pennsylvania
DEPARTMENT OF TRANSPORTATION
LOCAL TECHNICAL ASSISTANCE PROGRAM

UNPAVED & GRAVEL ROADS

Roads Scholar I Course

Revised April 16, 2018

Pennsylvania Local Technical Assistance Program (LTAP)

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The Pennsylvania Local Technical Assistance Program (LTAP) shares transportation knowledge, improves road maintenance and safety skills, and puts research and new technology into practice at the local level through:

Training: Workshops are scheduled throughout the state and can be requested as a road show.

Technical Assistance: LTAP technical experts are available by phone, by email, and in person to help townships troubleshoot specific issues on their roadways.

Newsletter: LTAP distributes a quarterly newsletter, *Moving Forward*, which features the latest news and new practices and technologies.

Technical Information Sheets: Tech sheets provide useful, technical information on such topics as effective stop sign placement, how to use the MUTCD, paving roads, and other safety and maintenance issues related to local roads.

Website: LTAP's website, www.ltap.state.pa.us, is a valuable tool that provides up-to-date information on workshops, news items, LTAP Advisory Committee members, tech sheets, newsletters, and other resources.

All LTAP services are offered at NO Cost to Municipalities!!!

Roads Scholar Programs I and II

- Professional certification program
- Must complete 10 (I) and 8 (II) approved workshops within a three-year period
- Pass (70%) an in-class quiz taken at the end of each workshop which consists of 12 questions
- Successful completion of the American Red Cross CPR training also earns you one workshop credit.

You MUST include your name/contact information on the answer sheet for credit.

COURSE OBJECTIVES

The participant will be able to:

- Provide an understanding of the components of an unpaved and gravel road.
- Provide an understanding of the principals of maintaining an unpaved and gravel road.
- Understand the importance of using good materials and their proper application.
- Understand the importance of drainage.
- Review the origins of road dust and introduce control materials and measures.
- Understand how to evaluate when to pave an unpaved road.

AGENDA

- Pre-Quiz
- The Road System
- Components of a road
- Unpaved and Gravel Road Maintenance
- Areas of Concern
- Materials Selection
- The Importance of Drainage
- Managing Dust
- When to Pave a Gravel Road
- Project Examples
- Resources
- Post Quiz
- Additional Resources
    - Grader Operation and Safety
    - Alternative Technology and Innovations

HISTORY

Unpaved and gravel roads will provide excellent service for low traffic volumes and light vehicles. Heavy traffic volumes and loads can cause failure of unpaved and gravel roads, even when properly maintained, especially in wet weather.

Historically, road maintenance has been a labor-intensive process, including blading or smoothing.

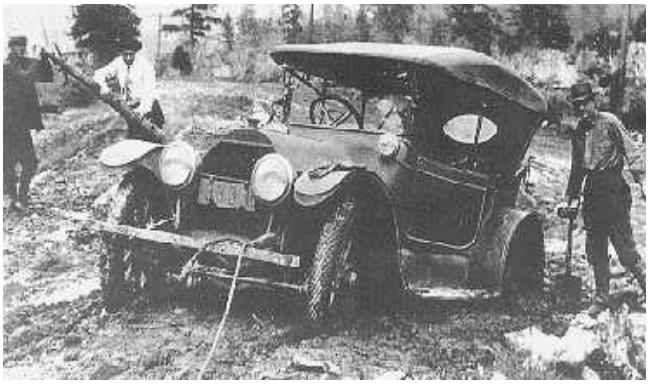
Grading and shaping, adding new material, and creating transitions was a challenging task.

THE ROAD SYSTEM

United States

According to the U.S. Department of Transportation, Federal Highway Administration (FHWA), there were **1.4 million miles of unpaved roads** in the United States in 2012. Unpaved roads account for about 35 percent of the more than 4 million miles of roads that make up our nation's transportation systems.

About 1.3 million miles of these unpaved roads are in rural areas, where local jurisdictions have ownership of about 1.2 million miles.



Pennsylvania

Pennsylvania has more than 25,000 miles of unpaved roads (1.7% of US), about 17,500 of which are owned by local municipalities and provide access for the state's agriculture, mining, forestry, and tourism industries as well as more than 3.6 million residents.

Unpaved Gravel Roads are a Non-Point Pollution Source

According to the Pennsylvania Department of Environmental Protection (DEP), non-point source pollution is responsible for 88 percent of all impaired stream miles in Pennsylvania. Dirt and gravel roads have historically been significant contributors of non-point source pollution, both in terms of sediment and dust.

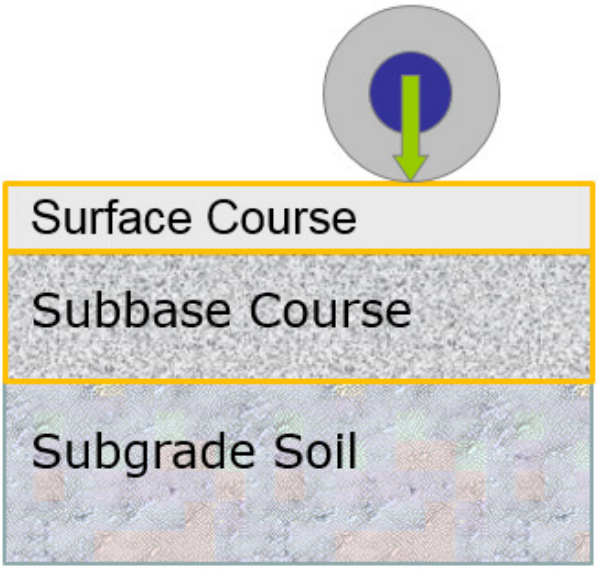
Most have evolved from primitive trails. Paths of least resistance first created by wild animals were later used by settlers. As needs and traffic increased, these traveled ways became roads which were gradually improved with gravel or crushed rock.

Little design or engineering went into these improvements. Using available materials and "keeping them out of the mud" were the extent of efforts to maintain a road. Engineered roadways are typically designed and constructed with the consideration to providing the correct shape of the finished cross-section of both the surface and shoulder. Paved roadways typically maintain this cross-section for an extended period of time with minimal maintenance.

Unpaved and gravel roads are more susceptible to the formation of ruts and potholes, especially during periods of wet weather. They are also more susceptible to loss of material and crown during periods of dry weather.

THE ROAD SYSTEM

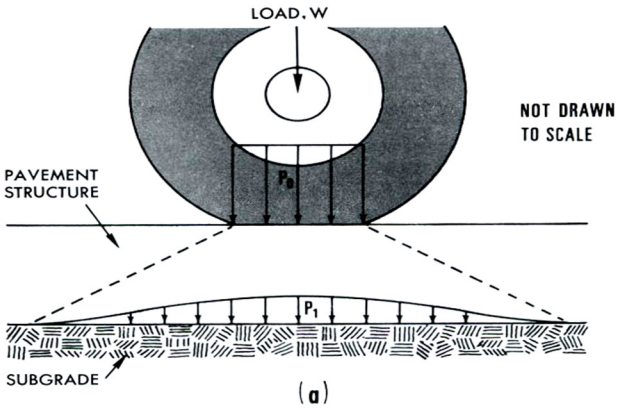
Unpaved and gravel roadway structures are constructed by placing aggregate surface course (DSA) on an aggregate subbase course (2A, 2RC, ballast, etc.). Both the surface and subbase courses provide structure by distributing load. The subbase course also provides improved drainage.



The load is ultimately transferred into the underlying subgrade soils.

Rutting of the surface and subbase are a result of overloading the subgrade soils.

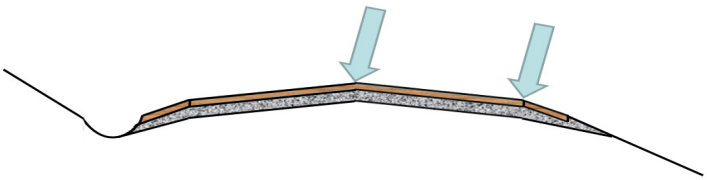
Poor roads often result from poor subgrades. When the subgrade consists of soft clays, silts and organic soils (i.e. water sensitive soils) that when wet, are unable to adequately support traffic loads.



If unimproved the subgrade will mix with the road base aggregate – degrading the road structure whenever the subgrade soils get wet.

To maintain unpaved and gravel roads properly, we must understand the three basic elements of the road:

1) A crowned driving surface (and subgrade) at a specified cross-slope.
2) A shoulder that slopes away from the driving surface.
3) A ditch.

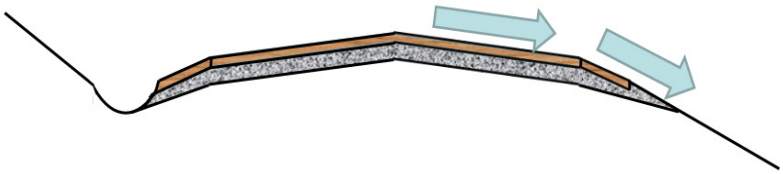


Crowned Driving Surface

Crown is the part of the roadway shape in which the center of the road is higher than the outer edge of the road surface; it is measured in cross-slope. Sometimes referred to as a "Straight A Shape" or "Flat A Shape".

Cross-Slope

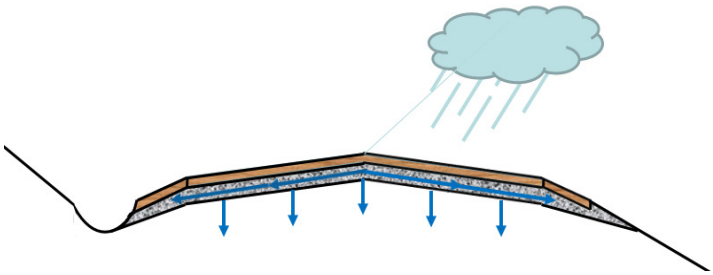
Cross-slope is a measurement of the percentage crown in the road. It is typically displayed in percent (%) or inches per foot ("/'). The shoulder is typically graded with a greater cross-slope than the roadway.



Crowned Subgrade

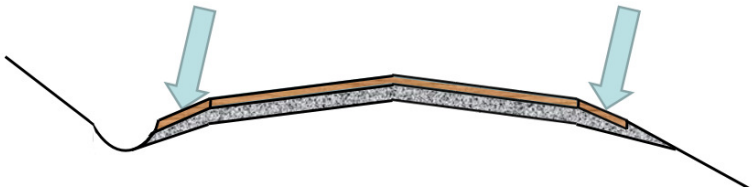
The subgrade is crowned to provide positive drainage and reduce water infiltration into the subgrade soils

Lack of a crowned subgrade will trap water, resulting in increased water infiltration, roadway instability, loss of crown, and higher maintenance costs.



