertical and horizontal movement at joints in PCC pavements influence the rate and severity of reflective crack development. Several pre-overlay methods are available to minimize crack development at the joints but the effectives of the methods can vary significantly. Since temperature-related shrinkage cracks occur in AC pavements, pre-overlay repairs may also influence the performance of AC overlays for AC pavements.

# CHAPTER 5

# SEA PAVEMENT DURABILITY

## 5.1 INTRODUCTION

The previous chapters have focused on one functional condition methodology, the Pavement Condition Index (PCI) survey. However, from the distress data that are collected during the PCI survey, additional functional indices can be computed such as the Structural Condition Index (SCI) and the Foreign Object Damage (FOD) condition indices. For airports, there are other visual condition indices that exist and can be used to rate the surface condition of flexible and rigid pavements.

In addition to visual assessments, other types of functional data that can be collected for airport pavements include, surface friction characteristics and surface smoothness. All of these data are used to determine the Remaining Functional Life (RFL), in years, of a pavement. However, in addition to the RFL, it is important to know the Remaining Structural Life (RSL) of a pavement. The RSL can be determined through materials testing in a laboratory and in the field, nondestructive deflection testing (NDT) using a Falling Weight Deflectometer (FWD), nondestructive testing using Ground Penetrating Radar (GPR), and structural analyses of these data. If aircraft fleet, annual operations, and traffic flow are known, a structural analysis of the data will provide allowable aircraft loads and departures, structural overlay or reconstruction thicknesses, and the Pavement Classification Number (PCN).

## 5.2 IMPROVED FUNCTIONAL ASSESSMENT

The results of this study have shown that results from a PCI survey can be very useful in assessing the performance of each pavement type in airports located in the southeast. However, Chapter 4 also demonstrates the importance of knowing the area-weighted average age of all sections that have the same surface type. When average ages are plotted in conjunction with PCI performance curves, true performance becomes more readily apparent in the comparison of several pavement types.

When age is plotted with performance models, the immediate question that should be asked is “What is the intended Design Life (DL) of each pavement type?” Although many factors can determine the Design Life of the pavement, the following are typical ranges for the Intended Design Life (IDL) of each pavement type that was evaluated in this study:

- Asphalt Concrete (AC): 20 to 30 years
- Portland Cement Concrete (PCC): 20 to 40 years
- AC overlays on AC: 10 to 20 years
- AC overlays on PCC: 10 to 15 years

When the average ages of each pavement type are compared with the IDLs in the SEA database, it is obvious that there are significant differences in performance of each pavement type within their IDL range. For example, the average age of PCC in the SEA database is 33 while the age of AC is 17. There are several factors that impact the average age including, but not limited to:

- Frequency of pavement rehabilitation work including:
  - Milling of AC pavements and overlay with AC or PCC
  - Overlay of PCC pavements with AC or PCC
  - Re-milling of existing AC overlays and overlay with AC or PCC
- Frequency of reconstruction
  - What is the agency-established PCI for failed AC pavements?
  - What is the agency-established PCI for failed PCC pavements?
  - Are APC pavements typically reconstructed, or milled and overlaid with AC?
- Pavement Construction Budgets
  - Have there been major increases or decreases in the amount of rehabilitation work?
  - Have there been major increases or decreases in the amount of new construction work?
  - Have there been changes in pavement preservation and maintenance work of aviation departments?

Because of the importance of Age in assessing performance, API proposes the concept of a Performance and Durability (PDF), which is defined as follows:

$$\mathbf{PDF} = \frac{(\mathbf{PCI_{awa}} * \mathbf{AGE_{awa}})}{(\mathbf{PCI_{cr}} * \mathbf{IDL})} \qquad \text{Equation 1}$$

Where:

PDF = Performance and Durability Factor
$PCI_{awa}$ = Area-Weighted Average PCI from MicroPAVER
$AGE_{awa}$ = Area-Weighted Average Age from MicroPAVER
$PCI_{cr}$ = Agency-Established Critical PCI by Use (e.g. runway)
IDL = Intended Design Life

The numerator in Equation 1 represents the benefit that an agency has realized from historical use of a specific paving material. Most pavement management systems express this benefit as the area under the performance curve as shown in Figure 18. As illustrated in this figure, the benefit will depend on the age and condition at which a specific type of repair is made to a pavement section. Performance models are used to predict the future PCI of a section before and after the treatment is applied. The amount of improvement in the PCI in the future depends on the projected PCI and the type of repair that is made to the section.

