Montana Association of
County Road Supervisors

MOTOR GRADER OPERATOR'S HANDBOOK

Local Technical Assistance Program

Department of Civil Engineering • Montana State University • Bozeman • Montana

Third Edition • September 1995

PREFACE

Montana Association of County Road Supervisors' Motor Grader Operator Certification

The majority of our local roads in Montana (90%) are gravel or dirt. Complaints about their maintenance are a constant headache for road supervisors and elected officials. In general, there are no set written standards of care and procedures that are followed. Training is intermittent and in some agencies may be non-existent.

The **Montana Association of County Road Supervisors'** (MACRS) solution to this problem is to provide a voluntary certification program on an individual or county basis. Once an equipment operator has had one year's experience working with motor graders, s/he is eligible for certification. This consists of passing a written test based on the ***Motor Grader Operator's Handbook*** and a practical, hands on evaluation of an operator's ability to perform certain tasks on a motor grader. When the operator has successfully completed these steps, a certificate will be sent to the operator's supervisor for signiture if s/he feels it is appropriate. The supervisor is usually the best person to adequately judge an operator's skills.

a. ***Motor Grader Operator's Handbook.*** The purpose of the handbook is to assist beginning and experienced county operators in providing safe, long lasting roads. It is a collection of the best information available on operating tips, roadway safety and roadway maintenance that every operator should know. There are study questions at the end of each chapter along with answers to study questions. Once an operator has mastered the handbook they will be given a comprehensive test. After passing the test he/she will be eligible to take the performance test on their own motor grader.

b. **Motor Grader Operator's Performance Test.** The purpose of the performance test is to evaluate the quality of an operator's performance, product, and safety in operation. Operators will be judged by an experienced operator approved by the Montana Association of County Road Supervisors. The test will be similar to the one used by the International Union of Operating Engineers as modified by the MACRS Committee on Motor Grader Operator Certification.

The First Edition of this handbook was published in September of 1990, and each county received at least one copy. The Second Edition was based on suggestions and questions that came up during motor grader workshops across the state. This 1995 edition incorporates new material, replaces outdated information, and tries to clear up some topics students found confusing during workshops. Future editions will be published as needed, as it is our wish to keep this handbook as current as possible. As always, comments, ideas and suggestions to make this the best possible training manual are always appreciated.

The LTAP staff will assist MACRS in publishing the performance test and coordinating individual tests. You may order a test by calling (800) 541-6671.

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FOREWORD

The purpose of this handbook is to assist beginning and experienced county motor grader operators in providing safe, long lasting local roads for the traveling public. The State of Montana has approximately 71,000 miles of roads. The Montana Department of Transportation maintains 81,000 miles; the cities maintain 2,500 miles, and the counties 60,000 miles. About 90% of the county roads are unpaved. It is recognized that funds for the construction, maintenance and operation of the local road system are limited. Therefore, this handbook is based on the fact that proper road maintenance reduces costs while keeping the roads in a safe, good condition for longer periods of time.

It is very important for you to go through the handbook chapter by chapter and master all of the material. There are study questions at the end of each chapter. Once you have mastered all the material you are eligible to take a final examination, which when you pass, will make you eligible to take the practical test on your own grader. You will need at least a year's experience operating a motor grader to pass the practical test. Then you will be certified as having completed all the Montana Association of County Road Supervisors requirements as a motor grader operator.

One might think we have overemphasized roadway safety. Operators should be aware that the public presently is spending more on county road accidents than they are on the roads themselves. In overall dollar terms about seventy million dollars are spent annually on accidents and only fifty million is spent on county roads. Thus, every operator should know the important part he can play in eliminating accidents. Sometimes two operators in the same road department do not agree on procedures. This can be a problem because one of the basic concepts of roadway safety is uniformity. The reason it is so important is that driver expectancy should be the same on all roads. Publishing this handbook is directed toward that end.

To be a good operator, you must expend a lot of time and effort. You need to know your equipment, your roads, proper operating procedures, the law, and the policies of your department.

Congratulations on your endeavor to become a better operator. If you have any questions regarding this program, please contact your county road supervisor.

Alan Jackson, Retired
Rural Technical Assistance Program
September 1990

Steve Jenkins, P.E.
Local Technical Assistance Program
August 1995

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2. Taking Control of Your Motor Grader (19 minutes) & How to Get More Out of Your Motor Grader (23 minutes), John Deere, #609

3. Motor Grader Operation – Part 1, Part 2, Part 3, Washington State Department of Transportation, 20 minutes each, #s 611, 612 & 613.

4. Blading Unpaved Roads, Federal Highway Administration, 22 minutes, #614.

5. Blade Patching and Blade Mixing, Montana Department of Highways, 23 minutes, #470.

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   - Patching Unpaved Roads, 12 minutes, #1907
   - Smoothing & Reshaping of Earth and Gravel Roads, 20 minutes, #1908.
   - Regravelling, 18 minutes, #1909.
   - Reshaping Earth & Gravel Shoulders, 16 minutes, #1910.
   - Replenishing Earth & Gravel Shoulders, 19 minutes, #1911.
   - Mechanical Cleaning of Unlined Ditches, 20 minutes, #1912.
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TO BORROW VIDEO REFERENCES (RENT FREE), Call or Write:

Local Technical Assistance Program
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Bozeman, MT 59717-0390
or
Call toll-free (800) 541-6671 or (406) 994-6100

Even though we have proofread the Handbook a number of times during production, there still may be errors that need to be corrected. If you find any errors, or if you feel something should be corrected, changed, added, or deleted, please use the "Found an Error" page in the back of the book to let us know.

Acknowledgements

In acknowledging assistance in any project, there is always risk of leaving someone important out. So the editors would like to universally thank everyone who was involved, from the people who took the time to respond with comments on the First Edition, to the MACRS members who felt this project was important enough, good or bad, to present their views.

This handbook would not have been possible, however, without the specific assistance of Roy Symons, Montana Department of Highways; and Doug Ford, Gallatin County.

"Thank you"

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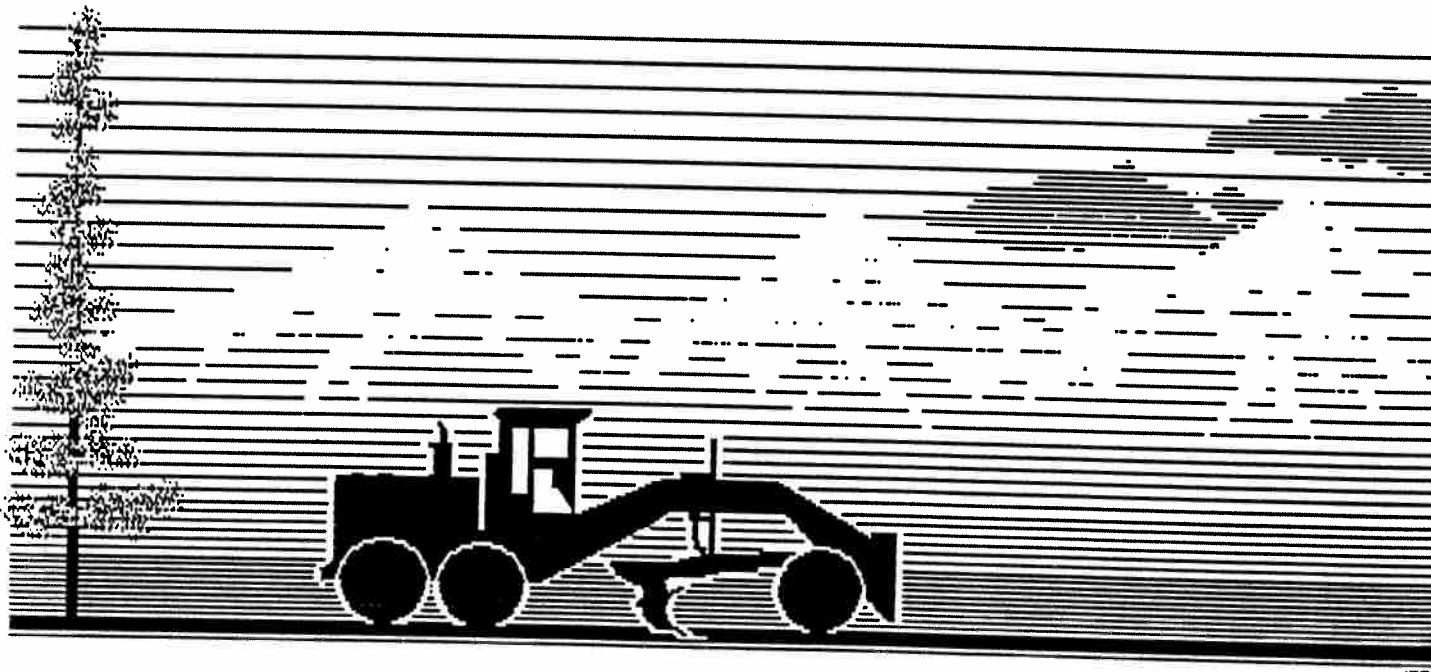


CHAPTER 1
MOTOR GRADER BASICS

1.1
GENERAL INFORMATION

There are a number of excellent references listed at the front. They should be used as supplemental material to the information contained in this handbook.

You are not expected to be a *trained mechanic*, however, you are expected to know enough about the equipment you operate to *recognize* mechanical defects that might occur during operation. Abuses to equipment occur from casual or uninformed operators. You are not asked to diagnose trouble when it arises, but to describe on Repair Orders the symptoms you have noticed, and to know when the trouble is serious enough to shut down a piece of equipment.

The motor grader is a complex machine, the operation of which requires good coordination, and to some extent, a certain natural ability. These skills are acquired through hundreds of operation hours. It is hoped this program will improve the performance level of present operators, and provide a knowledge base on which potential operators can develop skills.

Something to always keep in mind is the basic design of any machine that you are operating. A motor grader is designed to level or smooth an area. It has a long wheel base that can span short depressions or humps. The blade is carried in the center so the hump can be cut off, or a depression filled, by the action of the machine. Do not "fight" the controls as this will keep the machine from performing its job. The tandem wheels also allow the wheels to rise and fall without a severe effect on the frame of the machine.

The moldboard is pulled by a draw bar which is fastened in the center of the front wheels. This is designed to take the stress, so do not apply heavy pressure when you are operating in reverse and the blade is lowered. Moldboards provide flotation and more uniform traction.

The moldboard is attached to the circle near the center. This makes it necessary to watch both ends of the blade during operation. When you lift one end of the blade, the other end will go down about 1/4 the distance. If the circle is not level, the blade setting will change with the angle of the blade. All of these factors make it difficult to change blade settings while moving. The fewer changes you make while moving, the better your work will be.

It is important to operate the machine while sitting down so that you can feel movement in the machine. Learn to drive in a straight line. This can best be done by watching ahead, lining up some object, and driving toward it. Do most of your turning around in the borrow pits to avoid tearing the edge of the roadway with the tandems. Articulated graders can turn around on the roadway without dropping over the shoulders. Learning to use the advantages you gain with articulation are

worth the effort.

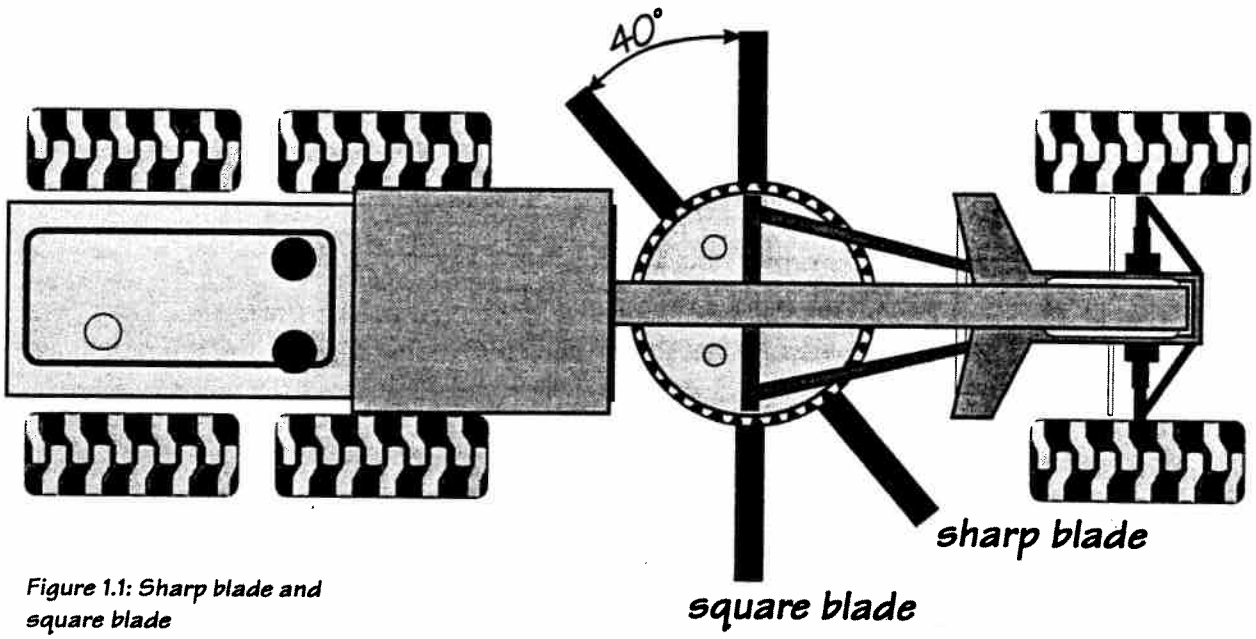


Figure 1.1: Sharp blade and square blade

Following are some common terms used in motor grader operation:

1. **Sharp Blade**: refers to the angle of the blade in relation to a line at right angles to the machine, and will be an angle greater than 30 degrees from that line.
2. **Square Blade**: also refers to the blade angle and will be from the right angle line to 30 degrees from that line.
3. **Pitch**: is the angle the cutting edge sits in relation to the road.
4. **Moldboard**: what the blade is fastened to.
5. **Cutting Edges**: the blade.
6. **Ice Blades**: serrated or saw tooth cutting edges.
7. **Loose Blade**: refers to setting the blade so that it touches the surface, but the weight of the blade is supported by the machine.
8. **Tight Blade**: refers to setting the blade so that it has some down pressure on the surface.
9. **Float**: the blade rests on the surface without any hydraulic pressure.
10. **Toe of the Blade**: the leading end of the blade.
11. **Heel of the Blade**: the following end of the blade.
12. **Articulating Frames**: frames that pivot in the middle of the machine for better traction and handling.

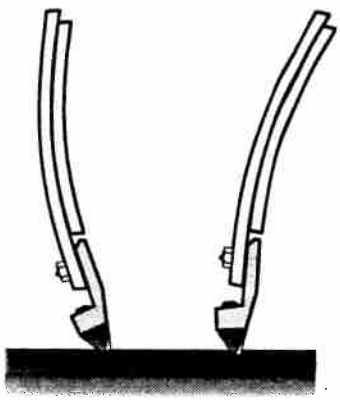


Figure 1.2: Pitch

There are many factors that influence blade settings. We will discuss these in the operation section of this manual as they pertain to the different operations being performed. Try to make as few changes as possible while moving and your work will come out better. Always remember that when you adjust

one end of the blade, the other end will also need adjustment. If you raise one end of the blade, the other will go down about 1/4 of the distance. Your blade setting will also change if you side shift or turn the blade. These factors are why it is best to make as few changes as possible while moving. The machine will work to level the area if you set it right before starting a pass. Learn the "feel" of the controls on your machine so that you know how fast or slow they move the blade.

Operating speed is an important factor of the quality of work you produce. When ditching or blading, you must not try to hurry. A higher rate of speed could cause the grader to bounce, gouging the surface rather than smoothing it. In extreme cases, the bouncing could cause you to lose control of the grader, producing a potential accident situation.

1.2
SAFETY FIRST — PROCEDURES

Prevention of accidents involving powered equipment is completely dependent on the person operating the equipment. No power-driven equipment, regardless of the type or the purpose for which it is used, can be safer than the operator. The manufacturer can incorporate features to make the operator's job safer, and controls to make it easier, however:

> AVOIDING SITUATIONS THAT MAY PRODUCE ACCIDENTS IS SOLELY UP TO THE PERSON AT THE CONTROLS, THROUGH FORETHOUGHT, JUDGEMENT AND SKILL.

A **careful operator** is the greatest safety device there is. **Stop accidents** before they stop you.

Most graders have been designed to incorporate every safety device possible. Even with all these safety features, however, there are still dangers. The operator must be extremely careful in the operation of a big machine like this. In order to help prevent accidents the following safety rules should be observed at all times.

1. Become well acquainted with the piece of equipment, the Operator's Manual, and Maintenance Manual. Know where all controls are located and what they operate.
2. All power equipment should be operated only by those who are responsible and delegated to do so.
3. In areas of possible danger, obey the decals located on the grader.
4. For safe operation observe proper maintenance and repair of all pivot points, hydraulic cylinders, hoses, snap rings and main attaching bolts, and inspect prior to each day's operation.
5. Keep the operator's platform free of debris.
6. Be sure no one is under or around the machine before starting.
7. Always face the machine when mounting and dismounting the grader.
8. Never jump from any machine.
9. Always maintain a firm grip on the hand holds while entering or leaving the

machine, and until you are in the seat or your feet are on the ground.

10. Clean your shoes of slippery materials to prevent slipping on steps, or off the pedals.
11. Keep windshield, windows, and mirrors clean at all times.
12. Pull the keys before servicing or repairing grader.
13. Check all controls to be sure they are operating correctly before putting the machine to work.
14. Do not leave the machine unattended with the engine running.
15. When shutting down, always cool engine 3 to 5 minutes. Lower all hydraulic equipment to the ground and set parking brake before leaving the cab.
16. Never coast the machine with transmission in neutral or with clutch disengaged. Maintain a ground speed consistent with conditions.
17. Avoid operation too close to banks or overhangs.
18. Be sure to shut the engine off when refueling, and do not smoke.
19. When you must work with hydraulic equipment raised, be sure to block it securely with blocks that will not crush.
20. Never operate the machine in a closed shed or garage: establish good ventilation and open the doors.
21. Do not oil, grease or adjust the machine when the engine is running, unless the operator manual specifies how to perform that operation.
22. Drive at speeds slow enough to insure safety and complete control, especially over rough terrain.
23. Increase the power gradually when pulling a heavy load or when driving out of a ditch or excavation.
24. Reduce speed when making a turn or applying brakes.
25. Keep brakes in proper adjustment. If you can't stop the machine, don't start it.
26. Never make repairs or tighten hydraulic hoses or fittings when the system is under pressure, when the engine is running, or when cylinders are under a load.
27. Be careful removing the radiator pressure cap when the radiator is hot.
28. Be very careful when using cold weather starting fluid. Wait at least ten minutes before using starting fluid if you have attempted to start the engine with a manifold heater. Crank the engine 5 to 10 seconds before attempting to use a manifold heater if you have used starting fluid first.
29. Always disconnect the battery ground strap before making adjustments on the engine or electrical equipment and before welding on any part of the unit. This will prevent dangerous sparks which create a fire hazard and may cause harm or damage. Disconnecting the battery also prevents accidental operation of the starter, or battery explosion.
30. Never permit persons other than the operator to ride on the grader.
31. Sound the horn before moving the grader.
32. Always look behind the grader before backing up.
33. Always be sure of water, gas, sewage, electrical and telephone line locations before you start any cut operations.
34. Always check overhead clearance, especially when transporting the unit.

(Know your maximum height before transporting.)

35. When deadheading the grader, always have the blade toed to the off traffic side, and carried high.
36. To prevent highway accidents, use workzone traffic control signs. Turn on yellow flashing cab lights whenever working on road surfaces. Display the "Slow Moving Vehicle" emblem.
37. Practice good housekeeping and clean out the cab at the end of each day.
38. It is the responsibility of the operator to make an inspection of the grader each shift. The use of defective or unsafe equipment is forbidden.
39. Look for leaks and check fluid levels.
40. Use safety equipment provided with the machine for your protection.

** Use common sense and good judgement. **

1.3
PRE-START PROCEDURES

1. Grease the machine according to the Operator's Manual. As you grease the machine, check for loose, worn, or broken parts; hydraulic system leaks; worn hoses; and leaks under the machine.
2. Check engine oil level.
3. Check coolant level in the radiator.
4. Check belts for adjustment and wear.
5. Check hydraulic oil level if equipped with hydraulic controls.
6. Check power steering reservoir.
7. Check air cleaner and connections and dump the dust cup if the machine has one.
8. Check fuel level and drain water from the fuel tank.
9. Check transmission oil level on power shift transmissions.
10. Lubricate the blade circle with graphite, diesel fuel or a mixture of diesel fuel and motor oil, according to Operator's Manual recommendations.
11. Check tires and wheels.
12. Check starting motor oil level if your machine has one.
13. After starting, check gauges, clutch free play, steering, lights and controls. Other checks indicated in the Operator's Manual may be necessary on certain types of machines, but these points cover the general checks.
14. Drain the condensate from the air tanks.

1.4
STARTING PROCEDURES

1. Make sure the parking brake is set and place the transmission in neutral.
2. For machines equipped with electric starting, open the throttle 1/4 and use the starter.
3. Always depress the clutch to lighten the load on the starter.
4. Never operate the starter continuously for more than 30 seconds. Then wait 2 minutes before using the starter again.
5. After the motor starts, check all gauges to see if they are operating. After 3

or 4 minutes of idling, set a fast idle to complete the warm-up.

6. Work the controls to make sure they operate and to warm up the hydraulic oil.

1.5
GENERAL SHUT-DOWN PROCEDURES AND END-TRIP CHECKS

1. Always cool out the engine for 3 to 5 minutes before shutting down.
2. Before leaving the cab lower all hydraulic equipment to the ground and set the parking brake.
3. Make a walk-around check including:
   - Loose, worn or broken parts
   - Hydraulic system hose and connection leaks
   - Any oil, grease, coolant or fuel leaks
4. After shutting down, check fuel, oil, coolant levels and blade wear; needed items can be brought out in the morning. If your blades are cupped in the middle and are not wearing straight, chances are you are not operating properly. See Chapter 3.1 "Drainage and Crowning" of a gravel road to find out how to correct this problem. If you have to change bits, order Video Tape #4002 for tips on easy blade changing. You should be able to change your blade bits in less than 15 minutes. Call the Rural Technical Assistance Program toll-free at (800) 541-6671 to order the video tape.
5. Clean accumulations of dirt or mix that might hinder the proper functioning of any sliding surface, pivot point or lubrication fitting. Hardened mix can be removed by pouring diesel fuel on the build-up area and allowing the mix to soften.
6. Always park the machine as near to level as possible.

1.6
STUDY QUESTIONS

1. TRUE or FALSE — A motor grader is basically designed to level and smooth.

2. TRUE or FALSE — The moldboard is designed to take stress when you are operating in reverse.

3. The fewer changes you make to the moldboard while moving, the...
   a. ...better your work will be.
   b. ...worse your work will be.

4. It is best to operate the machine while you are sitting down because _____.

5. The term "sharp blade" refers to the angle of the blade in relation to a line at right angles to the machine, and is an angle greater than _____ degrees from that line.

6. What is the blade pitch? _____.

7. What is a tight blade? _____.

8. If you raise one end of the blade the other will go down about _____ of the distance.

9. A high rate of speed can cause the grader to _____.

10. The greatest safety device is a _____.

11. Always _____ the machine when dismounting.

12. TRUE or FALSE — It is permissible to oil, grease, or adjust the machine when the engine is running.

13. When deadheading the grader, in what position should the blade be carried? _____.

14. Never operate the starter continuously more than _____ seconds. Then wait _____ minutes before using the starter again.

15. Park the machine as near _____ as possible.

1.7
ANSWERS TO STUDY QUESTIONS

1. True (page 1)
2. False (page 1)
3. a. ...better your work will be (pages 1,2)
4. because you can feel the movement in the machine (page 1)
5. 30 degrees (page 2)
6. the angle the cutting edge sits in relation to the road (page 2)
7. Setting the blade so that it has some down pressure on the surface. (page 2)
8. one - quarter (pages 1,3)
9. bounce (page 3)
10. careful operator (page 3)
11. face (page 3)
12. False (page 4)
13. blade toed to the off traffic side, and carried high (page 5)
14. 30 seconds; 2 minutes (page 5)
15. level (page 6)

CHAPTER 2
OPERATING INFORMATION

2.1
GENERAL INFORMATION

Following are some general operating tips to help prolong machine life and reduce breakdowns:

- Keep dirt out of engine openings by wiping off dirt and grease before opening filler necks and dipstick tubes.
- Be sure that containers used to carry oil and fuel are kept clean.
- Do not pour cold water in a hot engine.
- It is always a good idea to fuel at the end of the shift, in order to prevent condensation in the tank.
- ***Always come to a complete stop before changing gears for the direction of travel.***
- If you must leave the blade up at night, let it down on two short blocks. The machine can then be pulled as the blade will slide off of the blocks.
- Always use the decelerator, or throttle, to slow engine speed when shifting gears.
- Avoid unnecessary speed, particularly on rough ground. Do not spin the wheels — this is hard on the machine and tires and also makes the surface rough. Always engage the clutch smoothly and do not jerk the machine.

Most motor graders will have six or more control levers in addition to the usual brake, clutch, transmission and fuel controls. For specific application to any given machine, refer to the operators manual, but generally a grader will have the following controls:

1. **Blade Lift**: These two levers are used to lower and raise the respective ends of the blade.
2. **Scarifier**: This control lowers and raises the scarifier. This may be used to rip up any kind of hard material. Be sure to drive in a straight line when the scarifier is in the ground to avoid breaking shanks.
3. **Circle Reverse**: This lever changes the angle of the blade in relation to the machine. This angle is very important to you as it will determine how far material is carried in the moldboard. A **square blade** will carry material quite a distance whereas a **sharp blade** will cause material to form a windrow at the heel of the blade.
4. **Side Shift**: By using this control you can achieve a greater reach on your blade (e.g., as in ditching). It can be used to extend the reach of the mold-

board, in shoulder widening, to push material over a bank and to keep the machine on solid ground. Caution should be taken to keep the blade away from the tires.

5. **Front Wheel Lean**: This control will lean the wheels in either direction. This feature will make it much easier to turn the machine around. Always lean the wheels in the direction you want the machine to turn. They can also be leaned to help counter side-draft created by the pull of the blade when it is loaded. When you are working the machine on a slope, lean the wheels up-slope to help hold the machine in a straight line. Leaning the front wheels will lower the blade slightly.