Shoulders Important

Shoulders direct water away from the driving surface, providing additional support/stability for the edges of the roadway. In addition, they provide an additional safety feature by providing recovery for vehicles which stray from the roadway.



Ditches

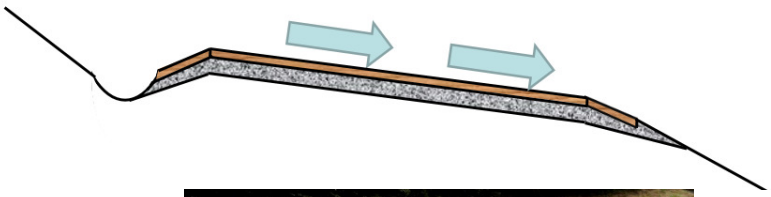
Ditches further direct water away from the entire roadway cross-section, insuring the long term stability of the roadway. The ditch is made up of the foreslope (adjacent to the road), bottom, and backlope (adjacent to the bank).

No Crown or Cross Slope

Standing water at any place within the cross-section is the major contributor to unpaved and gravel road distress and eventual failure. Having a good drainage system is important, but proper inspection and maintenance of that system is required to control water and its damaging influence.

Semi-annual inspection of the total system should be conducted. In addition, inspections after a major storm event should be done to make sure everything is still working and no major problems are developing.

Superelevation

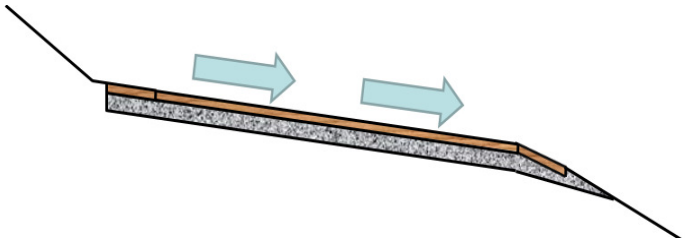


Superelevation is the grading of a consistent cross-slope over both lanes up to and through a horizontal curve to provide improved safety and comfort.

Superelevated roadway with consistent cross-slope.

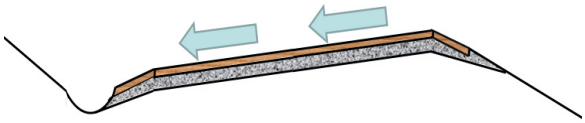
Outsloping

The road surface is shaped to drain water from the entire width of the road from the cut-bank or up-slope side of the road toward the fill-bank or down-slope side. The road is shaped to avoid collection or concentration of water in a ditch.



Insloping

The road surface is shaped to drain water from the entire width of the road toward the cut-bank or up-slope side of the road.



MAINTENANCE – ROADWAY CONDITION

Operators are responsible to keep the roadway properly shaped, including the shoulder, and the ditch.

Material is displaced from the road surface onto the shoulder area and ditch by:

- Erosion of material during heavy rains
- Traffic
- Winter plowing operations
- Heavy Vehicles

and requires maintenance.

More frequent blading or smoothing results in less frequent grading and reshaping and loss of material.

How Frequent does your municipality conduct blading and grading? Depends on:

- Road Type
- Drainage
- Weather
- Traffic Volume
- Special Events

As Needed

Frequency of any operations is really on an "as needed" basis and depends on a number of variables, road type and condition, drainage conditions, and the weather. How severe was the last storm? What is the traffic volume? Do we have a lot of trucks?

Smoothing/Blading and Spot Graveling

Gravel roads are generally maintained by routine blading and adding gravel as needed either by "spot graveling" or re-graveling entire sections. However, almost any gravel road will gradually begin to show distress over time 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 fore slope of the grade.

At certain intervals, virtually every gravel road requires some major rehabilitation. This involves reshaping not only the road surface, but the shoulder area and possibly the fore slope and ditch. This work may be accomplished with motor graders only depending on the extent of work needed to reestablish a good cross section on the roadway. Compaction equipment if available is always helpful. If material must be removed, loaders or excavators and trucks will be needed.

Reshaping Surface & Shoulders

Modern roadway maintenance is less labor intensive, typically, a motor grader (or simply a grader) is used for unpaved and gravel road maintenance. Maintainers, tractors, road rakes, and other pieces of heavy equipment are also used across the country.
Problems with surface and shoulder shape can usually be corrected with the motor grader alone. Spring is the best time for this work as there is minimal vegetative growth and moisture is often present. The reshaping of the driving surface and the road shoulder can be done by cutting material with the motor grader and relaying it to the proper shape and crown.

Major Reshaping

Severe rutting, loss of crown, gravel loss and deep secondary ditches or a combination of any or all of these calls for major reshaping. Often this type of damage occurs after a gravel road has been subjected to unusually heavy hauls, especially if this occurs during wet weather. Water retention throughout the roadway structure will compound the problem. 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. This requires a much greater effort than routine maintenance. Motor graders, disks, pulverizer-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, formal planning or design done. However, it is very important to rebuild a uniform cross section and pay attention to restoring good drainage. Only after this is done should good surface gravel be replaced.

Compaction

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. Pneumatic (rubber tired) rollers are most often used for compaction of gravel. Sometimes these rollers are mounted on the motor grader.

Steps for Compaction

- Scarify existing surface
- Spread new material
- Blend old and new material and establish cross slope
- Compact

Smooth, steel drum rollers are sometimes used, but good surface gravel needs to have a cohesive or binding characteristic, and this type of material can easily stick to a steel roller making them hard to use, especially when moisture in the gravel is at or above optimum.

Six inches of DSA was added to this road. The moisture content was high.

MAINTENANCE – GRADER OPERATION

Smoothing

Road surfaces are smoothed by dragging without breaking the hard surface crust. A dragging, rolling action created by the curve of the graders moldboard helps compact the road as it is blended. Smoothing is done when aggregates and fines are moist.

Smoothing Procedure

1) Determine the road length for smoothing.
2) Place temporary work zone traffic control.
3) Tilt the moldboard <u>forward</u> to create a dragging action.
4) Angle the moldboard at 30° to 45° to spread the loose material.
5) Tilt the front wheels 10° to 15° from vertical in the direction the aggregate is rolling across the blade.
6) Repair minor defects by hand.
7) Consider, periodically blading the surface against traffic to eliminate aggregate drift at bridges, culverts, intersections, and railroad crossings.

Reshaping

Unpaved and gravel road surfaces are reshaped to remove surface irregularities, restore roadway cross-slope and drainage, and remix the aggregate to improve surface stability. Reshaping should be done when the aggregate and fines are moist.

Reshaping Procedure

1) Determine the road length for reshaping.
2) Check if additional material needs to be added to the roadway.
3) Place temporary work zone traffic control.
4) Tilt the moldboard backward to cutting position.
5) Angle the moldboard at 30° to 45° to spread the loose material.
6) Tilt the front wheels 10° to 15° from vertical in the direction the aggregate is rolling across the blade.
7) Put enough down pressure on blade to cut shoulders and corrugated ridges.
8) Scarify the surface if required.
9) Provide additional passes, as needed.
10) Windrow remixed material to the center of the roadway.
11) Add additional material as needed.
12) Distribute aggregate evenly, blading the material to the proper crown.
13) Grade shoulder with cross-slope equal to or greater than the roadway.
14) Remove excess material, as required (bridges, intersections, etc.).
15) Compact surface aggregate with a roller.

Grader Operation

Proper operation of the grader is critical to maintaining a safe and passable unpaved and gravel roadway network.

The principals of establishing the roadway shape, or roadway geometry, are the same no matter what type of machine is used.

Operating speed in blading operations is a critical component of maintaining a good road surface. Operating speed must be SLOW enough so the machine remains stable.

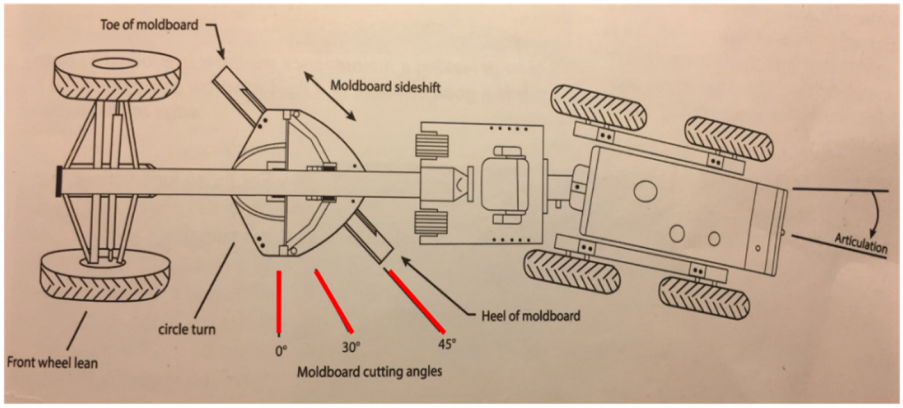
Top speed should be: 3 to 5 mph

The angle of the moldboard is also critical for good maintenance.

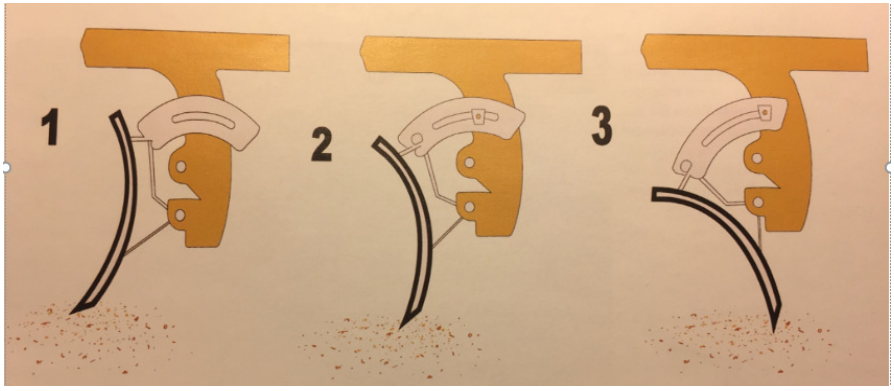
Some graders have either a fixed or adjustable blade.

The angle should be kept between 30 and 45 degrees.

Moldboard Angle



Along with the correct angle it is important to understand the pitch or "tilt" of the moldboard.



1) Blade in upright (vertical position. Provides for aggressive cutting.
2) Blade is slightly angled forward. Allows for spreading of material.
3) Blade is angled sharply forward. Allows for light blading or dragging.