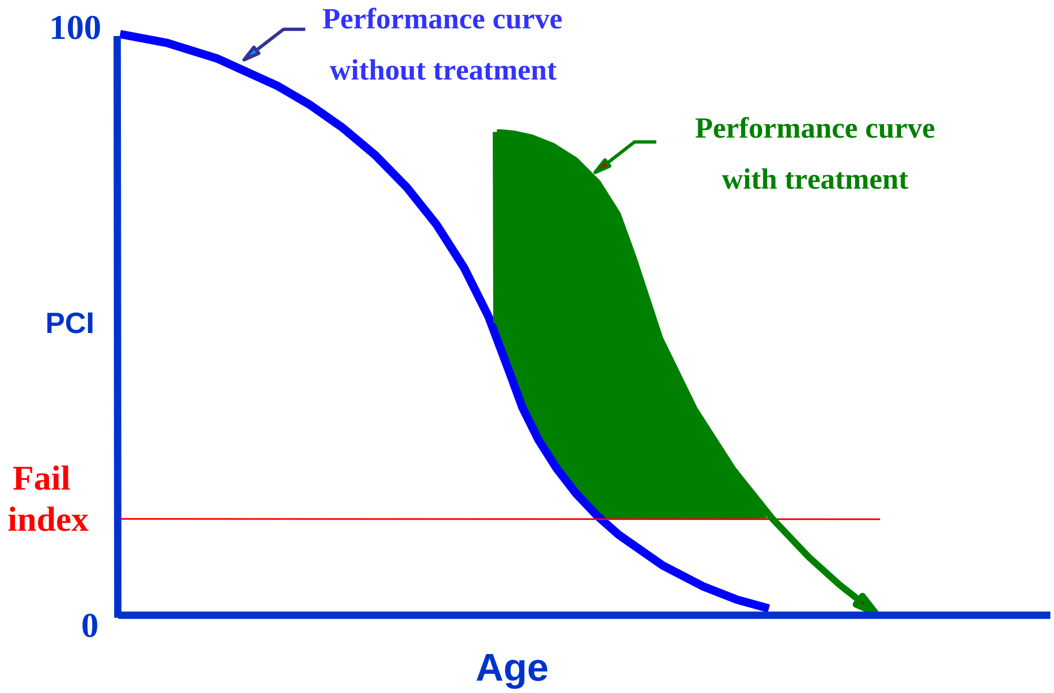


Figure 18: Benefit of repairing a pavement section in the future.

For the SEA database, the benefit that has been obtained for each type of pavement is maximized by maintaining the pavement at the highest possible PCI for the longest period of time before major rehabilitation work is accomplished. Although AC pavement sections in the database may not have historically had a design life that is as high as PCC sections, a higher benefit may have been realized if the PCI values are typically much higher than PCC pavements. Since the numerator incorporates the physical area of each section, it does provide a realistic indication of past performance in terms of condition and longevity.

The denominator in Equation 1 expresses the "Targeted Benefit" that is sought by an aviation department or owner for each type of paving material. The Targeted Benefit depends on the critical PCI and the Intended Design Life (IDL). The critical PCI values depend on the use and importance of the pavements as well as the predicted performance of paving material. The critical PCI that was illustrated in Figure 2 from only a performance perspective, can be further refined as shown in Figure 19.

Primary pavements generally include the runways, parallel taxiways, and the main apron. Secondary pavement may include crosswind runways that are used very little and taxiway connectors between the parallel taxiway and runway. Tertiary pavements typically include pavements that are used very little but have been kept in the active inventory by the airport.

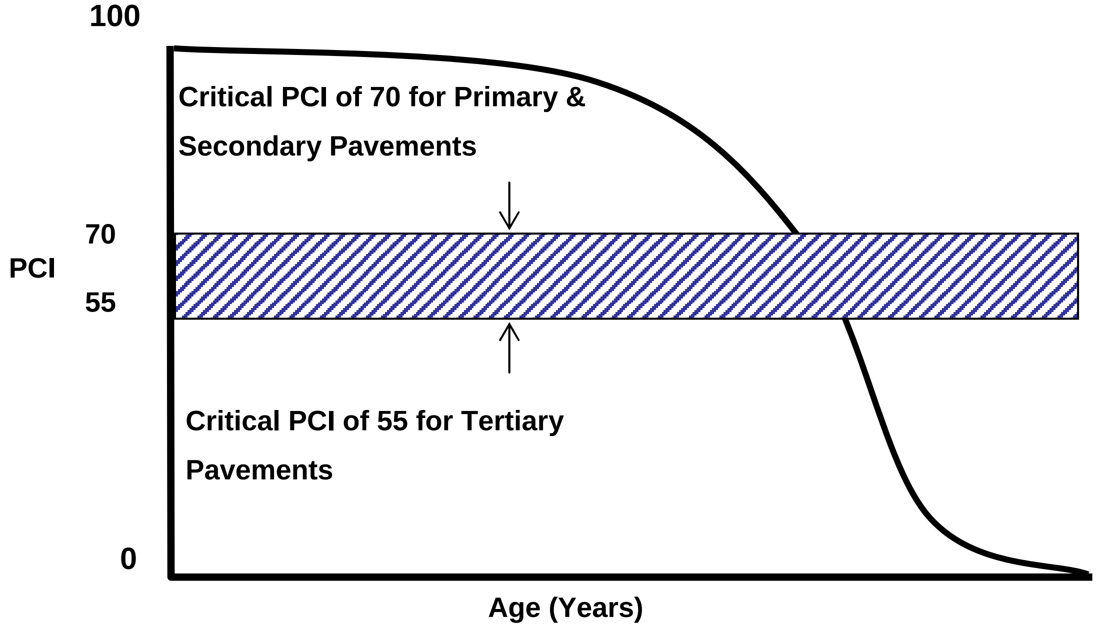


Figure 19: Illustration of critical PCI range based on pavement performance and use.

