Section I: Routine Maintenance and Rehabilitation

Understanding Road Cross Section

Everyone involved in gravel road maintenance must understand the correct shape of the entire area within the road's right-of-way. Figure 1 shows a typical cross section of a gravel road. If states have minimum standards or policies for low-volume roads, they must be followed.

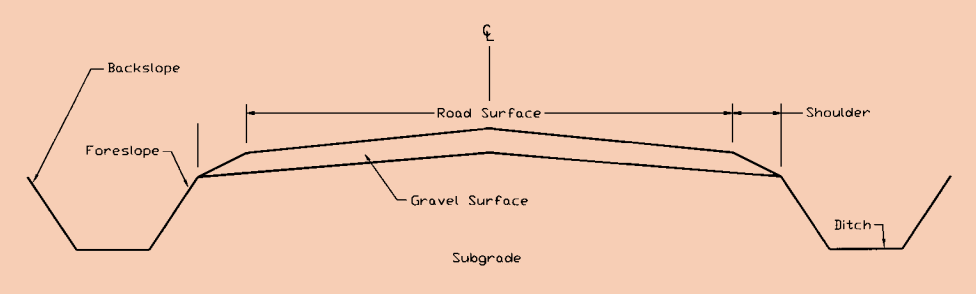


Figure 1: The components of the roadway cross section.

In order to maintain a gravel road properly, operators must clearly understand the need for three basic items: a crowned driving surface, a shoulder area that slopes directly away from the edge of the driving surface, and a ditch. The shoulder area and the ditch of many gravel roads may be minimal. This is particularly true in regions with very narrow or confined right-of-ways. Regardless of the location, the basic shape of the cross section must be correct or a gravel road will not perform well, even under very low traffic.

Paved roads are usually designed and then constructed with careful consideration given to correct shape of the cross section. Once paving is finished, the roadway keeps its shape for an indefinite period of time. Gravel roads are quite different. Unfortunately, many of them are not constructed well initially. In addition, gravel roads tend to rut more easily in wet weather. Traffic also tends to displace gravel from the surface to the shoulder area and even to the ditch during dry weather. Managers and equipment operators have the continual responsibility of keeping the roadway properly shaped. The shape of the road surface and the shoulder area is the equipment operator's responsibility and is classified as routine maintenance.

Keeping the foreslope and ditch established and shaped is often the maintenance operator's responsibility as well. Obviously, the whole idea here is to keep water drained away from the roadway. Standing water at any place within the cross section (including the ditch) is one of the major reasons for distress and failure of a gravel road. There is sometimes a need for specialized equipment to do major reshaping of the cross section,especially in very wet conditions. However, the operator of routine maintenance equipment must do everything possible to take care of

This road, located in Poland, has very poor cross section with no ditches. Consequently, water drains down the roadway itself and after many years of erosion,the roadway is several feet lower than its original elevation. (Courtesy of Mary O'Neill,Office of Remote Sensing, South Dakota State University)

This well-traveled road in Ecuador performs well in a region that receives approximately 200 inches average annual rainfall. (Courtesy of Ron Anderson, Tensar Earth Technologies, Inc.,USA)

the roadway since budgets often do not allow for the use of extra equipment and manpower on gravel roads.

The recommended shape of each part of the cross section will be discussed in detail later in this manual.When a gravel road is maintained properly, it will serve low volume traffic well. Unfortunately, most gravel roads will fail when exposed to heavy hauls even when shaped properly. This is due to weak subgrade strength and marginal gravel depths which are often problems with gravel roads. The low volume of normal traffic does not warrant reconstruction to a higher standard. However, improper maintenance can also lead to very quick deterioration of a gravel road, especially in wet weather. The maintenance equipment operators must always work at maintaining the proper crown and shape.

Example of a gravel road with good shape of cross section. Notice crown in driving surface and proper shape of shoulder and ditch.

An example of a well shaped gravel road shoulder that slopes away from the driving surface and drains water to the inslope and ditch.

Routine Shaping Principles

The distortion that was cut into this road surface is the result of operating a motorgrader too fast.The angle of the depressions which match the angle of the moldboard reveal this. This is not the same as "washboarding," which has different causes.

Grader operator cleaning a ditch and restoring shape to the foreslope and backslope.

The primary focus of this section will be the use of the motorgrader for gravel road maintenance. However, there are other devices used for the job that can work well. Front or rear mounted grading attachments for tractors, road rakes, and other devices of various designs are used in some areas of the country. The principles of shaping are the same no matter what machine is used.

Operating Speed

Operating speed in blading operations must not be excessive. This has caused problems on many roads. It is virtually impossible to do good work above a top speed of 3 to 5 mph.When the machine begins to "lope" or bounce, it will cut depressions and leave ridges in the road surface. Conditions including moisture, material, and subgrade stability vary; therefore, the maximum speed for good maintenance can vary.

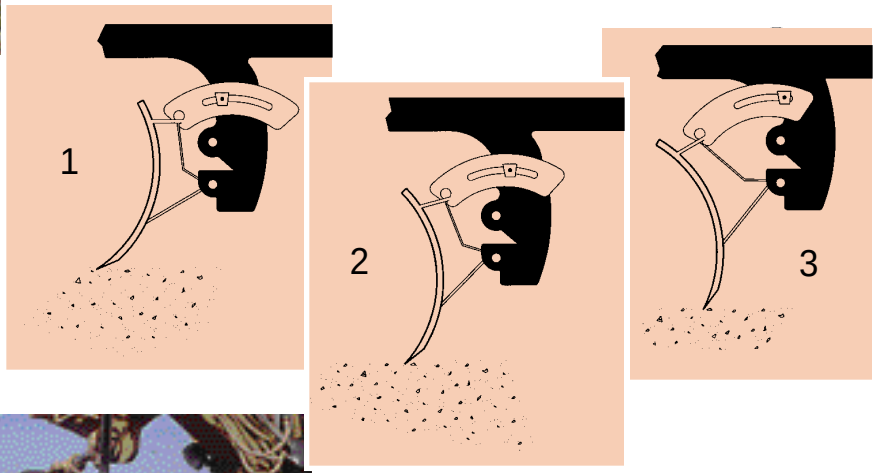
However, in virtually any condition, it is difficult to exceed 5 mph and still do a good job.

Moldboard Angle

The angle of the moldboard is also critical to good maintenance. This angle is fixed on some grading devices, but on motorgraders it can be easily adjusted. It is important to keep the angle somewhere between 30 and 45 degrees. It is a challenge to recover loose aggregate

This is an example of poor use of the grader. The moldboard is pitched back too far and is not angled enough.Notice the gravel builds up and does not fall forward to give a good mixing action.Also, the loss of material from the toe of the moldboard will create a high shoulder, which destroys good drainage across the shoulder to the ditch.