2.2. WINDROWS

When moving a heavy windrow or taking a heavy cut, use the front wheel lean. This will help to counter side draft that can pull the front of the grader off line. A sharp blade will enable you to move more material to the side, while a square blade will carry it along with the grader. Do not put too much load on the machine and spin the wheels. If necessary, split the windrow and make more passes.

2.3 BACK SLOPING

If a bank is too high and steep to get the machine on, the blade may be set out to one side of the machine (Figure 2.1). You can then drive along the bottom and cut the back slope in this manner.

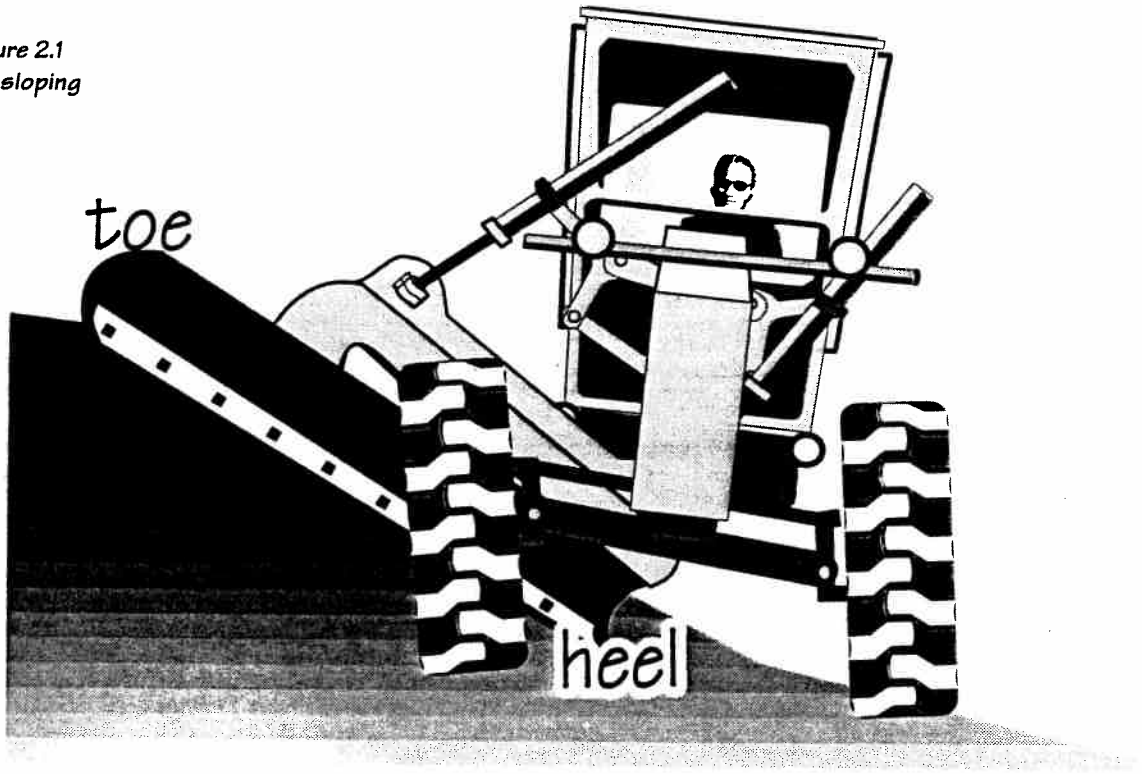
On most machines this adjustment must be made by manually adjusting the moldboard out the side. This can be done by changing the location of the blade attachment to the blade circle. The blade lift arms can then be manually lengthened, and by using the side shift control you can side shift to the extreme. One end of the blade can be raised and the other lowered to achieve the correct setting. The cut can then be adjusted by using the front wheel lean.

The final step in any ditch work is to check the ditch for drainage. This can be done with an eye level or simply by "eye-balling" it, but always make sure to check your work.

2.4 WIDENING SHOULDERS

Widening shoulders can be done in one of two ways: One method is to have trucks dump material on the road surface, as in repairing a washout on a steep shoulder. Dump material in such a position that as you work, the material will be carried into the location where it is needed. Work the material out over the shoulder, leaving it high. By working the material out slowly you will pack it into the hole as you work. Always pull some material in towards the road and save it for finishing work. After you have the hole packed full you can separate rocks and large chunks out of the windrow you saved by "high blading" it. Roll these over the

Figure 2.1
Back sloping



shoulder and use the small material to put a "finish" on the work.

The other method is to bring the material up on the road by cutting the back slope and ditch down. The material can be carried up on the road and finished as previously outlined.

Any time you want to separate large rock out of material in a windrow, set the blade 3" or 4" above the ground. This will leave the finer material and carry the rock and larger material into a separate windrow.

2.5
BLADE MIXING SALT AND SAND

Spread the material out at least the width of the blade, leaving a small windrow on each side. This will leave a smooth area several inches deep on which to spread the salt. Roll the small windrows back over the top of the salt making a "sandwich" of material, salt, and material. Then move to the outside and "pull" the material out of the "sandwich" in small windrows. This will use the full width of the blade to "roll" the material. The small windrow can then be pulled back to a central windrow. The salt and sand should then be mixed. If not, just repeat the process again.

2.6
BLADE MIXING OIL AGGREGATES

Aggregate should be dried and windrowed. When it is ready to mix, peel enough aggregate from the windrow to get a pad 2" to 3" thick, wide enough for

the distributor, and with a slope toward the large windrow. Also leave a small windrow on the outside of the material pulled out. The tanker or distributor can drive on this material to help spread the asphalt.

The motor grader can then follow the distributor, peeling more aggregate from the windrow and covering the asphalt with a 2" or 3" lift. Successive lifts are placed in this manner until the required asphalt is layered in the material.

Set your blade pitch so that the material will roll (spiral) and mix thoroughly. If the material starts to "ball", put it in a large windrow and cut shallow lifts off the top. In this way you can cut through the "oil balls". If the aggregate has considerable fines, blending can be difficult. Lower the blade so that it presses the layer of asphalt and aggregate, then back the motor grader over the mix. This will enhance aggregate coating as the asphalt migrates upward.

In general, always use caution when mixing: cutting too deep will allow foreign material into the mixture. Always be sure to clean the area you are going to use by cutting weeds and moving rocks and other debris. Allow plenty of room to mix. Be careful not to lengthen your windrows, and keep the ends tucked in. It will be much easier to mix if you keep the windrows even in depth.

For additional information on blade mixing and related topics, refer to Appendix A, Pages 62-71, in the *MDOH Asphalt Pavement Maintenance Reference Manual.*

2.7
BLADING APPROACHES

Many times there will be a high area in the center of the approach. Set the machine on the oil surface and drive into the approach, cutting this high area down and carrying the material toward the right-of-way boundary. Stop and leave the material in a pile near the end of the area to be worked. This may require more than one pass if the material is hard.

When you have this completed, turn the machine around and pick up the pile, windrowing it toward the oil surface. If additional material is needed, dump it on top of the windrow already formed.

Leave a windrow set up on the outside edge of the approach and drop any extra material in the blade in a pile along the edge of the oil surface. When setting up this windrow, use it to outline the approach. Turn the machine around again and set it up in the lane of traffic to turn into the approach. Pick up the windrow and drive with front wheels on the outside edge of the windrow to carry the machine into the approach without falling in the depression. This will cause the blade to lay the material in with the correct curve and angle. Repeat this pass without running on the windrow, but straddling it, to complete the first half of the approach. Any excess material can then be used on the other side of the approach by using the same steps. When completing the job, allow excess material to be strung out on the back of the approach.

The key to this operation is driving off the oil surface at an angle as this puts

the material down in the correct location.

2.8
BASICS OF BLADING AGGREGATE SURFACED ROADS

These roads need periodic maintenance to provide good ride and drainage characteristics. Set up your initial pass to bring aggregate to the center of the road. Set a square, loose blade with the toe on the shoulder. This setting will strike off high spots and carry the spoil to deposit in depressions. Any additional material will windrow in the center of the roadway. This prevents the loss of aggregate in the borrow pit. Close attention must be given to your blade to avoid problems. Always use care to maintain or re-establish the proper crown or super elevation.

Work in the direction of travel until you reach a safe turn-around point, then work back to your starting point. Feather your center-line windrow to the shoulder on the second pass in either direction. Extend the blade over the shoulder to keep from building a dam on the shoulder that would disrupt drainage characteristics (Figure 2.2). Don't work out of the effective distance of your signing. Move signs along as you progress down the road.

There are a few cautions that warrant constant attention:

1. Leaning the front wheels will lower the blade and establish a heavier cut.
2. Raising one end of the blade lowers the other end about ¼ as much as that end was raised.
3. Reversing the circle might be necessary to position the heel of the blade to

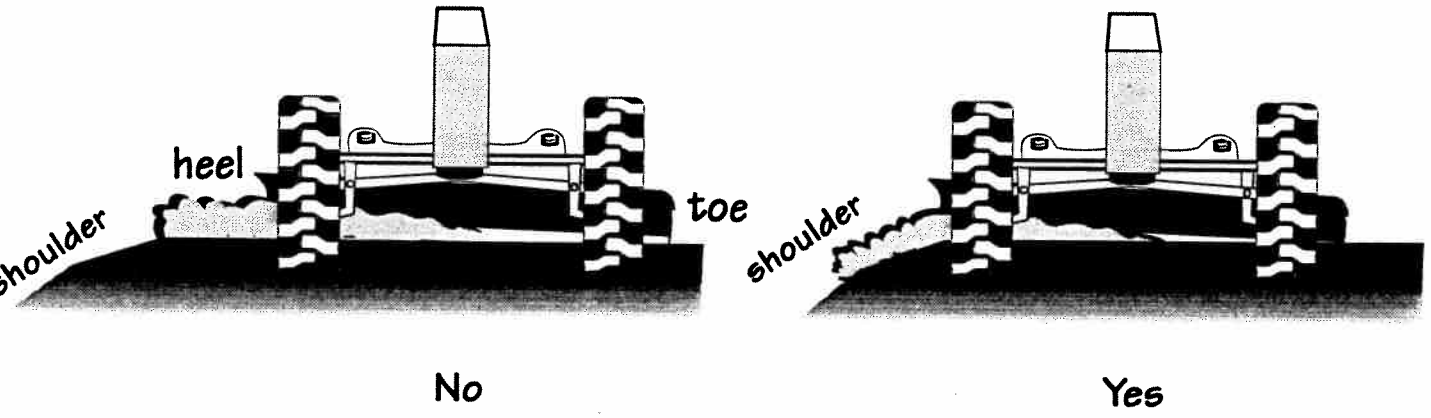


Figure 2.2
Blading shoulders

deposit any spoil on the high side of a super. This keeps from filling the low side ditch with spoil.

2.9
SNOW PACK & ICE

Cutting snow pack and ice with a motor grader has special hazards that require extreme caution on the part of the operator. Some simple equipment changes can

improve the operator's odds in these situations:

- ❖ The first and simplest change is to chain up.
- ❖ If the machine is not all-wheel drive, reverse the front wheels so the tread is opposite to that on the drive wheels. Always drive straight and do not use so much down pressure that the front wheels are raised to a point that steering is ineffective. Be careful of iron in the street; manhole covers, water shut-offs, and expansion joints can catch the blade and cause sudden, abrupt changes of direction for the front end of the grader.

2.10 PATCHING

If you have not patched before, the best way to start is to practice with dry aggregate. Also, you should review the "Blade Patching" and "Blade Mixing" Video Tapes (Montana Department of Transportation) listed in the references.

Patching will be discussed in several subsections. Different types of patches will require slightly different methods. The first area to discuss is general steps. Always keep in mind the major objectives are to level the area, have a good riding surface, and to leave a good appearance. To accomplish this, you must have straight shoulder lines and neat tapered ends to provide a smooth transition to the original surface. Plan the locations for the ends of patches. Adjust the length to avoid ending in a depression. When windrowing the material, try to keep the windrow as uniform as possible.

Patch Preparation

The first step in any patch is to cut off high spots and clean any old, cracked or broken oil mat out of the hole. It will be necessary to sweep dust or dirt off to achieve a good bond. The surface must be clean in order for the asphalt tack coat to stick to the mat. *If the shoulder is higher than the mat, cut the shoulder down level with the mat so water can drain away.* Take all material to be wasted off in the borrow pit and spread it out so that it is not a hazard to mowers. This also leaves a good appearance.

Be sure to extend the patch a short distance on each end so that the ends can be tapered. Where possible, stop and start the patch on level road. On very rough or deeply rutted roads, spread the tack coat on the area to be repaired, and dump the pre-mix on the tack coat. On better roads, dump the mix on dry pavement, then tight blade the mix into a windrow on the edge of the pavement. Apply the tack and tight blade the mix onto the tack area. Apply the rest of the tack, then establish the edges and spread the patch.

A square blade will tend to level more than a sharp blade, but it may tear the patch. The amount of angle you can use will depend on the amount of heat and moisture in the mix, and the type of material used to produce the mix. For example, on a hot afternoon you could use a much squarer blade than on a cloudy morning.

If you have an articulated grader, tuck the berm. When you get to the end of the tack, turn and articulate the front of the grader into the windrow. This will

straighten the end of the windrow past the end of the tack. Turn around. The extended material will fill the blade by the time you reach the tack line on the return pass.

Using articulation to turn around and approaching the material head on gives you better control of the material. It also gives you better visibility and avoids back blading. You don't have to drive over a pile at the end of the patch, and this gives you better blade control.

Half-Road Patches

On half-road patches, take the pre-mix to the center of the road first. Operate with a moderately square, loose blade for the first pass. The square blade will tend to even out pre-mix that is not dumped evenly. The loose setting will keep you from cutting into the old mat and getting chunks in the material.

When you reach the end of the tack, stop and lift the blade. At this time you can use the back blade process. Drive forward and line the machine up so that you straddle the windrow. Go to a sharp, tight blade. When backing up, be sure to back in a straight line. The back of the blade will carry material back to the starting end of the patch and will also help to break up any chunks in the pre-mix.

Windrow position is very important. Be sure you do not put the material out too far towards the shoulder. It should be placed in the approximate center of the area on a two-lane road. Again, position the machine to straddle the windrow. This pass is the second most important pass you will make. Have the outside edge of the windrow falling where you want the edge of the patch to be. It should be sitting on the edge of the existing mat. Be sure to drive ***straight*** during this pass. Before making this pass, be sure to have the windrow even in size so pre-mix will fall in a straight line leaving the blade. The exception to this might be if there is a deep hole in the center. You would need more material there, but allow extra room in this area to hold a straight line on the outside of the windrow.

When you reach the end of the patch, tuck the berm. Turn the machine around and approach the patch from the opposite direction. Always stop close to the end of the patch and on level road. Set the toe of the blade directly behind the outside

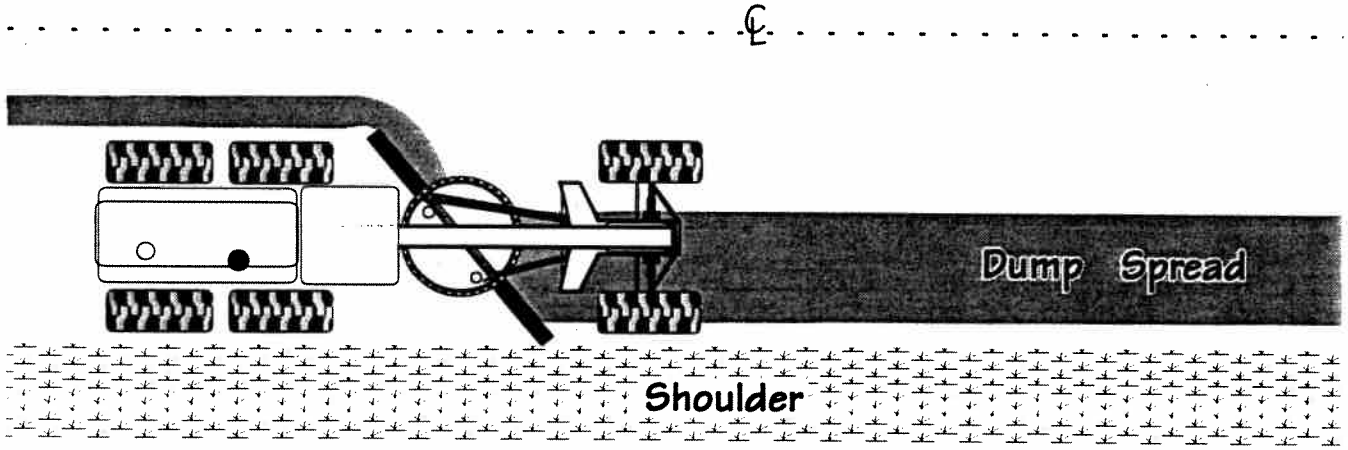


Figure 2.3: Establish the windrow at a uniform distance from the shoulder.

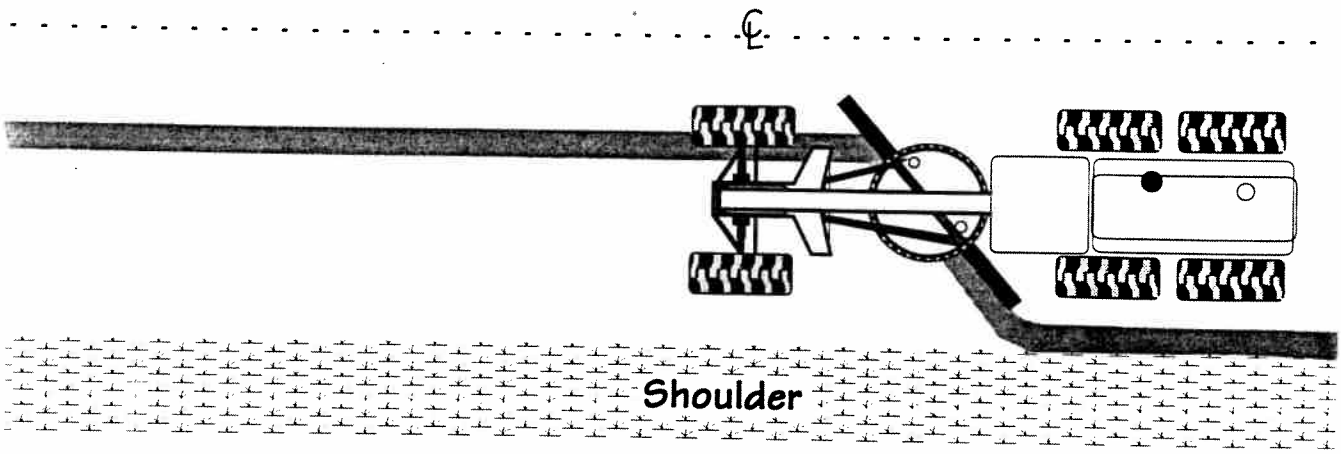


Figure 2.4: Positioning the windrow for the spread pass.

front wheel with a sharp angle. Be careful that the pre-mix coming out of the blade will not fall under the rear wheels. Set the blade down using a loose blade. When you drive forward, put the outside front wheel slightly up on the side of the windrow. The blade will pick up the pile as you drive up on the windrow: this will raise the blade slightly, making the taper for that end and packing the edge line.

Be sure to drive the same height up on the windrow all the way across the patch. This will leave a level area even though it was not level to start with. When you reach the other end, gradually edge back down onto the shoulder edge and this will lower the blade, putting the taper on this end. When the end of the tack coat is reached, cut the wheels into the windrow to leave a straight windrow. Running the tire on the edge of the windrow will carry the machine level across holes and high spots. The edge of the windrow will pack so material does not leak out of the blade, ruining the straightness of the shoulder line. It also gives you a level pass to guide from for the rest of the patch. *THIS IS THE MOST IMPORTANT PASS OF THE PATCH.*

The next pass will carry material out to the center of the road. Do not use as sharp a blade setting on this pass. The windrow will again even out. Position the machine to straddle the windrow and carry pre-mix to the center of the road. Stop on road level and tilt the front wheels toward the toe of the blade, setting the blade square and loose. As you drive forward, watch the blade: when it has material in it, begin to straighten the front wheels. This will raise the blade on both ends following the taper started by the first lay down pass. When you reach the other end, tilt the wheels back down to run in that taper and cut the front wheels to the shoulder and straddle the pile.

Stop, raise the blade, and turn the machine around. Approach the patch, stopping on level road. Use the wheel tilt method again, and set the blade at a sharp angle. You should have laid approximately two-thirds of the amount of pre-mix that was dumped on the patch. Use the rest of the material to put a finish on the surface of the patch. Do not tilt the wheels too far down. The blade will be close to the surface of the patch. By using a sharp and tight blade, any chunks will be carried in the blade, and drag marks will be eliminated.

Lay about ½ of the remaining material in this pass. The material should run out just before reaching the end of the patch and there will be no pile left. Back up and repeat the same pass straddling the windrow with the heel just even with the edge of your patch. Let a very small amount of material roll off the edge along with the chunks. This will insure that all drag marks will be filled and the surface will be even and clear across the patch. By leaving the chunks along the edge you can roll them down and leave a good appearance to the patch.

On tapered sections that change from one roadway width to another, or where you wish to re-establish a straight shoulder line, sometimes it is easier to work from the shoulder than the centerline. Establish a windrow from the dump spread approximately two feet from the shoulder; uniformity or exact distance is not crucial at this point.

Position the grader with the outside wheels right on the shoulder with a tight blade, sharp enough to cast the windrow beyond the inside wheels (Figure 2.3). This pass should run straight down the shoulder establishing the windrow at a uniform distance from the shoulder.

Turn around and without changing the blade setting, drive back down the shoulder line again (Figure 2.4). This pass puts the windrow in line with the shoulder, and in position for the spread pass.

You may not have the material run out just perfectly and you will have to take the windrow back to the center and then complete the patch. If this is necessary, do not carry the windrow clear to the edge. Leave room to put a wheel between the windrow and the edge and carry it back. Never come clear out to the edge until you are ready to finish the patch.

If you have just a small pile at the end of the patch, you can blend this back over the patch, but do not string it out down the road. If there is a lot of material left, shoot some more tack coat and put the pre-mix on this, extending the patch further down the road. Do not blade it off into the ditch and waste it.

One way to tell if the blade is the right height above the area already laid is to watch just behind the toe of the blade. It should just touch and roll a rock or two now and then, as you move along.

Always make as few passes as possible so the material will not separate. Too much working will separate the rocks and fines and the rocks will whip off of the surface. Remember that blade pitch is important. You want to force the material under the blade so that the surface will be tighter, but do not use so much pressure that the patch tears. Be sure that the toe of the blade is set correctly. If it is too loose, a ridge will be formed where the blade picks up the windrow.

These are the basic steps in laying any patch; if you follow them and practice, you will get good patches.

Full Road Patches

Full road patches may be accomplished by shooting tack coat on one side and windrowing the dumped material to the center. The other side can then be tacked and the material carried on across. By the time you reach the other shoulder, the material should be in position to set up your shoulder line.

Begin laying material as outlined. When you reach the center, blade material

across and set up that shoulder line. Again lay material to the center of the road. The remaining pre-mix can then be used to finish either side, depending on where it is needed, using the steps outlined for finish work. These steps will give you a "tight blade" and then a lift laid on top.

A half-sole is just a long patch, and the same steps are followed. One difference is that you will probably have to lay it in sections. When choosing a point to turn around, be sure to pick a spot where you can turn easily and which is off of the road surface. Do not turn the machine around on fresh laid oil mix as the tandems will tear it. Blend the ends back over the first section to eliminate all joint traces.

Remember that a square blade will tend to level more than a sharp blade. The additional reach will give this effect but it will also tend to tear the patch. Again, the amount of angle you can use will depend on the amount of heat and moisture in the pre-mix, and the type of material used to produce the pre-mix.

Most of your lay-down work should be done in low gear with the throttle open. This will give you "live" controls without excessive ground speed. Too much ground speed will cause a bounce in the machine, causing "wash boards" in the patch. If you have to dry the material, roll the entire windrow back and forth a few times, or spread it out and then pick it up. Be sure to pick it all up to avoid separation.

Dips

A short deep dip may be laid using a short cut. Extend the tack coat about a truck length on each side of the dip. Tin cans or any type of marker can be set on the shoulder to mark where the dip begins and ends. The pre-mix may be dumped in one pile. Drive over the pile taking as much material as you can and dropping it in the dip. Back up and set the blade with a tight and sharp angle to the shoulder. Pick up all the rest of the material and set up the shoulder line. Back up and begin to lay the patch. The material you put in the hole will support one front wheel and the windrow will support the other. When you come to the markers, ease the front wheel higher on the windrow and this will lay more material in the dip. Ease down at the other marker to run the end taper.

Finish the patch using the same methods as above. The advantage to working slowly is that you will not have to turn the machine around as often. A job is completed quickly by making fewer passes, not by going fast.

Road Center Patches

On patches where you do not have to form a shoulder line, such as a hole in the center of the road, just spread the material to one edge of the tack with a tight blade. Then straddle the windrow and leave the toe tight to the road. As you drive forward raise the heel slightly to begin laying material. Set both edges in this manner.

Bridge Ends

When patching a bridge end, set your shoulder windrow up so that it is very small as you come to the bridge. When you drive this windrow and approach the bridge, you will be able to run up on top of the small part and avoid the bridge rail.

Always lay towards the bridge on the shoulder cuts. Then follow the normal steps for the rest of the patch.

Run the taper from the end of the patch up to the bridge and make the rise gradual over the entire length of the patch. A gradual taper will prevent a jolting "bump" in front of the bridge.

Cattle-Guards

Patching cattle-guards requires caution as material can be easily lost down the hole. To avoid this, approach the cattle-guard watching the toe of the blade. When the material in front of the blade is close to the rails, use the circle reverse to square the blade so material will be pushed up close all along the length of the blade. Raise the blade and drive far enough forward to position the blade on the other side of the pile. Lower the blade and back up. This will carry the material away from the cattle-guard where it can be blended back over the patch. Handle both sides of the road in the same fashion.

Sharp Curves

When patching on sharp curves, ride higher on the windrow to allow for the tandems dropping down on the edge of the material as you turn.

Patch Compaction

The last step in laying a patch is to compact it by rolling. This is very important as it will prevent loss of surface material due to "kick off" from high speed traffic. It is best to use a roller, but if you do not have one, roll it down using the trucks to reduce the voids and raveling, thus increasing durability.