As shown in the denominator in Equation 1, the Targeted Benefit also depends on the IDL that is sought by an aviation department. For construction of aprons, an airport expects the new pavement to provide good performance until rehabilitation occurs at some point in the future. The surface must provide sufficient durability with minimal maintenance despite fuel and oil spills that often occur on an apron. Table 7 is an example of denominator values that represent the Targeted Benefit for various combinations of critical PCI values and IDLs.

As shown in Table 7, the denominator values (e.g. Targeted Benefit) range from a low of 1,100 to a high of 2,800 PCI-Years. If an airport wants to maximize the amount of time before they have to close a pavement facility for repairs, they might select an IDL of 40 years for a runway. On the other hand, if an airport has a Master Plan that shows there is a possibility of terminal ramp changes in 20 to 25 years, they may select an IDL of 20 years. For a taxiway that is not critical to airside traffic flow, an IDL of 30 may be selected. These three areas are represented by the blue-shaded cells in Table 7.

Table 7: Example Denominator Values for Equation 1.

| *Pavement Facility* | *Critical PCI* | *Intended Design Life (Years)* | | |
|---|---|---|---|---|
| | | *20* | *30* | *40* |
| *Aprons* | 55 | 1,100 | 1,650 | 2,200 |
| *Aprons/Taxiways* | 60 | 1,200 | 1,800 | 2,400 |
| *Taxiways/Runways* | 65 | 1,300 | 1,950 | 2,600 |
| *Runways* | 70 | 1,400 | 2,100 | 2,800 |

Table 8 shows the numerator (e.g. historical benefit) for all airports in the SEA database for each pavement type. A separate table could be prepared for each state using the results that were shown in Figures 9 through 12 and Table 4. Using the blue-shaded Targeted Benefits and the SEA historical results shown in Table 8, PDF values can be computed as shown in Table 9.

Table 8: SEA Numerator Values for Equation 1.

| *Pavement Use* | *Pavement Type* | | | |
|---|---|---|---|---|
| | *PCC* | *AC* | *APC* | *AAC* |
| *Aprons* | 2,564 | 1,043 | 1,047 | 886 |
| *Taxiways* | 2,517 | 1,218 | 1,168 | 988 |
| *Runways* | 3,014 | 1,710 | 974 | 958 |

Table 9: PDF Values for Targeted Benefits Illustrated in Table 7.

| *Pavement Use* | *Pavement Type* | | | |
|---|---|---|---|---|
| | *PCC* | *AC* | *APC* | *AAC* |
| *Aprons* ($PDF_{55-20}$) | 2.33 | 0.95 | 0.95 | 0.80 |
| *Taxiways* ($PDF_{65-30}$) | 1.29 | 0.62 | 0.59 | 0.51 |
| *Runways* ($PDF_{70-40}$) | 1.08 | 0.61 | 0.35 | 0.34 |

The PDF values in Table 9 range from a low of 0.34 to 2.33, keeping in mind that this table incorporates different IDLs, depending on the design objectives that were mentioned earlier. Based on the suggested PDF rating ranges shown in Table 10, Table 10 shows the results using a color-coded legend. Based on the example of Targeted Benefits that were presented in Table 7, the owner may not want to construct AC overlays on either AC or PCC runways.

Table 10: PDF Rating Guidelines.

| *PDF Rating Legend* | *PDF Values* | *Definition* |
|---|---|---|
| Good | > 1.00 | The "Historical Benefit" is greater than the "Targeted Benefit." Use of this pavement type should, on average, exceed the performance expectations of the owner. |
| Fair | 0.50 to 1.00 | On average, the "Historical Benefit" is less than the "Targeted Benefit." Use of this pavement type may not meet the performance expectations of the owner. |
| Poor | < 0.50 | There is an increased risk that this pavement type may not meet the performance objectives of the owner. "Historical Benefit" is much less than the "Targeted Benefit." |

Table 11: Comparison of PDF Analysis Results as Illustrated in Table 7.

| | *Pavement Type* | | | |
|---|---|---|---|---|
| *Pavement Use* | *PCC* | *AC* | *APC* | *AAC* |
| *Aprons* ($PDF_{55\text{-}20}$) | 2.33 | 0.95 | 0.95 | 0.80 |
| *Taxiways* ($PDF_{65\text{-}30}$) | 1.29 | 0.62 | 0.59 | 0.51 |
| *Runways* ($PDF_{70\text{-}40}$) | 1.08 | 0.61 | 0.35 | 0.34 |

The results that are shown in Table 11 for the SEA database include subscripts for the PDF values. For taxiways, the PDF values that are shown are based on a critical PCI value of 65 and an IDL of 30 years, which corresponds to a "Targeted Benefit" of 1,950 PCI-Years, as shown in Table 7.

