

A Field Resource for County and City **MOTOR GRADER OPERATION**



Local Technical
Assistance Program

ISRMSA

Iowa Streets and Roads
Maintenance Supervisors Association



This document was originally published under the sponsorship of the Nebraska Department of Transportation (DOT) and is being updated and reused with permission by the Iowa Local Technical Assistance Program (LTAP) in the interest of information exchange. The State of Nebraska and Iowa LTAP assume no liability for its contents or use thereof.

Operators should abide by department policies at all times. Material included in this guide should not supersede agency policies or those from an agency's insurance carrier.

Images used in this document are reused with permission from the Nebraska DOT, except where noted. The images are for educational purposes only and do not imply an endorsement of any products shown.

This document is designed to be used in conjunction with the Iowa LTAP Motor Grader Operator (MoGO) Student Guide, within the Iowa LTAP MoGO Course.

2022 Edition

© University of Nebraska Board of Regents

The University of Nebraska does not discriminate based on race, color, ethnicity, national origin, sex, pregnancy, sexual orientation, gender identity, religion, disability, age, genetic information, veteran status, marital status, and/or political affiliation in its programs, activities, or employment.

Iowa State University does not discriminate on the basis of race, color, age, religion, national origin, sexual orientation, gender identity, genetic information, sex, marital status, disability, or status as a US veteran.

Acknowledgments

This pocket guide was influenced by and compiled from many valuable sources:

- United States Navy. (2014). Equipment Operator, Basic, NAVEDTRA 14081.
- United States Army. (2000). Earthmoving Operations, 5-434.
- FHWA. (2015). Gravel Roads Construction and Maintenance Guide, FHWA-OTS-15-0002.
- Local Technical Assistance Program documents and personnel from across the country
- Caterpillar Inc.
- John Deere

This document was printed, updated, and reused with permission from the NE LTAP for use by the Iowa Local Technical Assistance Program.

Table of Contents

Safety for Operators and the Public	4	Intersections	32
Operator Safety.....	4	Controlled Intersection.....	32
Equipment Safety.....	6	Uncontrolled Intersection.....	33
Safety of the Public.....	7	Maintenance Need: Humped Intersection.....	34
One Call.....	9	Maintenance Need: Low or High Spot in the Middle of the Intersection.....	35
Elements of a Good Road	10	Maintenance Need: Low outside Radius	36
Drainage.....	10	Maintenance Need: “T” Intersections and Driveway Approaches.....	37
Roadway Profile.....	10	Driveways	38
Road Building & Maintenance Methods	18	Superelevation	40
4-Pass Maintenance Method.....	20	Reclaiming Material	42
The First Pass.....	22	Shoulder Maintenance	43
The Second Pass.....	24		
The Third Pass.....	26		
The Fourth Pass.....	28		
2-Pass Maintenance Method.....	30		

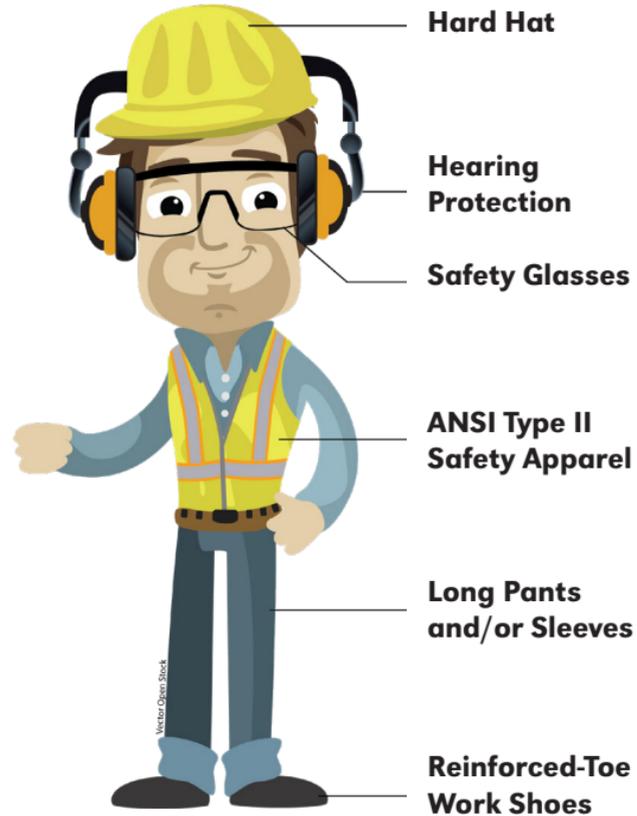
Safety for Operators and the Public

Safety is critical in all aspects of transportation. Actions by one individual can have significant consequences for that individual, his or her co-workers, and the traveling public.

Operator Safety

Personal Protective Equipment (PPE) protects operators and others. At minimum, all motor grader equipment operators should wear a high visibility safety vest or shirt visible from all directions and at a minimum of 1,000 feet. Transportation personnel are required to wear ANSI Type II or higher safety apparel when working in the right of way (ROW). An operator's department may require additional equipment for some or all tasks.

Seat belt use is mandated by federal, state, and agency regulation. Operators of motor graders and other heavy equipment used in road construction and maintenance activities are not exempt from these regulations.



Communication among personnel and with supervisors is essential. Operators should have access to a two-way radio at all times when operating equipment or working in the field. Training on use and procedures of the agency's communication equipment should be a priority for new personnel, as a refresher, or when updates are made to either equipment or procedures. Operators should use the communication system in a professional manner for agency business.

Operators should be awake and focused on the task at hand when on the job. Everyone has interruptions and distractions outside of work. Arriving at work ready to focus on the job is not only important for getting tasks done, but it is also a safety consideration. Distracted machine operation has similar risks to distracted driving.

Operating a motor grader while under the influence of drugs or alcohol is never acceptable.

Slower reaction times, blurred vision, poor decision-making, and drowsiness are just a few of the risks of driving impaired. If you have begun taking a new medication, over-the-counter or prescribed, check the label or ask the pharmacist if it can impair one's ability to operate heavy equipment.

Disclose any new medications to your supervisor immediately, as well as any known risks or restrictions related to operating a motor vehicle or heavy equipment.

Federal regulations require a first aid kit to be accessible by employees at all times. 29 CFR 1910.151(b) also requires one or more employees to be trained to administer first aid. Operators should work with their department's safety program manager to ensure the kits in their motor graders meet current requirements and are kept up to date.

Equipment Safety

Features, options, and care of the motor grader can have an important impact on safety.

Before operating any piece of equipment, an operator is responsible for reading and understanding the operator's manual for that piece of equipment. The operator's manual will include important safety messages, specific information for pre-, mid- and post- trip inspections, maintenance recommendations, and guidance for operation and use.

All department-required record-keeping should be completed legibly and thoroughly every day. The operator's daily record provides important records on both the operator and the machine. These records are the best defense in any complaints or litigation brought against the department. They are also important records for the superintendent to plan and budget upcoming work and equipment replacement as well as provide accountability for operators.

Operators should inspect their machines every day as recommended by the operator's manual. Proper, regular inspection improves machine efficiency, reduces the frequency and scale of breakdowns, and increases the machine's usable life. Routine maintenance prevents time and production loss while increasing the safety of the traveling public and operator.

Entering and exiting a machine should be done with three points of contact at all times. Operators should face the machine for both entering and exiting any piece of equipment. Keeping boots, steps, and all handles clean will prevent slips and falls. Jumping to or from the machine often results in leg and ankle injuries.

When in operation, the motor grader should be flagged and lit according to department policy. Increased visibility reduces crashes. Some departments also require cones or signage at the ends of roads being maintained.

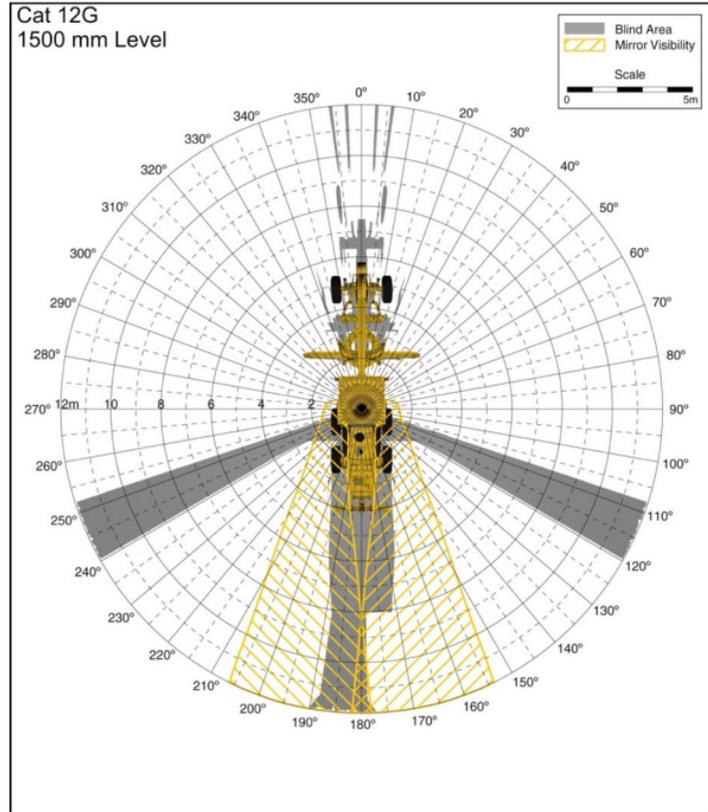
Operators should be aware of their surroundings.