Moldboard pitch or “tilt” refers to how much the moldboard is tipped forward or backward.The right pitch ranges from aggressive cutting (1), to spreading (2),to light blading or dragging action (3) for maintenance of gravel roads.



This is the other extreme of pitching the moldboard too far forward.The material will not roll across the face of the moldboard and does not mix.In addition to this, the cutting edge will not easily penetrate a hard surface, making it hard to trim out even light depressions in the road surface. It simply tends to skip along the surface with no real benefit.

Notice these examples of good pitch and angle. The gravel falls forward and moves across the moldboard very well. The cutting edge is close to vertical from the road surface, which makes a nice light trimming action for routine maintenance, and the angle is good,not allowing material to spill from the toe of the moldboard.

from the shoulder of the roadway without spilling material around the leading edge (toe) of the moldboard. Operating without enough angle is a primary cause of this spilling.

Moldboard Pitch

Along with correct angle, it is important to understand proper pitch or "tilt" of a moldboard. If the moldboard is pitched back too far, the material will tend to build up in front of the moldboard and will not fall forward and move along to the discharge end of the blade. This also causes excess material loss from the toe of the moldboard.It also reduces the mixing action that is desirable when recovering material from the shoulder and moving it across the roadway, leveling and smoothing it in the process. This mixing action is part of routine maintenance. Traffic tends to loosen material from the road surface and displace it to the shoulder area as well as between the wheel tracks. The stone will tend to separate from the sand and the fine-sized material.At the same time, small potholes and an uneven surface will develop. It is the job of the maintenance operator to recover the material, mix it again as it rolls along the face of the moldboard and restore good surface shape.

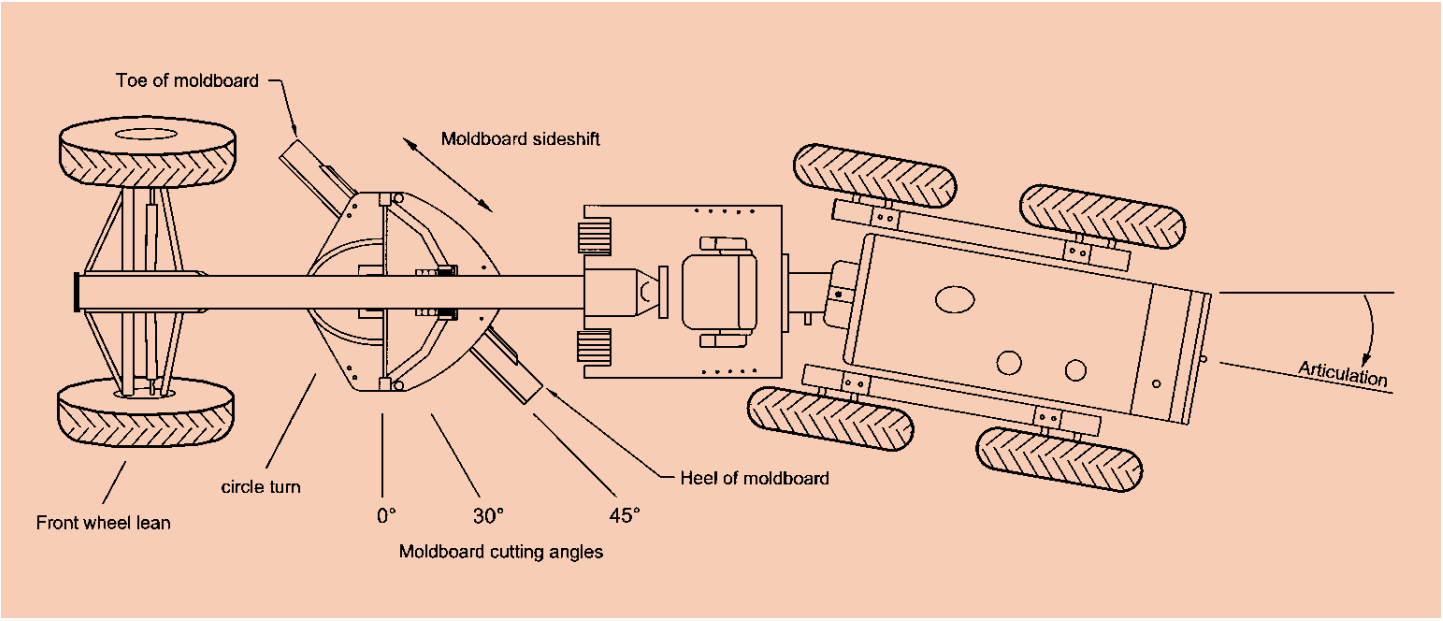


Figure 2:Illustration of an articulated motorgrader. (An illustration showing additional components of a motorgrader and recommended walk-around checks is shown in Appendix E.)

Motorgrader Stability

It can sometimes be hard to keep a machine stable, especially while carrying a light load of material. Counteracting machine bounce or "loping" requires experience in knowing the cause and then finding a solution.If a motorgrader begins to rock from side to side — often called "duck walking" in the field — it is usually caused by blade angle that closely matches the angle from corner to corner of the tires on the rear tandems. The solution is generally to stop, change angle slightly on the moldboard and slowly resume blading. Simply reducing speed will often eliminate the loping effect of a machine. Experimenting with different tire inflation pressures can also help stabilize a machine as well as leaning the front wheels in the direction that material is being moved. Filling tires with liquid ballast to about 70% capacity is sometimes done to increase traction, weight and stability of the grader. The ballast often used is a solution of calcium chloride and water. Stability problems that are constant and severe should be brought to the attention of your equipment dealer and/or tire supplier.

Articulation

Virtually all modern motorgraders are equipped with frame articulation. It can be an advantage to slightly articulate the machine to stabilize it even in a common maintenance operation.

Windrows

In some areas of the country, particularly arid or semiarid regions, it is common to leave a small maintenance windrow, sometimes referred to as an inventory windrow. This leaves a small amount of material to be picked up next time and worked back across the road for filling small depressions. This is a commonly accepted practice in some regions. In others, it is disapproved of and departments may even have policies forbidding windrows. This is often true in regions with narrow right-of-ways and narrow driving surfaces. Operators should follow department policy at all times. For those who allow the use of windrows, it is very important to keep them to a minimum. It can be very difficult to define what is acceptable and what is an excessive windrow. The windrow should also be placed near the edge of the roadway to allow as great a width for travel as possible. In the absence of a policy on this matter, be aware of the commonly accepted practices in your region and try to deviate as little as possible.

If a maintenance windrow is allowed by policy and used, try to keep it as light as possible. These examples show a light windrow being placed at the edge of the roadway and an obviously excessive windrow being left at the roadside. In the latter case, multiple passes should have been made to work out the vegetation and spread more of the material on the roadway, or perhaps some mechanical means of breaking up the lumps of sod such as a disk should have been used to allow more of the material to be spread on the roadway.

