CP ROAD MAP

shaping the future of **concrete pavement**

www.cproadmap.org

"Moving Advancements into Practice"

MAP Brief September 2019

Best practices and promising technologies that can be used now to enhance concrete paving

Overview of the *Guide for Concrete Pavement Distress Assessments and Solutions*

September 2019

ROAD MAP TRACK 6

PROJECT TITLE

Overview of the *Guide for Concrete Pavement Distress Assessments and Solutions*

AUTHORS

Michael Ayers, Tom Cackler, Gary Fick, Dale Harrington, Doug Schwartz, Kurt Smith, Mark B. Snyder, and Tom VanDam

EDITOR

Sabrina Shields-Cook

SPONSORS

Federal Highway Administration

National Concrete Consortium

National Concrete Pavement Technology Center

MORE INFORMATION

Dale Harrington

HCE Services, Inc.

dharrington@hceservices.com

The Long-Term Plan for Concrete Pavement Research and Technology (CP Road Map) is a national research plan developed and jointly implemented by the concrete pavement stakeholder community. Publications and other support services are provided by the Operations Support Group and funded by the Federal Highway Administration.

Moving Advancements into Practice (MAP) Briefs describe innovative research and promising technologies that can be used now to enhance concrete paving practices. The September 2019 MAP Brief provides information relevant to Track 6 of the CP Road Map: Concrete Pavement Construction, Reconstruction, and Overlays.

This MAP Brief is available at www.cproadmap.org/publications/MAPbriefSeptember2019.pdf.

Introduction

The Guide for Concrete Pavement Distress Assessments and Solutions, published in October 2018, is intended to assist with pavement preservation by helping to identify the causes and remedies for concrete pavement distress. By understanding the basic principles of concrete pavement preservation, engineers will be able manage their pavement networks to provide safe and dependable roadways while minimizing disruptions to the public for repair and maintenance activities.

Establishing a proactive approach to pavement condition monitoring and planned maintenance activities will reward owner agencies with not only long life from their concrete pavements but also reduced ownership costs and minimal disruption to the traveling public.

The number of failure mechanisms that may occur in concrete are fairly limited. However, most distress is a combination of more than one mechanism, exhibiting in an array of different forms. This manual goes into the details of the different types of distress observed in the field.

It is also important to remember that the presence of one or more distress type in a concrete pavement may not trigger corrective action by the engineer because such distress types may have limited impact on the pavement's overall functionality.

The authors and contributors to this manual have shared their wealth of knowledge and experience to help agencies achieve the goal of minimizing the cost of ownership of their concrete pavements.

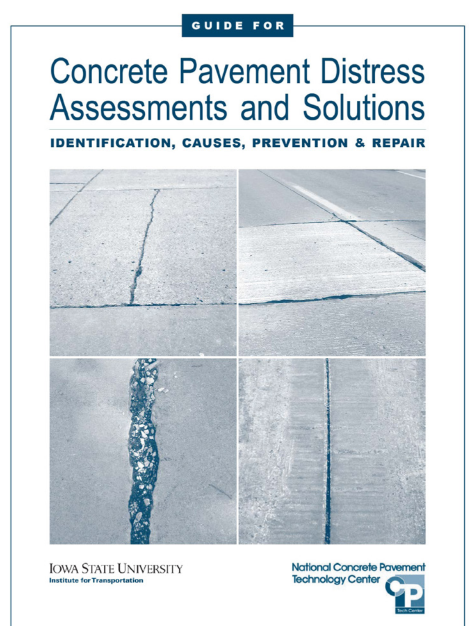
Who this Guide Is for

This guide was developed for transportation agency personnel and consulting engineers who are responsible for managing concrete pavement assets. Managing these assets includes monitoring pavement performance, developing project concepts, developing and administering pavement repair projects, and overseeing system maintenance. Users of this guide may include the following:

- Pavement inspectors and design engineers
- Field engineers responsible for developing project concepts
- Construction and maintenance staff responsible for administering contracts for repair of concrete pavement
- Asset management and pavement management engineers
- Consulting engineers

Why this Guide Was Developed

Pavements and their underlying support layers are a complex, interdependent system. The performance of this system is influenced significantly by traffic loading, climatic conditions, maintenance practices, the origi-



nal design, and the construction of the pavement structure, foundation layers, and drainage system. Over the life of a concrete pavement, distresses can occur—and, in most cases, the distresses can be attributed to multiple causes.