Always roll the shoulder first and work the material toward the center of the road. If your roller has a steel drum, allow 4" - 6" to hang over the shoulder but avoid letting the roller drum "tilt" back and forth as this will spoil your shoulder line. The rolling operation is very important to your work. Avoid turning the roller on the fresh patch. Normally, only roll the patch after it is completed. An exception would be a very deep hole. A small hole can be rolled with the grader wheel but on a large one a roller can be used.

Lay the material to the center and then roll the material on this lift. Another lift can be laid over this. Where heavy traffic might cause excessive packing or settling, deep lifts may be rolled individually.

If the material is more than 0.2 feet deep, lay it in equal lifts. It is best to roll small areas with the motor grader wheels, so that when the patch has stopped settling, it will be level. Do not over roll a patch as you can force the material out of the hole. About two trips across the patch will usually set it in place. This will vary depending on the weight and type of roller.

Compaction is a very critical element in asphalt pavement maintenance. Time and temperature can become important considerations because as the mix cools it becomes more difficult to work. Compaction usually involves three phases:

Phase 1: **"Compression"** or **"Breakdown"** passes are the first passes aimed at reducing the voids in the mix and expelling as much air as possible.

Phase 2: **"Intermediate"** rolling is the orientation process that positions the

particles and compacts the material. A further purpose of this intermediate compaction is to stabilize the mass to minimize distortion by traffic.

Phase 3: "**Finish**" rolling is to establish the final surface and remove any marks from prior rolling.

Patch Materials

The type of material used will affect your procedures to a great degree. The type normally used is mixed with a "cut back" asphalt. A medium cure (MC) asphalt is used as this type can be left in the stockpile for quite awhile. Lighter grades of MC are used when cool weather is encountered. Heavier asphalts should not be used when materials are to be stockpiled for long periods. A cut back oil is simply one that has an agent added to make it workable at a low temperature.

Aggregates with large amounts of fines will be hard to lay. This material is a "fluffy" or "sticky" type of pre-mix that tends to drag along the road without going under the blade. Fluffy pre-mix must be laid in deep lifts and rolled after every pass.

Hot plant mix using asphalt cement must be worked at very high temperatures. It is used mostly with a lay-down machine but sometimes you may be called on to lay it with the motor grader. It becomes unworkable rapidly, so speed is important.

Hot plant mix can be spread from the truck very evenly, so your first pass should set up the shoulder line. Lay it back one pass and then dress to the outside. This will complete laying that load in three passes. Just dump one or two loads at a time and lay each load in layers. If it is a wide road, lay it in strips and then dump a small amount on the center of the lift and dress it right to the edge to complete your finished surface. Be sure to roll each lift as you put it down, as you will be unable to get any compaction if it cools too much. If the lifts are too deep you will have to wait to put the roller on or the hot material will push out of the hole. This is why it is important to lay it in lifts. You will only have about three passes before the material becomes unworkable. You might get four trips on a hot afternoon, but better results will be obtained with only three.

For additional information on compaction, refer to ***The Asphalt Handbook***, Manual Series No. 4, 1989 Edition, The Asphalt Institute.

2.11
STUDY QUESTIONS

1. TRUE or FALSE — With the transmissions now available in the newer machines it is not necessary to come to a complete stop when changing from a forward gear to a reverse gear.

2. The first step in any patch is to _____ and _____.

3. The surface must be _____ in order for the asphalt tack coat to stick to the mat.

4. On a deeply rutted road, the pre-mix should be dumped on:
   a. the clean dry road surface
   b. the tack coat only

5. On half road patches, take the mix to _____ first.
   a. the center of the road
   b. the shoulder

6. TRUE or FALSE — When laying a blade patch you should never use the back blading process.

7. As a general rule the windrow of mix should always be as _____ as possible.

8. TRUE or FALSE — To help taper the ends of a patch you can run the front tire part way up the outside of the windrow.

9. The ends of a patch, whether it is a full patch or a half road patch, should always be _____.

10. TRUE or FALSE — Always make as few passes as possible so the material will not separate.

11. On full road patches, lay material to the _____.
    a. center of the road
    b. shoulder

12. TRUE or FALSE — A square blade may tend to tear the patch.

13. Too much speed may cause the machine to _____.

14. It's best to compact with a
    a. truck
    b. grader
    c. roller

15. Always compact patches from the
    a. centerline to shoulder
    b. shoulder to centerline

2.12
ANSWERS TO STUDY QUESTIONS

1. False (page 1)
2. Cut off the high spots and clean any cracked or broken mat out of the holes. (page 6)
3. clean (page 6)
4. b. the tack coat only (page 6)
5. a. the center of the road (page 6)
6. False (page 7)
7. even or uniform (page 6)
8. True (page 7)
9. tapered (page 8)
10. True (page 6)
11. center (page 9)
12. True (page 10)
13. bounce (page 10)
14. c. roller (page 11)
15. b. shoulder to centerline (page 11)

CHAPTER 3
BLADING AGGREGATE SURFACED ROADS

3.1
DRAINAGE
Crowning

If you do not know what caused the pothole you fixed yesterday, you will fix it again tomorrow. The same applies to other types of road defects. There are many factors which cause defects in aggregate surfaced roads. Each factor contributes to a specific distress in gravel roads. **Poor drainage** and an **improper ratio of fines to coarser aggregate** are contributing factors to most types of defects.

One of the keys to maintaining a smooth road is drainage. Standing water causes road material to separate and creates potholes. The best way to drain a road is by crowning it so the center of the road is higher than the shoulders. This can be done by cutting the crown into the road and by leaving more material in the center than on the shoulders when spreading the material back onto the road. The crown should be an A-shaped crown, NOT a parabolic crown.

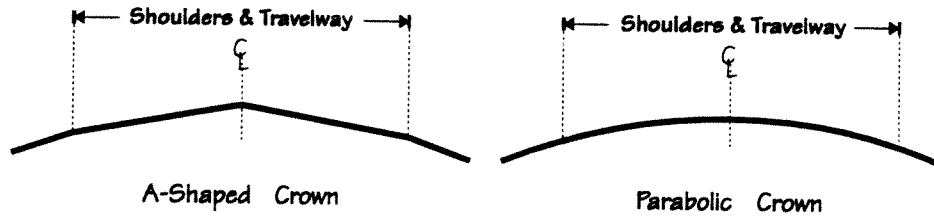


Figure 3.1: Road Crowns

What is a crown?

A road must be bladed so that the center is higher than the edges to allow water to drain into ditches as quickly as possible. That is accomplished by **blading a crown on the road.**

- Keeping a crown on the road is probably the most important part of blading because lack of a crown causes trapped water to break up the crust, producing potholes, washboards, and an overall rough road.
- The amount of crown is the amount of slope on the road. For good drainage, a road should have a crown of 1/3 to 3/4 inch for each foot of width measured from center of road to outside edges where road meets shoulder.

The most desirable crown is shaped like the letter A; in other words: a straight, sloped line from the center of the road down to the edge of the shoul-

der. The A-type crown is hard to maintain because motorists tend to drive down the middle of an aggregate surfaced road, straddling the crown. As traffic goes down the center of the road, it compacts the road surface on each side of the center line. Consequently, as you carry on your dragging operation, your cutting edge will wear faster in this harder, off-center area. This accounts for the moon-shaped wear in the cutting edge. The crown resulting from such a worn blade resembles an inverted letter U, or the shape of a parabola; thus, the term parabolic crown.

A bad feature of a parabolic crown is that it is relatively flat across the center of the road; it holds moisture longer and defeats the purpose of crown. When the roadbed is wet and ready for reshaping, you will be able (with new cutting edges) to rebuild the A-type crown.

The best way to ensure that a road has the proper crown is to use a crown gauge (slope meter) on the grader. The gauge or meter is attached to the grader to give a constant reading of the amount of crown as the road is being bladed.

Guidelines Needed for Road Crowns[1]

How much crown should an aggregate-surface road have? Written sources vary in their recommendations but seem to have led to a conclusion that the maximum crown should not exceed one inch per foot of width. For example, the NACE booklet "Blading Aggregate Surfaces" (1986) on page 14 states "For good drainage, a road should have a crown of 1/3 to ½ inch for each foot of width measured from center of road to outside edges where road meets shoulder." The 1992 NACE Action Guide "Road Surface Management" states: "the degree of crown is the amount of slope from the middle of the road toward the shoulder. Good drainage requires a crown of ½ to ¾ inch for each foot of width, measured from the center of the roadway to the outside edge." For many roads, a crown of ½ inch per foot is insufficient to carry water rapidly off the road. This is especially true if the road is on a grade or if the surface is of average or greater roughness. The AASHTO Maintenance Manual (1976) suggests a crown of ½ inch to one inch per foot for earth-aggregate surfaces (see Sections 2.300 and 2.560).

Like every aspect of design or maintenance, this issue has arisen in a number of tort liability cases. In several, a plaintiff has alleged that there was insufficient crown. Generally, the crown was about ¼ inch per foot in these cases in the location affecting an accident. At least one case is being litigated based in part on a plaintiff's allegation that a crown of ¾ inch per foot is excessive.

From reading a number of their depositions it is clear that most grader operators are aware of the need for an appropriate crown. However, few seem to have any specific value in mind. Although most roads seem to end up with enough crown, thanks to the skill, experience, and good judgment of the grader operators, a more definitive answer than "enough" would be better when a grader operator is asked how much crown a road should have. It is suggested that jurisdictions having responsibility for aggregate-surface roads

[1]"Guidelines Needed for Road Crowns", *Technology News*, by R. J. Carstens, Iowa State University, February 1989

establish guidelines for the amount of the crown.

In northern climates, the most desirable crown might vary from season to season. The maximum crown might be used in the spring when runoff from snow melt and spring rains present the greatest problems of surface drainage. A lesser crown might be more appropriate in the winter when ice on the road is likely to be of more concern than running water.

In any case, some guidelines are better than none to help prevent the occurrence of the road without crown. A road with insufficient crown will be a liability problem when it is the location of an accident.

In most cases, crowning will adequately drain a road surface. The wider the driving surface, the more difficult it is to keep the crown in a road. A heavily traveled road will usually become very wide, especially near intersections where there is a lot of stop-and-go traffic. This particular stretch of road will be extremely difficult to maintain. A hard packing type of material should be used in these areas if at all possible.

Ideally, potholes should be cut all the way to the bottom. This can rarely be done, and if the road is already low in the center, can create a "canal effect" that may be very difficult to fill. Since most of the holes will be in the center portion of the road, it is usually only possible to cut off the high spots and fill the holes with material gathered from cutting the shoulders. This is one reason why a road needs to be fairly wet when it is graded. With the proper amount of moisture, the material will pack in the holes without beating out. With too much moisture, the material gets splashed out of the holes by traffic.

Since loose, dry material won't compact in the center of the road to help create a crown, any rebuilding or reshaping of a road top must be done with an adequate amount of moisture present. In problem areas, the use of a water truck may be necessary.

Ditching

The first thing to do when cutting a ditch is to lay out a line. This can be marked with stakes visible from the cab to assist with cutting it straight. When you are ready to start, angle the blade sharply and place the toe or leading edge of the blade behind the front wheel. Set the toe tight and raise the heel up (Figure 3.2). Drive the machine down the row of stakes taking a cut of 1" or 2" in depth. This is called a **marker pass** and will help to keep the ditch straight. Do <u>not</u> make this cut so deep that you have trouble steering the motor grader. ***(Don't get greedy!)***

The next pass should be made with the same setting, but place the front wheel in the marker cut and put a load on the machine. Again, do not take more than the machine can handle. Put the motor grader in first gear and do not go too fast in case you hit a hidden rock. These settings will deliver the windrow under the grader and you will get better traction because you are not on loose material.

The next pass, set the blade tight on both ends (Figure 3.3) to deliver the material outside of the wheels. Next set the machine straddling the windrow and

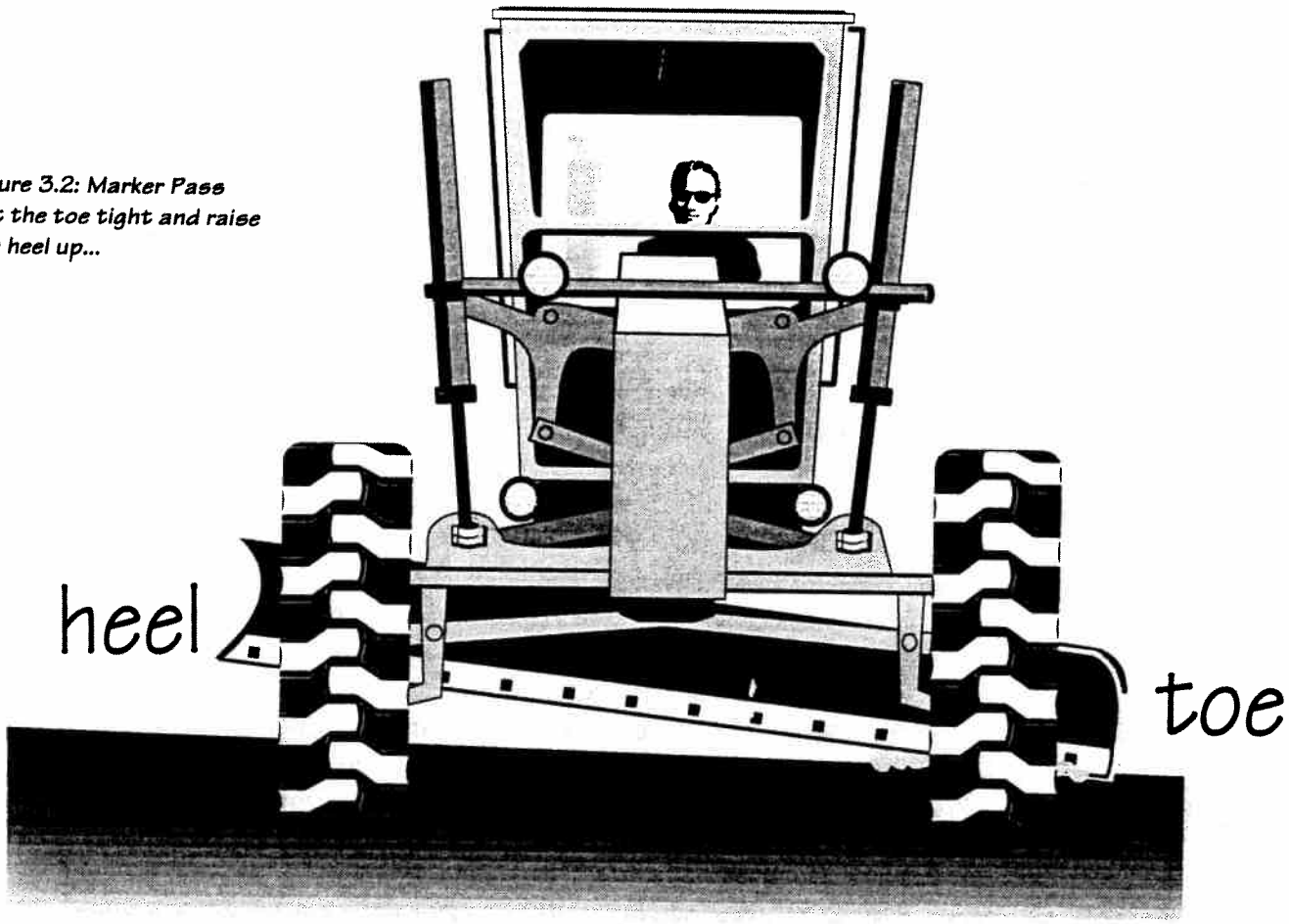


Figure 3.2: Marker Pass
Set the toe tight and raise the heel up...

carry the windrow away from the ditch bank. ***Always be sure to move the windrow before it becomes so large it is awkward to handle.*** If the ditch still needs to be deeper, repeat the steps as outlined except the marker pass. Normally when cleaning a ditch, the marker pass will not be necessary.

If a back slope is required, place one set of wheels in the ditch bottom and the other outside the ditch. Put the heel down with just enough angle to deliver the windrow outside of the wheels; put the toe down enough to cut the slope desired.

To clean the windrow out of the ditch without leaving anything in the bottom, set the blade so that the toe and the heel are inside of the wheels. It should be nearly parallel with the machine. Drive with one wheel in the bottom of the ditch and the other on the first slope. Have both ends set tight, but not cutting any deeper. This will move the material a short distance up the slope. You can then take a setting with a normal sharp blade and carry the material on up the slope to be disposed of, leaving the ditch bottom clean.

If a flat bottom ditch is desired, you can cut the flat bottom by taking the setting outlined above. The width can be set by the angle you put on the blade. The blade must also be leveled.

You may have trouble getting the blade between the wheels if it has extensions on it, but this setting prevents material from leaking around the

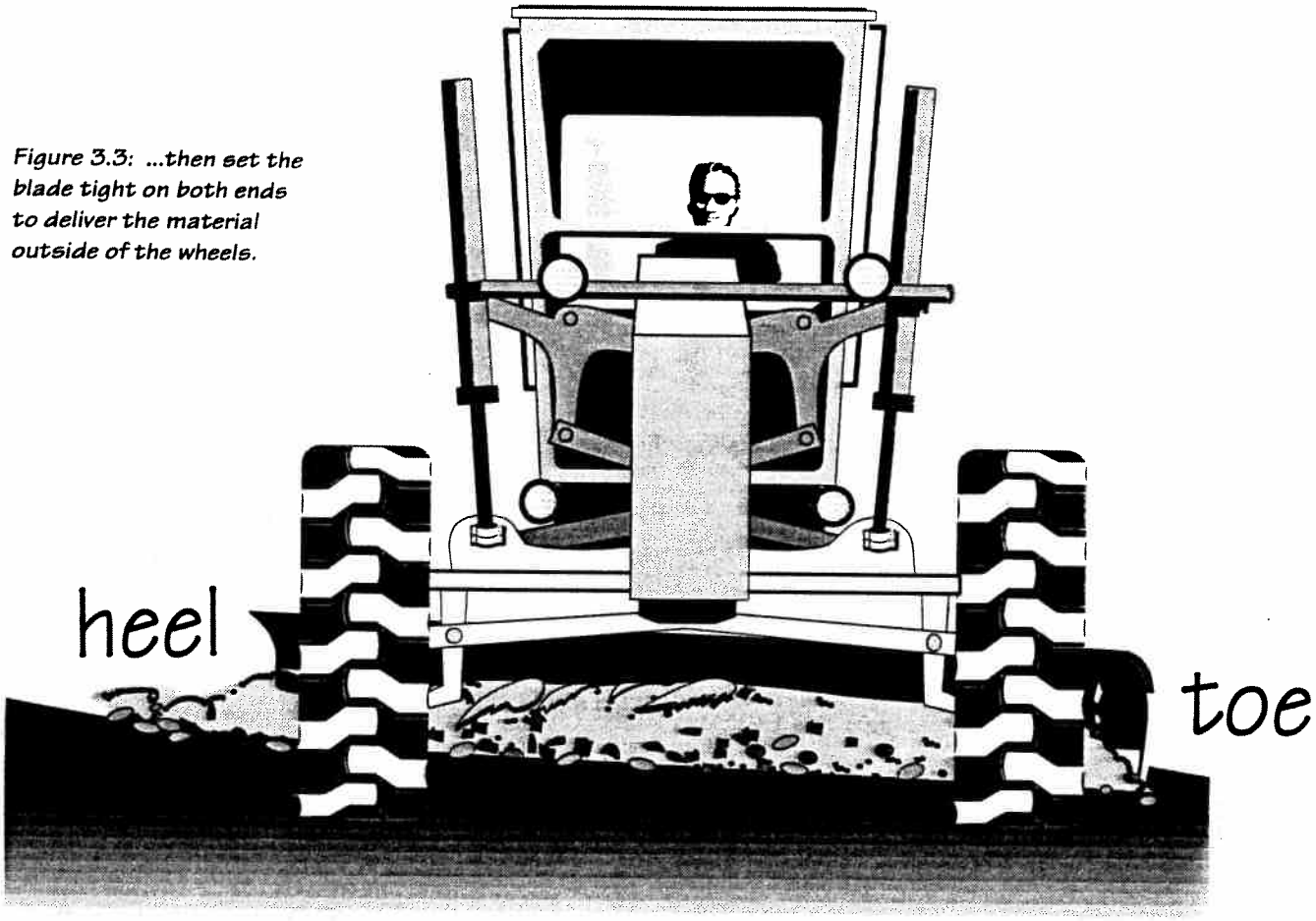


Figure 3.3: ...then set the blade tight on both ends to deliver the material outside of the wheels.

end and leaving some in the ditch bottom.

3.2
MATERIALS

All roads, even those that carry small amounts of traffic, should be built of materials and soils that will make them passable in all kinds of weather.

The soils used in road building differ. They may swell when wet, may break into fine pieces under heavy traffic, or may be so hard they are nearly unworkable.

Coarse soils or mineral particles are called ***aggregates***. Those that are very hard and not easily broken up are best to use for road surfaces and shoulders. The main types of aggregates are:

- Crushed stone – made by breaking or crushing rock, usually limestone.
- Gravel and natural sands – usually found in river beds or as natural deposits in old stream beds.
- Slag – a byproduct of iron and steel manufacturing
- Burnt clay or expanded shale – a byproduct of heavy industry or commercially produced as aggregate material.

Figure 3-4:
Aggregates of different sizes are blended with fines.

Blending Aggregates

The proper blend of different size aggregates on a road produces a surface that can be used in all types of weather. An aggregate surface is most economical for roads carrying low volumes of traffic because materials are usually available locally.

To make a wearing surface, different size aggregates are blended together and spread across the road base. The largest size is usually no more than one inch. Blending different sizes allows the pieces to lock and pack (compact) together to make a strong, tight surface.

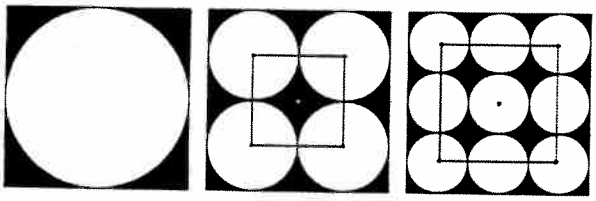


Figure 3-5:
Aggregate Density

Fine material (fines) is added to a mixture of different size aggregates to fill the small spaces (voids) between the pieces. Fine material, often called binder or mineral filler, is a very important part of the mixture because when water is added, it acts like cement to hold the aggregate together. Without enough fines, moist aggregate will not dry to form a hard-wearing surface. Dust blowing from an aggregate surface indicates that fines are blowing away.

Maximum Density:
Well Graded Material
Optimum Moisture
Compaction is usually started by grader

The addition of material is usually accompanied by blading and grading, although light applications of medium-sized and fine aggregates may be made occasionally to correct slippery conditions. When increasing the depth of the surface, filling depressions, restoring crown and profile, or correcting other problems that require coarse aggregates, well-graded aggregate mix should be dumped in windrows for spreading by a motor grader along the area to be repaired. Well-graded aggregates should have a maximum size of approximately one inch with approximately 10 to 25 percent passing a number 200 sieve. Fine aggregates needed to correct ravelling, and in some cases corrugations, are usually obtained by blading material from the shoulders and ditch lines. Fine aggregates can also be hauled and spread in a manner similar to coarse aggregates.

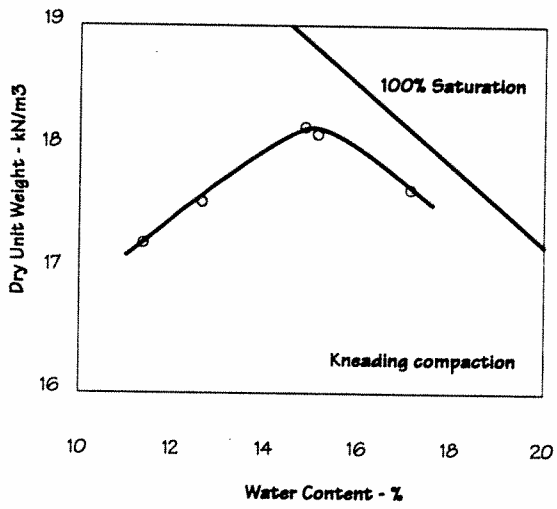


Figure 3-6
Strength of compacted samples of silty clay

Surface Stabilization

There is general agreement that the majority of gravel road surfacings will be improved by stabilization. If you can eliminate a reshaping job and a couple of smoothing jobs you can save a lot on maintenance.

Some surfacings are unstable because certain rock sizes are missing from the gradation. To

provide a stable surface the missing sizes need to be blended into the existing surfacing during reshaping activities.

Two reshaping activities should be scheduled to complete the process. The first reshaping allows collecting samples for analysis. The second reshaping is when missing sizes are incorporated.

Depending on the degree of sophistication in your department it may not be possible to determine missing sizes by sieve analysis. In this case an experienced supervisor can determine by observation what material needs to be added.

The most common gravel road surface defects — potholes and puddles, rutting, dust, surface softening, and corrugation — stem from the quality of surface material, level of maintenance, and amount of traffic.

Table 3.1
Recommended gradation for gravel road surface material

US Standard Sieve Size		200	80	40	20	10	4	3/8	1/2	5/8
Percent Range	from:	12	18	25	33	43	57	72	80	100
	to:	16	24	32	41	52	69	86	95	100

The information in the table above compares favorably with Montana Department of Highways (MDOH) *Standard Specifications*, Section 701.02, Crushed Top Surfacing Type "B", Grade 3, page 519, 1987 Edition.

The following remarks discuss gravel road maintenance in Finland, with many remarks applicable to Montana.

Gravel Road Maintenance Innovations: Selection of Material for Gravel Roads[2]

The best material for gravel roads should:

- ❖ Have sufficient amount of fine material that will pass through a 200-mesh sieve (i.e. silt and clay components). The recommended amount is that 12% to 16% pass through a 200-mesh sieve.
- ❖ Follow and stay within the gradation curve limits shown in Table 3.1.
- ❖ Have for reshaping and leveling a maximum grain size that doesn't exceed 16 mm (0.63 in.).

Table 3.2
Recommended amounts of crushed gravel.

AVERAGE DAILY TRAFFIC	Crushed Gravel yd³/mi WIDTH OF THE ROAD	
	20 feet	23 feet
500 - 1,500	104	122
200 - 500	67	78
100 - 200	37	43
- 100	25	28

In practice, the surface material often exceeds the particle size limits of sand-sized material. This should be avoided because an excess of the sand fraction reduces the stability of the surface material.

