PROJECT NO. 09-11

Pavement Maintenance Guidelines for General Aviation Airport Management

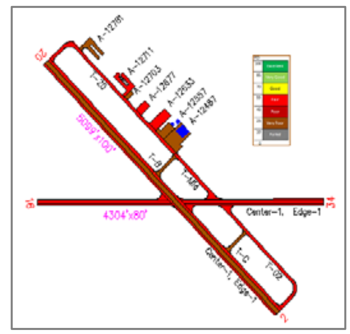
DRAFT FINAL GUIDEBOOK

Prepared for

Airport Cooperative Research Program

Transportation Research Board of the National Academies





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March 2016

ACKNOWLEDGMENT OF SPONSORSHIP

This work was sponsored by one or more of the following as noted:

- [ ] American Association of State Highway and Transportation Officials, in cooperation with the Federal Highway Administration, and was conducted in the **National Cooperative Highway Research Program,**
- [ ] Federal Transit Administration and was conducted in the **Transit Cooperative Research Program**,
- [x] Federal Aviation Administration and was conducted in the **Airport Cooperative Research Program,**
- [ ] Research and Innovative Technology Administration and was conducted in the **National Cooperative Freight Research Program,**
- [ ] Pipeline and Hazardous Materials Safety Administration and was conducted in the **Hazardous Materials Cooperative Research Program,**
- [ ] Federal Railroad Administration and was conducted in the **National Cooperative Rail Research Program,**

which is administered by the Transportation Research Board of the National Academies.

DISCLAIMER

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AUTHOR ACKNOWLEDGMENTS

The research reported herein was performed under ACRP Project 09-11 by the Texas A&M Transportation Institute at Texas A&M University.

Thomas J. Freeman, program manager of the Pavement Management Program, was the project director and principal investigator. The other authors of this report are Dr. Jeffrey D. Borowiec, Dr. Bryan Wilson, Dr. Maryam Sakhaifar, Assistant Professor of Civil Engineering, Texas A&M University. In addition, the work of Dr. Wayne J. Seiler, P.E., All About Pavements, Inc., was instrumental in developing the questionnaire and decision trees. Mark Coppock and Chris Bratlien were the principal programmers on the Airport Pavement Maintenance Tool.

ABSTRACT

This guidebook provides an overview of how to identify and resolve a pavement problem at a general aviation airport. It is a companion document to the field guide, online tool, and the final report. It also discusses treatment types and the benefit/cost data used in the tool. The guidebook contains the online tool user manual, instructions on how to use the field guide, and detailed lists of the distress types available in the tool.

QUICK SHEET

Pavement Maintenance Selection Tool (page 12)

Use the online Pavement Maintenance Selection Tool, available at http://acrp0911.tti.tamu.edu.

Classification (page 2)

Airport Category	Activity Level	Activity Type	Based Aircraft
National	Very High	Many jets and multiengine propeller aircraft	200/30 jets
Regional	High	Some jets and multiengine propeller aircraft	90/3 jets
Local	Moderate	Some multiengine propeller aircraft	33/no jets
Basic	Moderate to Low	Single-engine aircraft	10/no jets

Climate Zone (page 3)

Wet Freeze	Wet No Freeze	Dry Freeze	Dry No Freeze

Distress Types (page 8)

Asphalt Pavement

- Longitudinal cracking
- Transverse cracking
- Edge cracking
- Joint reflection cracking
- Block cracking
- Alligator or fatigue cracking
- Weathering
- Raveling
- Patching
- Roughness

Concrete Pavement

- Corner breaks
- Longitudinal cracking
- Transverse cracking
- Joint seal damage
- Patching
- Settlement or faulting
- Shattered slab/intersecting cracks
- Spalling

Pavement Management Best Practices (page 4)

- Use preventative maintenance.
- Use a formal airport pavement management system.
- Conduct routine pavement inspections.

PCI (page 9)

PCI	Rating	Description
100	Good	Only minor distresses.
85	Satisfactory	Low and medium distresses.
70	Fair	Some distresses are severe.
55	Poor	Severity of some of the distresses can cause operational problems.
40	Very Poor	Severe distresses cause operational problems.
25	Serious	Many severe distresses cause operational restrictions.
10	Failed	Pavement deterioration prevents safe aircraft operations.
0		

Treatment Options (page 10)

Asphalt Treatments	Concrete Treatments
Do nothing	Do nothing
Crack seal/fill	Crack/joint seal
Rejuvenator	Partial depth repair
Fog/coal tar seal	Full-depth repair (localized)
Slurry/micro	Cross-stitching/dowelbar retrofit
Chip/cape seal	Slab stabilization/jacking/underseal
AC overlay/mill+overlay	Concrete/asphalt overlay
Patch/reconstruct area	Grinding/grooving
Too severe-rehab/reconstruct	Too severe (rehab/reconstruct)

CHAPTER 1. INTRODUCTION TO AIRFIELD PAVEMENT MANAGEMENT

This guidebook helps airport management at general aviation (GA) airports determine the most efficient and effective maintenance options to optimize pavement life.

What's in This Guidebook

This guidebook provides:

Where to start when managing airfield pavement.
Pavement maintenance principles and guidance.
How to identify pavement distress types and their severities.
A user's manual for the online Pavement Maintenance Selection Tool.
How to use the field guide.
Details of the benefit/cost data found in the tool.
Lists, descriptions, and pictures of asphalt and concrete distress types.

This guidebook is a starting point and should be supplemented with its companion documents:

- **Final Report –** a technical report that delves into the questionnaire, data collection, and research behind this project.
- **Online Pavement Maintenance Selection Tool –** a user friendly web tool for determining the most appropriate pavement treatment and its cost (Figure 1). The online tool can be found at http://acrp0911.tti.tamu.edu.
- **Field Guide –** a paper equivalent of the online tool with treatment tables based on the airport's classification and climate zone (Figure 2).

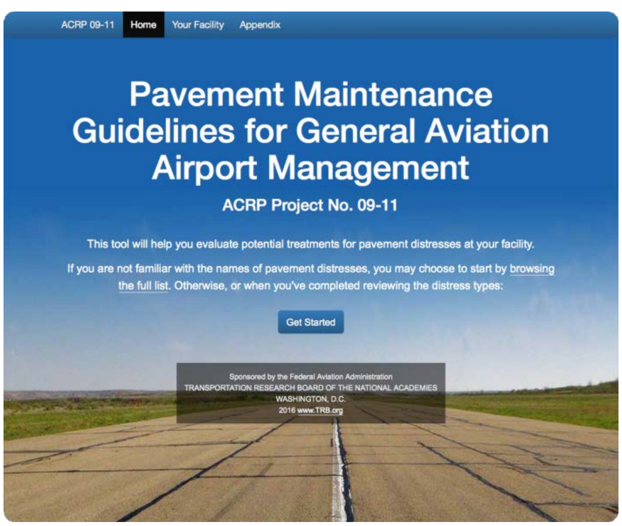


Figure 1. Online Tool Homepage.

Figure 2. Field Guide Cover.

Where to Start: Determine Your Airport's Classification and Climate Zone

Knowing your airport's classification and climate zone will help you choose the most appropriate pavement treatments. The color scheme of Table 1 matches the color scheme of treatment tables found in the field guide.

Table 1. Classifications and Climate Zones.

Classification Types	Climate Zone Types	
National	Wet	Freeze
Regional	Wet	No Freeze
Local	Dry	Freeze
Basic	Dry	No Freeze

General Aviation Airport Classifications

In 2010, the Federal Aviation Administration (FAA) assigned GA airports into the following subcategories: national, regional, local, and basic (FAA 2012). The categories focus on the role of the airport in communities and the nation, and not necessarily on airport size and features. Table 2 shows a description of each category.

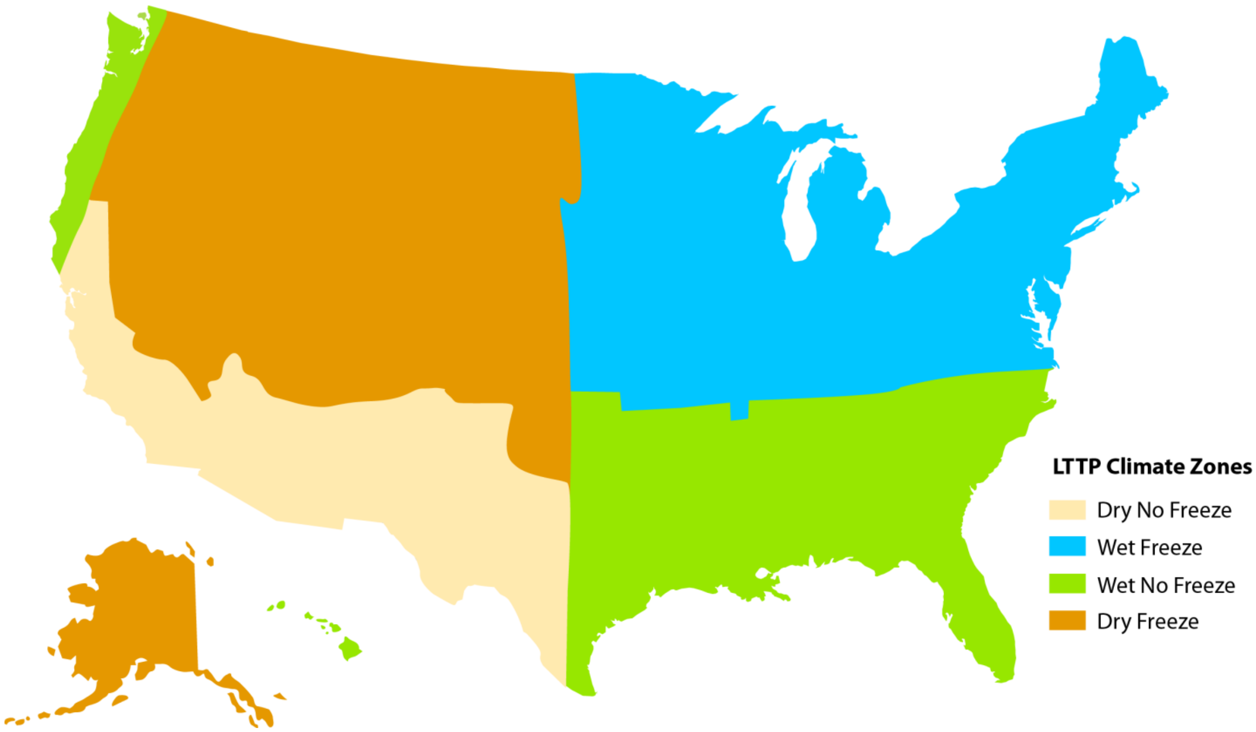
Table 2. New Category Definitions of General Aviation Airports.

Criteria Used to Define the New National Category (all numbers are annualized)
1. 5,000+ instrument operations, 11+ based jets, 20+ international flights, or 500+ interstate departures; or 2. 10,000+ enplanements and at least 1 charter enplanement by a large certified air carrier; or 3. 500+ million pounds of landed cargo weight.
Criteria Used to Define the New Regional Category (all numbers are annualized)
1. Metropolitan Statistical Area (MSA) (Metro or Micro) and 10+ domestic flights over 500 miles, 1,000+ instrument operations, 1+ based jet, or 100+ based aircraft; or 2. The airport is located in a metropolitan or micropolitan statistical area, and the airport meets the definition of commercial service.
Criteria Used to Define the New Local Category (all numbers are annualized)
1. 10+ instrument operations and 15+ based aircraft; or 2. 2,500+ passenger enplanements.
Criteria Used to Define the New Basic Category (all numbers are annualized)
1. 10+ based aircraft; or 2. 4+ based helicopters; or 3. The airport is located 30+ miles from the nearest NPIAS airport; or 4. The airport is identified and used by the U.S. Forest Service, or U.S. Marshals, or U.S. Customs and Border Protection (designated, international, or landing rights), or U.S. Postal Service (air stops), or has Essential Air Service; or 5. The airport is a new or replacement facility activated after January 1, 2001; and 6. Publicly owned or privately owned and designated as a reliever with a minimum of 90 based aircraft.

Source: (FAA 2012)

Climatic Zone

Climate impacts different pavement stresses, needs, and potential maintenance treatments. Figure 3 shows the climatic zones that were developed as part of the Long-Term Pavement Performance (LTPP) research.

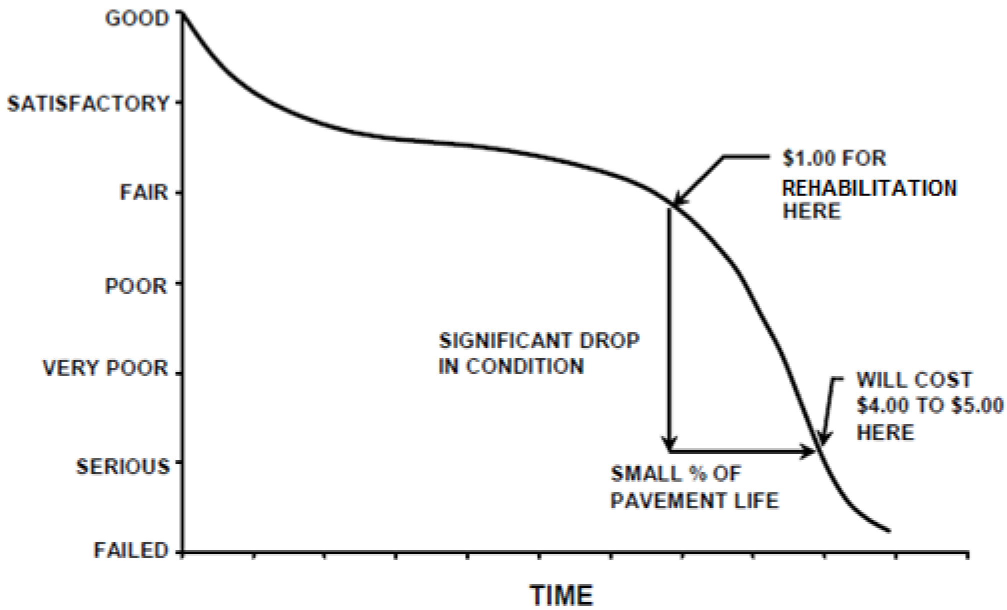


Source: (FHWA 2014)

Figure 3. LTPP Climatic Zones.

The Life of a Typical Pavement

Figure 4 shows an example pavement condition life cycle curve. The pavement condition creeps along the *Satisfactory* and *Fair* range for several years before entering into the *Poor* range and quickly dropping through *Very Poor* and into the *Serious* rating.



Source: (Shahin 2005)

Figure 4. Typical Pavement Condition Life Cycle.

Pavement Management Principles

An airport pavement management program maintains operational and safe pavement assets in the most cost-effective manner, while minimizing the long-term pavement costs.

Most GA airports currently choose a treatment to address the **current** needs (i.e., applying a fix after a problem has significantly developed). In many cases, the airport sponsor will rotate through a few familiar treatments without considering which treatment is actually the best long-term approach (FAA 2014).

Pavement management best practices are:

- Use preventative maintenance.

- Use a formal airport pavement management system.

- Conduct routine pavement inspections.

Use Preventative Maintenance

Preventative maintenance should be done in the *Good-Fair* range, delaying the significant drop in condition. A rehabilitation treatment should be done before the drop from *Fair* to *Poor/Serious* to avoid costly rehabilitation/reconstruction work. Too often, GA managers spend scarce resources at the bottom of this curve rather than making incremental investments for preservation at the top.

Use a Formal Pavement Management Program

Every airport should have a formal airport pavement management program (PMP). This is required for airports receiving grant funding through the Airport Improvement Program (AIP). A PMP is a recommended framework that can be adapted to your specific airport to take the guesswork out of when and what type of treatment to apply. The PMP "provides a consistent, objective, and systematic procedure for establishing facility policies, setting priorities and schedules, allocating resources, and budgeting for pavement maintenance and rehabilitation" (FAA 2014).

This process not only allows for establishing the current conditions of the airport's pavement but also the ability to predict its future condition using pavement condition indicators. The ability to project future deterioration rates allows for better planning and the ability to optimally schedule maintenance activities to avoid higher cost treatments in the future.

A PMP recommends a treatment by clearly illustrating a monetary benefit for investing in preventative maintenance, which assists the airport sponsor in lobbying for maintenance funding (Hajek et al. 2011).