Crown

Establishing proper crown in the gravel surface probably generates more controversy than any other aspect of good maintenance. How much crown is enough? Can one get too much? What is a recommended crown? These are frequently asked questions by local officials, the traveling public, and equipment operators.

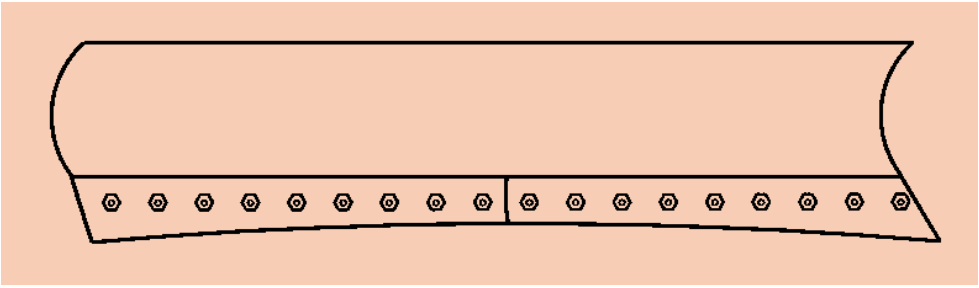
First of all,problems develop quickly when a gravel road has no crown. Water will quickly collect on the road surface during a rain and will soften the crust. This will lead to rutting which can become severe if the subgrade also begins to soften. Even if the subgrade remains firm, traffic will quickly pound out smaller depressions in the road where water collects and the road will develop potholes. A properly drained gravel road should have crown.

A road that lacks good crown.There is also centerline corrugation (washboarding),a problem that will grow worse when there is inadequate crown.

Yet an operator can also build too much crown into the road surface. This can lead to an unsafe condition in which the driving public does not feel comfortable staying “in their lane”or simply staying on the right side of the road. Because of the excessive crown,drivers begin to feel a slight loss of control of the vehicle as it wants to slide towards the shoulder. There is additional risk driving on gravel roads with excessive crown in regions that experience snow and ice cover. For these reasons drivers will tend to drive right down the middle of the road regardless of how wide it is.

A gravel road with a 26-foot driving surface, yet everyone drives in the middle. The primary reason is excessive crown.

This road located in New Zealand does not have adequate crown to drain water to the roadside. Consequently, potholes form. (Courtesy of Ken Skorseth,SD LTAP)

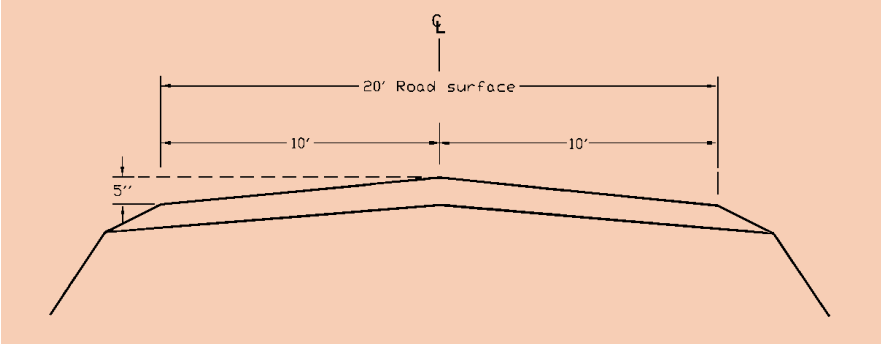


Problems from center wear in cutting edge.

What then is recommended crown? Recommendations from supervisors and skilled operators across the country indicate that at least 1/2 inch of crown per foot (approximately 4%) on the cross slope is ideal. It is also recognized that it is virtually impossible for any operator to maintain an absolutely uniform crown. However, try to deviate as little as possible. There are crown gauges available which can be used to determine existing crown. There are also very sophisticated electronic slope controls available for graders. These are found more often in construction operations than in maintenance, but certainly can be used for maintenance.

There is one further problem with crown that needs to be discussed. The ideal shape is a straight line from the shoulder up to the centerline of the road. This gives the road the same shape as the roof of a house, often referred to as a flat "A" shape. However, this shape can sometimes become rounded. The engineering term for this is "parabolic crown." This is virtually always a problem. The middle portion of the road will have considerably less crown than the outer edges. Water will not drain from the middle and potholes and ruts will form. The greatest cause of parabolic crown is excess wear at the center of the cutting edge. This is normal wear and will vary with types of gravel, width of road, wheel path location and other factors. A good operator will make an effort to avoid the parabolic shape on a roadway by keeping the cutting edge straight.

Roadway with parabolic crown.The outer edge of the road slopes too much. Gouging causes high shoulder, and center 1/3 of the road tends to be flat.



This road in New Zealand performs remarkably well because of good crown and good gravel quality in a region that receives nearly 150 inches of moisture a year! (Courtesy of Ken Skorseth, SD LTAP)

A simple method is to use a cutting torch and straighten the cutting edge whenever 1/2 to 3/4 inch or more of center wear exists. Another method is to use a thicker, harder section of cutting edge in the middle of the moldboard to resist wear. This will retard excess center wear, but generally will not eliminate it.

Another option is to use the modern carbide-tipped bits on the cutting edge. These are extremely wear-resistant and dramatically reduce center wear. There are also carbide insert or carbide-faced cutting edges that are very wear-resistant.

In summary, the recommended crown is a straight line from the shoulder to the centerline that rises approximately 1/2 inch per foot (or approximately 4%).

Road Shoulder

The road shoulder serves several essential functions. It is there to support the edge of the traveled portion of the roadway. But another important function is to provide a safety area for drivers to regain control of vehicles if forced to leave the road surface. Yet another important function is to carry water further away from the road surface to the foreslope and ditch.

In order for the shoulder to perform all of these functions, its shape is critical. First of all, the shoulder should meet the edge of the roadway at the same elevation. In other words, the shoulder should be no higher or no lower than the edge of the roadway. By maintaining this shape, the low shoulder or drop-off is eliminated which is a safety hazard and also reduces roadway edge support. But the other extreme, which is a high shoulder, should also be avoided. This will be discussed later.

It is also recognized that gravel roads in some regions, particularly those with very narrow right-of-ways, have very little shoulder area. In some cases, the edge of roadway is actually the beginning of the foreslope down to the ditch. But here again, it is important that there is not a steep drop-off or a ridge of soil to block drainage. Maintaining shoulders is a critical part of gravel road maintenance.

The photos above and below show good examples of gravel shoulders that match the edge of the roadway very well and drain water to the ditch.

A common condition along the edge of many gravel roads:the secondary ditch.