Like all equipment, the motor grader has blind spots. Operators are responsible for looking for obstacles and people who could be harmed by the machine's movements. Others should be trained to have the operator's attention and approach from an angle that is visible.

Proper operating speed should match the operator's skill, the task at hand, and roadway conditions. Operators should be prepared to slow down or speed up as conditions change.

Safety of the Public

All of the activities of the highway or street department reflect on the agency's efforts to provide a safe transportation system to the traveling public and comply with the appropriate laws and regulations. Roadways should be in travelable condition with hazards appropriately marked. **Areas of concern should be reported to the operator's supervisor immediately.**

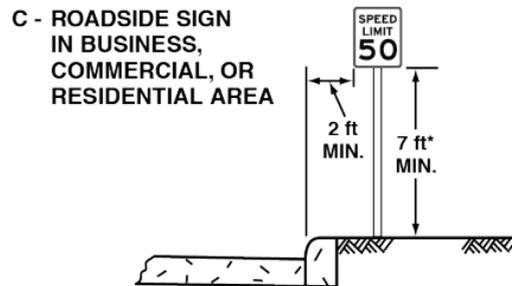
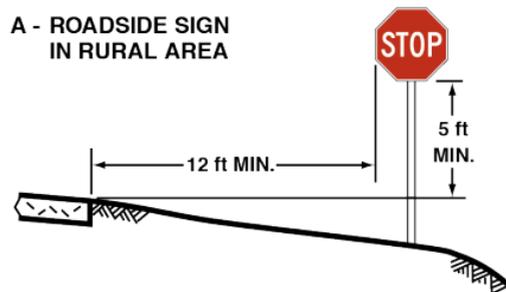


Some entities include sign maintenance in operators' duties and expectations while other entities have dedicated sign technicians. Whether operators are required to maintain signs or not, they should perform a cursory review of signs on their route daily.

Signs should be readable. The sheeting should be in good condition, and all text should be clear. Signs may need to be cleaned, repaired, or replaced if they are dirty or have been damaged by weather, vandalism, or something else.

Signs should be installed vertically, so the face of the sign is perpendicular to the roadway. Sign height and off-set should meet established minimums from the *Manual on Uniform Traffic Control Devices for Streets and Highways* (MUTCD) for rural and urban areas. Excerpts from Figure 2A-2 are shown. Posts that are no longer plumb should be replaced.

Operators should report any missing, vandalized, or damaged signs to their supervisor immediately.



*Where parking or pedestrian movements are likely to occur

MUTCD Figure 2A-2 excerpt

One Call

It is recommended that operators call for utility marking prior to any work that takes place off of the established road surface, including reclaiming material from ditches. However, some agencies don't require utility marking for work that is classified as maintenance. Follow your agency's policies on when to call. Requests should be made at least two business days prior to the work beginning.

	WHITE - Proposed Excavation		ORANGE - Communication, Alarm or Signal Lines, Cables or Conduit
	PINK - Temporary Survey Markings		BLUE - Potable Water
	RED - Electric Power Lines, Cables, Conduit & Lighting Cables		PURPLE - Reclaimed Water, Irrigation and Slurry Lines
	YELLOW - Gas, Oil, Steam, Petroleum or Gaseous Materials		GREEN - Sewers and Drain Lines

Uniform color code



1-800-292-8989

www.iowaonecall.com



Know what's below.
Call before you dig.

Elements of a Good Road

Drainage

The most important characteristic to maintaining a good road over time is adequate drainage. Excess water in the roadway leads to rutting and potholes, and destabilizes the road base. Establishing and maintaining a Modified “A” Cross Slope with a 4–6% slope (according to agency policy) in each lane is the most important thing an operator can do to encourage

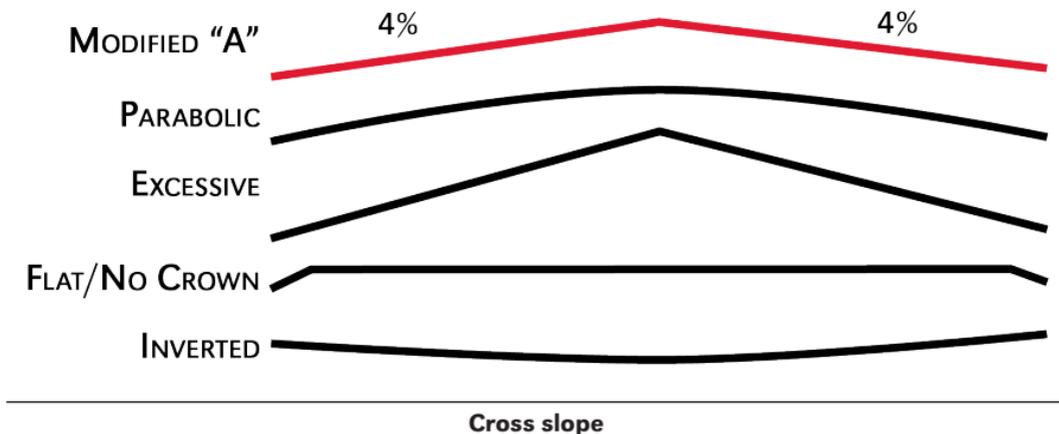
drainage. Profile and drainage are interdependent—one cannot exist without the other. The Modified “A” profile should resemble a low-profile roof when complete.