Airport Pavement Program Benefits

The use of a PMP can yield many benefits to the airport sponsor. The FAA Advisory Circular 150/5380-7B *Airport Pavement Management Program (PMP)* outlines these benefits (FAA 2014), which include:

- Increased pavement life.
- Objective and consistent evaluation of pavement condition.
- Systematic and documented engineering basis for determining pavement needs.
- Identification of budget/financial resources needed to maintain pavements.
- Documentation of current and future pavement conditions.
- Life cycle costs analysis for different maintenance alternatives.
- Identification of the impact of doing nothing on the airport and pavement.

Airport Pavement Management Program Components

FAA Circular 150/5380-7B also outlines the essential components of an airport PMP (FAA 2014). The FAA guidance outlined in the Advisory Circular is mandatory for any airport with projects funded with grant money provided through the AIP. While the airport can use any format it determines to be appropriate, the PMP should address and include, at a minimum, the following components:

- Pavement inventory.
- Pavement inspection schedule.
- Record keeping.
- Information retrieval.

Pavement Inventory

FAA guidance notes that the pavement inventory for each airport should include the following:

- Identification of all runways, taxiways, and aprons.
- Dimensions of pavement sections.
- Type of pavement surface.
- Year of construction/major rehabilitation.
- Whether AIP funds were used to construct, reconstruct, or repair the pavement.

These inventory records allow airports to know what pavement needs to be managed and how it is changing over time.

Pavement Inspection Schedule

FAA also requires its federally obligated airports to perform a detailed inspection at least once per year. It is also recommended that less comprehensive inspections of the airport's pavements be performed on a routine basis including daily, weekly, and monthly.

Record Keeping

Keeping good records is integral to the pavement management program. Airports must record and keep on file detailed information on all airport inspections and any maintenance performed on the pavement. The necessary records, at a minimum, must include:

- Inspection date.
- Location.
- Distress types found.
- Any maintenance performed or scheduled.

Information Retrieval

FAA does not dictate how the PMP is carried out—only the elements that are required. However, it is necessary for the airport sponsor to be able to retrieve the records when needed. Specialized software is available to assist in developing and maintaining an airport's PMP. They are also capable of generating specific types of reports that can assist an airport in the planning, scheduling, and budgeting of its pavement maintenance activities. Essentially, it allows airports to perform the recommended treatment at the optimal time, allowing for the most cost-effective approach.

In addition, FAA recommends the PMP include the available and anticipated funding and other resources available to provide for the pavement maintenance at your airport. This helps provide a clearer picture of when pavement maintenance activities can occur.

Additional information and resources are included in the FAA Advisory Circular 150/5380-7B *Airport Pavement Management Program (PMP)* (FAA 2014). This includes information on specific software packages used by airports in managing their pavement maintenance.

Conduct Routine Pavement Inspections

While a detailed pavement inspection is required annually for federally obligated airports, more regular, routine pavement inspections are also recommended. These can be done daily, weekly, and even monthly to provide for consistent pavement condition inventories over time. The following is adapted from the guidance in performing pavement inspections provided to Texas airport managers in *Pavement Management Program for General Aviation Airports* (TxDOT 2000).

Routine pavement inspections should be performed at least once per month. Dividing the pavement into discrete pavement sections can help in managing the inspection effort and maintaining good records. Each section, a runway, taxiway, or apron area, should be observed while recording the pavement's conditions and any distresses.

Performing the inspections includes the following activities:

- Walk or slowly drive the pavement section being inspected.
- Look for any pavement irregularities, damage, or deficiencies.
- Record the following information:
  - Date.
  - Pavement section being inspected.
  - Location of pavement damage, deficiency, or irregularity.
  - Extent of the damage, deficiency, or irregularity
- Note any corrective action taken or that needs to be taken.

Pavement inspections should take place either early or late in the day when the sun is low or just after a rain because at these times, shadows and moisture help to highlight and identify any deformities and deficiencies on the pavement surface.

CHAPTER 2. AIRFIELD PAVEMENT DISTRESS

You do not have to be a civil engineer to know if there is something wrong with a pavement. Most of the time, you can see a problem. The most widely used indicator for airfield pavements is surface distress. Surface distress is any visible imperfection of the pavement that indicates a structural deficiency.

To correct a pavement problem, you must first determine the distress type and then measure the pavement condition severity.

Determine the Distress Type

To determine the distress type, review descriptions and pictures found in Appendices A (**asphalt** pavements) and B (**concrete** pavements). Each distress type entry describes the appearance of the distress, possible root causes, and how it is measured. Table 3 lists distress types available in the online tool.

Table 3. Pavement Distress Types.

Asphalt Pavement	Concrete Pavement
• Longitudinal cracking	• Corner breaks
• Transverse cracking	• Longitudinal cracking
• Edge cracking	• Transverse cracking
• Joint reflection cracking	• Joint seal damage
• Block cracking	• Patching
• Alligator or fatigue cracking	• Settlement or faulting
• Weathering	• Shattered slab/intersecting cracks
• Raveling	• Spalling
• Patching	
• Roughness	

Pavement Distress Guidelines and Resources

There are various guidelines for defining and quantifying these distresses. These include:

- *Distress Identification Manual for the Long-Term Pavement Performance Program* (Miller and Bellinger 2003).
- *Pavement Design Guide* (Lenz 2011).
- *Pavement Preservation Manual - Part 2: Pavement Condition Data* (Utah 2009).

Specifically for airport pavements, see:

- *Airport Pavement Management Program (PMP)* (FAA 2014).
- ASTM D5340 (ASTM 2012).

Pavement Distress Indicators

As far as pavement maintenance is concerned, surface distress is the most critical indicator. Other pavement condition indicators can play a role. These are:

- Surface friction – the force that resists the sliding motion of a tire across the pavement surface, which is an essential aspect of aircraft safety during landing.
- Roughness – the ride quality or the bumpiness.
- Foreign object debris (FOD) – any trash, debris from aircraft, loose and broken pavement material, animals or animal remains, etc. that should not be present on an airfield pavement.
- Structural integrity – the ability of the pavement to bear a specific weight without being damaged.

Checking for FOD should be done on a routine basis, but should not be passed off as a distress survey. Routine skid, roughness, and structural measurements may not be necessary, if at all, for most GA airports. These can be contracted out on an as-needed basis.

For more information about these alternative pavement condition indicators, see Chapter 1 of the final report.

Pavement Condition Severity

What Is the Pavement Condition Index?

The Pavement Condition Index (PCI) is a score from 0 (failed) to 100 (perfect) that rates the ability of a pavement to perform its function effectively and safely. Engineers consolidate individual distress measurements (such as friction, roughness, FOD, and structural integrity) to calculate the PCI. For a runway, the condition indicators relate to the ability of aircrafts to accelerate or decelerate in a smooth manner and to the frictional capacity needed to stop the plane at landing.

Over a given area of pavement, engineers record distress types and assign a unique deduct value based on severity and extent. All the deduct values are then analyzed to produce a corrected deduct value, which is subtracted from 100 to obtain the PCI.

Table 4 shows the values in the rating scale, their description, and general pavement treatment that is recommended at that PCI (Hajek et al. 2011).

Table 4. PCI Rating and Recommended Pavement Treatment.

PCI		Rating	Description	Pavement Treatment
100		Good	Only minor distresses.	Routine maintenance only
85		Satisfactory	Low and medium distresses.	Preventative maintenance
70		Fair	Some distresses are severe.	Corrective maintenance and rehabilitation
55		Poor	Severity of some of the distresses can cause operational problems.	Rehabilitation or reconstruction
40		Very Poor	Severe distresses cause operational problems.	Rehabilitation or reconstruction
25		Serious	Many severe distresses cause operational restrictions.	Immediate repairs and reconstruction
10		Failed	Pavement deterioration prevents safe aircraft operations.	Reconstruction
0				

Airport managers need to be familiar with PCI and what the score means but do not need to know how to calculate it. The online tool created for this project calculates PCI and the impacts of maintenance activities to the PCI for the user based on the inputs given.

Measuring Distress Severity

Understanding the severity of pavement distresses is crucial to determining the appropriate treatment for your airport's pavement needs. At first, measuring the severity of particular pavement distresses can seem like a daunting task. In many cases, you can readily determine pavement distress severity when it comes to minimal conditions and severe conditions. Those in the middle become the more challenging task.

Each pavement distress is unique when it comes to determining severity. Guidelines for identifying distress severity have been developed by the U.S. Army Corps of Engineers for both asphalt and concrete pavements (U.S. Army 2009). These guidelines, which provide detailed definitions of each pavement distress and severity level are included in Appendices A and B of this guidebook for easy reference. Pictures are included in the appendices to assist in identification of both the distress type and severity level.

Pavement Maintenance Treatments

The types and uses of various pavement maintenance treatments are well-documented for both airport and highway applications. Table 5 lists the maintenance types used.

Table 5. Pavement Preservation, Maintenance, and Rehabilitation Options.

Asphalt Treatments	Concrete Treatments
Do nothing	Do nothing
Crack seal/ fill	Crack/joint seal
Rejuvenator	Partial depth repair
Fog/coal tar seal	Full-depth repair (localized)
Slurry/micro	Cross-stitching/dowelbar retrofit
Chip/cape seal	Slab stabilization/jacking/underseal
AC overlay/Mill+overlay	Concrete/asphalt overlay
Patch/reconstruct area	Grinding/grooving
Too severe-rehab/reconstruct	Too severe (rehab/reconstruct)

Once the chosen treatment for each distress combination has been identified, the asphalt or concrete pavement treatment hierarchy table is consulted to determine whether a single treatment or multiple treatments should be performed. For example, if one combination suggested a fog seal and the other combination suggested an overlay, only the overlay would be performed. However, if the second combination suggested a crack seal, both would be performed.

The recent ACRP synthesis, *Common Airport Pavement Maintenance Practices: A Synthesis of Airport Practice*, provides a thorough catalog of most of these treatment options (Hajek et al. 2011). The catalog includes construction descriptions/illustration, treatment selection criteria, typical service life/costs, and additional resources. This same synthesis also includes data of the frequency of treatment application and the perceived performance.

The online tool and its paper equivalent, the field guide, provide the user with recommended and acceptable treatment options. The online tool also provides a cost/benefit analysis.

See Chapter 3. Pavement Maintenance Selection Tool User Manual for guidance on how to use the online tool. Also see Chapter 4. How to Use the Field Guide.

Treatment Decision Trees/Matrices

Two common approaches described by the Federal Highway Administration to select a treatment are *decision trees* and *decision matrices*. The methods are essentially the same but organize and present the information in a different form. Hicks and Seeds suggest the following inputs to a decision tree/matrix (2000):

- Pavement surface type.
- Facility type (classification/traffic level).
- At least one current condition index (distress and/or roughness).
- Specific distress information (any prominent distress).
- Geometrics (in case pavement widening/shoulder repair is necessary).
- Environmental conditions.

For more details about the decision trees/matrices researchers used to develop the online tool, refer to the final report. For a thorough catalog of the most common treatment options and how they are accomplished, see *Common Airport Pavement Maintenance Practices: A Synthesis of Airport Practice* (Hajek et al. 2011).

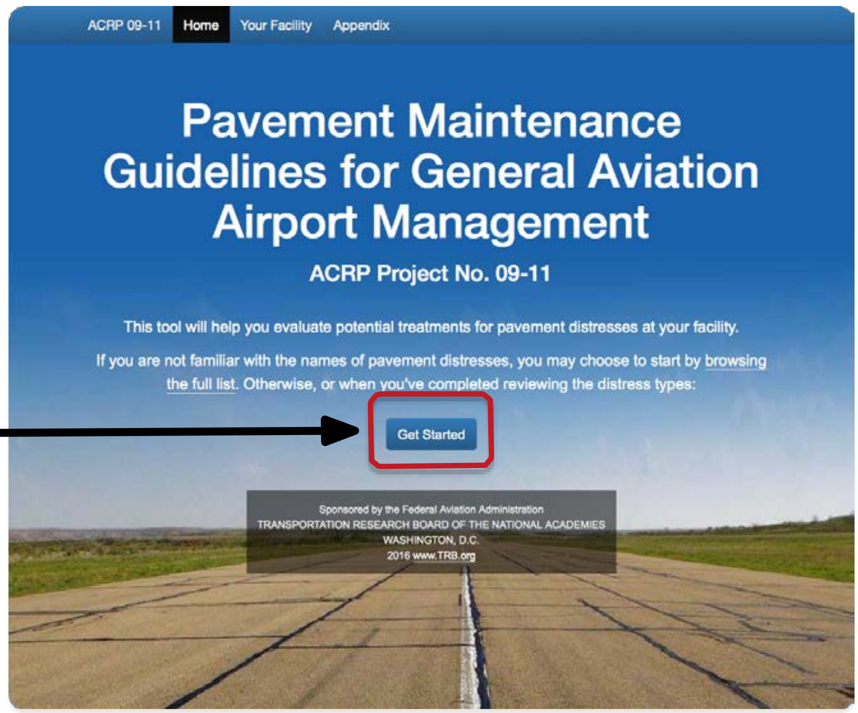
CHAPTER 3. PAVEMENT MAINTENANCE SELECTION TOOL USER MANUAL

This user manual provides step by step guidance on how to use the Pavement Maintenance Guidelines for General Aviation Airport Management online tool. To use this tool, you will need to determine your airport parameters and distress type/severity. You do not need a user account or login. This online tool was developed as part of this research project.

The online tool can be found at http://acrp0911.tti.tamu.edu.

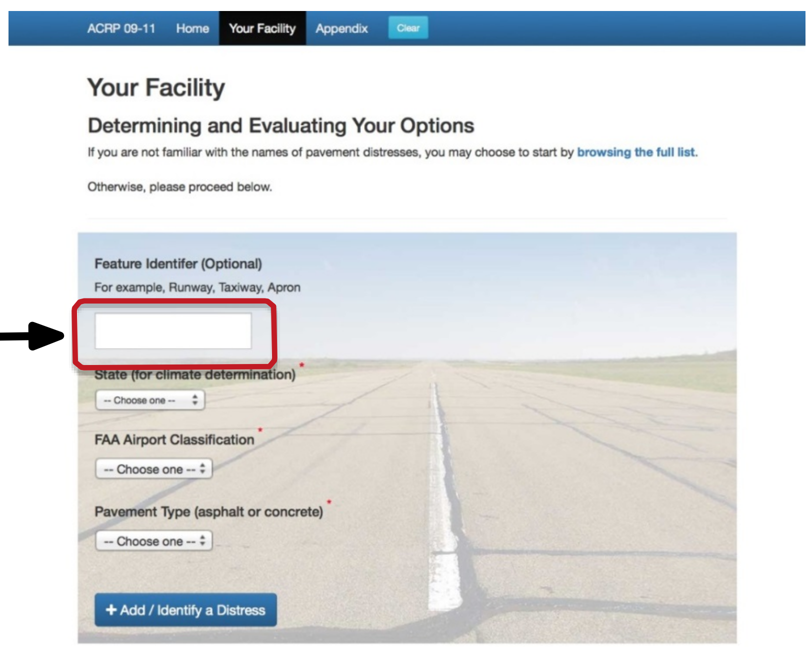
Getting Started

Choose **Get Started** or **Your Facility** from the Navigation menu at top to begin.