High Shoulders (Secondary Ditches)

This problem can be seen along gravel roads almost anywhere people travel. There are many slang terms used in the field such as “berms” or “curbs.” The engineering term for this condition is “secondary ditch” and it is a good description of the condition. When a gravel road develops a high shoulder, it destroys the drainage of water directly from the surface to the real ditch. This causes several problems. In relatively level terrain,the water collects here and seeps into the sub-grade, often causing the whole roadway to soften. In rolling and rugged terrain, the water quickly flows downhill along the secondary ditch,often eroding away a large amount of gravel and even eroding into the subgrade. This also creates a serious safety hazard. There are many reasons to work hard to eliminate secondary ditches.

Secondary ditch over six inches deep.

Causes of High Shoulders

What causes secondary ditches to form? There are several causes. They can develop from improper maintenance such as losing material from the toe of a grader's moldboard,which builds up a high shoulder, or from cutting too deep at the shoulder line with the toe of the moldboard. This is a particular problem when the cutting edge is not kept reasonably straight. But there are other causes, such as excessive "whip-off" of loose material from fast traffic,which tends to build up along the shoulder line. Also, heavy loads on gravel roads with weak subgrades can cause this. When heavy vehicles have to travel near the shoulder while meeting other vehicles, the roadway can rut while the shoulder area shoves upward. Yet another cause is the buildup of sand in northern regions where winter ice/snow control requires some winter sanding operations on gravel roads. An expert in the field once made this statement: "It is difficult to completely eliminate secondary ditches, but it pays to work hard to keep them to an absolute minimum." This is excellent advice. The time spent in dealing with a high shoulder (secondary ditch) will result in a road that is easier to maintain afterwards. But the real challenge is getting the job done.

Here, water has run down a secondary ditch or high shoulder and then eroded through the shoulder material at the bottom of a hill. This creates a hazardous condition.

Recovering and Spreading on Roadway

If a motorgrader is the only piece of equipment used on the job, generally more than one pass will be required to recover material from high shoulders. It is wise to place standard MUTCD warning signs such as "Road Work Ahead" since this is more than routine maintenance. If there is little or no vegetation on the shoulder, simply extend the moldboard out into the shoulder material and begin to pull it onto the roadway. If the amount of material is light, you may be able to do this in one pass. The material recovered is often good gravel that needs to be returned to the roadway surface.

Using grader to recover material from a high shoulder and restore correct shape to the shoulder.

Breaking up Sod and Vegetation in Recovered Material

Quite often, the material pulled out onto the roadway from the shoulder is very hard to spread because of the vegetative material in it. It will require multiple passes with the grader to get the job done. Many agencies are turning to other mechanical means of breaking up the material to make the road safe for traffic. This can range from something as simple as a disk or drag to sophisticated pulverizing equipment.

Windrow pulverizer fabricated by the Hyde County Highway Department of Highmore, South Dakota.

A commercially manufactured pulverizer.

A small rear-mounted tandem disk on a mower tractor.

A commercially manufactured rock rake, normally used in farming operations.

Pulling Shoulders and Covering

The material from a high shoulder is not always suitable to be reused on the roadway. It may be best to cut the material loose, pull it onto the roadway and then load and remove it. However, this can be very expensive. It is sometimes acceptable to pull the material and cover it. In several areas of the country, a method called "sweeping it under the carpet" is used. The following photo sequence shows how "sweeping it under the carpet" is done.

Make sure that the soils are suitable to be used as base material under the edge of roadway and shoulder before doing this. If you're not absolutely sure, try this on a test section of 1000 ft. or less to see how it performs. This method works best when there is a lot of sandy soil both in the subgrade of the roadway and also in the material recovered from the high shoulder. The sand will be unsuitable to recover and spread onto the roadway, but will be reasonably easy to cut and place under the gravel that will be placed back over it. If the road is scheduled to be regraveled, it is an excellent time to do shoulder work to get the roadway back into good shape.

Again, this is much more than routine maintenance and signs should be placed to warn motorists of roadwork being done. A better option would be to close the section of road being worked on if possible.

The existing surface gravel is cut loose and windrowed to the opposite side of the road.

The existing secondary ditch is then cut slightly deeper and the material is placed in the roadway.

The material from the high shoulder is then pulled into the cut that has just been made. Generally, this material will have to be worked several times with the grader to break it up enough to spread evenly.

The windrowed gravel is then brought back over the recovered material and the roadway is restored to proper crown and shape. The high shoulder has been eliminated.

Benefit of Mowing

Any of the procedures discussed for dealing with high shoulders are much easier to accomplish if a good job of mowing is done in advance. This is true even in routine maintenance operations. When grass or other vegetation grows high along the edge of the roadway, it becomes difficult to maintain a clean, uniform shoulder line. In a survey of operators in the state of Iowa, mowing the shoulders on gravel roads ranked as one of four primary functions needed to maintain a good gravel road! (Keeping proper shape, drainage, and straight cutting edges were the other three.)

The frequency of mowing depends on the region of the country and the climate. However, the cost of mowing is often offset by reduced costs of other maintenance as well as safer roads. In northern plains regions, there is yet another great benefit to mowing. By removing the standing vegetation, drifting snow will not be trapped on the roadway and snow removal costs can be drastically reduced. The best equipment for this is rotary or flail mowers, which do a good job of shredding the vegetation and are not as easily damaged or plugged by roadside trash.

Notice the dramatic difference in the road shoulders shown above and below. It becomes so much easier to recover gravel that has drifted to the edge of the roadway when the vegetation has been cut cleanly. It is particularly important to get rid of the vegetation prior to a shoulder-pulling operation.

Gravel Road Rehabilitation

Gravel roads are generally maintained by routine blading and adding gravel as needed either by "spot graveling"or regraveling entire sections. However, almost any gravel road will gradually begin to show distress that requires more than routine maintenance to correct. The most common problems that develop are "berms" or secondary ditches that build up along the shoulder line and the shifting of material from the surface to the shoulder area and even onto the inslope of the grade. This comes from gravel being displaced by traffic, winter plowing operations, erosion of material during heavy rain and sometimes from poor routine blading techniques. This often causes major problems with drainage. At certain intervals, virtually every gravel road requires some major rehabilitation. (35, 36)

This gravel road shows severe distress after being subjected to a heavy haul from trucks hauling wheat to a grain elevator. The problem was made worse by an unusually wet season.

Reshaping Surface and Shoulder

These can usually be corrected with the motorgrader alone. Spring is the best time for this as there is minimal vegetative growth and moisture is present. The reshaping of the driving surface and the road shoulder can be done by cutting material with the motorgrader and relaying it to the proper shape and crown.If possible, the use of a roller for compaction will greatly improve the finished surface. This will leave a denser, stronger, smoother surface that will be easier to maintain.

Reshaping Entire Cross Section

Severe rutting,loss of crown, gravel loss and deep secondary ditches — a combination of any two or more of these calls for a major reshaping. This requires a much greater effort.It often occurs after a gravel road has been subjected to an unusually heavy haul. This will be worse if a heavy haul occurs during wet weather.

