Gravel Road Maintenance

A Complementary Guide to
Problems Associated With Gravel Roads

University of New Hampshire
Technology Transfer Center

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Foreword

This handbook is intended to complement *Problems Associated With Gravel Roads*, a Federal Highway Administration publication. The contents of this handbook were adapted from *Motor Grader Operator's Handbook*, published by the Idaho Technology Transfer Center, June 1995.

Layout and formatting was done by Stefanie Fishman and Marisa DiBiaso, UNH Technology Transfer Center Project Assistants.

Technology Transfer Center
University of New Hampshire
33 College Rd, Kingsbury Hall
Durham, NH 03824-3591
(603) 862-2826 or (in NH) 800-423-0060

Email: t2.center@unh.edu
www.t2.unh.edu

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1.1 Safety First—Procedures

Prevention of accidents is dependent on the operator. Manufacturers incorporate features to make the operator's job safer and easier however, a careful operator is the best safety device. In order to help prevent accidents the following safety rules should be observed at all times.

1. Become well acquainted with the equipment, the Operator's Manual, and the 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 grade.
8. Never jump from the machine.
9. Always maintain a firm grip on the hand-holds while entering or leaving the machine.

10. Clean shoes of slippery materials to prevent slipping on steps or off the pedals.
11. Keep windshield, windows, and mirrors clean.
12. Remove the keys before servicing or repairing grader.
13. Check all controls to ensure they are operating correctly.
14. Do not leave the machine unattended while it is running.
15. Never coast the machine with the transmission in neutral or with clutch disengaged. Maintain a ground speed consistent with conditions.
16. Avoid operation too close to banks or overhangs.
17. Turn the engine off when refueling and do not smoke.
18. When working with raised hydraulic equipment, block it securely with crushproof blocks.
19. Operate the machine in well-ventilated areas.
20. Do not oil, grease, or adjust the machine while the engine is running.
21. Drive at slow speeds to insure safety and complete control, especially over rough terrain.
22. Increase the power gradually when pulling a heavy load or when driving out of a ditch or excavation.
23. Reduce speed when making a turn or applying brakes.
24. Keep brakes in proper adjustment.
25. Never make repairs or tighten hydraulic hoses or fittings while the system is under pressure, the engine is running, or the cylinders are under a load.

26. Use care when removing the radiator pressure cap and the radiator is hot.
27. Use care when using cold weather starting fluid. Wait at least ten minutes before using starting fluid if the operator has attempted to start the engine with a manifold heater. Crank the engine 5 to 10 seconds before attempting to use a manifold heater if the operator has used starting fluid.
28. 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 prevents sparks that create a fire hazard. Disconnect the battery to prevent accidental operation of the starter or an explosion.
29. Never permit anyone other than the operator to ride on the grader.
30. Sound the horn before moving the grader.
31. Always look behind the grader before backing up.
32. Know the location of water, gas, sewage, electrical and telephone lines before starting any operations (contact DigSafe.
33. Always check overhead clearance, especially when transporting the unit. (Know your maximum height before transporting.)
34. When deadheading the grader, always have the blade toed to the off traffic side, and carried high.
35. 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.
36. Keep the cab clean.
37. Do pre-trip inspections each shift
38. Use safety equipment provided with the machine for the operator's protection.

Use common sense and good judgement.

1.2 Pre-Trip Procedures

1. Grease the machine according to the Operator's Manual. 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. Empty the dust cup (if applicable).
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 applicable).

13. Drain the condensation from the air tanks.

1.3 Starting Procedures

1. Set the parking brake is set.
2. Place the transmission in neutral.
3. For machines equipped with electric starting, open the throttle 1/4 and use the starter.
4. Depress the clutch to lighten the load on the starter.
5. Never operate the starter for more than 30 seconds. Then wait 2 minutes before using the starter again.
6. 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.
7. Work the controls to make sure they operate and to warm up the hydraulic oil.
8. 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.

1.4 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. Walk-around the machine checking for:
   - 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. Blades cupped in the middle and are not wearing properly are a sign that the operator is not working properly (See **Crown, Slope Rates, and Superelevations** Section 1-5 in *Problems Associated With Gravel Roads*). It may signal that it is time to change blade bits.
5. Clean accumulations of dirt or mix hinder function the sliding surface, pivot point or lubrication fitting.
6. Always park the machine as near to level as possible.