## 5.3 SUMMARY

The SEA database analysis results show that use of PCI values as the only input in the selection of the pavement type for overlay or reconstruction work does not present an accurate assessment of the best option for the airport owner with regard to performance. There are different design lives for overlays and new construction. As a result, the average age of each pavement type should be considered simultaneously with the average PCI in assessing historical performance of pavements in the southeast. API has introduced the concept of a Performance and Durability Factor (PDF) and proposed a procedure for computing the PDF values and interpreting the results from a PDF analysis.

For IDLs of 20, 30, and 40 years for aprons, taxiways, and runways, Table 11 clearly shows that AC overlays on existing AC or PCC pavements will probably not meet the expectations of the airport owner. In addition, the results show that the best performance is obtained when runways are constructed of PCC rather than AC.

Likewise, aprons that are constructed with AC, or AC or PCC pavements that are overlaid with AC, have a high probability that they will not perform as well as PCC aprons. As shown in Table 11, the PDF factor for PCC aprons is almost 2.5 times greater than the PDF for AC or APC pavements. When compared to AAC aprons, the PCC PDF factor is almost three times larger than the AAC PDF.

# CHAPTER 6

# LESSONS LEARNED

## 6.1 INTRODUCTION

The pavement industry continues to find new methods and materials to construct airport pavements that will exceed performance expectations throughout the Intended Design Life (IDL). Performance data from pavement management systems have helped engineers and owners enhance new pavement designs. API used the SEA database to determine how joint spacing has affected PCC performance.

Several agencies have decided to limit the maximum joint spacing of PCC pavements because of the amount of early-age distresses that may occur when joint spacings are greater than 20 ft. As a result, both the US Air Force and the FAA now limit joint spacing to a maximum of 20 ft (FAA AC 150-5320-6E, 2009 and UFC 3-260-02, 2001) .

## 6.2 SEA PCC PAVEMENTS

Table 12 provides a summary of the PCC inventory in the SEA database. As shown, there are a total of 825 PCC sections, which represent 12.8 percent of the total number of sections in the SEA inventory. For the PCC pavements, 485 sections have both longitudinal and transverse joint spacings that are less than or equal to 20 ft. The remaining sections (340) have at either a longitudinal or transverse joint spacing that is greater than 20 ft.

The joint spacing analysis results show that at least 41 percent of all PCC sections have joint spacings that are greater than 20 ft. The lowest percentage occurs for those sections that have PCI values between 70 and 100 where 29 to 35 percent of the sections have joint spacings greater than 20 ft. However, for those sections that have PCI values below 70, 63 to 71 percent of the sections have joints spacings that are greater than 20 ft. Before drawing any conclusions, it is important to review the ages of the PCC pavement sections.

Figure 20 shows the area-weighted Age and PCI values for the PCC sections within each of the seven ASTM PCI categories. The results are very interesting because they show that PCC pavement sections with shorter joint spacing out perform the longer joint spacing until the average PCI drops below 55. At this point, PCC sections with longer joint spacing actually outperformed the sections with shorter joint spacing until the average PCI fell below 10. It is important to observe that the area-weighted average Age of all PCC sections is greater than 40 years when the PCI is below 55. As a result, all of these sections have exceeded an IDL (Intended Design Life) of 40 years.

Table 12: Summary of PCC Performance in SEA Database by Joint Spacing.

| *Simplified PCI Color Legend* | *ASTM PCI Color Legend* | *Number of SEA Sections* | *Number of PCC Sections* | *Number of Sections with PCC Jts > 20 ft* | *Number of Sections with PCC Jts < 20 ft* | *Percent of PCC Sections with Jts > 20 ft* |
|---|---|---|---|---|---|---|
| Good | 86-100 | 2,682 | 428 | 125 | 303 | 29.2 % |
| | 71-85 | 1,374 | 161 | 56 | 105 | 34.8 % |
| Fair | 56-70 | 1,300 | 78 | 49 | 29 | 62.8 % |
| Poor | 41-55 | 588 | 63 | 45 | 18 | 71.4 % |
| | 26-40 | 331 | 47 | 32 | 15 | 68.1 % |
| | 11-25 | 152 | 28 | 19 | 9 | 67.9 % |
| | 0-10 | 32 | 20 | 14 | 6 | 70.0 % |
| | Total | 6,459 | 825 | 340 | 485 | 41.2 % |

