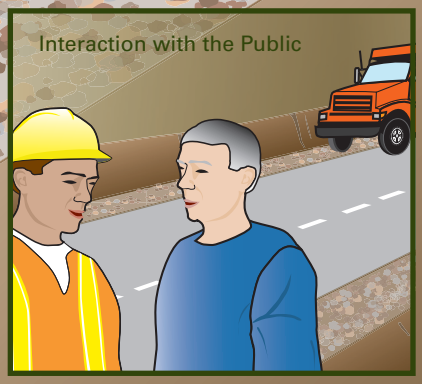
Local Roads
Maintenance Workers' Manual

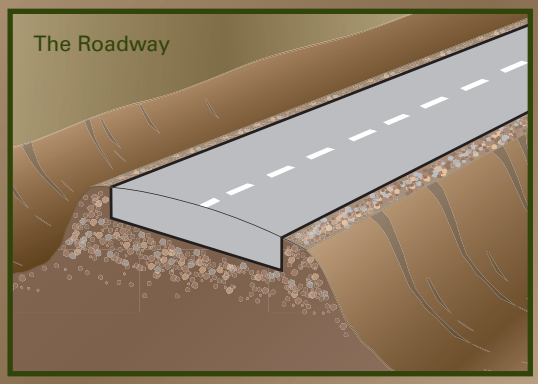
June 2006

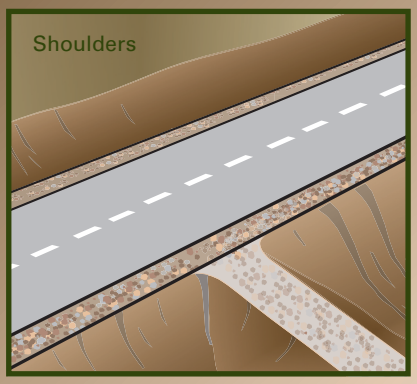
ctre
Center for Transportation Research and Education

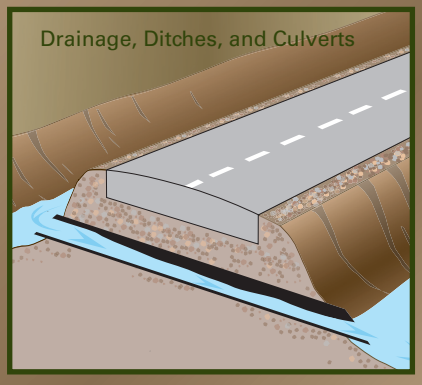
Iowa State University

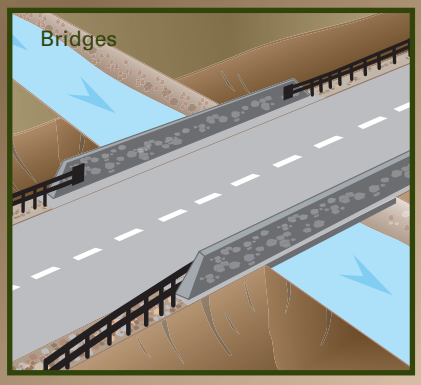
Iowa Highway Research Board Project TR-514











Disclaimer Notice

The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the information presented herein. The opinions, findings, and conclusions expressed in this publication are those of the authors and not necessarily those of the sponsors.

The sponsors assume no liability for the contents or use of the information contained in this document. This report does not constitute a standard, specification, or regulation.

The sponsors do not endorse products or manufacturers. Trademarks or manufacturers' names appear in this report only because they are considered essential to the objective of the document.

About CTRE

The mission of the Center for Transportation Research and Education (CTRE) at Iowa State University is to develop and implement innovative methods, materials, and technologies for improving transportation efficiency, safety, and reliability while improving the learning environment of students, faculty, and staff in transportation-related fields.

Technical Report Documentation Page

1. Report No. TR-514	**2. Government Accession No.**	**3. Recipient's Catalog No.**	
4. Title and Subtitle *Local Roads Maintenance Workers' Manual*		**5. Report Date** June 2006	
		6. Performing Organization Code	
7. Author(s) Duane E. Smith		**8. Performing Organization Report No.**	
9. Performing Organization Name and Address Center for Transportation Research and Education Iowa State University 2901 South Loop Drive, Suite 3100 Ames, IA 50010-8634		**10. Work Unit No. (TRAIS)**	
		11. Contract or Grant No.	
12. Sponsoring Organization Name and Address Iowa Highway Research Board (TR-514) Iowa Department of Transportation 800 Lincoln Way Ames, IA 50010		**13. Type of Report and Period Covered** Manual	
		14. Sponsoring Agency Code	
15. Supplementary Notes Visit www.ctre.iastate.edu for color PDF files of this and other research reports.			
16. Abstract This manual describes best roadway maintenance practices for Iowa's local roads and streets, from the center line to shoulders, ditches, and drainage, with chapters on public relations, bridge maintenance, and snow and ice control. Each chapter contains safety tips, information (as appropriate) on managing quality control, and a list of references for further information.			
17. Key Words roadway maintenance, maintenance best practices		**18. Distribution Statement** No restrictions.	
19. Security Classification (of this report) Unclassified.	**20. Security Classification (of this page)**	**21. No. of Pages** 152	**22. Price**

Form DOT F 1700.7 (8-72) **Reproduction of completed page authorized**

Local Roads Maintenance Workers' Manual

June 2006

Principal Investigator
Duane E. Smith
Director, Iowa Local Technical Assistance Program
Center for Transportation Research and Education (CTRE)
Iowa State University

Undergraduate Research Assistant
Christian Sax

Editor
Marcia L. Brink
CTRE Communications Manager

Illustrations/Graphic Design
Mina Shin
CTRE Graphic Designer

Sponsored by
the Iowa Highway Research Board
(IHRB Project TR-514)

Preparation of this report was financed in part
through funds provided by the Iowa Department of Transportation
through its research management agreement with the
Center for Transportation Research and Education,
CTRE Project 05-173.

Center for Transportation Research and Education
Iowa State University
2711 South Loop Drive, Suite 4700
Ames, IA 50010-8664
Phone: 515-294-8103
Fax: 515-294-0467
www.ctre.iastate.edu/

Table of Contents

List of Figures vii

List of Tables x

List of Acronyms x

Acknowledgments xi

Chapter 1: Introduction 1

Chapter 2: Interaction with the Public 5

Chapter 3: The Roadway 9

- Level B and C/Dirt Roads (Minimum Maintenance) 10
- Granular Surfaced Roads 12
- Asphalt Pavements 34
- Concrete Pavements 56

Chapter 4: Shoulders 71

Chapter 5: Drainage, Ditches, and Culverts 79

Chapter 6: Bridges 93

Chapter 7: Snow and Ice Control 107

Bibliography 127

Appendix A: Sample Door Knocker 129

Appendix B: Snow Fence Installations 131

Appendix C: Snow and Ice Control Equipment Checklist 135

Appendix D: Snow Plow Checklist 137

Appendix E: Snow and Ice Removal Pre-Trip Checklist 139

List of Figures

Figure 2–1. Sample referral card / **7**

Figure 3–1. Access point for level B road / **10**
Figure 3–2. Access point for level C road / **10**
Figure 3–3. New granular surface / **13**
Figure 3–4. Moisture test: wet / **14**
Figure 3–5. Moisture test: too dry / **14**
Figure 3–6. The cross section / **17**
Figure 3–7. Slope meter / **17**
Figure 3–8. Poor crown shape / **18**
Figure 3–9. Foreslope height / **18**
Figure 3–10. Angle of the moldboard / **19**
Figure 3–11. Moldboard in the cut position for regular grading / **19**
Figure 3–12. Moldboard in the cut position for regular grading / **19**
Figure 3–13. Moldboard tilted backward for heavier grading or more aggressive cutting / **20**
Figure 3–14. Moldboard tilted forward for smoothing / **20**
Figure 3–15. Moldboard tilted forward for smoothing / **20**
Figure 3–16. Driveway meets the road / **21**
Figure 3–17. Windrow forming a secondary ditch / **21**
Figure 3–18. Normal crown (top) and superelevation (bottom) / **22**
Figure 3–19. Lightly scarifying / **23**
Figure 3–20. Placing new material on the roadway / **24**
Figure 3–21. Adding water (optional) / **24**
Figure 3–22. Compacting the new material (optional) / **25**
Figure 3–23. Secondary ditch / **26**
Figure 3–24. Washboarding / **27**
Figure 3–25. Cutting out a washboard / **28**
Figure 3–26. Potholes / **29**
Figure 3–27. Rutting / **29**
Figure 3–28. Adquate moisture for applying dust control material / **31**
Figure 3–29. Well-maintained asphalt road / **35**
Figure 3–30. Rutting on an asphalt street / **36**
Figure 3–31. Fatigue cracking / **37**
Figure 3–32. High-severity fatigue cracking / **37**

Figure 3–33. Block cracking / **38**
Figure 3–34. Alligator cracking / **38**
Figure 3–35. Reflection cracking / **39**
Figure 3–36. Washboards / **39**
Figure 3–37. Pothole in asphalt pavement / **40**
Figure 3–38. Crack sealing / **43**
Figure 3–39. Surface patch and full-depth repair / **43**
Figure 3–40. Procedure for placing surface patch / **44**
Figure 3–41. Procedure for full-depth asphalt repair / **46**
Figure 3–42. Asphalt binder and aggregate are used for seal coats / **48**
Figure 3–43. Binder / **48**
Figure 3–44. Gravel aggregate / **48**
Figure 3–45. Cleaning the existing pavement surface / **49**
Figure 3–46. Spray bar coverage / **50**
Figure 3–47. Test for binder set / **51**
Figure 3–48. Pneumatic tire roller / **51**
Figure 3–49. Binder application rate / **52**
Figure 3–50. Well-maintained concrete road / **57**
Figure 3–51. High-severity transverse cracks / **58**
Figure 3–52. High-severity longitudinal cracks / **59**
Figure 3–53. High-severity D cracks / **59**
Figure 3–54. Map cracking / **59**
Figure 3–55. Spalling / **60**
Figure 3–56. Blowup / **60**
Figure 3–57. Scaling / **60**
Figure 3–58. Faulting / **61**
Figure 3–59. Corner break / **61**
Figure 3–60. Street sweeper / **63**
Figure 3–61. Routing cracks / **63**
Figure 3–62. Cleaning joints before applying / **63**
Figure 3–63. Joint with backer rod and filler / **64**
Figure 3–64. Concrete surface patching / **66**
Figure 3–65. Concrete full-depth repair / **68**
Figure 3–66. Removing full depth of slab / **69**
Figure 3–67. Vibratory screed / **69**

Figure 4–1. Well-maintained shoulders / **73**

Figure 4–2. Shoulder edge drop-off / **74**

Figure 4–3. Drainge point for driveways / **75**

Figure 4–4. Repairing edge drop-off / **76**

Figure 5–1. Ditch with good drainage / **81**

Figure 5–2. Edge drain / **84**

Figure 5–3. A flat ditch may not drain properly / **85**

Figure 5–4. Water-tight joints at an inlet / **87**

Figure 5–5. Culvert (profile view) / **88**

Figure 5–6. Culvert (section view) / **88**

Figure 5–7. Culvert (plan view) / **88**

Figure 5–8. Deep scour at culvert outlet / **90**

Figure 6–1. Observe bridge conditions when you are in the vicinity / **95**

Figure 6–2. Overgrown vegetation at guardrail / **96**

Figure 6–3. Gravel on bridge deck / **98**

Figure 6–4. Visible object markers at a bridge / **99**

Figure 6–5. Well-aligned bridge trusses / **100**

Figure 6–6. Elements to observe under the bridge / **101**

Figure 6–7. Evidence of deck seepage / **102**

Figure 6–8. Erosion around base of piers / **102**

Figure 6–9. Corroded, discolored steel beams / **103**

Figure 6–10. Abutments, bearings, and backwall with erosion and corrosion problems / **103**

Figure 6–11. Debris collected around a pier / **104**

Figure 6–12. Debris in river channel / **104**

Figure 7–1. Properly installed snow fences cause snow to collect downwind / **110**

Figure 7–2. Urban anti-icing operations / **113**

Figure 7–3. Cleared road / **115**

Figure 7–4. V snow plow / **117**

Figure 7–5. Tandom snow plow / **117**

Figure 7–6. Winging operations / **118**

Figure 7–7. Snow blower / **118**

Figure 7–8. Urban application of deicing chemicals / **119**

Figure 7–9. The lowest temperature at which different chemicals are effective / **120**

List of Tables

Table 3–1. Distresses and Maintenance Activities for Asphalt Pavements / **41**

Table 3–2. Distresses and Maintenance Activities for Concrete Pavements / **62**

Table 5–1. Quality of Drainage Determined by Dissipation Time / **82**

List of Acronyms

AASHTO	American Association of State Highway Transportation Officials
APWA	American Public Works Association
CDL	commercial driver's license
DOT	Department of Transportation
FHWA	Federal Highway Administration
HMA	hot mix asphalt
ISRMSA	Iowa Secondary Roads Maintenance Supervisors Association
LOS	level of service
LTAP	Local Technical Assistance Program
PCC	portland cement concrete
RWIS	road weather information systems
TRB	Transportation Research Board
NACE	National Association of County Engineers
ICEA	Iowa County Engineers Association
EPA	Environmental Protection Agency

Acknowledgments

The idea of developing a manual for roadway maintenance workers was originally championed by two Iowa county engineers, Mark Nahra, P.E., of Delaware County and Lance LeTellier, P.E., of Linn County. They envisioned a one-stop resource regarding best maintenance practices and procedures. Through their leadership and direction, the project was proposed to and ultimately funded by the Iowa Highway Research Board (TR-514).

A steering committee provided ongoing direction and support. The committee consisted of the following members:

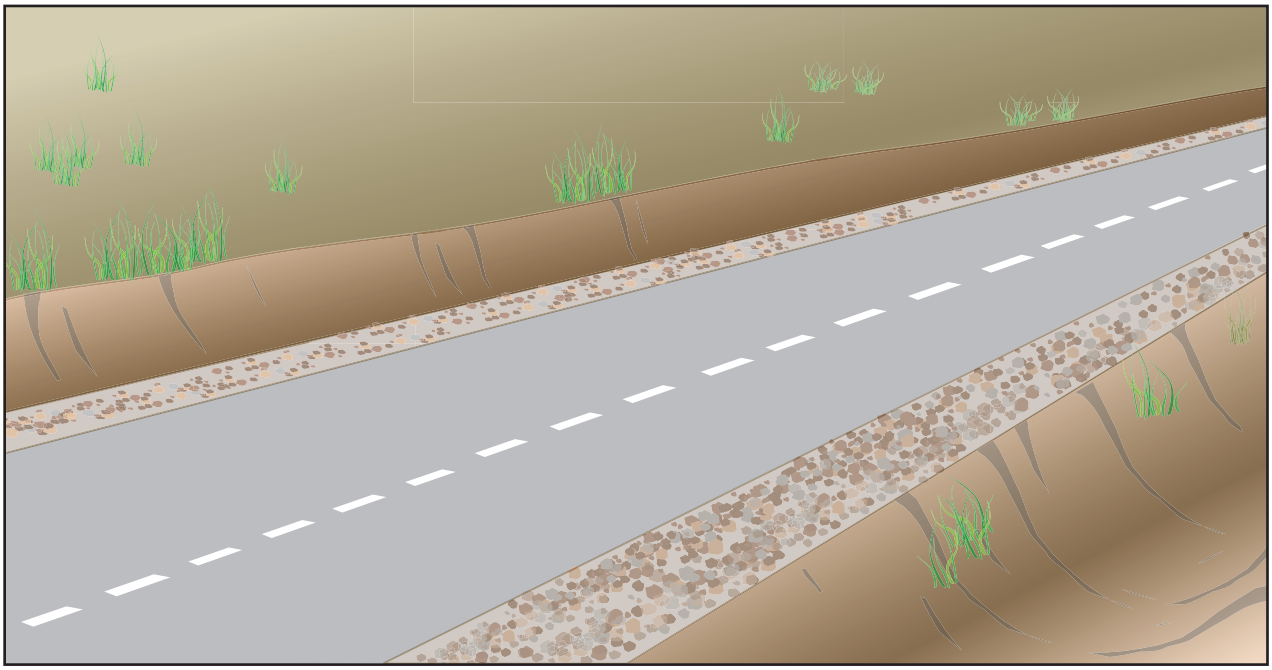
Mark Nahra	**Delaware County**
Lance LeTellier	**Linn County**
Dennis Clift	**Cedar Rapids**
Max Cox	**Monroe County**
Gary Rank	**West Des Moines**
Charlie Terrell	**Wapello County**
Chuck Jahren	**Iowa State University**

A special thanks goes to members of the Iowa County Engineers Association, the Iowa Chapter of the American Public Works Association, and the Iowa Secondary Roads Maintenance Supervisors Association for their support, input regarding the manual's content, and reviews and suggestions regarding draft chapters.

Photographs were provided by the following individuals and organizations. (Photo credits are acknowledged throughout this manual by the abbreviations in parentheses.)

- Department of Civil, Construction, and Environmental Engineering at Iowa State University **(CCEE/ISU)**
- Asphalt Paving Association of Iowa **(APAI)**
- Iowa Concrete Paving Association **(ICPA)**
- Indiana Local Technical Assistance Program **(LTAP-IN)**
- Bill Pidgeon, Lee County, Iowa **(Lee Co.)**
- Bret Hodne, City of West Des Moines, Iowa **(WDM)**
- Ettema, R., T. Nakato, and M. Muste. 2005. An Illustrated Guide for Monitoring and Protecting Bridge Waterways against Scour. Ames, IA: Iowa Highway Research Board (TR-515). **(Ettema, et al.)**
- Miller, J.S. and W.Y. Bellinger. 2003. Distress Identification Manual for Long-Term Pavement Performance. 4th Ed. FHWA-RD-03-031. Washington, DC: Federal Highway Administration. **(FHWA)**
- Skorseth, K. and A.A. Selim. 2000. Gravel Roads Maintenance and Design Manual. Washington, DC: Federal Highway Administration and South Dakota Local Transportation Assistance Program. **(LTAP-SD)**
- Lance LeTellier, Linn County, Iowa **(Linn Co.)**

Chapter 1:
Introduction



chapter contents

Overview of This Manual 2

General Guidelines for Maintenance Workers 2

Welcome to the Local Roads Maintenance Workers' Manual developed by the Center for Transportation Research and Education at Iowa State University. This manual provides general guidelines for Iowa's street and road maintenance workers in one convenient resource. It is being distributed to maintenance supervisors to use as a training tool with their crews.

Overview of this manual

The information is organized into seven chapters. The first two chapters cover introductory material and information to help road workers communicate effectively with the public. The next three chapters cover road maintenance topics "from the center line out"—the roadway, shoulders, and drainage—which is how maintenance activities are generally prioritized and budgeted. The final two chapters cover bridge maintenance and winter maintenance.

The manual focuses on why and how to perform maintenance activities. Each chapter is intended to stand alone. In general, each chapter is organized as follows:

- Safety tips
- Characteristics of good maintenance (the "why")
- Optimum timing and conditions for maintenance
- Maintenance activities (the "how")
- Bibliography

General Guidelines for Maintenance Workers

Some important concepts are repeated in several chapters and are worth stating here:

Always follow your agency's standards, policies, and procedures. Every city and county in Iowa is unique in many ways, with its own terrain, soil and erosion conditions, available maintenance materials, weather patterns, and responsibilities to citizens. In general, the suggestions in this manual are based on common best practices. However, they may not apply in all jurisdictions or all situations. Each jurisdiction has its own set of operating procedures, best practices, and ways of conducting roadway maintenance activities. Always check with your supervisor and follow your agency's standards, policies, and procedures.

Notify Iowa One Call (1-800-292-8989). Agencies are required by law to notify Iowa One Call at least 48 hours in advance of any surface excavation project, large or small. Iowa One Call will notify the owners/operators of underground facilities, who will dispatch personnel to the area to mark the location(s) of underground facilities so that maintenance workers can avoid damaging the facilities.

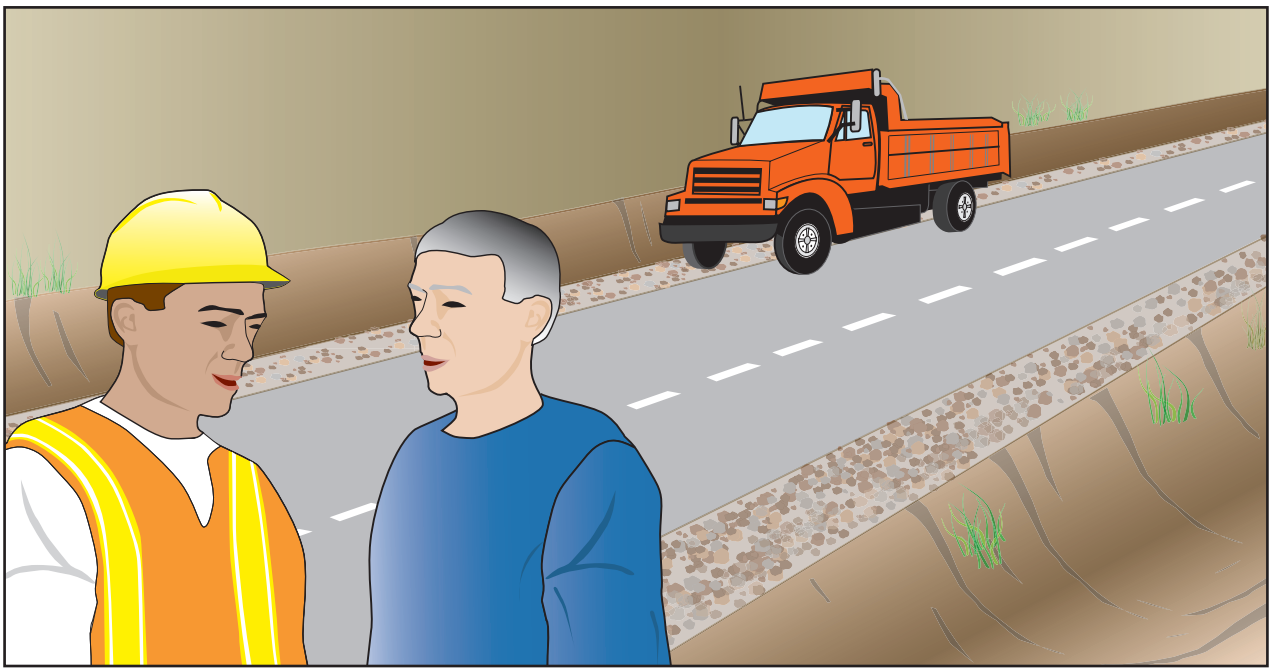
Quality control and worker training are critical. Quality control and a well-trained work crew ensure that the best equipment and materials are used on the job and that sound engineering principles, along with agency policies and procedures, are followed. Quality control involves monitoring and adjusting maintenance processes to comply with plans, agency policies, contract

specifications, and good practices. Quality control begins with checking that all equipment and materials are on site and meet specifications and that they are used for their intended use, according to directions and specifications. Routine inspections are also an important part of quality control. Equipment manuals contain checklists that describe a pre-construction inspection.

The work crew is in the best position to ensure quality control at the site when materials are incorporated and equipment is used. Ask your supervisor to define your quality control activities and responsibilities.

Set up appropriate work zones. A well-designed and properly signed/marked work zone helps keep maintenance workers and motorists safe. Set up work zones as described in the *Iowa Traffic Control Devices and Pavement Markings: A Manual for Cities and Counties; in the MUTCD,* part 6; and your agency's policies and procedures.

Chapter 2:
Interaction with the Public



chapter contents

Typical Interactions with the Public 6

What Do Citizens Want to Know? 6

What Should Citizens Expect from You? 7

What Should Citizens Not Expect from You? 7

Good Responses 7

Key Points to Remember 8

Interacting with the public may be the most important part of your day. You are the public face of your organization. When you do your job well and interact effectively, people trust and believe in you and your agency.

When you are asked a work-related question, be professional. Share only the agency position or information. Answer as thoroughly and efficiently as you can. When a question is outside your area of responsibility, refer the questioner to your supervisor.

This chapter briefly describes some of the many situations in which maintenance workers may interact with the public, what citizens expect from you, and some typically useful responses. The chapter concludes with some rules of thumb for communicating effectively with the public.

Typical Interactions with the Public

At various times people will want to talk with you about local streets and roads:

- You're conducting routine snow removal, and an adjacent property owner flags you down with a question about winter maintenance schedules.
- You're refueling at a local business, and someone at the next pump asks you about the county's fuel budget.
- While you're doing some routine pavement patching and joint sealing, a passing motorist tells you about a pothole on her street.
- You're relaxing at home, and someone calls to tell you about a sign that's down on a gravel road.

What Do Citizens Want to Know?

People may contact you for a variety of reasons:

- Citizens are interested in how their taxes dollars are spent. They may want to know about annual maintenance budgets or the cost of a specific project.
- Many citizens find your work interesting and are curious about how certain procedures are done.
- Sometimes people want to understand the background behind street- and road-related decisions made by the county supervisors or the city council. Citizens who want more information may see you as a communication link to your agency, to other departments, or to elected officials.
- It's not unusual for citizens to want to know about employment opportunities at your agency.
- Sometimes citizens will contact you to lodge a complaint or to tell you about a problem they've noticed.

What Should Citizens Expect from You?

Citizens should be able to expect the same treatment from you that you expect from others:

- Be honest, courteous, and respectful.
- Provide good service.

What Should Citizens Not Expect from You?

Sometimes citizens want information or a service from you that is the responsibility of another department or another government agency. Sometimes citizens have unrealistic expectations about the kinds of information you can provide.

In these situations, you can be most helpful by referring them to your supervisor or someone who is responsible for their concern. See the next section.

Good Responses

Remember, your responses reflect on your agency. Be courteous and professional.

Sometimes just listening can be useful. But silence can also be misunderstood as inattention, disagreement, or anger. Be sure to respectfully acknowledge all comments or questions.

Gestures, expressions, and vocal inflections also communicate. Be aware of what your body language is saying, especially in situations that may be tense for you.

In general,

- If a question is about something you can fix, respond.
- If a question is outside your area of responsibility, refer the question to whoever is responsible.
- It is always helpful to document all questions or comments from the public and report them to your supervisor.

RULE OF THUMB

It is always a good policy to document all questions or comments from the public and report them to your supervisor.

Useful Communication Tools

In some agencies, maintenance workers carry cards with contact information (name, phone and fax numbers, e-mail, etc.) for various services. When citizens have questions, workers can use the card to refer them to appropriate staff or offices. Figure 2–1 shows a sample card.

Another useful communication tool is a "door knocker": a flyer to hang on house doorknobs. These can be especially useful for answering questions / providing information in advance of specific road maintenance activities. See an example door knocker in appendix A.

CENTER COUNTY, Iowa
123 Main St., Centertown, IA 50000-0001
515-222-2219; fax 515-222-2200 (www.centercounty.com)

Joe Brown, Engineer
319-222-2220
joe.brown@centercounty.com

Board of Supervisors
319-222-2224

Mike Black, Roads Supervisor
319-222-2221
mike.black@centercounty.com

Assessor's Office
319-222-2225

Permits and Policies
319-222-2222

Conservation Office
319-222-2226

Planning and Zoning
319-222-2223
M–F 7:00 a.m. to 4:00 p.m.

Utilities
319-222-2227

Figure 2–1. Sample referral card

Following are some effective responses to questions or requests for information:

- That's a good question. I don't know the answer, but let me refer you to someone who will know the answer.
- [After responding to a question for which you are responsible.] That's a good question. Have I answered your concern?
- Thanks for your interest.

RULE OF THUMB

If you can fix it, respond.

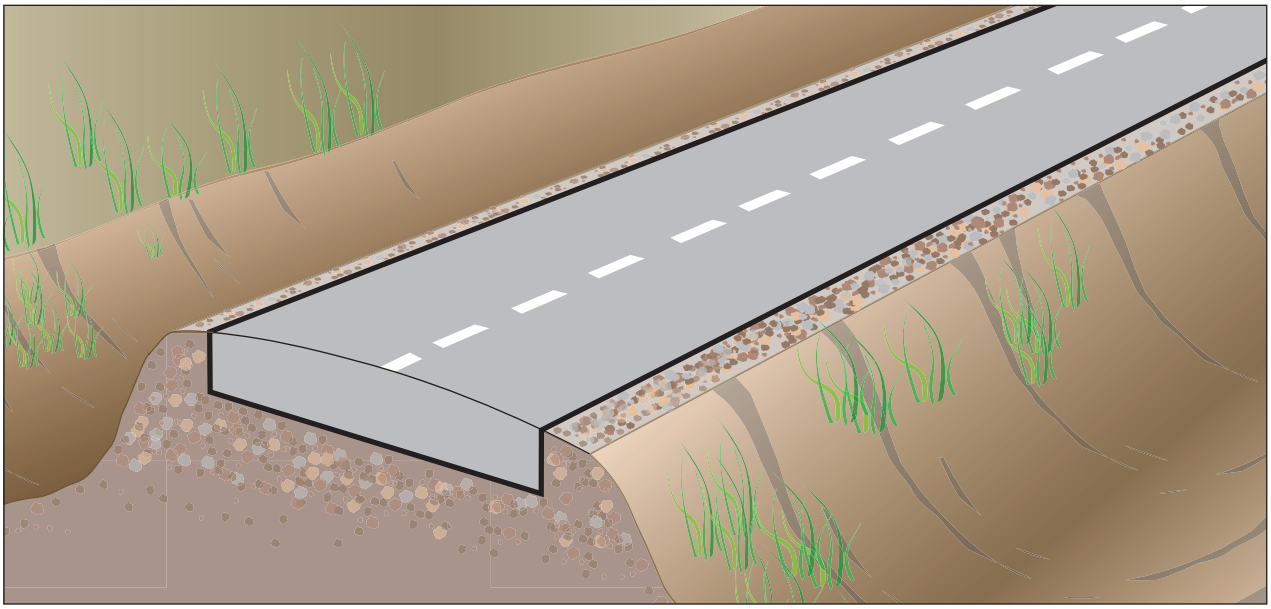
If you don't know the answer, pass the question on to someone who does.

Key Points to Remember

The following suggestions for interacting with the public are just good business practices. You may want to review this list with your supervisor and fellow maintenance staff and come up with your own suggestions:

- Always be professional and respectful.
- Know your agency's position on work rules and maintenance policies and procedures.
- If you don't know an answer, say so. Refer the questioner to your supervisor or other appropriate person.
- When you're asked a question, share only the facts. Don't represent your opinion as your agency's position or policy.
- Do not share your personal opinion. Do not argue. A good question to ask yourself is, "Do I want this conversation on the front page of the newspaper?"
- Be loyal to your agency. If you disagree with a policy or position, take it up with your supervisor, not with someone outside the organization.
- Have information for appropriate contacts readily available.
- Don't take questions or complaints personally. You are a symbol of the organization, much like the referee in a sporting event, and comments are not about you personally.
- Document all questions or comments from the public and report them to your supervisor.

Chapter 3:
The Roadway



chapter contents

Level B and C/Dirt Roads (Minimum Maintenance)..10
Characteristics of a Minimum Maintenance Road..10
Optimum Timing/Conditions for Maintenance.....11
Maintenance Activities 11
Activities for Level B Roads.....11
Activities for Level C Roads 11
Other Maintenance Activities.....11
Granular Surfaced Roads 12
Characteristics of a Well-Maintained Gravel Road..13
Optimum Timing/Conditions for Maintenance 14
Spring 15
Summer 15
Fall 15
Winter.....15
Definitions 15
Crown 15
Crust 16
Drainage 16
Riding Surface 16
Superelevation 16
Windrow 16
Maintenance Activities 16
Maintaining the Crown.....17
Blading in Special Situations.....21
Adding/Distributing Granular Material.....23
Repairing Problem Areas 26
Providing Dust Control.....30
Maintaining Gravel Alleyways and Streets 32
Purpose of Gravel Alley or Street Maintenance..32
Maintenance Activities.....32
Asphalt Pavements 34
Characteristics of a Well-Maintained Asphalt Pavement 35
Optimum Timing/Conditions for Maintenance Activities.....35
Spring/Summer/Fall.....35
Winter.....35
Asphalt Pavement Distresses 36
Rutting 36
Cracks 37
Washboards 39
Potholes 40
Selecting a Maintenance Activity 41
Maintenance Activities 42
Routine Maintenance 42
Surface Patching 43
Full-Depth Repair.....46
Seal Coat Repair 47
Hot Mix Asphalt Overlay.....54
For More Information 55
Concrete Pavements.....56
Characteristics of a Well-Maintained Concrete Pavement 57
Optimum Timing/Conditions 57
Spring/Summer/Fall 58
Winter 58
Concrete Distresses 58
Cracks 58
Joint Deterioation/Spalling 60
Blowups.....60
Scaling 60
Pavement Settlement 61
Faulting 61
Pumping 61
Corner Breaks 61
Pavement Failure 61
Maintenance Activities 62
Routine Maintenance 62
Temporary (Asphalt) Repair.....64
Joint Repair 64
Mud Jacking 65
Blowup Repair 65
Surface Patching 66
Full-Depth Repair 68

Level B and C/Dirt Roads (Minimum Maintenance)

Some public roads in Iowa exist only to provide access to open land, like fields or cattle-grazing areas. Iowa Code allows county boards of supervisors to designate such roads as Area Service B (level B) or Area Service C (level C) roads (see figures 3–1 and 3–2). Counties are then obligated to provide only minimum maintenance (MM) on these roads. In the case of level C roads, counties can also restrict access.

Boards of supervisors can designate level B and C roads through ordinance or resolution and generally do so only on the advice of the county engineer. Iowa has relatively few officially designated level B and C roads.