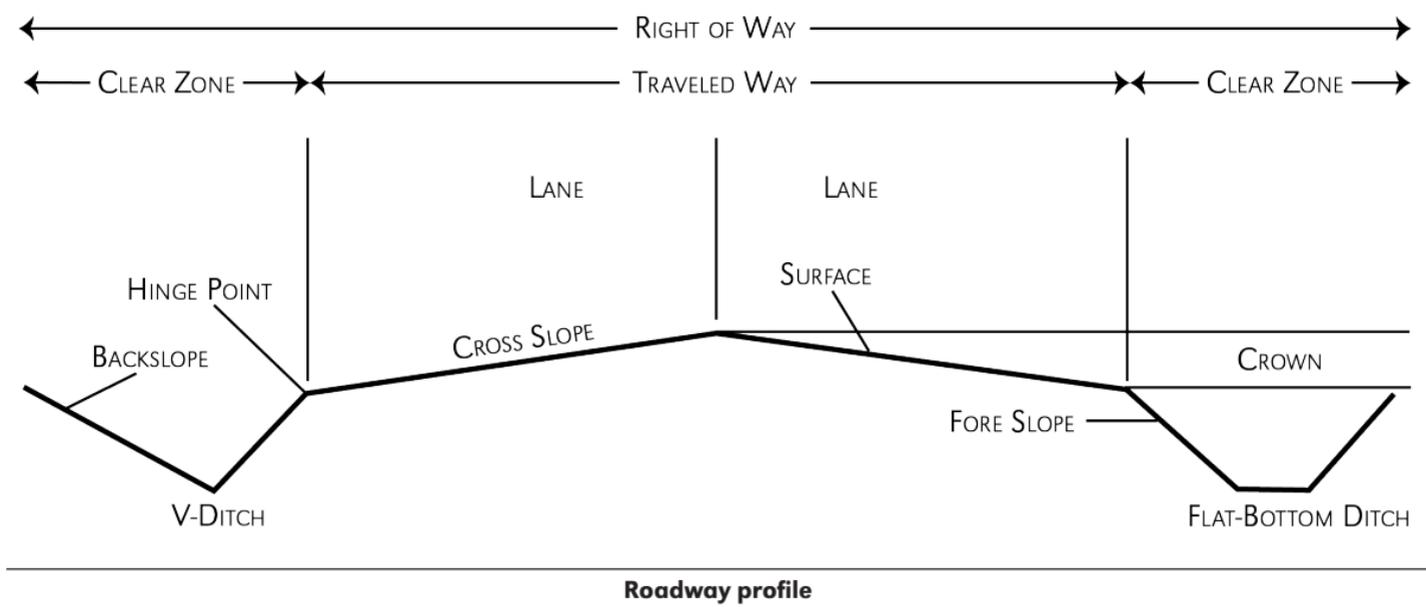
Roadway Profile

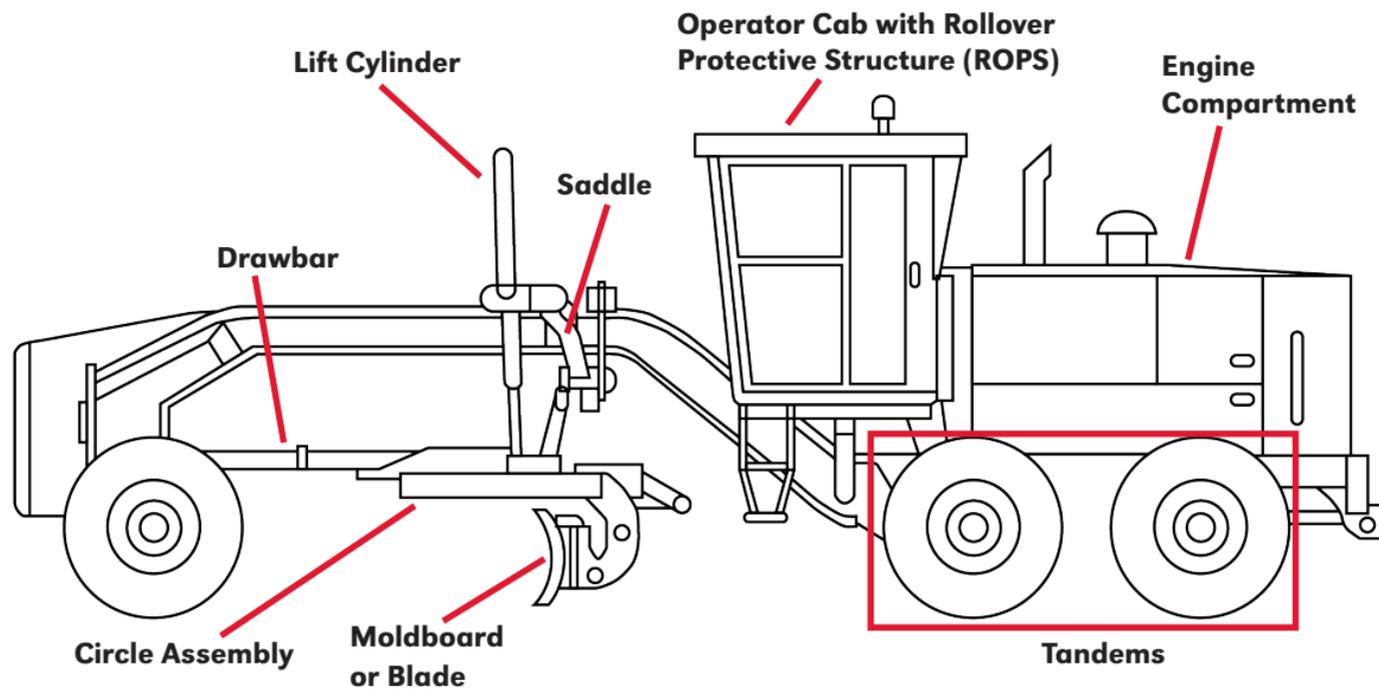
The Modified “A” profile is safest for the traveling public and provides for drainage.

The foreslope should slope away from the traveled lane at a rate no steeper than 1H:4V. Backslopes should be

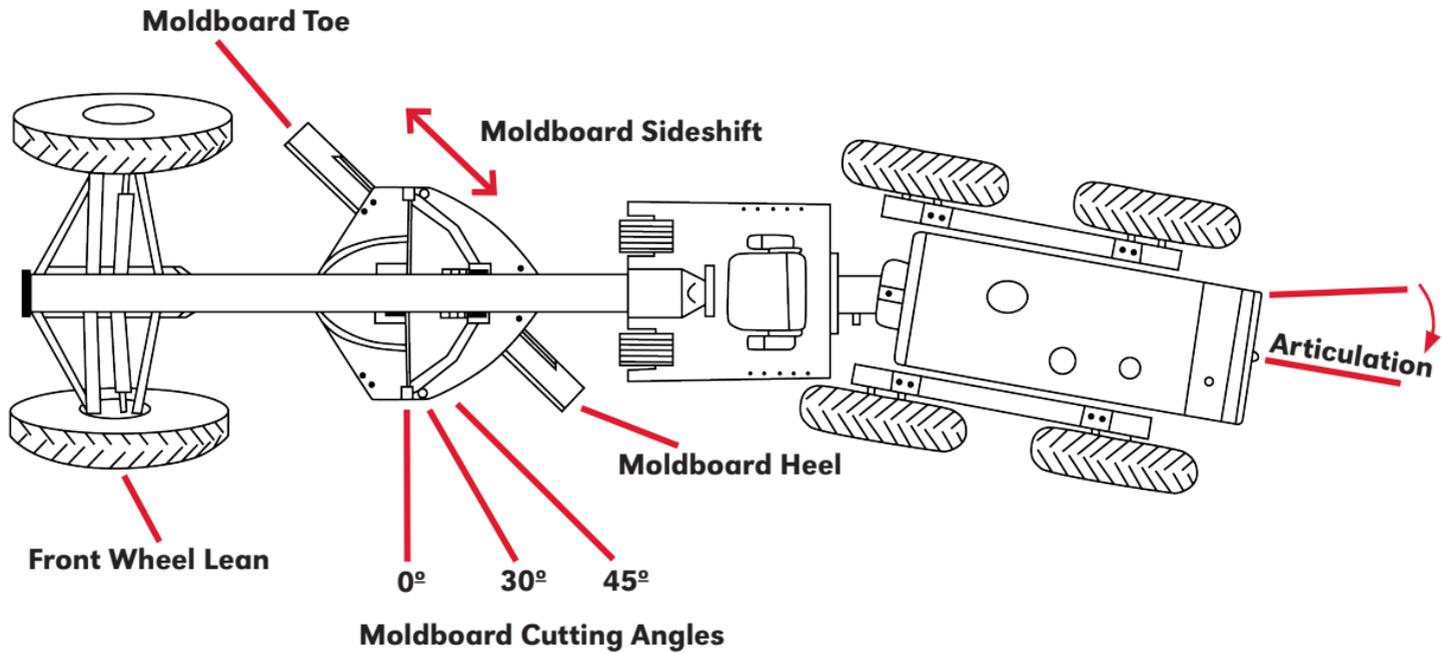
as gradual as possible for the terrain. These recommendations are safest for errant vehicles by reducing rollover crashes. Ditches can have a “V” bottom or a flatter bottom, depending on ROW available and terrain.







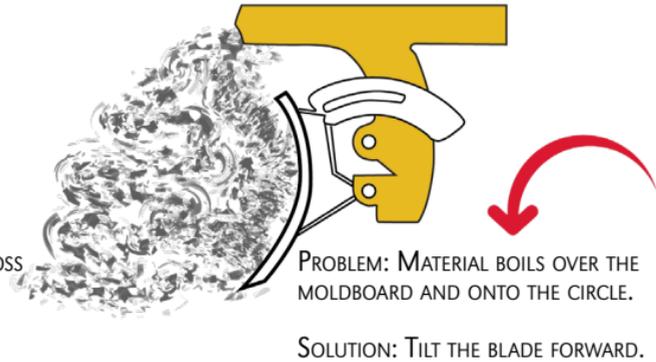
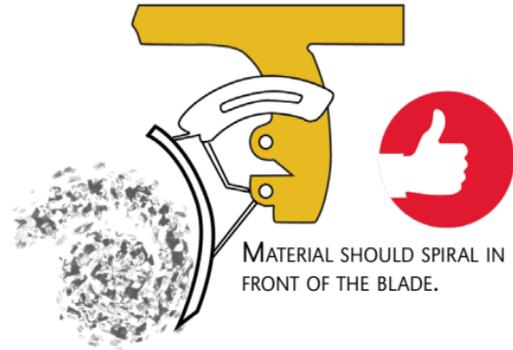
Parts of a motor grader - Side view



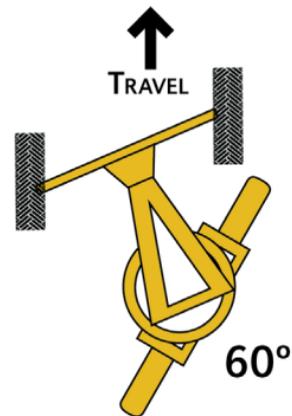
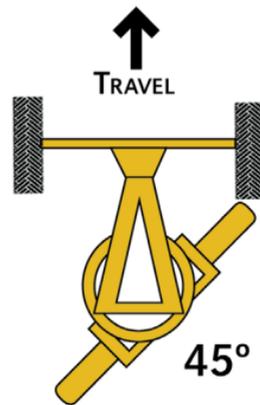
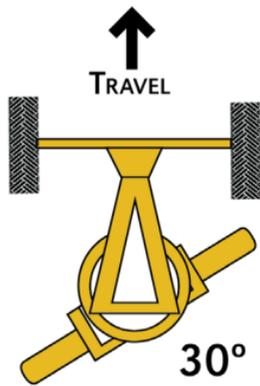
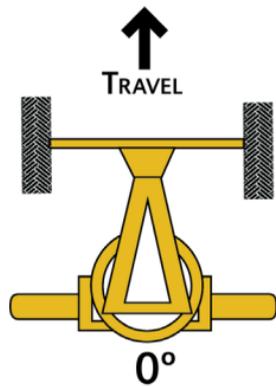
Parts of a motor grader - Overhead



Blade pitch

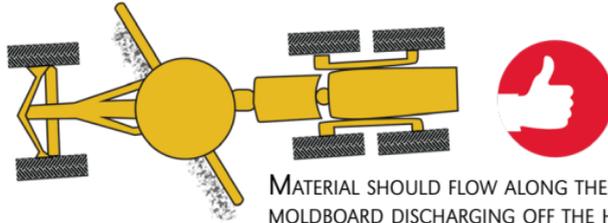


Troubleshooting blade pitch

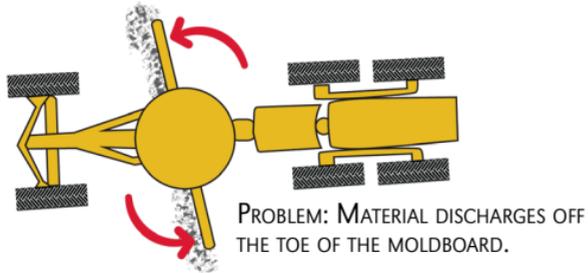


THIS BLADE ANGLE IS ONLY
ACHIEVABLE WITH ARTICULATION.

