



## Cat<sup>®</sup> Motor Grader Application Guide



# M Series Application Guide

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The motor grader is one of the most versatile earthmoving machines in use today. Its weight, horsepower, wide range of attachments, and maneuverability allow it to be used in many applications previously considered as work for other earthmoving machines. The number of uses to which the motor grader can be put is usually limited only by the operator's skill and experience. Motor graders work in a wide range of applications, from close tolerance finish grading to building a road start-to-finish.

A high percentage of motor graders are used in road maintenance, repair, rebuilding or snow removal work on provincial, and township roads. The main portion of this release is directed toward these applications, but some contractor applications are also covered. We will cover many applications and explain a normally accepted way of accomplishing the tasks. Varying conditions and soils may require modification of the methods described.

## N O T E

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**This guide does not replace the Operating & Maintenance Manual (OMM) that comes with every Cat Motor Grader. It is vital that you study and understand the OMM before operating any equipment. Safety must always be your number one concern. Before starting any work, make sure you understand the job requirements, your machine, and its limitations. Make sure the machine, any attachments and cutting edges have been properly maintained and the tires are at proper air pressure.**

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# Explanation of Motor Grader Terms

To understand motor grader applications we must first understand common terms used to describe the machine and its work area. **Figures 1 & 2** show machine components, **Figure 3** shows articulation modes, **Figure 4** shows Linkbar modes, and **Figure 5** and **Figure 6** show road cross sections.

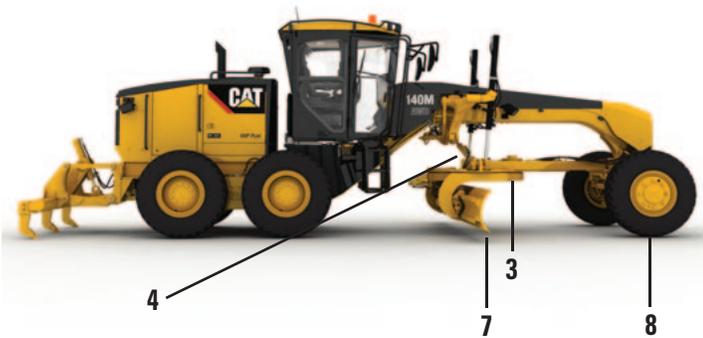


Figure 1.



Figure 2.

1. **Toe of moldboard.** Leading end — in relation to the direction of travel. Generally the moldboard end closest to the front tires.
2. **Heel of moldboard.** Trailing end — in relation to the direction of travel. Generally the moldboard end closest to the tandem tires.
3. **Circle turn.** Allows the circle and moldboard to be rotated 360 degrees to match the moldboard angle to the material or application. Moldboard angle is important: it allows material to roll along the moldboard and increase motor grader productivity. Normally a motor grader moves material across the area being graded, not straight ahead. It requires less horsepower to move material if it rolls across and off the moldboard and is not bulldozed. To accomplish this requires the use of several features at the same time such as the circle turn, drawbar sideshift and moldboard tip.

(An adjustable slip clutch protects the circle drive system from high horizontal forces in severe applications.)

4. **Circle centershift/Drawbar sideshift.** These cylinders allow the circle and drawbar to be sideshifted in relation to the main frame. It allows positioning the moldboard for special applications such as high bank sloping, maximum side reach, and to obtain desired cutting angles for proper material flow off the moldboard. It can also be used to increase visibility to the heel of the moldboard.
5. **Moldboard cutting angles.** The moldboard is considered to be at 0 degree angle when it is at a right angle to the main frame. This position would normally be used for bulldozing material straight ahead for short distances.

Lower angles of 10 to 30 degrees are normally used in light, free flowing material. Higher moldboard angles of 30 to 50 degrees are required when processing wet-sticky material, mixing large windrows, ditching and many other applications. Most motor grader work is done at moldboard angles of 10 to 45 degrees.

To maintain a similar material flow off the moldboard requires the use of a steeper blade angle when working material uphill, and reduced blade angle when working material downhill.

**6. Moldboard sideshift.** This arrangement allows the moldboard to be sideshifted in relation to the circle assembly to increase side reach, to work around stationary objects, and for many other uses.

**7. Moldboard tip.** *This is a very important feature:* its proper use will increase machine productivity, increase cutting edge life and could prevent machine damage.

The top of moldboard can be tipped ahead of or behind the cutting edge. This helps position the cutting edge at its proper angle to obtain the desired material cutting and rolling action. Maintaining a rolling action on the material while working will reduce horsepower required and provide maximum productivity.

Normally start with the moldboard top positioned approximately 2 inches (5 centimeters) ahead of the cutting edge. From this position, tip the moldboard forward or back to obtain and maintain the desired cutting-rolling action. Tipping the moldboard forward will increase moldboard throat clearance (distance between the top of the moldboard and the bottom of the circle).

Generally, a wider throat opening allows better material flow along the moldboard in all soil types. Material buildup into the circle area may increase circle wear. It can also stop material rolling action and cause it to be bulldozed. Bulldozing material requires more horsepower, more traction, and reduces motor grader productivity.

To cut hard material or for finishing work, tip the moldboard further forward than the start position. When finishing, tip the moldboard top 4 to 5 inches (10.2 to 12.7 centimeters) ahead of the cutting edge so the cutting edge is approximately 90 degrees to the cut surface. This moldboard tip position will generally position the drawbar parallel to the finished grade. When the drawbar is parallel to the finished grade, circling the moldboard will have little effect on the cross slope being cut. The amount of tip required will change slightly depending on the machine, tire size, cutting edge size (6 or 8 inch [15.2 or 20.3 centimeters]) and if cutting edges are new or worn.