Major reshaping often has to be done on the entire cross section and it may have to be done immediately regardless of the vegetative growth. Motorgraders, disks, pulverizers/mixers and rollers are often needed. These are not always available, but certainly make the job easier. The field supervisor's knowledge and the operator's skill in knowing how to rebuild the cross section becomes very important. These projects seldom have the benefit of much planning or technical assistance. There is seldom any surveying or staking done. But it is very important to rebuild a uniform cross section and pay attention to restoring good drainage. Only after this is done — and done correctly — should good surface gravel be replaced.

The same road as shown on the previous page approximately three months after the heavy haul was finished.The road was restored to remarkably good shape simply with the use of motor-graders doing a complete reshaping of the inslope, shoulder and surface with a small amount of surface gravel added.

Erosion Control

Having discussed the importance of reshaping a gravel road, there is another issue that must be addressed. When major reshaping is done outside of the traveled way, vegetation and ground cover will obviously be disturbed. This can lead to erosion of soil. The problem will vary depending on the region. In arid and semi-arid areas, the problem is small or non-existent.Areas which receive frequent rains, have rolling or rugged terrain, and have highly erodible soils, are particularly vulnerable. When vegetative cover is disturbed,there are problems that can arise. While trying to eliminate problems, new ones can be created such as clogged culverts and blocked ditches, pollution of streams and lakes, and eroded slopes which can shorten the life of improvements. You may be found in violation of state and federal regulations. Damage claims and lawsuits may be filed.

The solution to this issue is not to cancel plans for gravel road improvement,but to plan your work carefully and use methods of reducing or eliminating erosion. Here are some things to consider:

- Some regions have certain times in the year when frequent and heavy rainfall can be expected. Try to avoid major reshape work during those periods of time.
- Keep disturbed areas small. The more earth you disturb, the greater will be the risk of soil erosion. Set work boundaries and don't let work crews get outside of them.
- Consider stabilization of disturbed areas. Silt fences, mulching, erosion control blankets and other means should be considered.
- Keep water velocity low. Removing vegetative cover and topsoil generally increases the amount and speed of runoff. Keep slopes as shallow or gentle as possible. Keep ditch slope as gentle as possible. Shorten drainage runs and work to get vegetative cover reestablished as soon as possible after work is finished.
- Keep sediment within work boundaries. Sediment can be retained by filtering water as it flows (as through a silt fence), and ditch checks will retain dirty runoff water for a period of time until the soil particles settle out.
- Inspect recent work. This is vital to make sure channels haven't formed in ditch bottoms or on slopes, or around and under controls that were used. Be particularly vigilant after heavy rains.

Areas of Concern

This type of corrugation,"washboarding," is caused by lack of moisture, hard acceleration, aggressive braking, and poor quality gravel.

It is impossible to deal effectively with this problem if you do not understand the causes. Motorgraders are often blamed, but in reality, they seldom cause the problem.

There are three primary causes: the driving habits of people, lack of moisture, and poor quality of gravel. Driving habits are clearly evident when you observe washboarding at intersections, going up or down steep hills, leading into or out of sharp curves and sometimes even near driveways. These are all places where drivers tend to accelerate hard or brake aggressively. This is a major cause of washboarding. (24,33, 35, 36)

Lack of moisture will encourage washboard formation and prolonged dry weather can really aggravate the problem. This is because the crust that

There are special situations in gravel road maintenance that should be addressed. These are common to nearly all gravel roads and it is important to understand how to deal with them. These concerns are unique to gravel roads and practical solutions are recommended for each of these.

Dealing with Corrugation

The technical term is corrugation, but virtually everyone in the field refers to the problem as washboarding. This problem can bring more complaints than any other. It is very annoying to the driver and, when it becomes severe, can lead to loss of vehicle control.

This type of washboarding appears at an angle across the roadway with ridges and depressions two to three feet apart.It is caused by excess grader speed.

It is a good practice to loosen,mix, reshape gravel in a washboard-prone area while it is moist.

Another washboard-prone area is at the transition from paved to gravel sections as shown in this photo.

An effective tool for dealing with washboard areas is the front dozer equipped with carbide bits.

forms on the surface of a good gravel road will tend to loosen in dry weather. This allows the stone and sand-sized particles of gravel to "float" and the material can easily align itself into the washboard pattern under traffic.

The two causes just mentioned are completely out of the control of gravel maintenance operators and managers. The third primary cause — the quality of the gravel — is the cause we need to concentrate on. Good quality surface gravel is thoroughly discussed in Section II of this manual. Simply put, good gravel must have the right blend of stone, sand, and fines. The stone should be fractured and the fine-sized particles should have a binding characteristic, technically called "plasticity." This type of gravel resists washboarding. However, the maintenance operators also must do their part.

Virtually any gravel will develop some washboard areas under traffic. The key for the maintenance operator is to strive to keep the material blended. In dry conditions, the operator can only smooth the road temporarily. When moisture is present, it pays to quickly get out and rework these areas. The material should be cut to a depth of one inch or more below the depressions, mixed and relayed to the proper shape. If time allows, using the machine to apply wheel compaction to material will help reform the crust. If possible, use of a roller will improve the compaction.

With the best of maintenance, washboarding can never be completely eliminated.However, the key to reducing it is

to work hard at obtaining quality gravel with a good binding characteristic. The operator can then reshape trouble spots when moisture is present and most roads will perform quite well.

If a motorgrader causes washboarding, it is almost always the result of running at too great a speed. The ridges and depressions will be spaced further apart.

The solution to the problem is simple — reduce grading speed! Another problem can be improper tire inflation pressure or defective tires. This will cause a motorgrader to bounce or otherwise operate in an unstable manner.

Intersections

There is one important thing to understand in knowing how to shape a gravel intersection: is it a controlled or uncontrolled intersection? This means: does traffic have to stop or yield from side roads? If so, it is a controlled intersection as shown in Figure 3. The primary road on which traffic passes through should retain its crown and the intersecting roads should have crown gradually eliminated beginning approximately 100 feet before the intersection.At the point of intersection, the side roads are virtually flat to match the primary road. When the intersection is uncontrolled as shown in Figure 4,the roads should all have the crown gradually eliminated beginning approximately 100 feet from the intersection. The intersection itself becomes virtually flat, allowing vehicles to pass through without feeling a noticeable hump or dip from any direction. Be careful not to make the intersection lower so that water collects there.