Accurately identifying the distress, understanding the cause(s) of the distress and how to prevent it on future projects, and determining the proper repair procedures can be complicated. The purpose of this guide is to clearly address these elements in a user-friendly, uncomplicated, and comprehensive manner.

The need to cost-effectively manage pavement assets has become increasing more difficult and important. This is due to several factors. First, agency budgets are being stretched. Second, experienced staff is waning. Third, the public's demand to minimize disruptions while providing a safe riding surface is increasing.

Selecting a pavement preservation strategy that does not address the root cause of a distress can result in wasted resources and additional inconvenience to the public.

Historically, distresses in concrete pavements have been identified largely through visual surveys with limited investigation into the underlying cause(s) of the distress, and often with limited knowledge of how to cost-effectively maintain a concrete pavement in good condition. However, in the last few years, not only have significant technical advancements been made in distress assessment tools but more robust preservation treatment options have also been developed.

This guide incorporates proven and cost-effective solutions into a framework that assists you in matching the appropriate solution(s) to a given distress.

How this guide was developed

The National Concrete Pavement Technology (CP Tech) Center brought together leading national experts on concrete pavements in the engineering community to develop the technical content of this guide. In addition, a technical advisory committee with experience from Departments of Transportation (DOTs) and industry provided critical reviews and insights throughout development of this guide. The authors themselves have drawn upon their rich practical experience and lessons learned to make this a state-of-the-art resource for the management of concrete pavements.

Technical Advisory Committee

- Andy Bennett, Michigan DOT
- Chris Brakke, Iowa DOT
- Tom Burnham, Minnesota DOT
- Dan DeGraaf, Michigan Concrete Association
- John Donahue, Missouri DOT
- Brian Killingsworth, National Ready Mixed Concrete Association
- Kevin McMullen, Wisconsin Concrete Pavement Association
- Brad Mirth, Oklahoma DOT
- Andy Naranjo, Texas DOT
- Jim Pappas, Delaware DOT
- Randy Riley, Illinois Chapter, Inc. – American Concrete Pavement Association
- Gordon Smith, Iowa Concrete Paving Association/ National CP Tech Center
- Jeff Uhlmeyer, Washington State DOT
- Tom Yu, FHWA
- Matt Zeller, Concrete Paving Association of Minnesota

Authors

- Michael Ayers, Global Pavement Consultants, Inc. – Chapters 3, 12, 13, and 19
- Tom Cackler, Woodland Consulting, Inc. – Chapters 1 and 14
- Gary Fick, Trinity Construction Management Services, Inc. – Chapters 17 and 18
- Dale Harrington, HCE Services – Chapters 8, 12, and 19
- Doug Schwartz, Gateway Engineering and Training LLC – Chapter 9
- Kurt Smith, Applied Pavement Technology, Inc. – Chapters 2, 4, and 5
- Mark B. Snyder, Pavement Engineering and Research Consultants – Chapters 6, 7, 15, and 16
- Tom Van Dam, Nichols Consulting Engineers, Chtd. – Chapters 10 and 11

How to use this guide

This guide is intended to be used in combination with the Federal Highway Administration's (FHWA's) Distress Identification Manual for the Long-Term Pavement Performance Program (Miller and Bellinger 2014) in answering the following questions:

- Which distress is present?
- What caused it?
- How can it be prevented?
- Which repair options are available?

The chapters in this guide provide a detailed discussion of specific distresses that may need to be addressed. Each of the chapters is typically formatted as follows:

Chapter Number. Title of Distress

1. Description
    - Written summary of distresses
    - Images (with short description) of distresses

2. Severity
   – Opening dialogue
   – Table X. Summary of Severity of Distress
3. Testing
   – Field tests
   – Laboratory tests
4. Identification of Causes
   – Opening dialogue
   – Table X. Physical and Material/Chemical Causes of Distress
5. Evaluation
   – Distress subject(s)
      º Cause
      º Prevention
   – Table X. Summary of Causes and Prevention of Subject Distress
6. Treatment and Repairs
   – Repair type(s) for specific repair and selection
   – Maintaining pavement subject
7. References

Organization and Scope of this Guide

This guide is organized into three divisions and addresses the following pavement types:

Division 1: Full-Depth Concrete Pavements

- Jointed Plain Concrete Pavement (JPCP)
- Continuously Reinforced Concrete Pavement (CRCP)

Division 2: Concrete Overlays

- Bonded Concrete Overlay on Asphalt (BCOA)
- Bonded Concrete Overlay on Concrete (BCOC)
- Unbonded Concrete Overlay on Asphalt (UBCOA)
- Unbonded Concrete Overlay on Concrete (UBCOC)

Division 3: Laboratory and Field Testing

All previously listed pavement types.