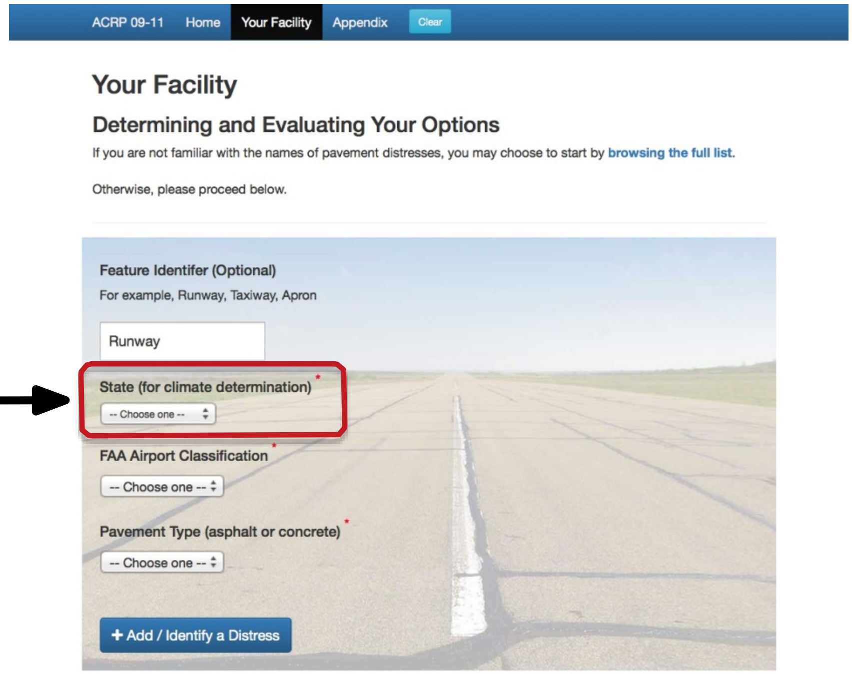


Input Airport Parameters

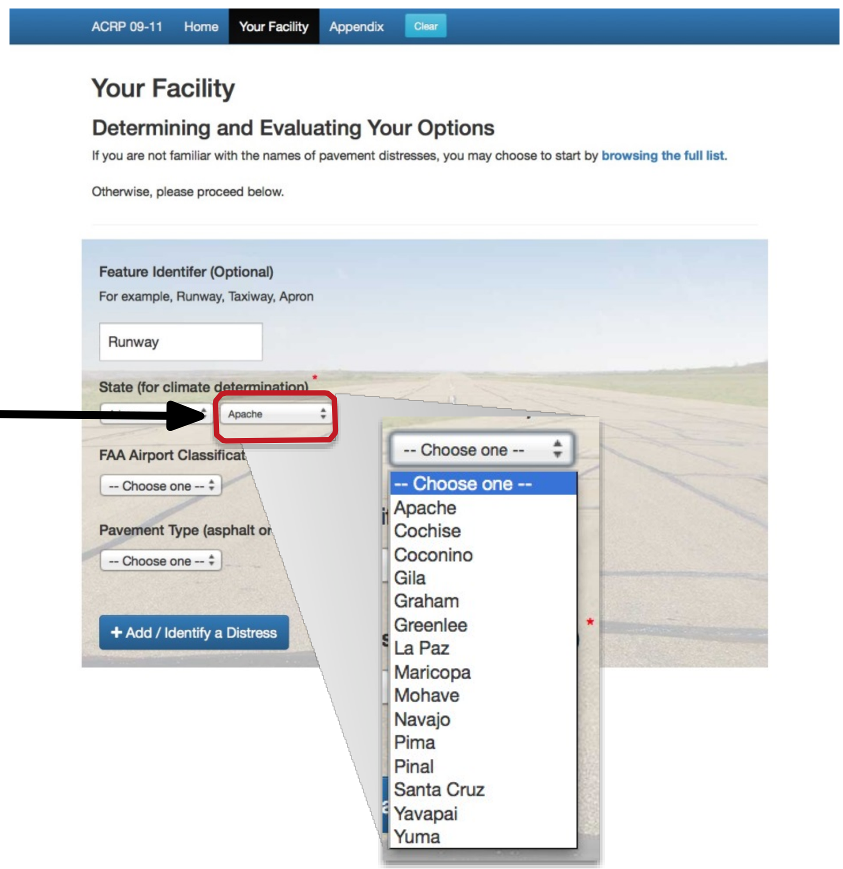
Enter an optional, identifying word or phrase to designate the feature being evaluated.

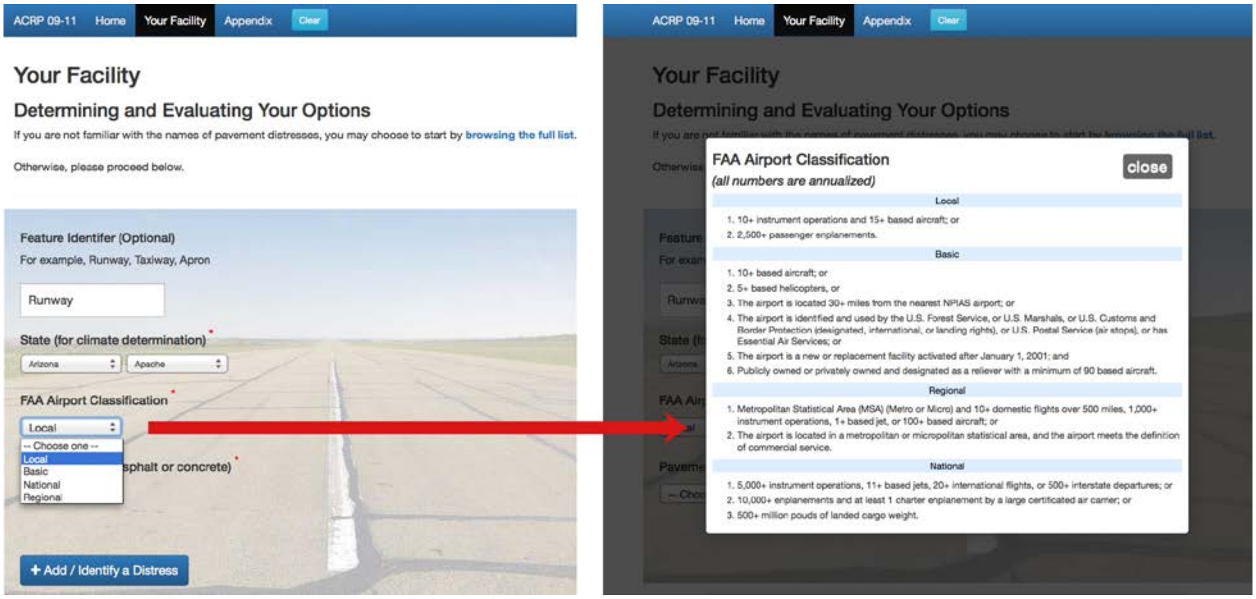


Enter your state. This is a required field.



Note that for some states, adding a county will be required to determine your facility's climate zone.

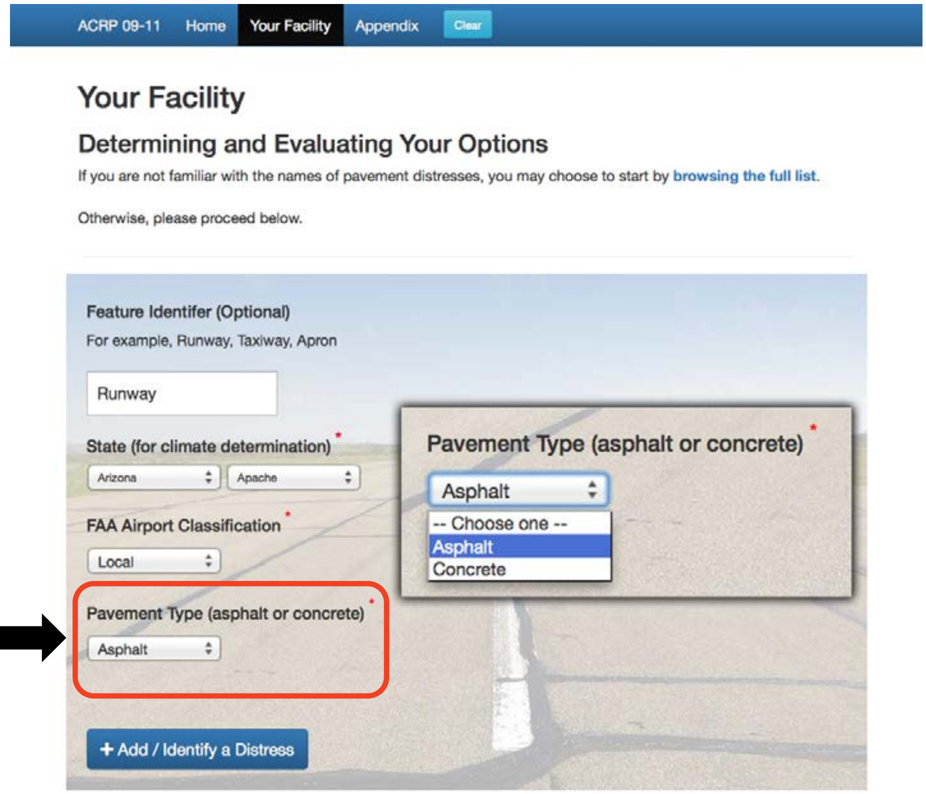




Pick your facility's FAA Airport Classification.

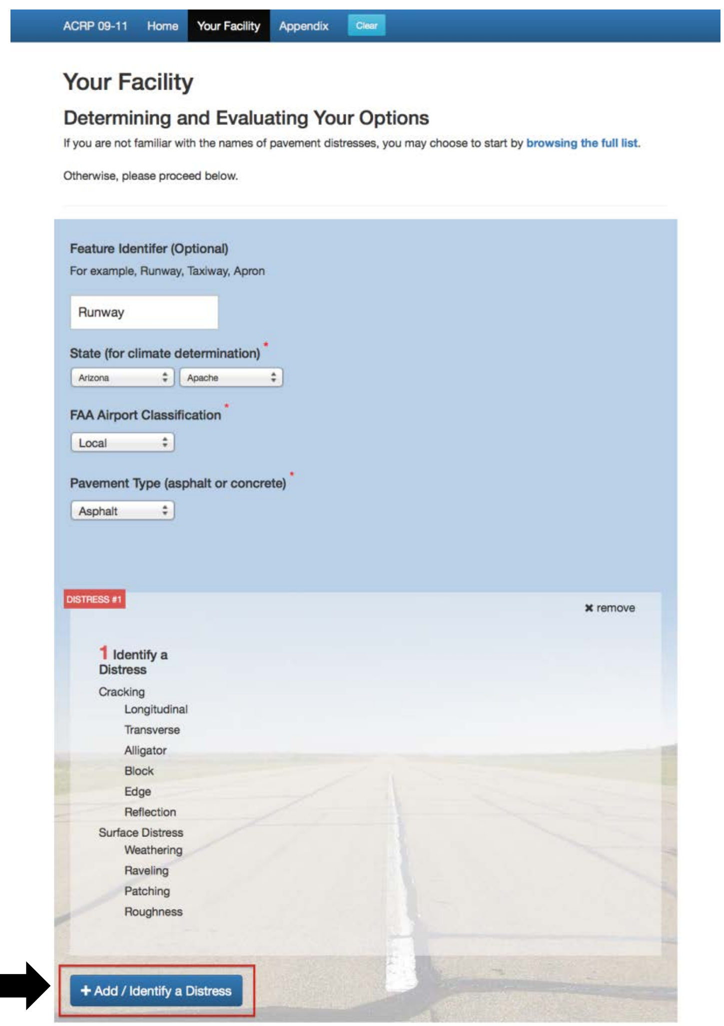
Note that your entries up to this point will be retained on your computer or tablet for subsequent evaluations with the tool.

Note that the FAA Airport Classification input has supplemental details that will pop up to assist the user.

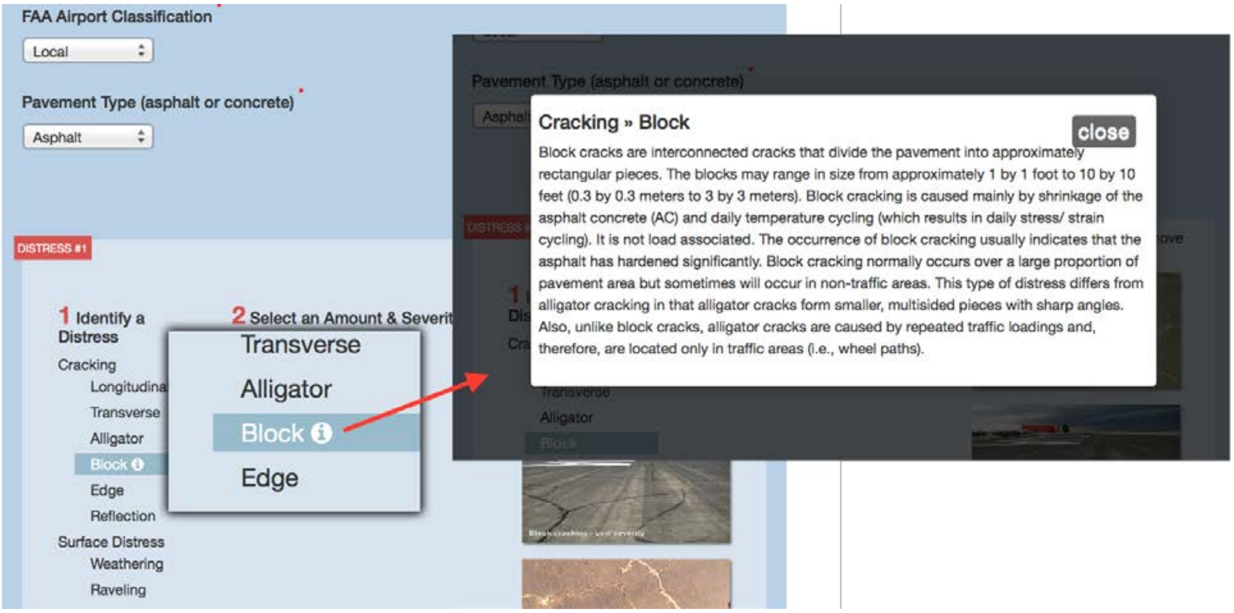


Choose the type of pavement used in the feature being evaluated.

Input Distress Type and Severity

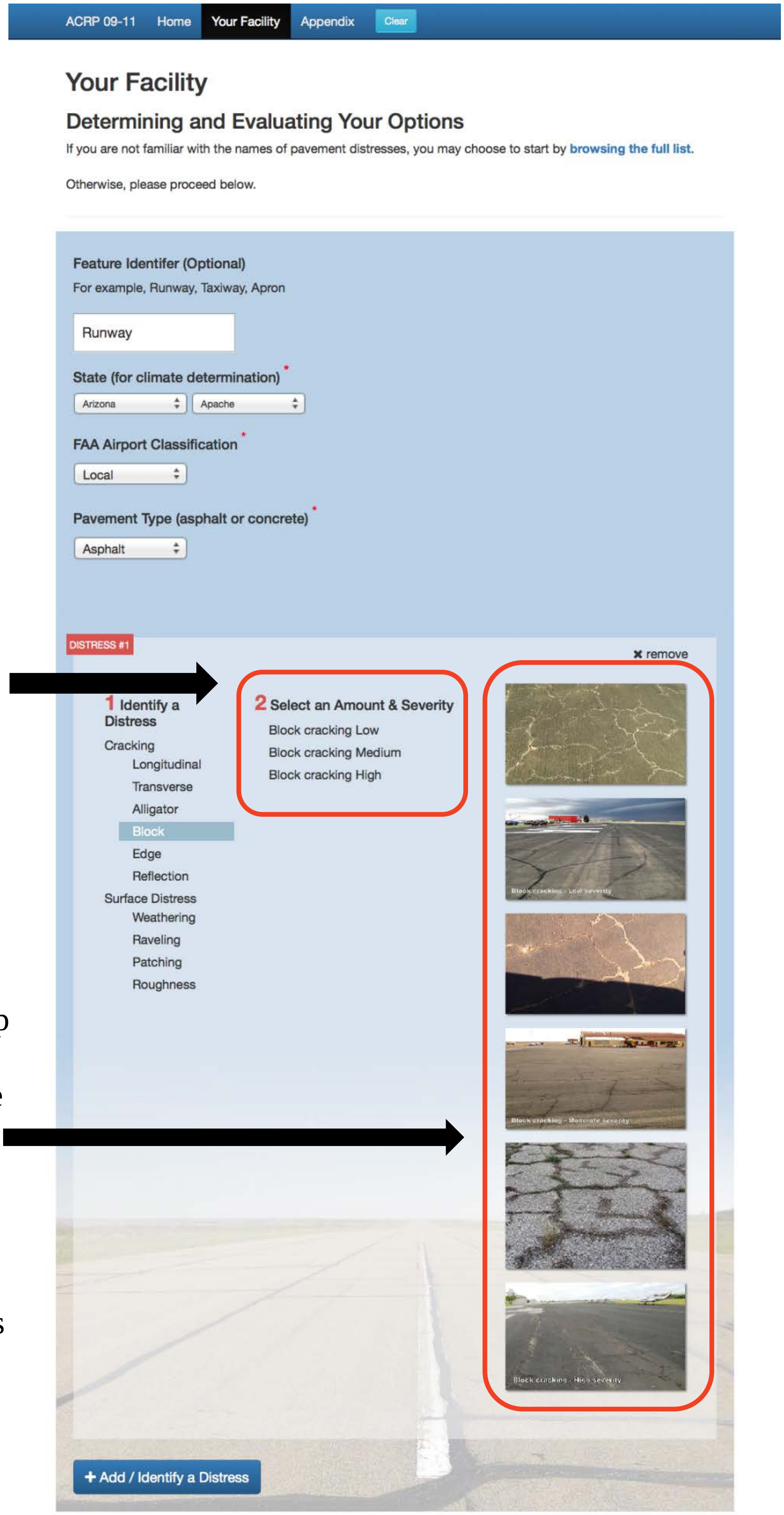


Click **Add/Identify a Distress** to begin describing the distress(es) observed in the current feature. Observe that a list of distresses possible for the chosen pavement type will appear.