Tipping the moldboard forward or back will change cut depth or blade height off the ground across the entire moldboard length. The tip control, for example, can be used to raise both ends of the moldboard for feathering material at the end of a cutting pass or for increasing cut depth over the entire moldboard length by use of a single control.

Cutting high bank slopes or deep ditches requires more forward tip on the moldboard to obtain the proper cutting-edge-to-material contact. Attempting to cut with the moldboard in the full rear position in these applications, or with worn cutting edges, could result in difficulty penetrating and cutting the material.

## N O T E

**Use caution when working with the moldboard at full back tilt. Damage can occur to the moldboard tip pivots, cutting edge attachment bolts and support area for the cutting edge. This may cause a reduction in cutting edge support.**

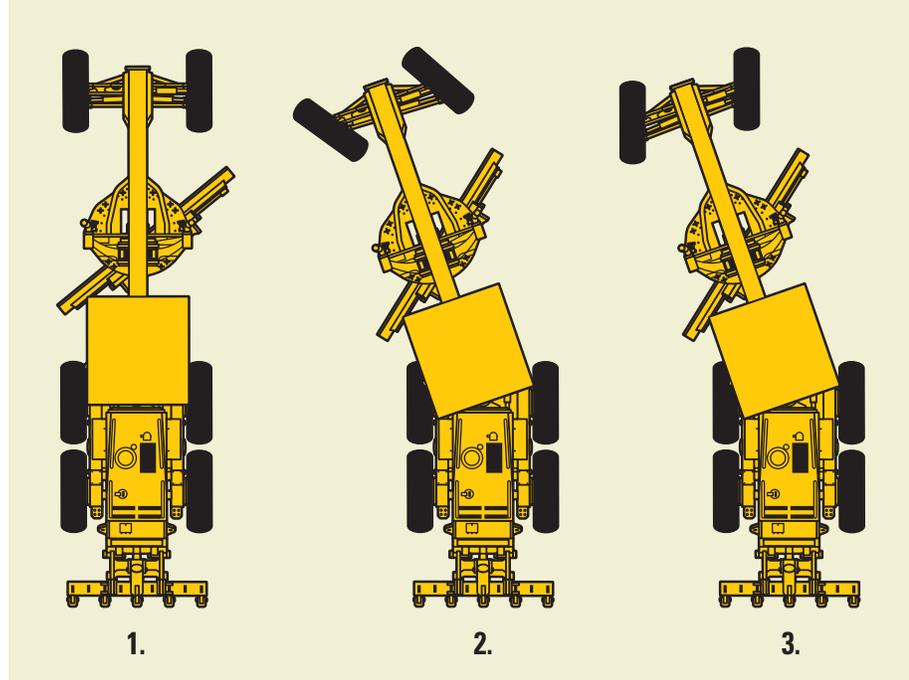
For maximum cutting edge life in road maintenance work, maintain a near constant tip angle. Frequent changes to tip position in this application result in accelerated cutting edge wear.

In general, tip the moldboard rearward for heavy clays and cutting packed snow or thick ice, after first penetrating the material with the moldboard tipped forward.

In snow removal work, tip the moldboard so the cutting edges are approximately 90 degrees to the work surface. This allows the moldboard to slide over the road surface with less damage TO THE ROAD and over many obstructions without damage to the machine.

**8. Front wheel lean.** Allows the front wheels to be leaned against the side draft caused by the angled moldboard. The top of the front wheels are normally leaned in the direction the material comes off the moldboard. Front wheel lean is used to keep the front wheels from sliding off the desired line, to shorten turn radius, and to reduce front sliding on slopes or in turns. It allows setting the front wheels in a vertical position when working slopes or ditches for better steering control. When cutting ditches, lean the top of the tires toward the top of the ditch (toward the centerline of the road) to help prevent sidewall and bead seating damage. When working a side slope and using articulation, lean the wheels down the slope. This technique can prevent the front axle oscillation from reaching its limit.

Using this control allows the operator to make slight steering corrections in finishing and other applications. It also allows varying the cut depth of the moldboard, and increases slope angle capability when cutting high or ditch back slopes.



**Figure 3. Modes of Operation**  
 1. Straight Frame, 2. Articulated Frame, 3. Crab Mode

## Frame Articulation

Caterpillar designed articulation with the strength needed to make it a working tool much like the moldboard tip or side shift. When used properly, this important feature can broaden a motor grader's application range and increase productivity. This release offers suggestions on using articulation, but you are encouraged to use it and determine your own uses.

Keep your operations simple. Complicated maneuvers just to use articulation seldom improve machine productivity.

All articulated modes reduce the need for additional equipment at the job site. Articulation helps the motor grader quickly and easily do jobs a rigid frame unit could not do or would have difficulty doing.

### Modes of Operation

#### Straight Frame

- Only front steering is used.
- This configuration is used by most operators.
- Front steer angle is 50 degrees left or right for maximum productivity even when articulated frame is not used.



**Center Hole**



**First and Second Hole from Center**



**Third Hole from Center**

**Figure 4. Modes of Operation**

- Normally used for long straight blading passes, most finishing, light to medium windrows, ditch cutting, ripping and scarifier work.

### **Articulated Frame**

- Use front steering and frame steering as required.
- Articulated frame gives the shortest turn radius for close quarter work, cul-de-sacs or corners.
- Improves maneuverability in all applications.
- Used to counter side draft from large windrows-blade loads, to change cutting width of the moldboard and reduce blade loads without use of the circle.
- Allows steering the leading end when reversing or in tight quarters for more control and safety.