Note: According to Iowa Code, all county roads not designated level B or C roads are Area Service A roads. Other than in the Code, however, the term Area Service A road is seldom used.

Characteristics of a Minimum Maintenance Road

- County ordinances or resolutions regarding such roads are being followed.
- Land owners adjacent to the roadway have access.

Figure 3–1. Access point for level B road (Linn Co.)

Figure 3–2. Access point for level C road (Linn Co.)

Optimum Timing/Conditions for Maintenance

Follow your local policy. Generally, level B and C roads are not maintained on a routine basis. Do the work as you have time, preferably in the spring and fall because that is when farmers need to use these roads to access fields for planting and harvest.

Be careful about performing maintenance when dirt roads are wet; your machinery may do more damage than good to the roadway if the roadbed is too moist.

Maintenance Activities

The following maintenance activities are generally required by Iowa Code for level B and C roads:

Activities for Level B Roads

- Install and maintain appropriate regulatory signs (for example, bridge postings).
- Install and maintain signs at all access points from other public roads, warning of the reduced level of service.

Activities for Level C Roads

- Install gates or other barriers to restrict access at all access points from other public roads.
- Install and maintain appropriate regulatory signs (for example, bridge postings).
- Install and maintain signs at all access points from other public roads, warning of the reduced level of service and restricted access.

Who Is Responsible for Barriers?

The Iowa Code requires adjoining landowners to maintain gates or other barriers that restrict access to level C roads. Barriers that are not adequately maintained by the landowner may be removed by the county, and the county is not obligated to replace them.

Other Maintenance Activities

Other than maintenance required by the Iowa Code, counties need to provide only the minimum maintenance specified in applicable county ordinances to keep level B and C roads open to traffic. Check your agency's ordinance or resolution for each specific road.

The following services are generally not provided on a regular basis for level B and C roads: blading, snow and ice removal, application of road surface materials, crown maintenance, repairs, maintenance of uniform width, or inspections.

Bridges on these roads are generally not maintained to carry legal loads, but should be posted as appropriate to advise of any load limitations.

Granular Surfaced Roads

Safety Tips for Maintaining Granular Surfaced Roads

Always check with your supervisor and follow your agency's safety policies and procedures.

Suggested personal safety gear

- Highly visible apparel

Advance preparations

- Be properly trained and familiar with all equipment, especially motor graders.
- Make sure an up-to-date first-aid kit, emergency contact information, and hand-held radios or cell phones are available at the work site.
- Perform pre-use check of equipment including lights, blades, and hydraulic system, making sure there are approved and activated warning lights.
- Make sure motor graders have orange flags attached to the end of the blade and slow-moving vehicle emblems attached to rear of the vehicle.

During operations

- If road is open to traffic use proper temporary traffic control, including flaggers if needed, as described in the *Iowa Traffic Control Devices and Pavement Markings: A Manual for Cities and Counties; in the MUTCD,* part 6; and in your agency's policies and procedures.
- For more extensive repair activities, consider short-term road closures with proper signing.
- Wear highly visibly apparel whenever out of vehicle.
- Do not allow riders in motor graders.
- Avoid backing large equipment and trucks without a spotter.
- Remove all temporary traffic control devices immediately when no longer needed.

An adequate crown and good drainage are critical for smooth, safe granular surfaced roads (generally called gravel or rock roads, no matter what kind of granular material, or aggregate, is on the surface). But gravel roads do not hold their shape well, even under normal traffic and weather conditions. Heavy loads, like some farm implements, and water from rain and melting snow and ice are especially hard on granular surfaced roads. Therefore, such roads must be regularly and properly maintained, as shown in figure 3–3.

The primary objectives of maintenance on granular surfaced roads are to provide adequate water drainage away from the surface and a comfortable, safe riding surface for vehicles. Another objective on roads with high traffic volumes or adjacent to residential dwellings may be to control dust.

Maintenance activities cover the traveled portion of the roadway through the shoulder. For a more thorough discussion of shoulder maintenance, see chapter 4.

Characteristics of a Well-Maintained Gravel Road

A well-maintained granular surfaced road will have the following characteristics:

- The road has a four to six percent crown with good crust and effective drainage.
- Granular material is distributed at an even depth across the road.
- Granular material is well graded (that is, an even distribution of fine and course materials).
- There are no or few potholes, washboards, ruts, secondary ditches, or other problems.

RULE OF THUMB

If you can drain it, you can maintain it.

Figure 3–3. New granular surface (LTAP-SD)

Optimum Timing/Conditions for Maintenance

If possible, conduct maintenance operations on gravel roads when moisture is present. Soft, wet surface material is much easier to move, cut, and re-compact than hard, dry material and makes it easier to cut out problems like potholes.

In Iowa, moisture conditions are generally best for maintenance in the spring and fall. They are also good during the first two or three days after a summer rainfall.

Some counties have regulations concerning adequate moisture levels for gravel road maintenance. Check with your supervisor, and follow your local policy.

RULE OF THUMB

In general, to determine if a gravel road is moist enough for routine maintenance activities squeeze a handful of the surface material. If it holds its shape, the material is moist enough. See figure 3–4.

If it doesn't hold its shape then it is not moist enough. See figure 3–5.

Then pack the material against your other hand. If the other hand gets wet, the material is too wet.

Figure 3–4. Moisture test: wet

Figure 3–5. Moisture test: too dry

Maintaining Dry or Frozen Gravel Roads

Even if a gravel road is dry or frozen, some routine maintenance—for example, blading, regrading curve superelevations, repairing secondary drainage ruts, and removing vegetation—may be necessary. Check with your supervisor, and follow your city or county policy.

The following times are just general guidelines.

Spring

- Restore the crown early in the spring.
- Repair problem areas such as potholes and washboarding.
- Avoid operating heavy equipment on saturated roads and in "frost boil" locations.

Summer

- Replace surface materials.
- Maintenance grading—restoring proper superelevation on curves, cutting vegetation, etc.—may be necessary, even in dry conditions.
- Apply dust control to selected locations; check your local policy.

Fall

- Perform final blading before winter and prepare for snow removal.
- Double-check for windrows and remove them.

Winter

- Suspend routine blading when freezing conditions persist.
- Conduct snow removal activities when needed.

Definitions

Crown

An adequate, A-shaped crown is important for drainage. A four to six percent crown is generally optimum.* If a gravel road has too little crown, water from rain or melted snow will collect on the road surface and soften the crust, which can lead to severe rutting and potholes under traffic. If there is too much crown, motorists may drive in the middle of the road because they feel as if their vehicles might slip off the road, especially when snow or ice is present.

Situations may exist in which less than four percent or more than six percent crown is desirable. Always follow your agency's policy.

RULE OF THUMB

After each rain, start blading at a different location on your roadway route so that you will eventually cover the entire area. Do not go in the same direction on your route every time.

RULE OF THUMB

Be aware that little-used gravel roads and gravel roads with dead ends are frequent targets of illegal dumping, especially if they appear to be poorly maintained. Don't ignore those roadway segments.

* The actual crown will vary, depending on roadway width. In general, wider roads require more crown than narrower roads. Some sources (e.g., South Dakota's *Gravel Roads Maintenance and Design Manual*) suggest a four percent crown. This book suggests five percent as an average.

Crust

The crust is the top two or three inches of roadway that has been compacted into a dense, tight mass with an almost impervious surface.

An adequate crust requires a good blend of stone, sand, and fine particles. See figure 3–6. Aggregates with too few fines will not form a crust, and excess fines will make the road slick in wet weather. Fractured or crushed stone is preferred to round gravel because the fractured surfaces will lock together. The crust material must be compacted at optimum moisture content—not too much, not too little—in order for the fines and larger materials to bond adequately.

Drainage

Drainage is the process of moving surplus groundwater or surface water by gravity or pumping. Water flows wherever gravity takes it. Roads need good drainage to accommodate the flow of water away from the center of the road. Otherwise, water will pool on or below the road surface, weakening the crust and causing the formation of potholes, washboards, or other problems. A road with poor drainage will eventually require major reshaping and extensive maintenance.

Maintaining good drainage on granular surfaced roads is achieved by properly constructing and maintaining the crown and crust.

Riding Surface

Riding surface is the smoothness or roughness motorists feel in the road. Maintaining a smooth, safe riding surface is achieved by properly constructing and maintaining the crown and crust, uniformly distributing appropriate granular materials, and eliminating potholes, washboards, and other surface problems.

Superelevation

At a curve, superelevation is the banking or sloping of a road upward from the inside of the curve to the outside. A proper superelevation enables vehicles to maintain a consistent speed through the curve. (The banked ends of racing tracks represent an exaggerated super elevation.) See Blading at Curves later in this chapter.

Note: Not all curves must be superelevated. Check with your supervisor.

Windrow

A windrow is formed by excess granular material left along the length of the shoulder, usually after blading. Windrows may cause secondary ditches to form, which can lead to erosion. Also, if a vehicle strays into a windrow, the driver may lose control.

Maintenance Activities

A primary maintenance activity is to maintain the crown and provide effective surface drainage. This can require special care in special situations, like intersections, railroad crossings, etc. Other activities include adding new materials and repairing problem areas.

Maintaining the Crown

Maintain the crown as a straight line from shoulder to centerline. The cross section should look much like the pitch of a roof, or a flat A shape. See figure 3–6.

Blade the crown to the final desired slope so that, after adding new material and resurfacing, there will be a uniform layer of granular material on the road.

Cross slope is based on approximately one-half inch rise per foot, or about five percent from the edge of the roadway to the center. Cross slopes commonly range from four to six percent. On newer grades with higher traffic counts, the slope should approach six percent because the crown tends to get "beaten out" of the road under traffic.

By using a slope meter, as in figure 3–7, the operator can measure the crown slope. Sophisticated electronic slope controls are also available for motor graders.

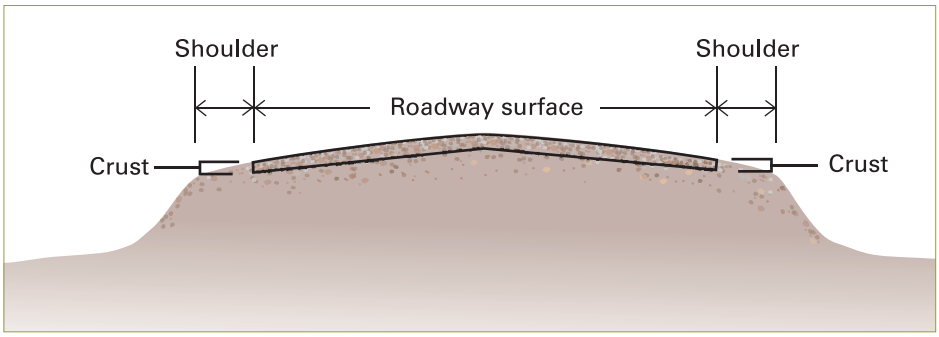


Figure 3–6. The cross section

Figure 3–7. Slope meter

RULE OF THUMB

While you're operating the motor grader, you may be able to use a cup of coffee to estimate the road's slope. Set the cup on a flat surface, and eyeball the angle between the surface of the coffee and the rim of the cup. (A slope meter should be your final guide.)

The road in figure 3–8 does not have adequate crown, and water sits on the road after a rainfall or snow melt.

Make sure the roadway edge is the same height as (not lower than) the top of the foreslope to the ditch, as shown in figure 3–9. This is critical for preventing the formation of secondary ditches.

Figure 3–8. Poor crown shape (LTAP-SD)

Figure 3–9. Foreslope height (LTAP-SD)

Adjust the angle and position of the moldboard, depending on the job at hand. For most blading purposes, rotate the moldboard to a horizontal angle of about 30 to 45 degrees. See figure 3–10.

To cut out ridges, washboards, and potholes, put the moldboard in the cut position. See figures 3–11 and 3–12. Be sure to put enough pressure on the blade to maintain your cut.

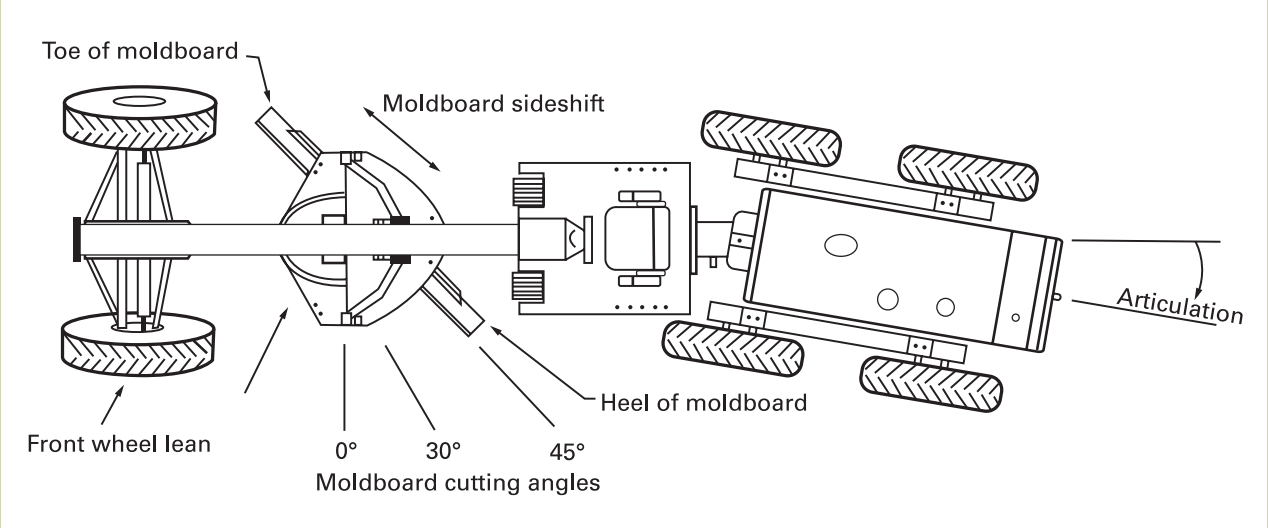


Figure 3–10. Angle of the moldboard (Adapted from LTAP-SD)

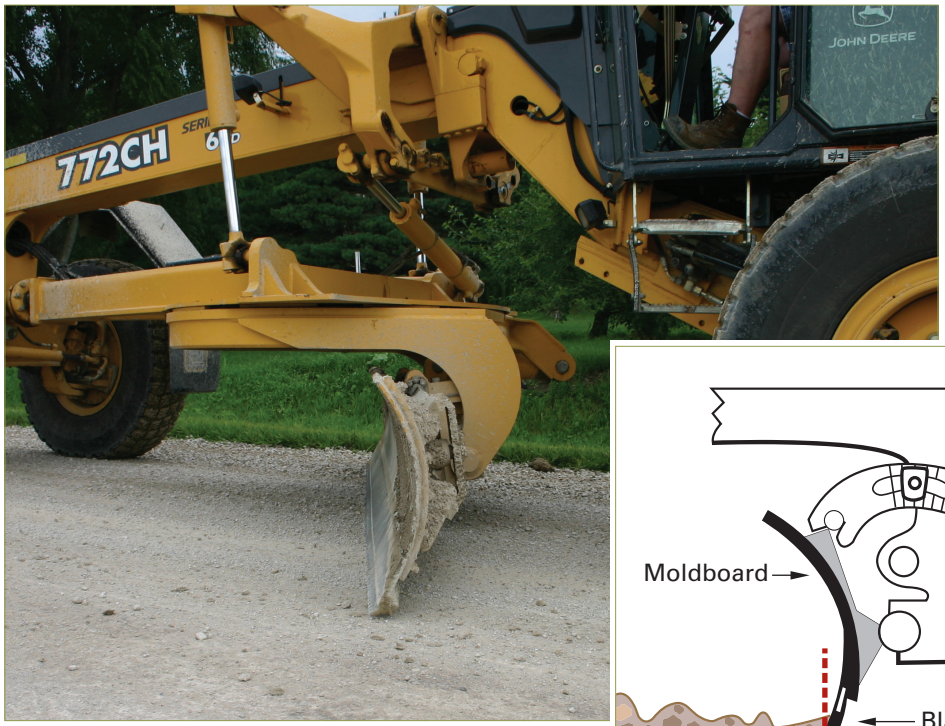


Figure 3–11. Moldboard in the cut position for regular grading

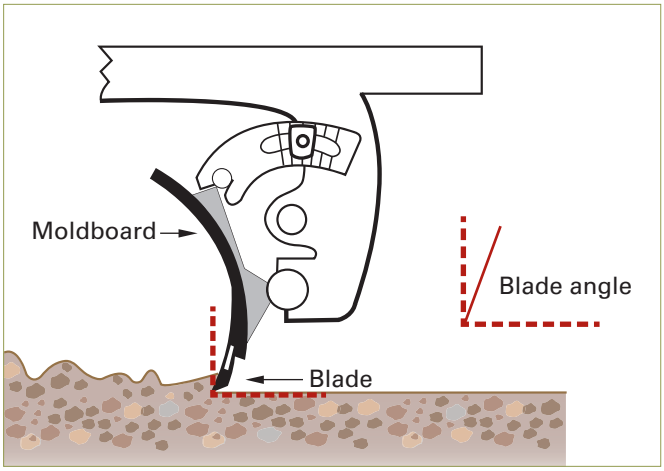


Figure 3–12. Moldboard in the cut position for regular grading (Adapted from LTAP-SD)

For heavier grading, tilt the moldboard back. See figure 3–13.

To create a compaction roll that smoothes the road and helps shape the crown, tilt the moldboard forward until the blade is perpendicular to the road. See figures 3–14 and 3–15. Move and roll the aggregate in a mixing action away from the shoulder and toward the center of the road.

To bring fine materials back across the road, the blade should be in the "float" position (if that feature exists on your grader). That is, there should be no down pressure except the weight of the blade. To do this, simply turn off the pressure to the blade.

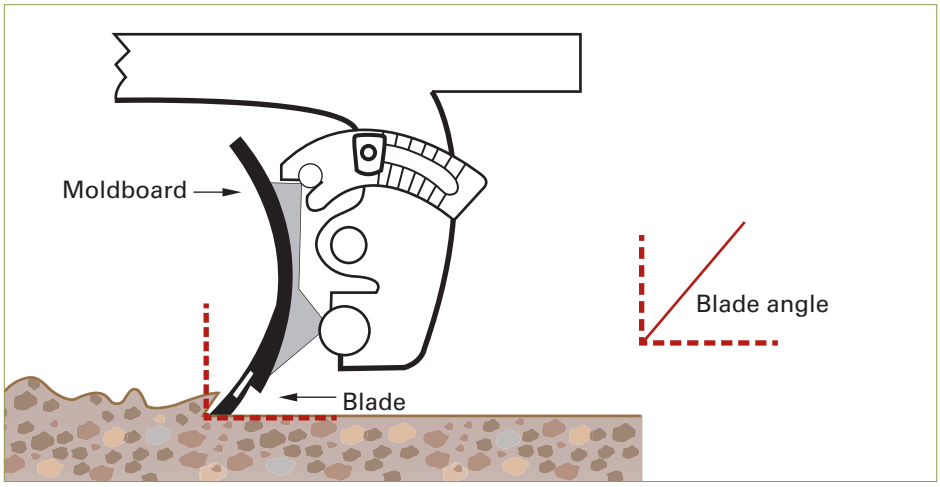


Figure 3–13. Moldboard tilted backward for heavier grading or more aggressive cutting (Adapted from LTAP-SD)

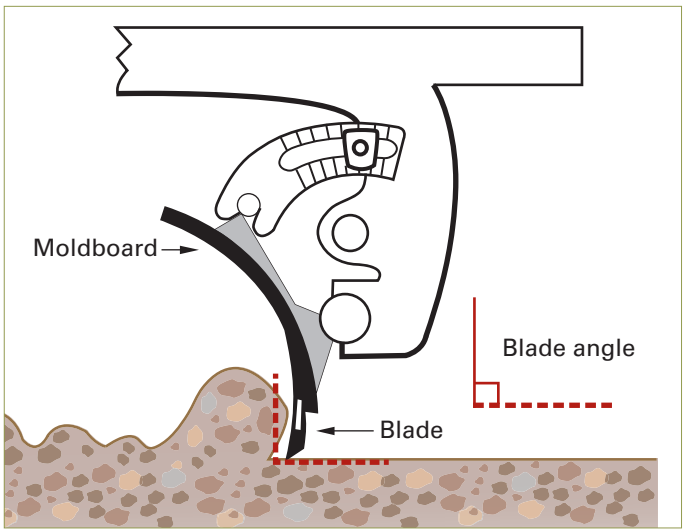


Figure 3–14. Moldboard tilted forward for smoothing (Adapted from LTAP-SD)

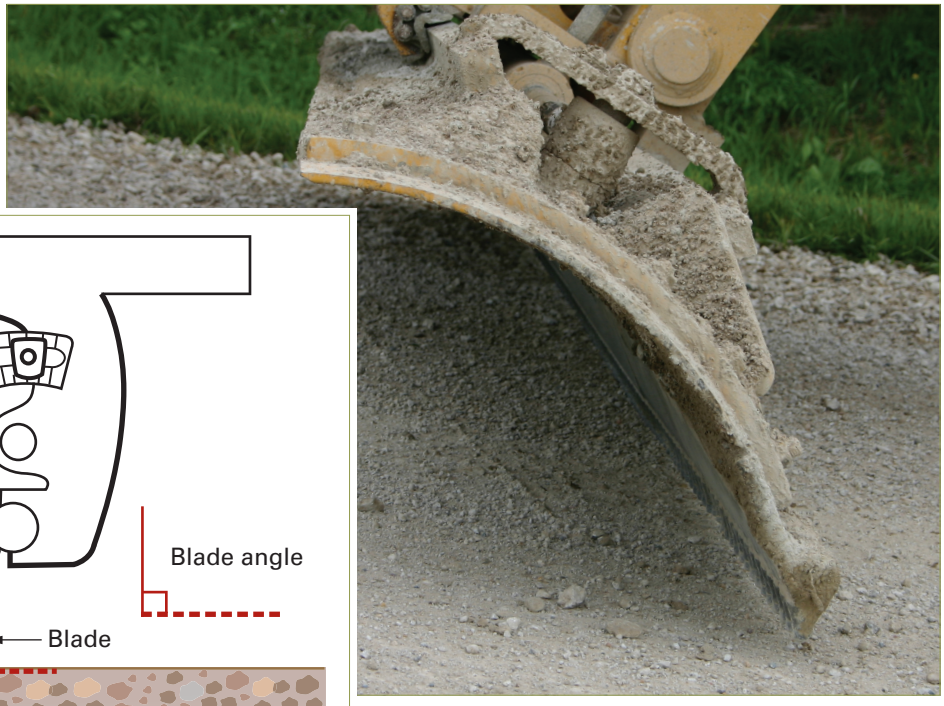


Figure 3–15. Moldboard tilted forward for smoothing

Blading in Special Situations

Take special care at driveways, curves, railroad crossings, and bridges.

Blading at Driveways

On a road with driveways, blade the road at a constant grade, then go back and fix the driveway areas by grading to a low point at the ditch line in the driveway. See figure 3–16.

Leaving a windrow across a driveway may cause small vehicles to get stuck. Leaving a windrow on a hill will cause a secondary ditch to form, resulting in erosion in the roadway surface. See figure 3–17.

Figure 3–16. Driveway meets the road

Figure 3–17. Windrow forming a secondary ditch

Blading at Curves

In general, there should be little or no crown in a curve. If the curve is to be superelevated, use the following procedure: As you approach the curve, transition from crown to superelevation, beginning about 250 feet before the curve. As you leave the curve, transition back to a regular crown about 250 feet after the curve.

A commonly accepted maximum superelevation on gravel roads is approximately six percent. A superelevation higher than six percent can be dangerous, especially where snow and ice can make roadways slippery. A higher superelevation also tends to cause aggregate to migrate to the bottom of the slope, or the inside of the curve.

RULE OF THUMB

You will have a near-perfect superelevation if you merely extend the five-percent cross slope from the inside of the curve across the entire width of the roadway. See figure 3–18.

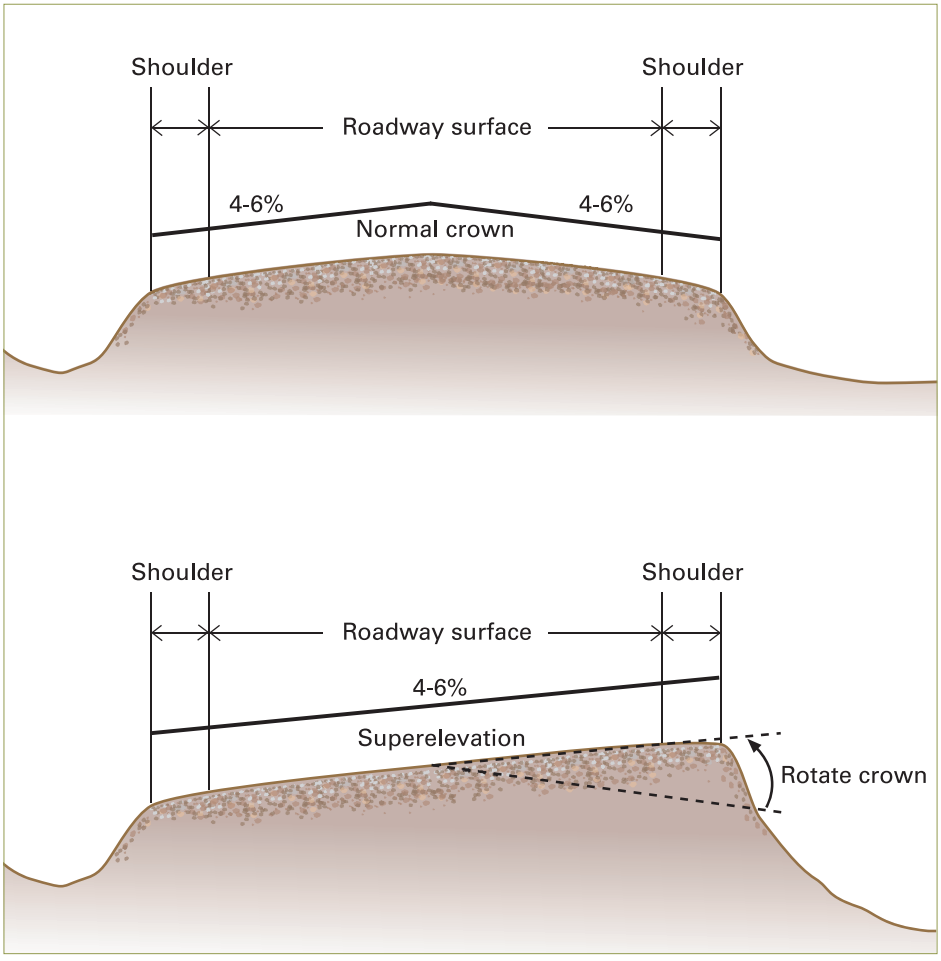


Figure 3–18. Normal crown (top) and superelevation (bottom)

Blading at Railroad Crossings

At railroad crossings, zero out the crown on both sides of the crossing for a distance of 20–30 feet. Be careful not to blade aggregate onto the rails, which could cause a train to derail. After blading, brush all loose aggregate off the track.

Blading at Bridges

Bridge approaches may need more frequent attention than other parts of the roadway because they are difficult to drain and the subbase beneath the crust is prone to settling, leaving potholes in the approach.

If a bridge deck is crowned, gradually reduce the road crown to match the bridge crown. If the bridge does not have a crown, gradually zero out the road crown to meet the elevation of the bridge deck.

Take care not to drag too much rock onto the bridge deck during blading operations.

Adding/Distributing Granular Material

The granular surface material is gradually knocked off, carried off, or ground up (this is especially true with soft limestone) by traffic. Adding new material to gravel roads is therefore a regular maintenance activity.

Before adding new material, prepare the road surface by scarifying it lightly to ensure a good bond and to blend the old and new materials together. See figure 3–19. Be careful not to cut out the crust when scarifying.

Figure 3–19. Lightly scarifying

When the new material is delivered by truck, it should be placed as uniformly as possible on the road. See figure 3–20.

Then use the motor grader blade to distribute the material uniformly across the roadway. Be sure to maintain proper crown.

After all the granular material is spread evenly over the roadway, normal traffic will generally compact the crust. However, if rollers are available, create a hard crust by compacting the surface with rollers. You may need to add water during this operation. See figures 3–21 and 3–22.

Figure 3–20. Placing new material on the roadway (LTAP-SD)

Figure 3–21. Adding water (optional) (LTAP-SD)

Spreading New Material

New rock is normally delivered to the roadway in trucks. To spread the material uniformly, the truck driver should strategically dump the rock while the truck is rolling. Here's how:

First, set the tailgate chains on the dump body to control the rate of spread, maintaining a gap of approximately 9 to 15 inches. As you approach the area needing rock, begin raising the dump body. At the appropriate location, trip the tailgate and continue raising the dump body, traveling at the appropriate speed for the desired rate of discharge. See figure 3–20.

When the load is fully discharged, lower the dump body, allow the tailgate to engage, and head for your next load.

Achieving the proper speed and tailgate setting is largely a matter of experience and feel. Skilled dump truck drivers usually watch their RPM meter instead of their speedometer.

Storage Windrows: Follow Your Local Policy

After new material has been delivered to the site, it may be useful to use the grader to move it to the side of the road for short-term (one day or less) storage until you can spread it evenly across the road.

Storing material temporarily like this keeps it out of the way of traffic, making it easier for vehicles to use the road while you're blading. It also promotes mixing of the old and new materials.

However, never store material at the side of the road for any length of time; see the problems associated with windrows, described on page 16.

Some counties and cities prohibit the use of storage windrows. Consult your supervisor before using this technique.

Figure 3–22. Compacting the new material (optional) (LTAP-SD)

Repairing Problem Areas

Do not simply fill problem areas (potholes and wash boarding) with more granular material. Doing so can become very expensive. It also results in non-uniform levels of granular material across the road, causing the problems to reappear quickly.

Secondary Ditches

Secondary ditches are a common problem in a granular surfaced road. They generally form when vegetation or windrows obstruct the flow of water from the roadway to the ditch as the top of the foreslope. Motor grader blading can inadvertently create secondary ditches if the operator is not careful. See figure 3–23.

Prevent the formation of windrows by blading carefully and maintaining the edge of the road level with the shoulder and/or the top of the foreslope. Be careful not to dig a ditch with the end of the blade.

Secondary ditches should be corrected as soon as possible after a rainfall. Also correct secondary ditches in the spring when there is little vegetation and plenty of moisture. Create a new crown, making sure that the edges of the road are level with the top of the foreslope so that water can flow directly off the road down the foreslope and into the ditch.

Figure 3–23. Secondary ditch (LTAP-SD)

Corrugation/Washboarding

Washboarding may occur under any of the following conditions:

- Where traffic frequently starts and stops; for example, at intersections. This generally creates a series of close ridges in the road. See figure 3–24.
- When the motor grader is driven too fast during blading. Driving too fast may cause the blade to bounce and cut ridges at an angle across the road. It can also cause the grader to "duck walk": One end of the blade catches the ground while the other end rises above the ground, and then the second end will get caught in the ground while the first rises.)
- If there are too many large particles and not enough fines, then the large particles may roll together creating piles or washboards.
- Where drainage rills or rivulets form on super elevation curves, and where drainage across the road cause erosion.
- Where crust or crown is inadequate and good drainage is not provided. See figure 3–8.

To prevent washboarding, drive at three to five miles per hour and follow good maintenance practices regarding material size and distribution, moisture, and compaction.

To correct corrugation and prevent it from recurring, you must cut it out of the road. Reconstruct the location, carefully remixing and compacting fine and course materials. You will usually have to make about four passes with the grader to get to the bottom of the corrugated area and blend the material adequately. See figure 3–25. Adequate moisture content is critical. See figures 3–24 and 3–25.

Figure 3–24. Washboarding (LTAP-SD)

RULE OF THUMB

Start-stop locations on steep hills may be especially prone to washboarding. In such locations, it may be helpful to reduce the top size of your aggregate. Finer material knits together better and may help reduce the formation of washboards.

Potholes

Potholes are caused by poor drainage and occur where water pools. See figure 3–26. Prevent potholes by maintaining adequate crown on the roadway. Perform temporary repairs of potholes by filling them with aggregate. Such repairs will not last long.

For a permanent repair, locate and fix drainage problems related to the potholes, then restore the area by cutting out the potholes, placing additional granular material, and blading and compacting the surface.

Rutting

Rutting may be caused by poor drainage. See figure 3–27. Sometimes it occurs in the center of the road when traffic in both directions uses the middle of the road as a tire lane which moves the surface material in that area, creating a rut.

To prevent rutting, make sure the crown is between four and six percent, there is an even distribution of material sizes, and the material is spread at an even depth and appropriately compacted with adequate moisture content.

To correct rutting and prevent it from recurring, cut out the potholes, placing additional granular material, and blading and compacting the surface.

When cutting out large potholes, corrugations, or ruts you may need to use your scarifier in order to cut deep into the crust and remove the surface defect. See figure 3–19.