Chapter 2 **Grader Operation**

2.1 Ditching

Good ditching begins with a well-marked lay-out line. Use stakes that will be visible from the grader. Create a marker pass to keep the ditch straight. Angle the grader blade sharply and place the toe or leading edge of the blade behind the front wheel. Set the toe tight and raise the heel (Figure 2.1). Drive the grader along the row of stakes taking a cut of 1" or 2" in depth. Do not make this cut too deep.

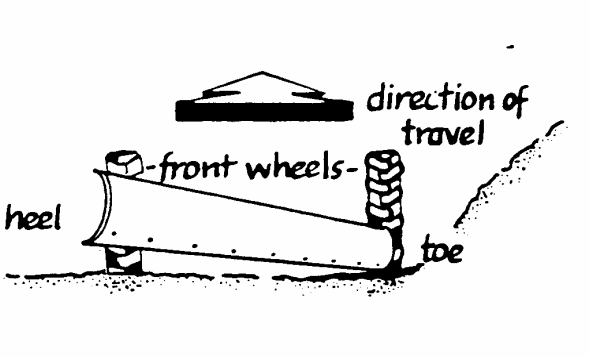

Figure 2. 1 Marker Pass Toe tight & heel raised. . .

Make the second pass with the same setting. Place the front wheel in the marker cut and put a load on the machine. Do not take more than the machine can handle. Put the grader in first gear and proceed slowly in case there is a hidden rock. These settings will place the windrow under the grader and enable the grader to get better traction as the machine is on solid ground.

On the third pass, set the blade tight on both ends (Figure 2.2) and move the material outside of the wheels. Then straddle the windrow with the grader and carry it away from the ditch bank. Always move the windrow before it becomes too large and awkward to handle. If the ditch needs to be deeper, repeat the steps as outlined omitting the marker pass. Normally when cleaning a ditch, the marker pass will not be necessary.

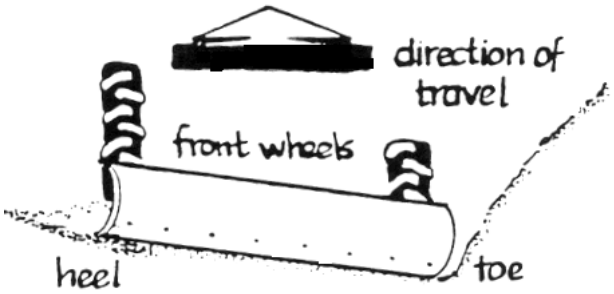

Figure 2. 2 . . . set the blade tight on both ends

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 a slight angle that will move the windrow outside of the wheels; put the toe down enough to cut the slope desired.

To remove the windrow from the ditch, set the toe and heel of the blade inside the wheels. The blade should be nearly parallel to 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. 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.

To create a flat bottom ditch, cut the flat bottom by using the setting outlined above. The width can be set by the angle put on the blade. The blade must be level.

When using extensions, the operator may have trouble getting the blade between the wheels. Extensions prevent material from leaking around the end and keep the ditch bottom clean.

2.2 Back Sloping

If the bank is too high and steep for the grader, the blade may be set out to one side of the machine (Figure 2.3). This will allow the operator to drive along the bottom and cut the back slope in this manner.

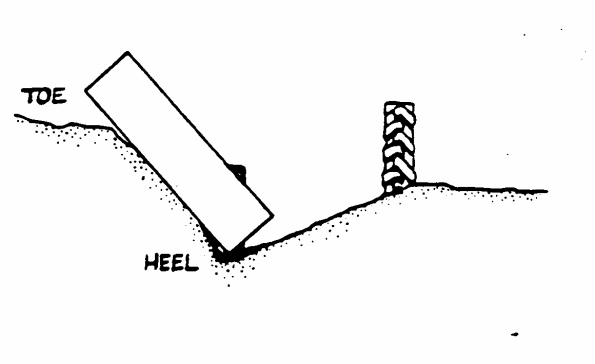

Figure 2. 3 Back Sloping

Most machines require manually making this adjustment by moving the moldboard out to the side. Change the location of the blade attachment to the blade circle. Lengthen blade lift arms manually and use the side shift control to side shift to the extreme. Raise one end of the blade and lower the other to achieve the correct setting. Use the front wheel lean to adjust the cut.