### **Crab Steer**

- Front wheels and rear frame travel in same direction.
- Increased side slope capability, allows off setting tandems away from edge fill for safety or to prevent road shoulder rutting.
- Used to level truck dumped material without running front of machine over pile.
- Keeps the entire machine on a smooth surface allowing faster finishing of the area.
- Used for large windrows.
- Articulation can prevent a machine from getting stuck and helps remove it should this occur.

## **Linkbar**

The centershift linkbar is designed to increase moldboard positioning and reach from the centerline of the machine. Repositioning the linkbar will increase the motor grader's productivity when ditching, backsloping and moving large windrows.

Cutting/cleaning ditches and backslopes when using the linkbar gives the ability to keep the mainframe running on a level surface at the top of the ditch or base of the slope while the moldboard cuts a slope beside the machine.

When moving large windrows with the linkbar repositioned either side of center, it is possible to run extremely steep moldboard angles and maintain adequate clearance between the moldboard and front tandem tires. This position also helps visibility to the toe and heel when operating with steep moldboard angles.

## **Modes of Operation**

### **Center Hole**

- This position is used for long straight blading passes, most finishing, and light to medium windrows.

## ***First and Second Hole From Center***

- This position is used for cleaning shallow ditches.
- Processing and moving large windrows.
- Used with articulation to build narrow flat bottom ditches and backfill curb radiuses.

## ***Third Hole From Center***

- This position is used for cutting ditch back slopes and high bank slopes.
- Cleaning deep ditches.
- Grading and dressing fill slopes.
- Disposing of sod and oversize rock on backslopes.
- Use with articulation to grade on steep slopes.

There are two recommended techniques for repositioning the linkbar. The first technique is for repositioning to the first or second hole either side of center. The second technique is for repositioning to the third or farthest hole from center. Assume the ditch or slope to be worked is to your right.

1. To reposition to the first or second hole either side of center, shift the drawbar/circle assembly to its maximum position towards the ditch/slope to be graded. Ground the moldboard by placing both lift cylinders in the float position. With the moldboard grounded, release the centershift lock pin with the toggle switch. When the light on the front console is illuminated, the pin is retracted.

With the lift cylinders still in the float position, move the centershift away from the ditch/slope to be graded. Example: If the centershift was moved to the right before grounding the moldboard and pulling the pin, now move the centershift to the left.

As the centershift cylinder is either retracted or extended (depending on the direction the linkage is being moved), the linkage will roll around freely moving the linkbar sideways. Line up the hole using the gauge on the back of the right lift-cylinder mount. Insert the pin with the toggle switch. When the light on the console goes out, the pin is in. Now sideshift the drawbar towards the slope to be cut and use the lift cylinders to adjust the slope angle to be cut.

2. To reposition to the third or farthest hole from center, start with the same procedures as listed above to release the pin. Once the pin is released take the lift cylinders out of float. Simultaneously lower the right end of the blade, move the center shift to the left and raise the left end of the blade. This will allow the linkbar to move into the third hole position.

# Road Cross Section Terms

Much of today's motor grader work involves the maintenance, snow clearing, and building county/township type roads. This includes smoothing, shaping the travel surface, and providing drainage to prevent road deterioration in inclement weather.

Keep in mind, the most important item in road maintenance is providing and maintaining a good drainage system.

The diagram below shows the cross section of a typical road and the terms used to describe each component.

1. **Road Width.** Normally 8 to 12 feet (2.4 to 3.7 meters) wide per vehicle lane but will vary depending on the width of the road right of way (ROW). Where the ROW is available, county road width including shoulders will be between 26 and 30 feet (7.9 and 9.1 meters) wide.
2. **Road Shoulder.** Normally 1 to 8 feet (0.3 to 2.4 meters) wide depending on the type of road being constructed.
3. **Road Crown.**  $\frac{1}{4}$  to  $\frac{1}{2}$  inch raise per foot (0.6 to 1.3 centimeter raise per meter) from the shoulder to the center of the road. This will vary with the type of wear surface used and annual rainfall expected.
4. **Travel Wear Surface.** Varies with geographic location and the type of road being constructed. The material can be dirt, gravel, crushed rock, asphalt or concrete.
5. **Road Ditch Slope.** This slope will vary depending on the type of road being constructed, the material type, ditch depth, and width of ROW. Whenever possible, keep ditch slopes flatter than 2:1. (In some geographic areas this is known as the fore slope or road shoulder slope.)