It may be a challenge to recover loose aggregate from the shoulder of the roadway without spilling material over the leading edge (toe) of the moldboard.

Positioning the moldboard too far front will result in material loss at the heel. It will also reduce the mixing action that is desirable when recovering material from road edges.

If the moldboard is positioned too far back, the material will tend to build up in front of the moldboard and will not move along the moldboard to the heel (or discharge) side of the moldboard.

A properly “pitched” or “tilted” moldboard will allow the material to be recovered from across the roadway and mixed in front of the blade, while leveling and smoothing the material in the process.

It may sometimes be difficult to keep the grader stable, especially when carrying a light load.

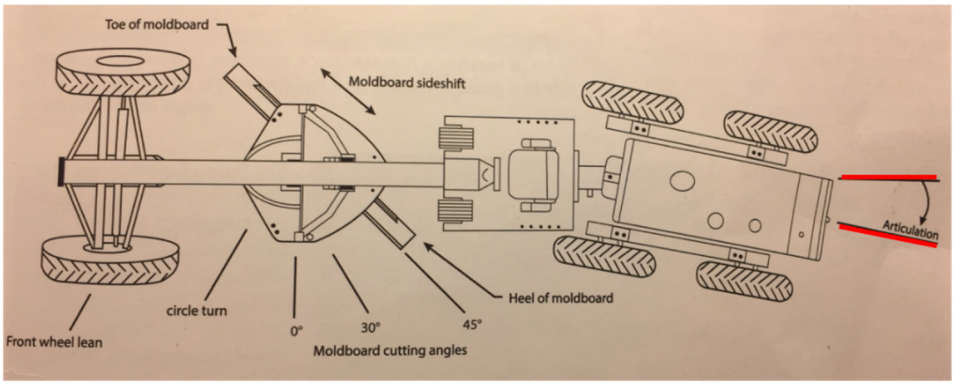
Stability Problems Include:

- Loping – Bounce in the machine, often speed related. This results in excessive cutting with high and low spots. Slow down.
- Duck Walking – Machine rocks from side to side, often a result of blade angle. This results in an uneven, rolling road surface. Stop and reposition blade angle.

Corrective Actions

- Slow down.
- Reposition the blade.
- Experiment with tire pressure.
- Lean the front wheels in direction the material is being moved.
- Fill the tires with a liquid ballast, which also increases traction and weight.
- Discuss severe and continuing problems with the equipment and/or tire manufacturer

Modern motor graders are equipped with frame articulation.
It can be an advantage to slightly articulate a machine to stabilize it even in common maintenance operations. More aggressive articulation allows a greater reach with the moldboard.



Windrows

Leaving windrows on or adjacent to the roadway is not considered to be good practice. In addition to creating a safety concern to the traveling public, windrows will restrict drainage and result in excessive erosion.

Crown and Cross-Slope

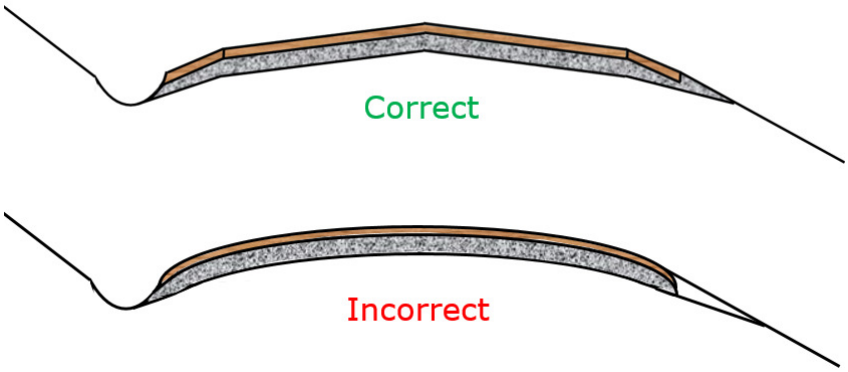
The typical cross-slope of a paved roadway is 2 percent or ¼ inch per foot.

In contrast, an unpaved or gravel roadway requires additional cross-slope to facilitate water movement across the rougher surface. The typical cross-slope of an unpaved or gravel roadway is 4 to 6 percent or ½ to ¾ inch per foot.

Is there such a thing as too much crown?

Too much crown can create an unsafe situation. Vehicles may have difficulty staying in their lanes and drivers may feel a loss of control as their vehicle wants to slide toward the shoulder. During, rain, snow, and ice events, this can lead to roadway departures. Roads with excessive crown encourage drivers to drive in the middle of the roadway; however, this may also result in vehicle damage to lower clearance vehicles.

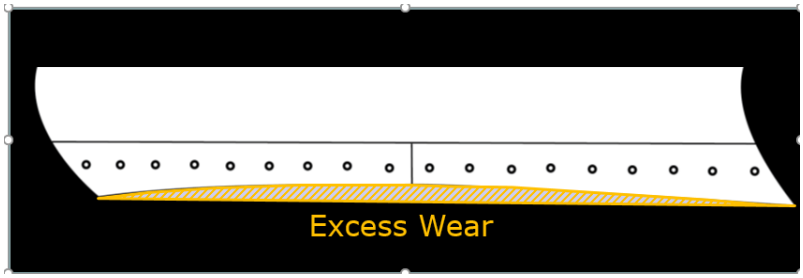
Parabolic Crown



The ideal surface shape is a straight line from the shoulder up to the center of the road. This gives the road the same shape as the roof of a house, often referred to as a "*Straight A Shape*". However, this shape can sometimes become rounded. The engineering term for this rounding of the surface is *parabolic crown*, which is virtually always a problem. Why? 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.

Excessive Wear

The greatest cause of a parabolic crown is excess wear at the center of the cutting edge

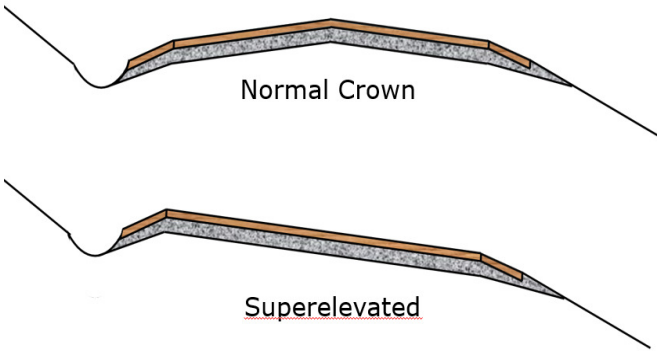


Roadway Transitions

Grader operators need to be aware of roadway transitions that affect grading activities, including:

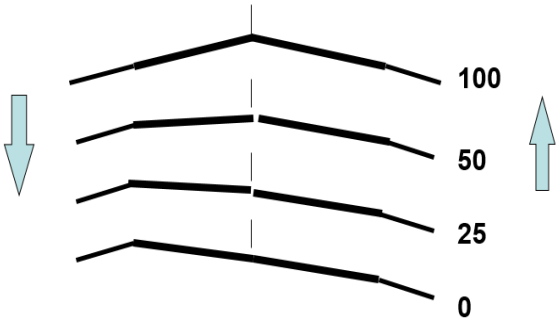
- Superelevation (curves)
- Intersection Transitions
- Bridge Transitions
- Railroad Crossings
- Driveways

Superelavation

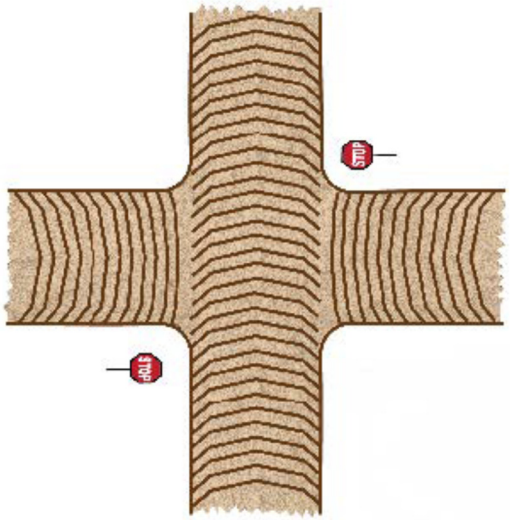


This is one of the biggest challenges in gravel road maintenance. It is sometimes called *banking a curve* in the field. The outer edge of the roadway is higher than the inside edge, and the road surface is shaped straight from the upper to the lower edge. As the operator approaches a curve, adjustments should be made with the moldboard to take out the normal crown and begin to transition into a straight A superelevated shape should be maintained uniformly throughout the curve. A gradual transition is then made at the other end back to a normal crowned road surface when you are once again on 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.

Transition normal crown to superelevated section and vice versa within 100 feet of curve.



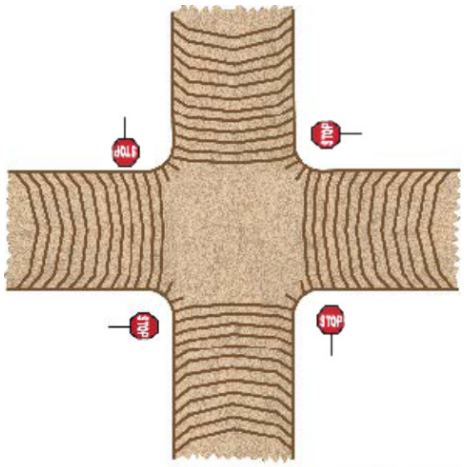
Unpaved Road Intersection Transition Two-Way



The primary road should retain its crown; the intersecting road should have its crown gradually eliminated.

There is one important thing to understand in knowing how to shape a gravel surfaced intersection: *is it a controlled or uncontrolled intersection?* This means: *does traffic have to stop at an intersecting road?* 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.

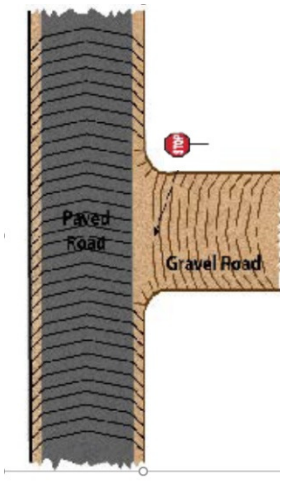
Unpaved Road Intersection Transition Four-Way



As neither roadway is the primary, the crown is gradually eliminated from both roads.

At the point of intersection, the side roads are virtually flat to match the primary road. When the intersection is controlled, in both directions 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 bump or dip from any direction. Be careful not to make the intersection lower so that water collects there.

Paved Road Intersection Transition



Gradually eliminate the crown from the gravel road prior to meeting the paved roadway.