Lastly, check the slope of ditch for drainage. Do this with an eye level or “eye-ball” it.

2.3 Widening Shoulders

There are two methods to widen shoulders.

1. When repairing a wash-out on a steep shoulder, dump material on the road surface. Use the grader to carry the material to the location where it is needed. Work the material out over the shoulder, leave it high. Work the material out slowly so it will pack into the hole as it is being worked. Always pull some material in towards the road and save it for finishing work. Once the hole packed full the operator can separate rocks and large chunks out of the windrow by “high blading” it (see below). Use the small material to put a "finish" on the work.

2. 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.

To separate large rock out of material in a windrow by “high-blading,” set the blade 3” or 4” above the ground. This will carry the rock and larger material out of the finer material and into a separate windrow.

2.4 Blade Mixing Salt and Sand

Spread the material out at least the width of the blade, leave 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. Use the full width of the blade to “roll” the material. Pull the small windrow back to a central windrow. The salt and sand will be well-mixed, if not, repeat the process.

2.5 Blade mixing Oil Aggregates

Dry and windrow the aggregate. Peel aggregate from the windrow to get a pad 2” to 3” thick and the width of the distributor. Leave a small windrow on the outside of the material that has been pulled out. Drive the tanker or distributor on the material to spread the asphalt.

Follow the distributor with the motor grader. Peeling more aggregate from the windrow and cover 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 the 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. This will cut through the “oil balls. Blending is difficult when the aggregate with considerable fines. To compensate, lower the blade so it presses the layer of asphalt and aggregate, back the motor grader over the mix. This will enhance aggregate coating as the asphalt migrates upward.

Always use caution when mixing: cutting too deep will allow foreign material into the mixture. Clear the area where the mixing will occur of weeds, rocks and other debris. Allow plenty of room to mix. Be careful not to lengthen the windrows and keep the ends tucked in. It will be much easier to mix if the windrows are even in depth.

2.6 Blading Approaches

If there is a high area in the center of the approach, set the machine on the oil surface and drive into the approach. Cut the high area down and carry the material toward the right-of-way boundary. Leave the material in a pile near the end of the area to be worked. If the material is hard this may require more than one pass.

When this completed, turn the machine around and pick up the pile, carry it toward the oil surface. If additional material is needed, place it on top of the pile already formed.

Leave a windrow on the outside edge of the approach. Drop extra material on the blade in a pile on the oil surface. When setting up the windrow, use it to outline the approach. Turn the machine around and leave it in the lane of traffic turning into the approach. Pick up the pile 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 leave the material in the correct curve and angle. Repeat the pass without running on the windrow straddle it to complete the first half of the approach. Any excess material can be used on the other side of the approach by employing these same steps. When completing the job, allow excess material to be left on the back of the approach.

The key to this operation is driving off the oil surface at an angle hat puts the material down in the correct location.

2.7 Basics of Blading Aggregate Surfaced Roads

Aggregate roads need periodic maintenance to provide smooth riding surface and drainage. To grade, set the initial pass to move aggregate to the center of the road. Set a flat, loose blade with the toe on the shoulder. This setting will strike off high spots and deposit the soil in depressions. Additional material will windrow in the center of the roadway. This prevents the loss of aggregate in the hollow. Always take care to maintain or re-establish the proper crown or super elevation.

Work in the direction of travel until reaching a safe turn around point. Work back to the starting point. Feather the centerline windrow to the shoulder on the second pass. Extend the blade over the shoulder to keep from creating a berm on the shoulder that would disrupt drainage (Figure 2.4).

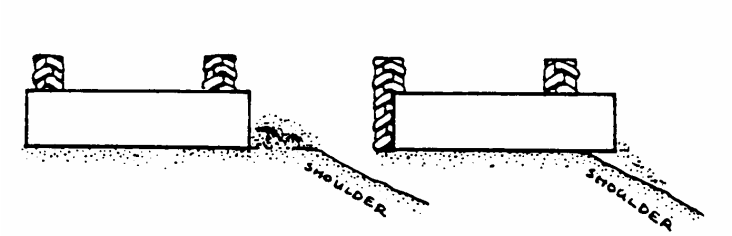

Figure 2. 4 Blading Techniques

Follow these precautions:

1. Leaning front wheels will lower the blade and establish a heavier cut.
2. Raising one end of the blade lowers the other end about 1/4 as much as that end was raised.
3. Reversing the circle might be necessary to position the heel of the blade to deposit any spoil on the high side of a super. This keeps from filling the low side ditch with spoil.