The ideal gradation can be easily obtained by two-phase crushing — using a jaw crusher and a cone crusher — of a rock or coarse gravel raw

[2]"Gravel Road Maintenance Innovations", *Better Roads*, 58:12, page 27, December 1988.

material. The crushed material should follow the upper of the two particle size limits.

For the best results, a gravel road surface using natural material should be a mixture of two fractions. To achieve the necessary density, smoothness, and water resistance, there has to be a clay material; the use of a coarse material is necessary for the stability and wear resistance of the layer. The amounts of clay and coarse material required are determined by doing a sieve analysis of the existing road surface material and from the material proportions calculating the amounts of new material. Because traffic tends to wear and break down the road surface material, the new material should follow the upper, or coarser, of the two particle size limits. Table 3.2 shows how much crushed material should be added yearly.

3.3
SMOOTHING (DRAGGING) GRAVEL ROADS

To keep a road in good condition, the road surface and shoulders must be maintained. The surface of the road is smoothed by dragging.

Smoothing should be done when there is moisture in the road. It is uneconomical to smooth a dry road because material loosened by the smoothing will blow away.

Properly blended aggregate and fines will dry to form a hard crust that provides a wearing surface. The crust will carry traffic until it breaks; it also sheds water to keep the base stable. To keep the crust intact, put only enough pressure on the blade to smooth surface and drag excess material across the surface. Additional material may be added to keep the crust intact.

Eventually traffic and climatic conditions will completely break down the crust and the road will need reshaping.

Smoothing is limited to leveling the road surface when it becomes rough and uneven. The intent is to keep the stable crust, not to destroy it by cutting into it.

Smoothing can be done by drags, rakes, and underbody blades. Here we will discuss smoothing with a motor grader.

A dragging, rolling action created by the curve of the grader's moldboard helps compact the road surface as it is bladed. Blading speed will depend on the grader, pressure of tires, and condition of the road surface. Going too fast will cause the grader to bounce, making a good job impossible.

To drag the road surface:

- Check grader blade (cutting edge) to make sure it is in good condition.
- Shift moldboard so end of blade is at edge of road and at beginning of shoulder.
- Tilt moldboard forward to get a dragging rather than cutting action.
- Angle moldboard at about 30° to 45° to spread loose material to center of the road.
- Lean or slightly tilt front wheels about 10° to 15° from the vertical in the direction aggregate rolls across blade.
- Periodically blade surface of the road against the flow of traffic to eliminate drifting of aggregate onto ends of bridges, culverts, intersections, and

railroad crossings.

- ❖ Stop to repair minor bad spots such as holes, rutted areas and poor surface drainage conditions. Always have a shovel available.

Smoothing is normally done in two passes (one round):

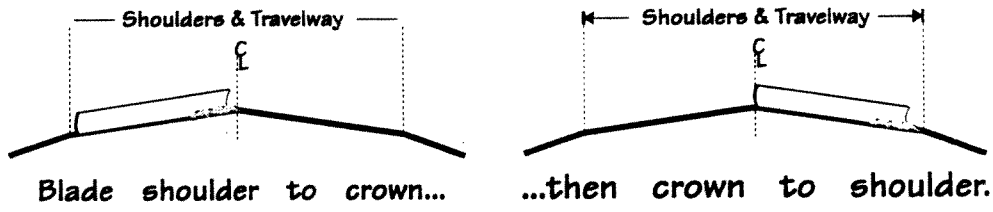


Figure 3.7: Smoothing Gravel Roads

3.4
RESHAPING GRAVEL ROADS

Reshaping a road involves more than just smoothing the surface. Reshaping a gravel road requires cutting through the crust of the roadway to create a new smooth surface. Reshaping should be performed when the roadbed is moist., as a dry hard surface is difficult to cut and can damage the blade.

After a period of rainfall or slow-melting snow, traffic scatters the aggregate, flattens the crown, makes potholes and deep ruts in the road, and produces a rough surface with ridges that look like a washboard. These conditions cannot be

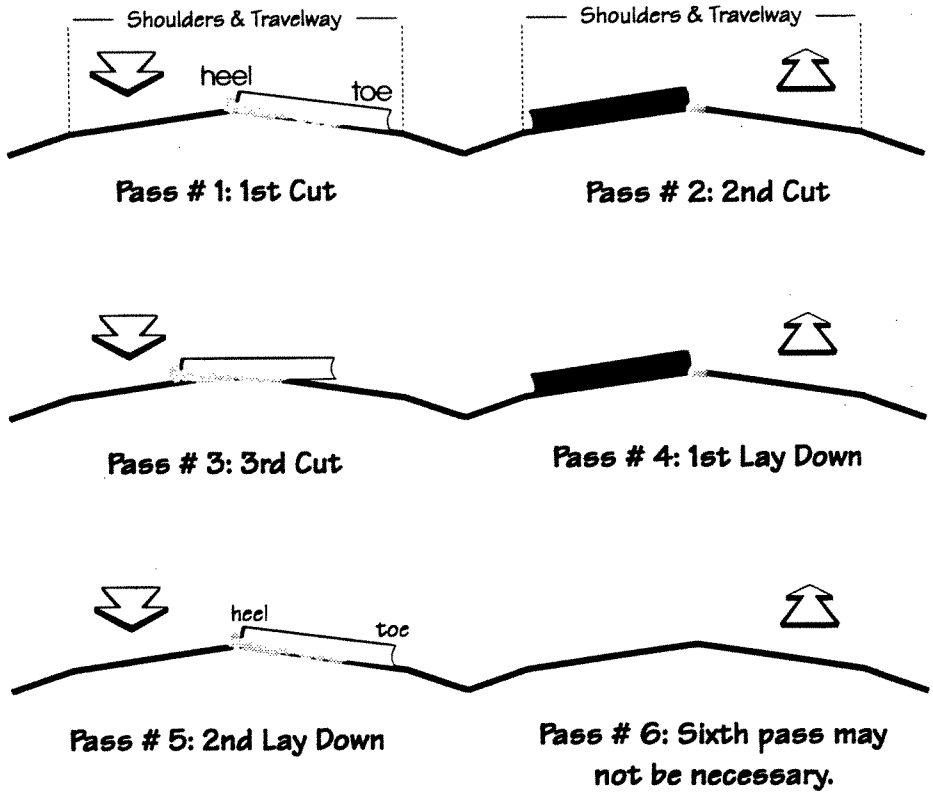


Figure 3.8: Reshaping Gravel Roads

(Note: A pass is one way; a round is there and back again. If the sixth pass were not necessary, how many rounds are there in this example? Answer: 2 ½)

corrected by just smoothing the surface — you must reshape the aggregate base.

Reshaping involves remixing the aggregate base to get a proper *blend* of fines and different size aggregates and blading this blended material into a properly crowned road surface. When remixing, you may need to add additional aggregates and fines to road surface and shoulders, particularly in rough spots or washed-out places.

The development and maintenance of a proper crust can bring great personal satisfaction, since the quality of the crust and its length of useful life depend on the skill used in blending coarse and fine materials which, together with moisture, form the desired crust.

The art of proper blending is a cut-and-try proposition depending on types of materials at hand. Experience will provide know-how to determine the correct blend.

The crust that forms what is left of the old wearing surface is broken up during remixing, often with a **scarifier**. The scarifier is an attachment to the grader used when the crust is too hard to cut easily with the grader's blade.

After the aggregate base is remixed, it is bladed to obtain a smooth road surface with the proper crown. (A new set of cutting edges, of course, gives the best results.) Traffic will compact this base, and a crust will form to give a new smooth wearing surface.

Reshaping procedures

As with smoothing, reshaping should be done when the aggregate is moist. If reshaping is done in dry weather, water must be added to the aggregate to make it moist.

The blade is pitched slightly back to create a cutting action. The toe is placed at the edge of the shoulder, while the heel is at the center of the road. Lean the wheels 10° to 15° so the material is carried toward the center of the road and windrowed there. Proceed at 3-5 mph. Use enough downward force on the blade to cut to the bottom of potholes, washboarding and rutting in the roadway.

In case of deep potholes that cannot be repaired just by cutting, scarify the potholes at least two to four inches below the bottom of the hole prior to reshaping.

On the second pass, spread the windrowed material back across the same side of the roadway, restoring the original crown and shape of the road.

Repeat this procedure on the opposite side of the roadway.

When you use rollers instead of traffic to compact a newly reshaped road, the extended life of the reshaping job will usually more than pay for the rolling costs.

3.5 CURBING

A windrow of excess material that is left on one or both shoulders can create a dam and cause water to stand on the road. This windrow can also become a traffic hazard and a nuisance for mowers and snow plows. "**Curbing**" can have the same effect as leaving a windrow of excess material on the shoulder. Curbing is caused by making a deep cut in the shoulders inside the actual shoulder line. After a while this causes a curb and gutter inside the shoulder line that keeps

water from draining away into the borrow pit. The grader operator should occasionally pull these curbs onto the road and leave the good material on top and waste the oversized rock and grass into the borrow pit. It is very important to make every effort to separate all the usable material out of these stacks or curbs before wasting the excess material into the borrow pit. Once the material has been dumped over the edge, it is very difficult to get it back on the road surface. Again, this waste material should be feathered along the foreslope and not left in a stack or a windrow. If there is a small, uniform stack of good material left after the last pass, the operator can pack it down with the tires of the grader instead of pushing it off the road.

3.6
VEGETATION & OVERSIZE ROCK

Oversized rock and loose vegetation should be sorted out of the road material and dumped in the borrow pit. A rock rake may be needed to help sort excess rock. Any material that must be wasted into the borrow pit should be feathered so as not to create a hazard for mowers or snow plows.

The grass and weeds growing along the edge of a road can cause all kinds of problems. On a narrow, low volume road, tall grass may cause drivers to confine their driving to the center of the road. This will make the road even narrower and may become dangerous. If this grass is pulled in with the gravel during grading, it can be difficult to separate. Early mowing will help, but there always seems to be some vegetation to deal with when grading a road.

It is harder to separate grass from gravel in wet conditions than when both are dry. If there is a lot of grass on a fairly narrow road, it may be wise to wait for dry conditions before grading. If the road must be graded while wet, it might be best to stay out of the grass as much as possible.

If vegetation is still a problem, there are a few things to try:

- Run a very slow square blade while spreading.
- Make extra passes while spreading to help separate the grass.
- If the machine has a moldboard tilt, try tilting the blade forward to create more of a dragging action. If the grass happens to spread out without bunching up, it can be left on the road and traffic will beat it out.
- If the grass and weeds cannot be separated easily, a stack may have to be left on the shoulder and worked out after it dries.

In dry conditions, the technique is much the same. When the grass breaks up and spreads out on the road with the gravel, it may look a little ragged, but the traffic will pack the gravel and disperse the grass and weeds.

Problems often occur when the vegetation bunches up and drags under the blade, leaving ruts and furrows. With a slow or square blade, the ruts will run parallel to traffic. With a fast or sharply angled blade, the ruts will run more across the line of traffic, making a much rougher driving surface. Sometimes the operator may have to leave the long parallel ruts just to get rid of the grass.

Grass and sod growing off the road and on the end slope add strength, stability, and definition to the shoulder.

Oversize Rock

Usually, when a road is graded, the blade will pick up a lot of large rock from the shoulder. This rock is called "**oversize**". It can be a problem and a nuisance just like vegetation, but there are several ways of dealing with it.

If the operator has a lot of material to work with, he may want to leave some of the smaller oversize on the road. If there is enough material to leave 2 inches on the road, then any oversize under 2 inches can be left. If there is adequate moisture in the material, the 2-inch rock should compact with the road material and not become a problem.

Any rock that the operator doesn't want left on the road can be sorted out and dumped into the borrow pit.

Many of the same techniques that are used to sort vegetation can be used to sort oversized rock; however, more than the usual number of passes may be required.

The blade should be set very sharp so that no oversize is left on the road along with the road material. After each pass, there will be more and more oversize in the windrow. When there is mostly oversize in the windrow, and with the windrow close to the shoulder, the blade should be set at a slow or straight angle and the rock should be pushed off the road as far as possible.

If a square or straight blade is used to sort oversize, some of the larger rock will spill out the toe of the blade. An extra pass may be necessary to push these rocks off the road.

Many times when sorting oversize, rocks will hang up under the blade and make ruts in the road. When there are rocks dragging under the blade, the blade will often bounce over these rocks and leave a pile of material in the road. This can be picked up in a later pass.

There is no way to get all the oversize off the road and any rocks left will separate from the road material and be whipped off the road by traffic.

If there is too much oversize left on the road, a rock rake may be needed to finish the job. Any stack of oversize left on the shoulder should then be bladed into the borrow pit.

3.7
NEW CRUSHED GRAVEL & PIT RUN LAYOUT

When new crushed gravel is hauled onto a road, the grader operator has several things to contend with:

- ❖ The project must be properly signed to prevent anyone from driving into the stacks of material.
- ❖ If the trucks should dump on the left side of the road as they are traveling, so the drivers can line up with the shoulder of the road, use a flagman to avoid head-on collisions.
- ❖ The trucks should have spreader chains set to spread the gravel to the desired length.
- ❖ On a road with heavy traffic, the operator may have to windrow the gravel after every round of trucks have dumped.

To windrow the gravel, set a sharp blade and heel the gravel toward the

shoulder on which it is dumped. It may take a few passes to push the material into a windrow. Leave about a tire width between the windrow and the edge of the shoulder.

To lay out the windrow, set a medium blade and, using the toe, take about 6 inches or so of material out of the stack. The first pass will fill in any holes or dips in the road. Leave a stack with the heel but don't worry if it isn't uniform. After several passes the material will even out.

Always be aware of trying to stay level with the grader while pulling material from the stack. If the machine doesn't feel level, adjust the controls for the next pass, and try to level the road.

Take only as much material with each pass as the machine will comfortably handle. It will take several passes to lay out the windrow.

When the last of the windrow has been pulled out, there should be several small windrows across the road. While keeping a level blade, bring these into one windrow and leave it about a foot from the shoulder.

Turn the machine around and set a square blade with the toe well outside the front tire and the heel just outside the rear tire.

Lean the front wheels toward the windrow to allow more reach with the toe of the blade. If the stack is small, take it all in one pass. The gravel will slough out the toe end of the blade and fill the space between the windrow and the shoulder. If the stack is too big, take two or more passes.

Once all the material is off the shoulders, there should be a small windrow of gravel left. Use this to finish the shoulders and to fill any low spots with a slow square blade.

3.8
LAYING NEW PIT RUN GRAVEL

If a road has never been graveled, needs building up, or has been newly rebuilt, pit run gravel will be used to provide a base before the crushed gravel can be applied.

Laying pit run gravel is very similar to laying crushed gravel; the main differences will be in the amount and size of the material.

Usually, the trucks will dump the pit run gravel on the road without spreading it out. If it is spread, it will not be spread as much as crushed gravel.

The first few passes are very important. There will not be much room for the grader to work. Use a tight, square blade for the first pass and be careful to keep that pass as level and even as possible.

Take small bites so that the machine has no trouble handling the material. There will be a tendency for the blade to pull the machine into the stack. Use wheel lean to counter this pull. It is easy to lose traction in the loose, coarse material.

Keep taking small bites and be careful to keep each lift level. Be sure to maintain enough width for the machine to work. As more material is pulled away from the stack, there will be a tendency for the road to become narrow. This will probably be the base for a finished road, so plenty of width will be needed.

Once there is a good working surface, use the same techniques as with crushed gravel to finish laying the pit run.

The pit run surface will be quite rough and may even require a roller to smooth it out. In most cases, crushed gravel should be applied as soon as possible.

3.9
BLADES & CUTTING EDGES

The condition of the grader cutting edge affects how fast and well a road can be smoothed or reshaped. A lot of power is needed to cut washboard ridges and blend materials. Using a worn out cutting edge reduces the working speed of the grader by about half. Check the condition of your grader cutting edge each time you start to blade to see if it needs replacing.

You can tell if you are blading properly by looking at the used bit pile in your yard. The used bits should be straight. If they are badly cupped, chances are the county roads have parabolic crowns and poor drainage. Parabolic crowning is caused by not achieving a straight cross slope from the centerline to shoulder, and may develop during blading with bits that are worn or cupped in the middle.

The easy way to ensure even wear on the bit is to maintain a straight cross slope from centerline to shoulder, with equal force all the way across the moldboard. The hard way is to blade one mile on the right half of the roadway, and the next mile on the left side of the roadway so that the wear on the bit will be even.

You can cause excessive wear on the bits by blading dry roads. In order to determine if there is enough moisture in the road, take a handful of the material in front of the blade and make a fist. If it crumbles, it is too dry. If it stays together in a ball, it is just right.

3.10
STUDY QUESTIONS

1. The best way to drain a road is by _____.

2. The proper shape for a crown is _____.

3. Adequate _____ should be present to insure compaction when rebuilding or reshaping a road.

4. _____ is caused by making a deep cut in the shoulder inside the shoulder line.

5. Why should all excess rock and vegetation be "feathered" out along the borrow ditch?
_____.

6. It is easier to separate vegetation from gravel when it is:
   a. wet
   b. dry

7. The blade angle for separating vegetation is:
   a. square
   b. sharp

8. The blade angle for separating oversized rock is:
   a. square
   b. sharp

9. If oversized rock can't be sorted out by the grader, a _____ may be needed to finish the job.

10. When dumping new gravel, trucks should dump on the _____ side of the road.

11. Always try to keep the machine _____ when laying new gravel.

12. Run a _____ blade when finishing a newly graveled road.
   a. square
   b. sharp

13. TRUE or FALSE — To provide stable road surfaces missing rock sizes need to be blended in.

14. TRUE or FALSE — If you can stabilize the road you can save a lot on maintenance.

15. Potholes, dust surface softening, and corrugation are caused by (select 3):
   a. quality of surface material
   b. level of maintenance
   c. amount of traffic
   d. motor grader operator pay

16. TRUE or FALSE — The ideal surface material gradation is to have two sizes of aggregate missing.

17. Which type of material provides stability and wear resistance of the top layer?
    a. coarse material
    b. fine material

18. Which type of material provides water resistance?
    a. coarse material
    b. fine material

19. The best time to clean ditches is:
    a. before the rainy season
    b. after the rainy season
    c. summer
    d. winter

3.11
ANSWERS TO STUDY QUESTIONS

1. crowning (page 1)
2. A-shaped (page 1)
3. moisture (page 13)
4. Curbing (page 10)
5. To avoid becoming a hazard to traffic and a nuisance to snow plows and mowers. (page 10)
6. dry (page 10)
7. square (page 10)
8. sharp (page 32)
9. rock rake (pages 11)
10. left (page 12)
11. level (page 12)
12. square (page 12)
13.
14.
15.
16.
17.
18.
19.

CHAPTER 4
ROADWAY SAFETY

4.1
STORY OF AN ACCIDENT

It was a school Monday in January, and Mary was in a rush. She lived with her husband and four school-aged kids on a graveled county road in Montana. They had just missed the school bus, so Mary was hurrying them into the car to try and catch it.

"Jerry is in my seat!" "She hit me!" The kids were in orbit as she tried to calm them down and keep them in their seats. She drove quickly to catch the bus: it was a good 20 miles to school and she didn't want to drive that far.

As Mary came around a curve she saw the school bus had stopped to pick up children. She braked and honked her horn. She didn't realize the bus was standing on a patch of ice; before Mary knew it, she had slammed into the back of the bus.

There was damage to the bumper and grill, but that wasn't the bad part. Jerry had a big purple, black, and blue bump on his forehead from hitting the windshield, and had broken his glasses. Her daughter thought she had a broken arm.

As she was getting out of the car she noticed the county blade operator coming down the road in his motor grader on the way to work. Mary waved him down and asked for help. "I'm paid to blade roads, not help people" he said as he drove off.

But the worse had yet to happen: as Mary stood in the road watching the motor grader leave the scene, a rancher with a stock trailer came around the corner and ran into Mary's car!

COMMENTS: You might think we have to work hard to find such a case, but unfortunately we don't. This story is based on an actual Montana case. Other real cases include a Cenex truck driver who was fatally injured when he lost control of his truck due to dips in a county road, and a driver of an 18-wheeler who lost control on a curve because it was allegedly bladed flat, with no super, and should have been signed. He is now a paraplegic.

It almost goes without saying that when someone is faced with large medical bills, or the death of a loved one, they will seek recourse by suing the county.

These cases point out the need for trained motor grader operators. First, you should know that it is state law that your county provide safe roadways for the traveling public. A court case example is BUCK versus STATE, 723P2D210, 213 (MONT 1986), "The state must keep its highways in a reasonably safe condition for ordinary use." You should also know it is the ***law*** that your county follow the *Manual on Uniform Traffic Control Devices* (MUTCD) when putting signs up on

a county road (61-8-206 Montana Codes Annotated). You should attend training on the MUTCD and in roadway safety, available through the Rural Technical Assistance Program. The list of references at the beginning of this handbook provide more reading on this important subject.

In the case of Mary's accident, what should the motor grader operator have done? Follow road department policy is the easy answer, but some counties have no written policies. Not having written policies can present problems for a judge and jury in that it could easily be interpreted as the county road department not caring about its responsibilities.

The motor grader operator is required to act as a prudent or reasonable person would. In this case, where the roadway was obstructed, he should have rendered first aid, marked the area to prevent further accidents, called for medical help, called the highway patrol and called his road supervisor.

In taking your Montana Drivers License exam you are required to know that you must report all accidents over $400 to the Highway Patrol. The manual also suggests giving first aid, and references the Montana Good Samaritan law that states ". . . any . . . person, who in good faith, renders emergency care or assistance without compensation . . . at the scene of an emergency or accident is not liable for any civil damages for acts or omissions other than damages occasioned by gross negligence or by willful or wanton acts or omissions by such person in rendering such emergency care."

New regulations have redefined the requirements for a "chauffeur's" license. The license manual, under procedures for handling accidents, states: "When you're involved in an accident or come upon an accident, you need to take prompt and proper action to prevent further damage or injury. The basic steps to be taken at accidents are: protecting the area, notifying the authorities, caring for the injured, and collecting information."

But let's take a look at how this case might come out if it went to court. Mary, or the driver who ran into Mary's car, could well sue the county, and even name the motor grader operator for being negligent. Most lawsuits involving roads are based on negligence, which means someone like a motor grader operator does something wrong. **Negligence is a tort (wrong), and is actionable in court.**

Tort law provides a remedy in situations where one party is injured at the hands of another. Negligent conduct must be established. There is a four point test that must be satisfied to prove negligence. If there is not sufficient evidence to convince a jury on any one of the points there is no case.

4.2
FOUR POINT TEST TO DETERMINE NEGLIGENCE

1. DUTY — It must be shown that there was a duty for the motor grader operator or county to conform to a particular standard of conduct or care that would protect Mary or the driver who ran into Mary's car. As previously mentioned, the county has a duty to keep its roads in a reasonably safe condition. The fact that the motor grader operator did not perform his duty by helping at the accident scene, or

see to it that the roadway was cleared of damaged vehicles might be enough to sway a jury.

2. BREACH — It must be shown that the motor grader operator breached his duty (broke his obligation). Did he, for example, do what a reasonable operator should have done: help at the scene, erect warning signs, see that the damaged vehicles were removed from the roadway?
3. CAUSE — It must be shown that there was a connection between the motor grader operator's conduct and the injury to Mary and the other driver. The other driver may not have hit Mary and her children if the operator had cleared the road or erected warning signs.
4. DAMAGE — It must be shown that some harm was done to Mary or the other driver. The jury would consider both the vehicular damage and the medical bills.

4.3
SOVEREIGN IMMUNITY & THE LEGAL SYSTEM

When the United States inherited England's legal system, it also inherited the feudal doctrine of "**Sovereign Immunity**". The King, who possesses supreme authority and jurisdiction, makes all the rules. Because he is free from external authority, he cannot disobey rules or be held accountable, as the rules simply adapt to meet his needs. People who work for the King are also protected by sovereign immunity as they operate under his authority. From this belief that the King can do no wrong came the belief that "the Government can do no wrong."

Over time, the courts have nibbled away at the doctrine of sovereign immunity, and states and local governments are not immune from lawsuits. Most common lawsuits against local agencies occur when something is not in compliance with MUTCD standards, or when accidents occur due to unsafe roads.

A local agency's best defense against litigation is to know the standards and to act in a "reasonable and prudent" manner.

Currently, the legal system is concerned with the condition called "Comparative Negligence". The court will first try to determine negligence, then assign "negligence percentage values" to all those parties involved. For example, if they find that the driver is 50% in error and the county is 50% in error, the county would be required to pay half of the damages. It is common for fatalities to be assessed at 1 million dollars.

One area in which local agencies are commonly liable for tort claims is where signs are left in place that do not apply. The US Forest Service recently paid $7.56 million because a work zone sign was left up months after construction was complete.

4.4
MANUAL ON UNIFORM TRAFFIC CONTROL DEVICES (MUTCD)

The concept of uniform traffic control devices is a popular one. The idea that you can understand the signs and markings in New York, Montana, or for that matter, Canada, Europe, and other participating countries has great merit.

Montana has made it the law that all agencies including counties will use the MUTCD (61-8-206 MCA). The railroad crossing sign is the only sign that is mandatory. Remember that if a sign is warranted (meets the MUTCD requirements) and you decide to put it up, you must install it in accordance with the MUTCD. What might not be obvious is that if there is an accident, the lawyers and courts will look at the evidence. If the device is the wrong design, size, distance, height, reflectivity, etc., the county could end up liable.

Design

Uniformity in design includes shape, color, dimensions, legends, and illumination or reflectorization. Detailed drawings of typical standard signs approved for use on streets and highways are available to State and local highway and traffic authorities, sign manufacturers, and similarly interested agencies. All symbols shall be unmistakably similar to those shown in the MUTCD, and where a word message is applicable, the wording shall be standardized as shown in the MUTCD.

Shapes

Standard sign shapes are:

Octagon – shall be reserved exclusively for the **Stop Sign.**

Equilateral triangle – (with one point downward) shall be reserved exclusively for the **Yield Sign.**

Round – shall be used for the advance warning of a **Railroad Crossing** and for the **Civil Defense Evacuation Route Marker.**

Pennant – (isosceles triangle with its longest axis horizontal) shall be used to warn of **No Passing Zones.**

Diamond shape – shall be used only to **Warn of Existing** or **Possible Hazards** either on the roadway or adjacent thereto.