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. When potholes become severe, the gravel needs to be cut out and relayed to correct the problem. However, be careful not to push gravel out onto the pavement since this causes a dangerous loss of skid resistance on the pavement. The technique of "backdragging" is useful in these operations. In order to cut out and 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.

Bridge Transitions

Road approaches to bridge may need more frequent attention.

At bridges, we need to transition into the existing bridge deck profile if flat and gradually eliminate crown, if crowned, transition road crown to bridge crown.

Note: Road slopes back away from bridge, creating low points for road and ditch drainage to outlet through a vegetative filter strip and not directly into the stream. Bridge approaches are problem areas which demand special attention and probably more maintenance. When traffic moves from a rigid bridge deck to a more flexible dirt and gravel road surface, the impact forces can cause problems. So be particularly attentive to this area.

Bridges need to have good drainage. Usually drainage openings are provided in the deck, called scuppers, which drain directly to the stream below. Keeping the deck clean is imperative not only for good drainage and longer bridge life but also for prevention of sediment into the stream.

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. Cut them out and fill them, but don't push gravel onto the deck.

Bridge approaches are problem areas which demand special attention and probably more maintenance. When traffic moves from a rigid bridge deck to a more flexible dirt and gravel road surface, the impact forces can cause problems. So be particularly attentive to this area.

Consider paving a 25 foot bridge approach.

Keep bridge decks clean and free draining.

Gravel buildup is especially detrimental to this timber deck. Material traps moisture, causing deterioration of the wooden deck.

Railroad Crossings

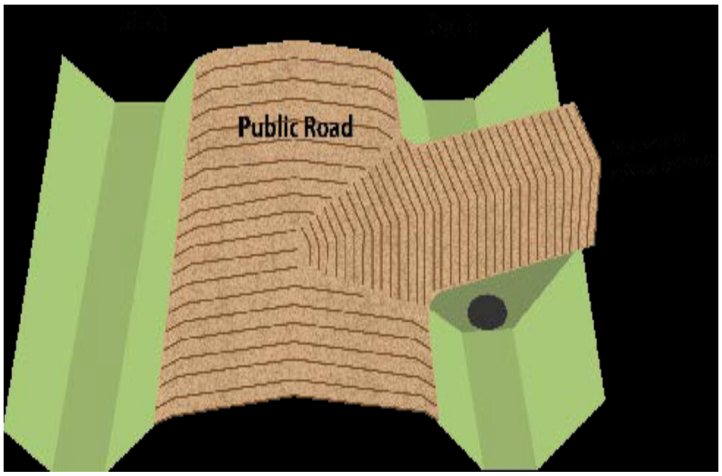
Maintaining a road that intersects a rail crossing is very similar to bridge approaches or intersections with paved roads. Always begin to eliminate the crown approximately 100 feet away and shape the road to match the crossing. Be extremely careful about keeping gravel out of the flangeways along the rails. This can cause a derailment, particularly when it combines with snowpack and frozen material. 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 the railroad.

REMOVE excess material from flangeway.

DO NOT grade over rails.

Careless maintenance has filled the rail flangeways on this very low volume crossing. This crossing is hazardous and has a high potential to cause a derailment.

Public Road-Driveway



A public road should maintain a normal crown as it passes driveways. Too often, poor maintenance of either the driveway or the road, result in the buildup of material at the driveway.

The driveway entrance should always match the edge of the public road and shed water into the ditch line not the road. A driveway permitting process can help address driveway concerns.

Public Road-Driveway

- Grade to driveway
- Grade low point at ditch line
- Do not leave windrow across driveway

Road shoulders provide several important functions:

- Support the edges of the roadway.
- Carry water away from the road.
- Constructed to avoid an edge drop-off.
- Provide a recovery area for errant drivers.

In order for the shoulder to perform all of these functions, its shape is critical. First, the shoulder should meet the edge of the roadway at the same elevation. In other words, the shoulder should begin no higher or no lower than the edge of the roadway. By maintaining this shape, the low shoulder (or drop-off), which is a safety hazard, is eliminated and improves roadway edge support. But the other extreme, which is a high shoulder, should also be avoided, as it prevents proper drainage.

AREAS OF CONCERN

This section covers areas of concern, visual indicators and potential solutions. All solutions are not covered in this class. Attendees should attend LTAP's Drainage Class for additional solutions or United States Department of Agriculture – Forest Service "Environmentally Sensitive Road Maintenance Practices for Dirt and Gravel Roads"

Subsurface Water

Causes:

- Road intercepts subsurface flow.
- Road crosses wetland.
- Water table naturally high.
- Soils poorly drained.

Visual Indicators of Problems:

- Presence of or change in wetland vegetation.
- Frequent ruts and potholes in road surface.
- Springs, seeps, or obvious wet areas in road.
- Water pooled on road edge.
- Unstable cutslope or fillslope.
- Accelerated erosion of ditch

Potential Solutions:

- Underdrains
- French drains
- French mattresses
- Permeable fills

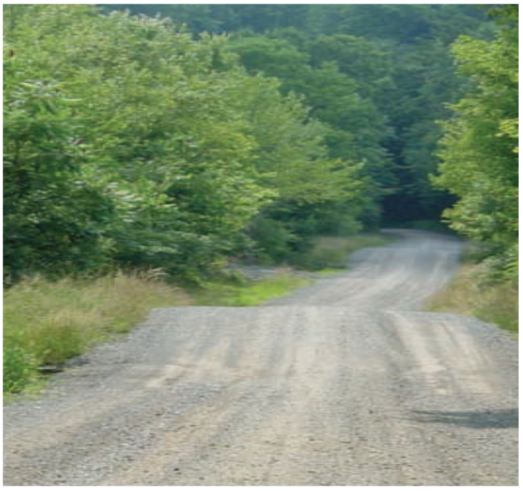
Surface Drainage

Causes:

- Loss of road shape.
- Inadequate drainage features.
- Inconsistent drainage design with topography and or use.
- Changes or increase in traffic use.
- Infrequent maintenance.

Visual Indicators of Problems:

- Rutting and potholes in road surface
- Corrugation
- Flowing or ponding water on road



Potential Solutions:

- Crown, outslope, inslope road shape
- Grade breaks
- Broad-based-dips
- Conveyor belt diversions

Roadside Ditches

Causes:

- Excessive water volume for ditch capacity.
- Insufficient or ineffective ditch relief outlets.
- Run-off from another source (hillslope, driveway, outside the right-of-way).
- Entrenched road template.
- High Shoulders

Visual Indicators of Problems:

- Flowing or ponding water in the ditch.
- Erosion, scour, or downcutting of ditch.
- Ditches draining directly to streams or wetlands.

Potential Solutions:

- Outsloping.
- Raising of the road profile.
- Removal of berms.
- Low maintenance ditches.
- Disconnecting ditches from streams.

Ditch Outlets

Causes:

- Too much water volume for ditch capacity.
- Cross pipes too deep.
- Poor road shape.
- Entrenched roads.
- Lack of pipe inlet and outlet protection.
- Road and stream are hydrologically connected.

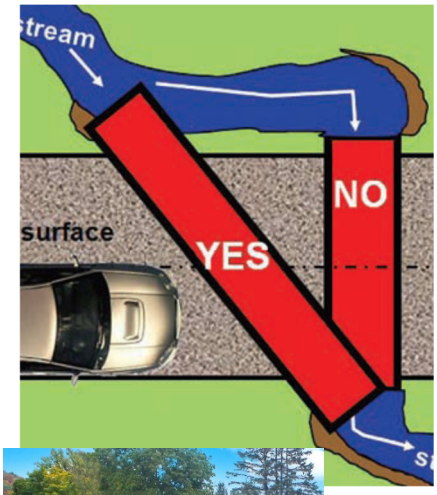
Visual Indicators of Problems:

- Erosion at ditch outlet.
- Sediment delivered to stream (hydrologic connectivity).
- Long trenches cut for outlet.
- Disconnected turnouts.
- Ponding of water in ditch.

Potential Solutions:

- Outsloping.
- Raising the road profile.
- Shallow cross pipes.
- Through-the-bank pipes.
- Headwalls and endwalls.

Stream Crossings



Causes:

- Insufficient crossing capacity for flows and associated bedload.
- Poor crossing alignment.

Visual Indicators of Problems:

- Frequent flooding.
- Scour.
- Culvert plugging with debris.
- Gravel bar deposition at culvert inlet/outlet.
- Downcutting at culvert inlet/outlet.

Potential Solutions:

- High-water bypass.
- Improved fords and low-water crossings.
- Improved stream crossings/bank-full width.
- Improved stream crossings.
- Improved alignment.

High Shoulders

What causes high shoulders?

- Improper Maintenance
  - Loosing material off the toe when grading.
  - Cutting too deep.
- "Whip off" of surface material.
- Rutting from heavy vehicles.
- Material Shoving from heavy vehicles.
- Buildup of antiskid materials.

NOTE: High Shoulders are also referred to as secondary ditches.

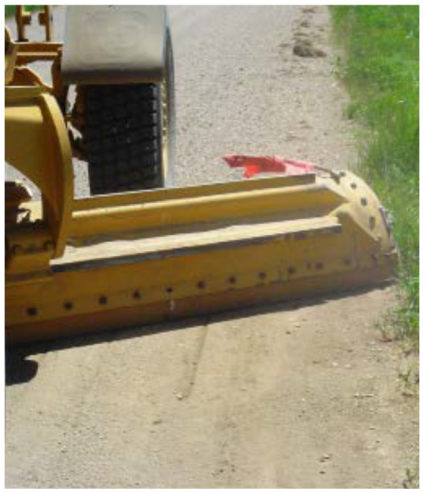
A condition known as *high shoulders* can occur along gravel roads almost anywhere people travel. Many slang terms such as "berms" or "curbs" are used in the field to refer to this condition. The engineering term for this condition is *secondary ditch* and it is a good description of the situation. When a gravel road develops a high shoulder, it restricts the surface water from draining into the designed ditch. This causes several problems.

Moldboard Gouging

In relatively level terrain, the water collects at the shoulder line and seeps into the subgrade, 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 the subgrade. This also creates a serious safety hazard. There are many reasons to work hard to eliminate the high shoulder or secondary ditch.

Pulling the Shoulders

Material from high shoulders may be appropriate to be recovered and returned to the roadway surface (pulling the shoulders).



If a motor grader is the only piece of equipment used on the job, generally more than one pass will be required to recover material from high shoulders. This process is often referred to as *pulling the shoulder.* Place appropriate temporary traffic control signs to warn road users – 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.

The recovered 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, load it, and remove it. Although this can be time consuming and expensive, it is better to remove it than to place it on the surface and contaminate the existing gravel. If a road is scheduled to be re-graveled, it is an excellent time to do shoulder work to get the roadway back into good shape.