Division 1: Full-Depth Concrete Pavements Chapters and Distresses

Chapter 1- Introduction

This chapter helps to identify where more detailed guidance on full-depth pavement distress can be found within Division 1 of this manual. A brief overview of each chapter is provided along with a photo of what this type of distress may look like.

When determining the best options for repairing a particular distress, it is important to have a general understanding of the characteristics of common full-depth concrete pavement types. Jointed plain concrete pavement (JPCP) and continuously reinforced concrete pavement (CRCP) each have their own design and performance characteristics. A brief explanation of each is provided.

Chapter 2 - Surface Defects

Minor deformities or imperfections that are limited to the surface of a concrete pavement are often referred to as surface defects. These defects can include map cracking (also called crazing), plastic shrinkage cracking, scaling, surface polishing, surface wear, and popouts/mortar flaking. These distresses typically do not significantly detract from the structural integrity of the pavement, but can have an impact on its functional performance and its aesthetic appeal.

Chapter 3 - Surface Delamination

Surface delamination (subsequently referred to as delamination) in concrete pavements is closely related in appearance to scaling and spalling. However, the mechanism of failure is different, as is discussed in detail in this chapter.

Delamination may be viewed as the development of a horizontal crack within the slab that results in separation of the surface layer to a depth of 0.5 to 2 in. (12.5–50 mm) from the remaining concrete. Delamination may be limited or widespread depending on the basic cause of the separation. Although delamination is normally seen adjacent to pavement joints and may extend 3 ft (1 m) or more into the slab, it can also occur anywhere in the slab.

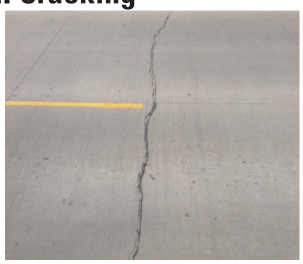
Scaling, as discussed in Chapter 2 of this manual, has a similar appearance to delamination, but does not extend beyond approximately 0.5 in. (12.5 mm) in depth. Compression spalling at joints or transverse cracks, discussed in Chapter 8, may also appear similar but is due to the intrusion of incompressible materials.

De-bonding of a bonded concrete on concrete overlay or separation of the lifts in two-lift paving is discussed in Chapters 15 and 16 and is not considered in this discussion of delamination.

Chapter 4 - Material Related Cracks

Materials-related distresses (MRD) are failures that occur in concrete pavements as the result of the properties of the materials in the pavement and their interaction with the environment (Van Dam et al. 2002). MRDs in concrete pavements are commonly typified by a network of multiple, closely spaced cracks, often accentuated with staining or deposits. However, visual inspection alone cannot confirm the presence or absence of material-related issues. Laboratory testing of pavement core samples is required to definitively confirm the mechanisms that may be contributing to distress.

Chapter 5 - Transverse /Diagonal Cracking



Cracking refers to a distinct fracture in a jointed concrete pavement. Transverse cracking, also called mid-panel or mid-slab cracking, is oriented laterally across the pavement and perpendicular to the pavement centerline; whereas diagonal cracking is oriented obliquely across a slab, at roughly a 30–60 degree angle from the pavement centerline. Slab cracking may also develop longitudinally, in which the crack is oriented parallel to the pavement centerline. This chapter focuses on transverse and diagonal cracking, with Chapter 6 providing detailed information on longitudinal cracking.

Regardless of orientation, these types of cracks are differentiated from map cracking or other surficial cracking (see Chapter 2) in that they are distinct cracks that typically extend through the entire thickness of the slab. Moreover, these cracks can also develop in conjunction with one another to produce what is often referred to as a shattered or broken slab (in which the slab is divided into three or more pieces). Although cracking is perhaps the most common structural distress in concrete pavements, not all cracks are necessarily indicative of structural failures.

