

Stages-of-Hydration Charts

Chapter 4 contains several variations of stages-of-hydration charts (figure 3). These charts, based on a general time-heat curve, illustrate changes in heat generated by hydration during concrete's first hours and days. Accompanying text explains chemical changes during hydration and their effect on concrete properties, which are roughly represented by the time-heat curve. The changes are grouped according to five stages of hydration.

Variations of the chart illustrate and describe the effect of various materials, construction practices, and other variables on hydration. The IMCP manual, however, is not a chemistry book; even the most detailed sections of chapter 4 and the accompanying illustrations of hydrating cement provide only an overview of hydration based on general concepts.

Early-Age Cracking References

Chapter 5 (concrete properties) ends with a discussion of early-age cracking. Although not a property of concrete, early-age cracking can be related to several properties. The final pages of chapter 5 are specially formatted, one- and

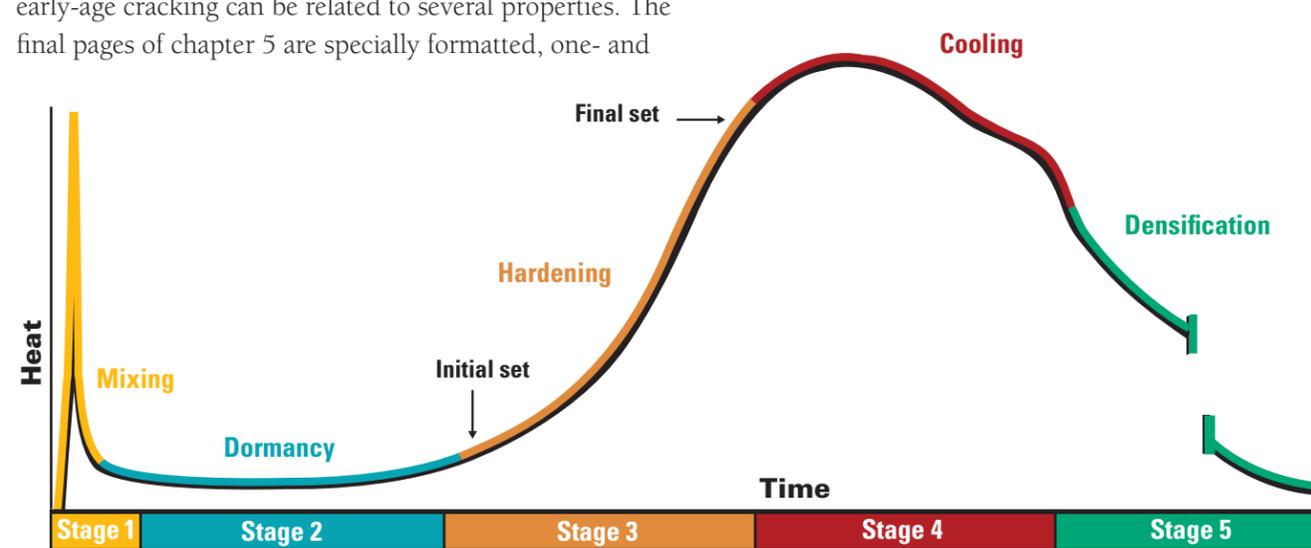


Figure 3. The five stages of hydration mapped on a heat vs. time curve

two-page descriptions of various early-age cracks. These pages could be good stand-alone references.

Suite of Q/C Tests

Chapter 9 on quality control ends with one- or two-page descriptions of various quality control tests. They follow the same structure: Why do this test? What is the theory behind it? In general, how is it run? What equipment do you need? How do you interpret the results? etc. These descriptions do not substitute for formal testing methods. They just give readers a quick understanding of why and when particular tests are conducted.

Troubleshooting Tables

All of chapter 10 is a set of tables organized by the time at which various problems may occur with the mix or slab. For every potential problem, there is a list of possible causes, potential actions, and references to pages in the manual that give more information about the phenomena described. Again, these troubleshooting pages could be a good stand-alone reference.



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A summary of chapter 1 (pages 1–5) of the *IMCP Manual* (reference information on page 4)

Introduction to the IMCP Manual

This document is one of a set of technical summaries of chapters 1 through 10 of the *Integrated Materials and Construction Practices for Concrete Pavements: A State-of-the-Practice Manual* (IMCP manual). Together, these summaries provide a general overview of information in the manual and introduce its important concepts. To be useful as training documents, the technical summaries should be used in conjunction with the manual.