Hover your cursor over each distress and click the Circle-i icon to view an information box describing it.

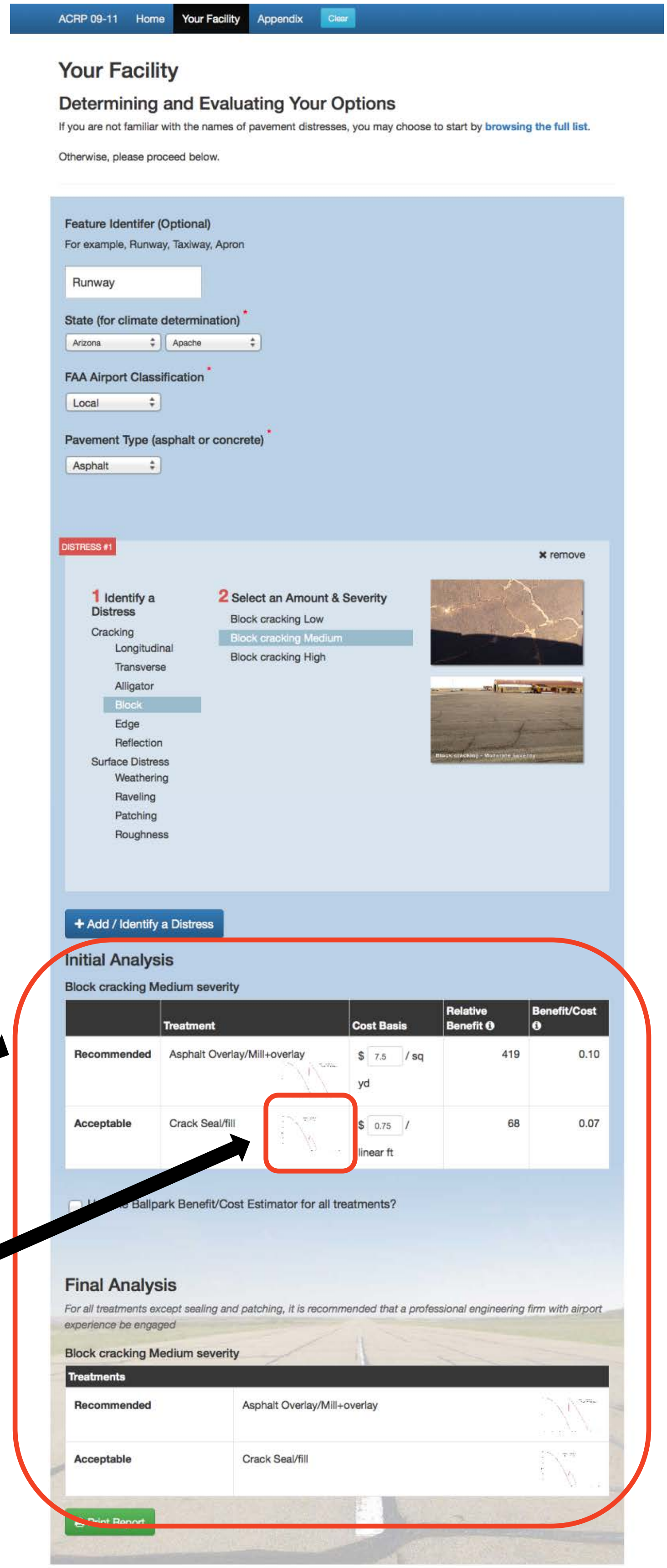
Select an appropriate choice under **Select an Amount & Severity**.



When you choose a distress, a second group of choices will appear, as well as photos of the distress.

Click a photo for a larger view to help you determine which distress your features is experiencing.

Select a Treatment Type

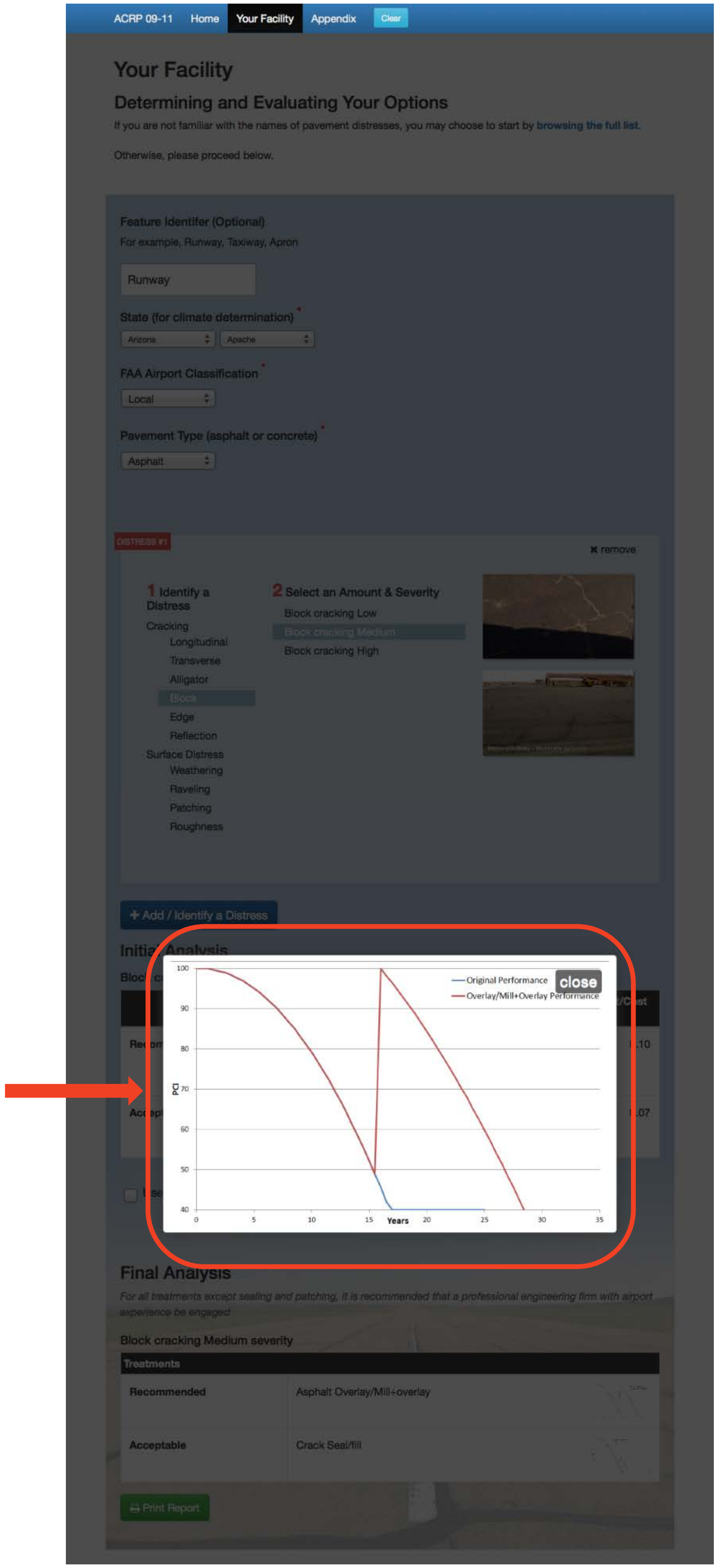


When you do so, a summary table appears listing a recommended and acceptable treatment.

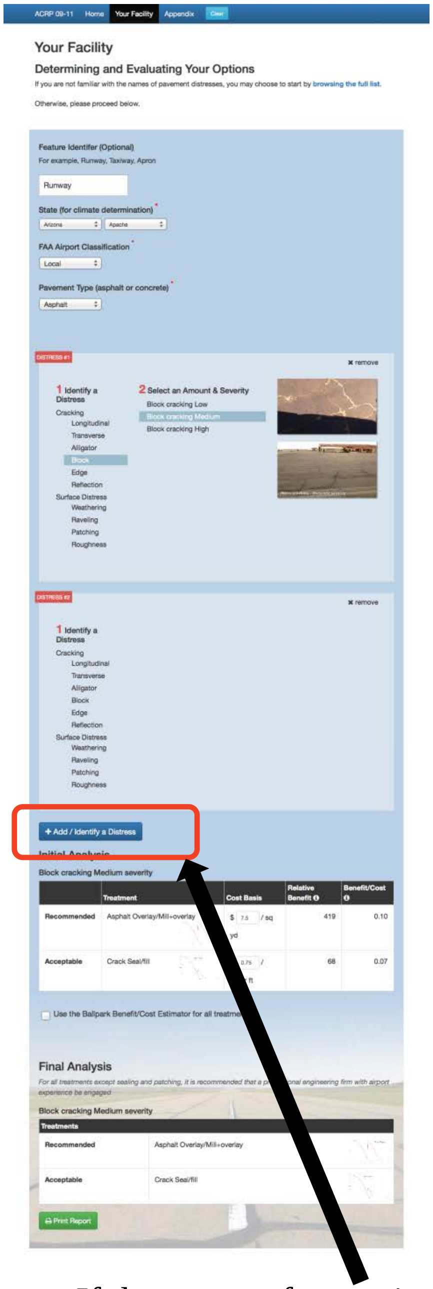
In the treatment cells, click the graph icon to view a PCI curve, indicating the estimated increased performance that the treatment can do to extend the life of the pavement being evaluated.

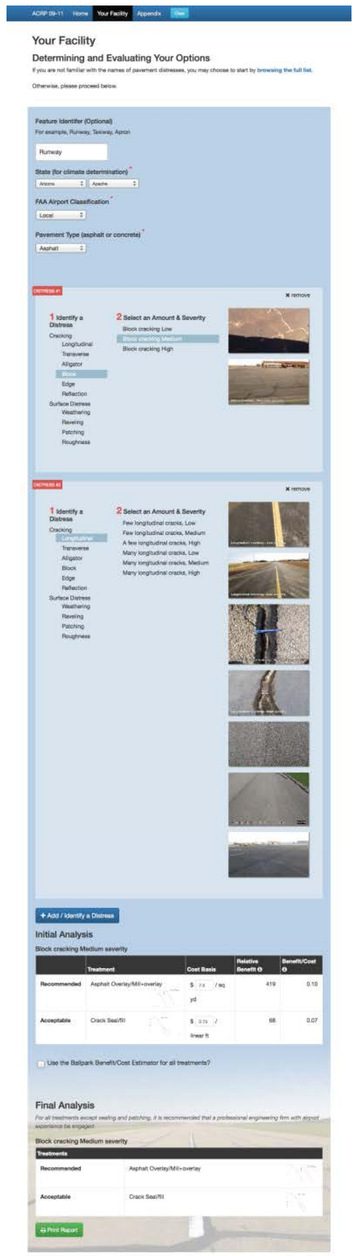
See Chapter 5 in this Guidebook for information about the relative benefit and benefit/cost numbers.

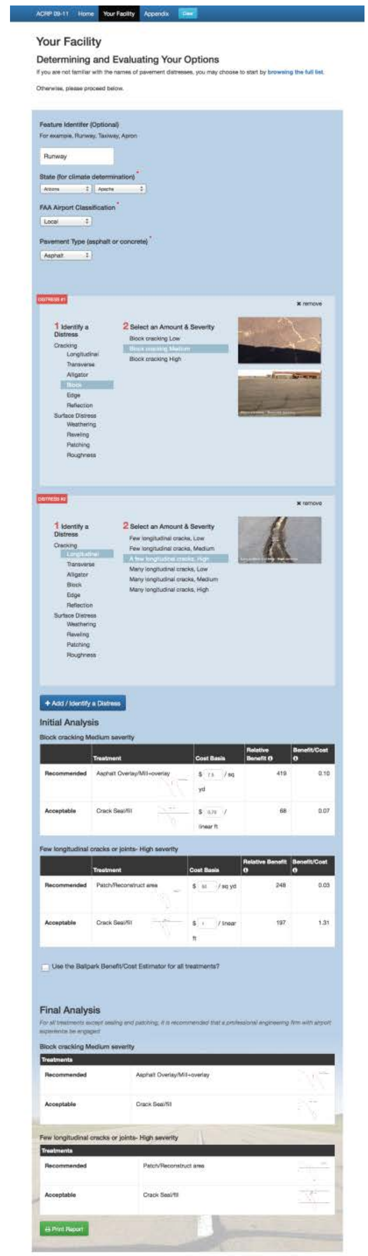
If the current feature is experiencing just one distress, skip to page 21 to use the Ballpark Estimator.



Input Additional Distresses





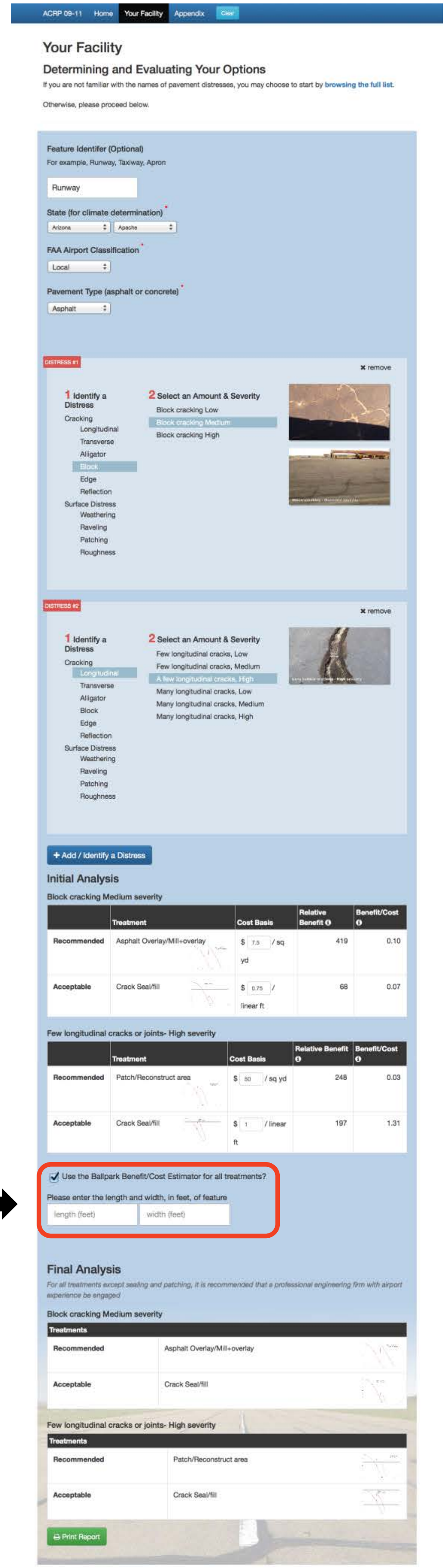


If the current feature is experiencing more than one distress, again click **Add/Identify a Distress** and follow the preceding steps to identify as many distresses as applicable.

In most cases, a single treatments table will appear in the Final Analysis section, combining the recommended and acceptable treatments for the distresses identified.

Pictured is an instance where multiple recommended treatments exist, so multiple tables are shown.