Rectangle – (ordinarily with the longer dimension vertical) shall be used for regulatory signs, with the exception of **Stop Signs** and **Yield Signs.**

Rectangle – (ordinarily with the longer dimension horizontal) shall be used for **Guide Signs**, with the exception of certain route markers and recreational area guide signs.

Trapezoid – may be used for **Recreational Area Guide Signs.**

Pentagon – (point up) shall be used for **School Advance** and **School Crossing Signs.**

Other shapes are reserved for special purposes; for example, the **shield** or other characteristic designs for route markers and the **crossbuck** for railroad crossings.

Illumination and Reflectorization

Regulatory and warning signs, unless excepted in the standards covering a particular sign or group of signs, shall be reflectorized or illuminated to show the same shape and color both by day and night.

Application of Warning Signs

Warning signs are used when it is deemed necessary to warn traffic of existing or potentially hazardous conditions on or adjacent to a highway or street. Warning signs require caution on the part of the vehicle operator and may call for reduction of speed on a maneuver in the interest of his own safety and that of other vehicle operators and are valuable in safe-guarding and expediting traffic. The use of warning signs should be kept to a minimum because the unnecessary use of them to warn of conditions which are apparent tends to breed disrespect for all signs.

Even on the most modern expressways there may be some conditions to which the driver can be alerted by means of warning signs. These conditions are in varying degrees common to all highways, and existing standards for warning signs are generally applicable to expressways.

Typical locations and hazards that may warrant the use of warning signs are:

1. Changes in horizontal alignment
2. Intersections
3. Advance warning of control devices
4. Converging traffic lanes
5. Narrow roadways
6. Changes in highway design
7. Grades
8. Roadway surface conditions
9. Railroad crossings
10. Entrances and crossings
11. Miscellaneous

Placement of Warning Signs

Warning signs shall be erected in accordance with the general requirements for sign position.

Since warning signs are primarily for the benefit of the driver who is unacquainted with the road, it is very important that care be given to the placement of such signs. Warning signs should provide adequate time for the drive to perceive, identify, decide, and perform any necessary maneuver. This total time to perceive and complete a reaction to a sign is the sum of the times necessary for Perception, Identification/understanding, Emotion/decision making, and Volition/execution of decision, and is here referred to as the PIEV time. The PIEV time can vary from about 3 seconds for general warning signs to 10 seconds fro high driver judgement condition warning signs.

Figure 4.1 shows the standard for proper height and offset in mounting signs. Figure 4.2 shows how regulatory signs (Stop, Yield, speed, Bridge Posting, etc.) are placed near intersections.

Typical Applications for Workzone Traffic Control Devices

In construction and maintenance workzones, work duration is a major factor in determining the number and types of traffic control devices to be used.

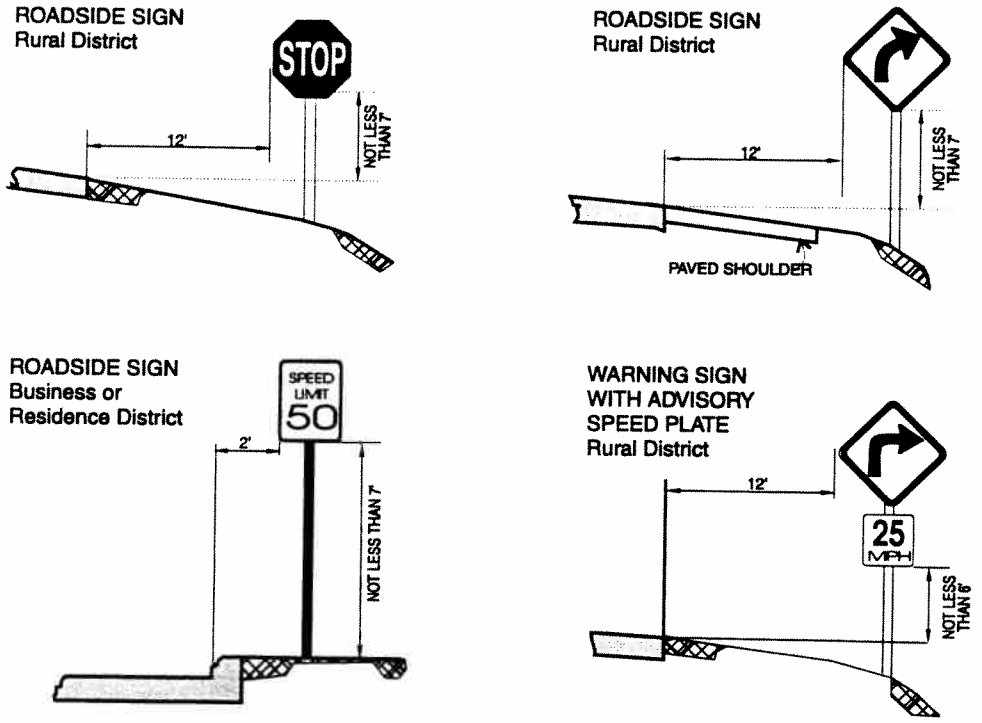
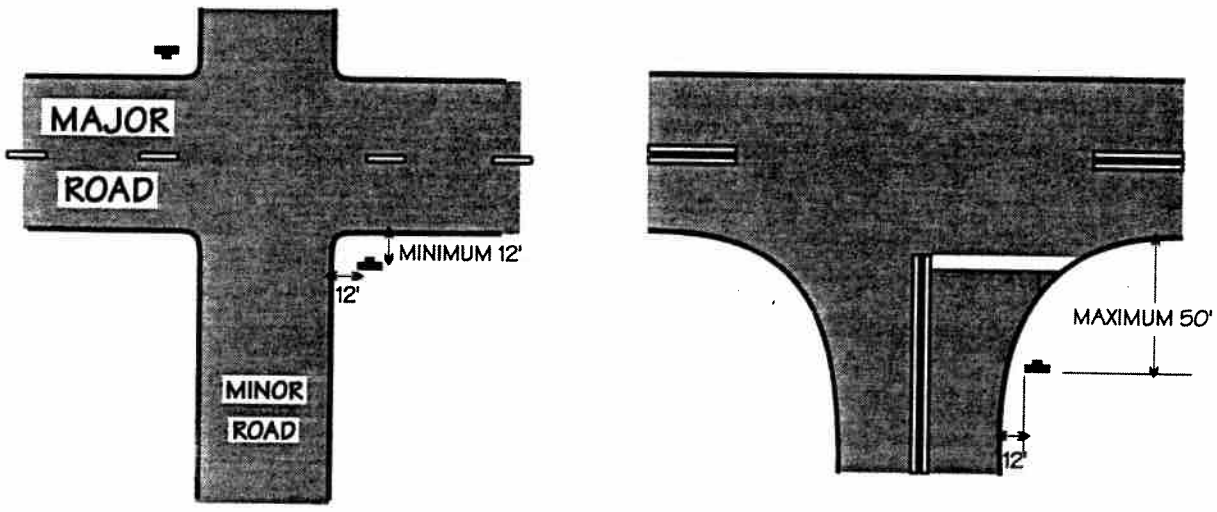


Figure 4-1
Height & Lateral Location of Typical Rural Signs



MINOR CROSSROAD

WIDE THROAT INTERSECTION

Figure 4-2
Typical Locations for Stop & Yield Signs on Rural Roads

Examples of types of work might include:

- **Short-term stationary** – daytime work that occupies a location from 1 to 12 hours;
- **Short duration** – work that occupies a location up to 1 hour; and
- **Mobile** – work that moves intermittently or continuously.

Short-Term Stationary. Most maintenance and utility operations are short-term stationary work. The work crew is present to maintain and monitor the temporary traffic control zone. The use of flaggers is an option. Lighting and/or retroreflective devices should be chosen to accommodate varying seasonal, climatic, and visibility situations.

Mobile and Short-Duration Operations

As compared to stationary operations, mobile and short-duration operations are distinct activities that may involve different treatments. More mobile devices are needed (e.g., signs mounted on trucks), and larger, more imposing, and more visible devices can be used effectively and economically. For example, appropriately colored and marked vehicles with flashing or rotating lights, perhaps augmented with signs or arrow displays, may be used in place of signs and channelizing devices. The trade-off is economical because work duration is short. Mobility is essential, for the crew is always onsite, and some of the vehicles may be required for the work activity or crew transportation. Safety is not compromised, as numerous small devices are merely replaced by fewer, more dominant and effective devices.

Short Duration. Short-duration activities are generally considered to be those in which it takes longer to set up and remove the traffic control zone than to perform the work. Typically, such operations can be accomplished in 60 minutes or less. There are hazards involved for the crew in setting up and taking down the traffic controls. Also, since the work time is short, the time during which motorists are affected is significantly increased when additional devices are installed and removed. Considering these factors, it is generally held that simplified control procedures may be warranted for short-duration work. Such shortcomings may be offset by the use of other, more dominant devices such as special lighting units on work vehicles.

Mobile. Mobile operations include activities that stop intermittently and then move on (e.g., pothole patching and litter pickup) and those that move continuously (e.g., pavement striping). Mobile operations often involve frequent short stops, each as much as 15 minutes long, for activities such as litter cleanup, pothole patching, or utility operations, and are therefore similar to stationary operations. Warning signs, flashing vehicle lights, flags, and/or channelizing devices should be used. With operations that move slowly (less than 3 mph), it may be feasible to use stationary signing that is periodically retrieved and repositioned in the advance warning area.

Mobile operations also include work activities in which workers and equipment move along the road without stopping, usually at slow speeds. The advance warning area moves with the work area. Traffic should be directed to pass safely. Parking may be prohibited, and work should be scheduled during off-peak hours.

For some continuously moving operations such as street sweeping, where

volumes are light and visibility is good, a well-marked and well-signed vehicle may suffice. If volumes and/or speeds are higher, trucks are typically used as components of the traffic control zones. Appropriately colored and marked vehicles with signs, flashing or rotating lights, and special lighting panels move as part of a train behind the work vehicles.

A shadow or backup vehicle equipped as a sign truck, preferably supplied with a flashing arrow display, should follow along the work vehicle. Where feasible, warning signs should be placed along the roadway and moved periodically as the work progresses. In addition, vehicles may be equipped with such devices as flags, flashing vehicle lights, truck-mounted attenuators, and appropriate signs. These devices may be required individually or in various combinations, including all of them, as determined necessary.

Mobile operations that move at speeds greater than 20 mph, such as snowplowing operations, shall have appropriate devices on the equipment, (i.e., rotating lights, signs, or special lighting) or shall use a protection vehicle with appropriate warning devices.

Safety should not be compromised by using fewer devices simply because the operation will frequently change its location. Portable devices should be used. Flaggers may be used, but caution must be exercised so they are not exposed to unnecessary hazards. The control devices should be moved periodically to keep them near the work area. If mobile operations are in effect on a high-speed travel lane of a multilane divided highway, flashing arrow displays should be used.

4.5
ADDITIONAL TRAINING

By now we hope we have convinced you that there are standards of care for which motor grader operators and counties are responsible. A valid question that can come up in court is: "Are your road department personnel trained in highway safety and the MUTCD?"

There are several courses taught yearly at different locations in Montana, where you can receive training.

1. **International Municipal Signal Association (IMSA) Certification Course For Traffic Signs & Markings Technicians** —This two day training covers the MUTCD which every agency in Montana is required by law to follow. Participants are encouraged to sign up early so they can receive study guides prior to the workshop.
2. **Safety Management** — This two day course is an effort to assist local agency personnel in lowering the likelihood of unnecessary legal actions. Topics discussed are clear zones, sight distance, road surfaces, slopes, signs, markings, guardrails, bridgerails, barriers and work zone signing.
3. **Workzone Traffic Control** — discusses the five parts of a Traffic Control Work Zone while applying local situations and problems. Safety, uniformity and liability issues are the main focus.
4. **Risk Management & Tort Liability**
5. **Traffic Control Practices for Low Volume Local Roads**

6. **Sign Management Systems** — this workshop has been developed to provide state and local highway agencies with a tool for assembling and maintaining a sign inventory system. The SMS introduces a systematic review process and tracks the age and condition of signs.

4.6
STUDY QUESTIONS

1. A motor grader operator's (county's) duty to maintain a safe roadway is based on:
   a. law
   b. public opinion
   c. personnel manual
   d. county budget

2. True — False: In Montana it is mandatory you follow the *Manual on Uniform Traffic Control Devices* (MUTCD).

3. The Montana Chauffeur and Commercial Vehicle Operator's License requires what action when you are in or come upon an accident? (select four)
   a. protect the area
   b. notify authorities
   c. care for the injured
   d. collect information
   e. call a lawyer

4. You are required to make a written report of all accidents to the Highway Patrol that have damage over?
   a. $200
   b. $250
   c. $300
   d. $400

5. True — False: Negligence on the part of a motor grader operator is a tort (wrong), and you can be taken to court.

6. The four points required to prove negligence are: (select four)
   a. It must be shown there was a duty.
   b. It must be shown the duty was breached (broken).
   c. It must be shown the breached duty caused the accident.
   d. It must be shown there was damage.
   e. It must be shown the motor grader operator was a county resident.

7. The only sign that is mandatory according to the *Manual on Uniform Traffic Control Devices* (MUTCD) is: (select one)
   a. Stop sign
   b. Curve sign
   c. Railroad Crossing
   d. Road Closed

8. True — False: There are training courses available in Montana that deal with the MUTCD and roadway safety.

9. What emergency devices does your county require that you have available in your county vehicle/ equipment at all times?
   a. three portable reflectors
   b. fire extinguisher
   c. first aid kit
   d. blank accident report & pen
   e. county policy

10. True — False: If you give reasonable first aid to an accident victim you can be held liable.

4.7
ANSWERS TO STUDY QUESTIONS

1. a) law (page 1)
2. True (page 1-2)
3. a) protect the area; b) notify authorities; c) care for the injured; and d) collect information. (page 2)
4. d) $400 (page 2)
5. True (page 2)
6. a) there was a duty; b) the duty was breached; c) the breached duty caused the accident; d) there was damage (page 2-3)
7. c) Railroad Crossing (page 4)
8. True (page 8)
9. County Policy
10. False (page 2)

CHAPTER 5
DEALING WITH THE PUBLIC

5.1
BLADE OPERATOR'S ROLE

The reputation of the road department and the county is only as good as the reputation of each county employee. When it comes to budget time these perceptions can have a dramatic effect. If you have a positive attitude and know your job, that is the image the public will receive.

How often do you say to yourself, "Am I doing a good job? Is the public we serve satisfied with our service?" When your phone rings or you are stopped at roadside, are you eager to find out about problems and get feedback, or do you consider dealing with the public an imposition?

We would like you to consider the public as the most important part of your operation. They are why you are there — without their support someone else will soon be doing your job. Unfortunately the public in general has a negative attitude about public employees, sometimes with good reason. They expect that we will be rude, arrogant and unresponsive. There are ways, however, that we can develop our communication style to make our contacts with the public more positive.

5.2
WAYS TO RESPOND TO THE PUBLIC

You are operating your motor grader and a rancher flags you down and proceeds to unload on you as to how poor he thinks the road is, and he wants to know what the county is going to do about it. How do you handle this situation? Some points in effectively dealing with an upset citizen are:

1. **Defuse the confrontation**
   a. Let him have his say. Don't interrupt. He has thought about the situation he wants to talk to you about for hours, if not days. He has probably already decided that its no use talking to you because you aren't going to listen.
   b. Ask him, in a nice way, when he is finished, if there is anything else bothering him. Your goal is to be sure he has had his say. Say to him you think you can at least explain why things are the way they are and what the county plans for the future are.
   c. Watch for signs that he is winding down. His body language can tell you a lot. Clenched hands and tight facial expressions are examples that he is still upset. One of the best ways to defuse anger in another person is for you to show concern. It is hard to argue with someone who is concerned with your problem.

2. **Take charge**
   a. Express your concern and understanding of the rancher's frustration.
   b. If you know the answer, tell it. Be sure to point out why the county operates the way it does. For example, if the repair or maintenance is scheduled in the future, tell him that each year the county assesses the roads and comes up with a priority list for projects, if that is the case.
   c. If you don't know the answer, don't bluff. Restate the problem in your own words to be sure you and the rancher are in agreement as to just what the problem is.
3. **Close the discussion**
   a. Tell the rancher you need to find more information or discuss the problem with your boss.
   b. Give him a time when he will hear back from you. Don't become part of the problem by failing to get back at the appointed time.
4. **What to say when the answer is "no"**
   a. State specifically the research you did and the law, administrative guideline, policy, procedure or budget constraint that was the basis for your negative decision. Do not apologize for the rules.
   b. Tell the rancher of any appeal process available. Tell him you are sorry you could not help and that you wish you could have.
   c. If the rancher wants to talk to the boss, refer him graciously.
5. **Keep your supervisor informed.** He needs your feedback on how the public is being served.

5.3
WHY AREN'T OUR COUNTY ROADS IN BETTER SHAPE?
An open letter from the County Commissioners, Sweet Grass County

The public and public officials in some locations in Montana ask this question with good reason. The only season some of these roads are in excellent shape is in the dead of winter when they are frozen solid. This article is an attempt to explain what is wrong, and surprisingly, some of the things the traveling public can do to help.

Many of the gravel roads in Montana were built long ago. Some of them have poor foundations that were not intended to carry today's traffic. Some of them have alignment problems creating safety hazards. The road surfaces on poorly aligned curves are extremely difficult to maintain, because the fast moving vehicles tend to throw the gravel into the ditch. To have an understanding of what is going on with a particular road, one has to have some idea of how roads in general built and maintained.

The composition and life of a gravel road is not overly complicated. Assume that we are talking about a road that is in reasonably good shape. It has at least the minimum 60 foot required right-of-way. It has ditches on both sides that are adequate for drainage and snow removal. There are no soft spots in the base. No irrigation water is allowed to run in the ditch, and the road has a proper graveled surface.

There should be four to six inches of surface material containing all sizes of

angular, not rounded, material from small particles of clay binder up to 3/4 inch stone. This material may be extremely difficult to find in some areas of Montana. The surface layer locks together (not possible when using round stone) forming a thick crust that helps support vehicles and sheds water. There should be a crown in the road and no vegetation on the roadway surface. This will allow water to run freely to the ditch and not puddle in the roadway causing potholes.

Now if you have less than the above, you are probably riding on a very rough road. But don't lose heart. Despite the fact that counties have more miles of road to maintain than they have money for, they do have a plan for rehabilitating about twenty miles of worn out road a year. County officials are constantly working with the public in many ways to economically improve the road system, including establishing gravel pits and obtaining right of way. They monitor their budgets closely to purchase the minimum equipment necessary for road rehabilitation. This includes graders, dump trucks, grid rollers, and a water truck.

The best time (or only time) to reshape a gravel road is when it has moisture in it. The moisture helps bond the particles, aiding their compaction into a dense mass. The surface forms into a thick crust that will repel rain. Once the dry weather comes and the road sets up, the road work is done for the year (unless you have a water truck and want to work in dry weather). Attempts at grading a dry road cuts the peaks into the valleys of washboards. This looks nice and smooth, but the next vehicle that passes kicks the fines out again. In most cases you are better off not grading a dry road.

What can be done to help preserve a reshaped road?

Keep down the speed! Vehicles at high speeds unravel the very top of the road. This causes dust. Losing the dust (fines) allows the coarser stones to become easily dislodged. Gravel roads lose about an inch of surface material every year. This amounts to about 500 tons per mile. Dust is a safety hazard and detrimental to crops. As the roads wear down, the lost material must be replaced at public expense.

Don't drive in the same track! Almost everyone has a tendency to drive right down the centerline, flattening the crown, and causing wheel ruts. Drive on the right side of the road. This is especially important right after the road has been graded and it is still compacting under wheel loads. If traffic would slow down and help compact the whole road, it would last longer.

Don't overload a vehicle! This will cause a road to rapidly deteriorate. An overloaded grain or logging truck will cause particles to grind together, breaking them up and creating more dust and fines. If there is already a weak foundation, it will push the road into it.

Once you have approximately 100 vehicles per day (some say less), a gravel road is almost impossible to maintain. This is true even if you have the best materials and design. Then it requires constant grading and the addition of water or chemicals to control dust and provide for stabilization.

The above section is based on an LTAP news release. Note that the Sweet Grass County Commissioners made it into an open letter for use in educating the public. It contains some excellent information that every motor grader operator should be

aware of. For example, the reference to 60 foot of right-of-way is contained in Montana Law as follows:

> *Section 1339. Width of highways. The width of all public highways, except bridges, alleys and lanes, must be sixty feet unless a greater or less width is ordered by the Board of County Commissioners on petition of the persons interested. Act approved March 2nd, 1903.*

5.4
STUDY QUESTIONS

"We hope the following questions seem very basic to you, and that you can answer them by using common sense."

1. Name the most important person in public relations in your road department: _____.

2. TRUE — FALSE: The best way to defuse a confrontation with an upset citizen is to interrupt when he/she is talking.

3. TRUE — FALSE: An upset citizen has probably rehearsed what he/she wants to say several times before they confront you.

4. TRUE — FALSE: It is good practice to thank a citizen who reports a road hazard because they can act as your eyes and ears in places you don't have time to cover.

5. TRUE — FALSE: If you don't know an answer, tell them anything because they won't know the difference.

6. TRUE — FALSE: It is best to carry a notepad and pencil to record citizens complaints.

7. TRUE — FALSE: Roads built years ago generally have good bases because they have been compacted by a lot of traffic.

8. TRUE — FALSE: Years ago standards for sight distance, vertical and horizontal curves were more strict than they are now.

9. County road right of way as specified in Montana Statutes is:
   a. 80 feet b. 60 feet c. 50 feet d. 40 feet

10. The ideal gravel road surface is:
    a. 4 to 6 inches, angular material, all sizes, no fines
    b. 4 to 6 inches, pit run, all sizes, clay binder
    c. one foot of pit run
    d. 4 to 6 inches, angular material, all sizes, clay binder

11. TRUE — FALSE: Gravel roads in extremely dry areas should be bladed flat without a crown to trap moisture.

12. TRUE — FALSE: The best time to reshape a gravel road is when it is dry.

13. TRUE — FALSE: When you smooth a dry road, what happens when the traffic drives on it?

14. TRUE — FALSE: Overloaded vehicles help gravel roads because they compact them.

15. TRUE — FALSE: Even if a gravel road has a good foundation and is constructed with the best materials available, once it carries over approximately 100 vehicles a day, it is very difficult to maintain and should be considered for paving.

5.5
ANSWERS TO STUDY QUESTIONS

1. yourself (page 1)
2. False (page 1)
3. True (page 1)
4. True
5. False (page 2)
6. True
7. False (page 2)
8. False. Current standards are contained in *A Policy on Geometric Design of Highways and Streets, American Association of State Highway and Transportation Officials Green Book,* 1984. For example, on page 465 it lists the minimum width of the traveled way for a design speed of 50 miles per hour and traffic less than 250 vehicles per day as 20 feet plus 2 foot graded shoulders on each side. For bridges with a design speed of 50 miles per hour and 400 vehicles a day or under the minimum clear roadway width of a bridge is the traveled way 20 feet plus 2 feet on each side for a total of 24 feet. If the bridge design speed is 30 miles per hour or under the minimum clear roadway width of a bridge is the traveled way 18 feet plus 2 feet on each side for a total of 22 feet.
9. b) 60 feet (page 2)
10. d) 4 to 6 inches, angular material, all sizes, clay binder (page 2-3)
11. False
12. False (page 3)
13. Traffic kicks out the fines (page 3)
14. False (page 3)
15. True (page 3)

CHAPTER 6
ADDITIONAL INFORMATION ABOUT GRAVEL ROADS

6.1
IMPROVEMENTS TO THE SURFACE MATERIAL OF GRAVEL ROADS

Improvements to the surface material of gravel roads is a rainy season task. If the work is completed during dry weather, the road has to be watered to a depth of 5 to 10 cm (2 to 4 in.). Moisture is needed during te upgrading of the old surface, and when mixing and compacting. If a clay material is to be introduced, then about 3 to 5 cu. yds./road mile will be needed. The spreading of clay is very sensitive to rain, and surplus clay makes the wet road surface very slippery.

Dust Binding

Correct proportioning of the ideal gravel road surface materials will reduce the amount of dust produced. To ensure dust binding, some road departments make annual applications of dust suppressants. There are two basic application methods: deep mixing and surface application.

Mechanized Maintenance

The focus of gravel road maintenance is on light mechanization, freeing heavier equipment for other tasks. Graders and tractor-towed levelers (drag graders) are used. Drag graders are made up of a steel frame equipped with wheels, three or more leveling blades, a windrow spreader, and tilt regulators. Rough adjustment and lifting into a transporting position can be done mechanically or hydraulically.

Engineers report that the use of a drag grader cuts maintenance costs from about $8 to $10 per road mile to $5.50 to $6.50 per road mile.

The leveler is mainly an anti-corrugation device. In addition to the leveling of corrugated surfaces, it will fill minor potholes and remix the surface material. During the rainy season, the road surface can be quickly leveled and dried with a leveler, thus avoiding further road damage.

During the leveling operation, the first set of leveling blades cut and remove the tops of the corrugations. The middle blades mix the loose gravel surface material. Finally, the windrow spreader at the rear evenly spreads the material.

Keeping the road level not only improves the riding quality, but also allows for rapid rainwater drainage.

When the road needs regraveling, a leveler is an excellent device for mixing the new and old surface materials. It is regularly used when clay material is added to compensate for the loss of fine particles from the road surface in front of the drag grader.

Before starting work, the tractor driver checks the blade fittings, adjusts them,

and adjusts the tilt of the device. Special attention must be paid to the position of the gravel spreader at the rear. After a short drive, additional adjustments may be needed. During work, the height of the leveler can be adjusted either hydraulically or by the tractor's lifting device, thus increasing or decreasing the depth of the blades. Depending on the depth of cut, the capacity of the leveler is 10 to 15 mi./hr.

The use of a drag grader doesn't totally replace the need for a grader, which is needed to reshape and add the camber to the road. A grader is also needed for larger leveling work.

Surface Gravel Screening

For the coarse fraction of gravel road surface material, the oversize particles can cause problems. Thus, natural material has to be screened. A portable screening plant has been used with very good results.

The portable plant is made up of a feeder unit with a primary screen, a 40-ft. conveyor and a two-level screen with unloading heights of 8 to 11.5 ft. The equipment is powered by a diesel engine and the screen and other adjustments are hydraulically controlled.