2.8 Snow Pack and Ice

Using a grader to cut snow pack and ice can be dangerous. Use extreme caution. Simple equipment changes can improve safety. Use chains and, 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. Do not use too much down pressure on the front wheels; do not raise the front to a point that steering is ineffective. Avoid the iron in the street: manhole covers, water shut-offs, and expansion joint. These can catch the blade and cause sudden, abrupt changes of direction- for the front end of the grader.

2.9 Patching

Practice patching with dry aggregate. The major objectives of patching are to level the area, have good riding surface, and leave a good appearance. Keep shoulder lines straight and ends tapered 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.

2.9.1. Patch Preparation

Begin patching by removing high spots and removing water and debris out of the hole. This is necessary to achieve a good bond. A clean surface ensures the asphalt tack coat will stick to the material. If the shoulder, level it so water will drain

away. Move excess material to a borrow pit, spreading it so that it is not a hazard to mowers.

Extend the patch a short distance on each end so that the ends are tapered. When possible, stop and start the patch on level road. On 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 rest of the tack, establish the edges, and spread the patch.

A flat blade will level more than a sharp blade, but may tear the patch. To determine the pitch of the blade will be determined by 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, use a much flatter blade than on a cloudy morning.

If the grader is articulated, tuck the berm. At 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; that material will fill the blade by the time grader reaches the tack line on the return pass.

Use articulation to turn around and approach the material head-on for better control of the material. It also provides better visibility.

2.9.2. Half Road Patches

On half-road patches, move the pre-mix to the center of the road. Operate with a moderately flat, loose blade for the first pass. The flat blade will even out the pre-mix. This loose setting will keep the machine from cutting into the old mat and getting chunks in the material.

At the end of the tack, stop and lift the blade. Then use the back blade process: moving forward, straddle the windrow. Go to a sharp, tight blade. Back up in a straight line. The back of the blade will carry the material to the starting end of the patch and break up chunks in the pre-mix.

The windrow position is very important. Place the material in the approximate center of the road. Position the machine to straddle the windrow. The outside edge of the windrow should fall where the edge of the patch will be and should sit on the edge of the existing material. Before making this pass, have the windrow even in size so pre-mix will fall in a straight line as it leaves the blade. If there is a deep hole in the center more material may be needed there. Allow extra room to hold a straight line on the outside of the windrow. Drive straight.

At 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 front wheel with a sharp angle. Use care so 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 driving forward, put the outside front wheel slightly up on the side of the windrow: The blade will pick up the pile as operator drives along the windrow: this will raise the blade slightly, making the taper for that end and packing the edge line.

To leave a level area, drive the same height up on the windrow all the way across the patch. At the other end of the windrow, 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. 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. This gives 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 on 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 premix to the center of the road. Stop on road level and tilt the front wheels toward the toe of the blade, setting the blade flat and loose. Drive forward, watching 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. At 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.

On machines that do not have leaning front wheels, the toe of the blade must be raised as you drive, and then the heel raised, to run the taper in. All other steps will be the same.

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. This will have laid approximately two- thirds of the amount of pre-mix. Use the remaining 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 1/2 of the remaining material in this pass. The material should run out just before reaching the end of the patch. Back up and repeat the same pass straddling the windrow with the heel just even with the edge of the 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.

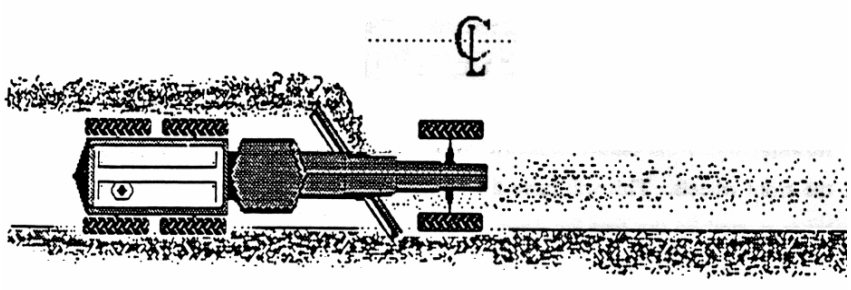

Figure 2. 5 Straight shoulder lines

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 2.5). This pass should run straight down the shoulder establishing the windrow at a uniform distance from the shoulder.