Chapter 6 - Longitudinal Cracking

A clear rupture through the full depth of a jointed concrete pavement is referred to as a crack. Longitudinal cracking is nearly parallel to the pavement centerline or lane-shoulder joint. Longitudinal cracks vary from map or surface cracks because they extend through the entire depth of the pavement. Other types of cracking include transverse, diagonal, and slab cracking. This chapter will focus on longitudinal cracking.

Chapter 7 - Corner Cracking

Corner cracking (also known as a "corner break") is a distinct full-depth fracture in a jointed concrete pavement. Corner cracks intersect adjacent transverse and longitudinal joints at an angle of approximately 45 degrees with the direction of traffic. The lengths of the sides are rarely less than 1 ft (0.3 m) and are always less than one-half the width of the slab (by definition) on each side of the corner. Cracks with longer legs are considered diagonal cracks (see Chapter 5).

Chapter 8 Spalling

Transverse and longitudinal joint/crack spalling in concrete pavements is one of the most common, if not the most predominant, concrete pavement distress. Joint spalling is joint deterioration, which refers to cracking, chipping, or fraying of the concrete slab joint or crack edges of the transverse and longitudinal joints. The spalling may develop predominantly in the top few inches of the slab, or may develop at a greater depth below the surface, depending on the environmental conditions, eventually reaching full pavement depth. Spalling problems include loose debris on the pavement, shallow vertical drops and roughness. According to FHWA, spalling is any cracking, breaking, chipping, or fraying of the slab edge within 12 in. from the face of the transverse or longitudinal joint. It can be expanded both in width and depth through continuous deterioration.

Chapter 9 - Faulting

Faulting is the difference in elevation across a joint or crack in a pavement due to loss of load transfer and is a symptom of loss of uniform subgrade support. The loss of uniform support is due to pumping, which is the expulsion of soil and water due to traffic through a pavement joint, crack, or pavement/shoulder edge resulting in lack of load transfer.

Chapter 10 - Joint Warping and Curling

Concrete slabs placed on grade undergo non-uniform volumetric changes due to temperature and moisture gradients. With regards to the temperature gradient, this changes throughout the day. The slab is normally colder on the top than the bottom from late at night through mid-morning, resulting in a negative temperature gradient. Under these condi-

tions, the slab will have a tendency to undergo upward curling due to the lower surface temperature. As the top of the slab warms in the course of the day, its temperature will become greater than that at the bottom developing a positive temperature gradient, resulting in a tendency to develop downward curvature as the concrete at the surface expands.

Chapter 11 - Blowups

A blowup is a result of localized upward movement or shattering of a slab along a transverse joint or crack (Miller and Bellinger 2014). Blowups often occur after heavy rainfall occurs followed by high temperatures resulting in high expansion buildup of pressure that can be dramatically released as the pavement thrusts upwards and/or shatters. Contributing factors are incompressible in the joint, high coefficient of thermal expansion (CTE) of coarse aggregate as the concrete temperature increases, and long transverse joint spacing.

Chapter 12 - Subgrades and Bases

Other than vehicle loading, the principal cause of distress in concrete pavements is volume change, or, put another way, movement (i.e., either in the concrete itself or in the underlying support system). The volume changes result in movements in the concrete that either exceed the design parameters of the pavement when distresses occur or when not anticipated in the design. The volume change in concrete itself has been covered in other chapters of this manual. This chapter is devoted to the distresses in the concrete pavement due to volume changes in the subgrades and bases.

The distresses from volume change (movement) in concrete pavement from the subgrade and base typically show up as cracking as the result of settlements or heaves of the subgrade/base. Therefore, this chapter has been developed and formulated around settlement and heave categories since they do represent the majority of subgrade and base distresses.

Chapter 13 - CRCP

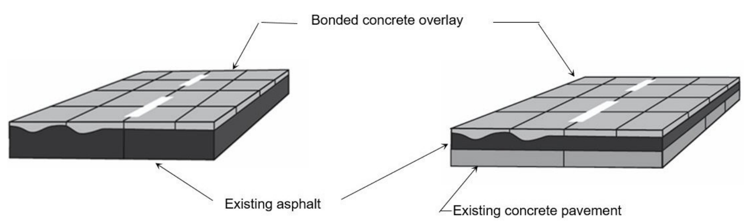
Continuously reinforced concrete pavements (CRCP) are generally used for heavily trafficked roadway applications. These pavements differ from the more widely used jointed plain concrete pavements (JPCP) due to the presence of continuous longitudinal reinforcement ranging from approximately 0.70 to 0.80 percent of the cross-sectional area of the pavement slab. Transverse reinforcement is also typically used but consists of individual bars placed at approximately 3 ft (0.9 m) spacing.