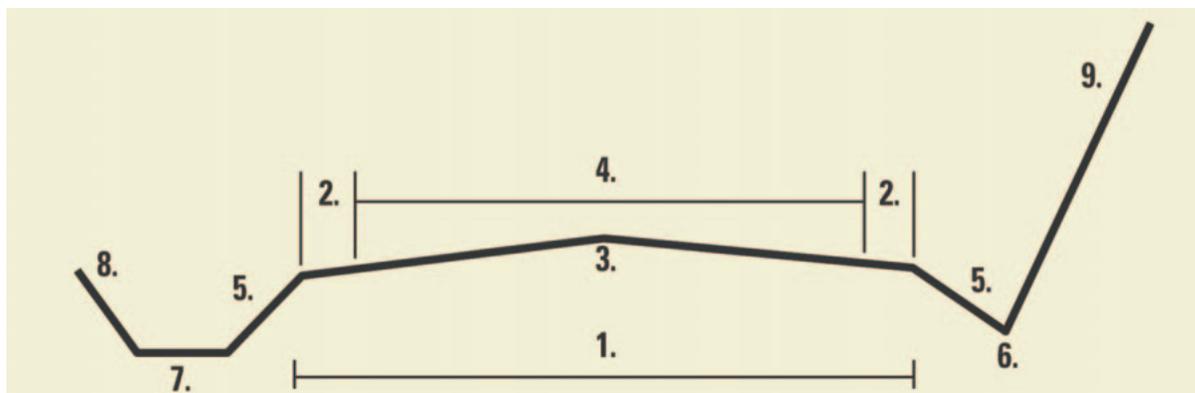


Figure 5. *Crowned Cross Section — Straightaway*

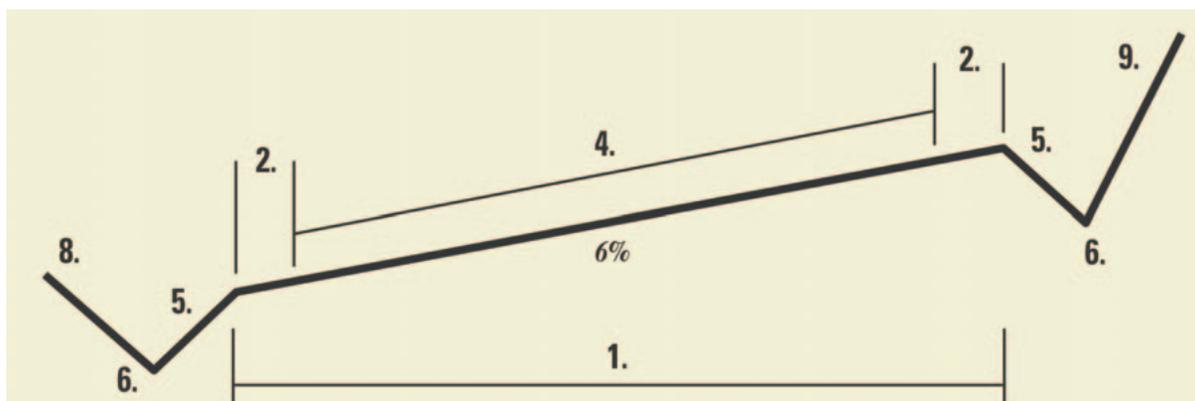


Figure 6. *Super Elevation Cross Section — Curves*

# Road Maintenance Tips

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6. **Vee Ditch.** This is the most common ditch used in road construction. Its depth and slopes vary depending on the same factors as above, but in general this type of ditch should be at least 2 feet (0.6 meters) lower than the road travel surface to provide adequate drainage. A vee ditch should be designed to move water away from the road surface as quickly as possible. Standing water will seep into the road structure and weaken or damage it.
7. **Flat Bottom Ditch.** This type of ditch is used where large amounts of rain or snow fall and where extra material is needed to raise the road height. The flat bottom ditch requires a wider road ROW be available. The ditch bottom width depends on the amount of rainfall expected, soil type or amount of material needed to raise the road surface to its desired height.
8. **Backslope.** This slope will vary depending on many of the same factors found in ditching and bank sloping. Normally the backslope will be steeper in rocky areas and flatter in unstable material. In areas of high snowfall the backslope should be kept as flat as possible to allow storage for the snow and to reduce snow drifting.
9. **High Bank Slope.** This application is similar to ditch back sloping.
10. **General.** In areas of high annual rain or snowfall, raise the road travel surface high enough to prevent water from seeping under the road and being pumped to the surface by traffic, which leads to surface damage. This raised elevation allows snow to blow off the road, reduce drifting and the amount of plowing required.

The wear surface of many county/township roads are asphalt or other hard surfaces, but gravel, crushed rock, sand or native soils is still prevalent in many areas. Traffic forms ruts by displacing this material onto the shoulder or ditch slope. A rippled surface called washboarding forms at stop signs, hills, in turns and in areas of acceleration or braking. Snow plowing operations and weather also displace this cover material.

For best results dress the road when moisture is present: after a rain or after the road has been sprayed by a water wagon.

Maintain straight cutting edges by trimming them with a torch or, if wear is not severe, by dragging the cutting edges on a smooth concrete surface. Replace edges before wear occurs on the bottom of the moldboard and reduces cutting edge support.

Shape the road crown and cut lightly in the spring or when moisture is present. Drag the surface when hard and dry, with the cutting edge near 90 degrees to the surface.

Cut to the depth of major potholes. Don't fill these holes with loose dry material, because traffic will quickly displace the loose material and the holes will reform.

Maintenance work is normally done with the centershift lock pin in the center position, and the drawbar and circle centered under the mainframe.

For maximum machine stability, the mainframe should be straight or articulated only slightly. Articulating the rear frame toward the toe of the moldboard approximately 2 to 5 degrees (1 to 1.5 times the width of the tire) will frequently help reduce the machine's tendency to bounce.

Start with the moldboard top 2 inches (5.1 centimeters) ahead of the cutting edge. Then adjust to the material and conditions.

Use of full rear tip could cause material penetration problems and damage the moldboard bottom or pivot area, especially if the cutting edges are worn.

Use only enough down pressure to accomplish the task. Excessive down pressure on a hard dry surface causes rapid cutting edge wear, requires more horsepower and fuel, and reduces productivity. Sliding and tire spinning increases front and rear tire wear. In extreme cases, excessive down pressure may cause the cutting edges to splinter, which could cause tire damage.