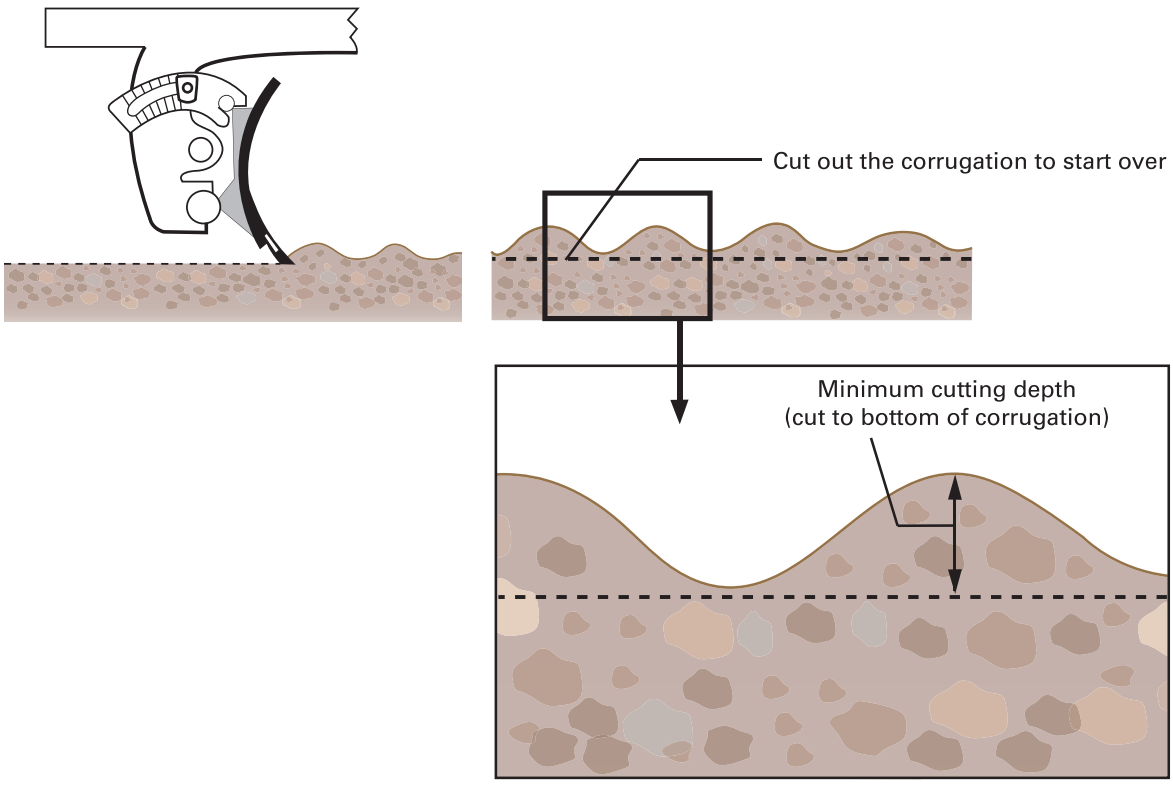


Figure 3–25. Cutting out a washboard (Adapted from LTAP-SD)

Figure 3–26. Potholes (LTAP-SD)

Figure 3–27. Rutting

Providing Dust Control

All granular surfaced roads, whether natural gravel or crushed stone, will produce dust under traffic. The amount of moisture in the area has a great effect on the amount of dust. The quality of granular material also has a major impact. Limestone develops the most dust. Glacial gravel, with highly plastic clay, is less prone to developing dust.

Applying dust control products on higher-volume granular surfaced roads may be cost effective. In addition to reducing dust, such products can help keep small granular particles on the road and prevent larger stones from being moved to the side of the road, thus reducing the need for blading.

Applying Dust Control Products (or dust stabilizers)

Following are some general tips:

- Make sure the road has a uniform crown (between four and six percent) and good drainage.
- Do not compact the road surface before application. In fact, scarify a minimum of one to two inches of the road surface, leaving a uniform depth of loose material across the road.
- Do not apply if rain is forecast. Rain will wash away your product and you may have to reapply .
- If you are using a new product, you may want to start by treating a 500–1,000-foot test section. This will allow you to see how the product works before applying it to the entire roadway.
- Select an application rate and stick to it throughout the entire application process. This will leave you with a consistent roadway.
- Treat one side of the road and then immediately treat the other side to achieve a consistent application.
- After application, immediately open the road to traffic. Traffic will pack the product into the road surface material.
- Some manufacturers of dust control products recommend not blading the surface at all after applying their products. Blading will break the bond that the product has made with the gravel on the roadway.

RULE OF THUMB

If potholes or other surface defects appear after dust control material has been applied, you may need to blade the road for safety reasons. Check with your supervisor.

Moisture Considerations

To be effective, dust control materials should be applied when the road surface material is moist. (See the rule of thumb on page 14.) The optimum moisture level is 13 to 18 percent. Figure 3–28 shows a roadway with this amount of moisture.

Kinds of Dust Control Materials

The most common types of dust stabilizers used on roadways are chlorides, resins, natural clays, and soybean oil.

Chlorides are the most common dust control materials. Calcium chlorides come in a flake or a liquid form and are very effective if properly used.

Magnesium chloride is available in a liquid form and is very effective if properly used.

Never apply chlorides to dry gravel. Moisture is necessary to help the chlorides penetrate the road surface and coat the granular material. Without moisture, chlorides aren't effective, and you will have to reapply.

Resins (lignin or tree sap) are available under various commercial names. They work best when incorporated into the gravel surface. They provide cohesion to bind particles together.

Natural clays like bentonite will still develop dust in dry weather. They are somewhat difficult to transport and to mix with granular surface material.

Soybean (or other vegetable) *oil* penetrates a gravel surface and provides a light bonding of the gravel that effectively reduces dust. However, vegetable oils tend to harden and may make the roadway more difficult to maintain.

Motor Oil is Not for Dust Control

It is illegal to use motor oil or used crankcase oil as dust control material. These waste products have heavy metals and other hazardous materials in them and may pollute the environment. If you see oil on the road, notify your supervisor.

Rejuvenating Dust Control Treatments

Calcium chloride and magnesium chloride are water friendly. After a rain, you can do touch-up maintenance on a gravel road treated with chlorides, and the dust-control properties will be rejuvenated. The same is not true for roads treated with resins, clays, and vegetable oils.

Figure 3–28. Adquate moisture for applying dust control material

Maintaining Gravel Alleyways and Streets

Some communities (especially those with older, established neighborhoods) have gravel alleyways that accommodate off-street parking, access to garages, and access for waste pickup and utility repairs. Some communities also have gravel streets, where the drainage is managed through side ditches along the length of the street. Gravel streets are more common where traffic volumes and speeds are very low and where there is little if any truck traffic.

Purpose of Gravel Alley or Street Maintenance

Like rural gravel roads, gravel alleyways and streets require regular maintenance. Generally, the purpose of urban gravel-way maintenance is to do one or more of the following:

- Remove moderate to severe potholes.
- Replace surface material that has washed out.
- Control or restore the surface elevation and drainage features.
- Provide dust control.

Watch for Obstacles

Equipment operators maintaining city streets and alleyways are often working in confined areas, sometimes in the vicinity of parked vehicles or other obstacles. In such situations, take extra care. Be aware of your surroundings.

What's an Appropriate Crown?

The crown on urban gravel streets is generally lower, about two to three percent. The crown on gravel alleyways will likely be even less due to limited space.

Maintenance Activities

In many ways, maintaining gravel alleys and streets is similar to maintaining rural gravel roads. The following information highlights special considerations for urban settings.

Pre-Maintenance Activities

- Locate all manholes, intakes, and other conflicting utility features.
- To keep rock out of the storm sewer system, remove intake grates and cover the opening with fabric, plastic, or wood. (Hold the covering in place with the grate.)
- Locate potential obstacles to avoid during maintenance activities. Such obstacles may include the following:
  - Parked vehicles
  - Overhead wires, cables, and branches
  - Telephone poles
  - Garbage cans

Maintenance Activities

- On narrow gravel streets and alleyways, you may have to lay material under the grader, between the wheels, so that material does not end up in lawns. (Have a plan for retrieving the windrow.)
- When adding material to an alleyway, take care not to drastically raise the elevation of the final surface, which could force rain water or runoff into garages and back yards.
- When applying any dust control material to the new gravel, blend the dust control material into the gravel with the blading action.
- After shaping the final surface profile with the grader, roll the edges with either the grader or with truck tires. This compacts the flow line and gives a more finished look to the street or alleyway.
- Use shovels or brooms to clean alley approaches of residual rock.

Follow-Up Activities

When maintenance activities are finished, remove the protective coverings from intakes, clean the intake area, and replace the grates.

Asphalt Pavements

Safety Tips for Maintaining Asphalt Surfaced Roads

Always check with your supervisor and follow your agency's safety policies and procedures.

Suggested personal safety gear

- Hard hat (if visiting an asphalt production plant)
- Heavy gloves
- Hard-toed footwear for working around hot asphalt
- Ear protection (for working around noisy equipment like jack hammers)
- Safety glasses with side shields
- Highly visible apparel

Advance preparations

- Be properly trained and familiar with all equipment and materials.
- Know procedures for emergency treatment of burns from hot asphalt.
- Be trained in avoiding heat-related illnesses, like heat exhaustion.
- Make sure an up-to-date first-aid kit, emergency contact information, and hand-held radios or cell phones are available at the work site.

During operations

- If road is open to traffic use proper temporary traffic control, including flagger(s) if needed, as described in the *Iowa Traffic Control Devices and Pavement Markings: A Manual for Cities and Counties; in the MUTCD,* part 6; and in your agency's policies and procedures.
- Consider temporary road closures if traffic can be diverted.
- Wear highly visible apparel when you're not in a vehicle.
- Be aware of and take steps to avoid heat-related problems like heat stress and exhaustion.
- Follow manufacturer recommendations and use caution when heating and using asphalt materials.
- Do not park work vehicles or equipment on both sides of the road.
- Be aware of construction equipment, especially backing trucks, paver, and rollers.
- Ensure that all obstructions and unneeded temporary traffic control are removed from the road well before darkness.
- Use proper lifting techniques or request assistance to lift heavy objects.
- Workers should be provided periodic breaks and rest room accommodations.
- Remove all temporary traffic control immediately when no longer needed.

Traditional maintenance treatments for hot-mix asphalt (HMA, or simply asphalt) roads include sweeping, crack sealing, pothole patching, full-depth patching, and thin maintenance surfaces like seal coats and asphalt overlays. A well-maintained asphalt roadway is shown in figure 3–29.

Characteristics of a Well-Maintained Asphalt Pavement

- The roadway cross slope provides effective drainage.
- There are no unsealed cracks, alligator cracks, potholes, washboards, or ruts.
- Little to no ponding follows rain and/or ice melt.
- Surface water does not move to the subgrade.

Optimum Timing/Conditions for Maintenance Activities

Conduct maintenance operations on asphalt roads under dry to drying weather conditions. Water and asphalt are never a good combination.

Spring/Summer/Fall

Most asphalt maintenance activities can be conducted during the spring, summer, or fall. Conditions may vary so check the material manufacturer's instructions before applying.

Winter

Asphalt maintenance is seldom done during the winter. (Normally only cold mix is placed for the purpose of managing potholes during the winter.)

RULE OF THUMB

Conduct road inspections for drainage during or immediately following rainfall. Problems with drainage, sealed and unsealed cracks, and ponding of petroleum byproducts can be readily identified immediately. Cracks are very prominent as the pavement surface is drying.

Figure 3–29. Well-maintained asphalt road (APAI)

Asphalt Pavement Distresses

Typical distresses include ruts, cracks, washboards, and potholes.

Rutting

Ruts are surface depressions that run parallel to traffic and are located in the wheel path. See figure 3–30. Causes vary.

If the pavement has risen around the edges of the rut, the rut is most likely caused by a poor mix. The uplift is a result of traffic pushing the asphalt to the edges of the wheel paths.

If there are longitudinal cracks in the rut, the rut is most likely caused by structural failure of the subbase. The pavement is being pushed down onto the base or subbase.

If the rut is not accompanied by uplift on the edges or longitudinal cracking, the rut is a result of poor compaction during construction and the vehicle loading has compacted the asphalt.

Progressive rutting (rutting that continues to grow deeper and wider) is a result of poor subbase, very poor mix, or road design that is inadequate for actual loads. If progressive rutting is present, use of a slurry seal or micro-surfacing should be avoided until the ruts become dormant or no longer grow.

Figure 3–30. Rutting on an asphalt street

Cracks

Cracks develop over time due to flexing pavement and temperature changes that cause expansion and contraction. Cracks allow water to move through the pavement and infiltrate the pavement base and subbase. Infiltrated water decreases the load carrying capacity of the base and subbase. If not repaired or prevented, this cracking effect will grow, leading to deformation of the pavement, potholes, and ultimately the degradation of the pavement surface.

Fatigue Cracking

Fatigue cracks are a series of interconnected cracks in early stages of development that occur in areas subjected to repeated traffic loadings such as the wheel paths. See figures 3–31 and 3–32. These cracks develop into many-sided, sharp-angled pieces, usually less than one foot long on the longest side. In later stages, the cracks characteristically develop with an alligator scale pattern.

Figure 3–31. Fatigue cracking (CCEE/ISU)

Figure 3–32. High-severity fatigue cracking (CCEE/ISU)

Block Cracking

Block cracking is a pattern of cracks that divides the pavement into approximately rectangular pieces. See figure 3–33. Rectangular blocks range in size from approximately 1 to 100 square feet.

Alligator Cracking

Alligator cracks are interconnected cracks that have the appearance of alligator scales. See figure 3–34.

Alligator cracking is typically found in wheel paths and is normally accompanied by rutting. Alligator cracks form in areas of repeated traffic loads that cause high stress in the bottom of the pavement. This stress cracks the pavement and the cracks propagate to the surface. The surface cracks begin with hairline longitudinal cracks and, as the pavement ages, the cracks begin to interconnect.

Figure 3–33. Block cracking (CCEE/ISU)

Figure 3–34. Alligator cracking (CCEE/ISU)

Reflection Cracks

Reflection cracks are cracks in an overlay that have "reflected" upward from cracks or joints in the pavement below. See figure 3–35.

Washboards

Washboards are a series of ruts in the road running transverse to the road. See figure 3–36.

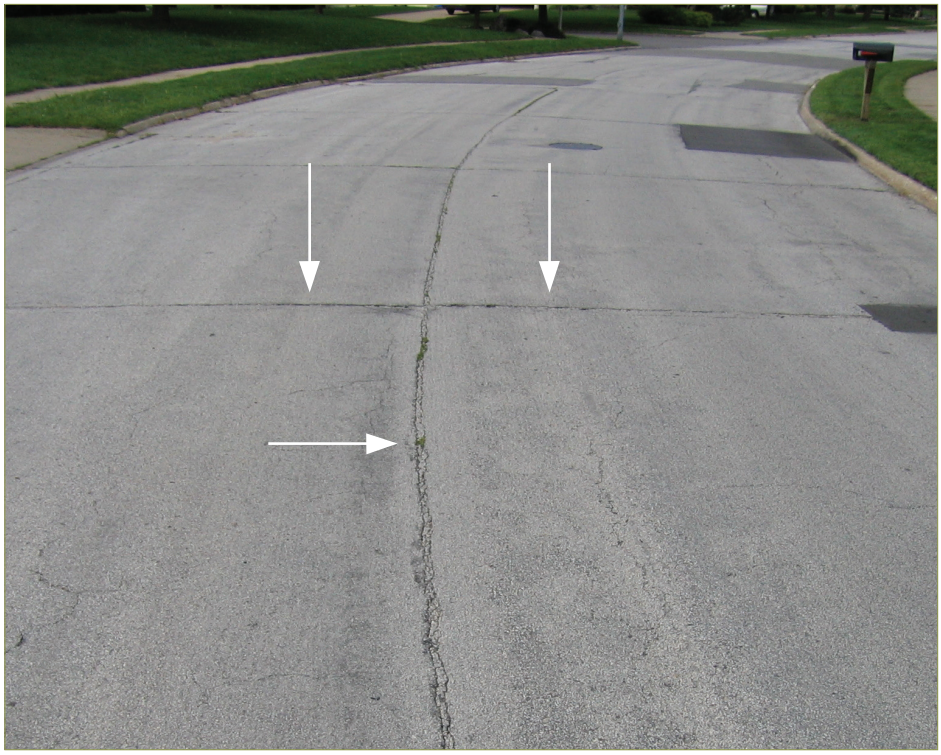


Figure 3–35. Reflection cracking (CCEE/ISU)

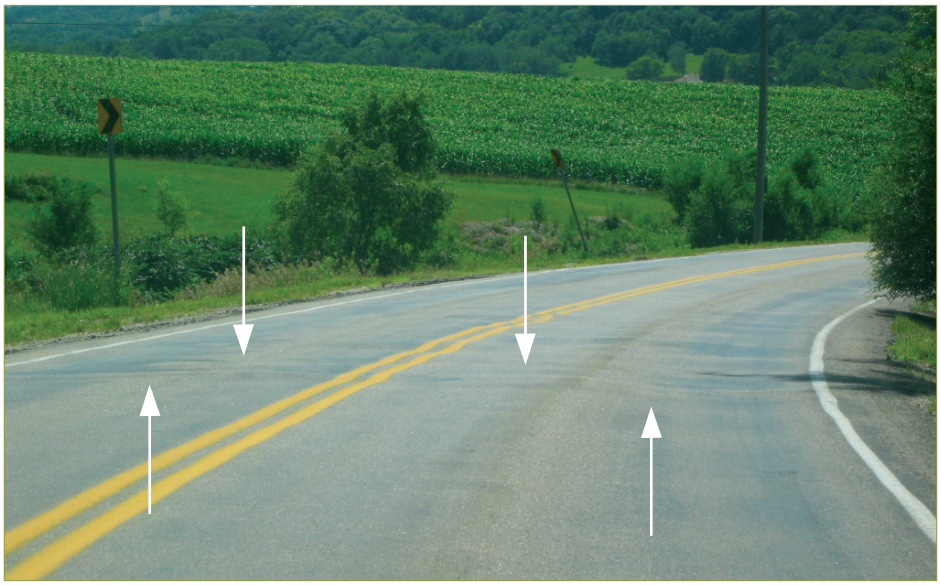


Figure 3–36. Washboards (CCEE/ISU)

Potholes

Potholes are bowl-shaped holes of various sizes in the pavement surface, with a minimum width of three inches. See figure 3–37. For purposes of classification, low-severity potholes are less than one inch deep, moderate potholes are from one to two inches deep, and high severity potholes are greater than two inches deep.

One way potholes form is when water becomes trapped beneath the pavement surface. (Water can infiltrate through cracks or poor drainage.) In the winter, the sub-surface water freezes and expands upward against the pavement. This action creates a void under the pavement, and vehicle loads are not transferred to the base and subbase. Vehicles add more stress until the pavement surface collapses into a hole. The hole grows as traffic breaks the edges of it.

Figure 3–37. Pothole in asphalt pavement (CCEE/ISU)

Selecting a Maintenance Activity

A key to effective asphalt pavement maintenance is to first identify the pavement distresses (described above) and then determine the most effective maintenance activity. See table 3–1.

Selecting the most effective maintenance activity involves several factors:

1. Type and extent of distress
2. Roadway classification and traffic volumes
3. Cost of treatment
4. Availability of qualified staff and/or contractors
5. Availability of quality materials
6. Time of year for maintenance

Reviewing the records of the road will also aid in selecting the most effective maintenance activity. Records should include the following:

1. Routine maintenance activities
2. Pavement base and subbase design
3. Pavement section boundaries
4. Pavement age
5. Type and extent of previous maintenance treatments
6. Traffic volumes
7. Environmental impacts

Table 3–1. Distresses and Maintenance Activities for Asphalt Pavements

Distresses	Maintenance Activities				
	Routine Maintenance				
	Crack Sealing	Surface Patching	Full-Depth Repair	Seal Coat Repair	HMA Overlay
Ruts			X		X
Cracks	X			X	X
Washboards			X		X
Potholes		X	X		

Maintenance Activities

Routine Maintenance

The goal of routine maintenance is to prevent or delay pavement distresses. Routine maintenance includes regular street sweeping and crack sealing.

Street Sweeping

Sweeping removes dried, caked mud, abrasives, and other debris from the road surface. Clean road surfaces help keep drains clean, make travel safer for bicyclists, and ensure good surface drainage.

Crack Sealing

Crack sealing prevents water from infiltrating through the pavement into the base and subbase. Typically the public works or secondary road department rents equipment for crack sealing every other year or as needed. Seal cracks in the spring or fall when temperatures are moderately cool and the pavement cracks are open. The work can usually be accomplished within a month's time.

The following instructions are general guidelines. Check with your supervisor, and follow your local policy.

See Safety Tips on page 34.

Preparing for Sealing

Follow these preparation guidelines:

1. Rout or saw-cut cracks to provide clean, uniform surfaces for sealant to adhere to and a reservoir for sealant.
2. Use an air compressor and an air wand to clean cracks of dirt, dust, and remnants from sawing or routing. Contamination in a pavement crack will cause poor sealant bonding.

Applying the Sealant

After all cracks are blown clean, seal the cracks:

1. Apply sealant at a temperature of 350°–410°F with the delivery hose and wand of the melter applicator. Take appropriate safety precautions when handling this hot material.
2. Pour an even bead of sealant into the crack no higher than ½ inch above the pavement surface. If it's higher, it could be damaged by snow plows or street cleaning equipment, and it may flow over the pavement surface.
3. To remove excess sealant, run a U-shaped squeegee or sealing shoe over the bead to flatten the sealant over the crack, move the sealant to the bottom of the crack, and remove excess sealant. The squeegee creates a U-shaped seal, allowing for contraction and expansion of the pavement during pavement temperature changes. See figure 3–38.
4. Keep traffic off the newly crack sealed surface. This will minimize tracking of material and allow for maximum adhesion to the surface. On occasions where this is not feasible, a light coating of sand spread over the sealant will act as a blotter and allow opening the street to traffic sooner.

Surface Patching

Surface patching is an interim repair using all-weather asphalt materials. See figure 3–39.

Figure 3–38. Crack sealing (CCEE/ISU)

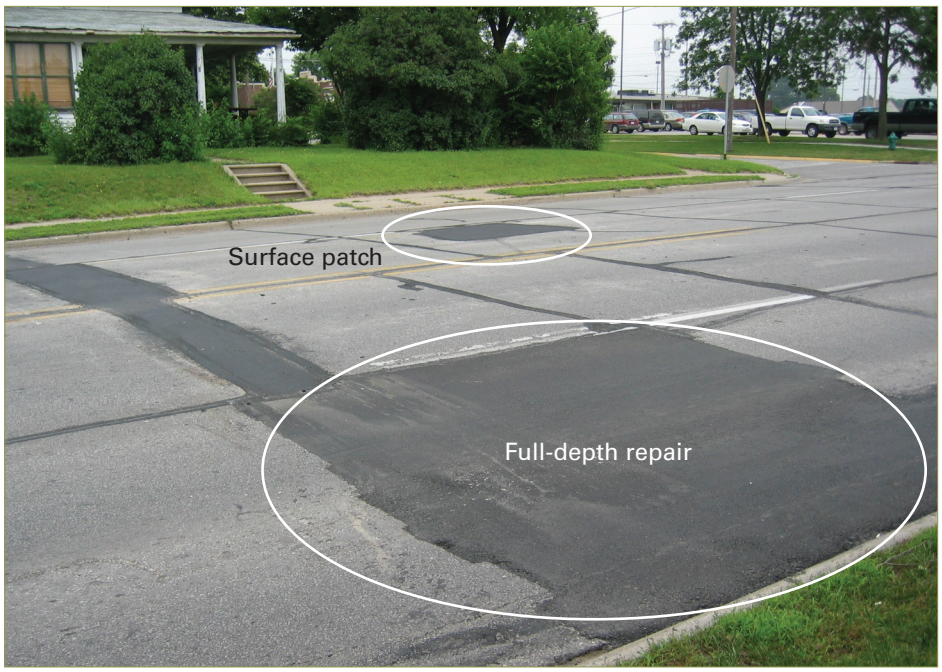


Figure 3–39. Surface patch and full-depth repair (CCEE/ISU)

Before patching, correct drainage problems that likely caused the pothole formation, in order to prevent recurrence. Ensure a proper base is in place.

Patch with an all-season patch material. This material will work well in most conditions, including wet. In fact it is preferable to wash out the area to be patched to avoid having a dusty surface. See figure 3–40.

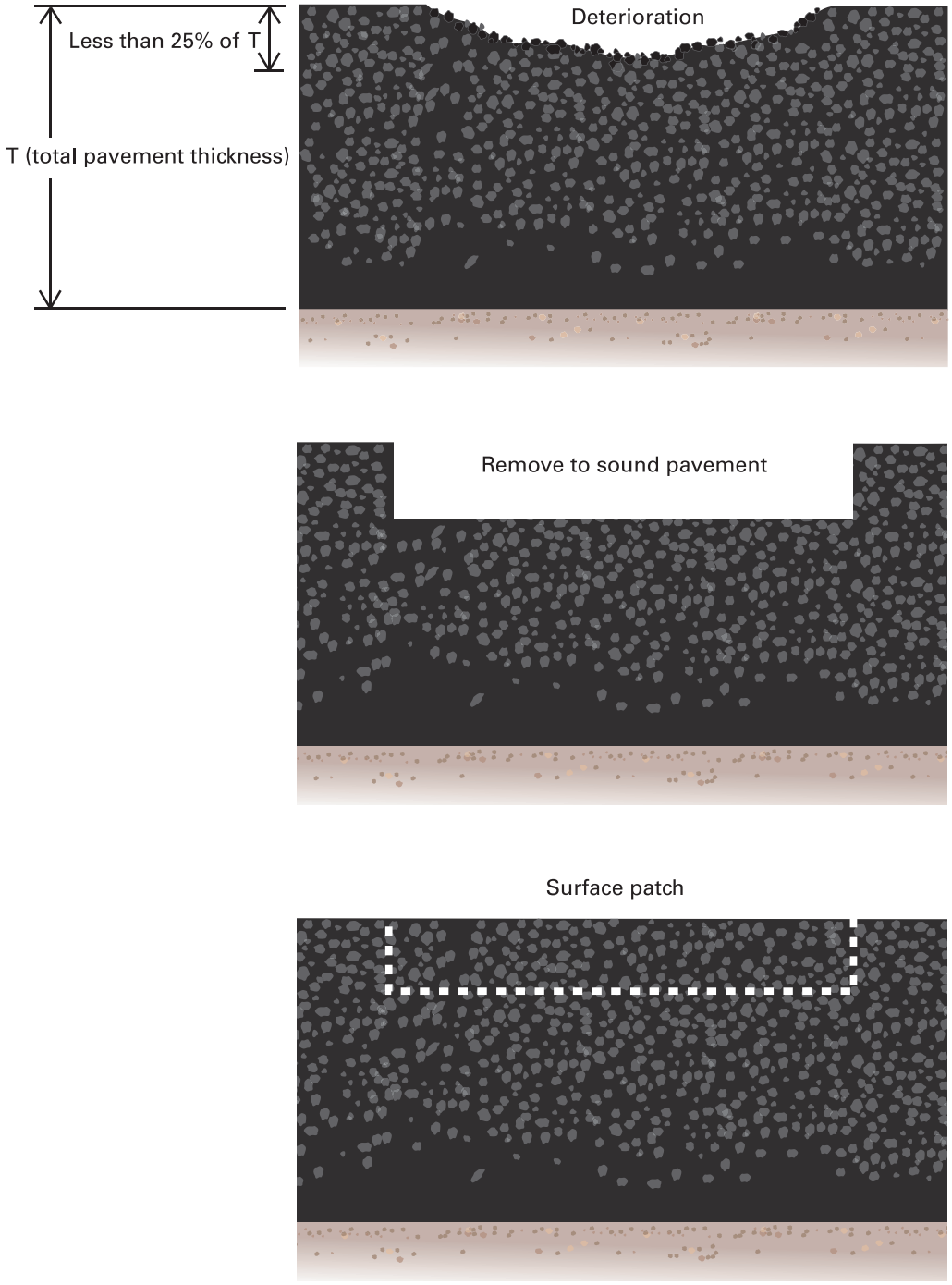


Figure 3–40. Procedure for placing surface patch

Preparing for Surface Patching

Follow these preparation guidelines:

1. Make sure warning lights attached to vehicles are on and in proper working order.
2. Use a shovel, broom, air hose, or mechanical sweeper to clean the area to be patched. It must be clean and free of water, debris, and other loose material before patching.

See Safety Tips on page 34.

Placing the Patch

After the area to be patched is clean, place the surface patch.

1. Fill the pothole with patching material until it is slightly higher than the surrounding surface area.
2. Smooth the area with a shovel or lute, leaving the patch slightly higher than the adjacent surface.
3. Compact the patch using a hand tamper, truck tire, or vibratory roller. The patch should now be consolidated and flush with the pavement surface.
4. Clean the area of any residual debris and haul it away.

RULE OF THUMB

If deterioration is 25 percent or less of the total pavement thickness, apply a surface patch.

If deterioration is more than 25 percent of the total pavement thickness, apply a full-depth repair.

Alternative Patching Materials

Commercial products are available for cold-weather pavement patching and for use in adverse weather conditions. Such products cure rapidly and have good flexibility for withstanding extreme changes in temperature.

Before applying these products, make sure pavement is frost free, dry, and free of coatings, dirt, oil, or other contaminants. Saw cut the perimeter of the patch to a minimum depth of ½ inch. Remove loose and deteriorated pavement.

Full-Depth Repair

This is a permanent repair for distresses larger and/or deeper than surface degradation. It involves removing and replacing the distressed section of the slab, from top to bottom. See figures 3–39 and 3–41.

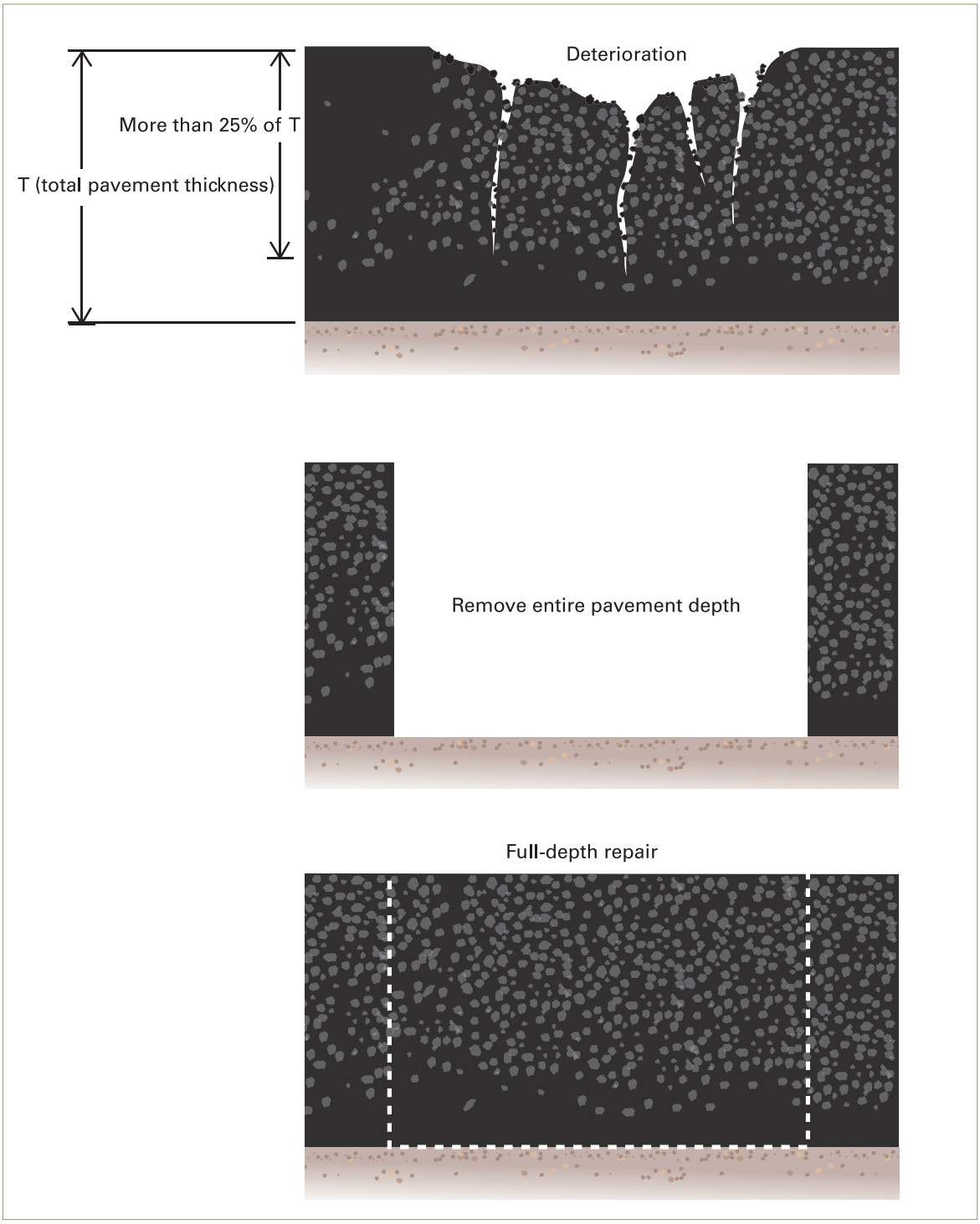


Figure 3–41. Procedure for full-depth asphalt repair

Preparing for Full-Depth Asphalt Repair

1. Make sure the warning lights attached to vehicles are on and in proper working order.
2. Clean and dry the surface before removing deformed pavement material.

See Safety Tips on page 34.

Placing a Full-Depth Repair

Full-depth patching should be done in lifts, or layers, of 2½ inches maximum.

1. Saw cut around the area.
2. Remove material with a jack hammer, picks, shovels, broom, air hose, or mechanical sweeper.
3. Apply a tack coat to the edges of the existing pavement.
4. Replace in lifts, or layers, of 2½ inches maximum.
5. Compact with a vibratory roller.
6. Reapply pavement markings if appropriate.
7. Allow traffic to drive on repair when the new asphalt is cool enough to touch.

Seal Coat Repair

A seal coat is an application of an asphalt binder followed by an application of aggregate. A seal coat fills cracks and low spots, waterproofs the surface, and provides a wearing course for traffic. Seal coats are also known as chip seals, tar and rock (informal description), oil and rock, and surface seal.