Division 2: Concrete Overlay Chapters and Distresses

Chapter 14- Introduction

Division 2 addresses the family of bonded and unbonded concrete overlays and distresses that are unique to each overlay type. When determining the best options for repairing a particular distress, it is important to have a general understanding of the characteristics of the different types of concrete overlays. Although some distresses in concrete overlays are the same as full-depth concrete pavement, there are unique differences. Concrete overlays are placed over existing asphaltic and concrete pavements that have some degree of distress in them. How the distresses in the underlying pavement are addressed varies for the different overlay types. When addressing distresses that develop in the overlay itself, it is important to understand basic design approaches for each type of overlay.

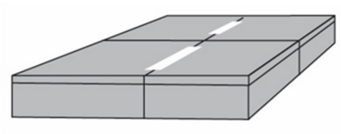
Chapter 15 – Bonded Concrete Over Asphalt & Composite (BCOA)



Distress mechanisms that are specific to BCOA, include the following: loss of (or failure to develop) adequate bond strength between the concrete overlay and the underlying asphalt, non-uniform support of the concrete overlay panels, and improper sawing of the joints (locations and/or depth). Each of these mechanisms may, in turn, have more than one potential cause (e.g., non-uniform support may result from poor or inadequate pre-overlay repairs, asphalt layer stripping, or other issues).

The resulting BCOA distresses are generally described in conventional terms (i.e., corner breaks or corner cracking, transverse and longitudinal cracking, reflection cracking, wide joints, transverse joint faulting, and joint spalling), but their causes can often be traced to somewhat different mechanisms than for conventional pavement distresses with the same names.

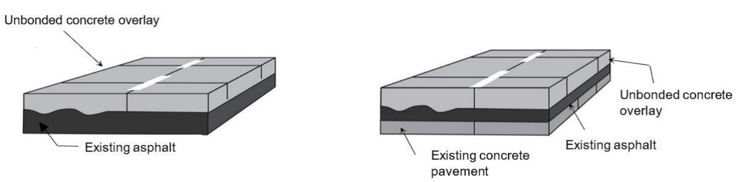
Chapter 16 – Bonded Concrete Over Concrete (BCOC)



Bonded concrete overlays are relatively thin (typically 2–6 in. [50–150mm]) concrete layers that are bonded to a pre-existing concrete pavement surface to create a paving layer that acts monolithically. The development and maintenance of the bond between the two layers is directly considered in the overlay thickness design and is, therefore, essential to the performance of the system.

Bonded concrete overlays are also susceptible to a few unique distress mechanisms. For BCOC pavement, these mechanisms are generally related to improper sawing of the joints (locations and/or depth), loss of (or failure to develop) adequate bond strength, inadequate repair of the underlying pavement prior to overlay, and use of the bonded overlay on a poor candidate project. The resulting distresses may initially appear to be conventional cracks or spalls, but their causes can be traced to different mechanisms than that of conventional pavement cracking and spalling.

Chapter 17 – Unbonded Concrete Over Asphalt & Composite (UBCOA)

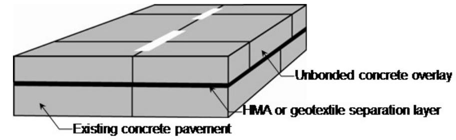


The design of UBCOA treats the existing pavement as a stiff subbase and not part of the overlay thickness. UBCOA thicknesses have traditionally been somewhat thinner than what would be required by traffic estimates for a full-depth concrete pavement placed on a granular subbase. Typical thickness ranges from 4 in. to 11 in. These concrete pavements can be designed as jointed plain concrete pavement (JPCP), with or without load transfer or continuously reinforced concrete pavement (CRCP). Joint spacing for JPCP unbonded overlays should be a function of the design thickness.

Each of the distresses covered in Chapters 2 through 13 can be observed in unbonded overlays. However, some of these distresses may manifest themselves differently in UBCOAs. So, for a given distress observed in a UBCOA, the cause(s) may be as described in the appropriate distress chapter for a non-UBCOA pavement; or the cause may be related to the design and construction of the UBCOA.