The gravel to be screened is loaded into the feeding bin, which has a capacity of 4.5 cu. yds. The bin can also be easily removed for manual loading. The screen, which is located at the end of the conveyor over the dumper, grades the material into three sizes. The equipment can be adjusted at the site manually and towed from one site to another by truck.

Grader Attachments

The motor grader is the basic piece of equipment for gravel road maintenance, whatever additional equipment is in use. All the heavy tasks such as reshaping and scarifying the road surface and ditch opening, should be reserved for the grader.

Before the rainy season starts, all ditches should be open and clean. With a ditch-plow mounted on the side of the main blade, a side ditch can be opened and cleaned in one pass. The plow can be adjusted hydraulically and an outer wing spreads the material away from the ditch, so that rain won't wash it back.

6.2
WHEN TO PAVE A GRAVEL ROAD

A Word About the Term "Paved". What is meant by a "paved" road? For some, a light chip seal coat is considered paving. For others, paving is four or more inches of bituminous asphalt or "hot mix". The primary purpose of a pavement is to protect the subgrade. As the loads get heavier, the pavement thickness must be increased.

Generally speaking, bituminous concrete (hot mix asphalt) has little real load-bearing capacity of its own until it reaches a thickness of two inches. In fact, the Asphalt Institute has a firm policy of recommending a minimum pavement thickness of 4 inches full depth asphalt or 3 inches asphaltic concrete

[1] *"When to Pave a Gravel Road", Helping Hand Guide #2.* Kentucky Transportation Center, April 1988.

plus a suitable granular base even for low volume roads. Their research shows that 4 inches of hot mix will carry about 10 times as much traffic as 2 inches of hot mix when constructed over thin granular bases.

A pavement less than two inches thick primarily protects the base materials by shedding water and providing a smooth riding surface. Such a road is more properly called a surface-treated road. Roads with thin pavements must have excellent drainage designed into them and be diligently maintained throughout their service life.

In this paper we will consider even a light surface treatment as paving, however. The assumption is that, when a town first applies a chip seal treatment, for example, it has taken a first step toward eventually achieving a load-bearing pavement.

Introduction

Two-thirds of the highway system in the United States and more than 90 percent of all the roads in the world are unsurfaced or lightly surfaced low volume roads. In Montana more than 58,000 miles of local roads have gravel[2] surfaces.

Most local roads were not designed with the same considerations used in the design of state and interstate highways. Most have evolved from primitive trails. Paths of least resistance first created by wild animals were later used by settlers. As needs and traffic increased, these traveled ways became roads which were gradually improved with gravel or crushed rock. Little engineering went into these improvements. Using available materials and "keeping them out of the mud" were the extent of efforts to maintain a road.

As paving occurred, the tendency was to make minor modifications to the foundations of the evolved road and to seal or pave the surface. As a result, many low volume roads in Montana now have continual maintenance problems because of inadequate base support in addition to alignment and drainage problems.

To add to the problem, roads throughout Montana are experiencing ever-increasing weights and volumes of traffic. Population growth and tourism make traffic demands. Coal trucks and other commercial vehicles are carrying heavier loads than ever before. These higher volumes and greater weights are putting a steadily increasing strain on local road maintenance and reconstruction budgets.

Gravel or paved: a matter of trade-offs

The decision to pave is a matter of trade-offs. Paving helps to seal the surface from rainfall, and thus protects the base and subgrade material. It eliminates dust problems, has high user acceptance because of increased smoothness, and can accommodate many types of vehicles such as tractor-trailers that do not operate as effectively on unsurfaced roads.

In spite of the benefits of paved roads, well-maintained gravel roads are an effective alternative. In fact, some local agencies are reverting to gravel roads. Gravel roads have the advantage of lower construction and sometimes lower maintenance costs. They may be easier to maintain, requiring less equipment and possibly lower operator skill levels. Potholes can be patched more effectively. Gravel roads gener-

[2]Gravel as used here may refer to sand and gravel, or to crushed stone.

ate lower speeds than paved surfaces. Another advantage of the unpaved road is its forgiveness of external forces. For example, today vehicles with gross weights of 100,000 pounds or more operate on Montana local roads. Such vehicles would damage a lightly paved road so as to require resealing, or even reconstruction. The damage on a gravel road would be much easier and less expensive to correct.

There is nothing wrong with a good gravel road. Properly maintained, a gravel road can serve general traffic adequately for many years.

Should we pave this gravel road? A ten part answer

When a local government considers paving a road, it is usually with a view toward reducing road maintenance costs and providing a smooth riding surface. But is paving always the right answer? After all, paving is expensive. How does a county or city know it is making the most cost-effective decision?

We will consider ten answers to the question "should we pave this gravel road?" In fact there are ten parts to one answer. If one of the ten is not considered, the final decision may not be complete. The ten answers taken together provide a framework for careful decision making.

Answer # 1 – After developing a road management program

If the road being considered for paving does not fit into a county-wide road improvement program, it is quite possible that funds will not be used to the fullest advantage. The goal of a road management system is to improve all roads or streets by using good management practices. A particular road is only one of many in the road system.

A road management system is a common sense, step-by-step approach to scheduling and budgeting for road maintenance work. It consists of surveying the mileage and condition of all roads in the system, establishing short-term and long-term maintenance goals, and prioritizing road projects according to budget constraints.

A road management system helps the agency develop its road budget and allows the use of dollars wisely because its priorities and needs are clearly defined.

Through roadway management, local governments can determine the most cost-effective, long-term treatments for their roads, control their road maintenance costs, and spend tax dollars more wisely. Local governments that stick with the program will be rewarded with roads that are easier and less costly to maintain on a yearly basis. Pertinent information about all roads will be readily available for years to come instead of scattered among files or tucked away in an employee's head.

1. **Inventory the roads** — The amount of time and the miles of road in a county or city will determine how much detail to go into.
2. **Assess the condition of the roads** — Develop simple and easy techniques to use each year. Maintain a continuing record of the assessed condition of each road so that changes in condition can be noted easily and quickly.
3. **Select a road management plan** — Select the most appropriate treatment to repair each road, bridge, or problem area.

4. **Determine overall needs** — Estimate the cost of each repair job using generalized average costs and tally up the total. Establish long range goals and objectives that in turn will help the agency justify its budget requests.
5. **Establish priorities** — Keep roads in good shape (preventive maintenance) and establish a separate budget, or request a temporary increase, to reconstruct really bad roads.
6. **Maintain an accurate cost record-keeping system.**

Answer # 2 – When the Local Agency is committed to effective management

A commitment to effective management is an attitude. It is a matter of making sure that taxpayer's money is well spent — as if it were one's own money. It does not mean paving streets with gold but it does mean using the best materials available. It does not mean taking short cuts resulting in a shoddy project but it does mean using correct construction techniques and quality control. A commitment to effective management means planning for 5 or even 10 years instead of putting a band-aid on today's problem. It means using good management techniques instead of the "seat of the pants" method. It means taking the time to do things right the first time and constructing projects to last.

Consider a child's treehouse compared to a typical three-bedroom house in a Montana town. Because each protects people from the wind and rain each comes under the definition of a shelter. However, the tree house was built with available materials and little craftsmanship. The other was planned, has a foundation, sound walls and roof and, with care, can last hundreds of years. One is a shack and the other is a family dwelling. Only one was built with a commitment to excellence.

Many roads are like the treehouse. They qualify under the definition but they are not built to last.

The horse and buggy days are over. We are in an age of travelers' demands, increasing traffic, declining revenues and taxpayer revolts. We are expected to do more with less. **Building roads to last requires an attitude of excellence.** Such an attitude helps to make better decisions, saves money in the long run, and results in a better overall road system.

Answer # 3 – When traffic demands it

The life of a road is affected by the number of vehicles and the weight of the vehicles using it. Generally speaking, the more vehicles using a road, the faster it will deteriorate.

The **average daily traffic** volumes (ADT) used to justify paving generally range from a low of 50 vehicles per day to 400 or 500. When traffic volumes reach this range, serious consideration should be given to some kind of paving.

Traffic volumes alone are merely guides. **Types of traffic** should also be considered. Different types of traffic (and drivers) make different demands on roads. Will the road be used primarily by standard passenger cars or will it be a connecting road with considerable truck traffic? Overloaded trucks are most damaging to paved roads.

The **functional importance** of the highway should also be considered. Gener-

ally speaking, if the road is a major road, it probably should be paved before residential or side roads are paved. On the other hand, a residential street may be economically sealed or paved while a road with heavy truck usage may best be surfaced with gravel and left unpaved until sufficient funds are available to place a thick load-bearing pavement on the road.

Answer # 4 – After standards have been adopted

Written standards in the areas of design, construction and maintenance define the level of service we hope to achieve. They are goals to aim for. Without written standards there is no common understanding about what a local government is striving for in road design, construction and maintenance. In deciding to pave a gravel road, is the local government confident it would be achieving the desired standards?

Design and construction standards do not have to be complex. It takes only a few pages to outline such things as right-of-way width, traveled way width, depth of base, drainage considerations (such as specifying minimum 18" culvert pipe), types of surfacing and the like.

Maintenance standards address the need for planned, periodic maintenance. A good maintenance plan protects local roads which, for most counties, represents many millions of dollars of investment. It also is an excellent aid when it comes time to create a budget.

Considerations include: How often shall new gravel be applied to a gravel road? (Some roads require it more than others.) How many times per year are roads to be graded? How often and in what locations should calcium chloride or other road stabilizers be applied? What is our plan for checking road signs? (Because of legal liability, a missing sign can be very costly if not replaced.) What is our plan for ditching and shouldering?

Answer # 5 – After considering safety & design

Paving a road tempts drivers to drive faster. As speed increases, the road must be straighter, wider, and as free as possible from obstructions for it to be safe. Paving low volume roads before correcting safety and design inadequacies encourages speeds which are unsafe, especially when the inadequacies "surprise" the driver. Because of the vast mileage of low volume roads it is difficult to reduce speeds by enforcement.

Roads must be designed to provide safe travel for the expected volume at the design speed. To do this a number of physical features must be considered:

- Sight distance
- Alignment and curves
- Lane width
- Design speed
- Surface friction
- Superelevation

It may be necessary to remove trees or other obstructions such a boulders from the road's edge. Some engineers insist that no road should be paved that is less than 22 feet wide. If this standard is accepted, gravel roads must be widened before paving. Bridges may need widening. Considering these and other safety and design factors in the early stages of decision making can help to achieve the

most economical road and one that will meet transportation needs. It makes no sense to pave a gravel road which is poorly designed and hazardous.

Answer # 6 – After the base & drainage are improved

"Build up the road base and improve drainage before paving." This cardinal rule cannot be stressed enough. If the foundation fails, the pavement fails. If water is not drained away from the road, the pavement fails. **Paving a road with a poor base or with inadequate drainage is a waste of money.** It is far more important to ask "does this road need strengthening and drainage work?" than to ask "should we pave this gravel road?"

Soil is the foundation of the road and, as such, it is the most important part of the road structure. A basic knowledge of soil characteristics in the area is very helpful and can help avoid failures and unneeded expense. Soils vary throughout Montana. For highway construction in general, the most important properties of a soil are its size grading, its plasticity, and its optimum moisture content.

There is a substantial difference in the type of crushed stone or gravel used for a gravel road riding surface versus that used as a base under a pavement. The gravel road surface needs to have more fines plus some plasticity to bind it together, make it drain quicker and create a hard riding surface. Such material is an inferior base for pavement. If pavement is laid over such material, it traps water in the base. The high fines and the plasticity of the material make the wet base soft. The result is premature pavement failure.

For help in a given situation the [State] Highway Department should be contacted. They can be helpful in determining its adequacy as road material.

Answer # 7 – After determining the costs of road preparation

The decision to pave a gravel road is ultimately an economic one. Policy makers want to know when it becomes economical to pave.

There are two categories of costs to consider: total road costs and maintenance costs.

Local government needs to determine what the costs are to prepare a road for paving. Road preparation costs are the costs of construction before paving actually takes place.

For example, if standards call for a traveling surface of 22 feet and shoulders of two feet for a paved road, the costs of new material must be calculated. Removing trees, brush or boulders, adding new culverts or other drainage improvements, straightening a dangerous curve, improving slopes and elevations, constructing new guardrails, upgrading signs and making other preparations — all must be estimated.

Costs will vary greatly from project to project depending on topography, types of soils, availability of good crushed stone or gravel, traffic demands and other factors. One important factor is the standards. That is one reason why we should carefully consider what is contained in the road policy (# 4 above).

For larger projects it may be desirable to hire an engineering consulting firm (another cost) to design the road and make cost estimations. For smaller projects construction costs can be fairly closely calculated by adding the estimated costs of

materials, equipment and labor required to complete the job.

Answer # 8 – After comparing pavement costs, pavement life & maintenance costs

A second financial consideration is to compare maintenance costs of a paved road to maintenance costs of a gravel road. To make a realistic comparison we must estimate the years of pavement life (how long the pavement will be of service before it requires treatment or overlay) and the actual cost of paving.

It is at this point that we can begin to actually compare costs between the two types of roads.

Consider the following maintenance options:

A. For both paved and gravel roads, a local government must:
   - maintain shoulders
   - keep ditches clean
   - clean culverts regularly
   - maintain roadsides (brush, grass, etc.)
   - replace signs and signposts

B. Paved roadways require:
   - patching
   - resealing (chip, slurry, crack seal) every 8-10 years
   - striping

C. Gravel roadways require:
   - regraveling
   - grading and stabilization of soils or dust control

Table 6.1: Gravel Road Maintenance Costs

GRAVEL ROAD MAINTENANCE PER MILE								
	Number of Years	**1**	**2**	**3**	**4**	**5**	**6**	**TOTAL**
GRADING								
	Equipment	270	280	290	300	310	320	$1,770
	Labor	90	100	110	120	130	140	$690
REGRAVEL								
	Materials	-	-	4,000	-	-	-	$4,000
	Equipment	-	-	2,500	-	-	-	$2,500
	Labor	-	-	2,300	-	-	-	$2,300
STABILIZATION / DUST CONTROL								
	Materials	800	900	1,200	920	950	975	$5,745
	Equipment	30	35	70	40	50	60	$285
	Labor	100	110	150	125	140	150	$775
TOTAL		$1,290	$1,425	$10,620	$1,505	$1,580	$1,645	$18,065

Table 6.2: Estimated Costs of Different Paving Options

PAVING OPTIONS

(Costs and road life are estimates and may vary.)

Option	Life	Cost / Mile	Cost / Mile / Year	Calculations	Maintenance / Mile / Year
Chip Seal - Double Surface Treatment	6 yrs	$20,533	$3,422	Based on the price of $1.75 per s.y. 20 ft. wide x 5,280 ft. = 105,600 s.f. 105,600 s.f. / 9 = 11,733 s.y. 11,733 s.y. x $1.75 = $20,533	?
Bituminous Concrete-Hot Mix	12 yrs	$58,080	$4,840	Based on the estimated price of $30 per ton; 1 s.y. of stone and hot mix/cold mix 1" thick weighs about 110 lbs. Therefore 3" = 330 lbs. per s.y. 11,733 s.y. (1mile of pavement) x 330 lbs. = 3,871,890 lbs. 3,871,890 lbs. = 1936T x 30 $/T = $58,080	?
Cold Mix	8 yrs	$48,390	$6,048	At $30 per ton, using the same formula as hot mix, 2 1/2" of cold mix equals 1,613T 1,613T x 30 $/T = $48,390	?

These costs must be determined before any conclusions can be reached regarding the most cost-effective pavement method. The thinner the pavement, the greater the maintenance cost. Traffic, weather conditions, proper preparation before paving and many other factors can affect maintenance costs. No [Montana] data exists upon which to base estimates of maintenance costs on low volume roads of these three paving options; and, therefore we offer no conclusion as to the "best" way to pave.

Since the maintenance options in "A" are common to both paved and gravel roads, they do not have to be considered when comparing maintenance costs. These costs for either type of road should be about the same. But the costs of the maintenance options in "B" and "C" are different and therefore should be compared.

Table 6.1 shows costs for maintaining gravel roads over a six year period in a hypothetical situation. If records of costs are not readily available, you may use a "best guess" allowing for annual inflation costs.

Three paving options are listed in Table 6.2. Each includes estimated costs for paving and an estimated pavement life. You should obtain up-to-date cost estimates and expected pavement life figures for these and other paving options by talking to the [State] Department of Highways, contractors, and neighboring towns and counties.

Let's consider the cost of a double surface treatment operation and the projected cost of maintaining it before anything major has to be done to the pavement (end of pavement life). We see in Table 6.2 that the estimated cost to double surface treat one mile of road is $20,533. Estimated maintenance costs over a six-year period could be:

Patching	$1,800	Total Maintenance	$4,300
Striping	$500	Construction	$20,533
Sealing	$2,000		
Total Maintenance =	$4,300	Total cost over six years =	$24,833

When we compare this cost to the cost of maintaining an average mile of gravel road over the same period of six years ($18,065), we find a difference in dollar costs of $6,768. It is not cost beneficial to pave in this hypothetical example, even without considering the costs of road preparation (#7).

This is not a foolproof method, but it does give us a handle on relative maintenance costs in relation to paving costs and pavement life. The more accurate the information, the more accurate the comparisons will be. The same method can be used in helping to make the decision to turn paved roads back to gravel.

Answer # 9 – After cumparing user costs

Not all road costs are reflected in a highway budget. There is a significant difference in the cost to the user between driving on a gravel surface and on a paved surface. User costs, therefore, are appropriate to consider in the pave/not pave decision. By including vehicle operating costs with construction and maintenance costs, a more comprehensive total cost can be derived.

Vehicles cost more to operate on gravel surfaces than on paved surfaces, often 2 or 3 times greater than for bituminous concrete roads in the same locations. There is greater rolling resistance and less traction which increase fuel consumption. The roughness of the surface contributes to additional tire wear and influences maintenance and repair expenses. Dust causes extra engine wear, oil consumption and maintenance costs. Figure 6.2, from AASHTO's *A Manual on User Benefit Analysis of Highway and Bus-Transit Improvements*, shows the impacts of gravel surfaces on user costs. For example, an average running speed of 40 MPH on a gravel surface will increase the user costs of passenger cars by 40% (1.4 conversion factor). The general public is not aware

To use this chart, determine the type of vehicle, the speed and the type of road surface. Follow the speed line vertically to the vehicle type. Go horizontally to multiplier factor of road surface. Multiply the cost of travelling on a paved surface by this number to determine the cost of operating the same vehicle on gravel surface or dirt surface. Example: If it costs 28¢ per mile to operate a passenger car* at 40 mph on pavement, it will cost 39¢ per mile to operate it on a gravel road at the same speed and 50¢ per mile on a dirt road.

*1984 Federal Highway Administration Statistics quotes an operating cost of 28¢ per mile for an intermediate size passenger car traveling on average suburban pavement. You must determine your own vehicle operating costs on pavement in order to use these multiplicative factors to calculate operating that vehicle on gravel roads.

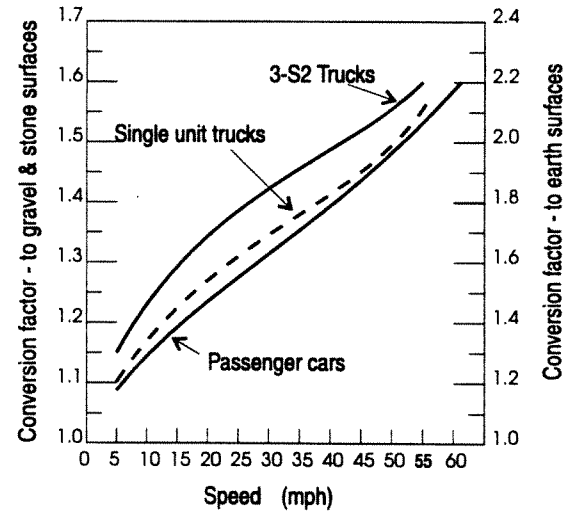


Figure 6.1
Calculating User Costs

that their costs would actually be less if some of these roads were surface treated.

Add to the gravel road maintenance the user costs over a six-year period. Estimate an average daily traffic (ADT) of 100 cars and 50 single unit trucks, traveling at 40 mph. Estimate that it costs 25¢ per mile to operate the vehicles on pavement. Using the chart in Figure 6.2, we see it costs 1.4 times as much (or 35¢) to drive a car 40 mph one mile on gravel road and 1.43 times as much (or 36¢) to drive a single unit (straight frame) truck 40 mph on mile on gravel road:

100 cars x 365 days x 10¢ added cost x 1 mile = $3,650
50 trucks x 365 days x 11¢ added cost x 1 mile = $2,008

User costs for the gravel road are $5,659 per year, or $33,954 for a six-year period. Assuming we still do not consider road preparation costs, it now appears justified to pave the road. Such an approach can be used to establish a "rule of thumb" ADT; e.g., some agencies give serious consideration to paving roads with an ADT above 125.

Answer # 10 – After weighing public opinion

Public opinion as to whether to pave a road can be revealing, but it should not be relied upon to the exclusion of any one of points 1 - 9 already discussed. If a decision to pave is not based on facts it can be very costly. Public opinion should not be ignored, of course, but there is an obligation by government leaders to inform the public about other important factors before making the decision to pave.

Local government may consider using "stage construction design" as an approach to improving roads. This is how it works. A design is prepared for the completed road, from base and drainage to completed paving. Rather than accomplishing all the work in one season, the construction is spread out over three to five years. Paving occurs only after the base and drainage have been proven over approximately one year. Crushed gravel treated with calcium chloride serves as the wearing course for the interim period. Once all weak spots have been repaired the road can be shaped for paving.

There are some advantages to keeping a road open to traffic for one or more seasons before paving:

- ❖ weak spots that show up in the sub-grade or base can be corrected before the hard surface is applied, eliminating later expensive repair;
- ❖ risky late season paving is eliminated;
- ❖ more mileage is improved sooner;
- ❖ the cost of construction is spread over several years.

Note: Advantage may disappear if timely maintenance is not performed. Surface may deteriorate more rapidly because it is thinner than a designed pavement.

Summary

Some local roads are not well engineered. Today, larger volumes of heavy trucks and other vehicles are weakening them at a fast rate. Paving roads as a sole means of improving them without considering other factors is almost always a costly mistake. Counties and cities should consider ten points first. Carefully considering them will help to assure local government officials that they are making the right decision about paving a gravel road.

6.3
FILTER FABRICS: INSTALLATION OF GEOTEXTILES ON LOW VOLUME ROADS[4]

This section provides the basic knowledge for the selection and installation of the proper geotextile and aggregates for use in eliminating perennial boggy spots and trouble areas.

Soil is the foundation material for all roads, whether in the form of native undisturbed subgrade materials, transported material or native embankment material. Vehicle loads are transmitted to the roadbed and if adequate support does not exist, severe rutting or washboarding will result.

In the fine-grained materials of Montana roadbeds, the stability is moisture dependent. In areas where there is poor drainage or subsurface water conditions, it is almost impossible to keep the roadway from rutting. Even though gravel is added to these locations, the roadway will produce ruts as soon as the next rainfall occurs. Placing a geotextile, or fabric as it is sometimes called, with four inches of gravel on these locations will eliminate the rutting and provide all weather service for the roadway. For vehicles weighing 60,000 - 80,000 pounds, the amount of gravel should be at least eight inches.

MINIMUM WEIGHT
4 oz/square yard
ASTM D 1910

MINIMUM GRAB TENSILE
90 pounds
ASTM D 1682

MINIMUM ELONGATION
60% (at break)
ASTM D 1682

PUNCTURE STRENGTH
30
ASTM D 751

EQUIVALENT OPENING
60 minimum
170 maximum
CORPS OF ENGINEERS
CW-02215-77

(NOTE: if excessive vehicle weights or high volume/high velocity vehicle traffic is expected, the minimum values should be increased.)

Table 6.3:
Geotextile Specifications

Selecting a Geotextile

First, let's look at the two distinct types of fabrics available for roadway applications. The first type is the ***woven*** geotextile. This type resembles burlap in appearance in that the fibers are actually machine woven. Woven fabrics are very high in tensile strength properties; however, the properties of elongation and permeability are lower and these fabrics are not recommended for separation applications on low volume gravel surfaced roads.

The second type, and the type which is recommended for this particular application, are the ***non-woven*** fabrics. These fabrics are made from fibers placed in a random arrange-

[4] "Filter Fabrics: Installation of Geotextiles on Low Volume Roads", *Rural Technical Assistance Program Newsletter*, Oklahoma State University, July 1987.

ment and bonded together by various processes such as needlepunched, spunbonded, melt bond, etc. These fabrics resemble the lining in the trunks of automobiles. Non-woven fabrics do not have the tensile strengths of the wovens but they have tremendous elongation and permeability properties which enable them to give excellent performance on the problem spots on low volume roads. The minimum requirements for a fabric to be used on a low volume gravel surfaced road are shown in Figure 6.3.

Site Preparation

Ideally, the roadbed should be graded smooth and a crown established in the roadbed. If the roadway has deep ruts when placing the fabric and gravel, it will take additional gravel to fill the ruts adding to the cost of the operation. Second, and most important, a loaded dump truck, with its bed raised could tip over on its side if the rear wheels should fall off into the rut.

It is not mandatory to fully compact the section of roadway to be repaired prior to placing the fabric and gravel. In most cases, this would be very difficult to achieve, chiefly because this area is usually highly saturated with water. When the roadbed material is dry enough to hold up a motor grader and loose enough to fill in the ruts, use the motor grader to shape the roadbed, filling in the ruts and establishing a crown.

In the case of an emergency or unusual condition such as a spring in the roadbed, it will not be possible to shape the roadbed. These conditions will be discussed later.

Placing the Fabric

Once the roadbed has been shaped the fabric can be rolled out. Since most manufacturers produce the textiles in roll widths of 12 ½ feet to 15 feet, it generally will take 2 rolls side by side to completely cover the roadbed. The first roll is lined up on one edge of the roadbed, starting about 20 feet away from the problem areas, and rolled out for about 20 feet. The second roll is lined up on the other edge of the roadway and overlaps the first roll near the centerline of the road. All overlaps should be a minimum of 12 inches whether they are on the centerline or where one roll stops and another begins.