Remove Vegetation on Shoulders

Any of the procedures discussed for dealing with high shoulders are much easier to accomplish if appropriate 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. A survey of operators in the State of Iowa indicated 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 others.

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.

There are four primary causes of corrugations:

1) **Driving habits** are clearly evident when you observe corrugation at intersections, going up or down steep hills, going 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 corrugations. In some situations, corrugations can occur on the entire road section especially when traffic speed is high.

2) **Lack of moisture** will encourage corrugation formation and prolonged dry weather can aggravate the problem. This is because the crust that 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 loosen or "float" and the material can easily align itself into the corrugation pattern under traffic.

The two causes just mentioned are completely out of the control of equipment operators and managers. The third primary cause is the cause that needs special attention.

3) **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 corrugations and will reduce the problem significantly. Lack of crown is the fourth cause. If water cannot drain off of the travelled way and corrugation begins to form, the water will quickly accumulate in the depressions and soften that area of the surface. Traffic will then make the depressions deeper as tires strike the depressions and force aggregate out and up into greater ridges.

4) **Lack of crown on the road surface**. Virtually any gravel will develop some corrugations 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 1 inch or more below the depressions, then mixed and relayed to the proper shape. If time allows, using the machine to apply wheel compaction to the loosened material will help reform the crust. <u>If possible, use a roller to improve the compaction.</u> With the best of maintenance, corrugation can never be completely eliminated. However, the key to reducing it is to work hard at obtaining quality gravel with a good binding characteristic. Another option is to test the existing surface gravel and add material on the roadway to modify it to a suitable gradation and plasticity. It must be thoroughly mixed with the motor grader. Thereafter, trouble spots can be reshaped when moisture is present and most roads will perform quite well with limited blade maintenance.

Soft & Weak Subgrade

Soils tend to become soft and weak when they are poorly drained and subjected to high groundwater, capillary action, surface or subsurface flow.

Areas with soft and weak subsoils require additional maintenance and reshaping. Generally, there are only a few solutions:

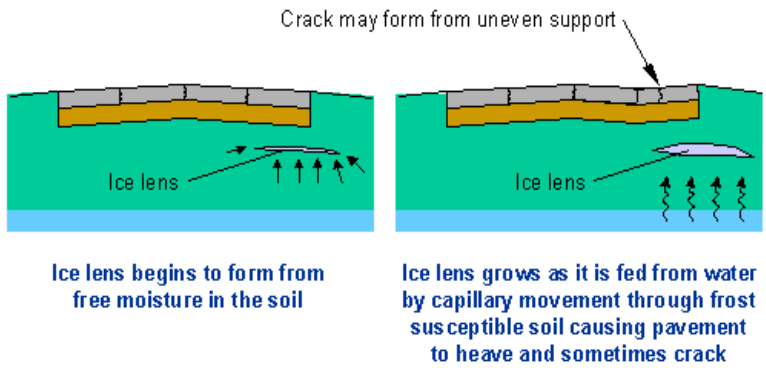
1) Excavate and remove the weak, wet soil, replacing them with good material.
2) Utilizing geosynthetics (geotextile, geogrid) to provide separation and/or stabilization.
3) Full Depth Reclamation (FDR)

Frost Heave

Silts and clays exhibit a high potential for “capillary action”, which draws water upward from soils below. These soils combined with water and freezing weather, cause heaving and driving objects upward in the soil.

Frost heaves no longer need to be a problem. This Figure shows the formation of ice lenses as water is pulled up by capillary action from the water table

REMEMBER: Silts and clays exhibit a high potential for "capillary action", which draws water upward from soils below. These soils combined with water and freezing weather, causes heaving, driving objects upward in the soil.



The height of rise of water in soil through capillary action can be significant as this table shows, depending on the soil type – again right back to geology and soils

Soil Type	Height of rise (feet)
Small Gravel	0.1 – 0.4
Coarse Sand	0.5
Fine Sand	1 – 3
Silt	3 – 30
Clay	30 – 90

Water

Water can be highly destructive as it:

- Increases distress action, base failure.
- Lubricates, causing loss of support, reduced strength, facilitates pumping.
- Expands when frozen, causing damage and frost heave.
- Causes erosion.

ROAD MATERIAL – MATERIAL SELECTION

What type of material do we need to choose for a durable, low maintenance unpaved and gravel road?

- Aggregate used as a wearing surface is different than aggregate used as a subbase course.
- Aggregate durability and drainage characteristics are very different for an unpaved and gravel road.

Materials such as PennDOT 2A, 2A (Modified), and 2RC are "well graded" and incorporate aggregate of different sizes. <u>They were developed to be used as a subbase course.</u>

They are made with a larger top size material and smaller percentage of fine material; provides good strength and drainage. They are not for use as a driving surface.

Materials such as AASHTO 8, 57, and 67 are "uniformly graded" and are predominantly the same sizes. They were developed as structural aggregates for other uses such as concrete, hot mix asphalt, and bituminous chip seals.
They provide good strength when bound (with cement or asphalt). They are not for use as a driving surface.

The standard PennDOT aggregate specifications were intended for use with conjunction of asphalt and concrete roadway construction. When utilizing these materials as a driving surface, they:

- Will not form surface crust to bind the material together.
- Are difficult to maintain.
- Contribute to a significant loss of aggregate due to traffic action.
- Are a less durable material when exposed to traffic <u>(more dust and sediment created</u>).

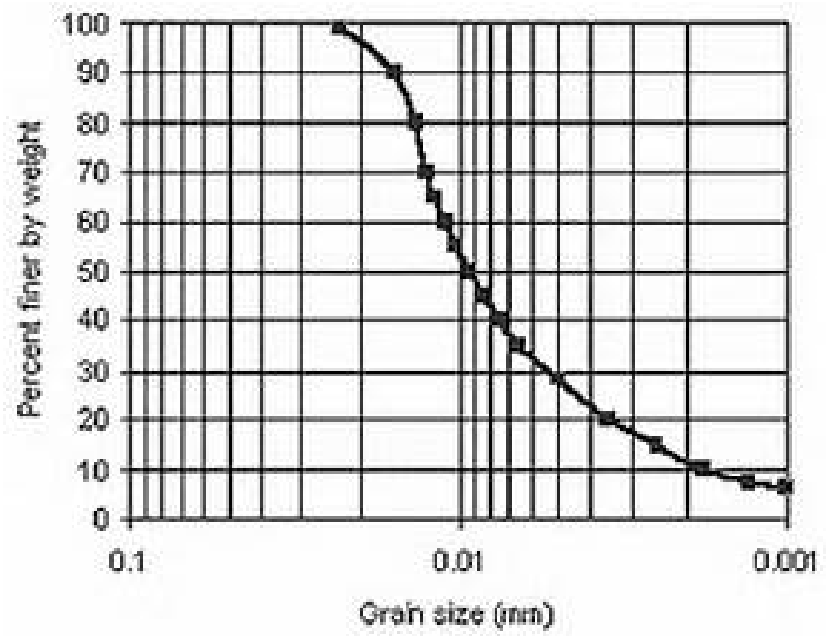
PennDOT did not have a specification for the manufacture of an appropriate aggregate driving surface aggregate (DSA) until the 1990's. This specification was developed to provide:

- Even distribution of aggregate to achieve density, strength, and durability.
- A smaller top size aggregate.
- Intermediate size aggregates to fill voids.
- More fines to bind the material together and aid in compaction.
- Less aggregate loss due to traffic action.
- A more durable material <u>(less dust and sediment created</u>).

Particle Size

Determine particle size distribution by gradation tests

Aggregate classification will utilize grain size distribution analysis. After the aggregate is sieved, a grain size distribution curve is developed to help the engineer determine the distribution of particle sizes in the curve. Engineered aggregates are blended, including percentages of each specific size aggregate specified in the mix.



Aggregate	2"	1-1/2"	1"	3/4"	1/2"	3/8"	4	8	16	100	200
PennDOT DSA		100%		65-95%			30-65%		15-30%		10-15%
PennDOT 2A	100%			52-100%		36-70%	24-50%	16-38%	10-30%		
AASHTO 57/ PennDOT 2B		100%	95-100%		25-60%		0-10%	0-5%			
AASHTO 67			100%	90-100%		20-55%	0-10%	0-5%			
AASHTO 8					100%	85-100%	10-30%	0-10%	0-5%		

DSA Spec & QA

Driving Surface Aggregate (DSA) and Material Requirements are found in:
PennDOT Publication 447 and Section MS-0450-0004

Material must be obtained from a source listed in PennDOT Bulletin 14 if using Liquid Fuels monies.

Material Certification Required: MS-447A
Aggregate gradation must fall within the ranges in the specification.

Aggregate	2"	1-$^{1}/_{2}$"	1"	$^{3}/_{4}$"	$^{1}/_{2}$"	$^{3}/_{8}$"	4	8	16	100	200
PennDOT DSA		100%		65-95%			30-65%		15-30%		10-15%

Quality Control

All aggregates must meet these criteria:

- Durability (Hardness) – harder aggregates are less likely to break down under traffic, creating dust and sediment affecting stream quality. (must be less than 40 percent).
- pH (acidity/alkalinity) – pH can affect water quality of nearby streams. Aggregate will be within the range of pH 6 – pH 12.45.
- Soundness (resistance to disintegration by sodium sulfate) – simulates breakdown of aggregate when frozen.
- Derive 95 percent of the aggregate mix from the crushing of clean rock material. If 10 percent of the aggregate mix does not pass the #200 sieve, utilize up to 5 percent external source material approved by the engineer to the mix.
- Do not add clay or silt. Material must not exceed Plasticity Index (PI) rating of 6.

Bidding

Once you bid your driving surface aggregate material what are the first steps in purchasing the material? You are likely making a significant investment in material, so:

- Ask for material testing information. The optimum percentage moisture is to be determined using Standard Proctor Test.
- Visit the quarry
- Check the parent material
- Check the moisture content and fines.
- Look at the stockpile. Segregation is normal.
- Mix the stockpile
- Talk with the supplier.

Handling & Placement

Prior to conducting any work, erect all required Work Zone Traffic Control as outlined in PennDOT Publication 213.

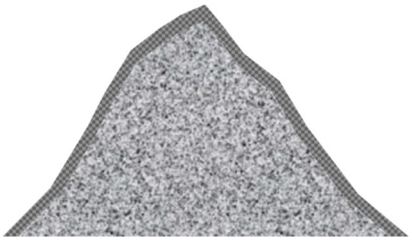
- Prepare subgrade as specified in Publication 408, Section 210.
- Do not place DSA on soft, muddy, or frozen areas.
- Correct unsatisfactory subgrade conditions by scarifying, reshaping, and compacting.
- Crown ½ to ¾ inch per foot (4 to 6 percent), flat "A" cross-slope. NOTE: both the subgrade and surface should be crowned.
- When required place separation fabric.