In road maintenance, cutting edges will wear quicker in the center than at the ends. Three section edges are sometimes used: carbide edges in the center, hardened edges at the ends. Check edge wear frequently to prevent moldboard damage.

## To Extend Cutting Edge Life in Road Maintenance, Maintain a Constant Tip Position

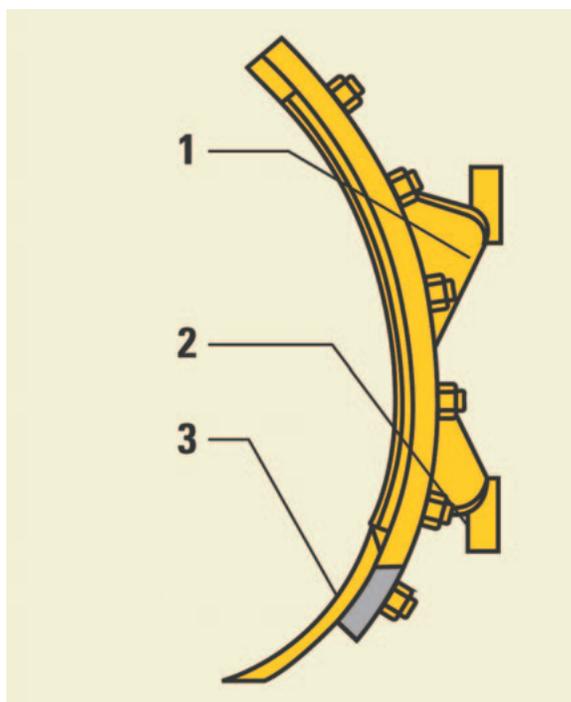


*Side view of moldboard cutting edge*  
1. Footprint

The cutting edge tip angle can effect edge life when maintaining roads.

The tip angle should position the cutting edge at 90 degrees to the road surface. In this position, down pressure on the moldboard places less stress on the cutting edge and retaining bolts. The edges will have a tendency to ride over objects possibly preventing machine damage.

The fixed tip angle presents a constant edge thickness to the wear surface for longer life. If you change the tip angle often in this application, the sharpened edge will wear quickly, shortening its life.



*Cross section of moldboard cutting edge*  
1. M Section Reinforcement, 2. Slide Rails, 3. Cutting Edge

New moldboards are designed to give support to cutting edges. To maintain this support, the edges must be replaced before wear occurs on the bottom edge of the moldboard (shown in gray at bottom of illustration.) Wear in this area reduces cutting edge support.

Bent ends of the moldboard also reduces edge support. Repair damage before installing new edges.

Cutting edges have good support in the forward direction, but **use caution when back dragging material or backing up with the moldboard close to the ground.** A broken cutting edge could result.

For long life in road maintenance, use the thickest edges that allow you to do the job. In hard material if you use excessive down pressure, the machine's front end appears light. If penetration is a problem use thinner cutting edges, a serrated edge or a scarifier to loosen the material.

Cutting edges with carbide tipped replaceable teeth are offered by several manufacturers. They generally give longer life than standard hardened edges. The Cat GraderBits™ System provides four types of tips: **standard**, **wide**, **penetration** and **sharp**. The teeth can be individually replaced or repositioned for wear. They can be placed in a solid or serrated configuration depending on job needs.



**Standard bits** are used on larger units where penetration is not a problem but the material is abrasive.

A **wide bit** is used on each end of the standard arrangement. Use of all wide bits supplies a continuous edge. (Note wide bit in photo.)

**Penetration bits** are used on mid sized graders and where penetration is a problem.

**Sharp bits** are used on smaller motor graders and where penetration is a problem.

Bit types can be mixed to customize the edge to material or conditions.

Cutting edge condition is very important for keeping the proper road profile. Cutting edges are a major expense in this application, so check their condition frequently.

## Know Your Job's Cutting Edge Requirements and Select the Proper Type for Your Conditions

For the best machine stability in road maintenance, use the widest possible pass width. Keep the moldboard angle as square to the frame as possible. If material starts to flow around the leading end of the moldboard, increase the blade angle.

Keep machine travel speed as high as possible for maximum productivity but low enough to prevent machine bounce.

The cutting width of a pass will depend on the length of the moldboard and the moldboard angle used. This chart shows the width of coverage for different length moldboards and several blade angles.

### M O L D B O A R D L E N G T H

	12 Foot 3.7 meters	14 Foot 4.3 meters	16 Foot 4.9 meters
30° blade angle	10.3 ft 3.1 m	12.25 ft 3.7 m	13.7 ft 4.2 m
45° blade angle	8.5 ft 2.6 m	9.9 ft 3 m	11.3 ft 3.4 m

Four passes are normally required to maintain a 28-foot (8.5-meter) wide road (24-foot [7.3 meter] wide traffic lanes with 2-foot [0.6 meter] shoulders).

In this application, on wider roads, blade extensions are frequently used on one or both ends of the moldboard to increase pass width and reduce the number of machine passes required. These extensions are of lighter construction than the parent moldboard.



When backsloping, the extension must be installed on the toe to obtain the heel clearance required.

Caution, using it on the leading end in tough or rocky material may damage the extension.

When two extensions are installed, they should be used only in light maintenance work and will need to be removed for some jobs, as their length restricts blade positioning.