Continue to roll the first roll out keeping about 20 feet ahead of the second roll. This will allow for periodic shifting of the rolls to keep the alignment correct. If conditions are windy when unrolling the fabric, the ends and sides will need to be weighted down to keep the fabric from blowing. This can be accomplished by putting shovel fulls of gravel or soil from the borrow ditch on the ends and sides to keep the fabric down. Depending on the velocity of the wind, a spacing of eight to ten feet is generally sufficient to keep the fabric weighted down. It is recommended to place the first roll on the downwind side of the road. The second roll will overlap the first roll in the direction the wind is blowing, keeping the wind from picking up the edge of the first roll near the centerline.

When the two rolls are rolled out and additional rolls need to be placed, fold the ends of the first two rolls back over on top of themselves about two feet. Start

the additional rolls in the same manner as the first rolls with the ends next to the folds of the first rolls. As soon as the additional rolls are rolled out a short distance, pull the folded fabric over the ends of the additional rolls. Continue lapping the fabric in the same direction each time new rolls are placed. ***This is necessary as the gravel must be spread in the same direction the fabric is lapped.*** If the fabric has folds in it, flatten the folds in the same direction the fabric is lapped and weight the folds down as flat as possible.

The type of gravel to be placed on the fabric will chiefly depend on the local sources available. A "crusher run" gravel is probably the most common type of gravel to use. The gravel should range in size from a maximum of ¾ to 1 ½ inches in diameter and have at least 10% fines or dust. This dust should not contain any significant amount of clay. The gravel should have angular sides as with crushed stone as opposed to a round river gravel. The ideal material would conform to the following specifications:

Table 6.4: Gradation requirements

GRADATION REQUIREMENTS
(Percent Passing)

SIEVE SIZE	1 ½ in	¾ in	No. 4	No. 200
(mm)	(37.5)	(19.0)	(4.75)	(0.075)
Percent Passing	100	90-100	30-85	10-25
Plasticity Index	6-15			
Liquid Limit	Not more than 35			

Placing the Gravel

As stated previously, the gravel must be spread in the same direction the fabric is lapped. Spreading the gravel into the lap can cause the fabric to separate resulting in unprotected spots in the roadbed. Once the roadbed has been shaped and the fabric rolled out over the problem area, the gravel trucks can dump the gravel.

The two most common operations will be using end dump or belly dump trucks. The end dump trucks can either dump the gravel while driving forward or they may back dump. An experienced driver can chain the tailgate and spread the gravel very close to the required thickness of four inches. This will save considerable time in the blading operation. The belly dump trucks will dump in windrows and the motor grader will pull the material from the windrows and blade the gravel across the fabric.

The truck drivers should be cautioned against sudden hard stops or takeoffs while the trucks are on the fabric. Sudden sliding or spinning of the truck tires can tear the fabric. A smooth continuous rolling movement is advised. Under no conditions should an operator attempt to turn the steering wheel while the equipment is stopped as this will tear the fabric.

A motor grader will be needed to spread the gravel evenly across the fabric. The moldboard on the grader should be tilted forward to give a dragging action. The grader operator should ***not*** try to spread the gravel in thin lifts (less than 2 ½ inches). Trying to blade a thin lift will cause the gravel to lock together and will drag the gravel across the fabric. This will result in tearing of the fabric. The end result should be a four inch thickness of gravel across the fabric. Avoid turning the front wheels of the grader while it is not moving, as this too will tear the fabric.

In the event of having to place fabric and gravel in boggy or extremely wet and soft locations the following techniques are recommended:

- Roll the fabric across the problem area, starting about 30 feet from the soft area.
- End dump trucks can be used to place the gravel if the trucks back dump the gravel, keeping at least 4 inches of gravel between the tires and the fabric.
- Otherwise, the end dump trucks should dump the gravel in a pile on one end of the fabric. A small dozer or front end loader can then push the gravel out ahead of the machine as long as four inches of gravel is between the tracks or tires of the equipment and the fabric.
- ***Don't*** use a motor grader to spread the initial layer of gravel. The front wheels of the grader are about ten feet in front of the blade and will be on the bare fabric. This will cause the fabric to be pushed down into the mud, making large ruts.

Summary

- Shape the roadway and establish a crown.
- Roll the fabric across the problem area. Weight the ends, sides, and folds as necessary.
- Spread the gravel in the appropriate manner and in the direction of the laps.
- In soft conditions, keep four inches of gravel between the machinery and the fabric.
- If grading is required at a later date, care should be taken not to cut too deeply on a pass. Instead, cut only about one inch at a pass.

6.4
STUDY QUESTIONS

1. The ideal minimum pavement thickness according to the Asphalt Institute is how many inches?
   a. 2" b. 4" c. 6" d. 8"

2. A road management system consists of (select all that apply):
   a. condition rating the roads
   b. establishing short-term and long-term maintenance goals
   c. prioritizing road projects according to budget constraints
   d. maintaining an accurate cost record-keeping system

3. The minimum Average Daily Traffic (ADT) used to justify paving a gravel road is:
   a. 50 b. 60 c. 80 d. 100

4. TRUE or FALSE — Paving a road requires less attention to roadway safety features because vehicles will be traveling faster.

5. TRUE or FALSE — In considering maintenance of paved roads you must plan for a chip seal every 8 to 10 years.

6. An average running speed of 40 MPH on a gravel surface will increase the user costs of passenger cars by:
   a. 10% b. 20% c. 30% d. 40%

7. Filter Fabrics should be used on roads composed of:
   a. fine grained soils with boggy spots and trouble areas
   b. stable soils that drain well

8. Which type of fabric is recommended for low volume gravel road surfaces?
   a. woven fabrics
   b. non-woven fabrics

9. It (IS) (IS NOT) mandatory to fully compact the section of roadway to be repaired prior to placing the fabric and gravel.

10. All overlaps using filter fabric should be a minimum of _____ inches whether they are on the centerline or where one roll stops and the other begins.

11. The gravel spread on top of the fabric must be spread _____ as the fabric is lapped.
    a. in the same direction
    b. in the opposite direction

12. Truck drivers spreading the gravel should be cautioned against (select two):

a. turning the wheel while the equipment is stopped on the fabric
b. sudden hard stops or takeoffs
c. topping off his fuel tank

13. When grading a road that has filter fabric in it, care should be taken not to:
a. cut too deep
b. cut too shallow

6.5
ANSWERS TO STUDY QUESTIONS

1. b) 4" (page 2)
2. all of the above: a), b), c) and d) (pages 4)
3. a) 50 (page 5)
4. False (page 6)
5. True (page 8)
6. d) 40% (page 10)
7. a) fine grained soils with boggy spots and trouble areas (page 12)
8. b) non-woven fabrics (page 12)
9. IS NOT (page 13)
10. 12 inches (page 13)
11. a) in the same direction (page 14)
12. a) turning the wheel while the equipment is stopped on the fabric and b) sudden hard stops or takeoffs (page 14)
13. a) cut too deep (page 15)

CHAPTER 7
ROAD DUST SUPPRESSANTS

7.1
ROAD DUST SUPPRESSANTS[1]

The Problem

Dust is more than just a nuisance on unpaved roads:

- By obscuring the vision of drivers, dust clouds are a traffic hazard.
- Dust can carry several hundred feet, penetrating nearby homes and covering crops. Crop growth is stunted due to the shading effect and clogged plant pores.
- In human health, dust is a common cause of allergies and hay fever and may be a conveyor of diseases.
- Fine abrasive particles greatly increase wear on moving parts of a vehicle.
- The loss of a road binder, in the form of dust, represents a significant material and economic loss.

The severity of a dust problem is determined primarily by the speed and amount of traffic on the unpaved road. The condition is aggravated by long dry spells, softer road aggregates that abrade under traffic to produce more dust, and initially excessive soil binder in the surface mix. Without binder material and adequate moisture, the coarser material will be thrown or washed away from the road surface. The road begins to ravel, rut, and washboard; deterioration accelerates until costly repairs are needed.

The Solution

Dust control using chemical or mechanical suppressants can be justified when:

- paving is not feasible for lack of funds or limited use of the road,
- the cost of materials and application is low,
- stage construction of the road is planned.

The problem of dust from unpaved roads is a worldwide problem. Methods of treatment in the United States range from spraying roads with chemicals, chiefly chloride compounds and resinous adhesives, to utilizing geotextiles in road reconstruction.

When chemicals are applied to the road surface to control dust

- the surface should first be crowned and shaped to final grade, to assure good drainage,
- for all but resinous adhesives, the road must be prewetted with water (if natural moisture is lacking) to assist chemicals in penetrating the surface,

The Choices

A number of organic and inorganic chemical mixes are available for use as dust

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[1] "Operating Tips: Road Dust Suppressants",. Northwest Technology Transfer Center, Winter 1986. Originally published by the University of Missouri-Rolla Transportation Technical Assistance Office.

palliatives; synthetic fabrics are also available for physically containing the road materials. Appendix I contrasts the attributes, limitations, typical applications, and sources of materials used to suppress road dust. No ranking is implied by their order. The selection of a particular dust suppressant will depend not only on its performance characteristics, but also on the type and volume of traffic, roadway condition, and product cost (material, freight, and application) to achieve the desired level of dust control. These criteria will vary significantly. Some successful cost-saving measures have been reported, for example, treating only a center strip of the roadway on less-traveled roads or spot-treating on a cost-share basis with roadside residents.

The adhesive and waterproofing character of bituminous materials is well known, but cost is usually prohibitive unless the treatment precedes some type of asphalt paving. Lignin derivatives are natural cements that bind the dust particles, aided by associated sugars which act as hydroscopic agents; they are also excellent dispersing agents for clays, meaning reduced water penetration during wet periods. Various hybrid products are emerging (for example, a bitumen-lignin dust control agent), which pose opportunities for cooperative test projects.

For a complete listing of road dust supressants, see Appendix I.

7.2
Relative Effectiveness of Road Dust Suppressants[2]
"The Colorado Study"

Abstract

The relative effectiveness of commercially available road dust suppressants in abating fugitive dust emission and loss of fines from unpaved road surfaces was assessed in a field based research project. The dust suppressants studied, lignin derivatives and chloride based compounds, were used on unpaved road test sections during the severe dusty months (late spring to fall) of 1993 and 1994 in Colorado.

To measure the relative effectiveness of the different dust suppressants, comparative fugitive dust emission studies were conducted on several unpaved road test sections using the Colorado State University Dustometer, a dust sampling device developed in this research. In addition, total aggregate loss from the surfaces of the test sections was measured. Based upon the prevailing costs, analyses were performed to determine the economics of using the different dust suppressants.

The research indicated that the use of the three dust suppressants studied reduced fugitive dust emission from the unpaved roadways by 50-70%. The total aggregate losses from the treated test sections were 42-61% less than that of the untreated control test section. The cost savings of retaining aggregate on the treated test sections more than offset the costs of the dust suppressants, resulting in an estimated cost savings of 30-46% over the untreated control test section.

[2]A paper by T.G. Sanders, J.O. Addo, A. Ariniello and W.E. Heiden, Colorado State University, 1994

Introduction

While unpaved roads carry a small portion of the nation's traffic, they provide a vital link in the nation's economy. Of the nearly 4 million miles (6.5 kilometers) of road network in the continental U.S., it is estimated that about 65% are unpaved. One major problem associated with unpaved roads is traffic generated fugitive dust. To residents living along unpaved roads, the airborne dust penetrates their homes causing nuisances and health problems such as hay fevers and allergies. The fine suspended dust particles contribute significantly to the particulate matter loading in the atmosphere. According to air pollution studies, nearly 34% of the particulate matter in the atmosphere originates from unpaved roads nation wide, making unpaved roads one of the major man-made sources of fugitive dust. In addition to environmental degradation, the generation of dust means loss of aggregate and subsequent road surface deterioration as the loss of road surface fines in the form of dust leads to the formation of ruts, potholes and corrugations. These conditions represent a significant material and economic loss.

The severity of the dust problem is determined primarily by the volume of traffic using an unpaved road as well as the speed, weight, number of wheels of each vehicle, the abrasive resistance of the road surface and the amount of fines in the initial road surface material mix. The climatic condition of the region is also an important factor affecting the generation of dust from unpaved roads. Long dry spells that often occur in semiarid and arid regions aggravate the road dustiness.

The high maintenance cost of unpaved roads in terms of aggregate replacement, the increased public awareness of pollution problems and the high road user cost has led agencies responsible for the maintenance of roads to have a renewed interest in dust control measures. Frequently used dust control methods include reduction of vehicular speed, application of water and use of dust suppressing chemicals. Although dust suppression has been in practice for decades, quantitative studies on the effectiveness of the different road dust suppressants and their environmental impact have been virtually nonexistent.

The research reported in this paper summarizes a study conducted to evaluate, under field conditions, the relative effectiveness of some of the more commonly used road dust suppressants. Three commercially available dust suppressants were evaluated in the study: lignosulfonate (a byproduct of the paper making industry), calcium chloride and magnesium chloride (both deliquescent and hygroscopic compounds). The road surface material used was crushed gravel mix from a local gravel pit.

Experimental Design

The tests were performed on four unpaved road sections, each 1.25 miles long, in the Loveland area of Larimer County, Colorado. Three of the test sections were treated with the different dust suppressants, namely: lignosulfonate, calcium chloride ($CaCl_2$) and magnesium chloride ($MgCl_2$), while one of the sections was left untreated to serve as the control. All four test sections were part of the same stretch of an existing unpaved road.

Virgin crushed gravel material was used for the construction of the road surfaces. The gravel can be classified by the general name of scoria, according to the American Association of State Highway Officials Standard Specification. A sieve analysis was performed on the aggregate mix according to ASTM Test No. C-136. The results of the analysis are represented in Figure 7.1. The quantity of the material passing the No. 40 (425ìm) standard sieve referred to as fine sand/silt is 9.6%. The fines fraction is noted to be directly related to the amount of dust emission from an unpaved road surface. Other tests to determine the engineering properties of the aggregate were also performed. They included: Atterburg limits to determine the plasticity of the road surface material; Los Angeles abrasion to determine the abrasive resistance of the aggregate mix and specific gravity. The tests and the results are listed in Table 7.1.

Table 7.1
Aggregate Property Result

TEST	RESULTS
Atterburg Limits (ASTM No. D-423 & D-424)	Nonplastic and no cohesion
Los Angeles Abrasion Test (ASTM No. C-131)	30%
Soundness (ASTM No. C-88)	Not Determined
Specific Gravity (ASTM No. D-845)	2.60

Test Sections

The construction of the road test sections followed the procedures recommended in the highway engineering literature and that of the dust suppressants suppliers. Important application techniques for most dust suppressants include:

- road surface scarification,
- adequate grading and smoothing of the road surface,
- application of the dust suppressants in quantities sufficient for effective dust control,
- proper road finish procedure that includes the forming of the surface crown, optimum compaction of the road surface and proper drainage.

Approximately 4 inches (10.2 cm) of the virgin gravel material was laid on the existing roadway.

The primary equipment involved in the test section construction include:

- water trucks for adding water to the road surface material,
- motor graders for grading,

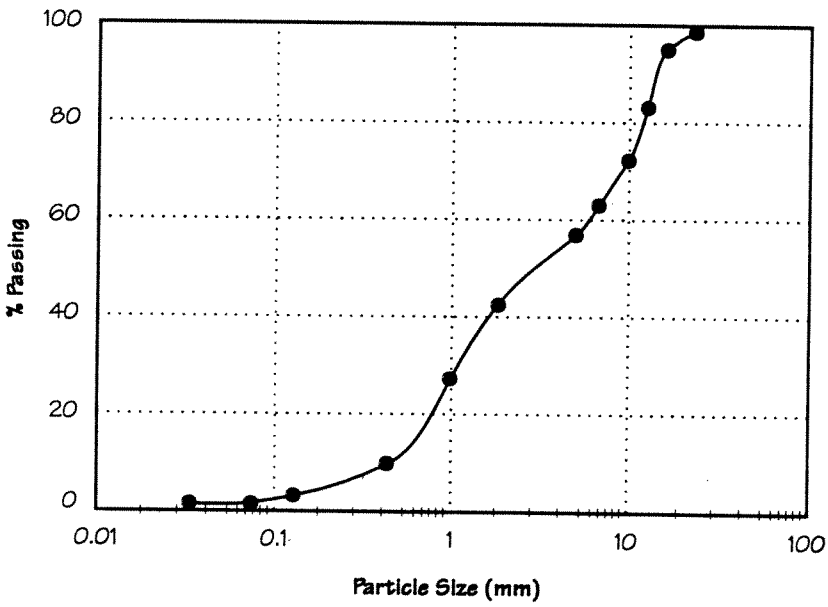

Figure 7.1
Cumulative Distribution of Aggregate Particle Sizes

mixing and shaping the roadway,

- ❖ a distributor truck with power spray bar for applying dust suppressant, and
- ❖ a vibratory steel drum compactor for compacting the road surface.

The application rate for the lignosulfonate as suggested by the supplier was ½ gal/yd^2 (2.3 lit/m^2) of road surface and the method of application was mixed-in-place. The application rates for the $CaCl_2$ and $MgCl_2$ were the same at ½ gal/yd^2 (2.3 lit/m^2) of road surface and the method of application was surface sprayed. The mixed-in-place application method involves the addition of the dust suppressant to the road surface material in-situ by mechanically mixing the suppressant with the road surface material. The surface sprayed application, on the other hand, involves the spraying of the dust suppressant under high pressure on the road surface after the road surface has been maintained (bladed, shaped and compacted).

Measurements

Three fundamental field measurements were made. They were traffic counts, fugitive dust emissions and total aggregate loss. The traffic survey of each test section was carried out by installing traffic counters at the beginning and end of each test section. The counters were left in place throughout the duration of the filed measurements which started in late May and ended in early October 1994.

The dust emission from each test section was measured throughout the test period using the Colorado State University Dustometer. The Dustometer is simply a moving dust sampler developed, field tested and used in this research. The device consists primarily of: 1) a fabricated metal box containing a 10 in. by 8 in. (25.4 by 20.3 cm) glass fiber filter paper, mounted to the bumper of a ¼ ton pickup truck on the driver's side rear tire, 2) an electric generator and 3) a high volumetric suction pump. The fabricated filter box has a 12 in. by 12 in. (30.5 by 30.5 cm) opening that is covered with a 450 micron mesh sieve which faces the tire. The micron screen prevents any non dust particles from being drawn onto the filter paper during dust measurement.

As the truck is driven at a constant speed of 45 mph (72.6 kph) a portion of the dust generated is collected on a preweighed filter paper in the filter box mounted on the bumper of the truck. At the end of a test run the filter paper is gently removed and stored. The filter box is refitted with a new preweighed filter paper and another test is run. The dust laden filter papers are later weighed in the laboratory. Figure 7.2 shows a schematic diagram of the Colorado State University Dustometer setup.

The total aggregate loss from each test section over the test period as a result of vehicular activity and erosion (wind and rain) was measured by documenting the elevations of the test sections right after construction and at the end of the test period after the test sections had received periodic maintenance. The initial elevations of the test sections were compared with the final elevations of the test sections and the differences represented the total aggregate loss.

The aggregate loss estimates were made at one-quarter mile points along each test section. Each one-quarter mile transect was divided into 3 ft (0.9m) intervals starting from the crown. Using a dumpy level, levels were taken at the 3 ft intervals

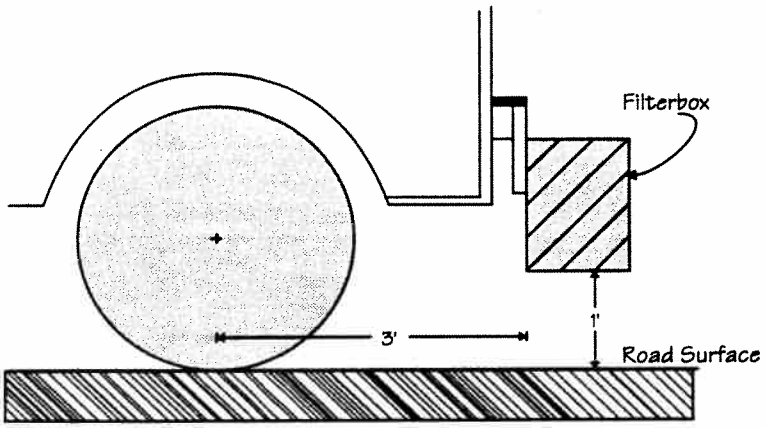

Figure 7.2: Schematic Diagram of the Colorado State University Dustometer Setup

to document the initial elevations of the roadways immediately after construction. The test sections were then open to traffic for the duration of the test period after which they received period maintenance without additional aggregate or dust suppressants. Following the same procedure used in taking the initial elevations, the final elevations were taken and the difference between the two elevations was used to estimate the total aggregate loss.

Research Results and Discussion

Traffic Survey

The results of the traffic counts for each of the four test sections are presented in Table 7.2. There is a direct correlation between the number of vehicles using a roadway and the degradation of the roadway. The extensive traffic survey done was to measure as accurately as possible the number of vehicles using each test section so that aggregate loss can be expressed as per vehicle per mile.

Although all four test sections were part of the same stretch of unpaved county road, it appears that the sections at the ends of the stretch, the lignosulfonate treated and the untreated test sections had higher traffic counts than the $CaCl_2$ and the $MgCl_2$ test sections located in the middle of the road. The lignosulfonate and the untreated test sections had Average Daily Traffic (ADT) of 515 and 538 respectively compared to 421 for the $CaCl_2$ and 448 for the $MgCl_2$ test sections.

Dust Measurement

The results of the fugitive dust measurements from each of the four test sections are shown in Figure 7.3. In all, 15 dust sampling measurements from each test section were made during the research period. Each data point in Figure 7.3 is an average of three measurements made by driving the Dustometer in the same driving lane in the same direction. The length of each test section was one mile. The dust measurements were initiated 16 days after the completion of the test sections. During the test period the treated test sections did not receive any periodic maintenance, while the untreated control test section received two periodic

Table 7.2
Traffic Survey on test sections

TEST SECTION	BEGINING	END (# of Vehicles)	AVERAGE	ADT
Lignosulfonate	85,326	59,746	72,536	515
CaCl2	59,746	58,659	59,203	421
MgCl2	58,659	67,680	63,170	448
Untreated	67,680	83,895	75,788	538

Duration of Test 141 days (app. 4.5 months)

maintenances.

The average ambient temperature and relative humidity during the test period was approximately 88°F (31°C) and 34%, respectively. The amount of dust sampled from the lignosulfonate treated test section varied from a low of 0.05 gms when the treatment was new to a high of nearly 0.6 gms measured towards the end of the test period. The $CaCl_2$ treated test section started with approximately 0.4 gms of dust and had a high of about 0.9 gms, while the $MgCL_2$ test section measured 0.08 gms of dust at the onset and had a high of approximately 0.7 gms measured towards the end of the test period. The untreated test section, however, averaged about 1.0 gm of dust measured each sampling period. It should be noted that the amounts of dust measured was only a portion of the dust generated by the left back wheel. Therefore, the dust measurements indicated only the relative effectiveness of each dust suppressant. It did not measure the amount of dust generated per vehicle.

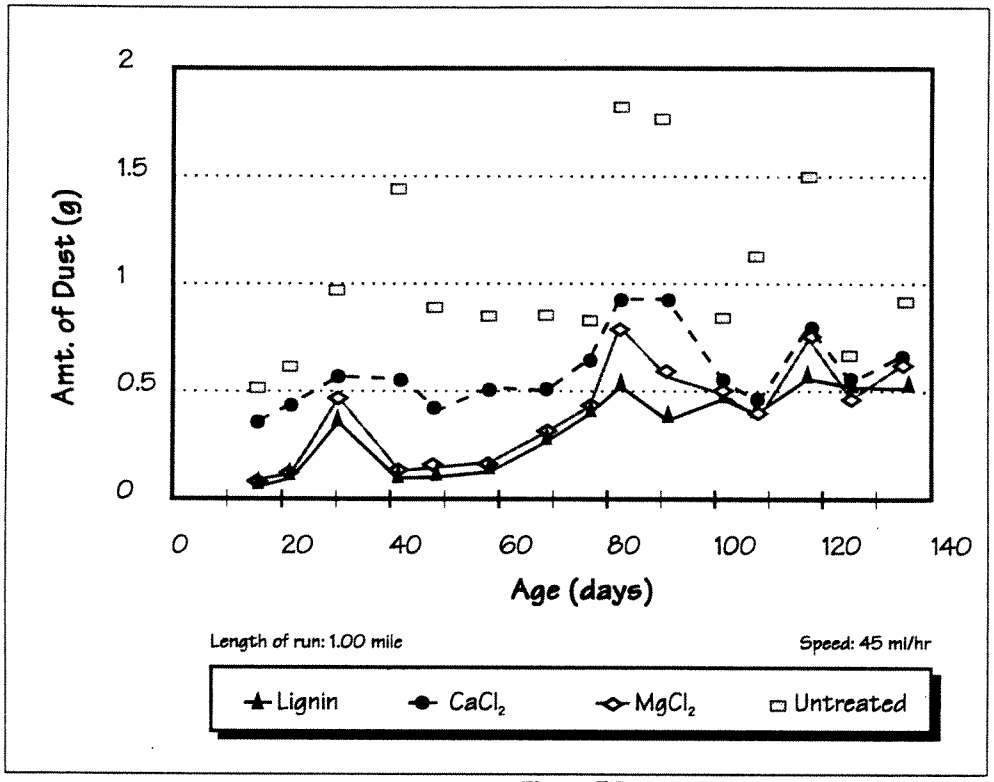

Figure 7.3
Dust Measurement from Test Sections

From Figure 7-3, it is apparent that all the dust suppressants were effective in reducing the amount of dust generated when compared to the amount of dust from the untreated section. In addition, as the treated test sections aged the amount of dust emissions increased. This is indeed expected since, with time, the treatments lose their effectiveness and the continuous vehicular activities accelerate the loss of road surface fines. Figure 7-3 also shows variations in the amount of dust sampled, these variations could be due to many factors, significant among them is the rainfall pattern during the test period. Depending upon the amount of rainfall and the prevailing weather condition prior to a dust measurement, higher or lower dust amounts could be measured. Rainfall events that did not produce runoff but gave the road surface just enough moisture to help vehicular compaction of the road surface and the rejuvenation of the dust suppressants in the case of the treated test sections, caused lower dust measurements. On the other hand, rainfall events that produced substantial runoff were noted to wash off the dust suppressants in the immediate top portion of the road surface allowing the fines to become loose and thus lost in the form of dust.

Aggregate Loss Measurement

Table 7-3 shows the measured aggregate loss from each of the test sections over the 4.5 month period in which the study was done. The table also contains the estimated annual loss based on the measured loss.