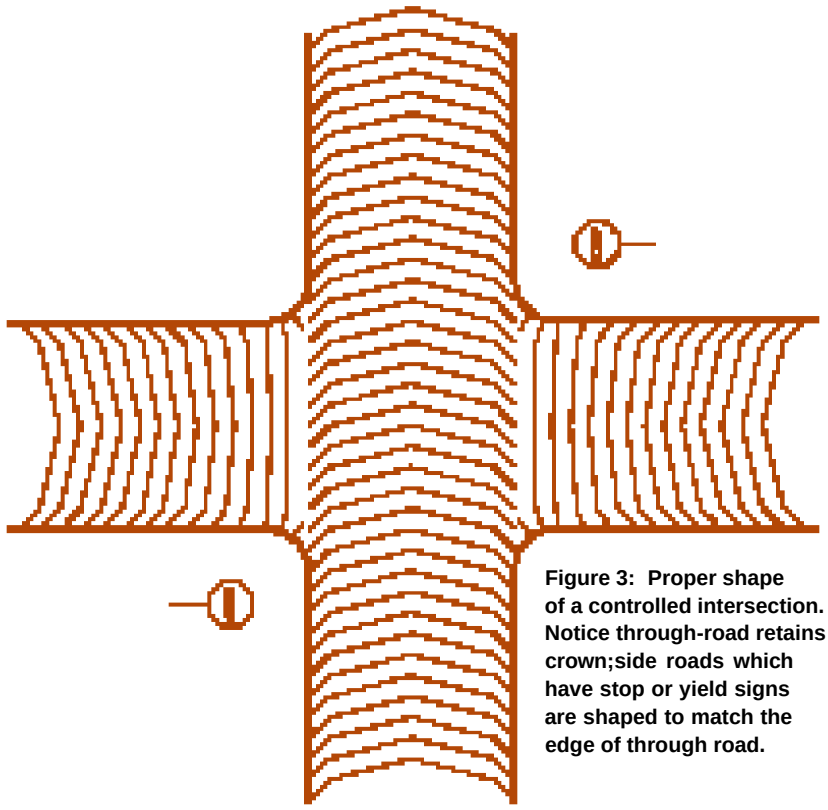


Figure 3: Proper shape of a controlled intersection. Notice through-road retains crown;side roads which have stop or yield signs are shaped to match the edge of through road.

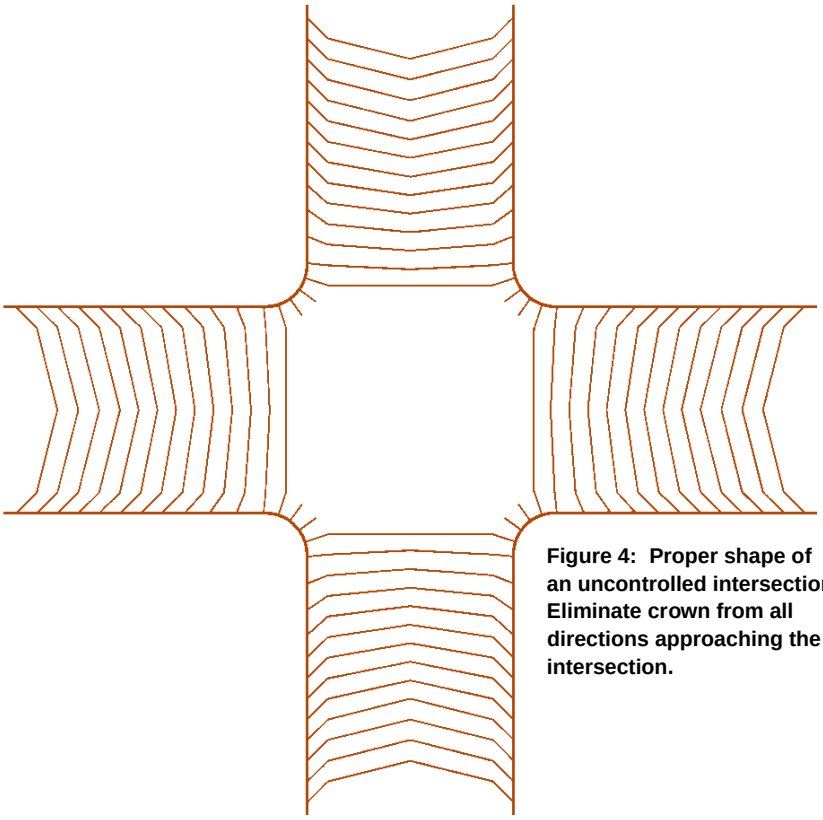


Figure 4: Proper shape of an uncontrolled intersection. Eliminate crown from all directions approaching the intersection.

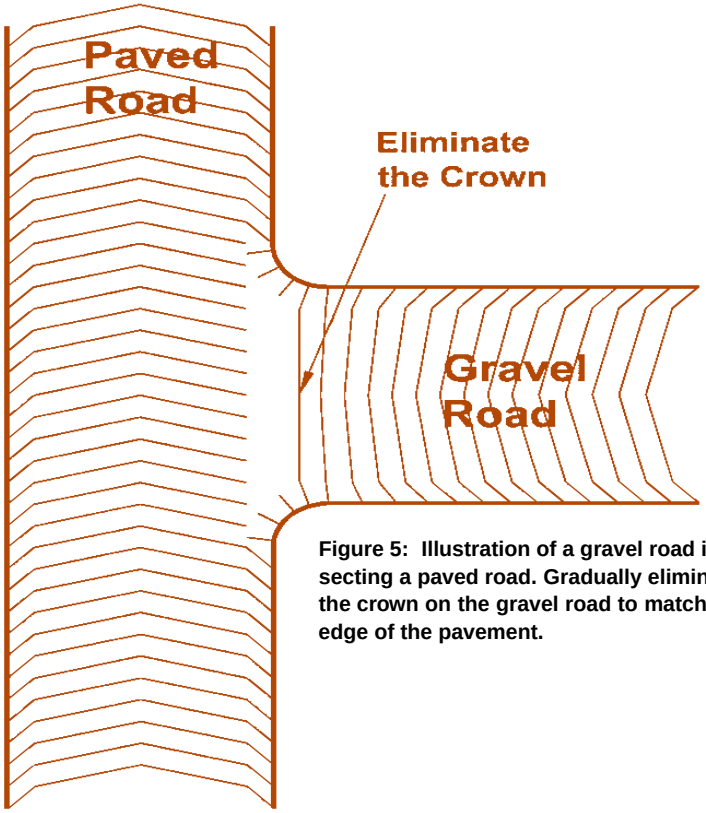


Figure 5: Illustration of a gravel road intersecting a paved road. Gradually eliminate the crown on the gravel road to match the edge of the pavement.

Intersections with Paved Roads

The rule for shaping these intersections is always the same. Begin to eliminate crown on the gravel road approximately 100 feet from the edge of the pavement. At the intersecting point, the gravel should match the paved surface. This requires continual attention since potholes can easily develop at the edge of pavement. However, be careful not to push gravel out onto the pavement since this causes a dangerous loss of skid resistance on the pavement.(35, 36) The technique of "backdragging" is useful in these operations. In order to fill a pothole at the edge of pavement, extra material may spill onto the pavement. Simply pick up the moldboard and set it down in front of the material, then back up and spread the excess back on the gravel road.