A good seal coat will have the following characteristics:

- An adequate crown (slope) on the roadway for good drainage.
- Few unsealed cracks, alligator cracking, potholes, or ruts.
- Little to no dust during or immediately after application.
- A smooth tight surface with little or no bleeding or raveling. (Bleeding of asphalt binder to the pavement surface may be caused by a too-rich binder or too high application rate of binder. Raveling—a rough, pitted surface due to loss of aggregate—may be caused by damage from traffic or road equipment, oxidation of the surface, or poor design.)

Materials

The two materials used for seal coats are binder (asphalt) and aggregate. See figure 3–42.

Binders consist of asphalt cutbacks or asphalt emulsions. Asphalt cutbacks are a mixture of asphalt binder with a cutter (naptha or kerosene). Once applied, the cutter evaporates leaving the asphalt binder behind. Asphalt emulsions are mixtures of asphalt binder, water, and a surfactant soap. The soap suspends the asphalt in the water until application. The water then evaporates leaving behind the asphalt binder. See figure 3–43.

Aggregates normally used for seal coats are quartzite, limestone, and pea gravel. See figure 3–44.

Figure 3–42. Asphalt binder and aggregate are used for seal coats (CCEE/ISU)

Figure 3–43. Binder (CCEE/ISU)

Figure 3–44. Gravel aggregate (CCEE/ISU)

Optimum Timing/Conditions for Applying Seal Coats

A new seal coat should be placed before structural distresses have occurred in the existing asphalt pavement or on a properly prepared stone base.

Application should take place during the hottest and driest months of the summer. The binders used for seal coat construction cure faster in hot, dry weather. Seal coat construction is normally not planned past September 15, when temperatures begin to drop and the likelihood of rain increases. Seal coating should be delayed if wind speeds are high. The wind affects the spray pattern from the distributor truck and can blow dust and other debris on the uncovered binder. Wind will also cause the binder to cure faster, decreasing the time available between binder application and aggregate application.

Preparing for Seal Coat Application

See Safety Tips on page 34.

1. Complete pre-seal coating activities, like crack sealing or patching.
2. Ensure all equipment is on site and functioning properly (check the equipment manuals):
   - Street sweeper
   - Distributor truck
   - Chip spreader
   - Pneumatic tire roller
   - Dump trucks for aggregate hauling
3. Ensure the materials are on site. The aggregate should be clean.
4. Sweep and clean the pavement to remove debris. See figure 3–45. Remove vegetation from cracks.
5. Cover utility access lids with construction paper so the material does not adhere to the lid.

Figure 3–45. Cleaning the existing pavement surface (CCEE/ISU)

Placing a Seal Coat

1. Spray the pavement with the binder.
   - Use roofing paper to make a sharp line across the pavement when starting and stopping application.
   - Align the binder application with the center line of the road. Align the nozzles and set the spray bar height as appropriate. See figure 3–46.
   - If using a slow setting emulsion, spray approaches or intersection radii first. If using a rapid setting emulsion, spray approaches and radii after the main road.
   - Apply only as much emulsion as the chip spreader will be able to cover with a load of aggregate. Calibrate this distance by measuring the distance the chip spreader travels on one load of aggregate.
2. In general, apply the aggregate before the binder has set, usually within two to three minutes after it has been applied or before the surface has turned black.

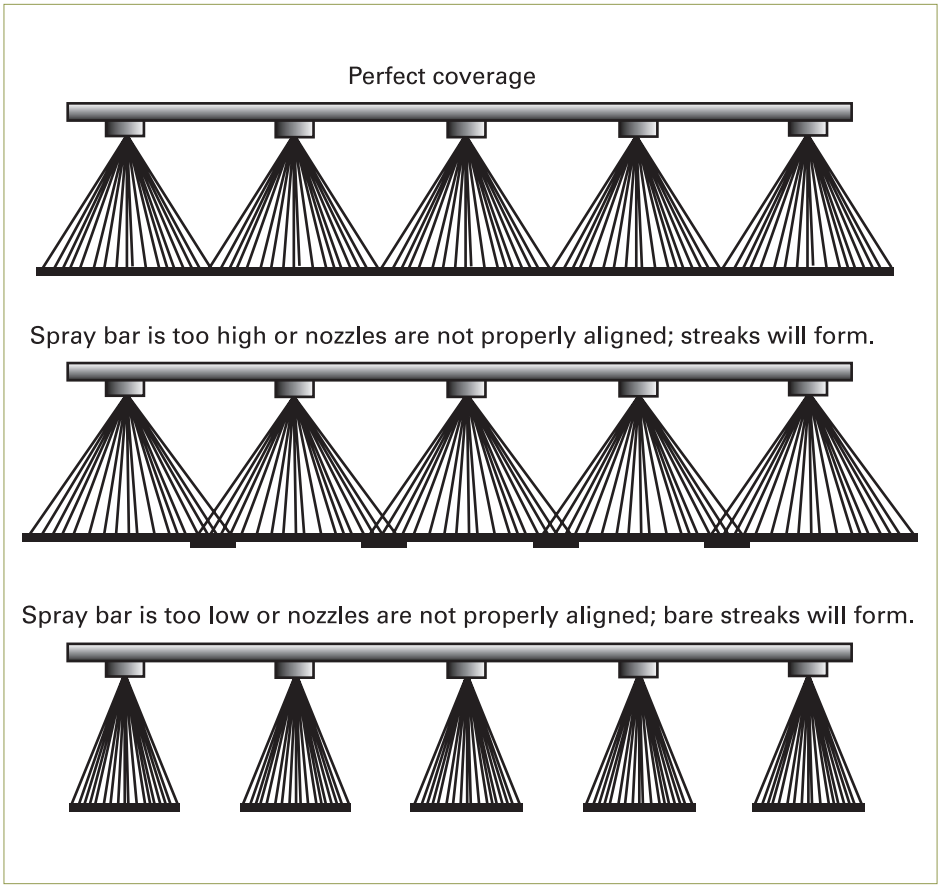


Figure 3–46. Spray bar coverage (CCEE/ISU)

Figure 3–47. Test for binder set (CCEE/ISU)

RULE OF THUMB

A simple test for making sure the binder has not set is to throw chips across the binder. If the chips bounce, the binder has set and the chips won't adhere. If the chips stick to the binder, it is time to apply the aggregate. See figure 3–47. However, if the binder begins to form a wave in front of the aggregate spreader, wait briefly for the binder to set up a little. (Binder waves cause corrugations in the seal coat.)

3. Roll the aggregate with a pneumatic tire roller closely behind the chip (aggregate) spreader. See figure 3–48.
   - Make two to four passes on a 24-foot wide roadway.
   - Do not start and stop the roller quickly. This will cause diffraction of the surface.
4. The following day, sweep up excess unbound aggregate.

Figure 3–48. Pneumatic tire roller (CCEE/ISU)

Application rates

Application rates will vary, depending on materials used and the condition of the surface. The following rates are guidelines:

Binder = 0.25–0.3 gal/yd^2. If the pavement is smooth with few voids, the application rate is less. If the pavement is rough with lots of voids, the application rate is higher. The amount of applied should be approximately 50 to 70 percent of the thickness of the aggregate.

Aggregate = 15–30 lb/yd^2. If the aggregate is not covering the binder, increase the aggregate application rate. If excess aggregate is visible, decrease the aggregate application rate. (Excessive aggregate fly rock (unbound aggregate) will be kicked up by traffic and may damage vehicles. Excessive fly rock leads to additional cleanup, dust, and haul-away costs.)

RULE OF THUMB

To check for proper binder application rate, remove a few stones that have been embedded in the binder by the pneumatic roller. About 50–70 percent of the aggregate should be covered with the binder. See figure 3–49.

If the tires on the chip spreader or roller are picking up aggregate, there's too much binder for the amount of aggregate. Check the binder application rate or increase the aggregate application rate.

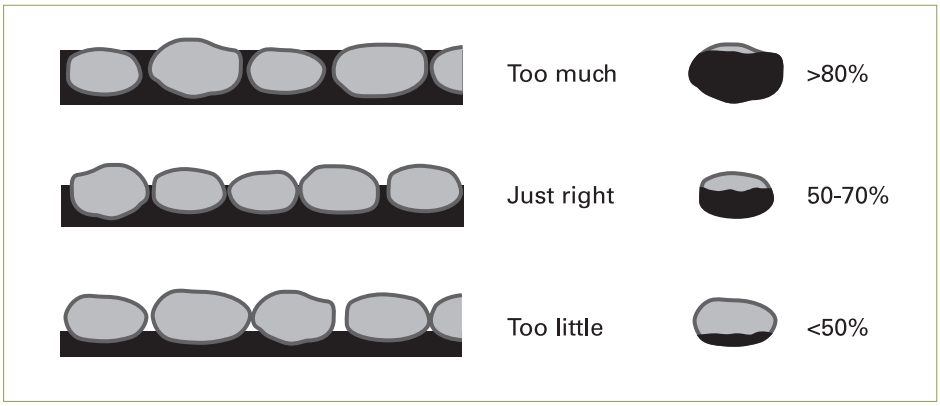


Figure 3–49. Binder application rate (CCEE/ISU)

Seal Coat Operations

The distributor truck driver ensures that

- The traffic control is in place.
- The aggregate is on site.
- The distributor truck is properly functioning with all of the nozzles properly aligned and cleaned and the spray bar at the right height.
- The pavement has been swept.
- Other equipment (chip spreader, roller, and aggregate truck) is on site and is prepared to begin construction.

During construction the distributor truck driver

- Maintains a proper distance in front of the chip spreader.
- Records the emulsion left in tank.

The chip spreader operator ensures that

- The gates are properly opened and aligned in order to apply a uniform aggregate spread.
- The belts, feeds, and augers are working properly.

During construction the chip spreader operator

- Maintains communication with the distributor truck operator.
- Tells the distributor truck operator when to stop because the chip spreader is running out of aggregate. This will prevent areas of binder from sitting too long.
- Watches the application to assure the application is consistent and there are no streaks.
- Makes sure aggregate is clean and free of debris.

The pneumatic tire roller operator ensures that the tires are at the specified air pressure, typically 45 psi or higher.

RULE OF THUMB

Everyone is responsible for quality control.

During construction the roller operator

- Checks to see if too much binder has been applied, causing the seal coat to bleed, or if not enough binder has been applied, causing the aggregate not to stick to the pavement.
- Checks to see if the proper amount of chips are applied evenly over the surface.
- Makes sure the roller is not changing directions too quickly, causing the aggregate to come unbound from the binder.

Foremen/worker ensure that

- The distributor application is consistent and not streaky.
- The chip spreader has a consistent application rate and is applying the aggregate roughly one pebble thick. If the aggregate is piling up in front of the aggregate fall, the application rate should be reduced.

Cleaning Up

1. Pick up all construction signs the next work day after the seal coat has been installed.
2. Clean the work zone and each driveway and parking area of debris.

Hot Mix Asphalt Overlay

A hot mix asphalt overlay is a new layer of asphalt over an existing asphalt pavement prepared stone base. Overlays can protect and add some strength to the existing pavement structure, reduce the rate of deterioration, and reduce deficiencies like ride quality. Overlays should not be applied to seriously distressed pavement systems.

See Safety Tips on page 34.

Preparing for a Hot Mix Asphalt Overlay

1. Grind two-inch to zero wedges at both start and stop points at the first lateral joint.
2. Lay tack paper and cold mix ramps.
3. Take special care to ensure that drainage will be maintained (e.g., bevel grind cross streets at flow lines).
4. Remove loose material and water from deteriorated areas. Clean, patch, and compact. (See Full-Depth Repair on page 46.)
5. Replace any failed areas of curb.
6. Make sure all manholes and intakes are working properly.
7. Count the number of risers and lids needed for manholes, water, gas, and monument castings. Inventory, check for fit, and place on site the day before the overlay is to be installed.

Other possible preparations:

8. Notify residents in advance when preparation work and overlay will be performed on their street.
9. Cut back low hanging limbs that equipment may break loose and that may contaminate the overlay material.

Day Before the Overlay

1. Sweep the street. Remove any grass and water in pavement cracks.
2. Telephone the asphalt plant and let them know your tonnage requirements. Keep them aware of any major breakdowns that force you to stop paving.

Placing the Hot Mix Asphalt Overlay

1. Have all traffic control and construction signs up and in place.
2. Spray the paving machine with release agent and heat the screed to operating temperature.
3. Remove cold mix ramps and paper.
4. After the street has been cleaned, apply a tack coat at the proper rate so as to avoid pushing or shoving the mat.
5. Contact the plant and have trucks loaded and dispatched to the project.
6. Identify areas where leveling courses need to be placed to fill in low spots, and pave as needed.
7. Make sure all risers and lids are in place.

8. At the beginning of the overlay section, set up the paver to run the finish course. Set the heated screed on lath to gain prior mat elevation.
9. Get all paver personnel in position with their tools.
10. Back the truck up to the paver. When contact is made, raise the truck box before the tailgate is tripped to deliver the mix to the paver hopper. This dumping procedure will cause the mix to slide against the tailgate. Upon tripping the gate, the mix will flood the hopper and reduce the amount of segregation that appears behind the screed.
11. If the truck needs to be pulled away from the paver after loading (due to incline or some other reason), before the paver starts, make sure the mix has not spilled on the street and piled up in front of the paver tracks. Remove any spills. Otherwise the paver will ride on this material, and the pavement surface will be irregular.
12. During paving, the hopper on the paving machine should be full at all times to ensure a constant flow of materials to the screed. In addition, the augers that move the mix in front of the screed should be turning most of the time so that the mix is uniform in density before compaction.
13. Compaction is accomplished with a rubber-tired roller (breakdown roller) and a steel-wheeled roller (finish roller). The rubber-tired roller provides energy to compact the mix; it should be as close as possible behind the lay-down machine but not so close that the mix is rutted or disturbed. The finish roller removes the wheel tracks left by the rubber-tired roller and should be as close as possible behind it without tearing the surface.
14. After paving and rolling operations have concluded, barricade the street to allow for cure time overnight. Notify police, fire, and transit of closure.
15. Schedule the overlay to be sand sealed at the end of the construction season.

Cleaning Up

1. Pick up all construction signs the next work day after the overlay has been installed.
2. Clean the work zone and each driveway and parking area of debris and excess asphalt.

For More Information

A series of pamphlets called Pavement Preservation Checklist Series developed by the Foundation for Pavement Preservation and the Federal Highway Administration provide useful information on the construction of seal coats and other thin maintenance surfaces. The pamphlets also define various quality control techniques for different surfaces and include quality control checklists. The pamphlets are available from the Iowa LTAP library. Contact 515-294-9481, hoganj@iastate.edu.

RULE OF THUMB

Asphalt Depth

Asphalt will densify approximately 20 percent after compaction. So if the layer being placed is to be 2 inches thick, the mix passing out from under the screed should be about 2½ inches deep to allow for compaction.

Laying Asphalt on Curb Edge

Laying asphalt on the curb edge takes more hand work than the pass down the crown of the roadway. Most driveways need a wedge placed at the opening to keep water from ponding. When constructing theses wedges, the correct amount of hot mix must be added to force water past the drive. The upper edge of the wedge should be squared off and tapped with a lute, then compacted before the mix cools.

Estimating Tonnage

On the final finish course pass, the supervisor needs to be aware of the tonnage going through the paver and the distance the paver travels per load. This will help in estimating the tonnage of the last truck load for the project.

Concrete Pavements

Safety Tips for Maintaining Concrete Surfaces

Always check with your supervisor and follow your agency's safety policies and procedures.

Suggested personal safety gear

- Hard hat
- Safety glasses with side shields to protect eyes
- Ear plugs or muffs (for use around jack hammers or other noisy equipment)
- Protective gloves for handling fresh concrete, to avoid skin irritation
- Heavy boots with hard-toe protection
- Rubber boots if you'll be standing in fresh concrete
- Highly visible apparel

Advance preparations

- Be properly trained and familiar with all equipment.
- Make sure an up-to-date first-aid kit, emergency contact information, and hand-held radios or cell phones are available at the work site.
- Be trained in avoiding heat-related illnesses, like heat exhaustion.

During operations

- If road is open to traffic use proper temporary traffic control, including flaggers if needed, as described in the *Iowa Traffic Control Devices and Pavement Markings: A Manual for Cities and Counties; in the MUTCD,* part 6; and in your agency's policies and procedures.
- Wear highly visible apparel when not in a vehicle.
- Do not park vehicles and equipment on both sides of the road.
- Be aware of and take steps to avoid heat-related problems like heat stress and exhaustion.
- Use proper lifting techniques or request assistance to lift heavy objects.
- Workers on foot should always be aware of backing equipment.
- Workers should be provided periodic breaks and rest room accommodations.
- If you are filling cracks and joints on concrete pavement, also refer to safety tips for asphalt.
- Remove all temporary traffic control immediately when no longer needed.

Traditional maintenance treatments for portland cement concrete (PCC, or simply concrete) pavements include routine sweeping and cleaning, joint and crack sealing, temporary (asphalt) repair, joint repair, mud jacking, and surface and full-depth repairs.

Characteristics of a Well-Maintained Concrete Pavement

- The roadway cross slope provides effective drainage.
- There are no unsealed cracks or unsealed joints.
- Little to no standing water follows rain and/or ice melt.
- Adjacent concrete sections settle evenly.

Optimum Timing/Conditions

The timing for full- or partial-depth patching depends on the condition of the subgrade that the concrete will be placed on and the temperature. Patching should not be conducted when air temperature is below freezing. If the newly placed concrete is frozen, it will lose its strength. See winter on the following page. The subgrade cannot be saturated or frozen, and it must be compacted and within moisture tolerances.

Some counties have guidelines for allowable moisture content and air and ground temperatures for placing concrete pavement. Check with your supervisor.

If properly protected from the elements, concrete can be placed in most environmental conditions.

Figure 3–50. Well-maintained concrete road (ICPA)

RULE OF THUMB

Concrete should never be placed on frozen or saturated subgrade. It should never be placed in weather conditions that would allow it to freeze.

Spring/Summer/Fall

Most types of concrete maintenance treatments can be placed during the spring, summer, or fall. Conditions for maintenance vary according to the treatment type, subgrade type, and subgrade conditions.

Winter

Concrete patching can be done in the winter. Fresh concrete needs to be protected from frost and freezing until it gains the required strength. Practically speaking, this means that the subgrade and the concrete adjacent to the patch must not be frozen. If the air temperature is expected to fall below 40°F in the 72 hours following paving, the American Concrete Pavement Association recommends covering the new pavement with insulating blankets, mats, or foam sheets.

Concrete Distresses

Cracks

Cracks develop or expand over time due to temperature changes that cause expansion and contraction. Some cracks are part of the construction process (e.g., cracks that form at joints), and some develop randomly as the pavement is stressed.

Cracks allow water to infiltrate the pavement base and subbase, potentially decreasing the pavement's load-carrying capacity. If not repaired or prevented, this cracking effect will grow, leading to deformation of the pavement and ultimately the degradation of the pavement surface.

Cracks that develop because of pavement stresses include transverse cracks, longitudinal cracks, D cracks, and map cracking.

Transverse Cracks

Transverse cracks run across the pavement, perpendicular to the shoulder. See figure 3–51.

Figure 3–51. High-severity transverse cracks (FHWA)

Longitudinal Cracks

Longitudinal cracks run parallel to the shoulder. See figure 3–52.

D Cracks

D cracking occurs at slab corners where longitudinal and transverse joints intersect. The failure is due to poor quality aggregate in the original concrete mixture. See figure 3–53.

Map Cracking

Map cracking is a pattern of interconnected random cracks that indicate failure in the subbase. See figure 3–54.

Figure 3–52. High-severity longitudinal cracks (FHWA)

Figure 3–53. High-severity D cracks (FHWA)

Figure 3–54. Map cracking (FHWA)

Joint Deterioration/Spalling

Joints are sawed in new pavement to induce cracking at desired locations. This helps relieve stresses and prevents random cracking. Joint deterioration like spalling is caused when water and debris fill the joint space, putting pressure on the concrete. See figure 3–55.

Blowups

Blowups are the upward movement of the pavement surface at transverse joints or cracks, generally during hot weather. They are generally caused by a buildup of pressure in the pavement, which causes the panels on each side of a joint to rise.

Blowups can be quick and violent. The concrete surrounding a blowup is often shattered, and pavement pieces may be thrown several feet. See figure 3–56.

Scaling

Scaling is the deterioration of the upper concrete slab surface, normally ⅛- to ½-inch deep, and may occur anywhere on the pavement. It may be caused by deicing chemicals or by inadequate application of curing compound. See figure 3–57.

Figure 3–55. Spalling (FHWA)

Figure 3–56. Blowup (FHWA)

Figure 3–57. Scaling (FHWA)

Pavement Settlement

Slabs sometimes settle, particularly bridge approach panels. A slab with tilted or uneven panels may indicate that subbase materials have migrated from beneath the slab.

Faulting

Faulting is a difference in elevation across a joint or crack. This is caused by the settlement of one or both of the slabs or by rocking of the slabs as traffic moves across the joint or crack. See figure 3–58.

Pumping

Pumping is the seeping or ejection of water and subbase from beneath the pavement through cracks. In some cases, detectable deposits of fine material eroded (pumped) from the support layers are left on the pavement or shoulder surface and stain the surface.

Corner Breaks

A corner portion of the slab may separate from the slab along a crack that intersects the adjacent transverse and longitudinal joints at an approximately 45-degree angle. The length of the sides varies and may extend up to one-half the width of the slab on each side of the corner. See figure 3–59.

Pavement Failure

A pavement is considered to have failed when the deterioration of the pavement becomes so severe that the only option for repair is to remove and replace the slab.

Figure 3–58. Faulting (FHWA)

Figure 3–59. Corner break (FHWA)

Maintenance Activities

Maintenance activities include routine maintenance, temporary repairs, joint repairs, joint and crack sealing, mud jacking, surface patching, and full-depth patching. See table 3–2.

Routine Maintenance

The goal of routine maintenance is to prevent or delay pavement distresses. Routine maintenance generally includes regular street sweeping and joint/crack sealing. Check with your supervisor, and follow your local policy.

Street Sweeping

Sweeping removes dried, caked mud, abrasives, and other debris from the road surface. See figure 3–60. Clean road surfaces help keep drains clean and make travel safer for bicyclists. See HMA comment for drainage.

Joint/Crack Sealing

Joints in concrete pavement are usually sealed during the construction process. Periodically, they will need to be cleaned and resealed to keep them free of water and sediment and to protect the subgrade from water intrusion. Random cracks, too, may need to be sealed or resealed. The following instructions apply to both joints and random cracks in concrete pavements.

The work will generally be done on an as-needed basis. It is usually completed in the spring or fall when temperatures are moderately cool and the joints are open.

The following instructions are general guidelines. For example, you may or may not be instructed to use backer rods. Check with your supervisor, and follow your local policy.

Table 3–2. Distresses and Maintenance Activities for Concrete Pavements

Distresses	Maintenance Activities					
	Routine Maintenance					
	Joint/Crack Sealing	Surface Patching	Temporary Repair	Joint Repair	Mud Jacking	Full-Depth Repair
Cracks	X					X
Joint Deterioration/Spalling	X			X		X
Blowups			X			X
Scaling		X	X			
Pavement Settlement			X		X	
Faulting			X		X	
Pumping				X		
Corner Breaks				X		X
Pavement Failure						X

Preparing for Joint/Crack Filling

1. Rout or saw-cut joints to remove existing sealant and other materials and to provide clean, uniform surfaces for filler to adhere to and a reservoir for sealant. Rout joints to a width of ⅜ to ½ inch and a depth of ¾ to 1 inch, per your supervisor's instructions. See figure 3–61.
2. In some agencies, you may then be instructed to sandblast the joints.
3. Use an air compressor and an air wand to clean joints of dirt, dust, and remnants from sawing/routing and sandblasting. Contamination in a joint will cause poor sealant bonding. See figure 3–62.

SAFETY

See Safety Tips on page 56.

RULE OF THUMB

For the sealant to adhere adequately, the surfaces of the joint must be completely clean and dry. Run your finger along the joint wall to test for cleanliness and dryness.

Figure 3–60. Street sweeper (WDM)

Figure 3–61. Routing cracks (WDM)

Figure 3–62. Cleaning joints before applying sealant (WDM)

Applying the sealant

After all joints are clean, finish the process (see figure 3–63):

1. If using backer rods in joints, place the rod to the proper depth to ensure the correct shape of the sealant reservoir. On road surfaces where grinding is planned at a later date, the backer rod and sealant should be installed so that the sealant is approximately ¼ inch below the road surface after grinding is complete.
2. Apply sealant according to specifications and the manufacturer's recommendations. The joint will be filled with a concave (∪) bead. The shape factor generally ranges from 1:2 to 2:1, depending mainly on the elasticity of the sealant material. Be guided by the type of material and its specifications on determining the proper shape factor.

SAFETY

See Safety Tips on page 56.

Temporary (Asphalt) Repair

For areas experiencing scaling, faulting, pumping, or blowups, a temporary repair using asphalt may be appropriate:

1. Blow out joints with compressed air.
2. Remove broken concrete and square up the sides of the area.
3. Apply a tack coat.
4. Place an asphalt wedge and compact it.

Joint Repair

For corner breaks, spalling, and D cracking, repair the area using a concrete mix:

1. Saw cut, break out, and remove loose material, leaving the faces of the removal vertical. A cutting torch or saw may be necessary for cutting pavement reinforcement. Normally the steel network is not reestablished.
2. Clean the hole with compressed air to remove moisture and debris.
3. Fill the hole with concrete mix, normally delivered by a ready-mix operation.
4. Consolidate the mix with a vibrator.

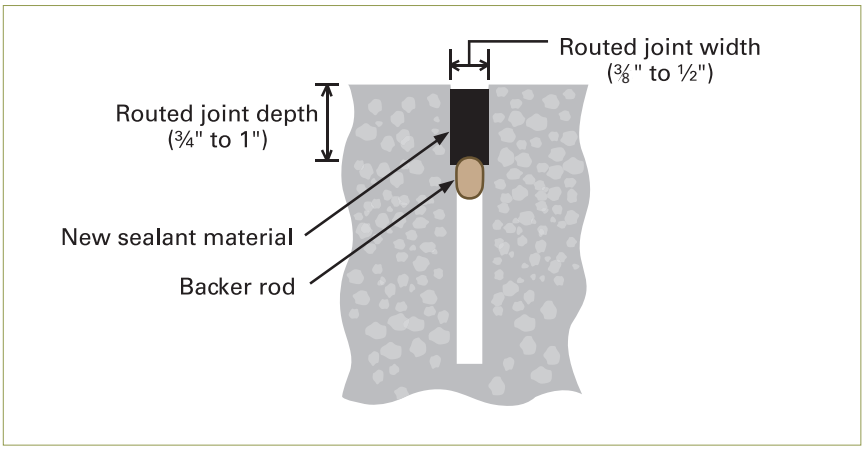


Figure 3–63. Joint with backer rod and filler

5. Screed and finish the surface, but do not add free water. (Adding free water to the surface dilutes the cement paste, and the surface is likely to scale off in the near future.)
6. Cure the concrete by covering with plastic, wet burlap, or a liquid curing compound. The burlap should be kept wet until the initial concrete strength is developed.

Mud Jacking

Mud jacking raises and adjusts a slab that has settled. Workable material is forced through holes drilled in the concrete slab. The material exerts sufficient pressure on the lower side of the slab to raise it before the material has traveled beyond the desired area.

1. Examine the site and determine low spots by using line or elevation levels as appropriate. Look for the points of water intrusion into the pavement and where the subbase material has been deposited.
2. Drill approximately 2-inch diameter core holes through the concrete slab at selected locations, or use preformed holes or previously drilled holes as appropriate.
3. Starting at the downhill portion of the void and working up, begin pumping the mud jack mix into the predrilled holes. As the mixture raises the slab to the desired elevation or the void fills to capacity, move uphill to the next set of drill holes. It's important to lift the slab uniformly to avoid cracking it.
4. Plug each hole temporarily once the hose is removed. Use a plastic plug or a burlap bag until the mixture has cured.
5. After the entire slab area has been adjusted to grade, clean out each hole and refill with a fast-setting cement grout.
6. Reseal any cracks and joints.

See Safety Tips on page 56.

Blowup Repair

Blowups often occur at the end of the day, and a temporary asphalt patch may be initially applied. Later a crew will return and perform a full-depth patch. When the permanent repairs are made, it is important that room be left for future pavement expansion or there will likely be another blowup at the same location.

Iowa One Call: It's the Law

Iowa law requires that anyone planning any form of excavation must contact the Iowa One Call notification system (1-800-292-8989) at least 48 hours in advance so that utilities can be located and marked. Always consult your supervisor before conducting any excavation, which may include mudjacking and full-depth repair.

Surface Patching

Apply a surface patch to repair corner breaks, scaling, D cracking, and construction joint deterioration where the depth of deterioration is no more than 25 percent of the total pavement thickness. See figure 3–64.

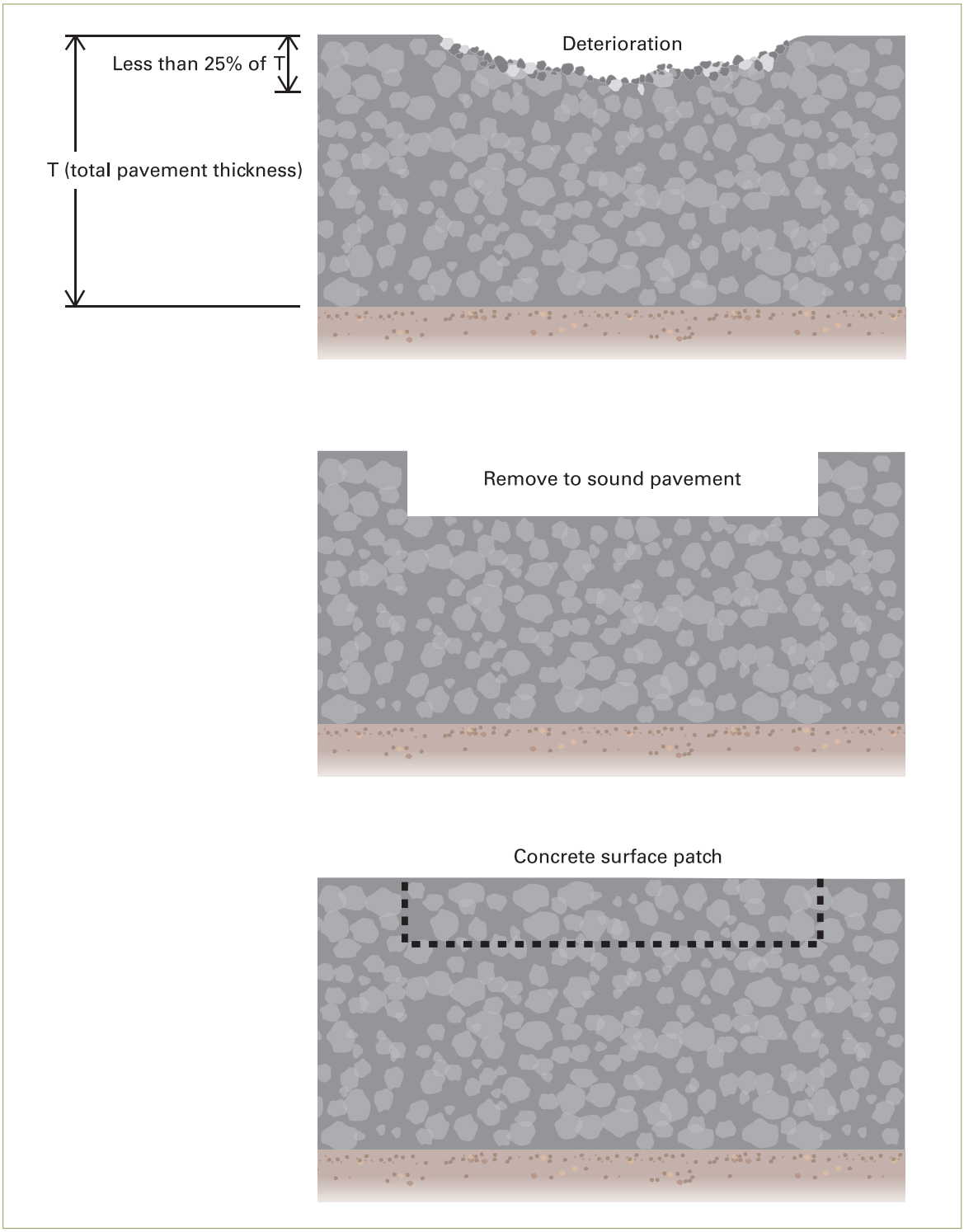


Figure 3–64. Concrete surface patching

1. Mark the area to be patched two to three inches outside the damaged area.
2. Remove surface concrete with light- to medium-weight hammers to avoid damaging the sound concrete on the bottom layer of the pavement slab.
3. Sandblast exposed concrete and clean the area with compressed air.
4. For other than pre-cast, place a form for reestablishing the shoulder edge.
5. In reinforced pavement (except for pre-cast repair) reestablish the reinforcement by overlapping and tying or welding with either a double-face 4-inch weld or a single-face 8-inch weld.
6. Brush in cement or epoxy grout.
7. Place low-slump concrete with adequate mechanical vibratory screeds.
8. Texture and cure the concrete.
9. Apply a double application of white pigmented curing compound.

See Safety Tips on page 56.

RULE OF THUMB

If deterioration is 25 percent or less of the total pavement thickness, apply a surface patch.

If deterioration is more than 25 percent of the total pavement thickness, apply a full-depth repair.