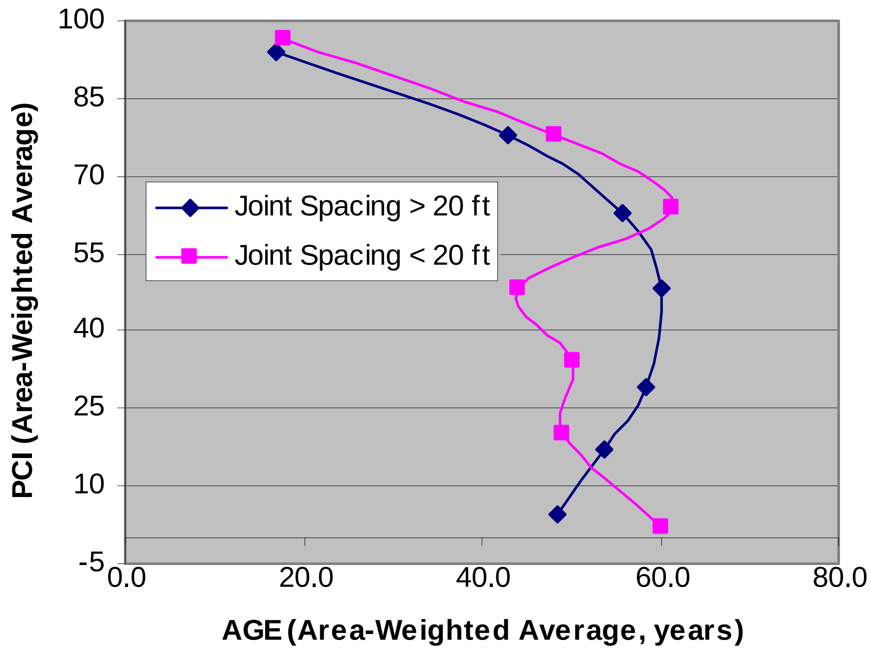


Figure 20: Comparison of Area-Weighted PCI and Ages by Joint Spacing.

## 6.3 OTHER JOINT SPACING STUDIES

Dr. Tom VanDam conducted his PhD dissertation research work at the University of Illinois (Van Dam et al, 1994). His work focused on pavement performance at general aviation airports throughout Illinois. During this study, he investigated several factors that impact pavement performance including the following:

- Aircraft Loads
- Climate
- Materials (e.g. AC, PCC, etc)
- Design Practices
- Construction Methodologies

One design practice variable that was investigated included PCC joints spacing. The results show that PCC sections with a joint spacing that is 25 ft or greater clearly do not perform as well as sections with joint spacings that are less than 20 ft. However, the results of the regression analysis indicate that PCC performance will continue to increase as joint spacing decreases. For example, those PCC sections with a 12.5 ft joint spacing performed much better than sections with a longer joint spacing.