This document briefly summarizes chapter 1. It describes why the IMCP manual was developed, the kind of information it contains, and how the material is organized. Anyone planning to study the IMCP manual or attend a related workshop will benefit from reviewing chapter 1 and/or this technical summary.

Purpose of the Manual

In general, the IMCP manual is an offshoot product of a pooled-fund study, Materials and Construction Optimization for Prevention of Premature Pavement Distress (or the MCO project) (TPF-5[066]). In that study, 17 States identified a suite of tests for optimizing concrete materials and mixes. The States discovered that they have different gaps in knowledge and practice. So, FHWA funded development of a one-source reference manual that describes best practices—how and why—to optimize materials and mixes.

The goal of the IMCP manual is to help readers understand how the materials in concrete interact and how that understanding can help personnel optimize concrete's performance at every stage of a paving project (figure 1). The intended audience is public and private personnel with various roles in concrete pavement projects: design engineers, quality assurance technicians, construction

contractors (managers and field supervisors), materials engineers, materials suppliers, etc.

The IMCP manual is not a full-blown concrete pavement design or construction course. It does not contain any information about maintenance and rehabilitation.

The content of the IMCP manual reflects the technical expertise of about 60 authors and reviewers from around the country. An oversight committee of 15 experts then provided advice and input to the development of a related workshop.

Chapter Topics

Chapter 2 of the IMCP manual discusses concepts of pavement design that are most important for optimizing concrete performance. It addresses pavement design types, structural and functional performance issues, concrete properties that are critical to its performance (these will

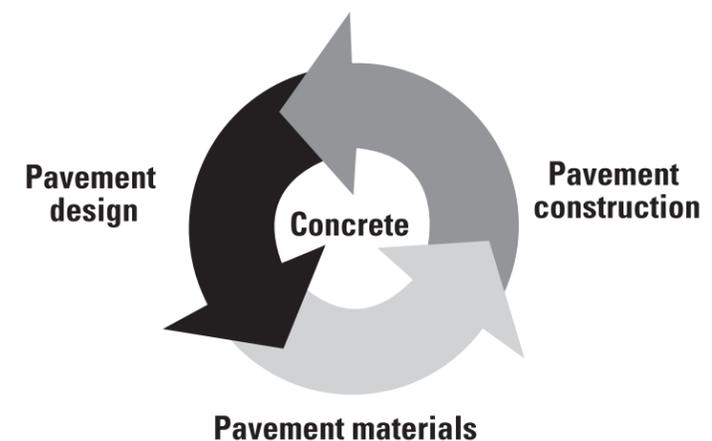


Figure 1. The IMCP manual helps personnel at every stage of a paving project optimize the concrete's ultimate performance.

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This technical summary is based on chapter 1 of the IMCP Manual (Taylor, P.C., et al. 2006. *Integrated Materials and Construction Practices for Concrete Pavement: A State-of-the-Practice Manual*, Ames, Iowa, Iowa State University [FHWA HIF-07-004] [www.cptechcenter.org/publications/imcp/]) and was sponsored by the Federal Highway Administration. (References for any citations in this summary are at the end of the chapter.)

Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the view of Federal Highway Administration or Iowa State University.

CP Tech Center Mission

The mission of the National Concrete Pavement Technology Center is to unite key transportation stakeholders around the central goal of advancing concrete pavement technology through research, tech transfer, and technology implementation.

National Concrete Pavement
Technology Center



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be covered thoroughly in chapter 5), site factors that affect concrete design, and construction issues that have to be taken into account. It also briefly describes overlay design considerations.

Every concrete mixture contains cements, water, and fine and coarse aggregates. Today, we also use many different kinds of supplementary cementitious materials and chemical admixtures. Chapter 3 describes all these materials in detail. It is a long chapter because this information is central to optimizing concrete performance.

Hydration, a chemical reaction between cement and water, is described in chapter 4. Ultimately, the products of hydration hold all the mix materials together in a durable concrete slab. Everyone in the concrete pavement business should understand at least the basics of hydration, so chapter 4 tells the story of hydration three times: first very simply, then with more details and illustrations, and then with more information about the chemistry involved. This third version includes information about materials incompatibilities. If you don't know anything about hydration, the repetition can help you understand it. Or, you can read the simplest description and skip the detailed sections if you prefer.