Handling & Placement Cont.

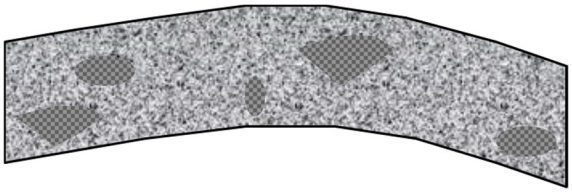
- Use acceptable methods to mix (DSA) and water to obtain optimum moisture content for the mix before delivery to the project.
- Use material containing optimum moisture to prevent segregation during stockpiling, hauling, placing, and to minimize water added during compaction.
- Maintain aggregate (DSA) at optimum moisture from before placement to compaction.
- Properly handle the material, including loading, hauling, and unloading of the trucks.
- Use tarps to cover 100% of the load's exposed surface from time of loading to immediately before placement.

Using aggregate from piles, without mixing prior to loading trucks, results in segregation.

Appearance in the Pile

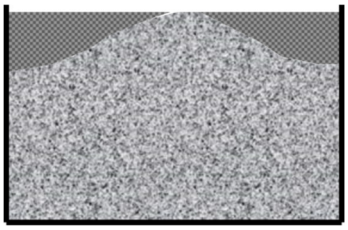


Effect on the Road

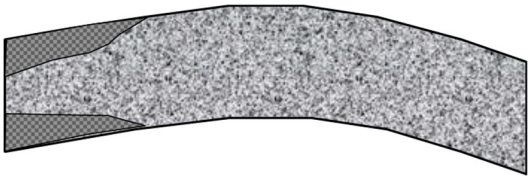


Improper loading and vibration can cause segregation during transport.

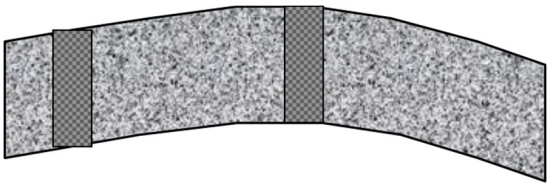
Appearance in the Truck



Effect on the Road



Cycling the wing or allowing the paver to run empty can also cause segregation.



Handling & Placement Cont.

- Place the (DSA) on the subgrade using a paver (preferred) or approved spreading equipment without causing segregation.
- Place (DSA) to a minimum un-compacted depth of 6 inches and a maximum un-compacted depth of 8 inches in one lift.
- The crown or side slope must range from ½ to 3/4 inch per foot, for road widths up to 20 feet.
- Material is to be delivered and placed at optimum moisture content +/- 1 percent as determined for that particular source.
- Compact DSA to between 95 and 100 percent of the maximum dry-mass (dry-weight) density for each 3,000 square yards with proper compaction equipment.

- Beginning on the lower or berm side of the crown, begin rolling and work to the top of the crown by overlapping the successive longitudinal passes. Utilize static mode on the initial and downgrade passes.
- Do not run the roller lengthwise directly over the crown. Compact to specified density requirements, using equipment specified is Publication 408.

IMPORTANCE OF DRAINAGE

"The three most important things to understand in building and maintaining roads are **drainage, drainage, and drainage**!"

When drainage is poor, the best efforts to rehabilitate or maintain roads will bring disappointing results. When water can be drained off of road surfaces and out of roadbed soils, the road will invariably become easier to maintain.

There are two main components to any municipalities' drainage network:

Surface drainage

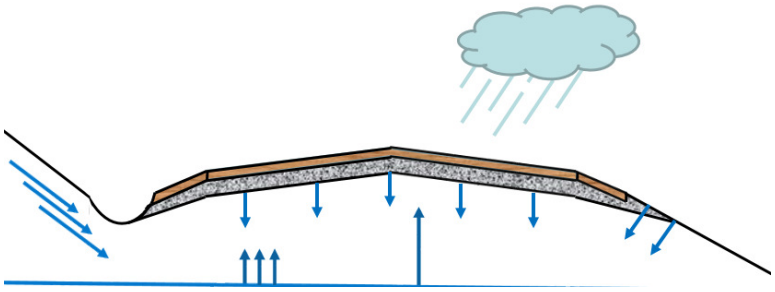
- Control of surface water caused by direct rainfall, melted snow, or surface runoff
- Includes the roadway, shoulders, and ditches/swales.

Subsurface Drainage

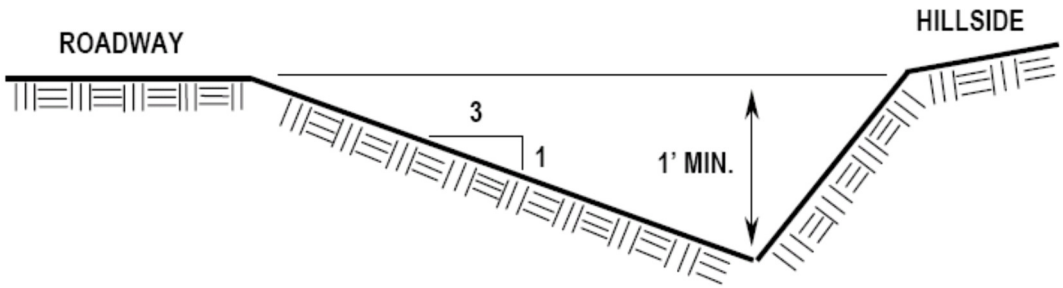
- Control of subsurface water in and around our road structure.
- Includes roadway base, underdrain, inlets, and culverts.

What is the source of moisture in an unpaved and gravel roadway?

- Capillary Action
- Rainwater
- Seepage from High Ground
- Infiltration through the Road Surface
- Infiltration from the Road Edge
- Upward Movement of Groundwater



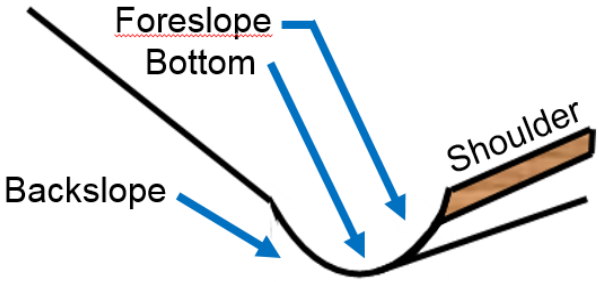
Roadside ditches and swales convey water both parallel to and away from the roadway. Lack of ground cover, water volume, and/or velocity may result in erosion of the roadside ditch. Lining with larger aggregate or geosynthetics may be necessary to reduce erosion.



Ditches:

- Prevent water from reaching the road base.
- Provide drainage of the road base.
- Can be natural or constructed, and can have many shapes.

What are a ditch's components?

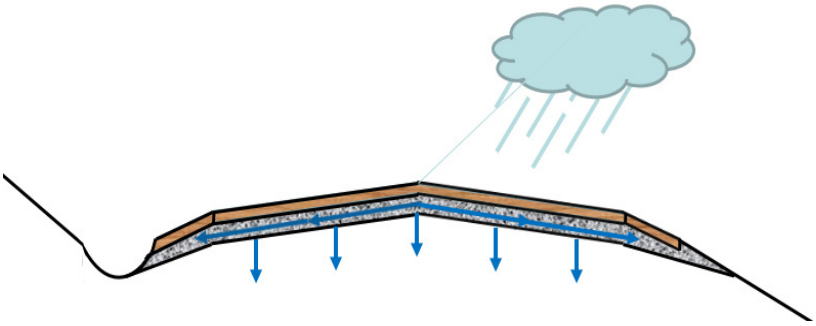


Ditches are made up of three main components. The foreslope ties the roadway shoulder into the bottom of the ditch. The bottom is also referred to as the flow line of the ditch. The backslope ties the bottom of the ditch into the adjacent bank.

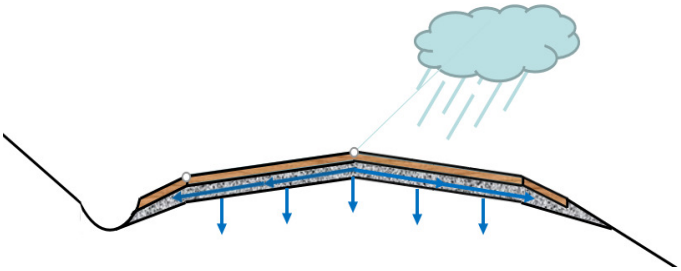
- Ditches must be maintained in a good, non-erodible condition.
- Maintain parabolic ditches when practical.
- Provide positive drainage.
- Don't create large edge drop-offs.
- Ditches must be properly seeded or line (geosynthetics or aggregates) to reduce erosion.
- Re-seed ditches after maintenance activities.

Subbase

- Free-draining road subbase beneath the road surface allows water to drain from beneath the roadway.
- Collector systems comprised of perforated pipe surrounded by free-draining aggregate with an outlet pipe or other prefabricated systems



- Base Drains, Edge Drains, and Under Drains collect water in a trench parallel to the road with a well graded aggregate and a perforated pipe to carry the water to an outlet away from the road. All subdrains need an outlet to get the water away from the road



- Base Drains, Edge Drains, and Under Drains are similar structures placed under and adjacent to the roadway, cutting off lateral movement of subsurface water and providing dewatering of the subgrade materials and soils.

- Regular and scheduled maintenance of drainage facilities is one of the most important functions of maintenance personnel.

- Drainage facilities should be inspected semi-annually and after each major storm event.

MANAGING DUST

One car making one pass on one mile of a dirt or gravel road one time each day for one year creates one ton of dust.

To a greater or lesser extent, all gravel roads will give off dust under traffic. After all, they are unpaved roads that typically serve very low volumes of traffic, and some dust will be generated from that traffic. The amount of dust that a gravel road produces varies greatly depending primarily on the type of gravel, volume and type of traffic and annual precipitation. In areas of the country that receive a high amount of moisture, the problem is greatly reduced.

Liability

- Dust is part of your road; vehicles grind the road fines into dust which then becomes airborne.
- Dust represents the loss of road fines which are necessary to bind the road aggregates into place and keep the aggregate in place.
- Dust means the road and the environment is deteriorating, if left uncontrolled, it will result in increased road maintenance costs and environmental pollution.
- Dust control is necessary as part of a proper maintenance program for all unpaved and gravel roads to prolong road life and protect the environment

Average Daily Traffic (ADT)

We need to look at dust control as a necessary routine maintenance item for all your roads - not only to prolong road life but also to protect the environment. You may consider some accepted guidelines on volume of traffic versus the need for dust control.