Full-Depth Repair

Apply a full-depth repair for corner breaks, scaling, D cracking, construction joint deterioration, and localized distresses where the depth of the deterioration is greater than 25 percent of the total pavement thickness or covers a large area. See figure 3–65.

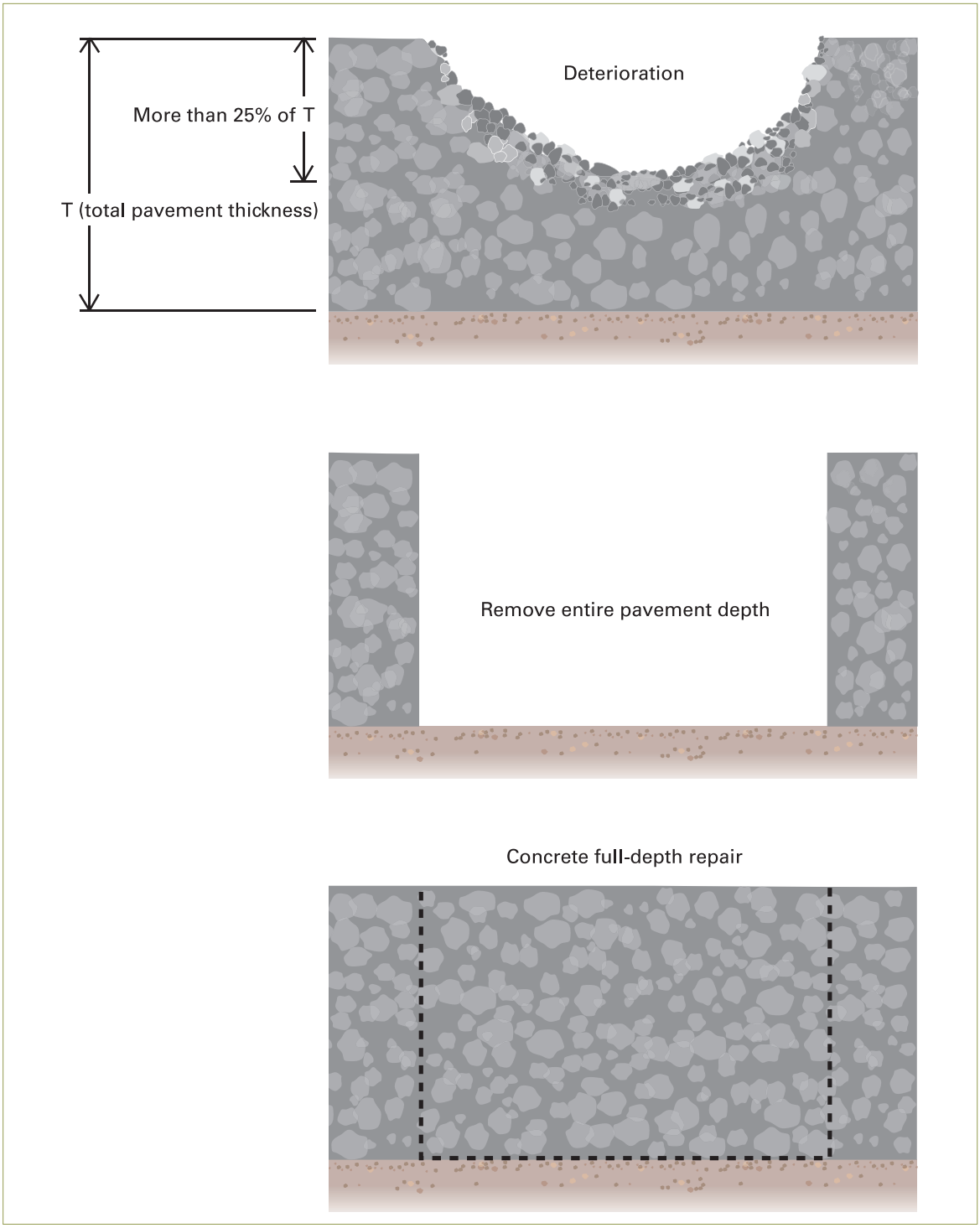


Figure 3–65. Concrete full-depth repair

1. Mark the area to be patched two to three inches outside the damaged area.
2. Saw cut and remove full depth of concrete slab without damaging adjacent concrete. See figure 3–66.
3. Remove any unsound base or subbase. If a pre-cast slab is to be used, the base or subbase needs to be restored and compacted. If a serious drainage problem exists, it should be corrected as with transverse, lateral subdrain, etc.
4. Other than pre-cast, place a form for reestablishing shoulder edge.
5. Sandblast exposed concrete and clean area with compressed air.
6. Use coated dowel bars and deformed rebars for load transfer in all full-depth repairs.
7. Place low-slump concrete with adequate mechanical vibratory screeds. See figure 3–67.
8. Texture and cure the concrete.

Figure 3–66. Removing full depth of slab (WDM)

Figure 3–67. Vibratory screed (WDM)

SAFETY

See Safety Tips on page 56.

BIBLIOGRAPHY

American Association of State Highway and Transportation Officials (AASHTO). 1997. *Highway Safety Design and Operations Guide.* Washington, DC: American Association of State Highway and Transportation Officials.

Andrle, S.J., K. Knapp, T.J. McDonald, and D.E. Smith. 2001. *Iowa Traffic Control Devices and Pavement Markings: A Manual for Cities and Counties.* Iowa DOT Project TR-441. Ames, IA: Center for Transportation Research and Education.

Bolander, P. and A. Yamada. 1999. *Dust Palliative Selection and Application Guide.* Final Report. 9977-1207-SDTDC. San Dimas, CA: United States Department of Agriculture, Forest Service, San Dimas Technology and Development Center.

Federal Highway Administration (FHWA). 2003. *Manual on Uniform Traffic Control Devices (MUTCD) for Streets and Highways.* 3rd Ed. Washington, DC: United States Department of Transportation, Federal Highway Administration.

Iowa One Call (IOC). 2006. Iowa One Call Home. http://iowaonecall.com/index.php.

Lunsford, G.B. and J.P. Mahoney. 2001. *Dust Control on Low Volume Roads: A Review of Techniques and Chemicals Used.* Final Report. FHWA LT-01-002. Washington, DC: United States Department of Transportation, Federal Highway Administration, Local Technical Assistance Program.

Miller, J.S. and W.Y. Bellinger. 2003. *Distress Identification Manual for Long-Term Pavement Performance.* 4th Ed. FHWA-RD-03-031. Washington, DC: Federal Highway Administration.

Skorseth, K. and A.A. Selim. 2000. *Gravel Roads Maintenance and Design Manual.* Washington, DC: Federal Highway Administration and South Dakota Local Transportation Assistance Program.

Transportation Research Board (TRB). 1991. *Hot-Mix Asphalt Paving Handbook.* Washington, DC: Transportation Research Board.

Walker, D. 1989. *Concrete PASER (Pavement Surface Evaluation and Rating) Manual.* Madison, WI: Wisconsin Transportation Information Center.

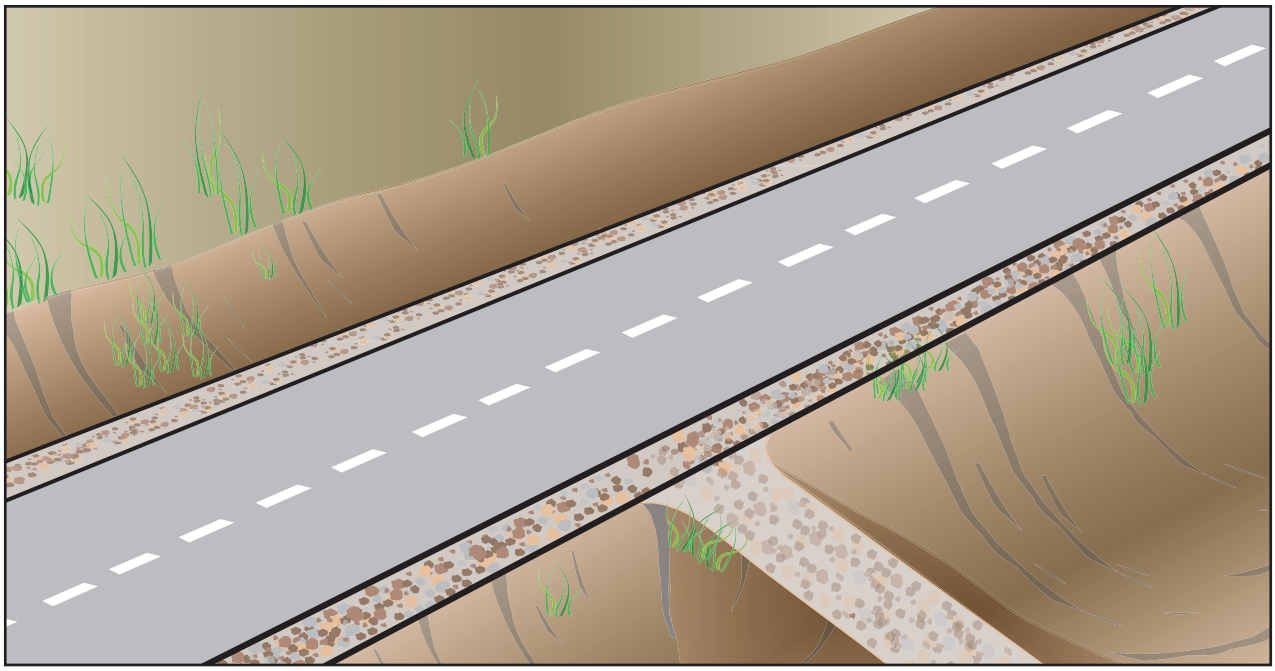
Walker, D. 1989. *Gravel PASER (Pavement Surface Evaluation and Rating) Manual.* Madison, WI: Wisconsin Transportation Information Center.

Walker, D. 2001. *Sealcoat PASER (Pavement Surface Evaluation and Rating) Manual.* Madison, WI: Wisconsin Transportation Information Center.

Walker, D. 2001. *Unimproved Roads PASER (Pavement Surface Evaluation and Rating) Manual.* Madison, WI: Wisconsin Transportation Information Center.

Walker, D. 2002. *Asphalt PASER (Pavement Surface Evaluation and Rating) Manual.* Madison, WI: Wisconsin Transportation Information Center.

Chapter 4:
Shoulders



chapter contents

Characteristics of Well-Maintained Shoulders 73

Optimal Timing/Conditions for Maintenance 73

Shoulder Maintenance Issues 74

Shoulder Maintenance Activities 75

- Repairing Edge Drop-Off, Erosion, and Secondary Ditches 75
- Repairing High Shoulders 75
- Mowing 75
- Managing Obstacles in the Clear Zone 76

Safety Tips for Maintaining Shoulders

Always check with your supervisor and follow your agency's safety policies and procedures.

Suggested personal safety equipment

- Highly visible apparel

Advance preparations

- Be properly trained and familiar with equipment.
- Make sure an up-to-date first-aid kit, emergency contact information, and hand-held radios or cell phones are available at the work site.
- Be sure all work vehicles have approved and activated warning lights.

During operations

- Use temporary traffic control, including flagger(s) if needed, as described in the *Iowa Traffic Control Devices and Pavement Markings: A Manual for Cities and Counties; in the MUTCD,* part 6; and in your agency's policies and procedures.
- Check sight distance for approaching traffic before starting work and adjust advance warning signs as needed.
- Wear highly visible apparel when out of your vehicle.
- Do not park vehicles and equipment on both sides of the roadway.
- Do not back equipment into traffic lanes without a spotter.
- Keep open roadway clear of loose aggregate and other debris.
- Do not leave edge drop-offs unprotected overnight.
- Remove all temporary traffic control immediately when no longer needed.

Shoulders are adjacent to the roadway and are considered an extension of the roadway. Shoulders serve several purposes. They

- Provide lateral support for the roadway.
- Expedite surface runoff from the roadway.
- Provide space for maintenance and construction equipment and activities.
- Provide a safe area for vehicles that accidentally leave the roadway and, in emergencies, accommodate slow-moving or stopped vehicles.
- Accommodate bicycles.

Shoulders may be the same material as the roadway but not necessarily. Shoulders are earth, granular, or paved with asphalt or concrete.

Note: Shoulders on minimum maintenance and granular surfaced roads are discussed in those sections in chapter 3.

RULE OF THUMB

To properly drain water, shoulders should meet flush with the driving surface and slope slightly away from the driving surface.

In general, shoulders narrower than eight feet should slope about ¾ inch per foot, and shoulders wider than eight feet should slope about ½ inch per foot. This amount of slope allows water to flow away from the roadway but not fast enough to cause erosion.

Characteristics of Well-Maintained Shoulders

In general, a well-maintained shoulder is flush with the roadway driving surface (that is, it is not higher or lower than the adjacent roadway), slopes slightly away from the driving surface, and has no erosion problems. See figure 4–1.

Many agencies generally consider an edge drop-off (between the shoulder and driving surface) greater than two inches to be excessive. Consult your supervisor and follow your agency's policy.

Optimal Timing/Conditions for Maintenance

As with the roadway itself, the optimal timing and conditions for maintaining shoulders depend on whether the shoulder is gravel, asphalt, or concrete. Consult the appropriate sections in chapter 3.

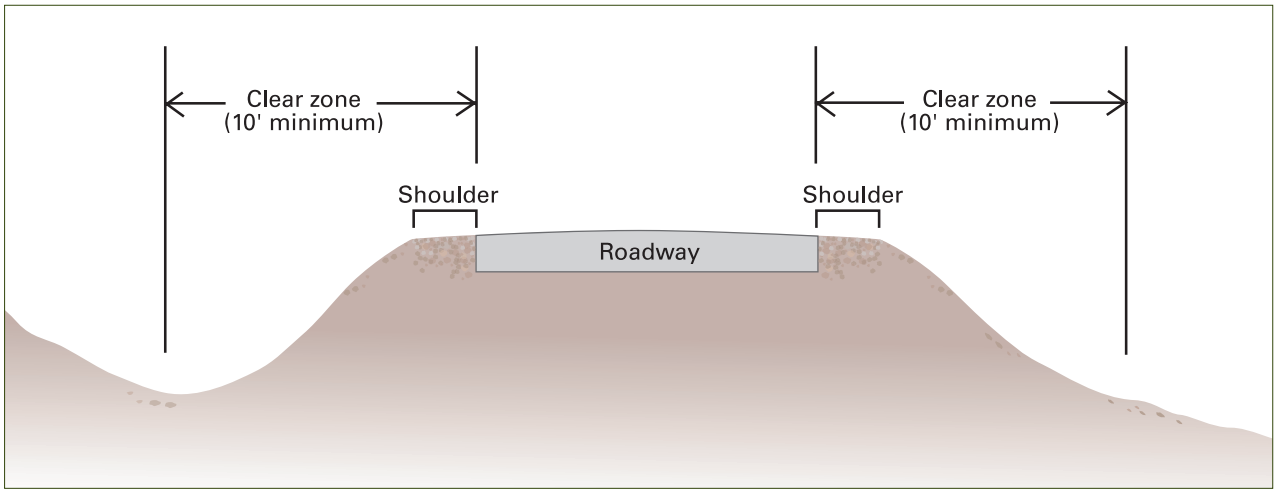


Figure 4–1. Well-maintained shoulders

Shoulder Maintenance Issues

In general, shoulders experience the same maintenance issues, and require the same maintenance activities, as do roadways made of the same material. See chapter 3 for specific information about maintaining various roadway surfaces.

The following deficiencies are specific to shoulders:

- Low shoulders, or shoulder (edge) drop-off. See figure 4–2. Drop-offs create a safety hazard to drivers and allow water to penetrate into the subgrade. Drop-offs are among the top accident-related conditions and a common source for tort claims against agencies that maintain roadways.

  Most edge drop-offs result from poor drainage, erosion of uncompacted shoulder materials (when the shoulder is earth or gravel), or settlement (when the shoulder is paved with asphalt or concrete).
- High shoulders. High shoulders create a safety hazard to drivers and restrict drainage away from the roadway. Earth shoulders that were originally flush with the adjacent roadway may, over time, become too high. Vegetation in the shoulder collects sediment and gradually breaks down, raising the level of the earth.
- Erosion. Shoulder erosion can cause (and may be caused by) poor drainage. Earth or gravel shoulders with steep slopes may be particularly prone to erosion.
- Vegetation. When vegetation is allowed to grow on earth shoulders, it can inhibit drainage, create secondary ditches, cause snow to drift, and create unsafe conditions for vehicles that leave the roadway.
- Secondary ditches. Secondary ditches can form in shoulders from excessive throw-off of material from gravel roads, when heavy vehicles travel near or on the shoulder, or when there is a lack of proper shoulder maintenance. Secondary ditches can cause many roadway problems that may result in the need to rebuild the roadway. See chapter 5.
- Fixed-object improvements within the clear zone. Such objects can be safety hazards.

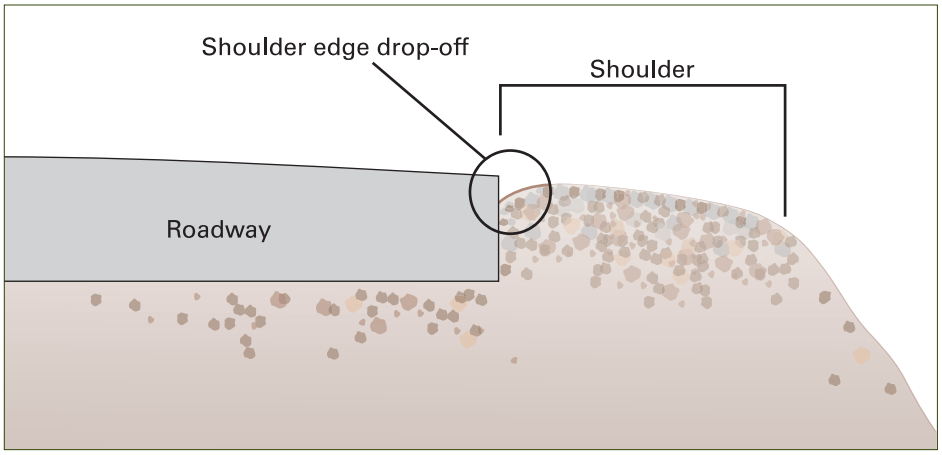


Figure 4–2. Shoulder edge drop-off

Driveways provide access from the roadway to adjacent land uses. Be aware of the area where the driveway interconnects with the shoulder. Be careful that maintenance operations do not negatively impact adjacent property owners. Figure 4–3 shows the proper drainage point for a driveway.

Shoulder Maintenance Activities

Repairing Edge Drop-Off, Erosion, and Secondary Ditches

Refill, reshape, and compact earth and gravel shoulders in accordance with the original design (figure 4–4). Paved shoulders, either concrete or asphalt, will need to have a fillet placed next to the roadway where the edge drop is excessive. Asphalt is most commonly used material for this activity.

Repairing High Shoulders

Shoulders higher than the adjacent pavement should be reshaped and compacted. If vegetation in the shoulder is part of the problem, use a mechanical mixer to break up roots and follow with blading.

Mowing

Mow earth shoulders regularly. Consult your supervisor, and follow your agency's policies and procedures.

Beware of Methamphetamine Trash

Shoulder-mowing crews should be alert for abandoned materials from methamphetamine-manufacturing labs. These hazardous materials require special handling. Consult your supervisor, and follow your agency's policy.

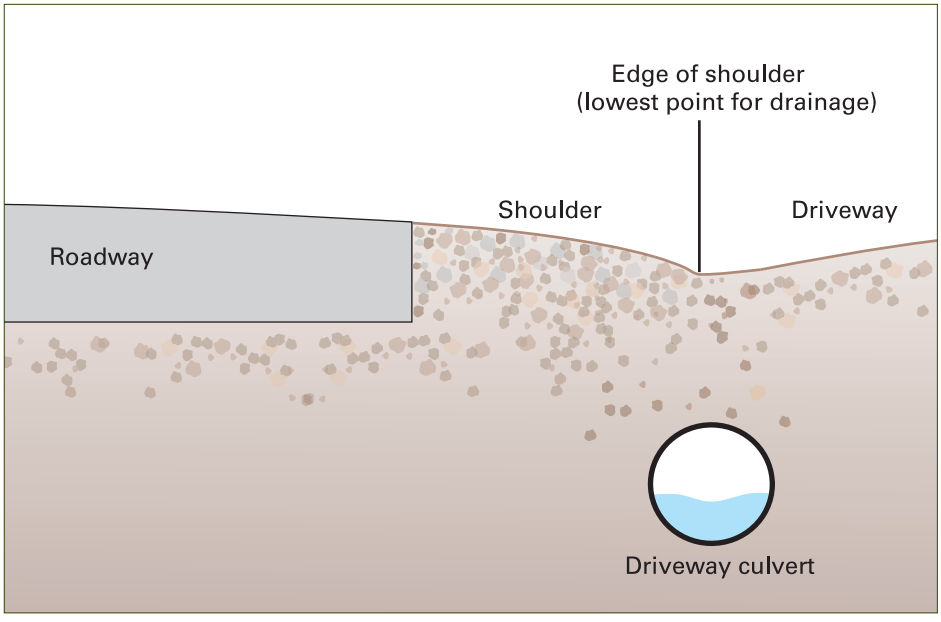


Figure 4–3. Drainge point for driveways

RULE OF THUMB

When dealing with fixed-object improvements in the shoulder, the appropriate treatment is generally to remove, relocate, retrofit, shield, or delineate, in this priority order. Consult your supervisor, and follow your agency's policy.

Managing Obstacles in the Clear Zone

Agencies must manage fixed-object improvements (like fences, utility poles, or culvert headwalls) located on the shoulder and within the clear zone. The goal is to eliminate collision hazards. If you see fixed objects in the clear zone, notify your supervisor.

Figure 4–4. Repairing edge drop-off (LTAP-IN)

BIBLIOGRAPHY

American Association of State Highway and Transportation Officials (AASHTO). 1997. *Highway Safety Design and Operations Guide.* Washington, DC: American Association of State Highway and Transportation Officials.

Andrle, S.J., K. Knapp, T.J. McDonald, and D.E. Smith. 2001. *Iowa Traffic Control Devices and Pavement Markings: A Manual for Cities and Counties.* Iowa DOT Project TR-441. Ames, IA: Center for Transportation Research and Education.

Federal Highway Administration (FHWA). 2003. *Manual on Uniform Traffic Control Devices (MUTCD) for Streets and Highways.* 3rd Ed. Washington, DC: United States Department of Transportation, Federal Highway Administration.

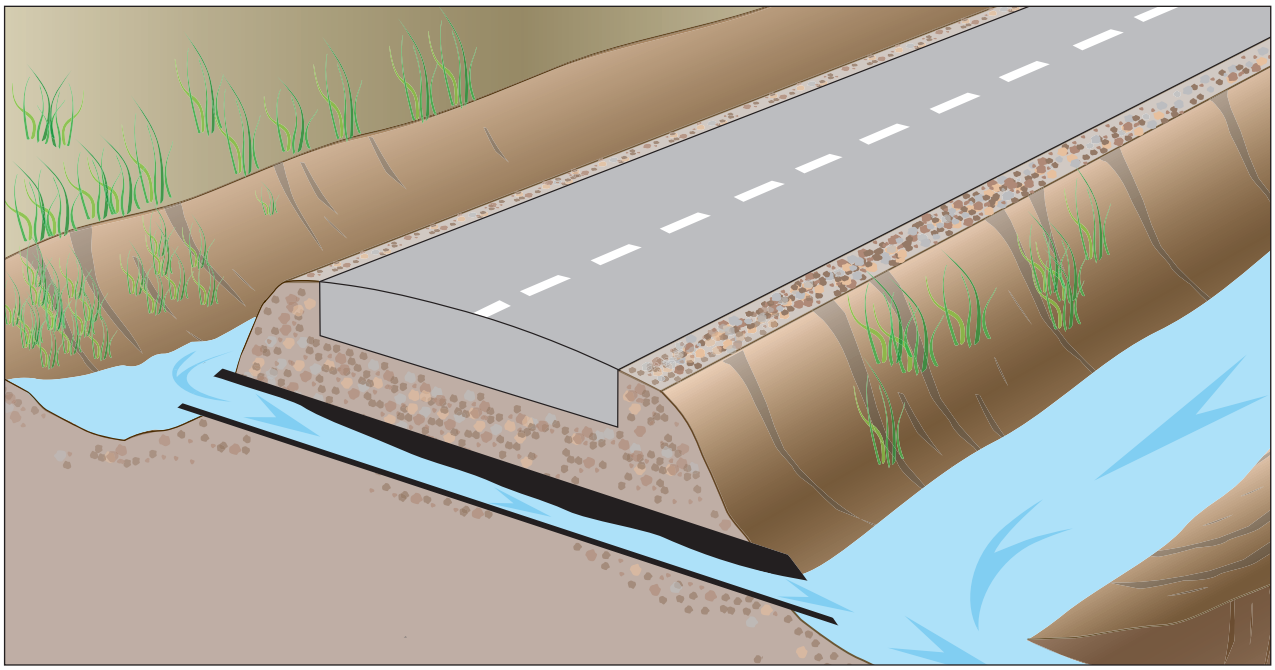
Hallmark, S.L., T.J. McDonald, D. Veneziano, J.L. Graham, K.M. Bauer, R. Patel, and F.M. Council. 2006. *Safety Impacts of Pavement Edge Drop-Offs.* Washington, DC: AAA Foundation for Traffic Safety.

Iowa One Call (IOC). 2006. Iowa One Call Home. http://iowaonecall.com/index.php.

Kannel, E. and T.J. McDonald. 2002. *Traffic Control Strategies in Work Zones with Edge Drop-Offs.* Final Report. CTRE Project 97-15. Ames, IA: Center for Transportation Research and Education.

Souleyrette, R., T.J. McDonald, Z. Hans, A. Kamyab, T. Welch. 2001. *Paved Shoulders on Primary Highways in Iowa: An Analysis of Shoulder Surfacing Criteria, Costs, and Benefits.* Final Report. Ames, IA: Center for Transportation Research and Education.

Chapter 5:
Drainage, Ditches, and Culverts



chapter contents

Characteristics of Good Drainage 82

Elements of Good Surface Drainage 82
- Crown 82
- Shoulders 82
- Slope 82
- Ditches 83
- Culverts 83
- Inlets 83

Elements of Good Subsurface Drainage 83
- Granular Drainage Layer 83
- Under Drains/Edge Drains 83

Optimal Timing/Conditions for Maintenance 84

Drainage Maintenance Activities 84
- Surface Drainage Maintenance Activities 85
- Subsurface Drainage Maintenance Activities 86
- Urban Drainage Systems 86
- Rural Culverts 88

Drainage Laws 91

Safety Tips for Maintaining Drainage, Ditches, and Culverts

Always check with your supervisor and follow your agency's safety policies and procedures.

Suggested personal safety equipment

- Hard hat
- Safety glasses
- Heavy gloves
- Hard-toed boots
- Highly visible apparel

Advance preparations

- Be properly trained in principles of excavation safety and be thoroughly familiar with equipment.
- Make sure an up-to-date first-aid kit, emergency contact information, and hand-held radios or cell phones are available at the work site.

During operations

- If road is open to traffic use proper temporary traffic control, including flagger(s) if needed, as described in the *Iowa Traffic Control Devices and Pavement Markings: A Manual for Cities and Counties; in the MUTCD,* part 6; and in your agency's policies and procedures.
- Wear highly visible apparel when out of your vehicle.
- When excavating, make sure a competent person trained in excavation safety is available at the work site.
- Do not enter a trench or excavation over four feet deep without proper shoring and/or sloping.
- Remove all temporary traffic control immediately when no longer needed.

There's an old saying that the three most important elements in road maintenance are drainage, drainage, and drainage.

Water on or under the roadway is the single most significant cause of damage to the roadway. Problems related to water include rutting, cracking, potholes, erosion, washouts, heaving, flooding, and premature failure of the roadway.

To prevent these problems and help ensure a roadway achieves its designed service life, you need to do three things:

- Get water off the road.
- Get water out of the road.
- Get water away from the road.

The solution: a good drainage system. Such a system includes several elements, all of which must function properly and be well maintained:

1. Surface drainage (crown, shoulders, foreslope and backslope, and ditches). See figure 5–1.
2. Subsurface drainage (pavement drainage layer, under drains/edge drains).
3. Inlet drainage structures (primarily in urban areas).
4. Culverts (primarily in rural areas).

Figure 5–1. Ditch with good drainage

Characteristics of Good Drainage

A successful drainage system will drain water away from the road in an adequate amount of time, as shown in table 5-1.

Elements of Good Surface Drainage

Crown

A road's crown should have sufficient slope from the pavement centerline to the edge to make sure water will effectively drain off the roadway surface. When the slope is too flat, water can pond on the surface and migrate through joints and cracks into the pavement or under the surface. This can lead to pavement cracking and potholes. Water that doesn't drain off the roadway can also present a safety hazard to motorists by introducing the possibility of hydroplaning.

Maintenance workers can affect the crown on gravel roads only. In general, a crown between four and six percent is adequate for gravel roads. See chapter 3.

Shoulders

To aid in drainage, shoulders should be flush with the adjacent roadway, slope slightly away from the roadway, and have no erosion problems or secondary ditches. Earth shoulders should be mowed in accordance with local agency policies and procedures. See chapter 4.

Slope

Slopes are normally referred to by the ratio of the run to the rise. For example a 4:1 slope is four feet horizontal distance to one foot vertical distance (run to the rise).

The degree of foreslope and backslope is determined by design standards (e.g., AASHTO's Green Book and Iowa DOT's design guide) and local conditions (e.g., cohesive soils, or rights of way). Local conditions may require that slopes be designed and constructed steeper or flatter than the design guides suggest.

Whatever slope has been designed and constructed should be maintained at the same ratio of run to the rise.

Table 5–1. Quality of Drainage Determined by Dissipation Time

Drainage Quality	Time for 50% Dissipation
Excellent	2 hours
Good	1 day
Fair	1 week
Poor	1 month
Very poor	(Water will not drain)

Ditches

Ditches collect runoff from the road surface. A well-maintained, smooth-flowing ditch will be free of heavy vegetation (tall grass, trees, cattails, etc.) and standing water, with enough grade to ensure self-cleaning and continuous flow. (Ditches with flat percent-of-grade allow residue or debris to settle and fill in the ditch. If sediment accumulates, water may erode a new path outside of the ditch area.)

Culverts

Culverts are well maintained when the flow line and the design slope from inlet to outlet still exist. No sections have settled, and all joints are tight and not separated. The curtain walls are not exposed, and the downstream channel has not started to erode.

Inlets

In well-maintained inlets, the inlet structures are straight and true, marking devices are in place and visible, and the surrounding pavement and joints are sound and water tight. The inlets are free of debris and silting, and the adjacent vegetation is not impeding the ditch drainage flow.

Elements of Good Subsurface Drainage

A subsurface drainage system carries water from beneath the pavement to appropriate drainage features, like ditches or storm drains. An excellent sign that this system is well maintained and in good working order is the absence of "frost heaves" in the winter months.

The elements of subsurface drainage include a granular drainage layer and subdrains (under drains and edge drains).

Granular Drainage Layer

A well-maintained granular drainage layer is uniform in thickness, the width detailed in the plans and specifications, and of the proper material gradation.

Under Drains/Edge Drains

A well-maintained system of transverse and longitudinal drainage pipes effectively intercepts and carries water out of the granular layer. Under drains carry water from the granular drainage layer to edge drains. Edge drains are installed under shoulders, longitudinally adjacent to the pavement. See figure 5–2.

Edge drains are constructed during roadway construction. Perforated pipe is installed in a trench parallel to the roadway, which is then backfilled with an open-graded aggregate. Caps of impervious soil are placed on top of edge drains to prevent surface water from draining into them. Filters may be used to prevent fine-grained soil from clogging the open-graded aggregate or the pipe itself.

Water from the under drains is collected in a non-perforated edge drain pipe that discharges into a roadside ditch or a storm sewer system.

All subdrains should maintain the flow lines and the design slopes. The outlet water flow should be clear and uniform, indicating that erosion is not occurring and the system is not clogged.

Optimal Timing/Conditions for Maintenance

The drainage system should be closely observed after a major storm event, when the effectiveness of the system will be most evident. In addition, culverts and other drainage features should be inspected on a routine schedule as directed by the policies and procedures of your agency. The results of these inspections should be recorded in a database.

Maintenance activities are generally scheduled when there will be the least damage to these features. For example, ditch cleaning will be scheduled when water in the ditch has dissipated (if possible) and there is some stability in the soil to support the weight of equipment. In addition, your supervisor will likely schedule regular drainage system maintenance, perhaps semiannually or in conjunction with drainage or roadway improvements.

Drainage Maintenance Activities

Maintenance operations include activities that focus on the road surface and then move out to the roadway edge and subsurface. Several activities related to surface and subsurface drainage are common to both rural and urban environments. (Activities specific to urban or rural environments are discussed separately later in this chapter.)

Iowa One Call: It's the Law

Iowa law requires that anyone planning any form of excavation must contact the Iowa One Call notification system (1-800-292-8989) at least 48 hours in advance so that utilities can be located and marked. Always consult your supervisor before conducting any excavation, which may include ditch-cleaning operations or other activities related to maintaining drainage systems.