Chapter 18 – Unbonded Concrete Over Concrete (UBCOC)

The design of UBCOCs treats the existing pavement and separation layer as a stiff base, and not as a part of the pavement thickness.



Thus, UBCOC thicknesses are only slightly thinner than what would be required by traffic estimates for a full-depth concrete pavement placed on a granular subbase. These concrete pavements can be designed as jointed plain concrete pavement (JPCP), with or without load transfer.

Each of the distresses covered in Chapters 2 through 15 should be consulted for additional information on the identification, causes, evaluation and treatment of the observed distresses found in UBCOCs. However, there are some of these distresses which may manifest themselves differently in UBCOCs. So, for a given distress observed in a UBCOC, the cause(s) may be as described in the appropriate distress chapter for a non-UBCOC pavement; or the cause may be related to the design and construction of the UBCOC.

Chapter 19 – Field Evaluation and Laboratory Testing Procedures

Field and laboratory testing is an important component in determining the cause of observed distresses. Field evaluation and laboratory testing is summarized in each chapter that pertains to a specific pavement distress. Each chapter then refers the reader to this chapter for a comprehensive analysis of a particular test or procedure.

Field Evaluation Testing Procedures

This section describes 14 different testing procedures for field evaluation. The procedures described are not all-inclusive but represent some of the most common field-testing procedures.

Laboratory Testing Procedures

The tests shown in this chapter are differentiated by concrete material tests and those used to characterize the base and subgrade materials. This list is not all-inclusive; note that new test methods and equipment may be available to address a specific testing need.

The descriptions of each test listed are brief and the actual testing guide should be referenced and followed when administering the testing procedure.

Where to Find Additional Information

Additional information on concrete pavement distresses can be found at the resources listed below.

- Guide for Concrete Pavement Distress Assessments and Solutions
  https://intrans.iastate.edu/app/uploads/2019/01/concrete_pvmt_distress_assessments_and_solutions_guide_w_cvr.pdf
- Concrete Pavement Preservation Guide
  http://www.cptechcenter.org/technical-library/documents/preservation_guide_2nd_ed_508_final.pdf
- Distress Identification Manual for the Long-Term Pavement Performance Program
  https://www.fhwa.dot.gov/publications/research/infrastructure/pavements/ltpp/13092/13092.pdf
- Guide for Partial-Depth Repair of Concrete Pavements
  http://www.cptechcenter.org/technical-library/documents/PDR_guide_Apr2012.pdf
- Guide to the Prevention and Restoration of Early Joint Deterioration in Concrete Pavements
  http://www.intrans.iastate.edu/research/documents/research-reports/2016_joint_deterioration_in_pvmts_guide.pdf
- Integrated Materials and Construction Practices for Concrete Pavements: A State-of-the-Practice Manual
  https://intrans.iastate.edu/app/uploads/2019/05/IMCP_manual.pdf

Reference Information for this MAP Brief

- Harrington, D., M. Ayers, T. Cackler, G. Fick, D. Schwartz, K. Smith, M. B. Snyder, and T. Van Dam. 2018. Guide for Concrete Pavement Distress Assessments and Solutions: Identification, Causes, Prevention, and Repair. National Concrete Pavement Technology Center, Iowa State University, Ames, IA. https://intrans.iastate.edu/app/uploads/2019/01/concrete_pvmt_distress_assessments_and_solutions_guide_w_cvr.pdf
- Miller, J. S. and W. Y. Bellinger. 2014. Distress Identification Manual for the Long-Term Pavement Performance Program. Fifth Revised Edition. FHWA-HRT-13-092. Federal Highway Administration, Office of Infrastructure Research and Development, McLean, VA. https://www.fhwa.dot.gov/publications/research/infrastructure/pavements/ltpp/13092/13092.pdf
- Van Dam, T. J., L. L. Sutter, K. D. Smith, M. J. Wade, and K.W. Peterson 2002. Guidelines for Detection, Analysis, and Treatment of Materials-Related Distress in Concrete Pavements, Volume 1: Final Report, FHWA Publication FHWA-RD-01-163. https://www.fhwa.dot.gov/publications/research/infrastructure/pavements/pccp/01163/