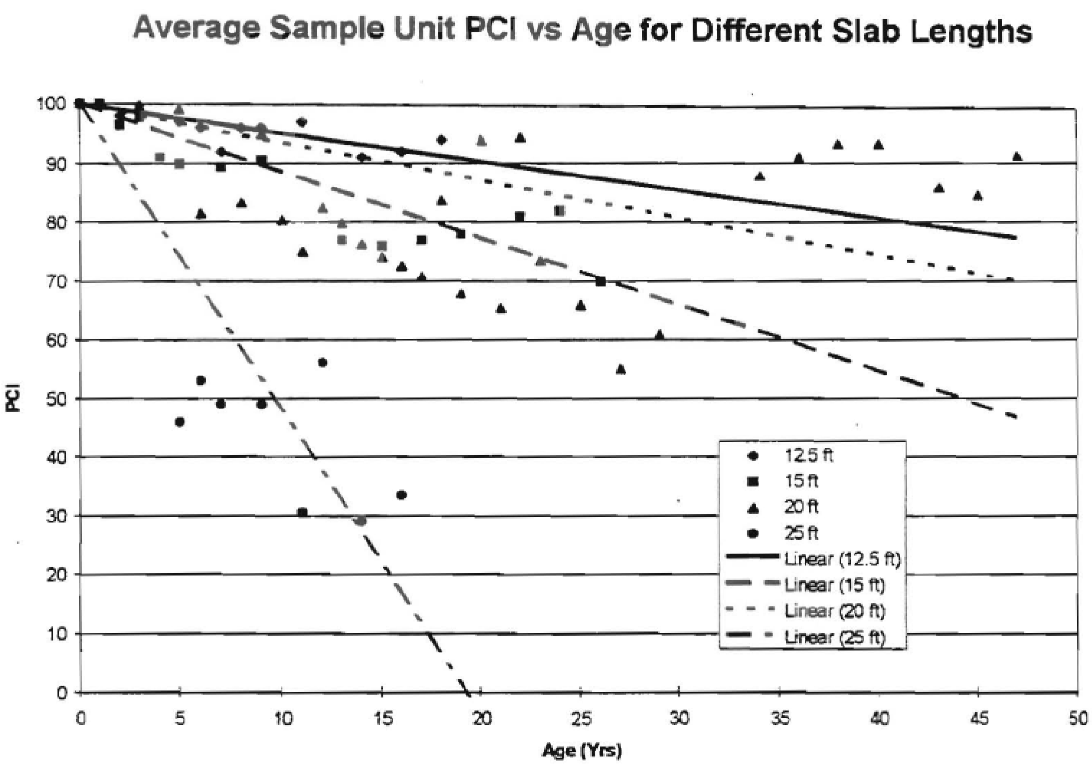


Figure 21: Joint Spacing Impact on Sample Unit PCI Values (VanDam).

The results by VanDam and others demonstrate that many variables impact the performance of jointed PCC pavements. Mix designs, design procedures, and construction methodologies are areas that must be carefully evaluated to minimize the risk of early-age distresses in PCC. The long term effects of climate and aircraft fleet mix changes are additional variables that may affect the rate at which PCC pavements deteriorate throughout their intended design life.

# CHAPTER 7

# CONCLUSIONS AND RECOMMENDATIONS

## 7.1 CONCLUSIONS

API evaluated the performance of all pavement types at airports located in three states in the southeast region of the United States. Georgia, Florida, and South Carolina provided MicroPAVER databases from their most recent PCI surveys that had been conducted as part of statewide APMS updates. These databases were merged to create a consolidated SouthEast Airport (SEA) database.

PCC pavements comprise a relatively small percentage of the total pavement inventory in the SEA database. Approximately 20 percent of Florida's pavements consist of PCC and 12 percent of the pavements in Georgia and South Carolina are PCC. During this study, API developed PCI performance models for several types of pavements as shown in Figure 17. For all pavement facilities, Figure 17 shows that PCC provides the best performance as the deterioration rate (PCI points per year) is lower than all other pavement types.

Additional performance models were developed by pavement type for aprons, taxiways, and runways as shown in Figures 22 through 24. These figures also show that regardless of the type of facility, PCC pavements perform better than AC, AAC, and APC pavements. In all cases, the PCC pavements will have a PCI rating of "Good" after 30 years of service.

Additional evidence that PCC pavements perform better and are more durable is that the area-weighted average ages of PCC pavements are always greater than the other types of pavements. For aprons, the average age (27 years) of the PCC is almost double that of any other pavement type. The same is true for taxiway pavements although the average age of APC and AC increases slightly to 16 and 17 years, respectively. Finally, for runways, the average age is an impressive 37 years, which is three times the age of APC and AAC pavements.

Although many variables impact PCC performance and their service lives, such as mix design, design practices, and construction methodologies; joint spacing is one key element in pavement design that should be evaluated very carefully. The Air Force and FAA no longer allow joint spacings that are greater than 20 ft. PCI results from the SEA database show that PCC pavements with joint spacings that are less than 20 ft outperform those pavements with joint spacings that are greater than 20 ft.