Blade angle

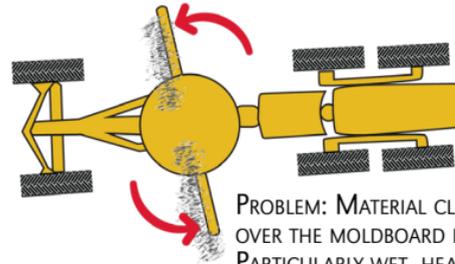


MATERIAL SHOULD FLOW ALONG THE
MOLDBOARD DISCHARGING OFF THE HEEL.



PROBLEM: MATERIAL DISCHARGES OFF
THE TOE OF THE MOLDBOARD.

SOLUTION: SHARPEN THE BLADE ANGLE.



PROBLEM: MATERIAL CLUMPS AND BOILS
OVER THE MOLDBOARD INTO THE CIRCLE.
PARTICULARLY WET, HEAVY MATERIAL.

SOLUTION: SHARPEN THE BLADE ANGLE.

Troubleshooting blade angle

Road Building & Maintenance Methods

Passes	Recommended Application	Advantages
2	<ul style="list-style-type: none"> Quick maintenance on roadways in good condition 	<ul style="list-style-type: none"> Operators can cover a lot of miles in a short period of time Keeps material evenly spread across the roadway, acting as a cushion to prevent washboarding, rutting, and general road deterioration
3*	<ul style="list-style-type: none"> Only recommended on closed roads 	
4	<ul style="list-style-type: none"> Basic road building Regular maintenance to improve roadway surfaces 	<ul style="list-style-type: none"> A complete process that allows operators to make adjustments to address problem areas Only blades with traffic Utilizes full power and function of the motor grader Allows for reuse of aggregate cast to the edge of the roadway by bringing that material back to the travelway
6*	<ul style="list-style-type: none"> Extensive road building, reshaping, or repair 	<ul style="list-style-type: none"> Completeness allows for extensive changes or repairs

Passes	Disadvantages
2	<ul style="list-style-type: none"> • Doesn't reshape road • Doesn't address problem areas
3*	<ul style="list-style-type: none"> • Requires blading against traffic, generally not recommended
4	<ul style="list-style-type: none"> • Requires more precise machine settings than some other methods • Requires more technical training for operators to achieve precise machine settings
6*	<ul style="list-style-type: none"> • An even more intense method requiring more operator skill, attention to detail, and time • Requires blading against traffic

** Note: The 2- and 4-pass methods are covered in this course and included in this pocket guide.*

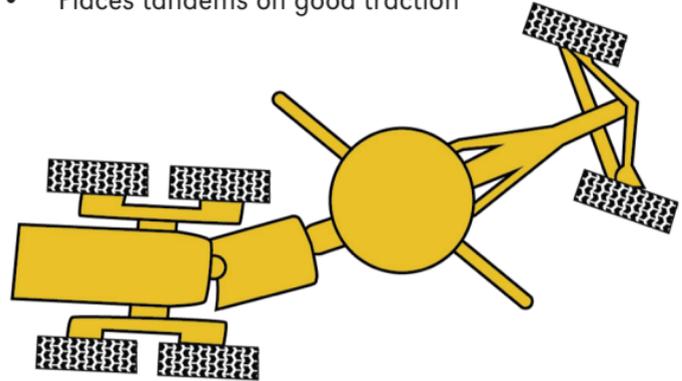
4-Pass Maintenance Method

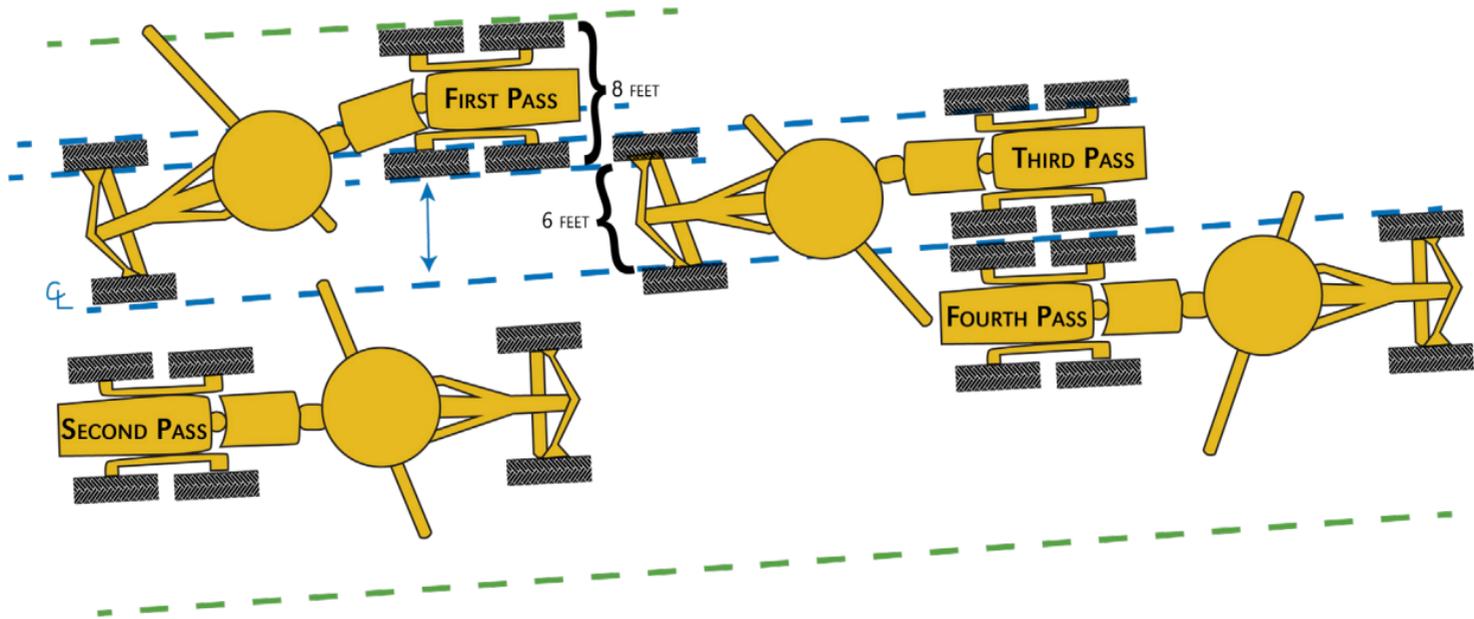
The four-pass maintenance method should be an operator's primary process for maintaining, reshaping, and correcting issues such as potholes or washboards on aggregate roads. The four-pass method is also an appropriate tool for road building.

Machine settings for the four passes are shown on coming pages.

Articulation Advantages:

- Increases ability to stay on a slope and carry a load
- Allows turning in a smaller area
- Places engine frame squarely behind load, counteracting side thrust
- Increases blade reach
- Easier steering when in reverse
- Increases maneuverability when stuck
- Places tandems on good traction





The First Pass

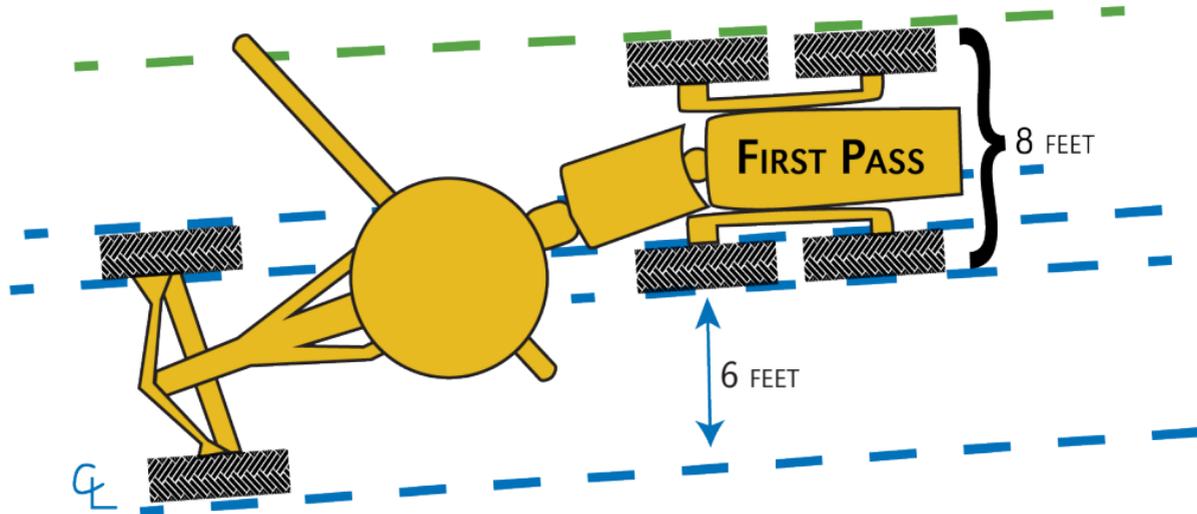
Goal: Pick up the windrow and establish the cross slope.