Without changing the blade settings, turn the machine around and drive along the shoulder line (Figure 2.6). This puts the windrow in line with the shoulder, and in position for spread pass.

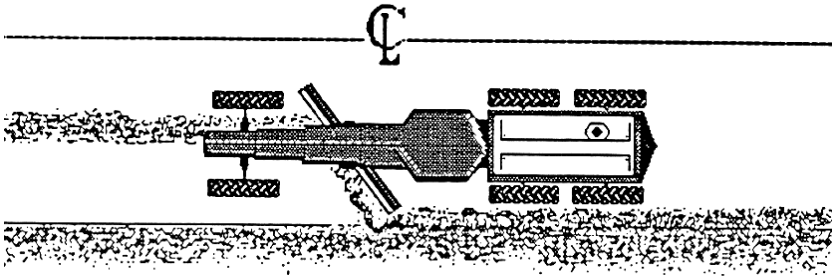

Figure 2. 6 Windrow position

Move left over material to the center of the road and complete the patch. Leave room to put a wheel between the windrow and the edge. Do not come out to the edge until the patch is ready for completion.

If there is a small pile at the end of the patch, blend this in; do not string it out down the road. If the waste material is large, cover with tack coat to apply the pre-mix. Do not blade if off into the ditch.

To verify the height of the blade level above the area watch behind the toe of the blade. It should just touch as the machine moves.

Make as few passes as possible so the material will not separate. Working the material too much will separate the rocks and fines. Blade pitch is important. 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.

2.9.3 Full Road Patches

Begin full road patches with applying tack coat on one side and windrowing the patching material to the center. Tack coat the other side of the road and carry the material across. Once this is completed, the material should be in position to for the shoulder line.

A half-sole is a long patch, and the same steps are followed except it should be laid in sections. 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 joints.

A flat blade will tend to level more than a sharp blade, which tends to tear the patch. The amount of angle used will depend on the amount of heat and moisture in the pre-mix, and the type of material used to produce the pre-mix. For example, on a hot afternoon use a much flatter blade than on a cloudy morning.

Lay-down work done in low gear with open throttle gives the operator “live” controls without excessive ground causing “wash boards” in the patch. 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.

2.10 Dips

To lay a short deep dip use a short cut. Extend the tack coat about a truck length on each side of the dip. Markers can be set on the shoulder to mark where the dip begins and ends. Dump the pre-mix in one pile. Drive over the pile taking as much material as the grader can and drop it in the dip. Back up and set the blade with a tight sharp angle to the shoulder. Pick up the rest of the material and set up the shoulder line. Back up and begin to lay the patch. The material placed in the hole will support one front wheel and the windrow will support the other. At the markers, ease the front wheel higher on the windrow placing more material in the dip. Ease down at the other marker to run the end taper.

Finish the patch using the same method as above. Working slowly and the grader will have to be turned around less often. Speed with a motor grader is made by making fewer passes not by going quickly.

2.10.1 Road Center Patches

To make patches when it is not necessary to form a shoulder line, spread the material to one edge of the tack with a tight blade. Straddle the windrow and leave a toe tight to the road. Drive forward raising the heel slightly to begin laying material. Set both edges in this manner.

If patches are long and require pre-mix from more than one truck, lay the loads back toward the work previously finished and blend the ends back over the finished work. Do not to leave any bumps.

2.10.2 Bridge Ends

When patching a bridge end, create a small the shoulder windrow on the bridge approach. Always lay the pre-mix towards the bridge on the shoulder cuts. Then follow the normal steps for the rest of the patch running the taper from the end of the patch up to the bridge and making the rise gradual over the entire length of the patch. A gradual taper will prevent a jolting "bump" in front of the bridge.

2.10.3 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.