Hand work with a shovel is necessary at times to complement grader work.

Bridge Approaches

Once again, the rule for shaping a bridge approach is always the same. Approximately 100 feet from the bridge, begin to gradually take the crown out of the gravel road so that you can match the bridge deck as closely as possible. Potholes can easily form at the edge of the deck. Keep them filled, but don't push gravel onto the deck. (35, 36)

The grader must fill potholes and depressions formed near the bridge approach.

Nice job of blade work to shape road to match bridge deck.

The technique of backdragging can save time.

Superelevation at Curves

This is one of the biggest challenges in gravel road maintenance and a situation that is not understood very well by many operators. This is sometimes called "banking a curve" in the field. The outer edge of the roadway is higher than the inside edge and the road surface is shaped straight from the upper to the lower edge.

Once again, as the operator approaches a curve, adjustments should be made with the blade to take out the normal crown and begin to transition into a straight, superelevated surface. This shape should be maintained uniformly throughout the curve. A gentle transition is then made made at the other end back to a normal crowned road surface when you are once again on

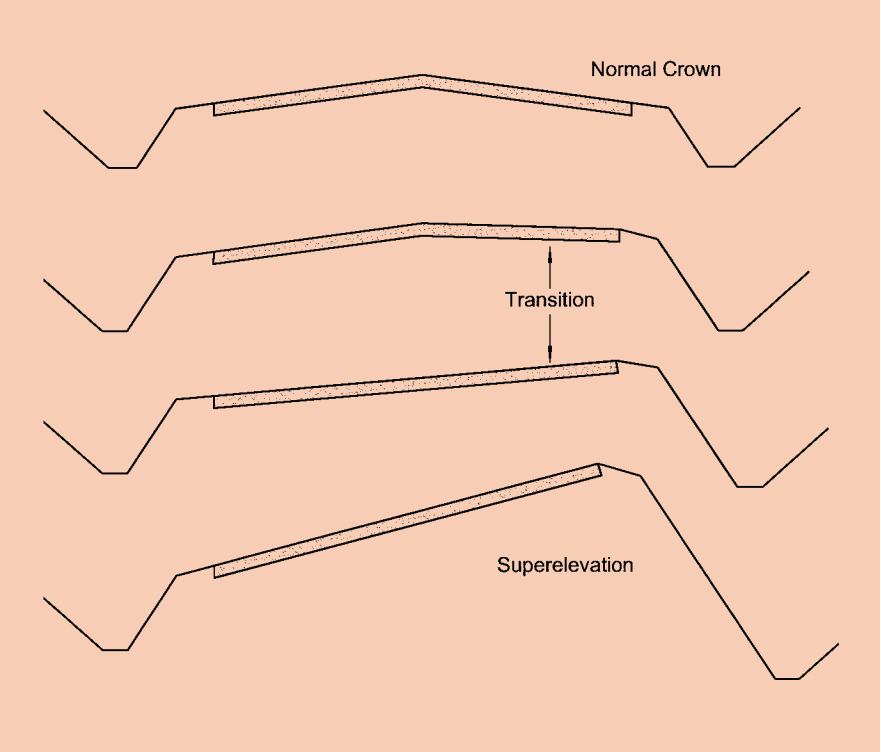


Figure 6: Illustration of the transition from a normal crown to the superelevated shape needed in a curve.

This photo shows lack of superelevation which can lead to accidents.

This superelevated road section makes driving safer.

a straight section of road. This requires constant attention during each maintenance pass over the road. Traffic will tend to displace the gravel towards the upper end of the road and the inside of the curve will become lower. Curves can very easily go out of proper shape. (1, 5, 7, 21, 24, 29, 36)

The correct amount of slope or "banking" of a curve can only be determined by engineering analysis. There is also a device available for determining the safe speed of a curve called a ball bank indicator. If you are unsure of correct shape on a curve, get professional advice if at all possible.

This road in Ecuador has excellent superelevation in the curve. It also has good shoulder drainage and ditches on both sides of the road. (Courtesy of Ron Anderson, Tensar Earth Technologies, Inc.,USA)

Grader working at a rural railroad crossing. The material that has been pushed into the flangeway should be removed.

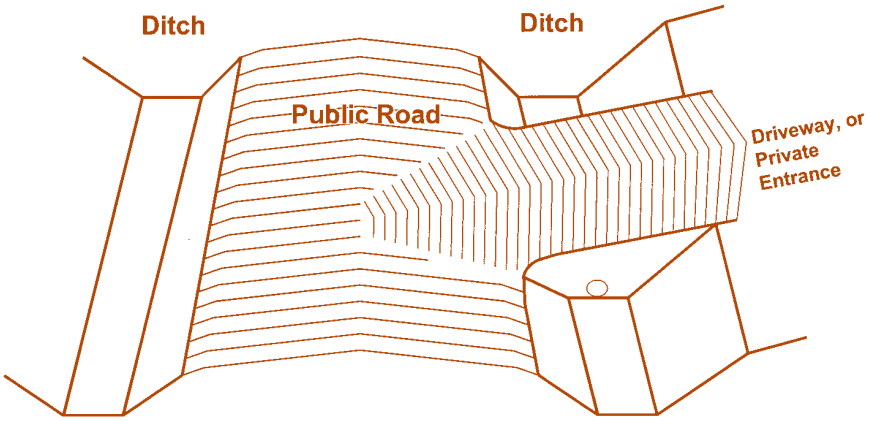


Figure 7: Improper matching of driveway and road edge

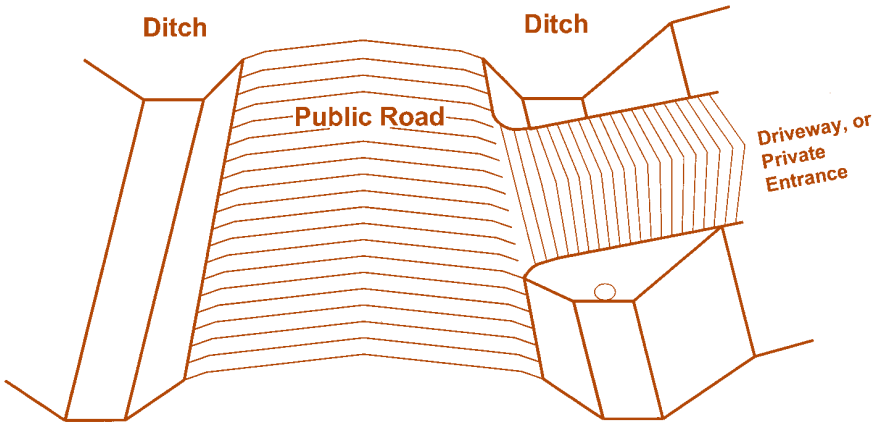


Figure 8: Proper matching of driveway and road edge

Railroad Crossings

Maintaining a road that intersects a rail crossing is very similar to bridge approaches or intersections with paved roads. Always begin to eliminate crown approximately 100 feet away and shape the road to match the crossing.A special consideration is to be extremely careful about keeping gravel out of the flangeways along the rails. This can cause a derailment — particularly when it combines with snowpack in northern regions of the country. Also, be extremely careful not to strike the rails themselves. In some cases, this could slightly displace the rails and again could cause a major disaster. If you snag or strike a rail with your equipment, report it immediately to your supervisor and the railroad. (35, 36)