Get a Cost/Benefit Estimate

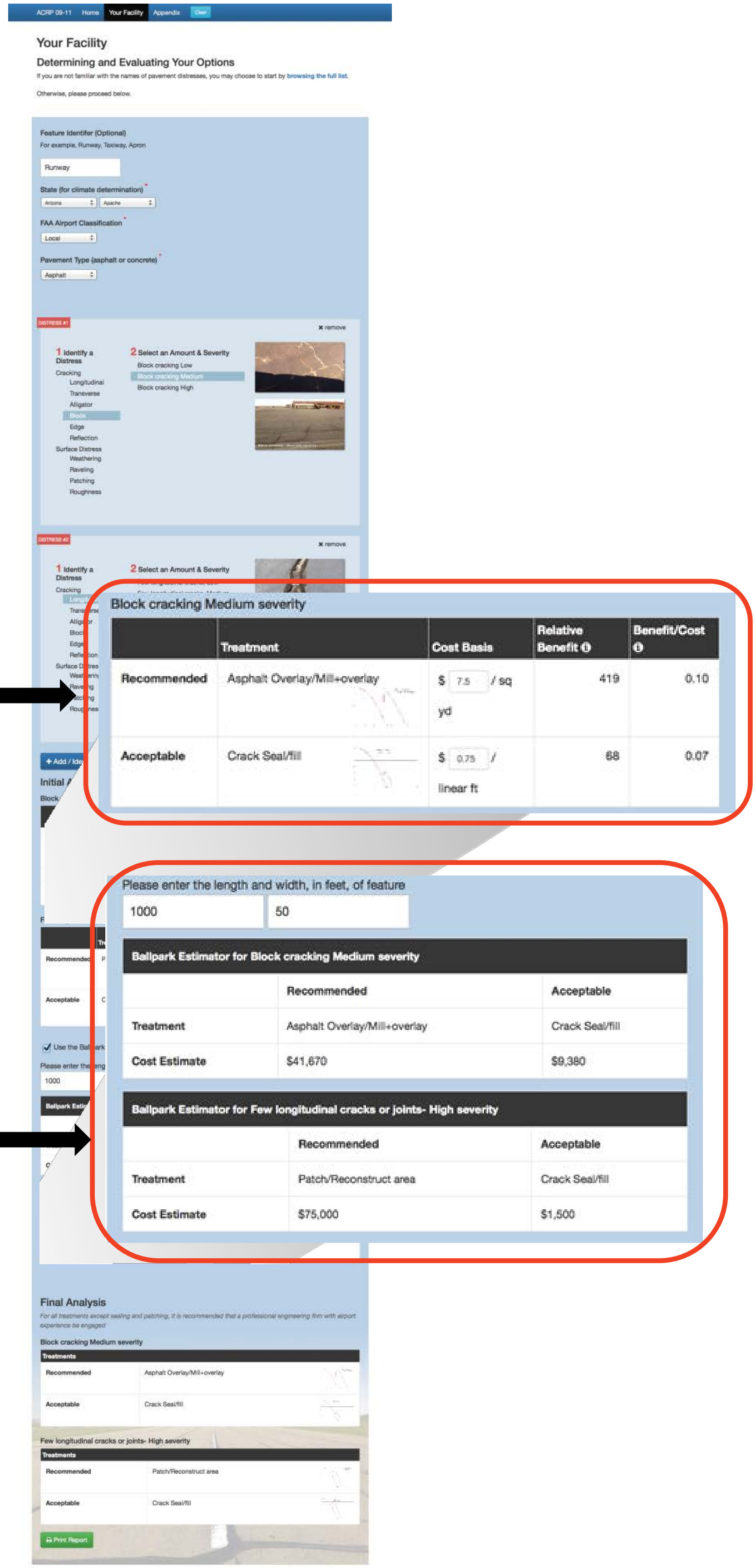


Click the **Use the Ballpark Benefit/Cost Estimator for all treatments?** checkbox to view and adjust cost estimates for treating the current feature.

These costs are based on the cost basis numbers for each treatment. You may adjust these costs as needed per treatment.

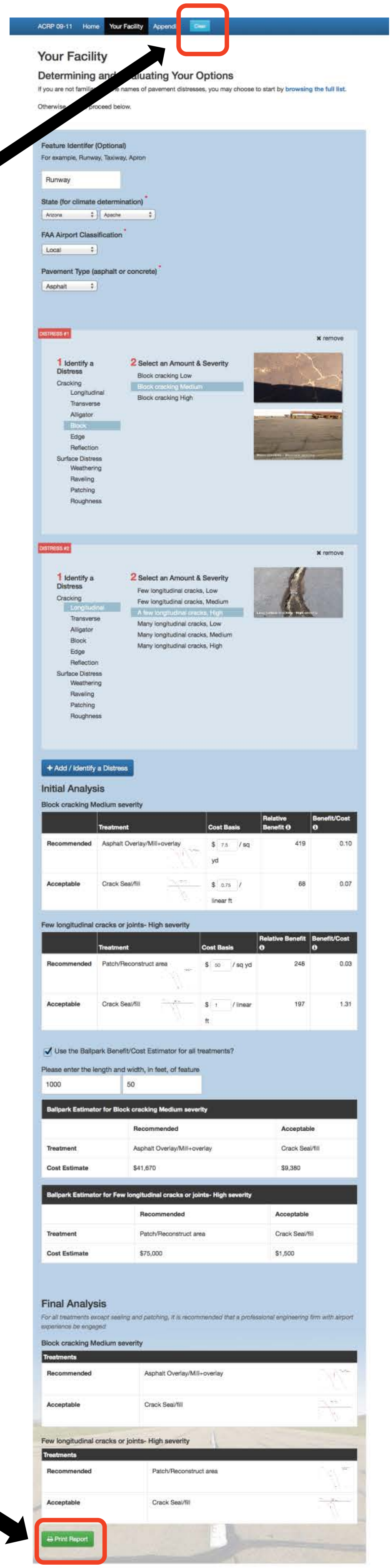
Note that as you change cost basis numbers and tab to the next field, the corresponding ballpark cost estimate will change as well.

When you enter a length and width for your feature,
(a) Ballpark Estimator table(s) will appear with estimated costs.



View Your Results

To clear your feature inputs to start evaluating another feature, click **Clear**.



To print the screen from your browser, click the Print Report button.

CHAPTER 4. HOW TO USE THE FIELD GUIDE

The *Field Guide for Airport Pavement Maintenance Recommendation Tool* provides pavement treatment options based on an airport's classification, climate zone, and distress type/severity. It serves as a paper version of the online tool.

The field guide provides guidance on choosing airport classification and climate zone. It also summarizes the most common distress types. For a comprehensive list of distress types and pictures, see Appendix A (asphalt) and Appendix B (concrete).

After determining your airport's parameters, you can flip through the tables to find an acceptable and recommended pavement treatment. The tables are color coded for easier reference.

Table 6 shows an example of one such treatment table. The pavement type (asphalt) and airport classification (basic) are in the left column, which applies to the whole table. The top row contains the climate zone (wet-no freeze) and the distress type (cracking).

Table 6. Treatment Table for Basic-Wet-No Freeze-Asphalt-Cracking.

	Wet – No Freeze: Cracking		
	Distress	**Acceptable**	**Recommended**
Basic	Few long crack, Low severity	Do nothing or rejuvenator	Crack seal/fill
	Few long crack, Med severity	Do nothing or rejuvenator	Crack seal/fill
	Few long crack, High severity	AC overlay/mill+overlay	Patch/recon area
	Many long crack, Low severity	Do nothing	Crack seal/fill
	Many long crack, Med severity	AC overlay/mill+overlay	Crack seal/fill
Asphalt	Many long crack, High severity	Crack seal/fill	AC overlay/mill+overlay
	Trans crack, 50ft apart, Low severity	Do nothing	Crack seal/fill
	Trans crack, 50ft apart, Med severity	Do nothing	Crack seal/fill
	Trans crack, 50ft apart, High severity	AC overlay/mill+overlay	Crack seal/fill
	Trans crack, 20ft apart, Low severity	Do nothing	Crack seal/fill
	Trans crack, 20ft apart, Med severity	Chip/cape seal	Crack seal/fill
	Trans crack, 20ft apart, High severity	AC overlay/mill+overlay	Crack seal/fill
	Block crack, Low severity	Do nothing	Crack seal/fill
	Block crack, Med severity	AC overlay/mill+overlay	Crack seal/fill
	Block crack, High severity	Chip/cape seal	AC overlay/mill+overlay

CHAPTER 5. UNDERSTANDING THE BENEFIT/COST USED IN THE ONLINE TOOL RESULTS

This chapter summarizes the methodology behind the benefit/cost results that the online tool produces. For a more in-depth look at the methodology, assumptions, and calculations, refer to the final report.

There are many ways to measure benefit/cost, including life-cycle costing, cost-effectiveness analysis, and longevity cost index. GA managers will get the most use out of benefit/cost.

Using decision trees/matrices narrows down the list of available treatments to two or three specific treatments for a given set of airport parameters. From there, a decision still needs to be made about the optimal treatment. Ideally, the user will have information on the expected treatment life (which can also vary), general material unit costs, and particular details of the construction procedure (expected downtime, specialized contractor training, seasonal availability, etc.).

Applications to GA Airport Managers

GA airport managers face a cycle of treating the worst off pavement first. This is the natural result of under-budgeting. But since the worst-first approach is *more* costly in the long run, GA airports benefit from using the online tool to see the impacts and cost savings from intervention earlier in the pavement life-cycle.

Pavement Life Span

Figure 5 and Figure 6 illustrate the life span of typical asphalt and concrete airfield pavement without any intervention, respectively. This life span is also known as its deterioration curve. Concrete has a much longer life span than asphalt.

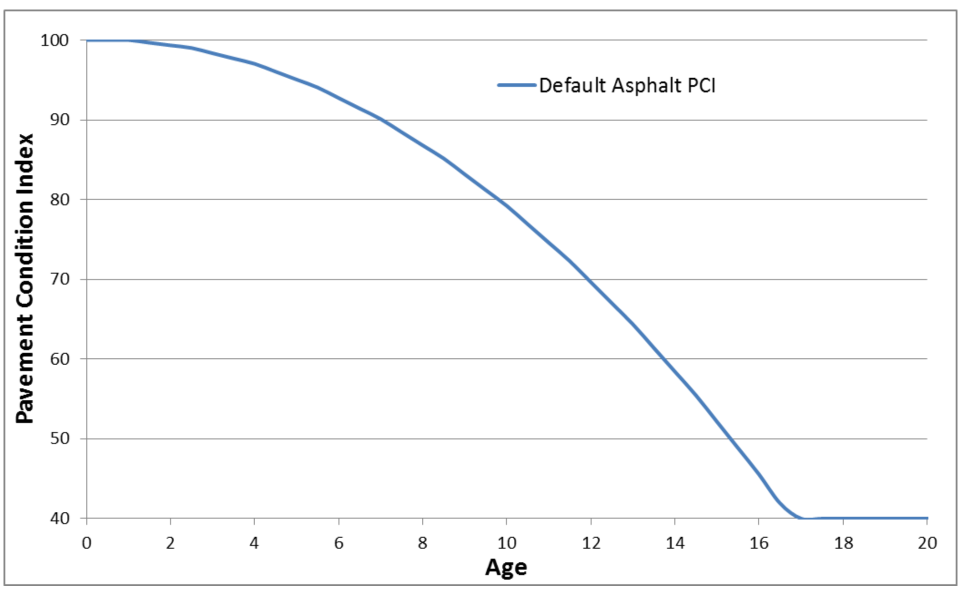


Figure 5. Default PCI vs. Age for Asphalt Pavement.

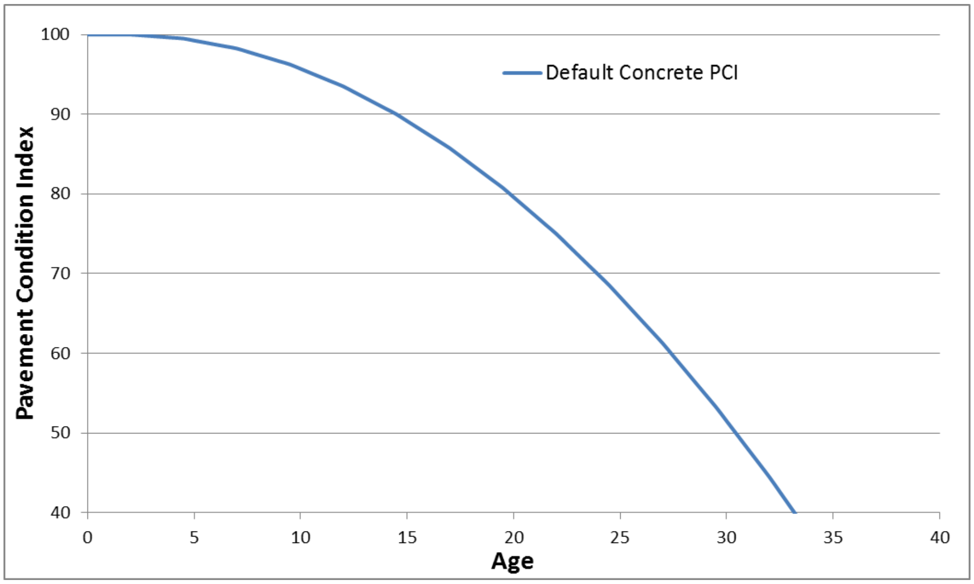


Figure 6. Default PCI vs. Age for Concrete Pavement.

Calculation of Relative Benefit

Relative benefit is a calculated value used for comparing treatment options. Figure 7 shows the calculation of relative benefit. In the graph, in year 10 of this pavement, the PCI has fallen to the low 80s. By applying a micro/slurry treatment, the PCI returns to 100 and the life of the pavement is extended by a few more years.

The shaded area, the relative benefit, is defined as the sum of the condition (expressed as PCI score) after applying a treatment, minus the condition had the treatment not been applied (expressed as a net PCI increase) for each year until the PCI score with treatment reaches the threshold value of 40, summed over the reported as PCI–Years (Figure 7).

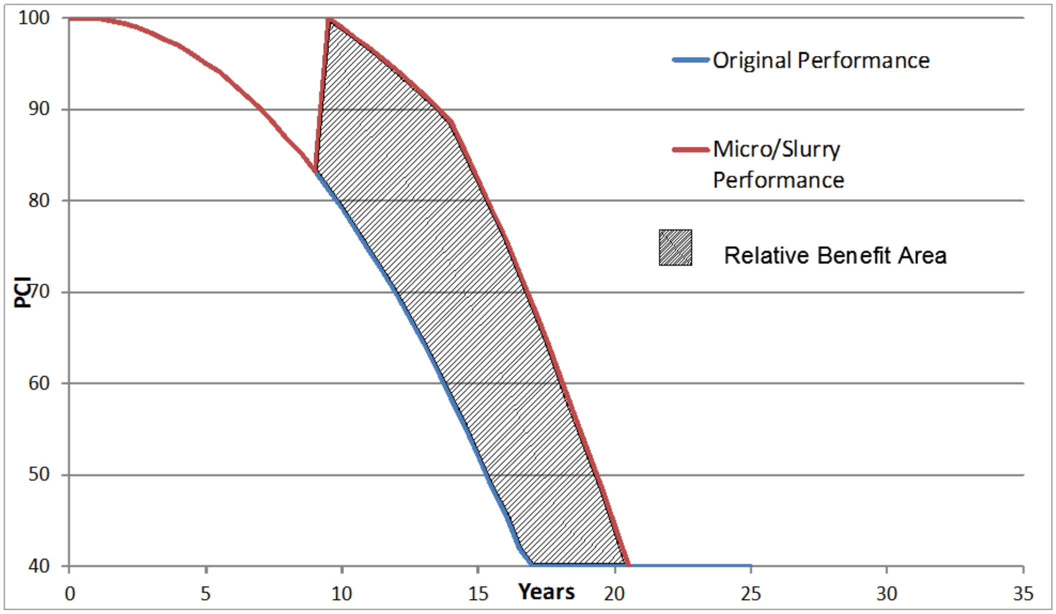


Figure 7. Illustration of Relative Benefit.

Calculation of Treatment Life

For benefit/cost data used in the online tool, researchers gathered data on the service life of each treatment and calculated a corrected average treatment life to use in relative benefit calculations.

Figure 8–Figure 11 show a range of results that treatments can do for a pavement's PCI and life span. Figure 8 graphs a treatment (such as a crack seal) that would extend the life of the pavement but not improve the PCI. In Figure 9, there is an increase in PCI, which extends the pavement life. Figure 10 shows the situation where the distress is eliminated and the PCI is increased to 100, but the treatment does not fully restore the pavement to new. Figure 11 illustrates the impact of complete reconstruction, which fully resets the PCI curve.