One of the elements of pavement design (chapter 2) is determining what properties we want the concrete to have for a particular project. Chapter 5 outlines all the properties of fresh and hardened concrete and their effects on concrete performance. The information in chapters 3 and 4 will help you understand chapter 5.

By the time you get to chapter 6, you will at least generally understand the materials in the mix and how they react together, as well as the various concrete properties. Chapter 6 describes a general approach to mix design and proportioning: selecting and combining available materials to get the desired properties for a particular project.

Chapter 7 describes the aspects of subgrade preparation and drainage that are critical for optimizing the concrete slab. Chapter 8 describes stockpile management, batching, placement, finishing, jointing, making field adjustments, protecting the new concrete, and adapting construction practices to the weather. Chapters 7 and 8 are relatively short; they focus only on the aspects of pre-construction and construction that are important for optimizing the concrete slab.

Chapter 9 describes why testing is important—before, during, and soon after construction—and offers a suite of tests that will help you monitor quality control from day one.

This chapter can be a quick reference, but it is most helpful if you have a fairly good understanding of the preceding chapters.

Sometimes, even with good pavement design, materials selection, mix design, and construction practices, things can go wrong. The final chapter 10 will help you recognize and fix problems before they become serious.

Navigational Tools

Of course, you know how to find your way around a book. Chapter 1, however, includes brief description of navigational helps designed in the layout of the manual (figure 2).

Thumb Index

On the outer edge of all pages is a colored thumb index. It will help you flip from chapter to chapter. This is a big manual, and the thumb index can be especially useful when you are looking up a cross-reference.

Cross-References

Because all the stages of a concrete project are affected by the others, the manual cannot simply describe one stage in a chapter and be done with it. So, every chapter cross-references related information in previous and later chapters.

Subject Index

If you want to know about a specific topic from the point of view of each of the chapters, use the subject index at the end of the manual. Again, the thumb index can help you flip quickly through the manual to check these references.

Special Formatting

Some of the information in the book is formatted differently to make it more useful.

Key Points

The first page of every chapter lists the main sections in that chapter. Every main section begins with a list of key points in that section. Following the key points, the text becomes more detailed. So, you can read as little or as much detail as you want about each subject.

Sidebars

Information is presented in sidebars for different reasons. Sometimes they highlight information that is useful but does not necessarily fit into the flow of the chapter. Sometimes they repeat and emphasize an important idea from the text. Sometimes they tell a story that helps explain information in the text.

Key Points

- Curing is the action taken to maintain moisture and temperature conditions in a freshly mixed concrete to allow hydration and pozzolanic reactions to proceed.
- Curing primarily affects the quality of the surface of a pavement, the zone that is impacted most by the environment and loading conditions.
- Curing compounds provide the most efficient means of providing curing for pavement concrete.
- Curing activities include controlling the temperature of the concrete during extreme weather.

Key Points for Every Major Section

Curing

Key Points

- Curing is the action taken to maintain moisture and temperature conditions in a freshly mixed concrete to allow hydration and pozzolanic reactions to proceed. Internal temperature and moisture directly influence both early and ultimate concrete properties (Khosravi, Kholifati, and Farnoushi 2002). Proper curing measures prevent rapid water loss from the mixture and allow more thorough cement hydration. It is essential to apply curing measures as early as possible after placing concrete and to continue them until enough hydration has taken place that the required bond strength properties have been achieved.
- A variety of curing methods and materials are available for concrete placement, including the following: water vapor or fog, wet burlap sheets, plastic sheets, insulating blankets, and liquid membrane-forming compounds. The most common method of curing is the application of a curing compound.

Curing Compound

Curing compounds are organic materials that form a film over the surface of the concrete and reduce the rate of moisture loss from the concrete (see Curing Compounds in chapter 3, page 64).

Note: On dry, windy days, or during periods when adverse weather conditions could result in plastic shrinkage cracking, an application of evaporation retarder immediately after final finishing and before all free water on the surface has evaporated will help prevent the formation of cracks. Evaporation retarder should not be confused with curing compounds.

The most common curing method for concrete pavements is the application of a liquid membrane-forming compound to the concrete surface. This material limits water evaporation to about 20 percent of unimpounded concrete when properly applied. A liquid membrane-forming compound that meets ASTM C 309 / AASHTO M 149 material requirements is adequate for most situations when applied at the following rates (ACPA 1994):

- 5.0 mL (2.00 flgal) for hot-weather applications.
- 3.75 mL (1.50 flgal) for hot-weather applications.
- 2.5 mL (1.00 flgal) for other applications.