Driveways

The public road should always retain its normal crowned shape while passing driveways. Too often the gravel builds up on the road at a driveway entrance as shown in Figure 7. This changes the shape of the roadway itself, which can cause loss of control of vehicles. These situations need to be reshaped. The driveway entrance should always match the edge of the public road as shown in Figure 8. (35, 36)

In heavily populated areas with gravel roads, poor installation of driveways can be a real problem. To reduce maintenance problems, implement a permitting process. It should address the proper control of grade to match road edge, adequate width, and drainage.

The solution to the problem shown in Figure 8 is demonstrated in a simple three-step operation which is shown on the next page.

Step 1. The operator restores the crown on the public road by removing excessive material extended from the driveway. Note the drop off created by this operation.

Step 2. The operator proceeds to correct the drop off at the end of the driveway by cutting the material loose and spreading it back on the driveway.

Step 3. The above two steps result in a well-shaped driveway that matches the edge of the public road.

Cattle Guards

A simple structure called a cattle guard is common in parts of the high plains and mountain west in the US. These devices are commonly found on low volume roads in national forests and on public lands where cattle or other livestock are allowed to graze on open range. The cattle guard allows traffic to pass from one parcel of land to another without opening and closing gates. The cattle guard is a series of heavy iron bars or pipes placed across the roadway, that generally appear like a heavy grate. There is a cavity below the bars or pipes that is generally twelve to eighteen inches deep. These structures confine cattle and other livestock since, by instinct, they will not cross them for fear of falling through the grate.

Cattle guards are a special maintenance challenge when installed on gravel roads. The approach to them should be treated much like blading up to a bridge deck. Begin to eliminate normal crown 50-100 feet from the guard. The road must then be shaped to match the cattle guard. However, gravel must never be spilled into the cavity below the grate. If this is done repeatedly, the hollow area below will be filled with gravel and cattle will simply walk out. Stop the grader two to three feet from the guard and backdrag loose material away from the structure. Then, handwork will often have to be done at the edge of the cattle guard to maintain a smooth crossing for traffic.

Example of good work done to reshape a roadway approaching a cattle guard and maintaining a very smooth crossing.

Soft and Weak Subgrade

Although it is extremely important to remove surface and subsurface water from the roadways, there are situations where water simply cannot be kept away. A good example is a section of road that passes through swampland or wetlands which naturally occur and cannot be drained. These areas will very often have weak subgrades, which cannot support heavy loads. Sometimes it is even hard to maintain the road for light traffic. The road will rut and pot-holes will be formed very quickly due to very poor soil support.

This gravel road with narrow right-of-way has turned to mud during wet spring conditions. It represents low-volume roads commonly found in several parts of the world.

A decision was made to stabilize the above road.A road crew is shown rolling out a fabric over the existing road surface.

This requires more than routine maintenance and reshaping if the problem is to be fixed permanently. Generally, there are only two solutions. One is to excavate and remove the weak, wet soil. Occasionally, the existing roadway is wide enough that after adding select material and shaping, the top width of the finished surface is adequate. In this case, undercutting will not be necessary. This "select material" will vary depending on what is available in the region. One thing is critical: it must be clean and drainable. It is also advisable to get engineering advice from consultants to make sure that materials are adequate before starting this rehabilitation challenge.

The second method is similar, except a product called a geotextile or geosynthetic is added. These products are often called "fabrics" and "grids" in the field. Here the procedure is virtually the same as described before, but a fabric and/or grid is placed over the subgrade soil before the select material is brought in.A woven or nonwoven fabric (geotextile) placed on the subgrade becomes a separator between the weak soil and the new material placed above it. The five photos shown on this and the next page demonstrate the proper sequence of placing geotextiles as explained in the following paragraphs. This prevents very fine, wet silt and clay type soils from pumping or migrating up into the new material. The pumping action occurs when traffic passes over the surface and the road deflects under the load.Pressure from the load will cause water in the subgrade to rise to the surface and carry fine soil particles with it. This will contaminate and weaken the new material very quickly and make it weak, undrainable, and unstable. A fabric prevents this by filtering

A truck is shown back-dumping a select, granular material onto the fabric.

The crawler/loader was used to spread the material over the fabric and is now being used to pull a grid roller to smooth the surface.

out the fine soils while allowing water to pass through it and drain out of the clean, granular material above.

A grid can also be used either in combination with or without fabrics. Grids are very strong geosynthetics which, in simplest terms, confine the material placed on them and do not allow lateral movement or "shoving" of the material.Grids have been rolled out over swamps and roads built over them with remarkably good results. The ability to carry and distribute the soil and traffic load is referred to as a snowshoe effect.Grids can also be placed within layers of select material. There are many types and variations of these products. It is wise to get good engineering advice when dealing with difficult soil stabilization problems.

Once the subgrade has been strengthened, a good coat of surface gravel can be placed and the road can be maintained as any other gravel road. The initial cost of stabilizing a weak road section can be expensive, but it will result in low maintenance costs thereafter, and will often make these projects cost effective.

The road now performs very well after the stabilization was completed.

Workers are shown using a combination of grid and fabric being placed over an extremely weak subgrade. This is in a region of Ecuador that receives average annual rainfall of nearly 200 inches. Approximately twelve inches of select, clean sand-type material will be placed over the grid to serve as a base. The fabric will be wrapped over the side of the sand layer to keep the edge from eroding away. Then another layer of grid will be placed and covered with approximately ten inches of crushed surface gravel which will become the driving surface.

A section of the same road during construction.Select material is being placed over the grid and fabric. Notice the evidence of extremely weak subgrade shown by the rut at the bottom of the photo. This rut was left by a light vehicle which traveled beyond the stabilized section. Yet this road will have to carry oil field traffic when finished.

Here is the finished road which has performed remarkably well while being used to carry extremely heavy loads during construction and equipment for oil field development. It is a good example of how an extremely weak subgrade can be stabilized and a gravel road built over it with minimum disturbance to the surrounding terrain and the environment.

(Photos on this page are courtesy of Ron Anderson, Tensar Earth Techologies, Inc.,USA)