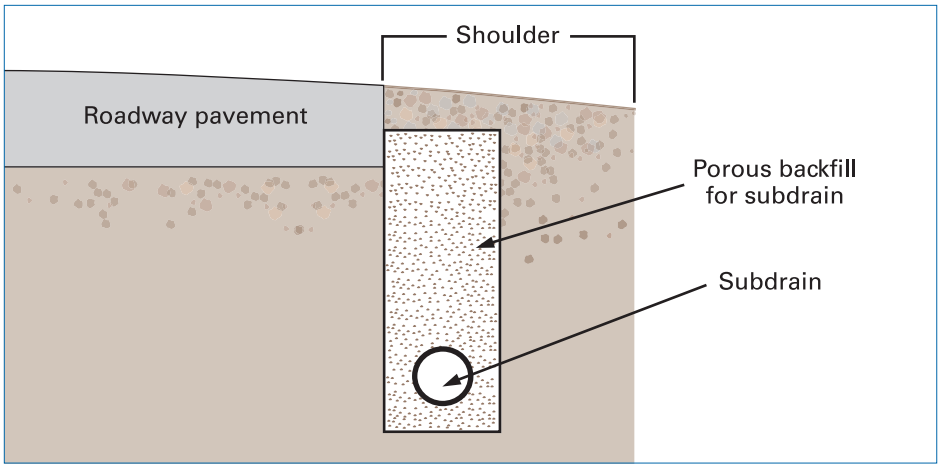


Figure 5–2. Edge drain

Surface Drainage Maintenance Activities

For information about maintaining crowns (on gravel roads) and shoulders, see chapters 3 and 4.

Maintaining Ditches

Motor graders and excavators are commonly used to clean ditches. Be careful when creating a steeper ditch grade. A too-steep grade may accelerate runoff enough to seriously erode the ditch. A too-flat grade will not drain properly, as shown in figure 5–3.

Beware of Methamphetamine Trash

When maintaining ditches, be alert for abandoned materials from methamphetamine-manufacturing labs. These hazardous materials require special handling. Consult your supervisor, and follow your agency's policy.

Figure 5–3. A flat ditch may not drain properly (Lee Co.)

Subsurface Drainage Maintenance Activities

The granular subsurface layer, under drains, and edge drains must be maintained.

Maintaining Granular Drainage Layer

Few routine maintenance activities are generally necessary for the granular drainage layer. As long as it stays clean and undisturbed, it will function as intended.

However, maintenance crews do need to be careful of the granular drainage layer when performing other maintenance activities. One of the best examples is full-depth pavement patching. When the deteriorated pavement is removed, the granular drainage layer is exposed. It is very important that this layer is not disturbed and or contaminated with dirt, etc., that would reduce its effectiveness.

Maintaining Subdrains

Few routine maintenance activities are generally associated with under drains and edge drains. As long as drains are clean and undisturbed, they will function as intended.

However, maintenance crews do need to be careful of these drains when performing other maintenance activities, like repairing shoulder edge drop-offs, foreslopes, and backslopes, and ditch-cleaning operations. Be aware of the location of drains and outlets and be careful not to damage them.

Urban Drainage Systems

Drainage issues unique to urban situations include water running from the pavement to a curb and gutter (shoulder) and then into a storm sewer system (ditch). (Curb and gutter inlets and storm sewers are also used in rural areas where shoulders and foreslopes on roads are easily eroded or backslopes are too steep to cut in a ditch. Sometimes a curb and gutter system will be used on the low side of horizontal curves to control erosion of the shoulder material and to manage edge drop-offs.)

Paved Curbs and Gutters

Curbs and gutters collect runoff water from the pavement and direct it to inlets. Maintenance activities include keeping curbs and gutters clear of debris and silt so that water can run freely to the inlets.

Inlets, Storm Drains, and Manholes

In enclosed drainage systems, water is collected from the curb and gutter by inlets and funneled through storm drains into an underground storm sewer. Storm sewer runs are connected by inlets (one storm drain) and manholes (where two or more storm drains meet) which, in addition to funneling water into the storm sewers, allow personnel to access the storm sewer.

Maintenance activities include the following:

- Remove debris and silt from inlets so that water can freely enter the storm sewer.
- Make sure the pavement around inlets and manholes is sound and has water-tight joints, which prevents deterioration of the structure. See figure 5–4.
- If the storm sewer lines are too flat, clean and flush them regularly.
- Clean drains regularly. If they are too flat, you may have to excavate and realign them to a grade that promotes good water flow.

Figure 5–4. Water-tight joints at an inlet

Rural Culverts

Culverts provide drainage under driveways, roads, slopes, and adjacent areas. Their grade and direction should conform as closely as possible to that of the water they are carrying. See figures 5–5, 5–6, and 5–7.

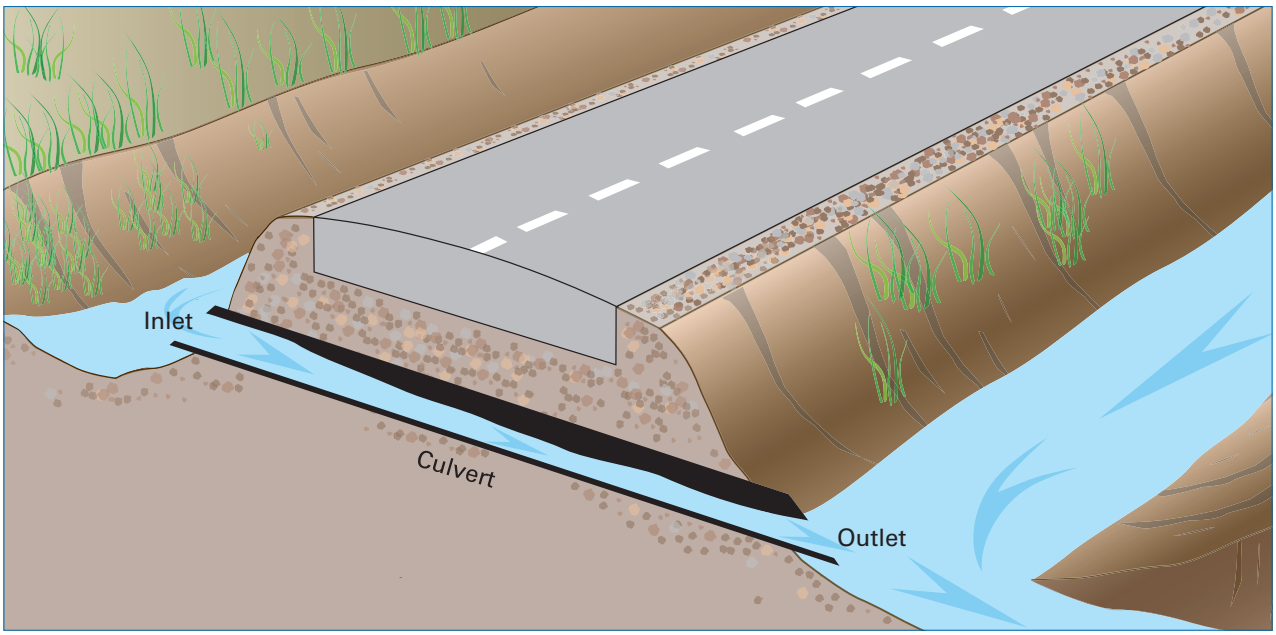


Figure 5–5. Culvert (profile view)

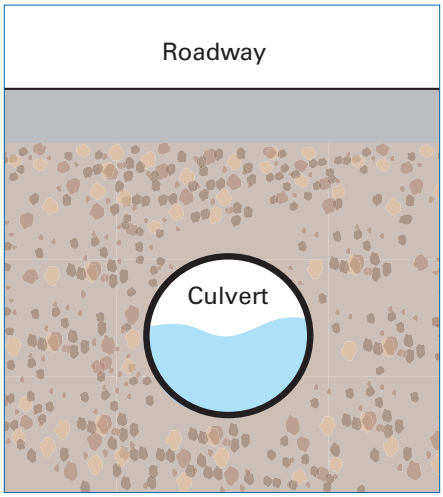


Figure 5–6. Culvert (section view)

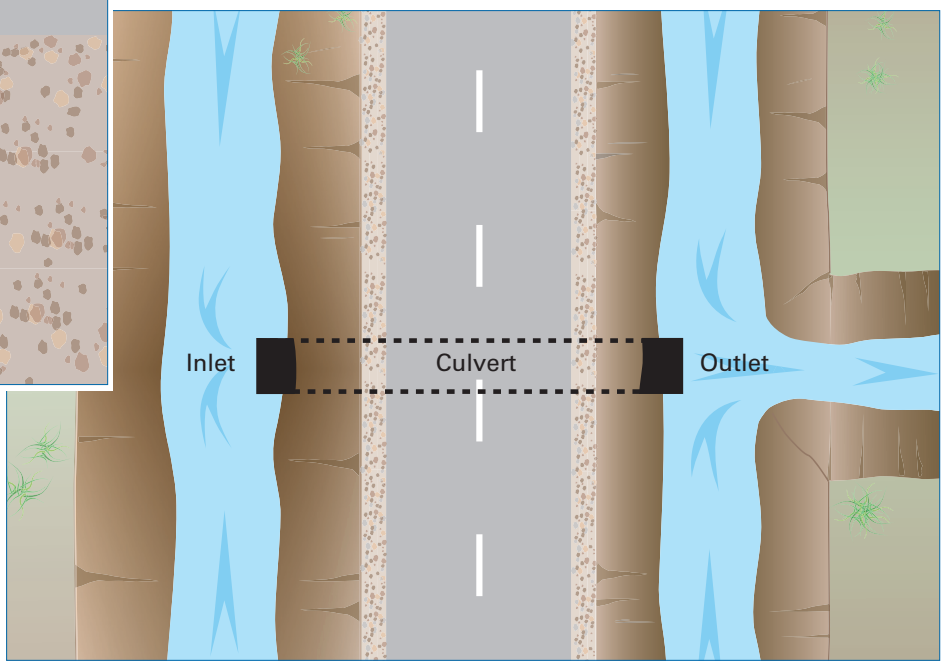


Figure 5–7. Culvert (plan view)

Culvert Observation Activities

Culverts are major drainage structures. Culvert failure can be catastrophic, causing serious injury or death, and costly restoration or reconstruction.

City and county road maintenance workers are generally not responsible for extensive culvert inspection and repair. However, as you drive over culverts in your jurisdiction or work in their vicinity, you can and should be aware of the signs of culvert stresses or other problems and report them immediately to your supervisor.

Signs of potential problems could include the following:

- A dip in the pavement over a culvert (could indicate settlement or a structural problem).
- High water lines (may indicate a drainage problem).
- Accumulated debris and/or signs of bank erosion upstream of the channel (may indicate a drainage problem).
- Debris on fence lines or backslopes.
- Erosion around the headwall.
- Wet ditches or vegetation (may indicate standing water).

Maintenance Issues for Culverts

You may also need to perform some basic housekeeping/maintenance activities as directed by your supervisor.

Clogs and Silting

Culverts get clogged because debris accumulates at the culvert inlet. They become silted when the grade is too flat and the flow is restricted.

To solve the debris/silt problem, conduct these maintenance activities:

- Stop debris upstream by using a barrier.
- Clean the culvert frequently, making sure debris can pass through the culvert.
- Steepen the culvert grade to promote self-cleaning.

Scour

Scour is erosion from water in a roadway ditch or a stream channel.

Scour may occur at culvert inlets if the inlet is choked with debris. Remove the debris to restore water movement. Another possibility is that the inlet capacity is simply inadequate. The makeup of the drainage area may have changed since the culvert's construction. In this case, the culvert will have to be reconstructed to provide a larger opening/capacity.

At outlets, scour occurs when a large volume of water is discharged at a high velocity. See figure 5–8. When scour occurs at outlets, curtain walls may be undermined. Repair the scour by backfilling the eroded area with suitable material, then placing riprap, concrete, or bituminous material to protect the outlet from further damage.

Abrasion

Culvert floors and sidewalls gradually deteriorate as a result of debris and sediment passing through the culvert. Inspect culverts at regular intervals for abrasive wear. Consider forming and paving a new invert or inserting a culvert liner, as directed by your supervisor.

Corrosion (Rust)

Metal pipe culverts experience corrosion when the protective coating is worn away by abrasion. Common maintenance is to replace the culvert or to insert a culvert liner. Consult your supervisor.

In concrete culverts, reinforced steel can be subject to corrosion in locations with very acidic water. There is no routine maintenance activity for this problem. When the deterioration becomes severe, a major repair of the culvert will be required.

RULE OF THUMB

Acidic water conditions (e.g., near a feedlot) may require plastic pipes or specially coated pipes instead of corrugated metal.

Leakage

Leakage occurs when culvert sections separate at the joints. This is caused by movement of the embankment material or by faulty construction joints. Water leaking out of joints will erode the surrounding material, causing the joints to separate more and, eventually, undermining the structure itself. Regularly inspect culverts for leaks and repair the joints.

Cracks

Cracks may occur in culvert collars, cut-offs, and wing walls. Repair these defects using a sand-cement mortar containing an anti-shrinking additive.

Damaged Culvert Ends

Metal culvert ends are susceptible to damage. Remove the damaged sections by excavating the backfill and cutting off and replacing them.

Figure 5–8. Deep scour at culvert outlet (Ettema, et al.)

Drainage Laws

A drainage district is a quasi-governmental agency that administers drainage issues within an established area. Drainage districts are generally responsible for maintaining tile lines within the districts. Street and road agencies, however, are responsible for responding to problems and coordinating repairs where tile lines outlet into or cross the right of way.

Before starting any work on tile lines, check with your supervisor and follow your local policy. Find and mark all tile lines in the area so you don't accidentally damage them. Any tile lines that are damaged must be repaired.

If you're going to divert drainage, make sure affected property owners have signed a release and that there's minimal likelihood that the diversion will cause any property damage.

The *Iowa Drainage Law Manual* is available from the Local Technical Assistance Program. The manual answers questions frequently asked by local road agencies. For a copy of the manual, contact the librarian, 515-294-2981, hoganj@iastate.edu. You can also download it, www.ctre.iastate.edu/pubs/drainage_law/index.htm. Development of the manual was sponsored by the Iowa Highway Research Board, TR-497.

RULE OF THUMB

The primary concept behind all drainage law: "Do no harm." Don't flood anyone, and don't cause erosion by sending water rushing downstream.

BIBLIOGRAPHY

American Association of State Highway and Transportation Officials (AASHTO). 1997. *Highway Safety Design and Operations Guide.* Washington, DC: American Association of State Highway and Transportation Officials.

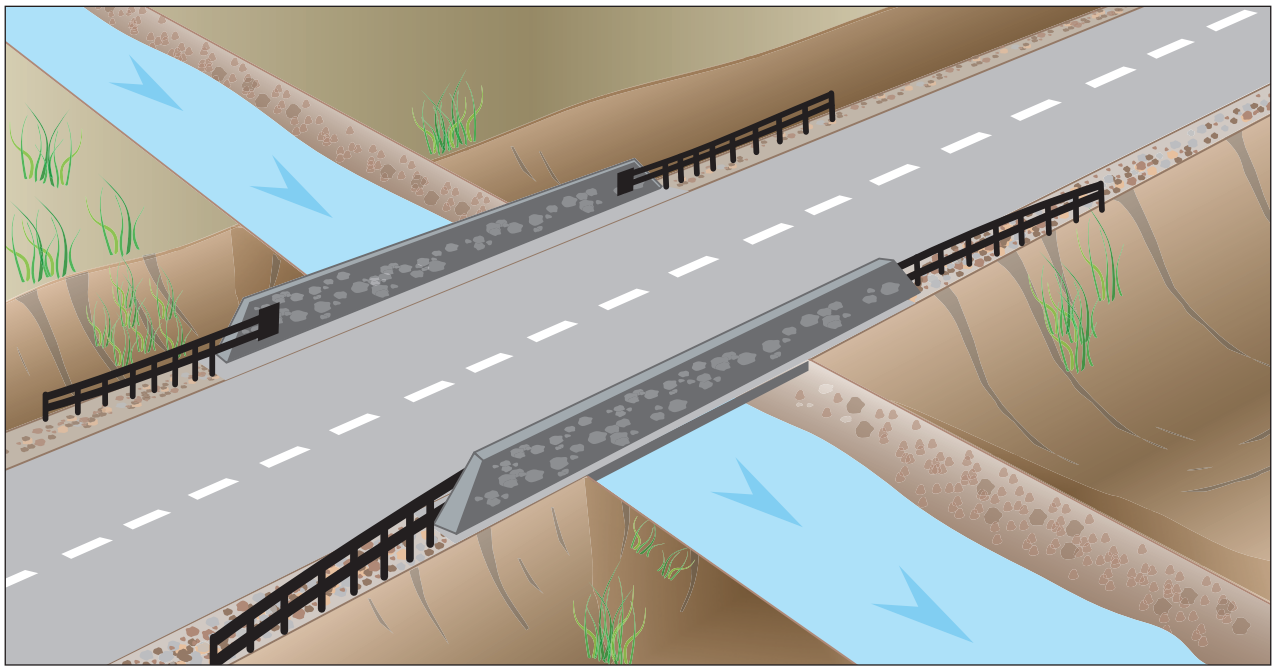
Andrle, S.J. and T.J. McDonald. 2005. *Iowa Drainage Law Manual.* IHRB Project TR-497. Ames, IA: Center for Transportation Research and Education.

Andrle, S.J., K. Knapp, T.J. McDonald, and D.E. Smith. 2001. *Iowa Traffic Control Devices and Pavement Markings: A Manual for Cities and Counties.* Iowa DOT Project TR-441. Ames, IA: Center for Transportation Research and Education.

Federal Highway Administration (FHWA). 2003. *Manual on Uniform Traffic Control Devices (MUTCD) for Streets and Highways.* 3rd Ed. Washington, DC: United States Department of Transportation, Federal Highway Administration.

Iowa One Call (IOC). 2006. Iowa One Call Home. http://iowaonecall.com/index.php.

Chapter 6:
Bridges



chapter contents

Characteristics of Well-Maintained Bridges.....95

Optimum Timing/Conditions for Maintenance.....95

Bridge Maintenance Activities.....96
- Bridge Washing.....96
- Debris Removal.....96
- Guardrail Mowing.....96
- Repairing/Replacing Wood Deck Planks.....96
- Repairing Concrete Deck Surface.....97

Bridge Observation Activities.....97
- Bridge Approach.....98
- Guardrail and Shoulders.....99
- Traffic Control Devices.....99
- Bridge Structure.....99
- Under the Bridge.....101
- Waterway.....104

For More Information.....105

Safety Tips for Maintaining Bridges

Always check with your supervisor and follow your agency's safety policies and procedures.

Suggested personal safety gear

- Snug-fitting clothing to avoid snagging
- Heavy gloves
- Hard-toed footwear
- Hard hat
- Ear protection
- Safety glasses with side shields
- Highly visible apparel (if working near traffic)
- Safety glasses

Advance preparation

- Be properly trained and thoroughly familiar with equipment like pile driver, backhoe, high-reach bucket, jack-hammer, etc.
- Make sure an up-to-date first-aid kit, emergency contact information, and hand-held radios or cell phones are available at the work site.
- Make sure work vehicles are equipped with approved and activated warning lights.

During operations

- If the road is open to traffic use proper temporary traffic control, including flagger(s) if needed, as described in the *Iowa Traffic Control Devices and Pavement Markings: A Manual for Cities and Counties; in the MUTCD,* part 6; and in your agency's policies and procedures.
- Wear appropriate safety gear and highly visible apparel whenever you're out of your vehicle.
- Don't climb on structures without proper safety devices such as tie-offs, safety rails, and/or netting.
- Use proper lifting techniques or request assistance to lift heavy objects.
- Remove all temporary traffic control immediately when no longer needed.

A bridge failure can be catastrophic. It can cause injury or death and can be very expensive to restore.

City and county road maintenance workers are generally not responsible for extensive bridge inspection and repair. However, as you drive over bridges in your jurisdiction or work in their vicinity, you can and should be aware of the signs of bridge stresses or other problems and report problems immediately to your supervisor. See figure 6–1.

You may also need to perform some basic bridge housekeeping/maintenance activities as directed by your supervisor.

Characteristics of Well-Maintained Bridges

Well-maintained bridges have the following characteristics:

- The operating width is the same as when the bridge was constructed.
- Structural members are free from damage and corrosion and are in the same alignment as when they were built.
- The deck is free of debris and deterioration.
- All traffic control devices are in place, well maintained, and visible.
- The channel is free of erosion, and the channel and structural members are clear of debris.
- The bridge railing is in good condition, and any approach guardrail is in place and properly aligned.
- Approach paving provides smooth access to the bridge deck.

Optimum Timing/Conditions for Maintenance

Most routine bridge maintenance will be conducted during the spring, summer, and fall. Some activities, like breaking up ice jams or removing debris affecting water flow, may be performed in the winter.

Figure 6–1. Observe bridge conditions when you are in the vicinity (Ettema, et al.)

Bridge Maintenance Activities

Consult your supervisor and perform routine bridge maintenance activities as directed. Such activities may include the following:

Bridge Cleaning

Clean decks, piers, abutments, and expansion joints. Before washing, remove and properly dispose of accumulated debris. You may be asked to blow incompressibles from the joints.

Debris Removal

Remove debris or excess vegetation from the bridge approach, bridge deck, under the bridge, and in the waterway. Do not leave debris where it will be picked up during the next high water event.

Guardrail Mowing

Remove overgrown vegetation from under and around guardrails.
See figure 6–2.

Approach Blading

See Blading at Bridges in Chapter 3, page 23.

Repairing/Replacing Wood Deck Planks

If you observe loose or broken bridge deck timbers, notify your supervisor immediately. Both loose and broken planks can create a safety hazard for drivers.

If the plank(s) is/are loose, tighten them immediately with existing or new bolts.

If the plank(s) is/are broken, remove and replace them immediately. Determine the number of planks to be replaced, and measure the lengths required. Bring new bridge planks to the site and cut them to length using a chain saw.

Figure 6–2. Overgrown vegetation at guardrail (CCEE/ISU)

Drill bolt holes in appropriate locations, and attach the planks to the girders and stringers with new bolts.

When the maintenance activity has been completed and the bridge deck is secure, report to your supervisor. Documenting the timing of maintenance repairs can be critical in liability lawsuits.

Repairing Concrete Deck Surface

Delamination of concrete bridge decks is usually first noticeable over the steel reinforcing bars (re-bar). It is generally caused by chloride ions that infiltrate the concrete deck, migrate to the bars, and corrode them. When steel corrodes, it expands up to eight times its original volume, pushing up on the concrete. Eventually the bond between the concrete and the re-bar is broken, and cracks develop in the concrete. Cracks will continue to develop until pieces of the concrete deck come loose.

The broken areas are like tooth decay; they will spread until the damaged areas are removed and filled with new material.

To determine the extent of delamination, drag a log chain over the deck. There will be a distinct hollow sound where the concrete deck has delaminated and is deteriorating. Mark this area with paint from a spray can. Be sure to check the entire bridge deck.

Remove the delaminated concrete with jack hammers and hand tools. Remove all of the deteriorated deck down to sound concrete. (You may find that the deterioration has developed under the re-bars.) Thoroughly clean the area with an air compressor and power and hand brooms.

If you are repairing the deck in the winter, place a temporary asphalt patch. (See Temporary (Asphalt) Repair under Concrete Pavement in chapter 3.)

If the weather is moderate or warm, place a concrete surface patch. (See Surface Patching under Concrete Pavement in chapter 3.) Before placing a concrete patch, apply a grout or bonding agent to the existing, cleaned surface to bond the new concrete to the existing concrete deck. Check with your supervisor and follow your agency's policies and procedures and the bonding agent manufacturer's instructions.

Finally, cure the new concrete by covering it with a liquid curing compound, plastic, or wet burlap, as directed by your supervisor. Curing allows the concrete to develop the required strength before traffic is allowed on the concrete.

Bridge Observation Activities

All agencies conduct routine, in-depth inspections of bridges. This manual does not describe such inspections in detail, because they are generally not the responsibility of road maintenance workers.

However, during the course of your regular road maintenance activities, you should routinely observe the general condition of bridges in your jurisdiction, as described in the next section. Conduct these observations on an ongoing basis, during all seasons of the year.

Report any potential problems to your supervisor. Defects, damage, erosion, or other serious flaws in bridges need to be addressed quickly.

When you are driving down the road and approaching a bridge, pay attention. Carefully observe the general condition of the roadway before the bridge, the traffic control and safety devices, the approach surface, and the bridge deck and structural members. Look over the edge of the bridge to see if there is any debris in the channel or erosion and debris around the structure.

Following are some suggestions of specific conditions or problems to watch for.

Bridge Approach

On gravel road approaches to bridges, look for the following potential problems:

- Poor crown transition from the road to the bridge deck (see Blading at Bridges in chapter 3)
- Too much aggregate and/or inadequate crust on the bridge approach, so that the aggregate migrates onto the bridge deck. See figure 6–3. Aggregate on the bridge deck may, in effect, narrow the operating width of the bridge.
- Standing water or erosion at the shoulder line

On paved road approaches to bridges, look for the following potential problems:

- Pavement distresses and excessive cracking
- Joint failures
- Erosion at the pavement edges
- Cracking or settlement of approach slabs
- Poor condition of expansion joint where the slab meets the bridge deck
- Poor ride

Figure 6–3. Gravel on bridge deck (CCEE/ISU)

Guardrails and Shoulders

Look for the following potential problems:

- W-beam rail sections badly bent out of shape
- Loose bolts
- Loose, broken, or rotted wooden posts
- Bent or badly off line steel posts
- Inadequate guardrail blister offering too little support of the end section
- Holes or ruts under the guardrail that vehicle wheels could drop into
- Traffic damage
- Too low or too high rail
- Overgrown vegetation under and around the rail

Traffic Control Devices

Typical traffic control devices (TCDs) at bridges include object markers, delineators, pavement markings, and signing. All TCDs should be easily visible and not damaged or worn. See figure 6–4.

Bridge Structure

Deck

On timber decks, look for the following potential problems:

- Loose nails, spikes, or fasteners
- Openings between planks over abutments and piers which allow dirt to sift through
- Split, worn, broken, or decayed planks

(To repair wood bridge decks, see Bridge Maintenance Activities earlier in this chapter.)

Figure 6–4. Visible object markers at a bridge (CCEE/ISU)

On concrete decks, look for the following potential problems:

- Cracking
- Leaching
- Exposed reinforcing
- Scaling
- Potholes
- Spalling
- Other evidence of deterioration

(To repair concrete deck surface, see Bridge Maintenance Activities earlier in this chapter.)

On steel decks, look for the following potential problems:

- Corrosion
- Unsound welds
- Loose welds where the deck is fastened to the stringers
- Dirt collected in open-grid decking on top of stringers
- Deteriorated paint

Structural Members

Observe the condition of trusses by sighting along the roadway rail or curb and along the truss chord members. Look for truss misalignment, either vertical or horizontal. Bent trusses may reduce the bridge's operating width and/or reduce the structure's soundness. Note any members damaged by vehicles.

Figure 6–5. Well-aligned bridge trusses (Lee Co.)

Under the Bridge

Pay attention to the condition of the underside of the deck, the structural members, the piers and columns, the slope protection, and the waterway. See figure 6-6.

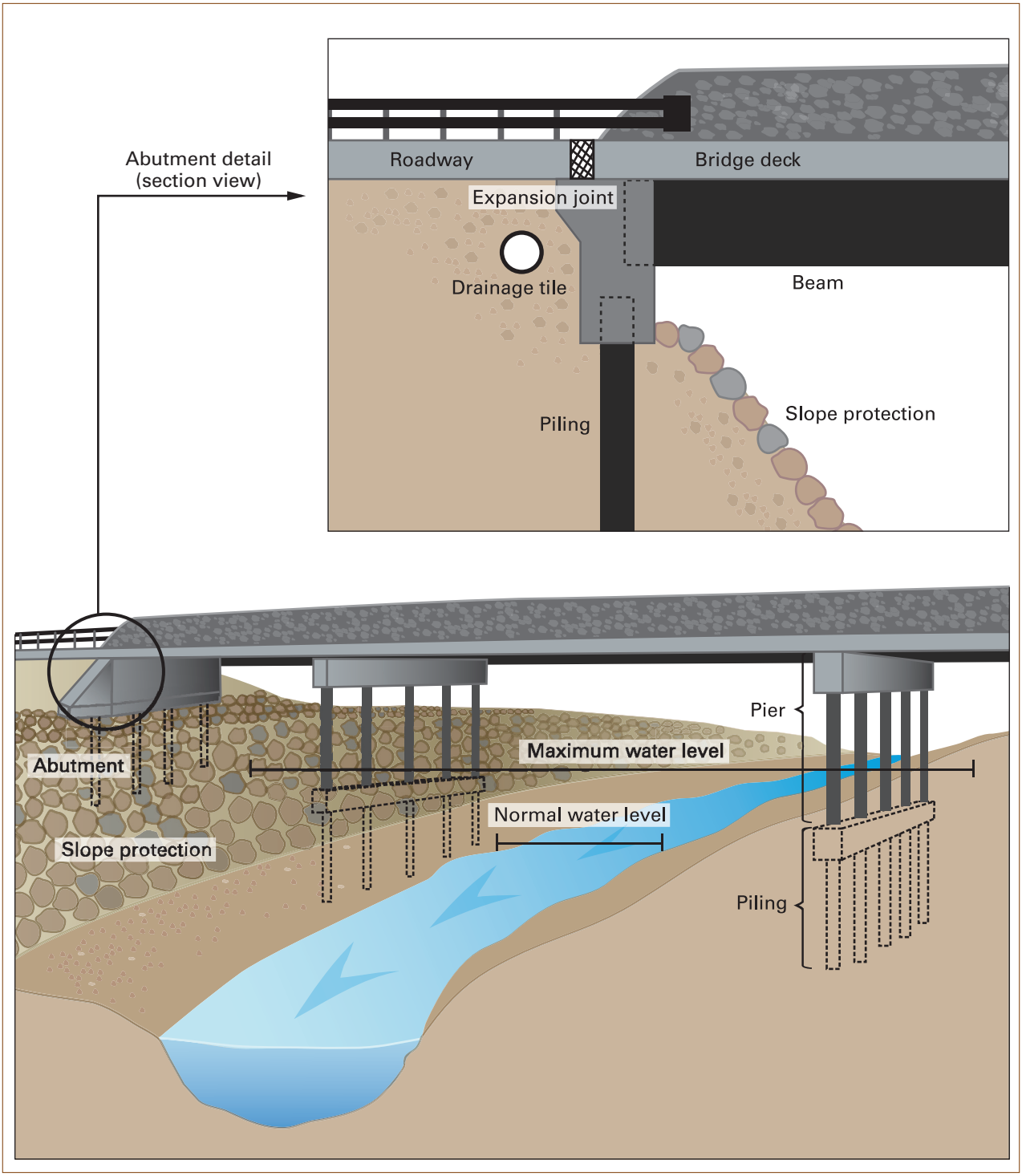


Figure 6–6. Elements to observe under the bridge (Adapted from Ettema, et al.)

Underside of Deck

Look for the following potential problems:

- Seepage (figure 6–7)
- Calcium deposits
- Cracks in the deck
- Exposed reinforcing

Piers and Columns

Look for the following potential problems:

- Erosion at the bottom of the columns (figure 6–8)
- Deteriorated concrete in the columns
- Pier caps that are cracked or out of alignment
- Piers that are damaged due to ice or other debris

Figure 6–7. Evidence of deck seepage (Lee Co.)

Figure 6–8. Erosion around base of piers (Ettema, et al.)

Structural Members under the Bridge

Structural members found under the bridge include the beams, which may be steel or pre-stressed concrete, and the abutments and backwalls. Look for the following potential problems:

- Steel beams that are corroded, discolored, or bent from being hit (figure 6–9)
- Pre-stressed beams that are cracked or have pieces missing, particularly on the bottom flanges
- Backwalls that are eroded or pushed out of alignment
- Abutments that are deteriorated or have erosion problems or leaking deck joint
- Bearings that are corroded or frozen up due to rusting (figure 6–10)

Figure 6–9. Corroded, discolored steel beams (Lee Co.)

Figure 6–10. Abutments, bearings, and backwall with erosion and corrosion problems (Lee Co.)

Bridge Slope Protection

The purpose of bridge slope protection is to control erosion and vegetation growth. On paved slope protection, look for the following potential problems:

- Broken panels (Broken panels may not need to be replaced if they are seated and generally conform to the slope.)
- Cracks (Although cracks themselves are not detrimental to the performance of slope protection, they should be sealed to prevent water intrusion, which may cause settlement and/or sliding of the panels.)

Most slope protection is riprap or revetment. Look for the following problems:

- Bare areas
- Exposed fabric
- Erosion
- Inadequate rock size

Drainage Systems

- Drainge systems should be repaired or replaced as necessary to prevent further damage. See figure 6–6 on page 101.

Waterway

Look for the following potential problems along the waterway:

- Debris collecting near piers or in the stream channel. (Debris accumulations may cause scour, redirect the stream channel, apply excessive hydraulic loads, or become a fire hazard. They should be removed as soon as possible. See figures 6–11 and 6–12.)

Figure 6–11. Debris collected around a pier (Ettema, et al.)

Figure 6–12. Debris in river channel (LTAP-IN)

- Damage to wing dams, etc., which protect the bridge or control the streambed. (Such damage should be scheduled for repair as soon as possible.)
- Sand and gravel bars that divert water flow and perhaps cause scour

For More Information

For in-depth bridge inspection and repair documents and courses, contact the Iowa Local Technical Assistance Program, 515-294-2481, hoganj@iastate.edu.

BIBLIOGRAPHY

American Association of State Highway and Transportation Officials (AASHTO). 1997. *Highway Safety Design and Operations Guide.* Washington, DC: American Association of State Highway and Transportation Officials.

Andrle, S.J., K. Knapp, T.J. McDonald, and D.E. Smith. 2001. *Iowa Traffic Control Devices and Pavement Markings: A Manual for Cities and Counties.* Iowa DOT Project TR-441. Ames, IA: Center for Transportation Research and Education.