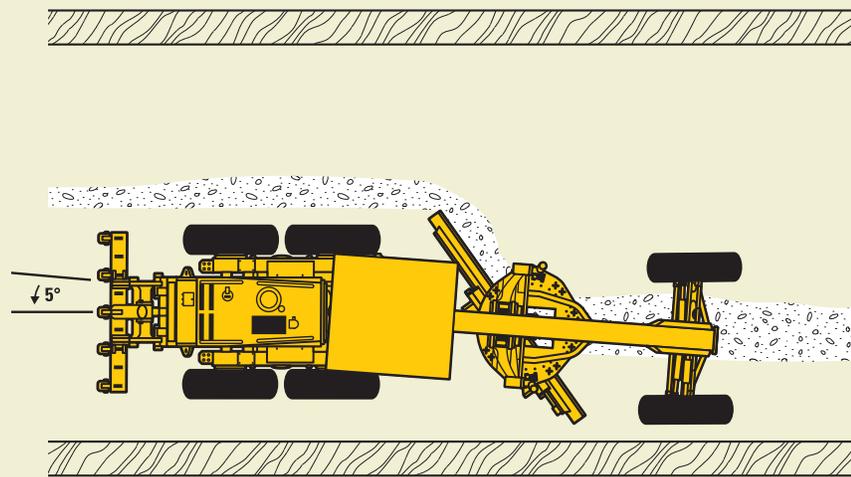
In rocky areas where control of the moldboard is desirable but there is a need to reduce vertical stress into the drawbar, circle and main frame, use a blade cushion arrangement for reduced maintenance and longer circle and drawbar component life.

An important feature in snow plowing or other high impact areas is the circle slip clutch. It will relieve horizontal impacts on the moldboard and circle and can reduce maintenance costs.

# Maintaining Road and Existing Ditches and Shoulders

For maximum machine stability when maintaining the travel surface, the motor grader's main frame should be straight with the drawbar and circle centered under the frame. For the widest possible pass width on the travel surface, keep the moldboard angle as square to the frame as possible. If material starts to flow around the leading end of the moldboard, or the rolling action dies, increase the blade angle. Keep machine travel speed as high as possible for maximum productivity but low enough to prevent machine bounce (4-7 mph [6-11 km/h]). On straight sections, steer the machine as straight as possible to maintain a straight shoulder and uniform crown to the road.

## Maintaining Roads Using Articulation



**Figure 7.** Aerial view of articulating rear frame toward toe of moldboard

Articulating the rear frame the moldboard 2 to 5 degrees frequently reduces the machine's tendency to bounce. This crab mode is extremely effective when cutting washboards from

the travel surface with the moldboard. When the motor grader is in the crab mode, the front axle is no longer running perpendicular to the direction of travel. This places one front tire slightly ahead of the other and allows one tire to be on top of a corrugation while the other is in the bottom. As the tires roll up and down through the washboard, the front axle will pivot up and down keeping the front mainframe stable. The degree of articulation required to make this technique work effectively will vary with the space between corrugations. **CAUTION:** Do not use the crab mode when scarifying washboarded areas. Crab mode could bend the scarifier shanks and/or linkage.

Winter snow plowing operations and traffic in all seasons forces gravel off the road onto the road shoulder and ditch slope. Traffic forces the shoulders to mushroom outward when roads are soft, widening the road. Ditches may require cleaning to restore drainage. Spring road maintenance normally includes repairing these problems.

Use straight or articulated frame for this work. Two examples are:



1. Move the linkbar to its maximum position toward the ditch. Side shift the drawbar to its maximum position.

With the frame in straight mode, position the motor grader on the road shoulder.

Circle the moldboard and side shift it to obtain the desired blade angle and desired reach into the ditch.

Raise the heel of the moldboard to match the ditch slope angle. Move the material up onto the road shoulder or onto the ditch slope as desired.

When the shoulders are soft, using articulation to offset the heavy rear frame away from the shoulder will prevent rutting and trapped water that cause shoulder damage.



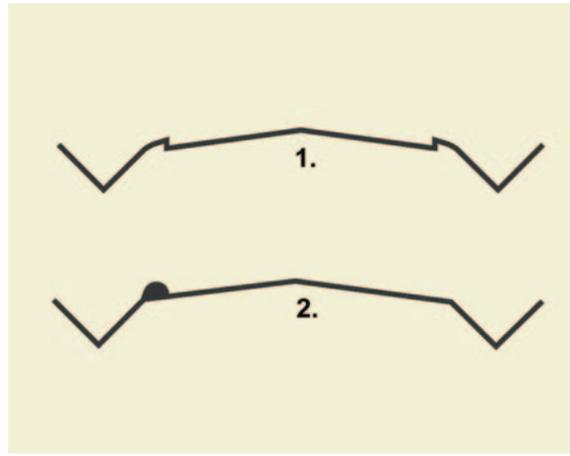
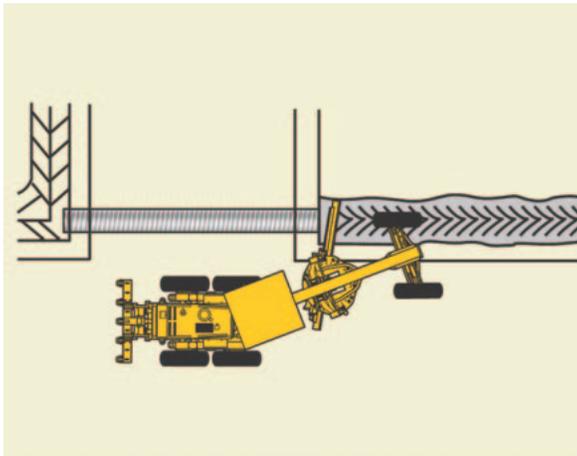
2. Using crab steer will allow running one front wheel in the road ditch or on the road shoulder slope to recover material moved there by traffic or snow plowing. Use crab steer to narrow shoulders, to maintain the desired road width, and to clean wet ditches.