2.10.4 Compaction/Rolling

The last step in laying a patch is to compaction. This 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, compact the trucks to reduce the voids and raveling, thus increasing durability.

Roll the shoulder first and work towards the center of the road. If the roller has a steel drum,

allow 4”-6” to hang over the shoulder. Avoid letting the roller drum “tilt” back and forth as this will spoil the shoulder line. Avoid turning the roller on the fresh patch. Roll the patch after it is completed except when there is a very deep hole. Small holes can be rolled with the grader wheels.

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 may vary depending on the weight and type of roller.

Compact or roll in lifts. Avoid rolling during the laydown giving the layers a chance to bond. Where heavy traffic might cause excessive packing or settling, deep lifts may be rolled individually.

Compaction is a 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.

2.10.5 Patch Materials

Materials will affect procedures to a great degree. The type normally used is mixed with a "cut back" asphalt. 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 are hard to lay. This material is "fluffy" or "sticky" 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 mix can be spread evenly, so the first pass should set-up the shoulder line. Use one pass to lay it back and then dress to the outside. One or two truck loads can be laid at a time, work in layers. On a wide road, work in strips placing a small amount on the center of the lift and move it to the right

Roll each lift as it is placed, as it is difficult to compact if it is too cool. When patching holes, use a

roller on each lift, as the material tends to push out of the hole. This is why it is important to lay it in lifts. After three passes the material becomes unworkable

Chapter 3 **Additional Information About Gravel Roads**

3.1 Surface Stabilization

There is general agreement that the majority of gravel road surfaces will be improved by stabilization. Surface stabilization saves maintenance time by eliminating the need for reshaping and smoothing.

Surfaces may be unstable because aggregate mix. That is to say that certain rock sizes are missing from the gradation. To provide a stable surface, the new aggregate needs to be blended into the existing surfacing during reshaping. Two reshaping activities should be scheduled to complete the process: collecting samples for sieve analysis and incorporating missing sizes into the surface. If sieve analysis can not determine what type of aggregate should be added, an experienced supervisor can determine by experience and observation.

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

Table 3. 1 Recommended graduation for gravel road surface material.

US Standard Sieve Size	200	80	40	20	10	4	3/8	1/2	5/8
% Range from:	12	18	25	33	43	57	72	80	100
to:	16	24	32	41	152	69	86	95	100

(*Gravel Road Maintenance Innovations*, Better Roads, 58:12, page 27, December 1988.)

Improvement to the Surface Material of Gravel Roads. Make improvements to the surface material of gravel roads during rainy weather. Work completed during the dry weather to be watered to a depth of 5 to 10 cm (2 to 4 in.). Moisture is needed during the upgrading of the old surface, when mixing and compacting. If adding clay material, add about 3 to 5 cu. yds./road mile. The spreading of clay is very sensitive to rain. Surplus clay makes the wet road surface very slippery.

Dust Binding Correct proportioning of gravel road surface materials will reduce dust. To ensure dust binding, some road departments make annual applications of calcium chloride.

There are two basic salt application methods: deep mixing and surface application. In the spring after the winter thaw, calcium chloride is spread on a scarified road surface–2 to 2.75 in. of loose material–with a spreader mounted in the place of the rear frame of a tipper body.

The recommended amounts of calcium chloride are shown in Table 6.2. The salt is mixed more thoroughly with a grader but more efficiently with a tractor-towed leveler (drag grader). The surface needs light compacting, but this can be completed by normal traffic. With the surface application, the calcium chloride is spread on a wetted – and usually leveled – road surface using 0.8 to 1.6 t. per road mile.

Table 3. 2 Amounts of crushed gravel road surface material required for maintenance. Amounts are in cubic yards per road mile per year.

Average Daily Traffic	Width of the Road (in feet)	
	20t	23
500 - 1,500	104	122
200 - 500	67	78
100 - 200	37	43
-100	25	28

Table 3. 3 Amount of calcium chloride applied during the spring dust binding. Amounts are in tons per road mile.

Average Daily Traffic	Width of the Road (in feet)	
	20t	23
500 - 1,500	4.8	5.6
200 - 500	3.2	4.0
100 - 200	1.6	2.4
-100	0.8	28

3.2 Mechanized Maintenance

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

The leveler is an anti-corrugation device. In addition to the leveling of corrugated surfaces, it will fill minor potholes and remix the surface material. During 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.