If the curing compound is inadequate or applied too late, the concrete will be susceptible to plastic shrinkage cracking, excessive curling, and scaling.

Therefore, for curing compound to be of benefit it should be applied as soon as possible after the water sheen has left the surface and curing is complete. The concrete surface should be damp when the compound is applied.

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In Text Cross References

	1. Introduction	2. Design	3. Materials	4. Construction	5. Performance	6. Safety	7. Preparation	8. Construction	9. Quality	10. Troubleshooting and Prevention
Chapter 1 Introduction										
Chapter 2 Basics of Concrete Pavement Design			56						12	22
Chapter 3 Fundamentals of Materials Used for Concrete Pavements	47	47	55	27	27	27	26		27	47
Chapter 4 Transformation of Concrete from Plastic to Solid			79	80	79	79	81		(A0)	79
Chapter 5 Critical Properties of Concrete	146	135	114	(A0)	134	106	141	106	112	(A0)
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Chapter 9 Quality and Testing	240	246	246	246	246	246	246	246	246	246
Chapter 10 Troubleshooting and Prevention	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Thumb Index on Every Page

Sample Page

Subject Index: Find Specific Information about Important Topics

1. Slump is Out of Specification

Potential Causes	Actions to Consider/Avoid	See Page
Change in water content or aggregate grading	Check aggregate moisture contents and absorptions.	44, 47, 183, 206,
	Check for segregation in the stockpile.	207, 211
	Make sure the batch water is adjusted for aggregate moisture content.	
	Conduct batch plant uniformity tests.	
Mix proportions	Check batch equipment for calibration.	207
	Check delivery ticket for correct admixture dosage.	207
Concrete temperature too high or too low	Adjust the concrete placement temperature.	127
Haul time	Check the batch time on the concrete delivery ticket. Haul times should not be excessive.	209

2. Loss of Workability/Slump Loss/Early Stiffening

Potential Causes	Actions to Consider/Avoid	See Page
Dry coarse aggregates	Make sure the aggregate stockpile is kept consistently at saturated surface-dry (SSD) (use soaker hoses if necessary).	206
Ambient temperature increases	Do not add water.	179, 182, 183, 206,
	Chill the mix water or add ice.	210, 226
	Sprinkle the aggregate stockpiles.	
	Use a water reducer or retarder.	
Transport time too long	Do not increase the water/cement ratio to a value greater than the maximum approved mix design.	
	Use a mix design that includes slag or fly ash.	
	Reject the load if greater than specified.	183, 209
	Use retarder in the mixture.	
	Use an agitator rather than dump trucks.	

Heat Signature (Adiabatic Calorimetry Test)

Purpose – Why Do This Test?

Heat signature is a representation of the heat of hydration generated by a specific concrete mix over time. Variations in the chemistry and dosage of portland cement and supplementary cement materials (SCMs), along with interactions between them and chemical admixtures, may be flagged by the heat signature.

Principle – What is the Theory?

Chemical reactions that occur as concrete hardens emit heat (heat of hydration). By insulating a standard cylinder of concrete from the influence of outside temperatures and using sensors to record the heat generated by the concrete, it is possible to measure the adiabatic heat signature of a concrete mix. A chart that plots time on the x-axis and temperature on the y-axis is produced from this data.

Test Procedure – How is the Test Run?

A concrete cylinder is placed inside an insulated drum that is equipped with temperature sensors that record the temperature inside the drum at 15-minute intervals. The temperature and time data are transmitted by computer to a centralized database, where data are stored and analyzed. For this research, the analysis period will range from 2 days up to 10 days.

Test Method

- Cast a standard concrete cylinder (6 in. x 12 in.) from concrete sampled at the project site.
- Place the cylinder inside the adiabatic calorimeter and seal it.
- Temperature sensors record the temperature inside the drum at 15-minute intervals.
- Data from the sensors are uploaded to a central database.
- Centralized database software is utilized for analysis and downloading reports.

Output – How Do I Interpret the Results?

The basic analysis of the heat signature consists of a graph of time vs. temperature. Plotting multiple samples on the same chart may reveal differences in the mix's chemistry (figure 9-5).

Figure 9-5. Heat signature sample plots

Figure 2. Several navigational tools and specially formatted pages can help readers find information.

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