Federal Highway Administration (FHWA). 2003. *Manual on Uniform Traffic Control Devices (MUTCD) for Streets and Highways.* 3rd Ed. Washington, DC: United States Department of Transportation, Federal Highway Administration.

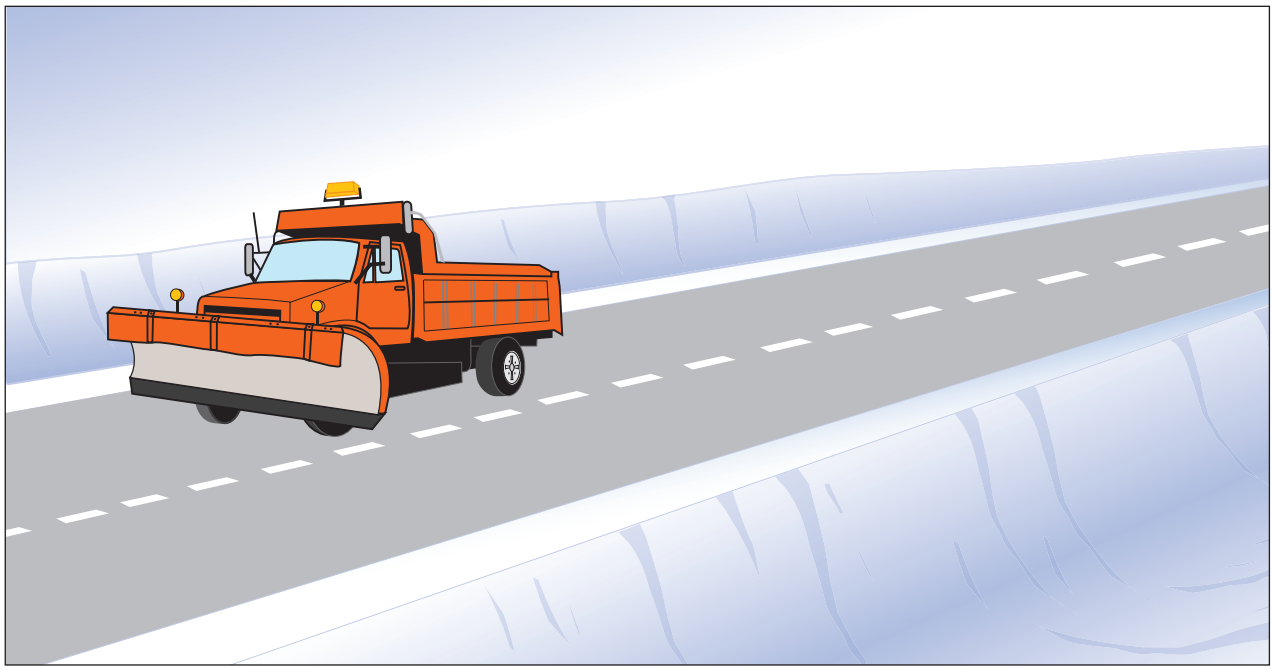
Iowa One Call (IOC). 2006. Iowa One Call Home. http://iowaonecall.com/index.php.

Knight, M.L., G.S. Wilson, W.J. Seger, and S. Mahadevan. 2004. Overlay Types Used as Preventive Maintenance on Tennessee Bridge Decks. Transportation Research Record 1866: 79–84.

Sprinkel, M. 2001. Maintenance of Concrete Bridges. *Transportation Research Record* 1749: 60–63.

Wipf, T.J., F.S. Fanous, F.W. Klaiber, A.S. Eapen. 2003. *Evaluation of Appropriate Maintenance, Repair and Rehabilitation Methods for Iowa Bridges.* Final Report. Iowa DOT Project TR-429. Ames, IA: Iowa Department of Transportation.

Chapter 7:
Snow and Ice Control



chapter contents

Characteristics of Effective Snow and Ice Control..110

Preparing for Winter Operations.....110
- Snow Fence.....110
- Prepare Equipment.....111
- Inspect Snow Plow Truck.....111
- Conduct Pre-trip Checklist.....111

Snow and Ice Control Strategies.....112
- Which Strategy to Use.....112
- Importance of Forecasting.....112
- Anti-Icing.....113
- Plowing.....115
- Deicing.....119

Chemicals for Anti-icing and Deicing.....120
- Salt.....120
- Calcium Chloride.....122

Enhancing Friction.....122

Keeping Records.....123

After the Storm.....124
- Material and Equipment.....124
- Sewer Drains.....124
- Snow Storage.....124

Safety Tips for Snow and Ice Control

Always check with your supervisor and follow your agency's safety policies and procedures.

Suggested personal safety gear

- Layers of clothes, extra gloves, heavy boots
- Shovel and ice scraper
- Flashlight for night operations
- Sunglasses for glare
- Water and/or hot liquid

Advance preparation

- Be properly trained and thoroughly familiar with all equipment and chemicals.
- Make sure an up-to-date first-aid kit, emergency contact information, and hand-held radios or cell phones are available in your vehicle.
- Be in good physical condition with adequate rest.
- Perform a pre-trip safety check of truck and equipment. Make sure the vehicle has adequate warning lights in good working order.
- Make a practice run of assigned route to check for obstacles and potential problem areas.
- Know the contact procedures for reporting crashes or equipment breakdowns.

During operations

- Dress in layers with heavy boots.
- Wear highly visible apparel when out of your vehicle.
- Plow at appropriate speed.
- Watch for pedestrians and other vehicles.
- Don't back up without a spotter.
- Operate wings carefully.
- Make sure warning lights are activated.

Today's motorists—and the needs of our economy—demand that roads be open and reasonably safe in almost any kind of weather. A road department's ability to remove snow efficiently and open roads quickly is often the standard by which the department is judged. Winter road maintenance is so important that many local governments size their entire road maintenance program—that is, the number of maintenance employees, the number and kind of vehicles, etc.—to accommodate winter maintenance activities. Snow and ice control is often a major budget item for many local governments.

Snow and ice control operations have two goals. First, make roadways passable. Second, provide adequate pavement friction to allow vehicles to brake, turn, and accelerate safely. This chapter discusses how road workers can help agencies meet these goals. Topics include preparing for winter operations, snow and ice control strategies, chemicals for anti-icing and deicing, enhancing friction, and post-storm activities.

Ten Commandments for Snow Fighters

1. Thou shalt present thyself to thy job physically and mentally fit and properly clothed for any emergency in order to withstand the rigors of thy task.
2. Thou shalt always inspect thy lights, windshield wipers, defrosters, flares, and other safety equipment before entering thy cab.
3. Thou shalt know thy spreading and plowing routes, as well as the performance of thy spinner and the life of thy plow blade.
4. Thou shalt faithfully remain alert in order to avoid guardrails, headers, stalled cars, manhole covers, railroad tracks, and mailboxes. Otherwise thee may smite thy windshield with thy head.
5. Thou shalt contain thy temper, even though cars and trucks pass thee on both sides and tailgate thee too close for comfort. Anger only multiplies thy prospects of coming to grief by accident.
6. Thou shalt use thy radio as briefly as possible—assuming thee is fortunate enough to have one. Remember thy fellow workers may need to communicate in an emergency.
7. Thou shalt interrupt the flow of power to thy spreader before attempting to free any foreign objects or blockage if thee treasures thy fingers.
8. Thou shalt render thy truck and spreader out of gear and stoutly set thy brakes before dismounting from thy cab.
9. Thou shalt govern thy speed according to conditions, else thee may wind up with thy truck upside down.
10. Thou shalt mind thy manners on the roadway, clearly signal thy intentions, and remember that it is more blessed to give than to receive.

[Adapted from the National Local Technical Assistance Program/Salt Institute. Source: Rural & Urban Roads, 1980]

Characteristics of Effective Snow and Ice Control

An effective snow and ice control program will have the following characteristics: Snow and ice are removed from (or prevented from reaching) roads, side streets, shoulders, and intersections in compliance with agency policies and procedures.

Preparing for Winter Operations

A detailed discussion of all pre-season preparations is beyond the scope of this book. The following sections provide guidelines for installing snow fences and for getting equipment ready.

Snow Fence

Preventing snow from drifting on or sticking to road surfaces is less expensive and time consuming (and safer for motorists and maintenance crews) than removing snow and ice from the road. Snow fences, both structural and "living," slow snow-laden winds, causing the snow to drop and collect downwind from the fence. Properly located and installed snow fences significantly reduce the need to remove drifting snow and accumulated ice from the road. See figure 7-1.

Structural or living snow fences with about 50 percent of the total surface area open for the wind to blow through have the largest snow storage capacity. (Denser fences have shorter drift lengths, allowing for closer setbacks, but denser fences also have less storage capacity.)

The most effective snow fence height is generally 6–16 feet. (Fifty-percent porous, structural fences that are less then 6 feet tall typically do not provide enough snow storage capacity.)

Locate structural snow fence far enough from the road that the downwind drift does not extend onto the road. The optimum distance for a 50-percent porous, structural fence is normally 35 times the height of the fence. For example, a 6-foot fence would create a drift of approximately 210 feet.

Figure 7–1. Properly installed snow fences cause snow to collect downwind (WDM)

Ideally, install structural snow fence perpendicular to the general prevailing winds. Sometimes, however, depending on wind and roadway angles, snow fence will have to be installed parallel to the roadway.

Leave a gap under the structural fence equal to about 10 percent of the fence height to improve snow-trapping efficiency. Do not leave horizontal gaps in structural or living snow fence.

Extend the end of the fence past the roadway area that you want to protect from the wind. The optimum extension is approximately 20 times the height of the fence. This is necessary to accommodate variations in wind direction and because the wind wraps around the ends of the fence.

Living snow fences—rows of trees, tall shrubs, or corn left standing in the field—can also be very effective.

Appendix B illustrates proper installation of 50-percent porous, structural snow fence on flat terrain, as well as the proper configuration for a living snow fence of standing corn.

Prepare Equipment

Different models of spreading equipment vary in spreading rates, and different materials spread at different rates. Therefore, each spreader should be individually calibrated for the specific material that will be used. Refer to manufacturers' recommendations.

To keep all winter maintenance equipment in top condition, local agencies have regular maintenance routines.

Inspect Snow Plow Truck

Snow plow trucks are the key to successful winter maintenance operations. Keeping them in good working order is essential.

After every use, equipment operators should inspect their snow plow trucks and other equipment and report needed repairs. It is critical to pay attention to all of the parts of the truck as well as the equipment attached to it.

Conduct Pre-trip Checklist

A pre-trip checklist is required for commercial driver's license (CDL) compliance. Following the checklist will help prevent equipment failure and resulting accidents, injuries, and deaths.

Equipment Checklists

For a sample equipment checklist, see appendix C.

For a sample snow plow inspection checklist, see appendix D.

For a sample pre-trip checklist, see appendix E.

If your agency has its own checklists, use them instead. As always, consult your supervisor, and follow your agency's policies and procedures.

Snow and Ice Control Strategies

There are three general strategies for snow and ice removal/control:

- Anti-icing—applying chemicals to prevent snow and ice from bonding to pavement.
- Plowing—removing accumulated snow and ice from pavement.
- Deicing—applying chemicals to break the bond between snow/ice and pavement.

Generally speaking, anti-icing is used immediately before or at the beginning of a storm. Plowing is conducted when the storm is active or while the wind is still blowing. Deicing is conducted after the storm and when snow and ice are frozen solid to the roadway surface.

Which Strategy to Use?

Not all agencies use all three snow and ice control strategies. Many agencies use a flexible combination of these strategies before, during, and after each particular storm. For example, it is common to simultaneously plow snow and apply salt or other chemicals. Any of these strategies may be combined with application of abrasives (see Enhancing Friction later in this chapter). Consult your supervisor, and follow your agency's policies and procedures.

Knowledge of past storms, as well as accurate predictions about the timing, duration, and severity of imminent storms, helps maintenance supervisors make informed decisions about which strategies and materials to use, chemical application rates, and frequency of treatment.

Current and predicted pavement temperatures are the most important data for selecting appropriate snow and ice control strategies. The effectiveness of deicing chemicals is directly related to pavement temperature, not air temperature.

Importance of Forecasting

A winter maintenance program is only as good as your agency's ability to accurately predict the onset of a winter storm. It is critical to know when a storm will arrive and how air and pavement temperatures are changing along with wind direction and velocity. Accurate information about pavement temperatures is especially critical for selecting appropriate materials. Salt brine, for example, becomes less effective as the temperature approaches 18°F. (See Materials Selection, later in this chapter.)

For reliable forecasts tailored to your jurisdiction, Iowa's local agencies can access the Iowa DOT's extensive road weather information system (RWIS) network and value-added meteorological service. In addition, it is useful to establish a network of local contacts—maintenance supervisors in neighboring jurisdictions—who can provide real-time information about an approaching storm.

Anti-Icing

Anti-icing is a proactive approach to snow and ice control. It consists of applying liquid chemicals (usually salt brine) to pavement before, or at the very beginning of, a storm. The chemicals create a barrier layer that helps prevent snow and ice from bonding to the pavement surface. Accumulating snow can be easily removed by snow plows, leaving the pavement relatively dry. See figure 7–2.

Anti-icing chemicals will become diluted as snow turns into water and as accumulating snow is removed by plows. To offset the dilution and maintain the barrier, you may need to reapply chemicals during the storm.

Consider carefully before reapplying chemicals during the storm; the chemical may quickly become diluted and/or be plowed off the roadway. It is generally good practice to reapply during a storm after you've plowed/scraped the snow off and before the temperature starts to fall and the snow and ice begin to bond (freeze) to the pavement. (After the storm is over, you can switch to deicing to help clear the road surface if you are using chemicals that will be active at the forecasted temperature.)

RULE OF THUMB

If snow is blowing across and off the road, consider carefully before applying anti-icing chemicals that may cause snow to stick to the roadway.

Benefits and Cautions

Anti-icing has several benefits:

- Anti-icing often reduces total chemical use and may reduce costs related to materials, equipment, and time.
- Because pavement conditions are better when ice formation is prevented, anti-icing may provide more mobility and safer service.
- Anti-icing helps prevent frost formation on the pavement for some time following application, and post-storm cleanup is generally easier and faster.

Anti-icing may be less effective during periods of heavy, freezing rain, in blowing snow conditions, or in intense snowfall. If a storm gets ahead of anti-icing efforts, agencies generally switch to normal deicing strategies.

Figure 7–2. Urban anti-icing operations (WDM)

Anti-Icing Preparation Checklist

- Order chemicals and provide for proper chemical storage.
- Inventory equipment.
- Test/calibrate application equipment.
- Make sure communication channels are functioning. Establish interagency agreements. Share your plans with the media.
- Understand your agency's policies and procedures regarding level of service (LOS), peak traffic levels, and operations.
- Plan routes and conduct dry runs to identify trip length and time, obstacles, and trouble spots.

Anti-Icing Guidelines

1. Apply anti-icing material immediately before or just as a storm begins to prevent bonding of snow or ice to the pavement.
2. Use accurate pavement temperature and other road weather information to decide when to begin applying chemicals.
3. Anti-icing is often effective for heavy frosts. Early application of chemicals is important for frost or light freezing drizzle.
4. Apply with stream nozzles so the material is distributed directly on the vehicle wheel paths.
5. Schedule applications on selected sections of the roadway (e.g., bridge decks) if the temperature and conditions could produce frost or black ice.
6. Consider spot applications on hills, curves, and intersections.
7. Apply material during low-traffic periods if possible.
8. When frost on the shoulder begins moving into the traveled lanes, reapply chemicals.

RULE OF THUMB

The surface can refreeze if precipitation or moisture on the pavement dilutes the chemical, or if temperatures drop below the effective temperature of the anti-icing chemicals.

Things Not to Do

1. Do not apply anti-icing chemicals with fan sprayers.
2. Do not apply chemicals when the wind is blowing hard enough to carry the material off the roadway. Be aware of areas that are sensitive to blowing chemicals.
3. Reapplication is not always necessary. Residual chemicals can remain on the roadway for several days.
4. Do not apply chemicals if the wind is blowing snow off the road.

Anti-Icing Training

The American Association of State Highway and Transportation Officials (AASHTO) has developed an interactive, self-directed training program to help road maintenance personnel understand and implement anti-icing effectively. The Anti-Icing/RWIS Training package is available to members of the National Association of County Engineers (NACE) free of charge. You can order your copy, through Iowa's Local Technical Assistance Program, 515-294-9481, hoganj@iastate.edu. Cities can borrow the Anti-Icing/RWIS Training package from Iowa LTAP.

Plowing

During and after a storm, use snow plows to clear roads as needed. See figure 7–3. Snow plowing is a challenge in both rural and urban areas. In rural areas operators must deal with blowing and drifting snow along with decreased visibility. In urban areas operators must deal with parked cars, narrow streets, and cul-de-sacs.

Timing/Scheduling

- Plow roads to remove snow and loose ice before applying deicing chemicals.
- Coordinate plowing activities with co-workers to avoid creating windrows at intersections and to prevent removal of another operator's applied materials.
- Keep your supervisor informed of changing road and weather conditions.

Techniques

- Remove snow from roads as quickly as possible to reduce compaction.
- Use underbody blades to help remove compacted snow or slushy snow.
- Use carbide edge inserts on snow plow blades to extend the life of the blades.
- Adjust the blade angle to maximize cutting efficiency or snow-throwing capabilities.
- Do not push or blow snow off a bridge into the water or onto traffic below.
- Know the height of your truck box, and raise the box only to move material to the back of the box.
- Avoid making sudden moves.
- Pace your speed to the general traffic's speed as much as possible.

RULE OF THUMB

Many agencies have snow ordinances that describe when snow plowing will be conducted and designate snow routes. Consult your supervisor, and follow your agency's policy.

RULE OF THUMB

Minimize dilution of deicing chemicals by plowing immediately before applying the chemicals.

Figure 7–3. Cleared road (WDM)

Cautions

- When plowing on a two-way road or street, stay on the proper side of the road.
- To avoid hitting obstacles, be aware of the width of your truck/equipment.
- Be aware of your surroundings, especially hazards like downed power poles, traffic signals, overhead structures, and power lines.
- Obey traffic laws and use your seat belt.
- Make sure your truck windows and lights are clean.
- Be courteous toward other drivers, bicyclists, and pedestrians.
- Be aware of your truck's changing braking abilities as the loaded box empties.

Avoiding Snow Clouds

Even a very light snow cloud behind your truck can temporarily reduce motorists' ability to see you (and your ability to see them) and increase your chances of being hit from behind.

Snow clouds can form during any plowing operation, but truck speed and wind contribute to clouds.

If you can, avoid plowing when it's windy. For example, if it is not essential to plow a shoulder immediately, postpone plowing until the wind has died down.

Equipment

Different equipment and configurations—snow plow trucks, V plows, tandem vehicles, wing plows, and snow blowers—can be used for snow removal, depending on storm conditions and severity. Following are common uses for various kinds of equipment:

V Plows: Deep Snow, Heavy Drifts

V plows are heavy and can move a lot of snow and punch through big drifts. See figure 7–4. To prevent getting stuck, however, the snow plow must travel at a slow forward speed. When using a V plow, start at the middle of the roadway and work your way toward the edges with additional passes.

Tandem Plows: Multi-Lane Facilities

When clearing a multi-lane facility, several snow plows working in tandem will remove snow more quickly. See figure 7–5.

Figure 7–4. V snow plow (WDM)

Figure 7–5. Tandom snow plow (WDM)

Wing Plow: Shoulders

After snow has been moved to the edge of the street or onto the shoulder, you can use a wing plow to move the snow further away from the roadway and reduce the potential for blowing snow to drift back onto the roadway. See figure 7–6. You can also use wing plows to clear snow from sidewalks or paths.

Snow Blower: Clean Up

In congested areas, use a snow blower to load snow into haul trucks for removal to a remote location. See figure 7–7.

Figure 7–6. Winging operations (WDM)

Figure 7–7. Snow blower (WDM)

Deicing

Deicing consists of applying chemicals to snow and ice to break their bond with the pavement. See figure 7–8.

If anti-icing strategies were not implemented before the storm, or if a storm "gets ahead" of anti-icing efforts, agencies may conduct deicing activities. Normally deicing is conducted when the temperature drops at the end of the storm activities and the snow/ice has bonded to the pavement.

Deicing chemicals work by lowering the freezing point of water. As the snow/ice turns to water, the deicing chemicals will become diluted and may need to be reapplied.

Figure 7–8. Urban application of deicing chemicals (WDM)

Chemicals for Anti-icing and Deicing

Common materials are sodium chloride or rock salt (NaCl) (dry, wet, or in solution, or brine), calcium chloride ($CaCl_2$), magnesium chloride ($MgCl_2$), and calcium magnesium acetate (CMA). Figure 7–9 shows the lowest temperatures at which these materials are generally effective. For applications rates, see your agency's procedures.

In Iowa, the most common deicing chemicals are salt and calcium chloride solutions. A salt solution or brine (23.3 percent concentration) freezes at 18°F; a calcium chloride solution (29.8 percent concentration) freezes at -20°F.

Salt

Salt is the most common deicing material used in Iowa. In addition to being an effective deicing material, salt provides immediate anti-skid protection while starting the melting process.

To effectively melt snow and/or ice (and therefore prevent or break the bond with the pavement), salt must be dissolved in solution. If dry salt is applied to a pavement, the necessary moisture for dissolution must come from pavement surface moisture or from humidity in the air. If the pavement temperature is below freezing, dry salt rapidly loses its effectiveness because moisture on the pavement needed to make salt solution is already frozen.

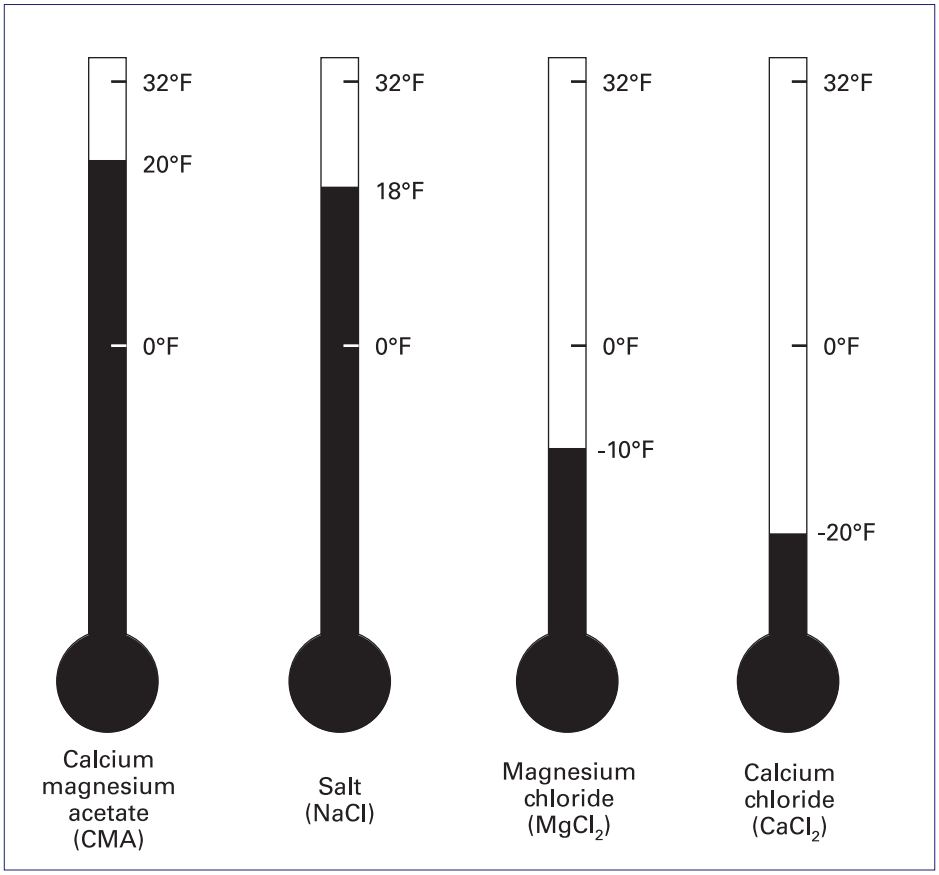


Figure 7–9. The lowest temperature at which different chemicals are effective

Guidelines for Applying Salt

- For deicing activities on two-lane pavements with low to medium traffic volumes, apply a windrow of salt in a strip along the centerline. Traffic will move salt off the centerline. The resulting salt brine will move down the pavement cross slope and toward the shoulders, melting snow and ice across the entire road width. With this application pattern, less salt is wasted (than with spinners, for example) and quickly gives vehicles clear pavement under at least two wheels.
- For deicing activities on multiple-lane pavements with medium to high traffic volumes, apply salt in a pattern that covers the full width of the roadway to provide melting action over the full width of the pavement.
- "Play the wind" when spreading salt. A strong wind blowing across a street or roadway can cause salt to drift as it comes out of the spreader, perhaps blowing salt onto the shoulder and into the ditch or into a street gutter. This is particularly true in rural areas where there are few wind breaks. How the wind affects spreading depends on both wind velocity and pavement condition. Use the wind to help distribute the salt where you want it.
- On super-elevated curves, apply salt to the high side of the curve so the brine will flow down and across the roadway.

RULE OF THUMB

If snow is blowing across and off the road, let the wind help with snow removal. In these cases, be careful not to wet the pavement surface by adding chemicals that will cause snow to begin sticking and creating slick spots on the roadway.

Pre-Wetting Salt

Pre-wetting salt has become common practice. Wetting provides moisture to make brine, resulting in faster melting action. In addition, wet salt has less tendency to bounce off the road or to be blown off by traffic, saving 20 to 30 percent in wasted salt, which can more than pay for pre-wetting.

Common chemicals used for pre-wetting salt are liquid calcium chloride and salt brine:

- Liquid calcium chloride is used widely for pre-wetting salt because it draws moisture from the air and releases heat when it dissolves. Applications of 6 to 10 gallons per cubic yard of salt are recommended. Calcium chloride has the added advantage of melting snow/ice at lower temperatures.
- Using salt brine to pre-wet is becoming more common because of its lower cost. Some agencies are producing their own salt brine solution (23 percent). Liquid calcium magnesium acetate and magnesium chloride are also used.

Some agencies pre-wet the salt by spraying it as it is loaded into the truck. However, the application is more uniform if truck-mounted equipment is used to spray the salt as it leaves the spreader. This also eliminates the problem of handling pre-wetted salt that is not immediately used.

Salt Brine

Salt brine is commonly used in Iowa for anti-icing activities. Salt brine is a mixture of approximately 23 percent rock salt and water.

Although commercial brine makers are available, many agencies manufacture their own brine makers with water tanks and PVC pipe. The brine can be stored in large tanks where it will be convenient for loading the material into saddle tanks on the sides of the V-box or anti-icing equipment.

Calcium Chloride

Calcium chloride is more expensive than salt and requires special handling. In addition, it tends to leave the pavement wet for a while, causing blowing snow to stick to the pavement. But calcium chloride is more effective in melting snow and ice at lower temperatures than salt and is faster acting. Calcium chloride draws moisture from the air and, when it dissolves, actually gives off heat. These unique properties make it valuable in severe conditions. Used strategically, usually in combination with salt, calcium chloride can be a useful and cost-effective deicing material.

Mixing even a small amount of calcium chloride with salt (see Pre-wetting Salt earlier in this chapter) can be very effective. The calcium chloride will start melting quickly, and the resulting brine and heat allow the salt to start working faster.

Store calcium chloride in moisture-proof bags until needed. Otherwise, its ability to draw moisture can cause it to cake into large chunks.

There are four methods of applying liquid calcium chloride:

1. Dispensed from a tank on the spreader at the same time the salt is spread on the road.
2. Applied to each loader-bucket of salt just before salt is placed in the spreader.
3. Applied to entire load of salt in the spreader.
4. Applied to entire salt stockpile before the winter season.

Enhancing Friction

Sand and other abrasives improve vehicle traction on snow and ice-covered roads. (Even dry or pre-wetted salt improves traction briefly after it is spread.) Abrasives can be used at all temperatures, but their use is especially important when it is too cold for chemical deicers to work. Since abrasives must stay on the surface to be effective, they should not be used when they will be covered with more snow or when they will be blown off quickly by traffic. Heavy traffic reduces the effectiveness of abrasives, requiring repeated application.

Sand is the most commonly used abrasive, but slag, cinders, and bottom ash from power plants are also used.

Sometimes deicing chemicals are mixed with sand. The sand gives immediate traction, and the chemicals melt the snow either immediately or when the temperature rises. However, to be effective the chemical must remain on the

pavement, which is difficult to achieve in most cases. Mixing salt with sand reduces the salt's melting effectiveness.

A minimum amount of salt (50 to 100 pounds of salt per cubic yard) must be mixed with abrasives to keep them unfrozen and usable. Pre-wetting sand with liquid deicing material is also effective. The chemical helps to anchor the sand into the ice surface, makes the sand easier to load from the stockpile, and causes the sand to spread more evenly from mechanical spreaders.

Keeping Records

During snow and ice control operations, equipment operators may be required to record their activities. Such records can serve two purposes: They help staff track and manage current operations, and they provide information to help supervisors and operators improve future operations.

The information to be reported on trip tickets will vary from agency to agency. Check with your supervisor. Sample information includes the following:

- Operator's name
- Vehicle ID
- Date(s) and duration of shift
- Description of roads treated
- Beginning and end times of each treatment cycle
- Treatment locations and time if not done on a prescribed cycle
- Type of treatment performed on each cycle or run
- Road and traffic conditions observed on each cycle or run
- Percentage of streets cleared, by classification
- Total personnel in the field
- Inventory of equipment and operational status
- Inventory of materials
- Number and extent of breakdowns, and future availability of equipment
- Accumulation of overtime
- Snow accumulation
- Planned operations

After the Storm

Conduct post-storm activities as soon as possible so you are ready for the next snowfall.

Material and Equipment

- Return unused materials to the stockpile.
- Wash trucks and clean equipment.
- Check all blades.
- Check skid shoes on wings for excessive wear.
- Look over all equipment and check for cracks in welds or any missing parts. Point out any problems to your shop mechanic.
- Do another walk around of the truck checking tires, lights, and wipers.

Sewer Drains

Clear drains so that melting snow and ice can move quickly off the road.

Snow Storage

Sometimes local agencies don't have room on or near the roadway to store the snow that has been plowed. This is fairly common in urban areas. To move the snow and completely clear traffic lanes and parking spaces, local agencies load the snow into trucks and haul it away to remote storage areas.

Storage areas may be on or near a lake or in remote open areas. They should be in locations that can handle the snow-melt runoff without overburdening existing drainage features and without violating Environmental Protection Agency requirements.

BIBLIOGRAPHY

American Association of State Highway and Transportation Officials (AASHTO). 1997. *Highway Safety Design and Operations Guide.* Washington, DC: American Association of State Highway and Transportation Officials.

Andrle, S.J., K. Knapp, T.J. McDonald, and D.E. Smith. 2001. *Iowa Traffic Control Devices and Pavement Markings: A Manual for Cities and Counties.* Iowa DOT Project TR-441. Ames, IA: Center for Transportation Research and Education.

Federal Highway Administration (FHWA). 2003. *Manual on Uniform Traffic Control Devices (MUTCD) for Streets and Highways.* 3rd Ed. Washington, DC: United States Department of Transportation, Federal Highway Administration.

Iowa One Call (IOC). 2006. Iowa One Call Home. http://iowaonecall.com/index.php.

Minnesota Local Road Research Board (LRRB). 2005. *Minnesota Snow and Ice Control: Field Handbook for Snowplow Operators.* Manual Number 2005-1. St. Paul, MN: Minnesota Local Road Research Board.

Salt Institute. 1991. *The Snowfighter's Handbook: A Practical Guide for Snow and Ice Control.* Alexandria, VA: Salt Institute.

BIBLIOGRAPHY FOR THIS MANUAL

AASHTO's *Green Book* and Iowa DOT's design guide

American Association of State Highway and Transportation Officials (AASHTO). 1997. *Highway Safety Design and Operations Guide.* Washington, DC: American Association of State Highway and Transportation Officials.

Andrle, S.J. and T.J. McDonald. 2005. *Iowa Drainage Law Manual.* IHRB Project TR-497. Ames, IA: Center for Transportation Research and Education.

Andrle, S.J., K. Knapp, T.J. McDonald, and D.E. Smith. 2001. *Iowa Traffic Control Devices and Pavement Markings: A Manual for Cities and Counties.* Iowa DOT Project TR-441. Ames, IA: Center for Transportation Research and Education.

Bolander, P. and A. Yamada. 1999. *Dust Palliative Selection and Application Guide.* Final Report. 9977-1207-SDTDC. San Dimas, CA: United States Department of Agriculture, Forest Service, San Dimas Technology and Development Center.

Federal Highway Administration (FHWA). 2003. *Manual on Uniform Traffic Control Devices (MUTCD) for Streets and Highways.* 3rd Ed. Washington, DC: United States Department of Transportation, Federal Highway Administration.

Hallmark, S.L., T.J. McDonald, D. Veneziano, J.L. Graham, K.M. Bauer, R. Patel, and F.M. Council. 2006. *Safety Impacts of Pavement Edge Drop-Offs.* Washington, DC: AAA Foundation for Traffic Safety.

Iowa One Call (IOC). 2006. Iowa One Call Home. http://iowaonecall.com/index.php.

Kannel, E. and T.J. McDonald. 2002. *Traffic Control Strategies in Work Zones with Edge Drop-Offs.* Final Report. CTRE Project 97-15. Ames, IA: Center for Transportation Research and Education.

Knight, M.L., G.S. Wilson, W.J. Seger, and S. Mahadevan. 2004. Overlay Types Used as Preventive Maintenance on Tennessee Bridge Decks. *Transportation Research Record* 1866: 79–84.