When regraveling a road 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.

A drag grader doesn't 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.

Light Compaction Equipment. With gravel roads, poor compaction encourages wear caused by traffic, rain damage, and dust formation. The use of compaction equipment is partly compensated for by material trucks delivering aggregate during roadwork, but additional compaction is necessary.

Surface Gravel Screening. For 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 constructed of a feeder unit with primary screen, a 40-ft conveyor and a tow-

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 unscreened gravel is loaded into the feeding bin, which has a capacity of 4.5 cu. yds. The bin can also be easily removed from manual loading. The screen, located at the end of the conveyor over the dump truck body, 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. All the heavy tasks such as reshaping and scarifying the road surface and ditching should be reserved for the grader.

In the spring, 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 way from the ditch, so that rain won't wash it back.

3.3 ROAD DUST SUPPRESSANTS

(Source: *Operating Tips: Road Dust Suppressant.* Northwest Technology Transfer Center, Winter 1986. Originally published by the University of

Missouri-Rolla Transportation Technical Assistance Office.)

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.
- 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 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.

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

- Paving is not feasible option for various reasons,
- 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 about resinous adhesives, the road must be prewetted with water (if natural moisture is lacking) to assist chemicals in penetrating the surface,
- A heavy rainstorm shortly after application (within 36 hours) will wash away most of the chemicals, and
- More than one treatment a year with diluted forms is generally necessary.

A number of organic and inorganic chemical mixes are available for use as dust palliatives; synthetic fabrics are also available for physically containing the road materials. Appendix A 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.

Calcium chloride has been used to treat unpaved road surfaces since the last century. It not only retards evaporation from the road during the heat of the day, but because of its ability to attract moisture, actually recaptures lost moisture at night or under other favorable humidity conditions. Other chlorides are widely used in the northwest, particularly for stabilizing the surfaces of haul roads. A mix of common salt and calcium chloride cuts the material cost appreciably, while controlling dust effectively.

Appendix A

Suppressing Road Dust

Chemical: Inorganic

Attributes	Limitations
Calcium Chloride	
• Starts to absorb water from air at 29% relative humidity (77%)	• Slightly corrosive to steel, highly corrosive to aluminum and its alloys' attracts moisture, prolonging active period for corrosion.
• Reduces rate of evaporation 3.4 times (vapor pressure of saturated solution at 77º F is mm Hg). Note: the lower the vapor pressure, the greater the ability to resist evaporation.	• Rainwater tends to infiltrate and leach out highly soluble chlorides, but if road has proper crown, most water is deflected away.
• Significantly increases surface tension of water film between particles, helping to slow evaporation and further tighten compacted soil as drying progresses.	• During dry periods, upward capillary action may cause chlorides to crystallize near road surface, where they can be leached away by sudden rain.
• Lowers freezing point of water solution to -60º F, minimizing frost heaves (30 % solution). Freezing of treated road not only begins at lower temperature but is gradual and seldom com-pleted.	• No cementing action; effective control only with well-graded, stable road mixes.
• Treated road can be regraded and recompacted with less concern for losing moisture and density.	• 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.

Applications	Sources
Typically 2 treatments/year Initial Flake 1.0 to 1.5 lb./sq.yd Pellet 0.6 to 1.3 lb./sq.yd 35% solution 0.2 to 0.3 gal/sq. yd Follow-up ½ to 2/3 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 spinners disk or positive-displacement units.	By product brine from manufacture of sodium carbonate by ammonia-soda process of bromine from natural brines Three forms: Flake, or type 1 (77 to 80% Concentrate 100# bags) Pellet, or type 2: (94 to 97% concentrate 80# bags) Clear Liquid: (32/35/38% concentrate tankers) Some brand names Liquidow Dow Flake Peladow Superflake.

Chemical: Inorganic

Attributes	Limitations
Sodium Chloride & Calcium Chloride Mix	
• Combines stabilizing action of sodium chloride with dust control of calcium chloride. • Compared to calcium chloride used alone, reduces cost 20 percent while losing less than 5 percent in dust control.	• Same limitations for these salts used individually.