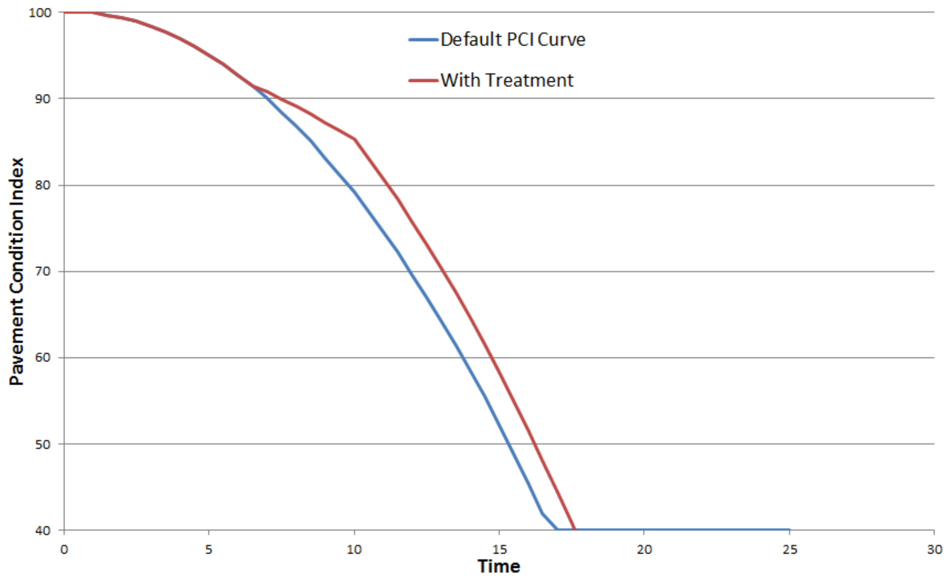


Figure 8. Example of Treatment Changing Deterioration Rate Only.

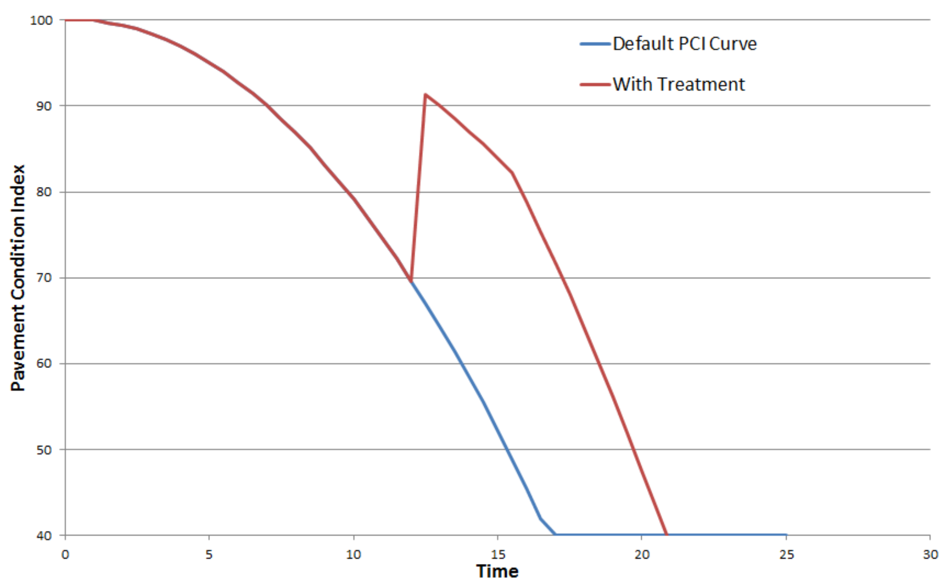


Figure 9. Example of Treatment Increasing PCI and Changing Deterioration Rate.

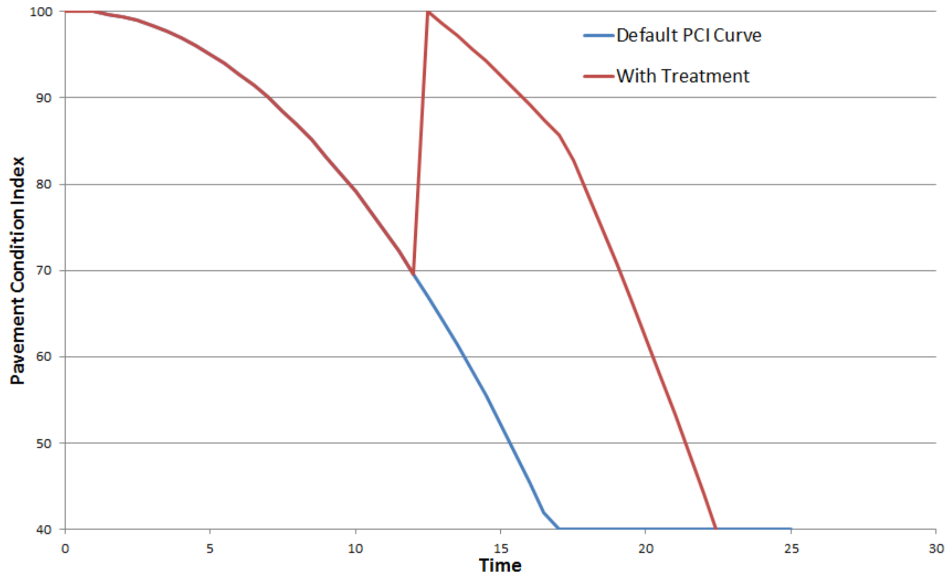


Figure 10. Example of Treatment Increasing PCI to 100 and Changing Deterioration Rate.

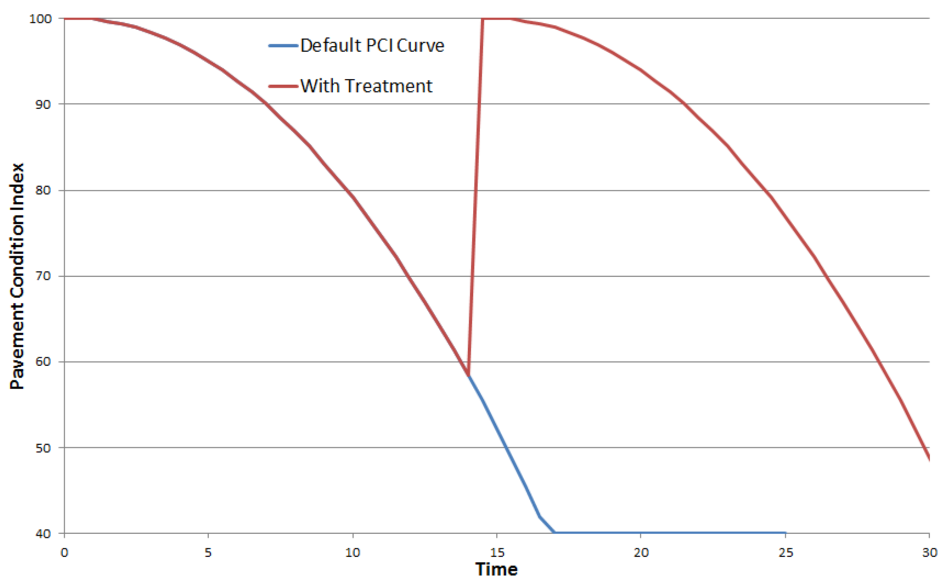


Figure 11. Example of Reconstruct Treatment Resetting PCI Curve.

Development of Cost Data

Researchers gathered cost data to use in the online tool for the purpose of benefit/cost comparison, not for calculating a total cost of a treatment. The repair costs for each distress type/severity/quantity/treatment type were calculated based on the distresses found within an idealized 5000 ft^2 (100 ft long by 50 ft wide) or 20 slab sample (typical slabs assumed to be 20 ft by 20 ft).

Materials and labor costs vary significantly among regions and contractors, and also drastically change over time and with market dynamics. Because of this tremendous potential variation in costs, the online tool user is allowed, and encouraged, to obtain quotes from a local contractor and input customized cost estimates for the analysis. The tool will allow the user to modify the cost data, enter the dimension of the feature (runway, apron, or taxiway) in which they are interested, and from that, calculate an approximate total cost.

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APPENDIX A – ASPHALT DISTRESS TYPES AND DESCRIPTIONS

The following information comes from *Asphalt Surfaced Airfields: PAVER^{TM} Distress Manual* (U.S. Army 2009).

Table of Contents

Distress Type	Page
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Alligator or Fatigue Cracking	A-13
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Raveling	A-16
Patching	A-18
Roughness	A-20

Cracking Problems

Longitudinal (Non-PCC Joint Reflective)

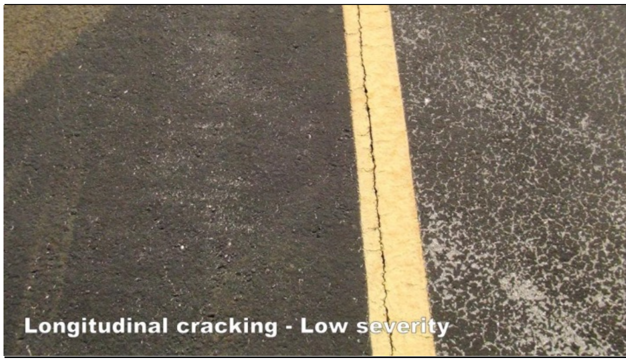
Description	• Parallel to the pavement's center line or laydown direction. • They may be caused by: (1) a poorly constructed paving lane joint, (2) shrinkage of the AC surface due to low temperatures or hardening of the asphalt, or (3) a reflective crack caused by cracks beneath the surface course, including cracks in PCC slabs (but not at PCC joints). • Transverse cracks extend across the pavement at approximately right angles to the pavement's center line or direction of laydown. They may be caused by (2) or (3). These types of cracks are not usually load associated. If the pavement is fragmented along a crack, the crack is said to be spalled.
How to Measure	• Measured in linear feet (m) • The length and severity of each crack should be identified and recorded. If the crack does not have the same severity level along its entire length, each portion of the crack having a different severity level should be recorded separately. For an example see "Joint Reflection Cracking." • If block cracking is recorded, longitudinal and transverse cracking is not recorded in the same area.

	Low	Medium	High
Severity Levels	Cracks have only light spalling (little or no FOD potential) or no spalling, and can be filled or non-filled. If non-filled, the cracks have a mean width of ¼ inch (6 mm) or less; filled cracks are of any width, but their filler material is in satisfactory condition.	One of the following conditions exists: (1) cracks are moderately spalled (some FOD potential) and can be either filled or non-filled of any width; (2) filled cracks are not spalled or are lightly spalled, but filler is in unsatisfactory condition; (3) non-filled cracks are not spalled or are only lightly spalled, but the mean crack width is greater than ¼ inch (6 mm), or (4) light random cracking exists near the crack or at the corners of intersecting cracks.	Cracks are severely spalled and pieces are loose or missing causing definite FOD potential. Cracks can be either filled or non-filled of any width.

Longitudinal Cracking (Non-PCC Joint Reflective) Severity Levels

Low

Few Cracks



Many Cracks

Longitudinal Cracking (Non-PCC Joint Reflective) Severity Levels	
Medium	
	
High	
	

Transverse Cracking (Non-PCC Joint Reflective)

Description	• Extend across the pavement at approximately right angles to the pavement's center line or direction of laydown. • They may be caused by: (1) shrinkage of the AC surface due to low temperatures or hardening of the asphalt, or (2) a reflective crack caused by cracks beneath the surface course, including cracks in PCC slabs (but not at PCC joints). • These types of cracks are not usually load associated. If the pavement is fragmented along a crack, the crack is said to be spalled.
How to Measure	• Measured in linear feet (m) • The length and severity of each crack should be identified and recorded. If the crack does not have the same severity level along its entire length, each portion of the crack having a different severity level should be recorded separately. For an example see "Joint Reflection Cracking." • If block cracking is recorded, longitudinal and transverse cracking is not recorded in the same area.

	Low	**Medium**	**High**
Severity Levels	Cracks have only light spalling (little or no FOD potential) or no spalling, and can be filled or non-filled. If non-filled, the cracks have a mean width of ¼ inch (6 mm) or less; filled cracks are of any width, but their filler material is in satisfactory condition.	One of the following conditions exists: (1) cracks are moderately spalled (some FOD potential) and can be either filled or non-filled of any width; (2) filled cracks are not spalled or are lightly spalled, but filler is in unsatisfactory condition; (3) non-filled cracks are not spalled or are only lightly spalled, but the mean crack width is greater than ¼ inch (6 mm), or (4) light random cracking exists near the crack or at the corners of intersecting cracks.	Cracks are severely spalled and pieces are loose or missing causing definite FOD potential. Cracks can be either filled or non-filled of any width.

Transverse Cracking (Non-PCC Joint Reflective) Severity Levels (20 or 50 Ft)

Low

Medium

High

Edge Cracking (Non-PCC Joint Reflective)

Description	• Occur within 4 ft of the edge. • They may be caused by: (1) a poorly constructed paving lane joint, (2) shrinkage of the AC surface due to low temperatures or hardening of the asphalt, or (3) a reflective crack caused by cracks beneath the surface course, including cracks in PCC slabs (but not at PCC joints). • These types of cracks are not usually load associated. If the pavement is fragmented along a crack, the crack is said to be spalled.
How to Measure	• Measured in linear feet (m) • The length and severity of each crack should be identified and recorded. If the crack does not have the same severity level along its entire length, each portion of the crack having a different severity level should be recorded separately. For an example see “Joint Reflection Cracking.” • Edge cracks are often treated differently than cracks in the middle of the pavement and are listed separately for this reason.

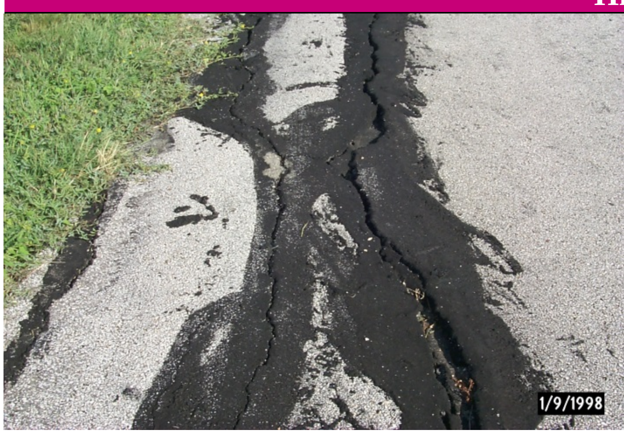
	Low	**Medium**	**High**
Severity Levels	Cracks have only light spalling (little or no FOD potential) or no spalling, and can be filled or non-filled. If non-filled, the cracks have a mean width of ¼ inch (6 mm) or less; filled cracks are of any width, but their filler material is in satisfactory condition.	One of the following conditions exists: (1) cracks are moderately spalled (some FOD potential) and can be either filled or non-filled of any width; (2) filled cracks are not spalled or are lightly spalled, but filler is in unsatisfactory condition; (3) non-filled cracks are not spalled or are only lightly spalled, but the mean crack width is greater than ¼ inch (6 mm), or (4) light random cracking exists near the crack or at the corners of intersecting cracks.	Cracks are severely spalled and pieces are loose or missing causing definite FOD potential. Cracks can be either filled or non-filled of any width.

Edge Cracking (Non-PCC Joint Reflective) Severity Levels

Low

Medium

High



Joint Reflection Cracking from PCC (Longitudinal and Transverse)

Description	• Occurs only on pavements having an asphalt or tar surface over a PCC slab. • This category does not include reflection cracking from any other type of base (that is, cement stabilized, lime stabilized). Such cracks are listed as longitudinal and transverse cracks. • Caused mainly by movement of the PCC slab beneath the AC surface because of thermal and moisture changes; it is not load-related. • Traffic loading may cause a breakdown of the AC near the crack, resulting in spalling and FOD potential. • If the pavement is fragmented along a crack, the crack is said to be spalled. Knowledge of slab dimensions beneath the AC surface will help to identify these cracks.
How to Measure	• Measured in linear feet (m). • The length and severity level of each crack should be identified and recorded. If the crack does not have the same severity level along its entire length, each portion should be recorded separately. For example, a crack that is 50 ft (15 m) long may have 10 ft (3 m) of a high severity, 20 ft (6 m) of a medium severity, and 20 ft (6 m) of a light severity. These would all be recorded separately. If the different levels of severity in a portion of a crack cannot be easily divided, that portion should be rated at the highest severity present.

	Low	Medium	High
Severity Levels	Cracks have only light spalling (little or no FOD potential) or no spalling, and can be filled or non-filled. If non-filled, the cracks have a mean width of ¼ inch (6 mm) or less; filled cracks are of any width, but their filler material is in satisfactory condition.	One of the following conditions exists: cracks are moderately spalled (some FOD potential) and can be either filled or non-filled of any width; filled cracks are not spalled or are lightly spalled, but filler is in unsatisfactory condition; non-filled cracks are not spalled or are only lightly spalled, but the mean crack width is greater than ¼ inch (6 mm); or light random cracking exists near the crack or at the corners of intersecting cracks.	Cracks are severely spalled with pieces loose or missing causing definite FOD potential. Cracks can be either filled or non-filled of any width.