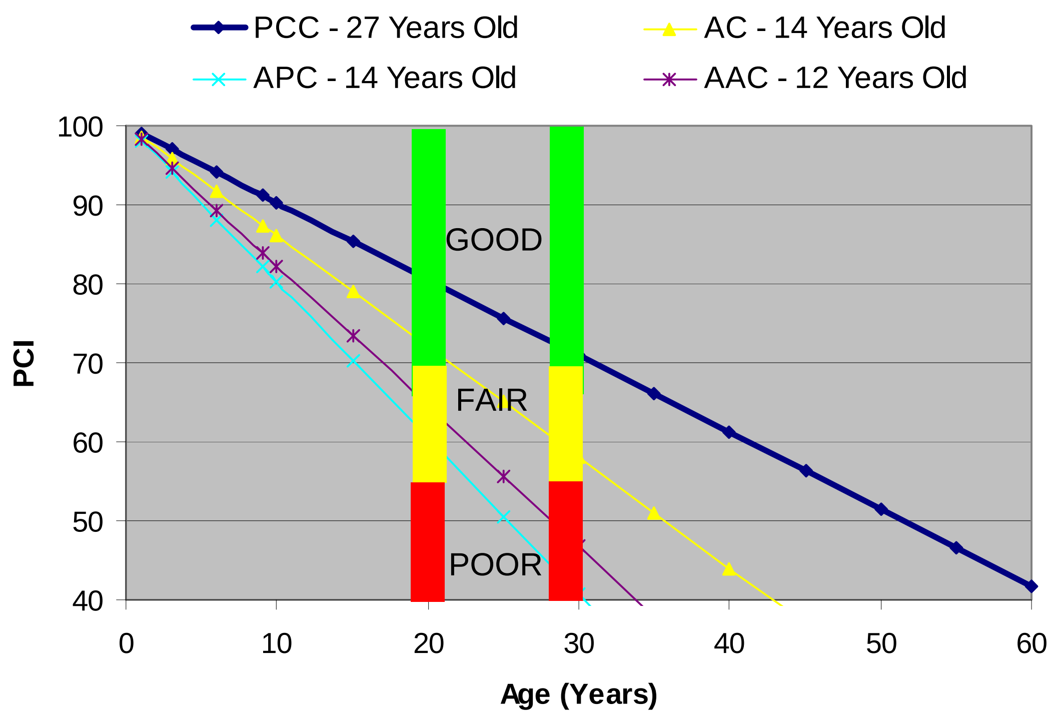


Figure 22: Predicted apron performance and current average age by pavement type.

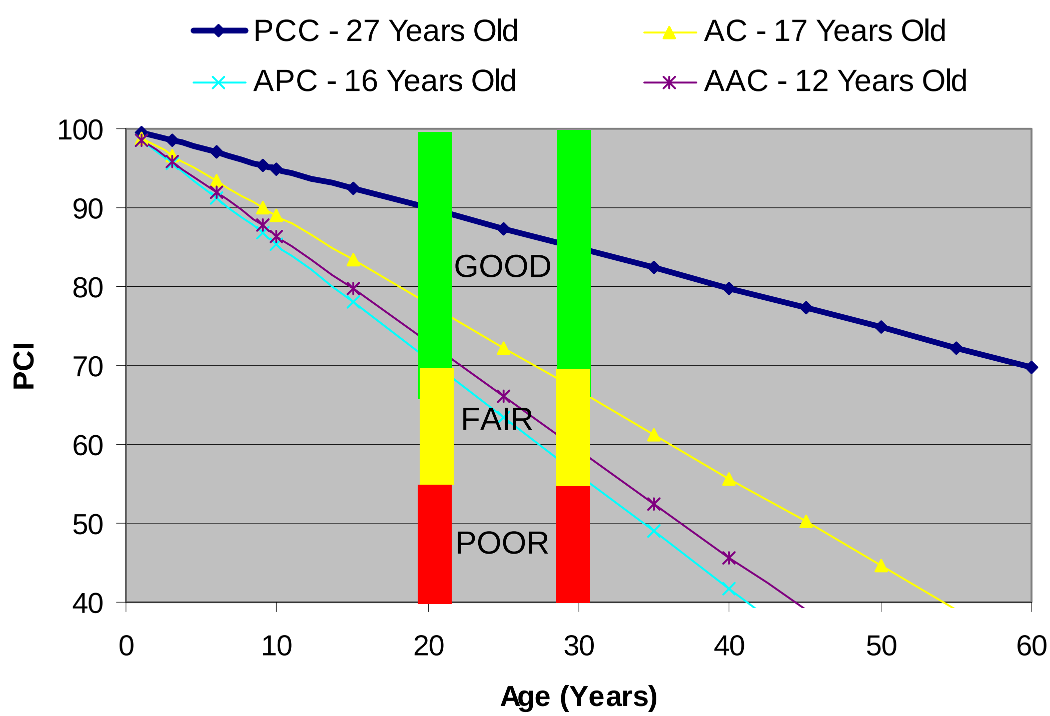


Figure 23: Predicted taxiway performance and current average age by pavement type.