Application	Sources
Typically 2 treatments/year Initial: 1 lb. mix/sq.yd Follow-up: ½ initial dosage	• 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

Chemical: Inorganic

Sodium Chloride

Attributes	Limitations
• Starts to absorb water from air at 76% relative humidity (77º)	• Moderately corrosive to steel in dilute solutions, but no worse than water in concentrated solutions; attracts moisture, thereby prolonging active period for corrosion.
• Reduces rate of evaporation 1.3 times (vapor pressure of saturation solution at 77º F is 18 mm Hg).	• As it becomes diluted or leaches out, disperses clay, which shrinks on drying and becomes more susceptible to blowing.
• Increases surface tension slightly less than calcium chloride.	• If over-applied, poses threat to plant and animal life as well as possible groundwater contamination.
• Lowers freezing point of water solutions to –6º F (25% solution)	• Not an effective dustproofer; thus typically used to stabilize road base and topped with calcium chloride to control dust
• When mixed into road base, effective improves mechanical stability.	
• Costs the least of any chloride salt.	

Application	Sources
• Generally higher dosages than calcium chloride treatment	• Occurs naturally as rock salt (mined mechanically or hydraulically) and brines (refined or evaporated). Some brand names: Morton salt Diamond salt

Chemical: Inorganic

Attributes	Limitations
Water	
• Poses no threat to the environment • Normally, readily available	• Evaporates readily, controlling dust generally for less than a day. • Costs more than other inorganic chemical suppressants because of repeated applications needed to achieve same level of control (labor intensive).

Application	Sources
• Frequency of treatments depends on temperature and humidity	

Chemical: Inorganic

Attributes	Limitations
Magnesium Chloride	
• Starts to absorb water from air at 32% relative humidity (77º).	• In concentrated solutions, very corrosive to steel, attracts moisture, thereby prolonging active period of corrosion. (Note: corrosive action of seawater on steel attributed to $MgCl_2$ content.) Some products may contain a corrosion inhibiting additive.
• Reduces rate of evaporation 3.1 times (vapor pressure of saturated solution at 77º is 7.6 mm Hg.)	• Rainwater tends to infiltrate and leach out highly soluble chlorides, but if road has proper crown, most water is deflected sideways into ditches.
• More effective than calcium chloride solutions for increasing surface tensions, resulting in a very hard road surface	• During dry periods, upward capillary action may cause chlorides to crystallize near road surface, where they can be leached away by sudden rain.
• Lowers freezing point of water solutions to -27º F (22% 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.	

Application	Sources
Typically 2 treatments/year Initial 30% solution 0.5 gal.sq. yd Follow-up: ½ initial dosage • Storage and handling same as for liquid calcium chloride. • Applied preferably with pressure spray bars (splash bars produce uneven applications).	• Occurs naturally as brine (evaporated); also by product of potash production. • Usually liquid form, 25 to 34 percent solution. Some brand names Dustgard Dus-top

Chemical: Organic

Attributes	Limitations
Bitumens & Tars or Resinous Adhesives	
• Binds soils because of asphalt's adhesive properties. • Serves to waterproof road. • May be adapted to suit wide range of soils, gravels, and traffic conditions.	• Under dry conditions, some may not maintain resilience; can form a crust and fragment under traffic loads. • Materials cost significantly higher than for other chemical suppressants.

Application	Sources
Generally 1 to 2 treatments/year • to 1 gal.sq./yd depending on road surface condition and dilution • Material sprayed using many types of equipment, from hand-held hoses to asphalt distributors.	• 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 • Bituminous emulsions: grade ss-1, ss-1h, css-1, or css-th mixes with 5+ parts of water by volume.

Mechanical

Road Fabrics

Attributes	Limitations
• Flexible, durable, water permeable, and highly resistant to soil chemicals. • Used as a separator, prevents intermixing of subgrade materials and base course, preserving drainage systems and load transfer capability. Structural section life is prolonged and maintenance costs reduces. • Controls dust production by preventing subgrade fines from "pumping" up into the aggregate. • In tension, reduces localized loads, over a larger area of subgrade, 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.	• High material cost, though installation cost is low. • Material degradation may result from exposure to ultraviolet rays (sunlight).

Application	Sources
• Placed during the road construction; no special equipment required.	• Manufactured from manmade 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