The rear tandems can be kept on the road travel surface away from the shoulder.

Extend the blade into the ditch to open a drainage path. This reduces standing water and possible road damage.

Crab steer can be used to reopen culverts blocked by material. If the ditch bottom is solid, place the front wheels in the ditch with the rear frame on the road travel surface, as shown above. Shift the circle toward the toe of moldboard, with the moldboard square to the mainframe and tipped to nearly two-thirds of its maximum forward tip capability.

Place the moldboard cutting edge into the ditch at the blocked end of the culvert, and set the blade angle to match the shoulder slope. Be careful not to damage the end of culvert.



Move slowly forward to remove the blocking material, then rotate the circle to pull the material up onto the road shoulder. Several short forward-reverse passes may be required to reach the bottom of the culvert. Continue on using one of the ditch cleaning techniques described previously.

In shallow ditches, this operation can also be accomplished with the machine on the road travel surface and the frame straight.

Use the linkbar and blade position shown at the bottom of page 12 (photo illustrating example 1) describing how to recover gravel or narrow the road in springtime repair operations.

It is very important to maintain the proper road crown for drainage. In many cases while maintaining the road surface, operators will cut below the existing shoulders leaving a ridge on each side of the road. In other areas a windrow of material is left on the road shoulder so material is available for the next maintaining pass.

In areas of high rainfall, both practices have an undesirable effect on road life. In most cases they should be avoided for the following reasons.

### *1. Shoulder Undercut, 2. Shoulder Windrow*

1. They block drainage by holding water on the shoulder causing the shoulder to become soft. Cutouts are often provided for drainage, but these require extra time, reducing productivity. Erosion occurs on the shoulder along the windrow and at the cutouts.

Material washed off the road at these cutout points damages shoulders and blocks ditch drainage.

2. If the windrow is not placed as close to the shoulder edge as possible, road travel width is reduced, possibly creating a driving hazard. If the windrow is placed close to the edge, material loss onto the ditch slope occurs. To recover this material, reposition the linkbar.

## **N O T E**

**The windrow of material should be processed and spread across the road evenly with only the oversize rocks or chunks of sod to kick over the slope.**

## Road Surface Washboarding

Washboarding of the road surface is highly undesirable from the standpoint of safety, vehicle ride and washboarding's effect on vehicle longevity.

Washboarding occurs mostly at areas where vehicles brake or accelerate and areas with deep and/or poor gradation of base material.

To remove washboarding, cut the corrugations to their full depth, then regrade the area with moist material that will compact. Corrugations filled with loose, dry material will reform quickly in areas of high vehicle traffic.



Corrugations are best removed by using a scarifier or a serrated type cutting edge (see page 10 photo of serrated edge).

Use these cutting edges to:

- Shape and rejuvenate the road travel surface by remixing the top with new material brought up from below to provide a better gradation of material at the road surface.
- Cut hard roads and areas that would otherwise need to be scarified. The depth of cut in this operation can be better controlled with these cutting edges.



- With a light cutting pass, they can comb rock — displaced by traffic or winter snowplowing — out of shoulder line grass without bringing large amounts of grass or dirt onto the roadway. (Note the right end of the moldboard in the grass on the shoulder.)

Used as a regular practice, this helps road drainage by preventing grass buildup along the road shoulder.

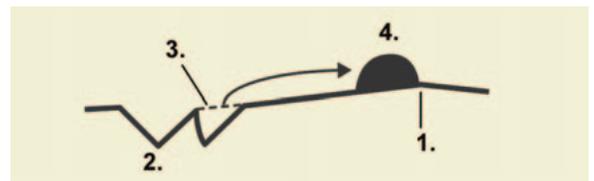
Serrated cutting edges can save you money that otherwise would have to be spent on new gravel. To reduce tooth breakage when using regular serrated edges on gravel roads, use the 6-inch cutting edge with 2-inch serrations.

## Rebuilding/Reshaping Roads and Shoulders

Before starting the actual earthmoving, determine what method will be used to dispose of excess soil and sod.

In areas of heavy sod, mow the ditch area as short as possible and dispose of excess grass to keep volume to a minimum. Disc the sod to break it up and mix it with soil. Then water and spread the mixture over the road surface or transport it to a disposal site.

In some areas a disc arrangement that attaches to the snow wing mast is used as part of the spring shoulder cleanup. This arrangement cuts and mixes the sod with dirt, reducing sod buildup.



1. Road Centerline, 2. Normal Vee Ditch, 3. Secondary Ditch, 4. Material from Secondary Ditch

Another sod disposal method is to cut parallel secondary ditches along the road shoulder and stockpile the excavated material onto the centerline of the road. The sod is then cut and placed into this ditch, wheel rolled and covered with the stockpiled material.

This method provides more area in which to place the sod, provides more cover material, and the road center will be unaffected as the sod decomposes.

The most frequently used method of sod disposal is to cut it, then spread it over the existing roadway to reshape and build up road height.

Cut the sod when moisture is present and cut it as thin as possible to keep down the bulk. When spreading sod, work at a very steep blade angle to reduce bunching and dragging under the cutting edge, which creates holes in the surface. Do not attempt to smooth this layer beyond shaping the road. Then wheel roll it or use a disc and compacting equipment to obtain as much compaction as possible.

When wheel rolling an area with the motor grader, offset the rear to obtain a wider compaction pass. Use material from the ditch and backslope to cover the sod as deeply as possible. Use this material to finish shaping and grading the road to its desired dimensions.