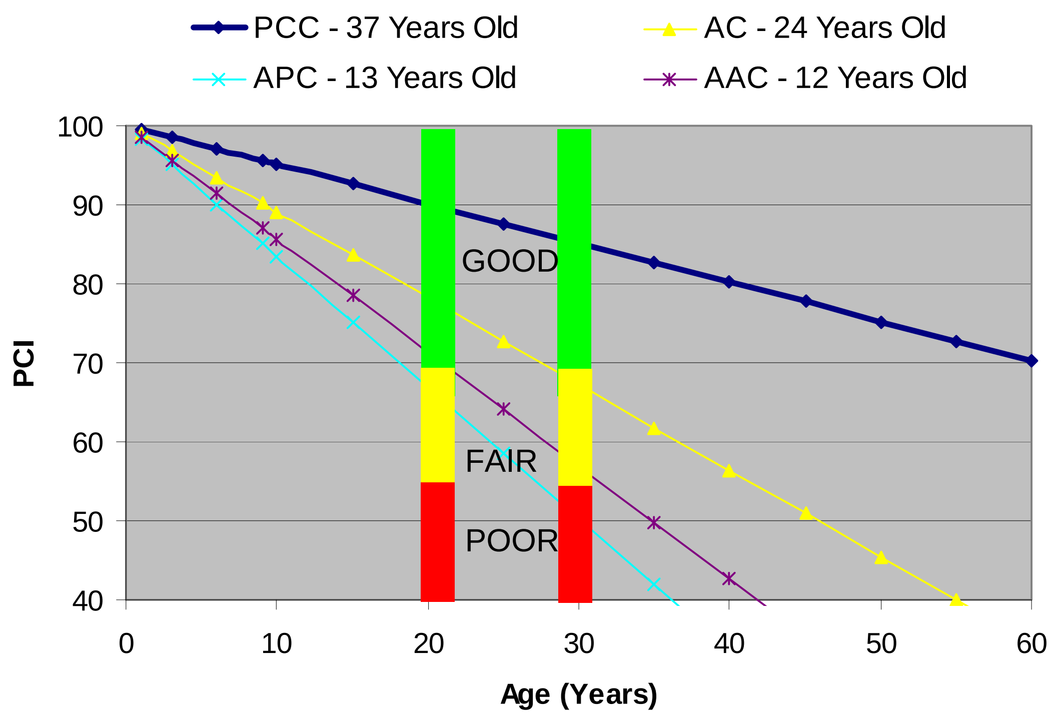


Figure 24: Predicted runway performance and current average age by pavement type.

## 7.2 RECOMMENDATIONS

When airport owners and designers investigate which type of pavement will provide the best return on their investment, they need to consider performance, a LCCA, and other tangible and intangible variables. This study focused on providing a tool to assist in the evaluation of performance. The results of this study show PCC pavements clearly outperform all other types of pavements and remain in service longer, as evidenced by the area-weighted ages of each pavement type.

Many owners consider only the historical condition (e.g. PCI) when they select pavement types for their airside facilities. But this approach does not account for the frequency of major rehabilitation work after an AC or PCC pavement is constructed. Although a LCCA will address the present worth of each pavement construction strategy, additional information should be used to supplement PCI results as owners consider performance in the selection of a pavement type that best meets their needs.

To address this need in performance assessment, API introduced the concept of a Performance and Durability Factor (PDF). While PCI values provide an indication of performance, they do not adequately account for durability, or the longevity of the pavements. The PDF factor is computed by comparing the “Historical Benefit” of a pavement type to the “Targeted Benefit” that is established by the owner or engineer. The Historical Benefit is a product of the area-weighted average PCI and Age values that can be obtained directly from MicroPAVER. The Targeted Benefit depends on the critical PCI values, or serviceability levels, and the Intended Design Life (IDL) values that are set by an owner.

Use of the PDF will allow the airport to evaluate the risk that a given pavement type may not meet their expectations (e.g. Targeted Benefit). As was introduced in this study, owners want to select a pavement type that provides the highest ratio of Historical Benefit to the Targeted Benefit. PDF values can be used to assess and assign Good, Fair, and Poor ratings for each type of pavement for each type of facility (e.g. apron, taxiway, and runway).

| *PDF Rating Legend* | *PDF Values* | *Definition* |
|---|---|---|
| Good | > 1.00 | The "Historical Benefit" is greater than the "Targeted Benefit." Use of this pavement type should, on average, exceed the performance expectations of the owner. |
| Fair | 0.50 to 1.00 | On average, the "Historical Benefit" is less than the "Targeted Benefit." Use of this pavement type may not meet the performance expectations of the owner. |
| Poor | < 0.50 | There is an increased risk that this pavement type may not meet the performance objectives of the owner. "Historical Benefit" is much less than the "Targeted Benefit." |

In the future, airport owners and engineers throughout the United States should evaluate the performance of the airport pavements by considering both the PCI and PDF values. Together, these values will not only provide a better measure of performance but they can also be used to develop improved LCCA models that have realistic estimates of the timing of future rehabilitation work.

# REFERENCES

Applied Research Associates, Inc., Airfield Asphalt Pavement Technology Program (AAPTP) 06-06, Draft Comprehensive Report "Life-Cycle Cost Analysis for Airport Pavements, March 2009.

ASTM D 5340-04, "Standard Test Method for Airport Pavement Condition Index Surveys," March 2005.

Federal Aviation Administration, FAA Advisory Circular 150/5380-7A, "Airport Pavement Management Program, September 2006.

Federal Aviation Administration, FAA Draft Advisory Circular 150/5320-6E, "Airport Pavement Design and Evaluation, February 2008.

Johnson, Christine, American Public Works Association, "Pavement (Maintenance) Management Systems," APWA Reporter, November 1983.

The Weather Channel, Monthly Averages for Temperature and Precipitation by City, May 2009.

United States Air Force, Unified Facilities Criteria (UFC), "Pavement Design for Airfields," June 2001.

Van Dam, T.J. et al, Illinois Transportation Research Center, Project IA-A1, FY 92 "Concepts and Practices for Considering GA Airport Pavement Performance and Longevity," December 1994.