Joint Reflection Cracking from PCC (Longitudinal and Transverse) Severity Levels

Low


Medium


High

Block Cracking

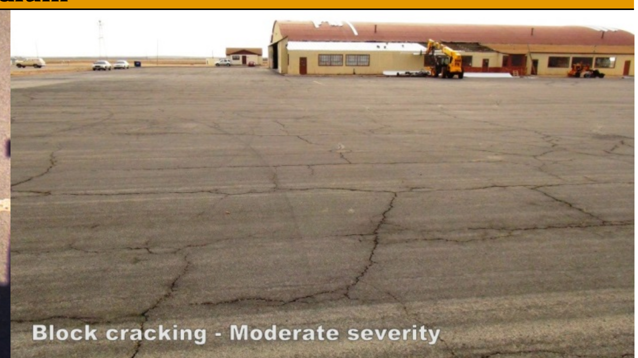
Description	• Interconnected cracks that divide the pavement into approximately rectangular pieces. • May range in size from approximately 1 by 1 ft to 10 by 10 ft (0.3 by 0.3 m to 3 by 3 m). • Caused mainly by shrinkage of the AC and daily temperature cycling (that results in daily stress/strain cycling). • Not load associated. • The occurrence of block cracking usually indicates that the asphalt has hardened significantly. • Normally occurs over a large portion of pavement area, but sometimes will occur only in non-traffic areas. • Differs from alligator cracking in that the alligator cracks form smaller, many-sided pieces with sharp angles. Also unlike block cracks, alligator cracks are caused by repeated traffic loadings and are located only in traffic areas (that is, wheel paths).
How to Measure	• Measured in ft^2 (m^2) of surface area. • Usually occurs at one severity level in a given pavement section; however, any areas of the pavement section having distinctly different levels of severity should be measured and recorded separately. • For asphalt pavements, not including AC over PCC, if block cracking is recorded, no longitudinal and transverse cracking should be recorded in the same area. • For asphalt overlay over concrete, block cracking, joint reflection cracking, and longitudinal and transverse cracking reflected from old concrete should all be recorded separately.

	Low	**Medium**	**High**
Severity Levels	Blocks are defined by cracks that are non-spalled (sides of the crack are vertical) or lightly spalled, causing no FOD potential. Non-filled cracks have ¼ inch (6 mm) or less mean width and filled cracks have filler in satisfactory condition.	Blocks are defined by either: filled or non-filled cracks that are moderately spalled (some FOD potential); non-filled cracks that are not spalled or have only minor spalling (some FOD potential), but have a mean width greater than approximately ¼ inch (6 mm); or filled cracks greater than ¼ inch that are not spalled or have only minor spalling (some FOD potential), but have filler in unsatisfactory condition.	Blocks are well defined by cracks that are severely spalled, causing a definite FOD potential.

Block Cracking Severity Levels

Low

Medium



High

Alligator or Fatigue Cracking

Description	• A series of interconnecting cracks caused by fatigue failure of the AC surface under repeated traffic loading. The cracking initiates at the bottom of the AC surface (or stabilized base) where tensile stress and strain are highest under a wheel load. The cracks propagate to the surface initially as a series of parallel cracks. After repeated traffic loading, the cracks connect, forming many-sided, sharp-angled pieces that develop a pattern resembling chicken wire or the skin of an alligator. The pieces are less than 2 ft (0.6 m) on the longest side. • Occurs only in areas that are subjected to repeated traffic loadings, such as wheel paths. • Would not occur over an entire area unless the entire area was subjected to traffic loading. (Pattern-type cracking that occurs over an entire area that is not subjected to loading is rated as block cracking, that is, not a load-associated distress.) • Considered a major structural distress.
How to Measure	• Measured in ft^2 (m^2) of surface area. • Many times two or three levels of severity exist within one distressed area. If these portions can be easily distinguished from one another, they should be measured and recorded separately. • If the different levels of severity cannot be easily divided, the entire area should be rated at the highest severity level present. • If alligator cracking and rutting occur in the same area, each is recorded separately as its respective severity level.

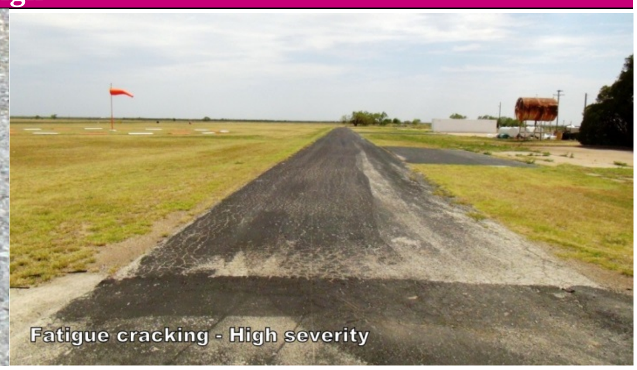
	Low	**Medium**	**High**
Severity Levels	Fine, longitudinal hairline cracks running parallel to one another with none or only a few interconnecting cracks. The cracks are not spalled.	Further development of light alligator cracking into a pattern or network of cracks that may be lightly spalled. Medium-severity alligator cracking is defined by a well-defined pattern of interconnecting cracks, where all pieces are securely held in place (good aggregate interlock between pieces).	Network or pattern cracking has progressed so that the pieces are well defined and spalled at the edges; some of the pieces rock under traffic and may cause FOD potential.

Alligator (Fatigue) Cracking Severity Levels

Low

Medium

High



Weathering (Surface Wear)—Dense Mix Asphalt

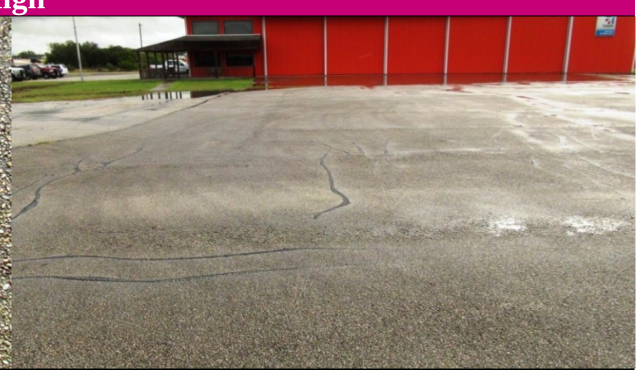
Description	• The wearing away of the asphalt binder and fine aggregate matrix from the pavement surface.
How to Measure	• Measured in ft^2 (m^2).
	• Surface wear is not recorded if medium or high severity raveling is recorded.

	Low	Medium	High
Severity Levels	Asphalt surface beginning to show signs of aging which may be accelerated by climatic conditions. Loss is the fine aggregate matrix is noticeable and may be accompanied by fading of the asphalt color. Edges of the coarse aggregates are beginning to be exposed (less than 1 mm or 0.05 inches). Pavement may be relatively new (as new as 6 months old).	Loss of fine aggregate matrix is noticeable and edges of coarse aggregate have been exposed up to ¼ width (of the longest side) of the coarse aggregate due to the loss of fine aggregate matrix.	Edges of coarse aggregate have been exposed greater than ¼ width (of the longest side) of the coarse aggregate. There is considerable loss of fine aggregate matrix leading to potential or some loss of coarse aggregate.

Weathering (Surface Wear) Severity Levels

Low

High



Raveling

Description	• Dislodging of coarse aggregate particles from the pavement surface.
How to Measure	• Measured in ft^2 (m^2) of surface area. • Mechanical damage caused by hook drags, tire rims, or snowplows is counted as areas of high severity raveling.

Dense Mix Severity Levels

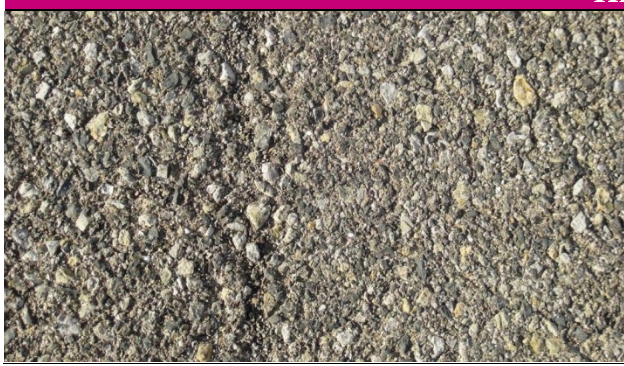
As used herein, coarse aggregate refers to predominant coarse aggregate sizes of the asphalt mix. Aggregate clusters refer to when more than one adjoining coarse aggregate piece is missing. If in doubt about a severity level, three representative areas of 1 yd^2 each (1 m^2) should be examined and the number of missing coarse aggregate particles counted.

	Low	**Medium**	**High**
Severity Levels	(1) In a yd^2 (m^2) representative area, the number of coarse aggregate particles missing is between 5 and 20, and/or (2) missing aggregate clusters are less than 2 percent of the examined yd^2 (m^2) area. In low severity raveling, there is little or no FOD potential.	(1) In a yd^2 (m^2) representative area, the number of coarse aggregate particles missing is between 21 and 40, and/or (2) missing aggregate clusters are between 2 and 10 percent of the examined yd^2 (m^2) area. In medium severity raveling, there is some FOD potential.	(1) In a yd^2 (m^2) representative area, the number of coarse aggregate particles missing is over 40, and/or (2) missing aggregate clusters are more than 10 percent of the examined yd^2 (m^2) area. In high severity raveling, there is significant FOD potential.
Slurry Seal/Coal Tar over Dense Mix	(1) The scaled area is less than 1%. (2) In the case of coal tar where pattern cracking has developed, the surface cracks are less than ¼ inch (6 mm) wide.	(1) The scaled area is between 1 and 10%. (2) In the case of coal tar where pattern cracking has developed, the cracks are ¼ inch (6 mm) wide or greater.	(1) The scaled area is over 10%. (2) In the case of coal tar the surface is peeling off.

Raveling Severity Levels

Low

High



Patching

Description	• A defect, no matter how well it is performing
How to Measure	• Measured in ft^2 (m^2) of surface area • If a single patch has areas of differing severity levels, these areas should be measured and recorded separately. For example, a 25 ft^2 (2.5 m^2) patch may have 10 ft^2 (1 m^2) of medium severity and 15 ft^2 (1.5 m^2) of low severity. These areas should be recorded separately. • Any distress found in a patched area will not be recorded; however, its effect on the patch will be considered when determining the patch's severity level. • A very large patch, (area > 2500 ft^2 [230 m^2]) or feathered-edge pavement, may qualify as an additional sample unit or as a separate section.

	Low	**Medium**	**High**
Severity Levels	Patch is in good condition and is performing satisfactorily.	Patch is somewhat deteriorated and affects ride quality to some extent. Moderate amount of distress is present within the patch or has FOD potential, or both.	Patch is badly deteriorated and affects ride quality significantly or has high FOD potential. Patch soon needs replacement.

Patching Severity Levels	
Low	
	
Medium	
	
High	
	

Roughness

Roughness, as used in this tool, is a combination of several distress types, which are corrugation, depression, and swell. Regardless of the distress type, select the category that matches the impact of the distress.

Corrugation

Description	• A series of closely spaced ridges and valleys (ripples) occurring at fairly regular intervals (usually less than 5 ft) (1.5 m) along the pavement. • The ridges are perpendicular to the traffic direction. • Traffic action combined with an unstable pavement surface or base usually causes this type of distress.
How to Measure	• Measured in ft^2 (m^2) of surface area. • The mean elevation difference between the ridges and valleys of the corrugations indicates the level of severity. • To determine the mean elevation difference, a 10-ft (3 m) straightedge should be placed perpendicular to the corrugations so that the depth of the valleys can be measured in inches (mm). The mean depth is calculated from five such measurements.

Severity	**Runways and High-Speed Taxiways**	**Taxiways and Aprons**	
L	< ¼ inch (6 mm)	< ½ inch (13 mm)	Corrugations are minor and do not significantly affect ride quality.
M	¼ to ½ inch (6 to 13 mm)	½ to 1 inch (13 to 25 mm)	
H	> ½ inch (13 mm)	> 1 inch (25 mm)	

Depression

Description	• Localized pavement surface areas having elevations slightly lower than those of the surrounding pavement. • In many instances, light depressions are not noticeable until after a rain, when ponding water creates birdbath areas, but the depressions can also be located without rain because of stains created by ponding of water. • Can be caused by settlement of the foundation soil or can be built during construction. • Cause roughness and, when filled with water of sufficient depth, could cause hydroplaning of aircraft.
How to Measure	• Measured in ft^2 (m^2) of surface area. • The maximum depth of the depression determines the level of severity. • Measured by placing a 10-ft (3 m) straightedge across the depressed area and measuring the maximum depth in inches (mm). • Larger than 10 ft (3 m) across must be measured by using a stringline.

	Maximum Depth of Depression		
	Runways and High-Speed Taxiways	**Taxiways and Aprons**	**Severity Levels**
L	⅛ to ½ inch (3 to 13mm)	½ to 1 inch (13 to 25 mm)	Depression can be observed or located by stained areas, only slightly affects pavement riding quality, and may cause hydroplaning potential on runways (see measurement criteria below).
M	½ to 1 inch (13 to 25 mm)	1 to 2 inch (25 to 51 mm)	The depression can be observed, moderately affects pavement riding quality, and causes hydroplaning potential on runways (see measurement criteria below).
H	> 1 inch (> 25 mm)	> 2 inch (> 51 mm)	The depression can be readily observed, severely affects pavement riding quality, and causes definite hydroplaning potential (see measurement criteria below).

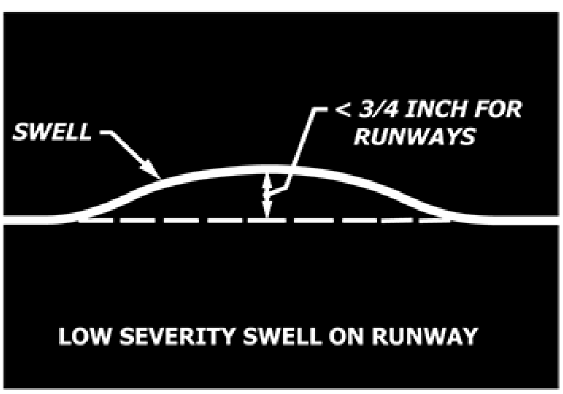
Swell

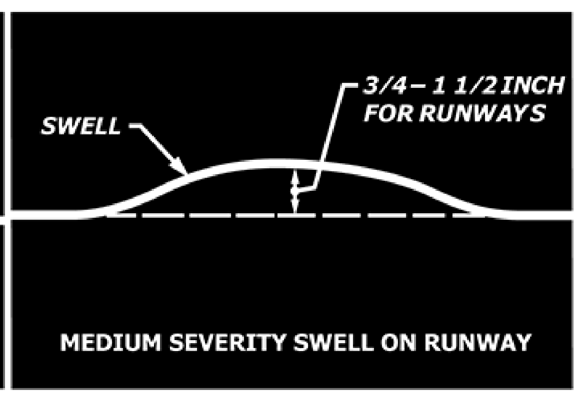
Description	• An upward bulge in the pavement's surface. • May occur sharply over a small area or as a longer, gradual wave. Either type of swell can be accompanied by surface cracking. • Usually caused by frost action in the subgrade or by swelling soil, but a small swell can also occur on the surface of an asphalt overlay (over PCC) as a result of a blowup in the PCC slab.
How to Measure	• Measured in ft^2 (m^2). • The severity rating should consider the type of pavement section (that is, runway, taxiway, or apron). For example, a swell of sufficient magnitude to cause considerable roughness on a runway at high speeds would be rated as more severe than the same swell located on an apron or taxiway where the normal aircraft operating speeds are much lower. • For short wavelengths, locate the highest point of the swell. Rest at 10-ft (3 m) straightedge on that point so that both ends are equal distance above pavement. Measure this distance to establish severity rating.

The following guidance is provided for runways:

Severity	Height Differential	Severity Levels
L	< ¾ inch (20 mm)	Swell is barely visible and has a minor effect on the pavement's ride quality. (Low-severity swells may not always be observable, but their existence can be confirmed by driving a vehicle over the section. An upward acceleration will occur if the swell is present).
M	¾ to 1½ inch (20 to 40 mm)	Swell can be observed without difficulty and has a significant effect on the pavement's ride quality.
H	> 1½ inch (40 mm)	Swell can be readily observed and severely affects the pavement's ride quality.