Set-up:

- Toe–outside right tandems
- Heel–to discharge windrow outside left tandems, riding tight on quarter crown
- Moldboard–shift all the way to the right
- Operating Speed–3rd or 4th gear
- Right front tire set inside left tandems
- Use right left cylinder as “straight” guide

Operation Tip:

Have a target object down the road. Keep that object in the same relative position to the lift cylinder, mirror, or other piece of the grader to serve as a guide to keep the pass straight.



The Second Pass

Goal: Reclaim displaced coarse aggregate to be blended with the windrow.

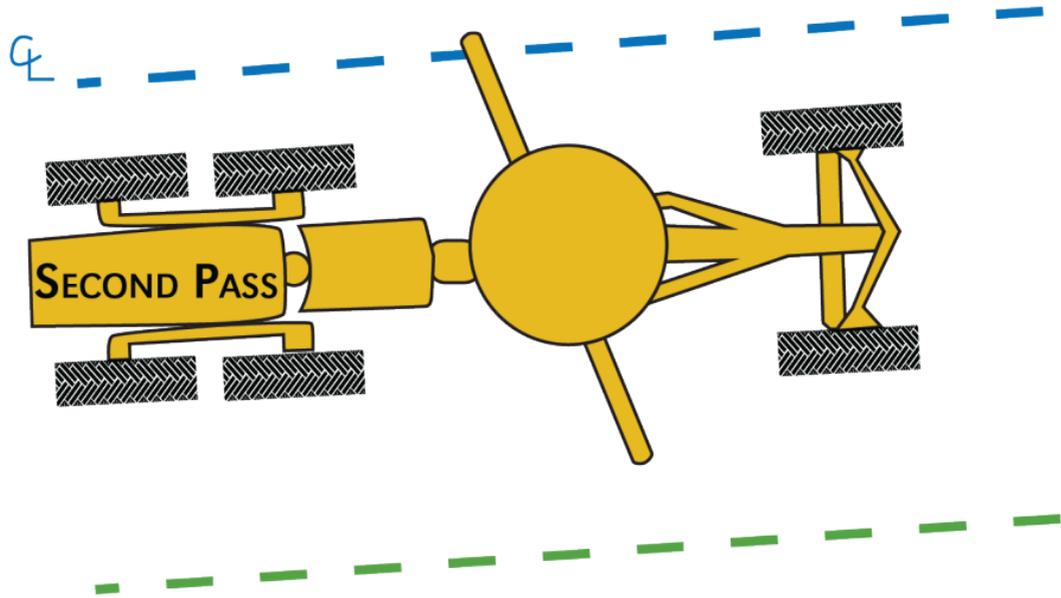
Set-up:

- **Blade Angle:** More square than the first pass to make a wider path and recover material.
- **Speed:** Operate at a speed that maximizes the blending of materials for current road conditions.
- **Articulation:** None. The circle and draw bar should be centered under the machine.

Operation Tips:

- Start with the blade square at the intersection to keep the intersection smooth. Angle the blade slightly to allow for the pickup of coarse material that has been displaced to the edge of the road. Move this material to the center and reincorporate it into the windrow which has the fine materials.

- This pass should also shave any light vegetation that may be growing on the edge of the road.
- Keep a smooth transition from the road to the bridge. Remember that bridges typically have a 2% slope, and the road should have 4% slope. Adjustments will need to be made for this transition. Begin this transition 100 feet from the bridge deck to achieve a gradual transition.



The Third Pass

Goal: Establish centerline crown and blend road surface material.

Set-up:

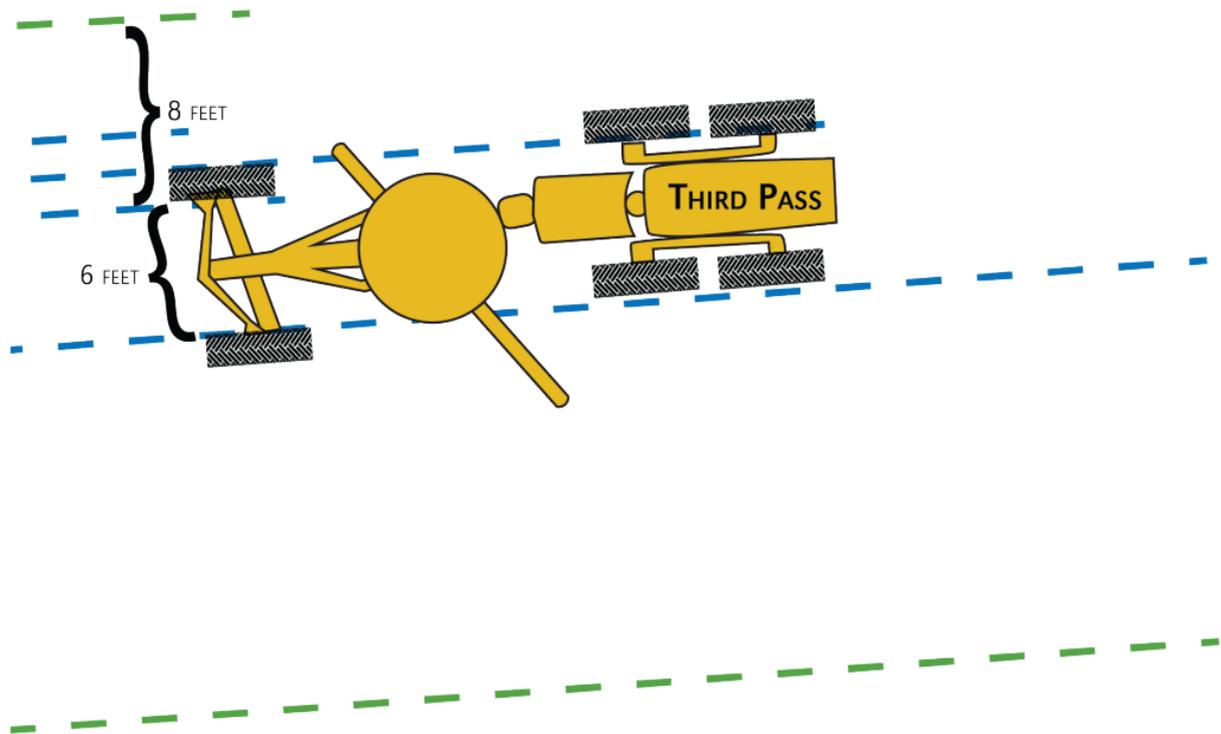
- Blade Angle:
 - The toe should follow the previous cut
 - The heel should establish the grade
 - No material should be lost from the toe
 - Angle will vary depending upon size of windrow, moisture content, material, and roadway width

- Articulation:
 - The machine should be articulated so the left front tire is set just outside the left tandems
 - The left front tire will ride adjacent to the left side of the centerline
 - The left tandems will be set to stay on the right side of the centerline

Operation Tips:

- On a roadway 28 feet wide, the right front tire will follow the tire track from the left tandems on the first pass

- There should be a small gap between the heel of the blade and the surface of the roadway



The Fourth Pass

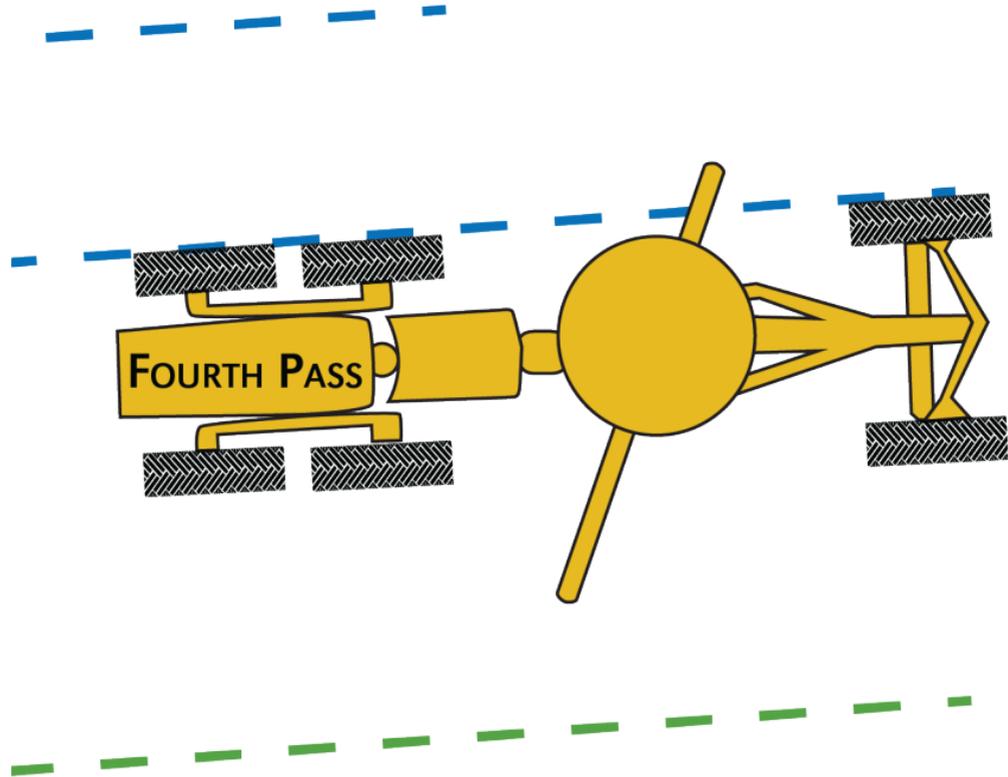
Goal: Further establish the centerline crown, mix aggregate material, and either feather out the aggregate or leave a maintenance windrow.