Lunsford, G.B. and J.P. Mahoney. 2001. *Dust Control on Low Volume Roads: A Review of Techniques and Chemicals Used.* Final Report. FHWA LT-01-002. Washington, DC: United States Department of Transportation, Federal Highway Administration, Local Technical Assistance Program.

Miller, J.S. and W.Y. Bellinger. 2003. *Distress Identification Manual for Long-Term Pavement Performance.* 4th Ed. FHWA-RD-03-031. Washington, DC: Federal Highway Administration.

Minnesota Local Road Research Board (LRRB). 2005. *Minnesota Snow and Ice Control: Field Handbook for Snowplow Operators.* Manual Number 2005-1. St. Paul, MN: Minnesota Local Road Research Board.

Salt Institute. 1991. *The Snowfighter's Handbook: A Practical Guide for Snow and Ice Control.* Alexandria, VA: Salt Institute.

Skorseth, K. and A.A. Selim. 2000. *Gravel Roads Maintenance and Design Manual.* Washington, DC: Federal Highway Administration and South Dakota Local Transportation Assistance Program.

Souleyrette, R., T.J. McDonald, Z. Hans, A. Kamyab, T. Welch. 2001. *Paved Shoulders on Primary Highways in Iowa: An Analysis of Shoulder Surfacing Criteria, Costs, and Benefits.* Final Report. Ames, IA: Center for Transportation Research and Education.

Sprinkel, M. 2001. Maintenance of Concrete Bridges. *Transportation Research Record* 1749: 60–63.

Transportation Research Board (TRB). 1991. *Hot-Mix Asphalt Paving Handbook.* Washington, DC: Transportation Research Board.

Walker, D. 1989. *Concrete PASER (Pavement Surface Evaluation and Rating) Manual.* Madison, WI: Wisconsin Transportation Information Center.

Walker, D. 1989. *Gravel PASER (Pavement Surface Evaluation and Rating) Manual.* Madison, WI: Wisconsin Transportation Information Center.

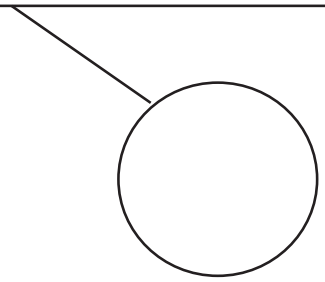
Walker, D. 2001. *Sealcoat PASER (Pavement Surface Evaluation and Rating) Manual.* Madison, WI: Wisconsin Transportation Information Center.

Walker, D. 2001. *Unimproved Roads PASER (Pavement Surface Evaluation and Rating) Manual.* Madison, WI: Wisconsin Transportation Information Center.

Walker, D. 2002. *Asphalt PASER (Pavement Surface Evaluation and Rating) Manual.* Madison, WI: Wisconsin Transportation Information Center.

Wipf, T.J., F.S. Fanous, F.W. Klaiber, A.S. Eapen. 2003. *Evaluation of Appropriate Maintenance, Repair and Rehabilitation Methods for Iowa Bridges.* Final Report. Iowa DOT Project TR-429. Ames, IA: Iowa Department of Transportation.

Appendix A: Sample Door Knocker



Date:_____

Dear Resident,

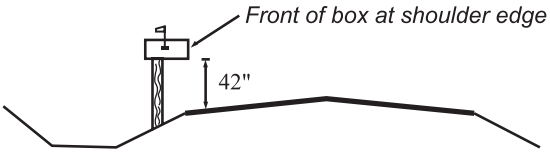
The Linn County Secondary Road Department will begin a grading project on _____. If you have a mailbox or other obstacles within the right of way, please remove them as soon as possible. You should coordinate a temporary location for the mailbox with your post-master.

When work is completed, install the mailbox so that the face of the mailbox is at the edge of the shoulder as shown below. Installation in this manner will allow the carrier to pull out of the lane of traffic to make deliveries. It will also allow the shoulder areas to be plowed more easily in the winter. Mailboxes that are within the roadway are more prone to being hit by vehicles or plowed snow.

The post office has informed us that the height of the mailbox is to be such that it can be reached from a car, approximately 3-1/2 feet above the ground.

We request that mailboxes be installed on a wood post no larger than 4"x4". This type of post is considered a "breakaway" post which may limit or reduce the possibility of serious injury if an accident should occur.

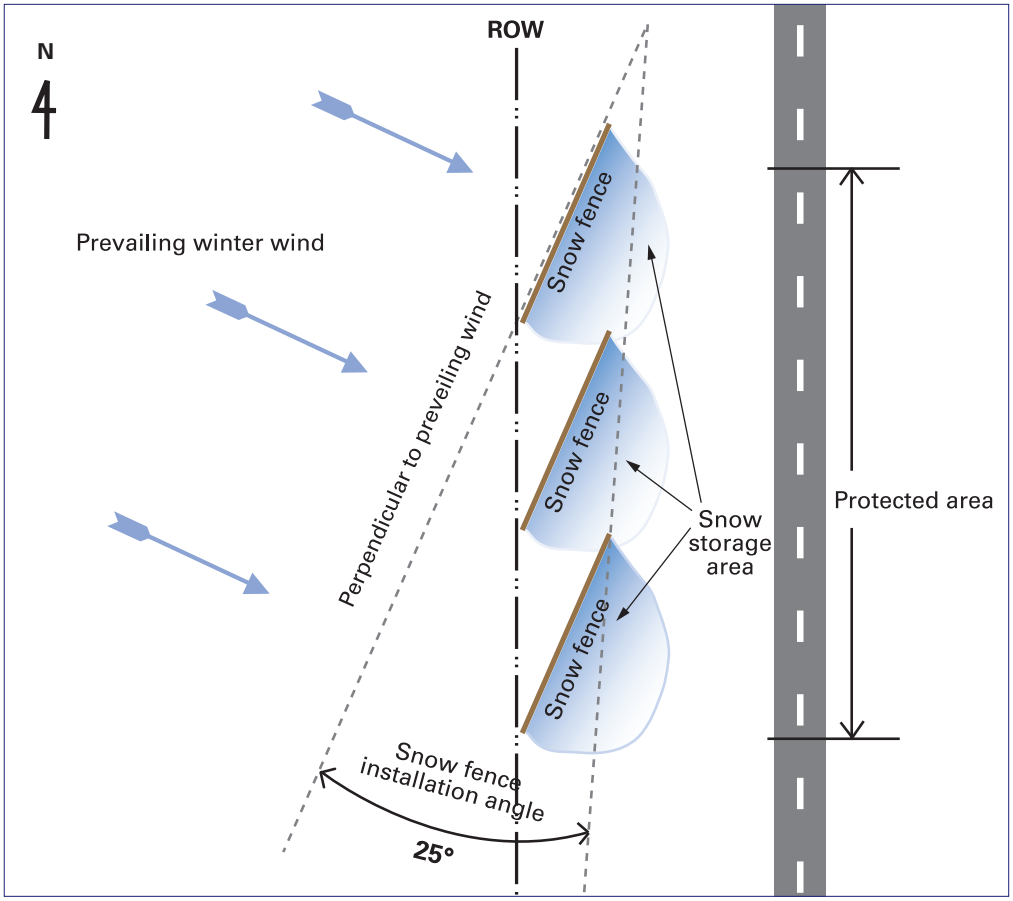
Concrete posts, milk cans and other types of mailbox holders are considered obstructions on the right of way which are prohibited by law.



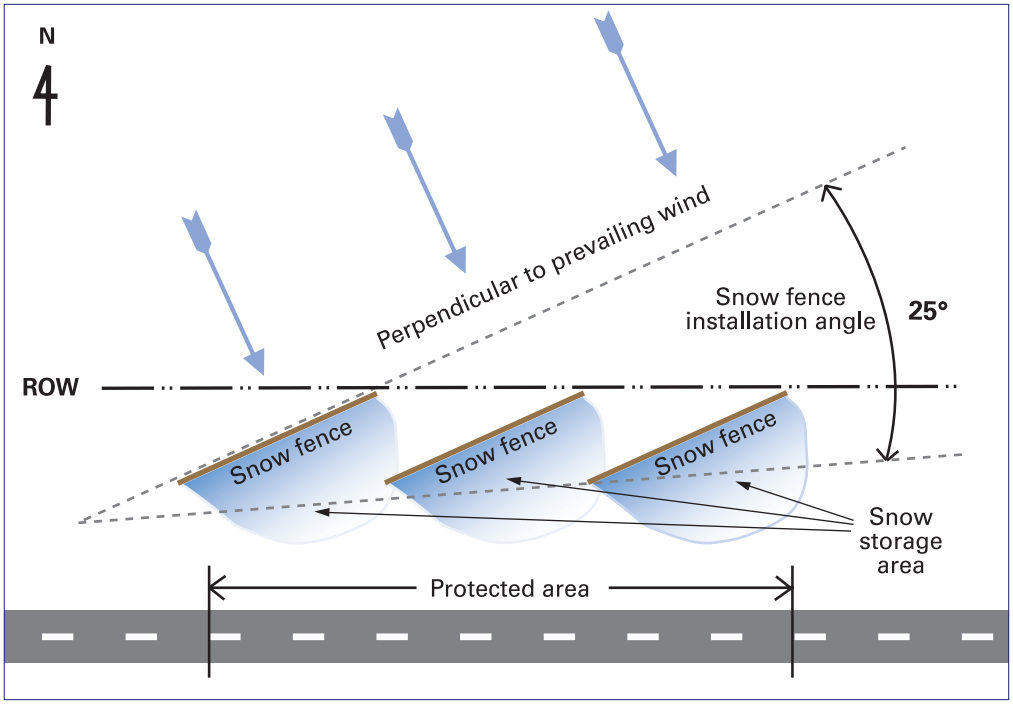
Linn County Secondary Road Department

1888 County Home Rd
Marion IA 52302
(319) 829-6400

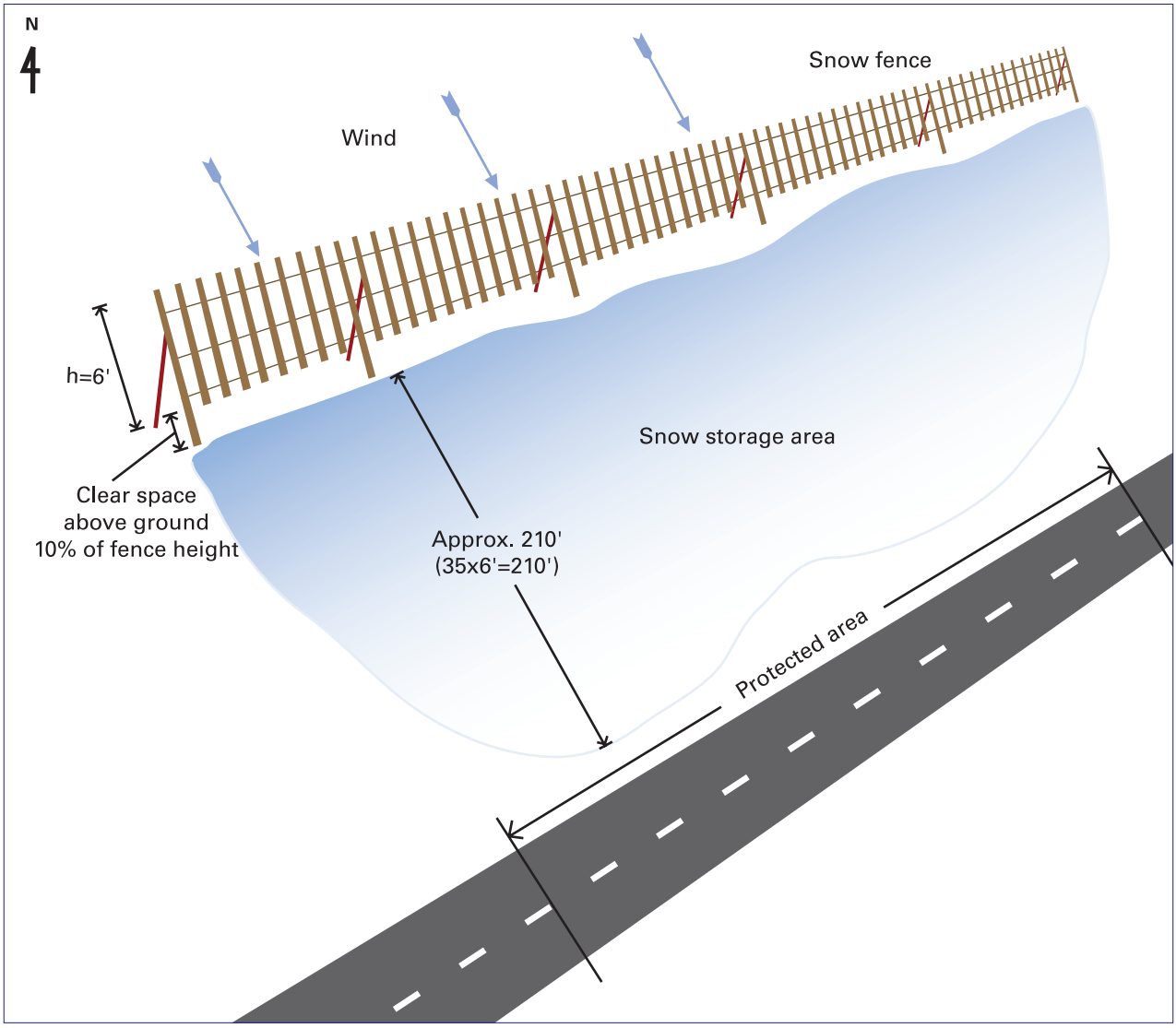
Appendix B: Snow Fence Installations



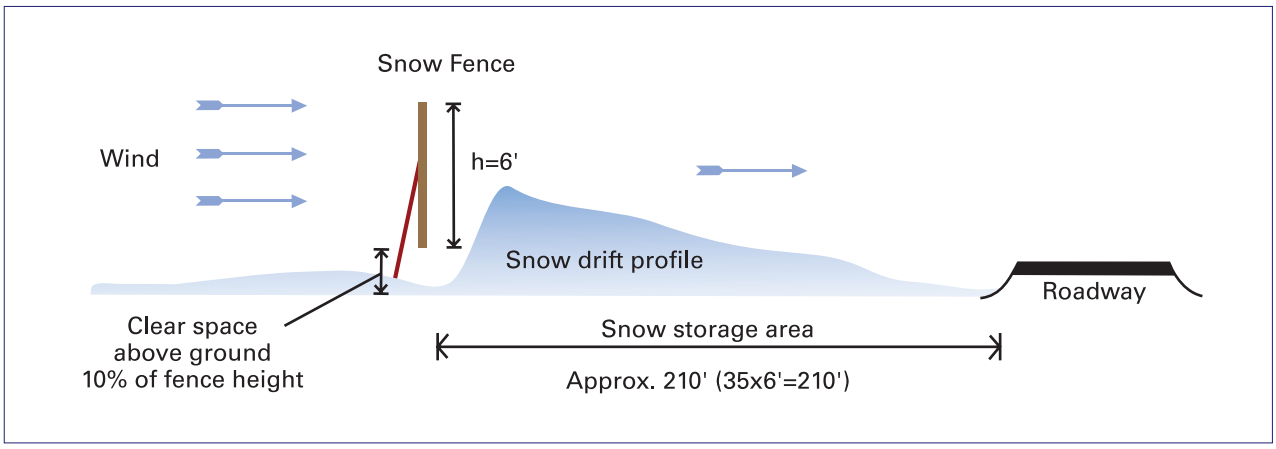
Snow fence location on north/south roadway



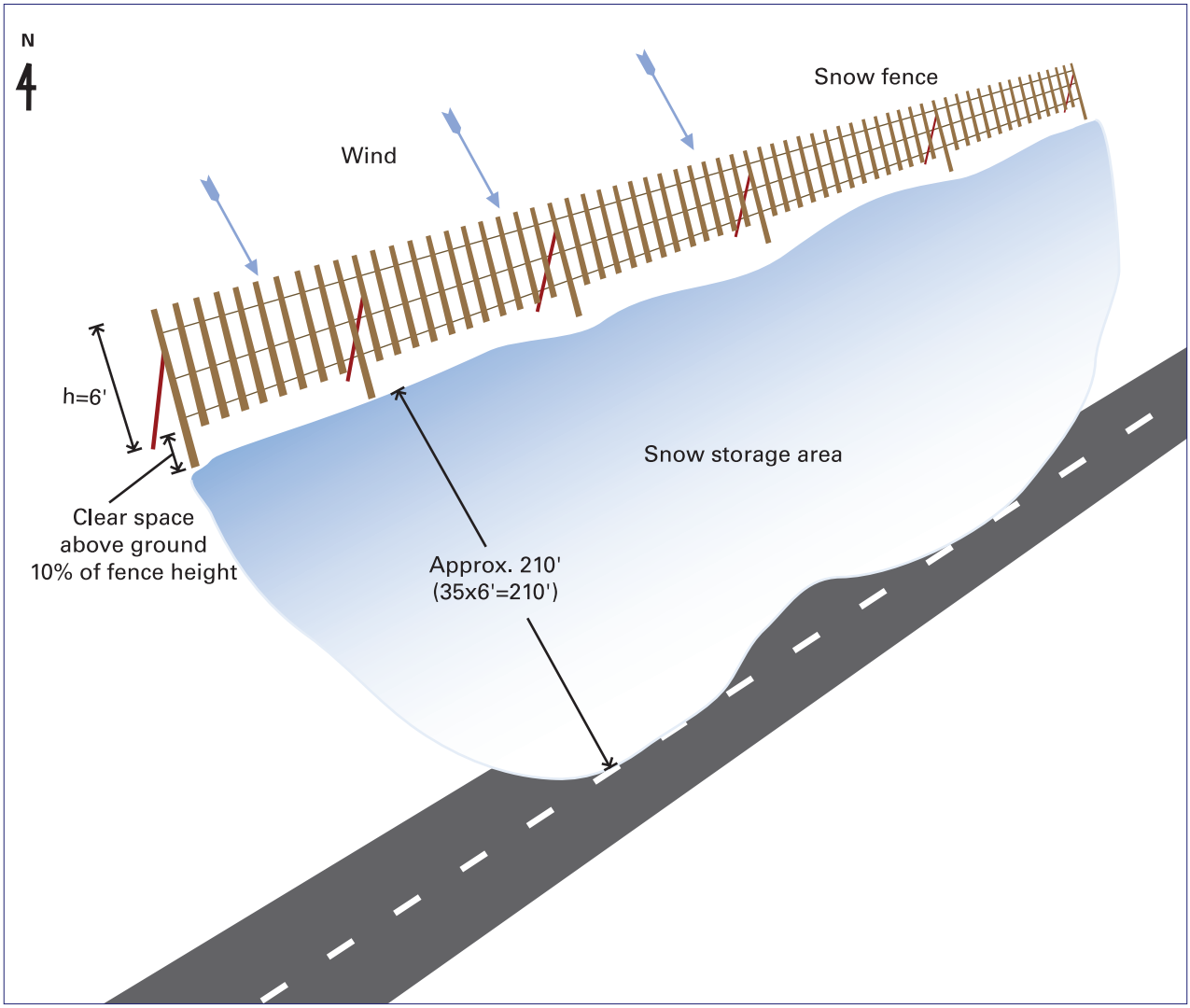
Snow fence location on east/west roadway



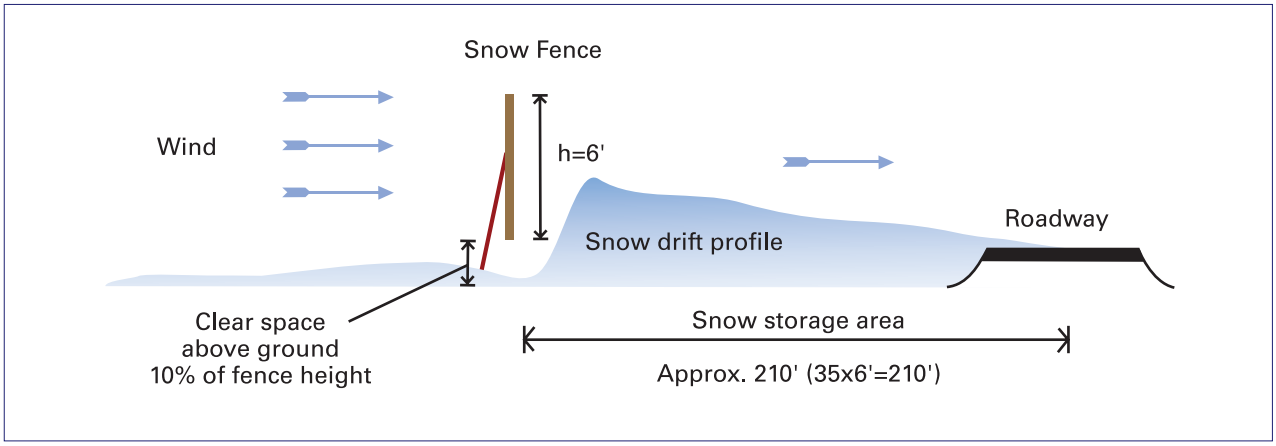
Proper snow fence installation (profile view): more than 35xh from roadway



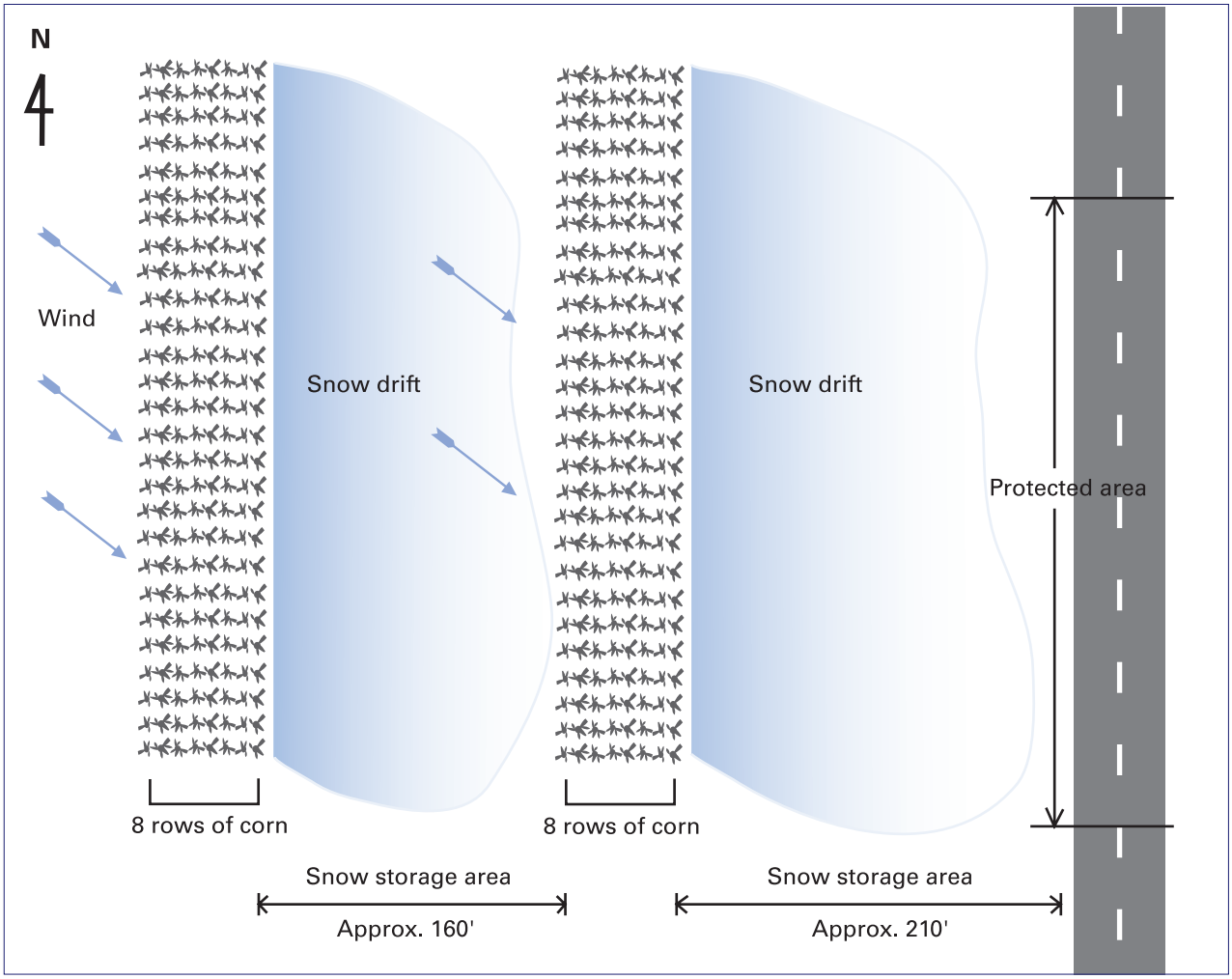
Proper snow fence installation (diagram view): more than 35xh from roadway



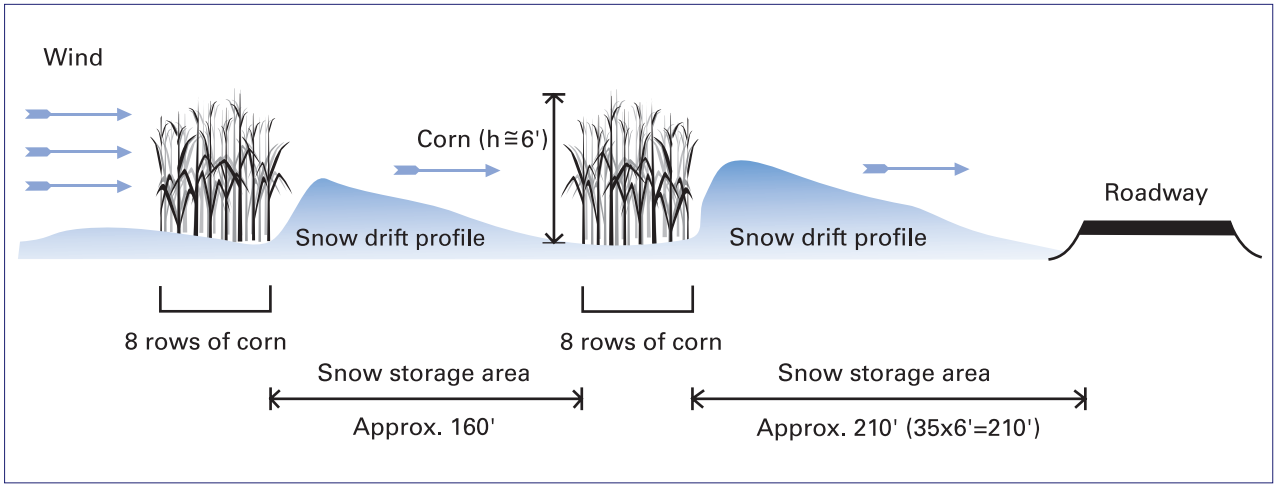
Inproper snow fence installation (profile view): less than 35xh from roadway



Inproper snow fence installation (diagram view): less than 35xh from roadway



Corn rows as a snow fence (plan view)



Corn rows as a snow fence (diagram view)

Appendix C: Snow and Ice Control Equipment Checklist

Spreaders

- ☐ Inspect pumps, hoses, controls, and fittings.
- ☐ Check spinners, augers, and auxiliary engines.

Hydraulic spreader controls

- ☐ The two major components are the pump and the controls, whether manual or automatic. Operators should become familiar with spreader controls. Understand how the auger, or conveyor, and the spinner react at various settings.

Snow plow blades

- ☐ Carefully inspect blades after each use. If blade wear is excessive it may damage the moldboard. Snow plow blades do not wear evenly and should be replaced when they are worn at any point.

Electrical equipment

- ☐ Inspect and service all lighting and electrical equipment regularly, including wiring and sockets.
- ☐ Carry ample stocks of parts for rotating flasher units, including lenses and lamps.

Safety equipment

- ☐ Make sure there are flashlights, flares, flags, safety vests, and first-aid kit in truck cabs.
- ☐ Don't start a run without securing your seat belt.

Plan for emergencies

- ☐ Know the locations and telephone number of emergency repair and refueling stations.
- ☐ Skilled personnel should be on hand in garages during storms to promptly carry out minor repairs.

  Replenish spare parts inventory immediately following storms, or at the first opportunity.

Appendix D: Snow Plow Checklist

Tires and wheels

- ☐ After the truck has been inside overnight, inspect wheels for oil and/or fluid leaks.
- ☐ Look for tire damage (e.g., deep cuts or severe weather wear). Tire tread should be a minimum of ⅛ inch.
- ☐ Inflate tires to the pressure indicated on the sidewalls.
- ☐ Make sure wheel lugs are tight and check to see if they have recently slipped. A mark to the side of each wheel lug is a good indication that the wheel has spun. Some mechanics center the valve stem between two lugs, then by just looking at the stem they can tell if the wheel has spun.
- ☐ Check the axle bolts for tightness.
- ☐ Look for leaking around the wheel seals.

Hoses

- ☐ Check for oil leaks along each hose and around each fitting.
- ☐ When the box is raised for hose inspection, make sure the box stops are in place. Lower the box onto the stops before beginning inspection.
- ☐ Hydraulic hoses should not be pinched or rubbing against another surface. Make a note of these potential problem areas.

Lights

- ☐ Amber warning lights mounted above the truck cab are on when the truck is operated.
- ☐ Make sure brake lights work properly.
- ☐ Check both high and low beams of head lights, chassis head lights, and higher plow lights.
- ☐ Turning signals must work properly.
- ☐ Check clearance lights, both in front of the cab and front rear corners of the dump box. (These lights help drivers see how wide your vehicle is.)
- ☐ Check spinner lights. They allow operators to see the material being spread.
- ☐ Check strobe lights, which help motorists see the truck when bad weather interferes with visibility.
- ☐ Check to see that all reflectors are in place: amber in front and red in back.

Under the hood

- ☐ Change fuel filters at the beginning of the winter season.
- ☐ Check for water in the fuel water separator and drain.
- ☐ Look for fuel leaks along the fuel lines and on the garage floor.

Engine oil

- ☐ Check the oil level.

- ☐ Check the color of the oil. A chocolate milky color could indicate anti-freeze is getting into the oil.
- ☐ Smell the oil. A burned smell may indicate engine overheating.
- ☐ Look around the engine compartment for oil leaks. (Small amounts of oil in and around an engine are normal.)

Engine coolant system

- ☐ Check the radiator coolant level and add coolant if necessary.
- ☐ Check for coolant leaks around hose connections.
- ☐ Look for wet spots on the radiator and garage floor.
- ☐ Inspect the fan belts for frays and cracks and report the problem areas.
- ☐ If the truck has a manual transmission, get under the truck and remove the transmission plug. The fluid level should be level with the check or fill plug.
- ☐ If the truck is an automatic transmission, check the transmission fluid level. Add transmission fluid if necessary, but don't fill beyond the full mark.

Truck toolbox

- ☐ Check the condition of tire cables or chains. Mount them to be sure that they fit.
- ☐ Make sure the toolbox contains a hand shovel, towing chains, extra plow and wing pins, extra pin safety clips, and any tools you may need out on the road.

Truck cab

- ☐ Keep the cab clean, with no loose items like pop cans, bottles, or log chains.
- ☐ Make sure the fire extinguisher is properly mounted and fully charged.
- ☐ Make sure the following items are in the cab: ice scraper, wisk broom or snow brush for brushing snow off your lights, flashlight, well-stocked first-aid kid (with CPR mask), and emergency reflector kit.
- ☐ Check the safety belts, making sure the locks work.
- ☐ Check the two-way radio and make sure the display or power light turns on.
- ☐ Check the dash lights and gauges to make certain they are all working.
- ☐ Make sure that you have accident report forms.
- ☐ Check the windshield for serious damage. Report any problems.
- ☐ Check the wiper blades for damage or aging.

Mounting brackets

- ☐ Check all brackets to make sure they are secure and that all bolts are in place and tight.

Heating and defrosting system

- ☐ As the engine heats up, make sure all heater fan speeds are operational and that the heat produced is adequate to keep windows clear.

Appendix E: Snow and Ice Removal Pre-Trip Checklist

Under the truck

- ☐ Leaks on floor
- ☐ Wires or hoses hanging down

Under the hood

- ☐ Oil and coolant
- ☐ Water separator
- ☐ Belts and hoses
- ☐ Signs of leaks
- ☐ Washer fluid level

Outside the truck

- ☐ Left mirror brackets
- ☐ Hydraulic diverter valve for proper position
- ☐ Lights and reflectors
- ☐ Left rear wheels, tires, hub, and springs
- ☐ Tailgate chains or supports for proper adjustment
- ☐ Sander doors for proper position
- ☐ Left rear wheel, tire, hub, and springs
- ☐ Sander hoses, fittings, and mountings
- ☐ Right rear wheels, tires, hub, and springs
- ☐ Wing for mountings, hoses, etc.
- ☐ Hydraulic tank sight glass
- ☐ Exhaust system
- ☐ Right front wheel, tire, hub, springs, and shock
- ☐ Plow for mountings, leaks, blades, and frame
- ☐ Left front wheel, hub, springs, and shock

Inside the cab

- ☐ Horn
- ☐ Mirror alignment
- ☐ Steering
- ☐ Wipers and washers
- ☐ Gauges
- ☐ Clutch operation
- ☐ Lights
- ☐ Brakes (including parking brake) and brake lights
- ☐ Backup alarm and backup lights
- ☐ Turn signals

- ☐ Heater and defroster
- ☐ Dump vibrator
- ☐ Radio for operation
- ☐ Brine application system
- ☐ Hydraulic functions of plow and wing
- ☐ Fuel level
- ☐ Miscellaneous items (shovels, toolbox, tire chains, tow chains, etc.)
- ☐ Personal items
- ☐ Loose items in cab
- ☐ Start engine
- ☐ Turn on sander and check auger and spinner