It is generally accepted that if the road has an ADT (average daily traffic) of less than 5 (that means five cars per day), you may not need dust control. Someone might tell you less than 10ADT. It really depends on the specific road and the roadside situation. An ADT of 1,000 may dictate paving the road, and some think anything over 500.

Dust Control Use

- Do you do use dust control?
  - partial - in front of residences
  - total roads
- Why do you use it or not?
- What do you use?
- How many times is it applied annually?

Benefits

- Reduced road maintenance costs
  - Reduced blading and regrading
  - Reduced regravelling
- Reduced sedimentation in ditches, pipes; and in water affecting plants, fish, and other aquatic life and drinking water reservoirs
- Reduced vehicle accidents with associated injuries and property damage.
- Reduced cleaning costs for homes, clothes, and vehicles
- Higher quality of life and property values for those living/working adjacent to the road.
- Reduced impact on dust sensitive vegetation such as orchards and crops.
- Reduced dust induced respiratory problems and other related health problems.
- Reduced vehicle maintenance costs from dust damage to moving parts.
- Reduced vehicle damage from flying aggregate such as broken windshields.
- Better "PR" (Public Relations).
  - Better Road
  - Better Municipality
  - Better Environment

Options

- Limit traffic volume (rarely feasible)
- Limit traffic speed
- Limit traffic weight
- Use a surface dust suppressant/palliatives
- Use stabilization and/or geotextiles
- Upgrade (pave) the road

Managing Dust – Palliatives

PennDOT Publication 447, Section MS-0440-0020, Dust Palliatives, directs municipalities to go to the Penn State Center for Dirt and Gravel Roads website for a list of Liquid Fuels eligible dust palliatives.

Considerations

- Compatibility with the Environment, including:
  - Toxicity - Clean Streams Law - mammals, fish and other aquatic life.
  - Effects on vegetation
- Ease of application
- Effectiveness to control dust
- Durability (how long will it last)
- Cost
- Road surface material and condition handling - MSDS (Material Safety Data Sheet)
- The product must match road materials – an analysis is crucial.
- Local climatic conditions should be considered.
- Dust control will not make a bad road good, but will keep a good road good.
- The placement of dust palliatives as a surface treatment on existing unpaved roadways or on roadways improved by grading or scarifying to a maximum of 1-inch depth.

Information you should require:

- MSDS Sheet
- Toxicity - Std. LD-50 and LC-50 Tests
- BOD (Biological Oxygen Demand)
- Solubility
- Leachability
- Corrosivity
- Reactivity
- Ignitability
- pH

Perform all required maintenance and repairs to road:

- repair unstable areas
- remove unsuitable material and replace with select material
- make necessary drainage improvements
- clean ditches
- grade and restore proper crown

Determine product & application rate:

- condition of road and type of wearing surface
- type of traffic, volumes, and speed
- degree of dust control required
- climatic conditions
- frequency of maintenance
- cost

When to apply:

- Spring application followed by reapplication as required for product and conditions
- No threat of heavy rains
- Damp surface

WHEN TO PAVE A GRAVEL ROAD

What is meant by a "paved" road? For some, a seal coat or surface treatment is considered paving. For others, paving is four or more inches of hot mix asphalt. The primary purpose of a pavement is to provide structure, distribute the vehicle load, and protect the subgrade.
As the loads get heavier, the pavement thickness must be increased.

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

In spite of the benefits of paved roads, well-maintained unpaved and gravel roads are an effective alternative. Gravel roads have the advantage of lower construction and sometimes lower maintenance costs.

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

It's a ten-step process:

Step 1: Develop a road improvement program.
If the road being considered for paving does not fit into the municipality's road improvement program, it is quite possible that funds will not be used to the fullest advantage.

The program should be designed to:

- Inventory the roads and assess their conditions.
- Determine maintenance strategies
- Establish maintenance priorities
- Does paving fit into the overall plan?

Step 2: Committed to an effective management strategy.
A commitment to effective management is an attitude. It is a matter of making sure that taxpayers' money is well spent, with a commitment to:

- Long range planning.
- Using proper construction techniques.
- Insuring the required preparatory work can be completed.
- Proving sufficient load carry capacity has been determined.

Step 3: Determine when traffic demands it.
The life of a road is affected by the number of vehicles and the weight of the vehicles using it. Generally speaking, the more vehicles using a road, the faster it will deteriorate.

- Rule of thumb is when ADT approaches 500
- Type of traffic must be considered
- Future development and needs must be considered

Step 4: Adopt design, construction, and maintenance standards.
Written standards in the areas of design, construction and maintenance define the level of service we hope to achieve. They are goals to aim for. Without written standards there is no common understanding about what a municipality is striving for in road design, construction and maintenance.

In deciding to pave a gravel road, is the municipality confident it would be achieving the desired standards?

Step 5: Consider safety and design.
Paving low volume roads before correcting safety and design inadequacies encourages speeds which are unsafe. Because of the vast mileage of low volume roads, it is difficult to reduce speeds by enforcement.
Consider:

- Sight distance,
- Roadway and bridge widths,
- Alignment, curves, and superelevation,
- Clear zones/hazards, to provide safe travel for the expected volume at anticipated design speed.

Step 6: Improve the base and drainage.
Does the road need strengthening and drainage work?

- If the foundation fails the pavement fails
- If the water is not drained away from the road the pavement fails

Do you have the time and money to do this?

Step 7: Determine the costs of road preparation.
Costs will vary from project to project.

In addition to base and drainage improvement, has the municipality considered tree removal, bank cut/fill, signing requirement, roadway realignment, bridge upgrades, guide rails, etc.
The decision to pave a gravel road is ultimately an economic one. Policy makers want to know when it becomes economical to pave.

Step 8: Compare pavement upgrade costs, pavement life cycle, and maintenance costs.
A second financial consideration is to compare maintenance costs of a paved road to maintenance costs of a gravel road. To make a realistic comparison we must estimate the years of pavement life and the actual cost of paving. It is at this point that we can begin to actually compare costs between the two types of roads.

- Gravel roads require grading, shaping, adding material, stabilization, and dust control.
- Paved roads require patching, sealing, line painting and resurfacing.

After comparing costs for one mile of road:

- Estimated cost to maintain a gravel road for 6 years based on the above maintenance: **$18,065 or $3,011/year**
- Estimated cost to upgrade the road and maintain it as Double Seal Coat for 6 years: **$24,833 or $4,139/year**
- Estimated cost to upgrade the road and maintain it as Hot Mix Asphalt for 12 years: **$62,920 or $5,243/year**

Which is most cost effective?

Step 9: Compare user costs.
Not all road costs are reflected in a highway budget. There is a significant difference in the cost to the user between driving on a gravel surface and on a paved surface.

- Vehicles cost more to operate on an unpaved and gravel road than on a paved surface.
- Increased costs due to a rougher surface, dust, increased oil consumption, engine wear maintenance costs and tire wear, as well as increased fuel usage.
- FHWA statistics indicate costs to operate a vehicle at 40 MPH to be 40 percent higher on an unpaved road as compared to a paved surface.

Step 10: Consider public opinion.
Public opinion as to whether to pave a road can be revealing, but it should not be relied upon to the exclusion of any one of steps 1-9 already discussed. If a decision to pave is not based on facts, it can be very costly. Public opinion should not be ignored, of course, but there is an obligation by government leaders to inform the public about other important factors before making the decision to pave.

The example projects are not in the workbook.

RESOURCES

LTAP Classes

Sign up for other related LTAP classes including:

- Drainage,
- Geosynthetics,
- Full Depth Reclamation,
- Work Zone Traffic Control….and many others

Course descriptions and registration available on the LTAP Website:
www.ltap.state.pa.us

LTAP Website

Commonwealth of Pennsylvania Department of Transportation Publication 447 "Approved Products for Lower Volume Local Roads" – 8/2016

US Department of Transportation "Gravel Roads Construction & Maintenance Guide" – August 2015

United States Department of Agriculture – Forest Service "Environmentally Sensitive Road Maintenance Practices For Dirt and Gravel Roads" – April 2012

Above resources available on the LTAP Website: www.ltap.state.pa.us

Penn State Dirt and Gravel Roads

The Pennsylvania State University, Center for Dirt and Gravel Road Studies "Environmentally Sensitive Maintenance for Dirt & Gravel Roads" – 2017

Available on the Center's Website: www.dirtandgravelroads.org

Additional training and grant opportunities are available through:
The Pennsylvania State University Center for Dirt and Gravel Road Studies Available on the Center's Website: www.dirtandgravelroads.org And your local County Conservation District www.pacd.org

RESOURCES

- When to Pave a Gravel Road – KY T2
- Economics of Upgrading IA
- Dust Pallatives USFS
- Field Guide for Unpaved Roads WY
- Gravel Road Maintenance NH

FOR MORE ASSISTANCE...

Call: 1-800-FOR-LTAP

Write: LTAP – Local Technical Assistance Program
Pennsylvania Department of Transportation
Bureau of Planning and Research
400 North Street, 6th Floor
Harrisburg, PA 17120

E-mail: LTAP@state.pa.us

Web Site: www.ltap.state.pa.us

EVALUATIONS

In three months, you will receive an evaluation form via email for this course. Please complete the form and email back to ltap@psats.org. Your evaluation is combined with other class participants to support the value of the training.

ADDITIONAL RESOURCES

GRADER OPERATION AND SAFETY

A **good operator** takes care of the machinery:

- Make a walk around inspection.
- Perform lubrication and maintenance.
- Confirm the fire extinguisher is properly charged.
- Keep all warning devices operational in good condition.
- Inspect the condition of the moldboard!

A sample maintenance checklist is included in your handouts.