Set-up:

- The machine should be straight-framed with no articulation
- Circle side shifted to the discharge side
- The moldboard angle should be set to not discharge material off of the toe
- Operating speed should be in third or fourth gear

Operation Tips:

- Operators should see two tire tracks, one on each side of the centerline. One set is from the third pass, and the other is from the fourth pass.
- Use excess material to smother vegetation.



2-Pass Maintenance Method

Goal: Perform light maintenance including distributing material evenly on the roadway and smothering light vegetation.

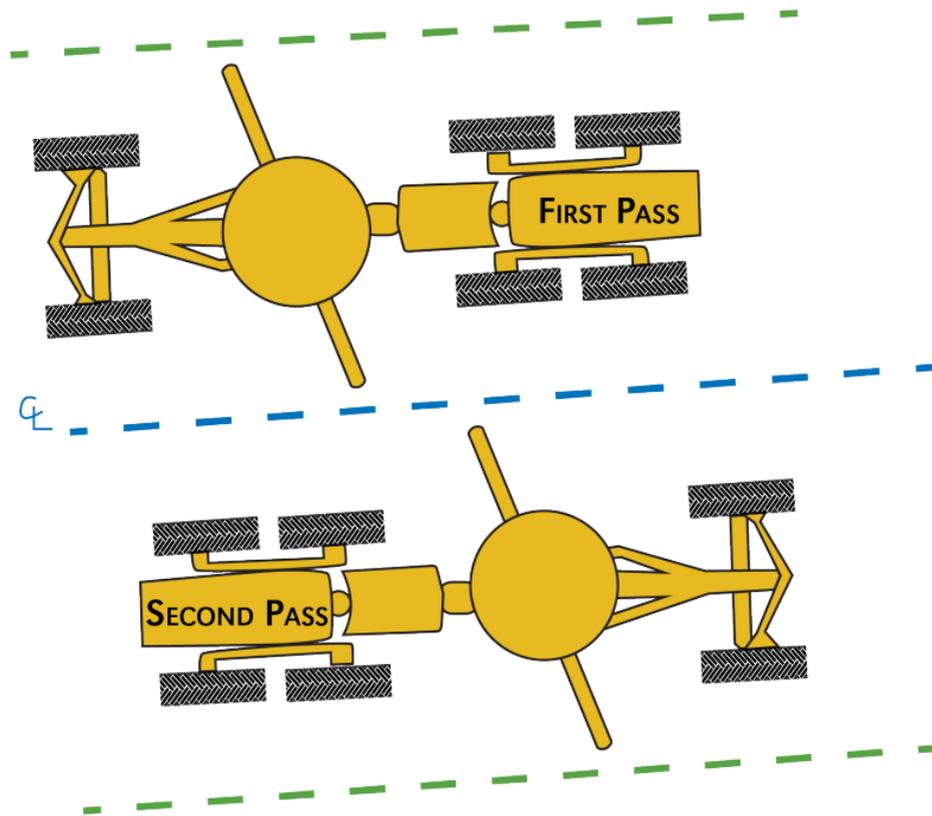
Set-up:

Set-up is like the second pass of the four-pass method.

- **Blade Angle:** More square than the first pass to make a wider path and recover material.
- **Speed:** Operate at a speed that maximizes the blending of materials for current road conditions
- **Articulation:** None. The circle and draw bar should be centered under the machine.

Operation Tip:

- Operators should also complete upkeep on intersections and remove excess material from bridges as a part of this maintenance method.

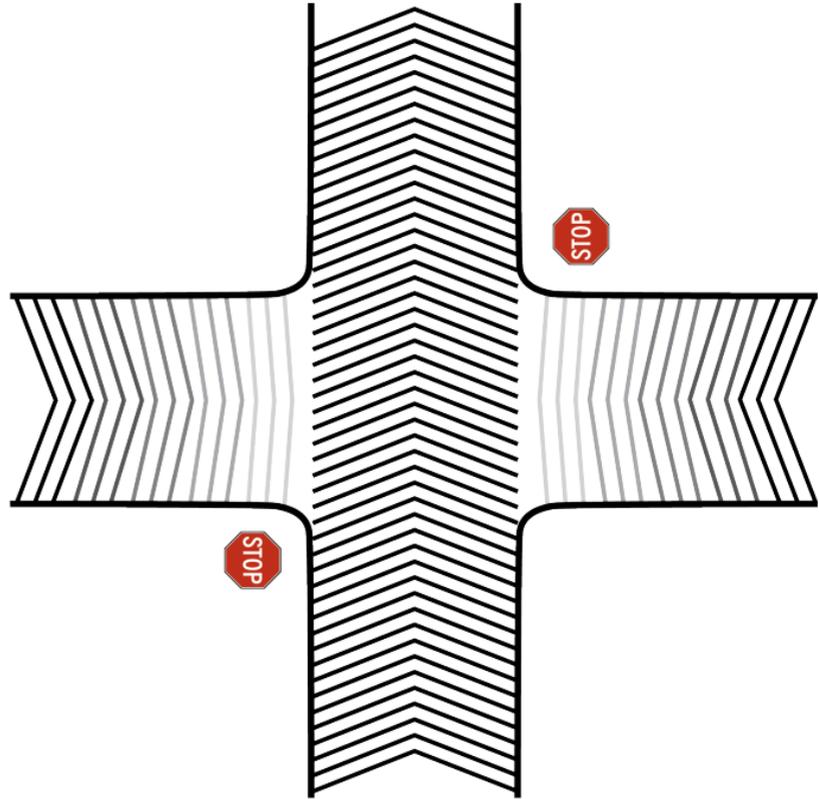


Intersections

Traffic needs to be able to drive through or turn, requiring smooth driving surfaces in many directions.

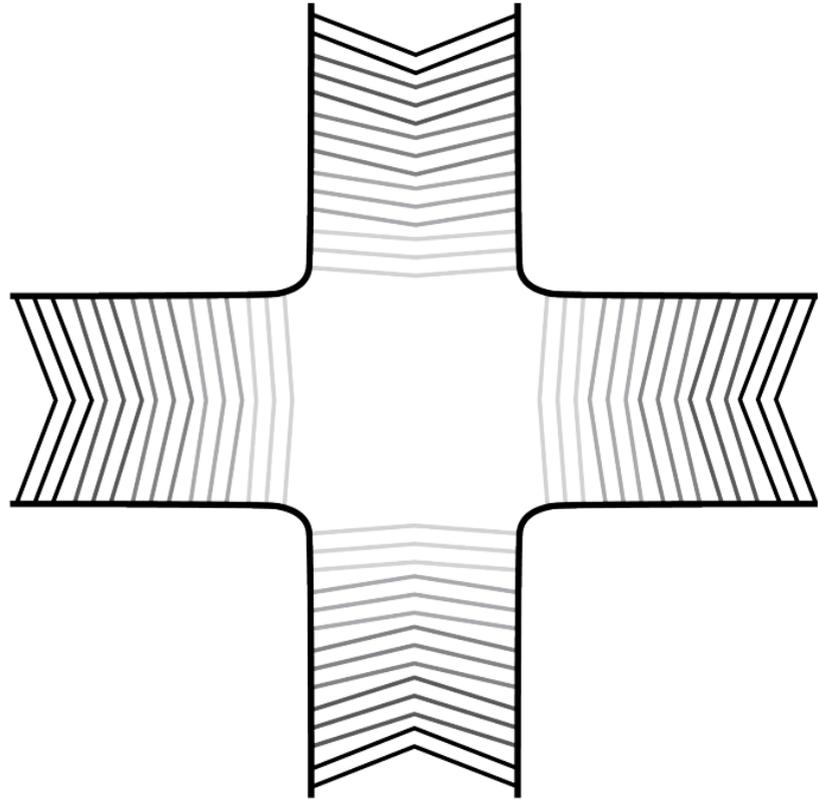
Controlled Intersection

Traffic patterns and sight distance generally determine signage. Maintain the 4% slope through the intersection on the primary road. The approaching roads should be tapered to nearly flat to join with the primary roadway.



Uncontrolled Intersection

The objective is for the approaches to be even from all directions. The intersection should not be flat, but the crown should be less than the standard 4% slope. It is important to maintain at least some slope for drainage.