Rate severity on high-speed taxiways using measurement criteria provided above. Double the height differential criteria for other taxiways and aprons.





APPENDIX B – CONCRETE DISTRESS TYPES AND DESCRIPTIONS

The following information comes from *Asphalt Surfaced Airfields: PAVER^{TM} Distress Manual* (U.S. Army 2009).

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Joint Problems

Joint Seal Damage

Description	• Any condition that enables soil or rocks to accumulate in the joints or allows significant infiltration of water. • Accumulation of incompressible materials prevents the slabs from expanding and may result in buckling, shattering, or spalling. • A pliable joint filler bonded to the edges of the slabs protects the joints from accumulation of materials and also prevents water from seeping down and softening the foundation supporting the slab. • Typical types of joint seal damage are: (1) stripping of joint sealant, (2) extrusion of joint sealant, (3) weed growth, (4) hardening of the filler (oxidation), (5) loss of bond to the slab edges, and (6) lack or absence of sealant in the joint.
How to Count	• Not counted on a slab-by-slab basis, but is rated based on the overall condition of the sealant in the sample unit. • In satisfactory condition if it prevents entry of water into the joint, it has some elasticity, and if there is no vegetation growing between the sealer and joint face. • Premolded sealer is rated using the same criteria as above except as follows: (1) premolded sealer must be elastic and must be firmly pressed against the joint walls; and (2) premolded sealer must be below the joint edge. If it extends above the surface, it can be caught by moving equipment such as snow plows or brooms and be pulled out of the joint. • Premolded sealer is recorded at low severity if any part is visible above joint edge. It is at medium severity if 10% or more of the length is above joint edge or if any part is more than ½ inch (12 mm) above joint edge. It is at high severity if 20% or more is above joint edge or if any part is more than 1 in. (25 mm) above joint edge, or if 10% or more is missing. • Rate joint sealer by joint segment. Sample unit rating is the same as the most severe rating held by at least 20% of segments rated. • Rate only the left and upstation joints along sample unit boundaries. • In rating oxidation, do not rate on appearance. Rate on resilience. Some joint sealer will have a very dull surface, and may even show surface cracks in the oxidized layer. If the sealer is performing satisfactorily and has good characteristics beneath the surface, it is satisfactory.

	Low	Medium	High
Severity Levels	Joint sealer is in generally good condition throughout the sample. Sealant is performing well with only a minor amount of any of the above types of damage present. Joint seal damage is at low severity if a few of the joints have sealer which has debonded from, but is still in contact with, the joint edge. This condition exists if a knife blade can be inserted between sealer and joint face without resistance.	Joint sealer is in generally fair condition over the entire surveyed sample with one or more of the above types of damage occurring to a moderate degree. Sealant needs replacement within two years. Joint seal damage is at medium severity if a few of the joints have any of the following conditions: (1) joint sealer is in place, but water access is possible through visible openings no more than ⅛ inch (3 mm) wide. If a knife blade cannot be inserted easily between sealer and joint face, this condition does not exist; (2) pumping debris are evident at the joint; (3) joint sealer is oxidized and “lifeless” but pliable (like a rope), and generally fills the joint opening; or (4) vegetation in the joint is obvious, but does not obscure the joint opening.	Joint sealer is in generally poor condition over the entire surveyed sample with one or more of the above types of damage occurring to a severe degree. Sealant needs immediate replacement. Joint seal damage is at high severity if 10% or more of the joint sealer exceeds limiting criteria listed above, or if 10% or more of sealer is missing.

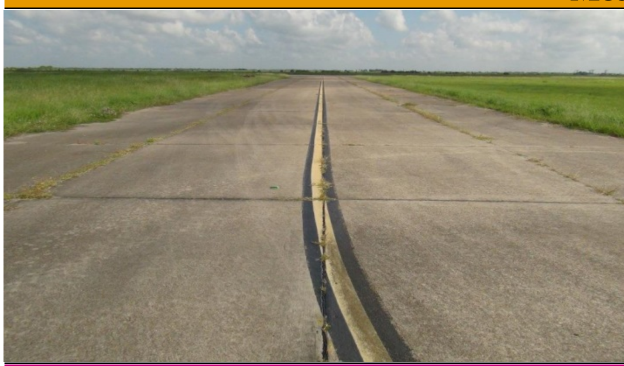
Joint Seal Damage Severity Levels

Good Condition (5 Year Old)

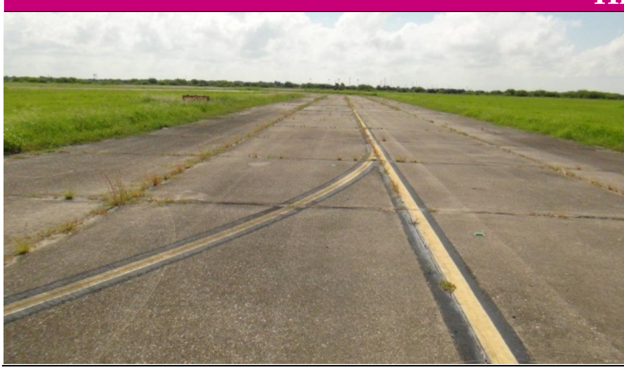
Joint Seal Damage Severity Levels

Low

Medium



High



Spalling

For the purposes of this tool, the two types of spalling (transverse/longitudinal joint and corner) are combined.

Transverse and Longitudinal Joint

Description	• Breakdown of the slab edges within 2 ft (0.6 m) of the side of the joint. • Usually does not extend vertically through the slab but intersects the joint at an angle. • Results from excessive stresses at the joint or crack caused by infiltration of incompressible materials or traffic load. • Spalling weak concrete at the joint (caused by overworking) combined with traffic loads is another cause of spalling. • Note: Frayed condition as used in this test method indicates material is no longer in place along a joint or crack. Spalling indicates material may or may not be missing along a joint or crack.
How to Count	• If the joint spall is located along the edge of one slab, it is counted as one slab with joint spalling. • If spalling is located on more than one edge of the same slab, the edge having the highest severity is counted and recorded as one slab. Joint spalling can also occur along the edges of two adjacent slabs. If this is the case, each slab is counted as having joint spalling. • If a joint spall is small enough, less than 3 in. (76 mm) wide, to be filled during a joint seal repair, it should not be recorded. • Note: If less than 2 ft (0.6 m) of the joint is lightly frayed, the spall should not be counted.

	Low	**Medium**	**High**
Severity Levels	Spall over 2 ft (0.6 m) long: (1) spall is broken into no more than three pieces defined by low- or medium-severity cracks; little or no FOD potential exists; or (2) joint is lightly frayed; little or no FOD potential. Spall less than 2 ft long is broken into pieces or fragmented with little FOD or tire damage potential exists. Lightly frayed means the upper edge of the joint is broken away leaving a spall no wider than 1 in. (25 mm) and no deeper than ½ inch (13 mm). The material is missing and the joint creates little or no FOD potential.	Spall over 2 ft (0.6 m) long: (1) spall is broken into more than three pieces defined by light or medium cracks; (2) spall is broken into no more than three pieces with one or more of the cracks being severe with some FOD potential existing; or (3) joint is moderately frayed with some FOD potential. Spall less than 2 ft long: spall is broken into pieces or fragmented with some of the pieces loose or absent, causing considerable FOD or tire damage potential. Moderately frayed means the upper edge of the joint is broken away leaving a spall wider than 1 in. (25 mm) or deeper than ½ inch (13 mm). The material is mostly missing with some FOD potential.	Spall over 2 ft (0.6 m) long: (1) spall is broken into more than three pieces defined by one or more high-severity cracks with high FOD potential and high possibility of the pieces becoming dislodged, or (2) joint is severely frayed with high FOD potential.

Corner

Description	• Raveling or breakdown of the slab within approximately 2 ft (0.6 m) of the corner. • Differs from a corner break in that the spall usually angles downward to intersect the joint, while a break extends vertically through the slab.
How to Count	• If one or more corner spalls having the same severity level are located in a slab, the slab is counted as one slab with corner spalling. • If more than one severity level occurs, it is counted as one slab having the higher severity level. • A corner spall smaller than 3 in. (76 mm) wide, measured from the edge of the slab, and filled with sealant is not recorded.

	Low	**Medium**	**High**
Severity Levels	One of the following conditions exists: (1) spall is broken into one or two pieces defined by low-severity cracks (little or no FOD potential); or (2) spall is defined by one medium-severity crack (little or no FOD potential).	One of the following conditions exists: (1) spall is broken into two or more pieces defined by medium-severity crack(s), and a few small fragments may be absent or loose; (2) spall is defined by one severe, fragmented crack that may be accompanied by a few hairline cracks; or, (3) spall has deteriorated to the point where loose material is causing some FOD potential.	One of the following conditions exists: (1) spall is broken into two or more pieces defined by high-severity fragmented crack(s) with loose or absent fragments; (2) pieces of the spall have been displaced to the extent that a tire damage hazard exists; or (3) spall has deteriorated to the point where loose material is causing high FOD potential.

Spalling (Corner) Severity Levels
Low

Medium

High

Cracking

Longitudinal, Transverse, and Diagonal Cracks (Mid-Panel Crack)

Description	• These cracks, that divide the slab into two or three pieces, are usually caused by a combination of load repetition, curling stresses, and shrinkage stresses. (For slabs divided into four or more pieces.) • Low-severity cracks are usually warping- or friction-related and are not considered major structural distresses. • Medium- or high-severity cracks are usually working cracks and are considered major structural distresses. • Note: Hairline cracks that are only a few feet long and do not extend across the entire slab are rated as shrinkage cracks.
How to Count	• Once the severity has been identified, the distress is recorded as one slab. If the slab is divided into four or more pieces by cracks, refer to the distress type Shattered Slab. • Cracks used to define and rate corner breaks, "D" cracks, patches, shrinkage cracks, and spalls are not recorded as L/T/D cracks.

	Low	**Medium**	**High**
Severity Levels	Crack has little or minor spalling (no FOD potential). If non-filled, it has a mean width less than approximately ⅛ inch (3 mm). A filled crack can be of any width, but the filler material must be in satisfactory condition; or the slab is divided into three pieces by low-severity cracks.	One of the following conditions exists: (1) filled or non-filled crack is moderately spalled (some FOD potential); (2) a non-filled crack has a mean width between ⅛ and 1 inch (3 and 25 mm); (3) a filled crack is not spalled or only lightly spalled, but the filler is in unsatisfactory condition; or (4) the slab is divided into three pieces by two or more cracks, one of which is at least medium severity.	One of the following conditions exists: (1) filled or non-filled crack is severely spalled, causing definite FOD potential; (2) a non-filled crack has a mean width greater than approximately 1 inch (25 mm), creating a tire damage potential; or (3) the slab is divided into three pieces by two or more cracks, one of which is at least high severity.

Longitudinal, Transverse, and Diagonal (Mid-Panel) Cracks Severity Levels (20% or 40% Slabs)

Low

Medium

High

Corner Break

Description	• A crack that intersects the joints at a distance less than or equal to one half of the slab length on both sides, measured from the corner of the slab. • For example, a slab with dimensions of 25 by 25 ft (7.5 by 7.5 m) that has a crack intersecting the joint 5 ft (1.5 m) from the corner on one side and 17 ft (5 m) on the other side is not considered a corner break; it is a diagonal crack. • However, a crack that intersects 7 ft (2 m) on one side and 10 ft (3 m) on the other is considered a corner break. • Differs from a corner spall in that the crack extends vertically through the entire slab thickness, while a corner spall intersects the joint at an angle. • Load repetition combined with loss of support and curling stresses usually cause corner breaks.
How to Count	• Recorded as one slab if it contains a single corner break, contains more than one break of a particular severity, or contains two or more breaks of different severities. • For two or more breaks, the highest level of severity should be recorded. For example, a slab containing both light and medium-severity corner breaks should be counted as one slab with a medium corner break. • Crack widths should be measured between vertical walls, not in spalled areas of the crack. • If the corner break is faulted ⅛ inch (3 mm) or more, increase severity to the next higher level. If the corner is faulted more than ½ inch (13 mm), rate the corner break at high severity. If faulting in corner is incidental to faulting in the slab, rate faulting separately. • The angle of crack into the slab is usually not evident at low severity. Unless the crack angle can be determined, to differentiate between the corner break and corner spall, use the following criteria. If the crack intersects both joints more than 2 ft (600 mm) from the corner, it is a corner break. If it is less than 2 ft, unless you can verify the crack is vertical, call it a spall.

	Low	**Medium**	**High**
Severity Levels	Crack has little or minor spalling (no FOD potential). If non-filled, it has a mean width less than approximately ⅛ inch (3 mm). A filled crack can be of any width, but the filler material must be in satisfactory condition. The area between the corner break and the joints is not cracked.	One of the following conditions exists: (1) filled or non-filled crack is moderately spalled (some FOD potential); (2) a non-filled crack has a mean width between ⅛ and 1 inch (3 and 25 mm); (3) a filled crack is not spalled or only lightly spalled, but the filler is in unsatisfactory condition; or (4) the area between the corner break and the joints is lightly cracked. Lightly cracked means one low-severity crack dividing the corner into two pieces.	One of the following conditions exists: (1) filled or non-filled crack is severely spalled, causing definite FOD potential; (2) a non-filled crack has a mean width greater than approximately 1 inch (25 mm), creating a tire damage potential; or (3) the area between the corner break and the joints is severely cracked.

Corner Break Severity Levels (10% or 30% Slabs)	
Low	
	
Medium	
	
High	
	

Shattered Slab/Intersecting Cracks

Description	• Cracks that break the slab into four or more pieces due to overloading or inadequate support, or both. • The high-severity level of this distress type, as defined as follows, is referred to as shattered slab. • If all pieces or cracks are contained within a corner break, the distress is categorized as a severe corner break.
How to Count	• No other distress such as scaling, spalling, or durability cracking should be recorded if the slab is medium- or high-severity level since the severity of this distress would affect the slab's rating substantially. • Shrinkage cracks should not be counted in determining whether or not the slab is broken into four or more pieces.

	Low	Medium	High
Severity Levels	Slab is broken into four or five pieces predominantly defined by low-severity cracks.	Slab is broken into four or five pieces with over 15% of the cracks of medium severity (no high-severity cracks); slab is broken into six or more pieces with over 85% of the cracks of low severity.	At this level of severity, the slab is called shattered: (1) slab is broken into four or five pieces with some or all cracks of high severity; or (2) slab is broken into six or more pieces with over 15% of the cracks of medium or high severity.

Shattered Slab/Intersecting Cracks Severity Levels (10% or 30% Slabs)

Low

Shattered Slab/Intersecting Cracks Severity Levels (10% or 30% Slabs)	
Medium	
	
High	
	

Patching

Description	• An area where the original pavement has been removed and replaced by a filler material – large (over 5 ft^2 [0.5 m^2]) or small (less than 5 ft^2 [0.5 m^2]). The online tool is designed for large patching.
How to Count	• If one or more small patches having the same severity level are located in a slab, it is counted as one slab containing that distress. • If more than one severity level occurs, it is counted as one slab with the higher severity level being recorded.

	Low	**Medium**	**High**
Severity Levels	Patch is functioning well with very little or no deterioration.	Patch deterioration or moderate spalling, or both, can be seen around the edges. Patch material can be dislodged with considerable effort, causing some FOD potential.	Patch has deteriorated to a state that causes considerable roughness or high FOD potential, or both. The extent of the deterioration warrants replacement of the patch.

Patching Severity Levels (30% or 50% Slabs)

Low

Medium

High

Settlement or Faulting

Description	• A difference of elevation at a joint or crack caused by upheaval or consolidation.
How to Count	• In counting settlement, a fault between two slabs is counted as one slab. A straightedge or level should be used to aid in measuring the difference in elevation between the two slabs. • Construction-induced elevation differential is not rated in PCI procedures. Where construction differential exists, it can often be identified by the way the high side of the joint was rolled down by finishers (usually within 6 in. [150 mm] of the joint) to meet the low-slab elevation.

Severity Levels

Severity levels are defined by the difference in elevation across the fault and the associated decrease in ride quality and safety as severity increases:

	Runways/Taxiways	**Aprons**
L	< ¼ inch (6 mm)	1/8 < ½ inch (3 to 13 mm)
M	¼ to ½ inch (6 to 13 mm)	½ to 1 inch (13 to 25 mm)
H	> ½ inch (13 mm)	> 1 inch (25 mm)

Settlement or Faulting Severity Levels (10% or 30% Slabs)

Low

Medium

High