MOTOR GRADER PREVENTATIVE MAINTENANCE CHECK LIST

Vehicle #_____ Date _____ PM Location _____ # Hours _____

	OK	REPAIR	FOLLOW UP
150 HOUR SERVICE (90 DAYS)			
Change Engine Oil & Filter	_____	_____	_____
Check Air Filter Elements – replace if necessary	_____	_____	_____
Check Exhaust System	_____	_____	_____
Check Air Inlet System for Leaks	_____	_____	_____
Check Wiring for Chafing, Loose Connections, etc.	_____	_____	_____
Check Battery Electrolyte Level	_____	_____	_____
Check Front End	_____	_____	_____
Check and Tighten Wheel Studs	_____	_____	_____
Check Drive Axle Oil	_____	_____	_____
Check Oil Level in Tandem Drives	_____	_____	_____
Check Parking Brake Adjustment	_____	_____	_____
Check Oil Level in Circle Drive Gear Box	_____	_____	_____
300 HOUR SERVICE			
Change Fuel Filter	_____	_____	_____
Change Hydraulic Filter & Clean Magnets	_____	_____	_____
Change Transmission Filter	_____	_____	_____
Visually Inspect Engine Mounts	_____	_____	_____
Take Oil Sample	_____	_____	_____
Check and Adjust Brake Pedal Linkage	_____	_____	_____
Steam Clean Radiator	_____	_____	_____
1000 HOUR SERVICE			
Steam Clean Engine	_____	_____	_____
Check and Adjust Engine Speeds	_____	_____	_____
Check and Adjust Valve Clearance	_____	_____	_____
Clean and Repack Front Wheel Bearings	_____	_____	_____
Clean Hydraulic Tank Breather Filter	_____	_____	_____
Check Pivot Pins and Bushings	_____	_____	_____
Road Test Prior to Releasing to Using Agency	_____	_____	_____

Performed by_____

The roadway is a work site. A **safe operator** wears all required Personal Protective Equipment (PPE) when in the field, including:

- Hardhat
- ANSI Certified High Visibility Safety Garment
- Long Pants
- Lightweight Shirt with a 6-inch Sleeve
- Boots with Safety Toe*
- Hearing and Eye Protection*
- Rain or Cold Weather Attire*

A **professional operator** is prepared for their job and carries a level and a shovel in good condition and knows how to use them!

A **qualified operator** is properly trained to perform their duties:

1. Read the operator's manual.
2. Always perform a pre-trip inspection.
3. Clean windows, lights, etc. and any debris from floor of grader.
4. Do not let anyone ride along (inside or outside).
5. Look, then check again, before backing up.
6. Drive at a slow speed in congested areas.
7. Give the right-of-way to loaded vehicles.
8. Watch for overhead dangers.

A **qualified operator** is properly trained to perform their duties cont.:

9. Know your work area: check weight limitations, types of surfaces, and clearances.
10. Report defective equipment immediately.
11. Stay focused on the job.
12. Select a safe parking area.
13. Wear seatbelts.
14. Wear Personal Protective Equipment (PPE).
15. Remove ignition key when leaving grader.
16. Ground the blade when leaving grader unattended.
17. Use colored flags at each end of moldboard when blading.
18. Shift blade to center and lock it when parking.
19. Be aware that boarding and exiting grader may put you in danger of slipping, tripping or falling. Use a three-point (two feet and one hand or one foot and two hands) approach when entering or exiting the cab.
20. Communicate with traffic:
    - Use flashing safety lights when blading.
    - Keep headlights on whenever operating.
21. Be alert to traffic waiting to pass, and provide the driving public passing opportunities.

Unpaved roads typically serve less than 500 vehicles per day, but are used by a wide range of vehicles (horse-drawn, bicycles, motorcycles, automobiles, trucks, farm machinery, etc.).
A **safe operator** erects all required Work Zone Traffic Control as outlined in PennDOT Publication 213. Prior to conducting any work.

A courteous operator should always keep in mind that one of the reasons they are working on the road is for the benefit of the traveling public using it. Be courteous and a good will ambassador for the municipality, appreciative of the fact that most drivers don't understand how difficult it is to do what you're doing.

ALTERNATE TECHNOLOGY & INNOVATIONS

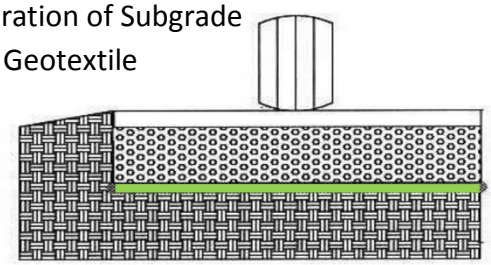
Full Depth Reclamation:

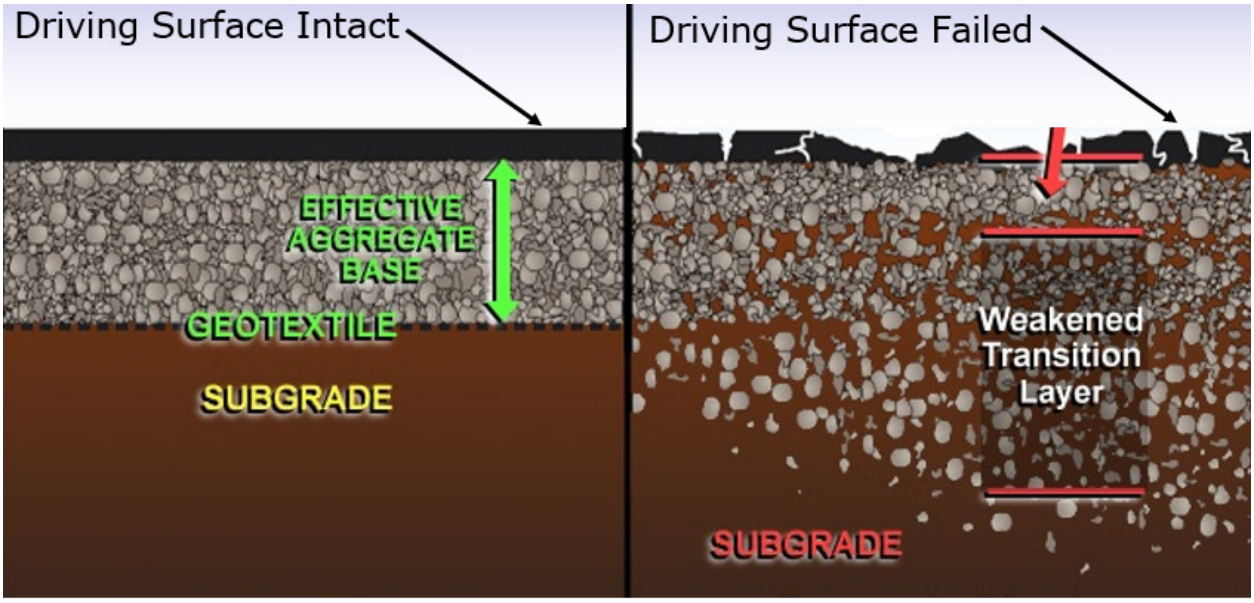
- Conserves energy, significantly reducing or eliminating trucking and other material handling issues.
- Eliminates heating fuel, since it is a cold process.
- Conserves materials by recycling 100 percent of the existing pavement materials (stone and asphalt) and subgrade soils, conserving limited resources.
- Crown and cross-slope easily restored.
- Minor grade changes can be made.
- Loss of curb reveal can be reduced or even eliminated
- Reflective cracks are eliminated
- Long-term cost-effective solution that addresses 100 percent of the cause of pavement failure, weak bases.
- Environmentally desirable by recycling all materials in-place, saving time, money and resources.
- Future maintenance costs are reduced.

Geosynthetics

- Geosynthetics can be used to help mitigate pavement damage and increase the bearing capacity of both the granular base and underlying soils.

Separation of Subgrade with Geotextile



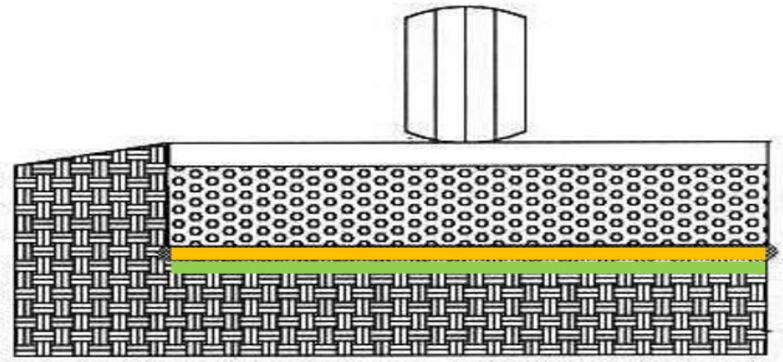


Roadway with intact granular base

Roadway with weakened granular base

The road system may benefit from the installation of geosynthetics (discussed later in the presentation). Without geosynthetics, soil materials from the subgrade could migrate toward the granular base, or from the granular base toward the subgrade due to traffic load. Geotextiles prevent this soil migration. Once the materials begin to mix, the pavement structure's ability to carry heavy traffic load is reduced, resulting in further pavement deterioration.

Separation and Stabilization of Subgrade with Geotextile and Geogrid



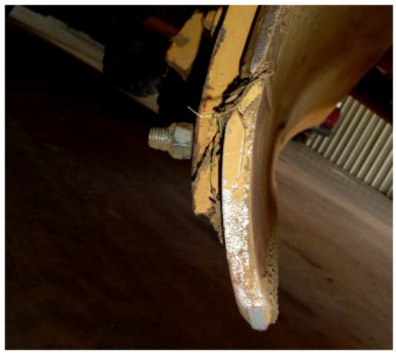
With very weak subgrades, it is often beneficial to combine the benefits of both separation and stabilization.

Carbide Tipped Cutting Bits

Carbide tipped cutting bits have been adapted for use on graders.

The bits allow an operator to cut out a washboard area or loosen hard surface material with much less time and effort than a conventional cutting edge. The bits also do some mixing of material as it is cut from the road. They do not work for every situation in maintenance but will perform very well in many maintenance and rehabilitation functions.

Carbide inserts and carbide faced cutting edges are more resistant to wear.



Another option 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. Carbide inserts and carbide faced cutting edges exceed the life of standard carbon steel.

Mixing Heads

Grader mounted mixing heads allow for the rapid inclusion of both liquid and dry stabilizers into the roadway surface.

Adding stabilization products or incorporating dust control agents into gravel roads is becoming more common. When the right product is selected for the in-situ material, these products increase the strength of gravel roads, reduce maintenance and gravel loss. Depending on the product used, it may also reduce road dust. In the past, this was often done with motor graders to loosen the surface, apply the product and then make many passes to mix the product prior to compacting and finishing the surface. The process can be done much more rapidly and accurately with commercially manufactured mixers.

Tractor Mounted Pulverizes

Tractor mounted pulverizes can also be used to pulverize, mix, and reclaim gravel.

Rollers

Grader mounted and towed rollers are also available and provide excellent initial compaction.

Electronic Slope Control

Electronic slope control has been used in the road construction industry for many years. The readout helps the operator grade the road at the proper cross-slope.

Small Tractor Mounted or Towed Blades

Small tractor mounted or towed blades can be used to fill small potholes and depressions. They are typically too light to handle reshaping or large windrows.