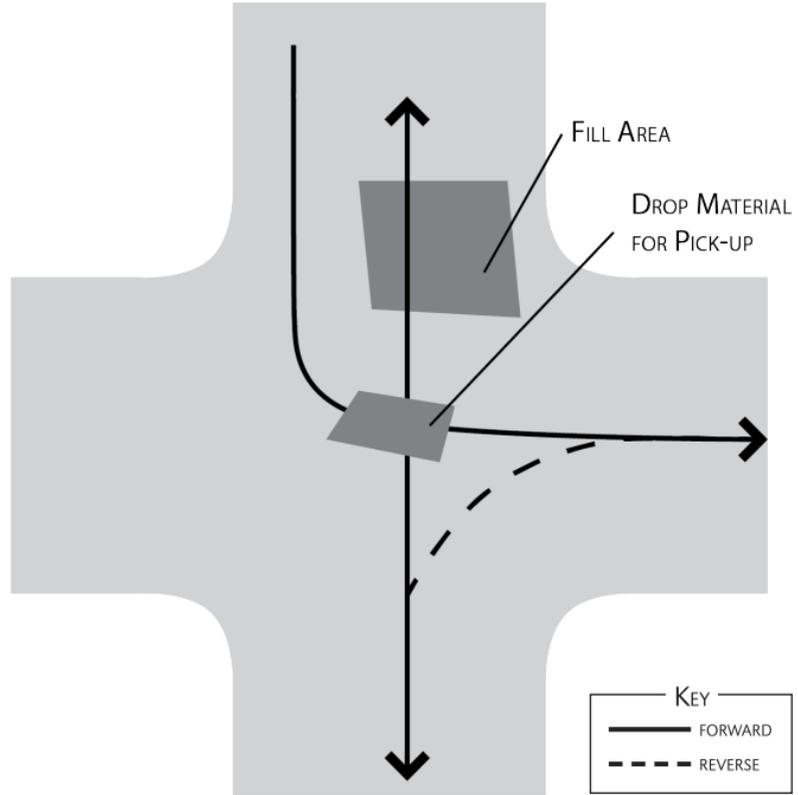


Maintenance Need: Humped Intersection

The approach area may be built up to even out the road surface.

Procedure:

1. Begin by turning toward the right, depositing material in the center of the intersection on the way to be available for the second pass
2. Back up to position the grader for the second pass through the intersection
3. Drive through the intersection picking up excess material left in the center to deposit in the fill area to make a smooth transition



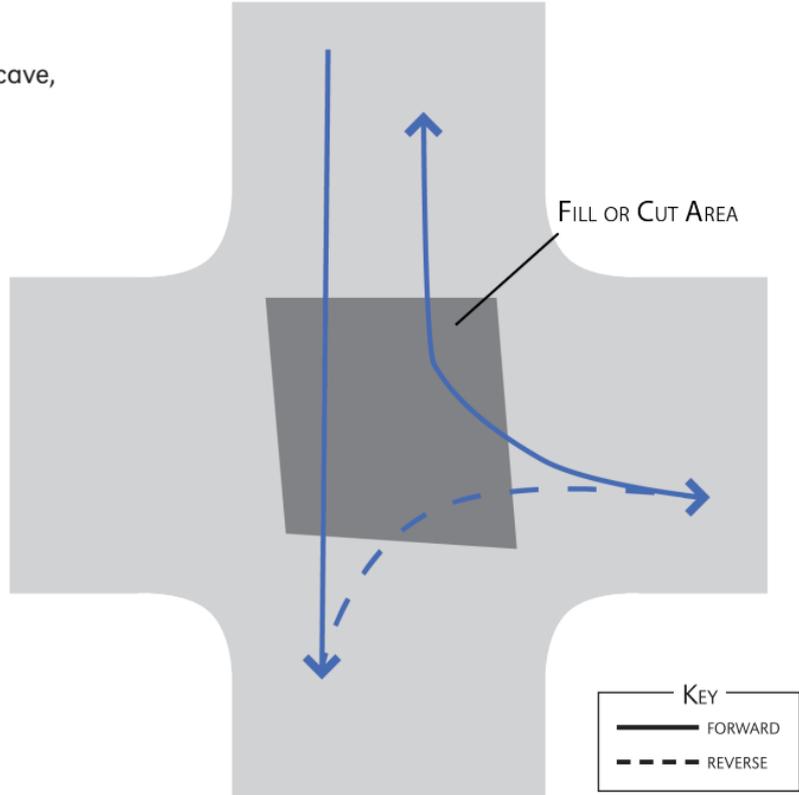
Maintenance Need: Low or High Spot in the Middle of the Intersection

The center of an intersection can be too flat or concave, creating an area where water collects.

Cut or fill as the roadway needs.

Procedure:

1. Drive through the intersection, cutting or filling as needed
2. Back up to the right
3. Turn right to proceed back through the intersection, cutting or filling as needed

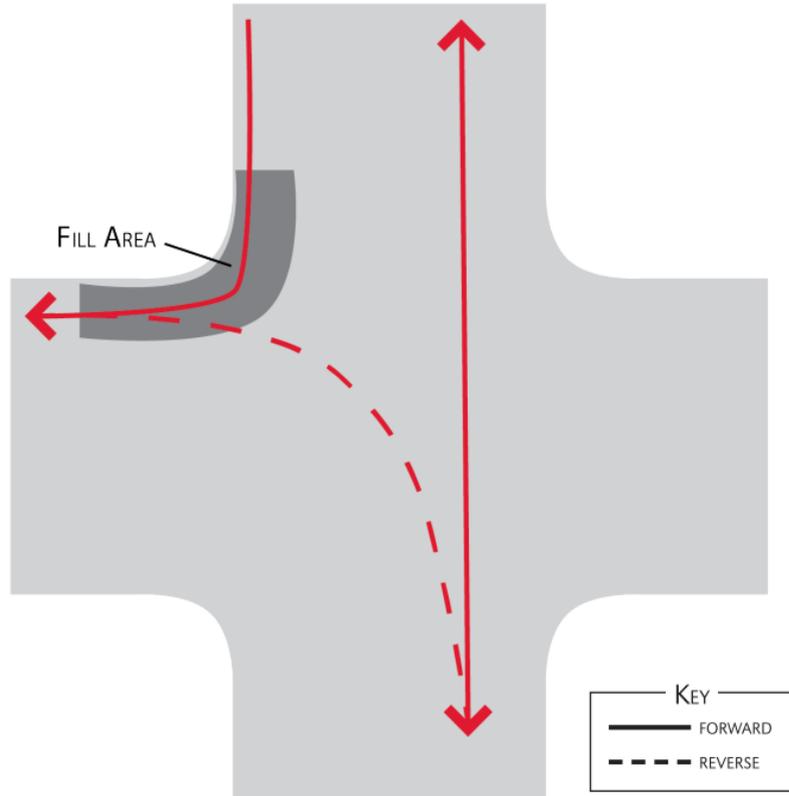


Maintenance Need: Low outside Radius

When the edge of the intersection curve is lost due to traffic cutting the corner, fill the area to re-establish the edge of the roadway.

Procedure:

1. Drive through the affected area, filling where needed
2. Back up to the left
3. Drive through the intersection for the next pass

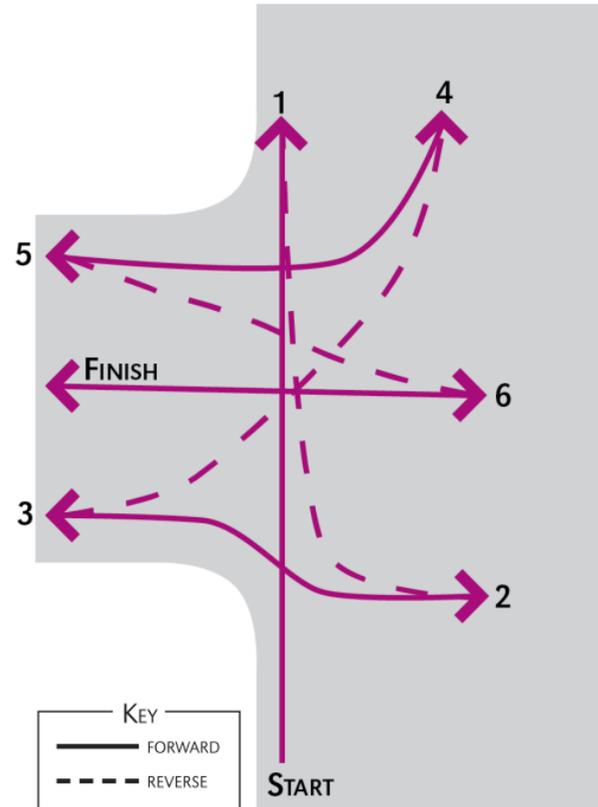


Maintenance Need: “T” Intersections and Driveway Approaches

“T” intersections and driveway approaches are prone to needed reshaping.