The aggregate loss from the treated test sections were measured as 0.288 in (5.80 mm) for the lignosulfonate, 0.276 in. (7.01 mm) for $CaCl_2$ and 0.204 in. (5.18 mm) for $MgCl_2$. The untreated test section loss was 0.612 in. (15.55 mm) which is approximately 3-times more than that of the $MgCl_2$ treated test section, 2.7 times more than the lignosulfonate treated test section and about 2-times more than the $CaCl_2$ treated test section. These measurements are consistent with results of other studies. One reported aggregate pullout from treated unpaved road surfaces as approximately 25-75% that of untreated test sections; this research showed a 33-45% aggregate pullout.

Aggregate pullout from unpaved road surfaces is due primarily to vehicular movement and therefore, the volume of traffic using the road test sections would

Table 7-3
Aggregate Loss Measurement

Test Section	Measured Aggregate Loss			Estimated Aggregate Loss in One Year
	(mm)	(inches)	(ft)	(inches)
Lignosulfonate	5.8	0.228	0.019	0.604
CaCl2	7.01	0.276	2.023	0.731
MgCl2	5.18	0.204	0.017	0.541
Untreated	15.55	0.612	0.051	1.622

Initial thickness of surface wearing course: app. 4 inches (102 mm)
Duration of measurement: 4.5 months

affect the total aggregate loss from the road test sections within a given time period. Since the traffic volumes for the road test sections evaluated were different, the aggregate loss from each test section can only be compared on a per vehicle basis. Table 7-4 shows the estimated total aggregate loss from each test section in tons/mile/year/vehicle. The estimated losses were computed considering a 33 ft (10 m) wide road and compacted density of 1.6 tons/yd^3 (note: road width does not have an impact on the amount of total aggregate loss).

The estimated total aggregate loss based on the 4.5 months measurement is 1.01 ton/mile/year/vehicle for the lignosulfonate treated test section, 1.49 and 1.04 tons/mile/year/vehicle for the $CaCl_2$ and $MgCl_2$ treated test sections respectively. The untreated test section on the other hand, loss an estimated total aggregate of 2.59 ton/mil/year/vehicle, 42-61% more than the treated test sections. Note that the estimated losses include: loss of fines in the form of vehicular-generated-dust and loses due to erosion (wind and rainfall).

Table 7-4
Estimated Total Aggregate Loss

Length of test section: 1.00 mi (5280 ft)
Width of test section: 33 ft
Compacted density: 1.6 tons/yd³

Test Section	ADT	Measured Aggregate Loss/ mi/4.5 months (ft)	Estimated Aggregate Loss/ mi/year (ft)	Estimated Aggregate Loss/ mi/year (ton)	Estimated Aggregate Loss/ mi/year/vehicle (ton)
Lignosulfonate	515	0.019	0.05	519.88	1.01
CaCl2	421	0.023	0.061	629.33	1.49
MgCl2	448	0	0.045	4665.16	1.04
Untreated	538	17	0.135	1395.47	2.59

Cost Analysis

Some of the major problems associated with unpaved roads are aggregate replacement cost and periodic maintenance cost. These items take a substantial portion of local government's budgets. In Larimer County, Colorado, for example, using 1994 budget figures, 12% of the total budget of the Road and Bridge Department was spent on aggregate replacement alone and another 17% on periodic maintenance of the nearly 700 miles of unpaved roads under the County's jurisdiction. The main economic reason for suppressing dust on unpaved roads is to prevent the loss of aggregate in the form of fines/dust as well as reduce the frequency of periodic maintenance required to keep the road surface in good condition. For this reason, in order for the relative effectiveness of the dust suppressants evaluated in this research to be ascertained, a cost accounting for each test section was done.

Table 7-5 represents the cost analysis. The unit prices of the three dust suppressants evaluated were the same at $0.285 per gal. The total cost of material (suppressant), labor and equipment for placing the treatments was $3,528 per mile for the lignosulfonate test section and $2,768 per mile each for the $CaCl_2$ and $MgCl_2$ test sections. The lignosulfonate treatment cost $760 more in labor and equipment than the $CaCl_2$ or $MgCl_2$ treatment. the difference was due to the different methods of applications of the lignosulfonate and the chloride compounds. A mixed-in-lace application was used for the lignosulfonate treatment while a surfaced sprayed application was used for the chloride compounds treatments. The compacted density of the roadway was 1.6 tons/yd^3 and the cost to replace the estimated lost aggregate was $11.57 per ton in place. The cost of periodic maintenance, which included the use of water trucks and compactors, was $529 per mile. Based on the 4.5 months study period it was estimated that the untreated test section would required eight periodic maintenances during the year while the treated test sections would required only two periodic maintenances.

Table 7-5 : Cost Analysis

Length of test section: 1.00 mi (5280 ft)
Width of test section: 3 ft
Compacted density: 1.6 ton/cu. yd.
Cost of gravel: $11.57/ton in place
ADT: Average Daily Traffic
PM: Periodic Maintenance
M+L+E: Material (suppressant), Labor and Equipment

Test Section	ADT	Measured Agg. Loss/ mi/ 4.5 months (ft)	Estimated Annual Agg. Loss/ mi (ft)	Estimated Annual Agg. Loss/ mi (ton)	Cost of Test Sections					
					Agg. Lost/ mi/ yr (dollars)	(M+L+E)/ mi/ yr (dollars)	PM/mi (dollars)	*PM yr	Actual Total Cost/ mi/ yr (dollars)	Actual Total Cost/ mi/ yr/ Veh (dollars)
Lignosulfonate	515	0.019	0.05	519.88	$6,015	$3,528	$529	2	$10,601	$21
CaCl2	421	0.023	0.061	629.33	$7,281	$2,768	$529	2	$11,107	$26
MgCl2	448	0.017	0.045	465.16	$5,382	$2,768	$529	2	$9,208	$21
Untreated	538	0.051	0.135	1395.47	$16,145	$0	$529	8	$20,378	$38

*The Periodic Maintenance was performed with a Water Truck and Compactor If this were being performed without these tools, we anticipate that the Periodic Maintenance would have to be done weekly in the case of the untreated test section.

Duration of study: 4.5 months

With reference to Table 7-5, the computed cost for the lignosulfonate treated test section per mile per year per vehicle is approximately $21, the costs for the $CaCl_2$ and $MgCl_2$ treated test sections are $26 and $21 respectively. The untreated test section cost $38/mi/yr/vehicle. This analysis indicates a 30-46% cost saving in the treated test sections over the untreated test section. The slight differences between the treated test sections costs could be just random and therefore not very significant. What is of importance, is the fact that the use of road dust suppressants reduced the overall total aggregate loss from the unpaved road surface as well as the frequency of periodic maintenance required to keep the road in good condition. This results in substantial cost savings especially when the ADT on the unpaved road is high.

Because of the high initial cost (material, labor and equipment) involved in applying dust suppressants, the question, "at what minimum ADT would the use of road dust suppressants be feasible?" was posed. The answer may be influenced by several factors, the most important of which is the cost of aggregate in place. Based on the aggregate loss measurement and cost figures for the different treatments

studied in this research, Figure 7-4 was developed to answer this question. As mentioned previously the cost of aggregate in place was $11.57/ton, the initial cost per mile of roadway per year in material (suppressant), labor and equipment for placing each treatment was $3,528 for the lignosulfonate test section, $2,768 each for the $CaCl_2$ and $MgCl_2$ test sections and $529 for the untreated test section (Y-intercept Fig. 4). The cost of periodic maintenance for each test section was $529.00/mile. Two periodic maintenances per year was assumed for the treated test sections and 8 per year was assumed for the untreated test section. Based on the traffic count in this research, the cost of aggregate in place and periodic maintenance cost, the slope of each curve was established.

With reference to Figure 7-4, it is obvious that at low ADT it is more economical to leave the unpaved road untreated. As the ADT increases, the cost of maintaining the untreated road increases. The point where a treated test section curve courses the untreated test section curve (indicated with vertical lines on Figure 7-4 at approximately 100 and 130) is the minimum ADT at which a particular treatment is economically feasible.

Since the cost of aggregate in place is such an important variable influencing the economics of this exercise, the minimum ADT's at which treatment is feasible was determined at different aggregate costs and the results are shown in Table 7-6.

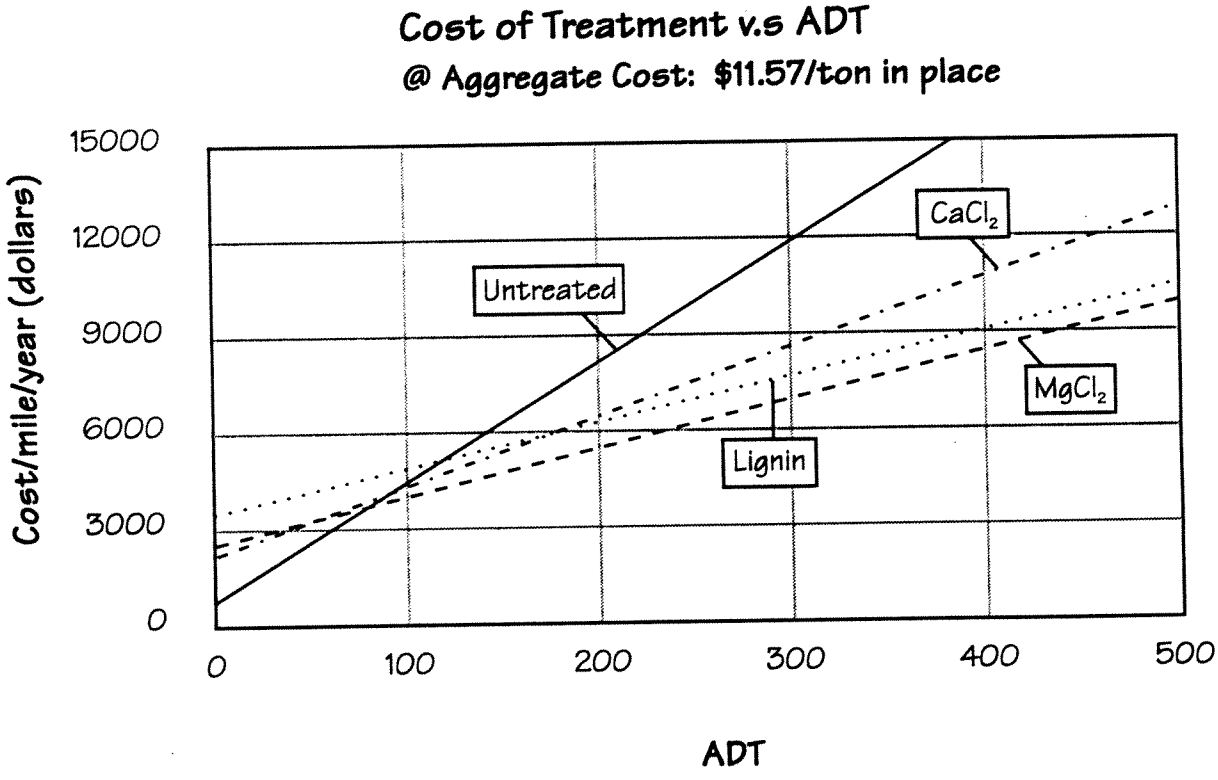

Figure 7-4
Cost of Treatment Versus ADT

Table 7-6: Minimum ADT at which use of Dust supressant is Economically Feasible

Cost of Aggregate per ton	Lignosulfonate	CaCl2	MgCl2
	ADT	ADT	ADT
$5.00	232	225	180
$7.50	180	180	140
$11.57	130	130	100
$15.00	105	105	80

The procedure followed in establishing the minimum ADT's for the different aggregate costs is the same as described above. The minimum ADT's at $5.00/ton, $7.50/ton and $15.00/ton in addition to the $11.57/ton were determined. From the results (Table 7-6) one can conclude that as the cost of aggregate in place increases, the minimum ADT at which the use of dust suppressants become economically feasible, decreases.

Conclusions

The following conclusions are based upon results of this field based research:

- Dust measurement data indicate that there is a substantial reduction in fugitive dust emission with application of chemical dust suppressants (50-70% reduction).
- Under high temperature and low relative humidity conditions, the lignosulfonate treated test section appears to produce less dust than the test sections treated with the chloride compounds during the t est period. However, field observations after the research was completed showed that the lignosulfonate test section produced equal or more dust than the chloride compounds. The driving comfort on the lignosulfonate treated test section was also found to be considerably less than on the chloride treated test sections, mainly because of pothole formations lignosulfonate test section after the test period.

There is an estimated total aggregate loss of 1.0 ton/mile/year/vehicle from the lignosulfonate treated test section, 1.5 tons/mile/year/vehicle from the $CaCl_2$ treated test section, 1.0 ton/mile/year/vehicle from the $MgCl_2$ treated test section and 2.6 tons/mile/year/vehicle from the untreated test section. this translates into a 42-61% reduction in total aggregate loss when unpaved roads are treated.

Cost analysis shows a 30-46% reduction in total annual maintenance cost for treated test sections over the untreated test section.

At ADT of over 120, the use of any of the dust suppressants evaluated proved to be cost effective. This is the traffic volume at which the economic feasibility of the use of dust suppressants will decrease as the cost of in place aggregate increases.

The minimum ADT at which the use of dust suppressants are economically feasible is variable depending on cost of aggregate in place.

Appendix A
Road Dust Suppressants

	Calcium Chloride	Sodium Chloride
ATTRIBUTES	• Starts to absorb water from air at 29% relative humidity (77°F). • Reduces rate of evaporation 3.4 times (vapor pressure of saturated solution at 77°F is 7 mm Hg). Note: the lower the vapor pressure, the greater the ability to resist evaporation. • Significantly increases surface tension of water film between particles, helping to slow evaporation and further tighten compacted soil as drying progresses. • Lowers the freezing point of water solution to -60°F, minimizing frost heave (30% solution). Freezing of treated road not only begins at lower temperature but is gradual and seldom completed. • Treated road can be regraded and recompacted with less concern for losing moisture and density.	• Starts to absorb water from air at 76% relative humidity (77°F). • Reduces rate of evaporation 1.3 times (vapor pressure of saturated solution at 77°F is 7 mm Hg). • Increases surface tension slightly less than calcium chloride. • Lowers freezing point of water solution to -6°F (25% solution). • When mixed into road base, effectively improves mechanical stability. • Costs the least of any chloride salt.
LIMITATIONS	• Slightly corrosive to steel, highly corrosive to aluminium and its alloys; attracts moisture, thereby prolonging active period for corrosion. • Rainwater tends to infiltrate and leach out highly soluble chlorides, but if road has proper crown, most water is deflected sideways into ditches. • During dry periods, upward capillary action may cause chlorides to crystallize near road surface, where they can be leached away by sudden rain. • No cementing action; effective control only with well-graded, stable road mixes. • Exothermic: releases heat as it dissolves, enough to be a safety hazard to workers mixing the dry form in water. • Spills of concentrate may kill or burn vegetation; reasonable care in handling required. • Should not be spread over bridge decks; spills must be cleaned quickly to prevent slick spots.	• Moderately corrosive to steel in dilute solutions, but no worse than water in concentrated solutions; attracts moisture, thereby prolonging active period of corrosion. • As it becomes diluted or leaches out, disperses clay which shrinks on drying and becomes more susceptible to blowing. • If over applied, poses threat to plant and animal life as well as possible ground water contamination. • Not an effective dustproofer, thus typically used to stabilize road base and topped with calcium chloride to control dust.
APPLICATIONS	Typically 2 treatments / year: Initial: Flake ..... 1.0 to 1.5 lb./sq.yd Pellet ..... 0.8 to 1.3 lb./sq.yd. 35% solution ..... 0.2 to 0.3 gal./sq.yd. Followup: ½ to 2/3 of initial dosage Can be stored in buildings, hoppers, silos, or covered piles. Must be airtight and protected from wet, humid conditions. Storage floor at ground level should be paved asphalt or treated concrete. Gravity feed systems required 45 degrees for flakes to flow, 35 degrees for pellets. Spread by tank trucks with pressure distributors and a spinner disk or positive-displacement units.	Generally higher dosages than calcium chloride treatment.
SOURCES	By-product brine from manufacture of sodium carbonate by ammonia-soda process and of bromate from natural brines. Three forms: Flake, or Type 1: (77 to 80% conc. 100# bags) Pellets, or Type 2: (94 to 97% conc. 100# bags) Clear Liquid (32 / 35 / 38% conc. tankers) Some brand names: LIQUIDOW PEADOW DOW FLAKE SUPERFLAKE	Occurs naturally as rock salt (mined mechanically or hydraulically) and brines (refined or evaporated). Some brand names: MORTON SALT DIAMOND SALT

	Lignin Derivatives	Road Fabric
ATTRIBUTES	• Greatly increases dry strength of soil; under dry conditions, outperforms bituminous binders. • During rain, disperses clay which in turn swells and plugs pores, reducing water penetration. • Tends to remain slightly plastic, permitting reshaping and additional traffic compaction. • With addition of calcium carbonate slurry to counteract corrosive, effects, solubility is reduces, thereby prolonging dust-laying capability. • Ammonium-base sulfonates are superior to sugar-free calcium-base sulfides for aggregate binding. • Material cost comparable to that of inorganic chemicals.	• Flexible, durable, water permeable, and highly resistant to soil chemicals. • Used as a separator, prevents intermixing of subgrade material and base course, thereby preserving drainage systems and load transfer capability. Structural section life is prolonged and maintenance costs reduced. • In tension, reduces localized loads over a large area of subgrade, thereby improving the support properties of the system. • Can reduce the amount of aggregate required in the initial design of unpaved structural sections. • If buried, can be expected to function indefinitely. • By preventing subgrade fines from "pumping" up into the aggregate, serves to control dust production.
LIMITATIONS	• Control depends on well-graded soil-aggregate mix, loosened to a depth of 1 to 2 inches prior to initial application; wearing surface silt and clay content needs to be 4 to 8% • May cause corrosion of aluminium and its alloys. • Surface binding action may be reduced or completely destroyed by heavy rain, owing to solubility of solids content in water. • Become slippery when wet, brittle when dry.	• High material cost, though installation cost is low. • Material degradation may result from exposure to ultraviolet rays (sunlight).
APPLICATIONS	Generally 1 to 2 treatments / year: 10 to 25% solution ..... 0.5 to 1.0 gal./sq.yd. Powder ..... 1.0 to 2.0 lb./sq.yd. Application methods same as for chlorides.	Placed during road construction; no special equipment required.
SOURCES	Water liquor of papermaking industry; contains lignin and carbohydrates in solution (lignin is natural cement that binds fibers of woods). Composition depends on raw materials (mainly wood pulp) and chemicals used to extract cellulose; active constituent is neutralized lignin sulfonic acid containing sugar. Common names: sulfite liquor, black or green liquor, sulfite lye, ammonium lignin sulfonate, calcium lignosulfonate. Some brand names: LIGNOSOL NORLIG RAY BINDER	Manufactured from man-made fibers, typically polypropylene, mechanically interlocked by needle-punching and heat bonding. Available in various weights and widths, by the roll. Some brand names: SUPAC MIRAFI TYPAR TREVIRA

	Sodium Chloride & Calcium Chloride Mix	Magnesium Chloride
ATTRIBUTES	• Combines stabilizing action of sodium chloride with dust control of calcium chloride. • Compared to calcium chloride used alone, reduces cost 20% while losing less than 5% in dust control.	• Starts to absorb water from air at 32% relative humidity (77°F). • Reduces rate of evaporation 3.1 times (vapor pressure of saturated solution at 77°F is 7.6 mm Hg). • More effective than calcium chloride solution for increasing surface tension, resulting in a very hard road surface. • Lowers freezing point of water solution to -27°F (22% solution). Freezing of treated road not only begins at lower temperatures but is gradual and seldom completed. • Treated road can be regraded and recompacted with less concern for losing moisture and density.
LIMITATIONS	• Same limitations as for these salts used individually	• In concentrated solutions, very corrosive to steel, attracts moisture, thereby prolonging active period of corrosion. (Note: corrosive actions of seawater on steel attributed to $MgCl_2$ content.) Some products may contain a corrosion -inhibiting additive. • Rainwater tends to infiltrate and leach out highly soluble chlorides, but if road has proper crown, most water is deflected sideways into ditches. • During dry periods, upward capillary action may cause chlorides to crystallize near road surface, where they can be leached away by sudden rain.
APPLICATIONS	Typically 2 treatments / year: Initial: 1 lb. mix/sq.yd. Followup: ½ initial dosage	Typically 2 treatments / year: Initial: 30% solution ..... 0.5 gal./sq.yd. Followup: ½ initial dosage Storage and handling same as for liquid calcium chloride. Applied preferably with pressure spray bars (splash bars produce uneven applications).
SOURCES	Salts mixed before applying: equal parts by weight of Cc-grade rock or evaporated salt with flake calcium chloride (if pellet, use 100# salt / 80# pellet.) Not available premixed.	Occurs naturally as brine (evaporated); also by-product of potash production. Usually liquid form, 25 to 35% solution. Some brand names: DUSTGUARD DUS-TOP

	Water	Bitumens and Tars or Resinous Adhesives
ATTRIBUTES	• Poses no threat to the environment • Normally, readily available.	• Binds soils because of asphalt's adhesive properties. • Serves to waterproof roads • May be adapted to suit wide range of soils, gravel and traffic conditions.
LIMITATIONS	• Evaporates readily, controlling dust generally for less than a day. • Cost more than other inorganic chemical suppressants because of repeated applications needed to achieve same level of dust control (labor intensive).	• Under dry conditions, some may not maintain resilience; can form a crust and fragment under traffic loads. • Waste oil subject to state regulations for handling and disposing of hazardous substances. • Use of cutback asphalt or products with cutback asphalt as a primary ingredient may be limited by the State Department of Health. • Material cost significantly higher than for other chemical suppressants.
APPLICATIONS	Frequency of treatments depends on temperature and humidity.	Generally 1 to 2 treatments / year: 0.1 to 1.0 gal./sq.yd. depending on road surface condition and dilution. Material sprayed using many types of equipment, from handheld hoses to asphalt distributors.
SOURCES		Tars (residues from coal) and bitumens (residues from crude oil) combined with lighter fractions of distillate; wide range of viscosities. Liquid asphalt: Grade SC - 70, SC - 250 Bituminous emulsions: Grade SS-1, SS1h, CSS-1 or CSS-1h mixes with 5+ parts water by volume.

FOUND AN ERROR

We have done everything possible to ensure that the information in this Handbook is correct, but occasionally errors do occur. If you find that any of the information in this Handbook is inaccurate, out of date, or just plain wrong, or if you find any "typos", please let us know. We will make any necessary corrections and try to make the next edition better!

I found an error in Chapter _____, Section _____.

The sentence reads

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The following changes should be made:

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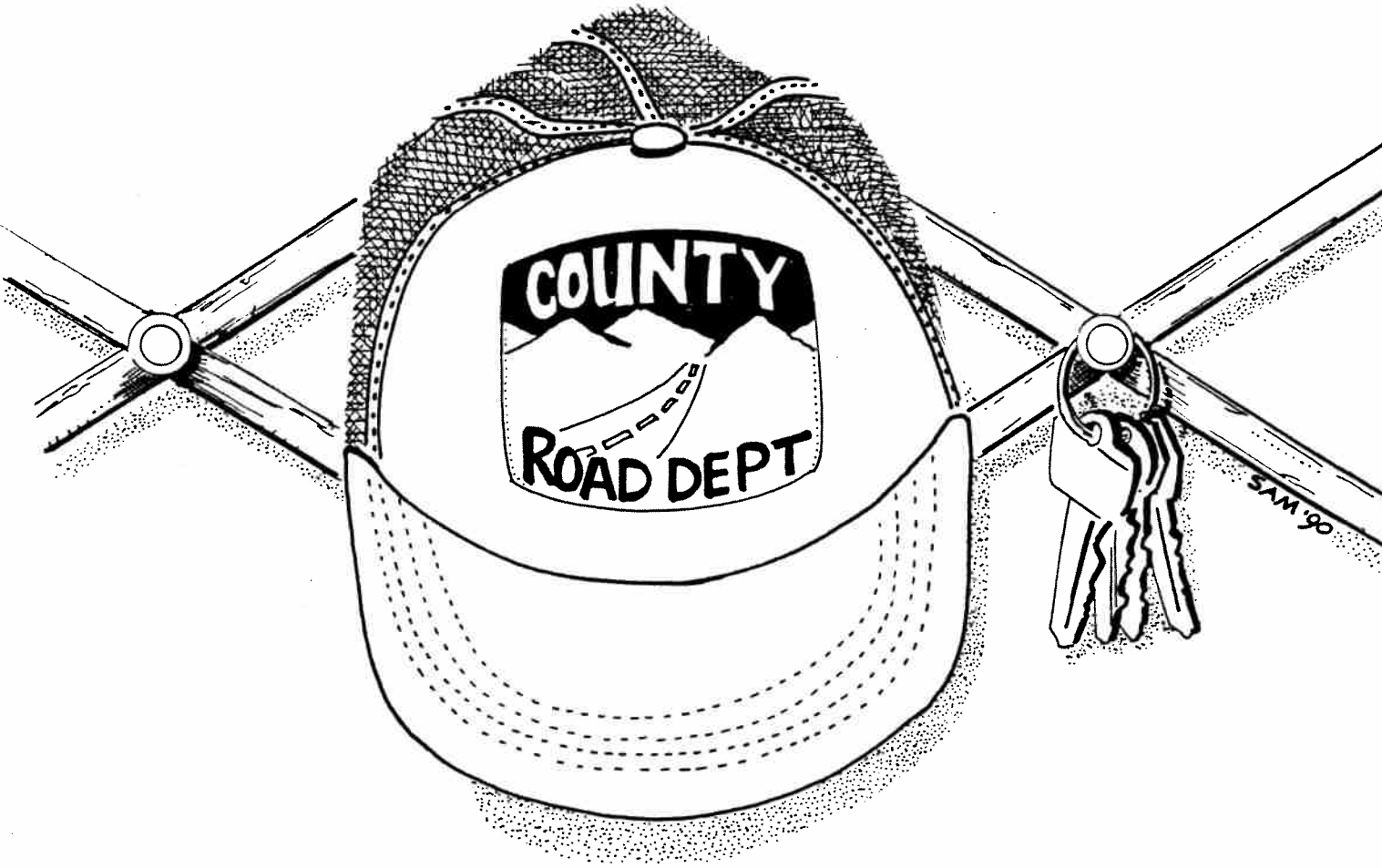
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