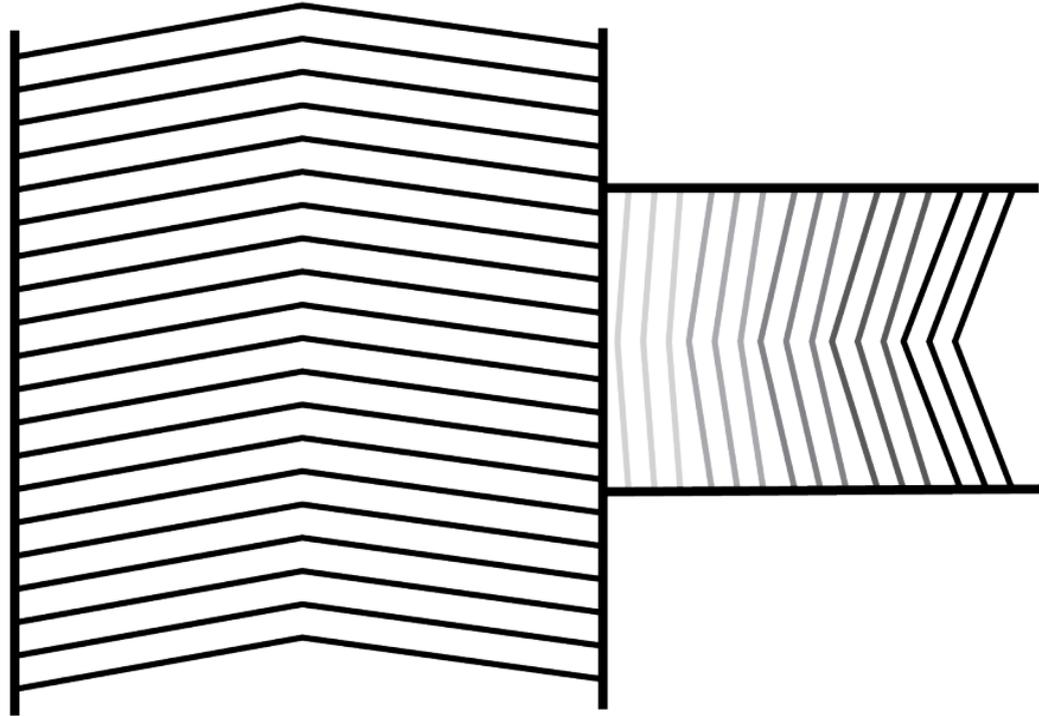
Procedure:

1. Drive through the affected area, filling or cutting where needed
2. Back up to the right
3. Drive through the intersection’s left side, filling or cutting where needed
4. Back up to the right
5. Drive through the intersection’s right side, filling or cutting where needed
6. Back up to the left, aiming for the center of the intersection
7. Drive through the center of the intersection, filling or cutting where needed

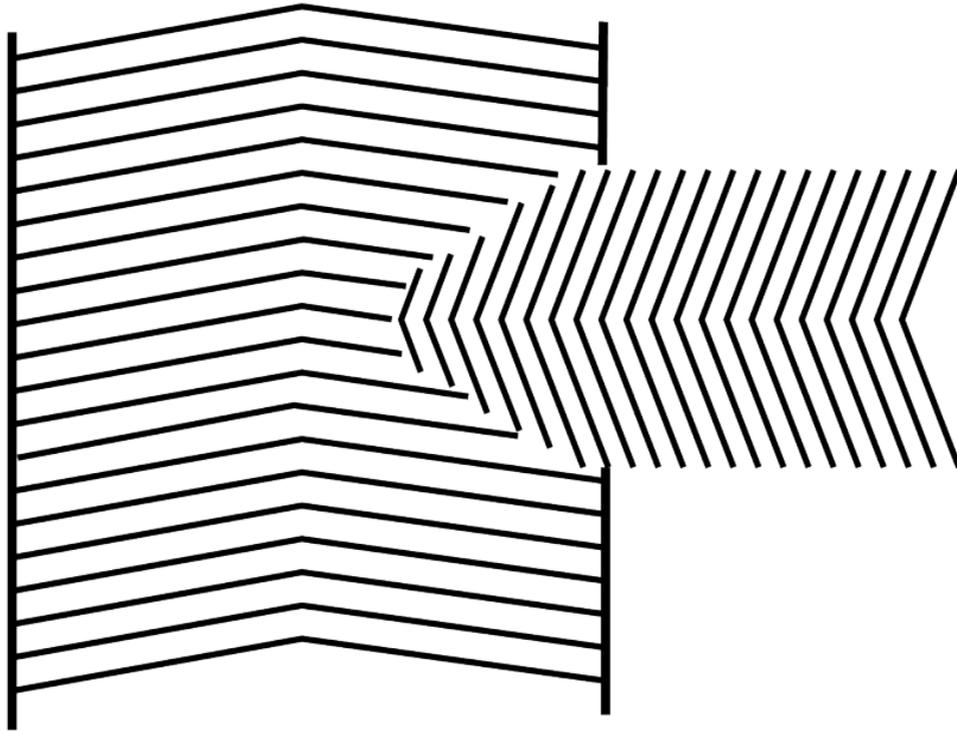


Driveways

The public roadway should maintain its profile past the driveway, as shown in the drawing on the right. Proceed through driveway approaches without modification to the machine settings or procedure.



Preferred road profile for driveways



The image on the left shows the buildup of material in the travel lane. This condition causes road users to veer towards the center of the road.

Not desirable for driveways

Superelevation

Superelevation is the change in the roadway profile in a curve to allow for drainage across the road profile. The elevated edge should be on the outside of the curve, and the lower edge should be on the inside of the curve. This is sometimes called “banking.”

Transition from the normal Modified “A” roadway profile to the superelevation slope gradually.

The amount or degree of superelevation should be determined for each location by an engineer. If site-specific plans are not available, the slope should not exceed 6%.

As traffic travels through the curve, gravel will tend to collect on the upper edge of the curve. It should be re-distributed across the travel lanes.

As vehicles, particularly trucks, cut the curve short, the inside of the curve may creep into the ditch. Maintain the hinge point and ditch profile to prevent the roadway from getting excessively wide.

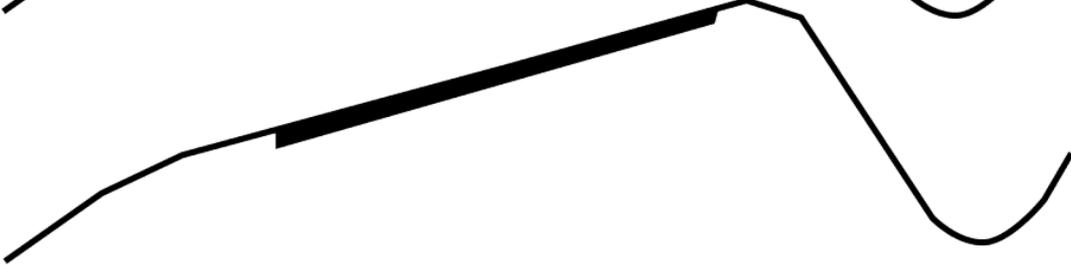
NORMAL CROWN



TRANSITION



SUPERELEVATION



Reclaiming Material

Reclaimed material can help:

- Prevent soft shoulders and wicking
- Re-establish road width, eliminate a berm or lip on the edge of the road
- Reclaim lost aggregate for the roadway surface
- Establish drainage
- Re-establish the road profile
- Replace binder material

Technique

1. Make a marking cut for easier control and straighter ditches
 - Position the toe in line with the outside edge of the front tire.
 - Set the blade for a straight or perpendicular pitch
 - Place the windrow between the tandems
 - Make a 3–6 inch cut with the toe of the blade
2. Continue with the deepening cut
 - Both tandems should be on the foreslope
 - Angle should be set to move the material up the slope
 - The material should be placed outside the tandems
 - Set the heel to place material on the edge of the road
 - After each cut, material should be windrowed away from ditching operations
 - If material is being lost off of the toe, adjust the blade angle
3. After the last cut, the roadway should have a good hinge point to allow water to drain and a recoverable foreslope for roadway departures

Shoulder Maintenance

Shoulders of paved roads can be maintained with the motor grader. Like aggregate roads, paved roads need good drainage. Wicking under the pavement can reduce the lifespan of the pavement or cause costly repairs.

Additionally, shoulder maintenance should repair areas where a shoulder drop-off has developed. Pavement drop-offs can cause rollovers as drivers who have left the roadway try to return. Providing a gentle foreslope also contributes greatly to making roadway departures safer.

For all shoulder work on paved roadways, appropriate temporary traffic control should be in place.

Shoulder maintenance involves three types of work: reshaping existing material, adding material to raise low shoulders, or removing material to lower high shoulders. For all types, operators should start with a straight-framed machine set as in the second pass or two-pass maintenance method. The blade should be at a sharper angle if more material is being moved.

Reshaping: Material is readily available

1. Blade shoulder and place windrow at the edge of the pavement
2. Spread material back across shoulder at the proper slope
3. Compact the shoulder with the grader

Raising a low shoulder: Bringing in material

1. Till or scarify existing shoulder material
2. Place material in low areas of the shoulder
3. Spread material to the rough grade level
4. Fine grade the shoulder
5. Compact the shoulder material

Lowering a high shoulder: Removing excess material

1. Cut high spots on shoulders
2. Pick up excess material and haul away

IOWA STATE
UNIVERSITY

Institute for
Transportation

iowaltap.iastate.edu