In many cases sod and other material will be brought onto the road surface windrowed, then loaded out and transported to a waste area.

In areas where small amounts of sod must be moved and sufficient space is available on the ROW (right of way), the sod can be deposited on the road backslope or, in some cases, moved completely off the ROW.

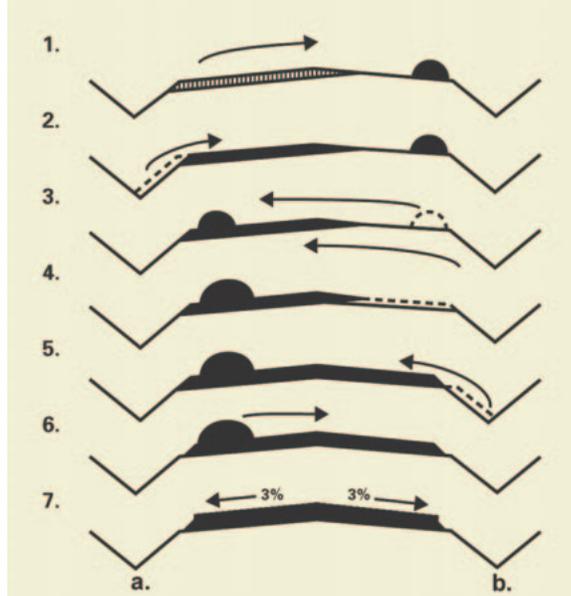
On narrow ROWs where the motor grader cannot operate on the backslope, use the high bank position to place small amounts of sod on the backslope.



Placing the moldboard toe near the front tire allows sod and other material to be cast up the slope, keeping it off the road travel surface.

## C A U T I O N

**When using this moldboard position, visibility to the toe is restricted. Use caution to prevent moldboard-front tire contact that could cause tire damage.**



*a. 1st Ditch, b. 2nd Ditch*

If the road has a good cover of gravel or crushed rock, loosen the material with a ripper/scarifier or by cutting with the moldboard.

1. Stockpile the good cover material by windrowing it to the opposite side of the road, away from the first ditch that you intend to cut or clean
2. Cut or clean the first ditch, placing the excavated material on the shoulder. Spread the excavated material evenly across the uncovered lane, placing it from the shoulder up to the centerline of the road. You will be spreading the excavated material in the lane from where you first removed the good cover material.
3. Windrow the stockpiled cover material back across the road, placing it on top of the excavated material that was spread. Leave this material in a stockpiled windrow.
4. Be sure to retrieve any good cover material that was under the original stockpiled windrow and add it to the stockpiled windrow.
5. Cut or clean the second ditch and spread the excavated material evenly across the uncovered lane.
6. Now spread the stockpiled cover material across both lanes evenly.
7. Use the cover material to finish the appropriate road cross section.

## N O T E

**This is a time-consuming technique, but since gravel and crushed rock are not readily available in some areas, it can be cost-effective.**

# Road Rebuilding

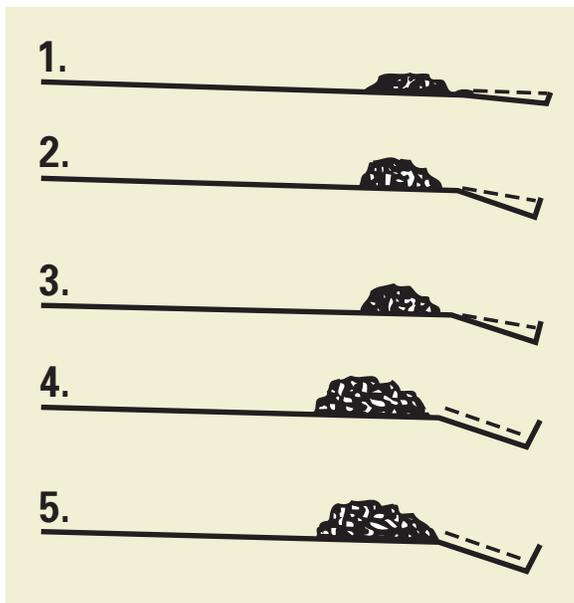
## Moldboard Positions Used in Vee Ditching

Tip the blade to place the top of the moldboard slightly ahead of the cutting edge (approximately 2 inches or 5.1 centimeters). From this position, tip the blade forward or back as needed to meet the material requirement. This is the normal tip position used unless specified otherwise.

On the marking pass have the blade at a steep angle to the frame (near 45 degrees), with the toe of the moldboard at the outside edge of the front tire. The heel of moldboard should be raised nearly full height to place material between the tandem tires. Adjust the moldboard to cut a shallow marking pass.

Circle the moldboard to an extremely steep cutting angle.

## Typical Ditch Cuts and Marking Ditch



Lean the top of the front wheels toward the heel of the moldboard, using only enough lean to counter side draft. Using excessive lean will cause the machine to wander off course.

On pass number 1, cut just deep enough to mark the intended line (4 to 6 inches deep or 10.2 to 15.2 centimeters deep). This pass should be made in first or second gear with the differential locked. **When marking a ditch through a tight curve, do not lock the differential.** Keep as close to the intended line as possible. Some slight ditch line corrections can be made on succeeding passes.

On pass number 2, place the front wheels into the marking ditch and cut deeper while holding the desired slope.

Succeeding cuts can normally be made at deeper and higher ground speeds than the marking pass. After several cutting passes, the shoulder windrow must be moved to the road center. Alternate between cutting passes and windrowing material toward the centerline as needed.

## C A U T I O N

On straight sections of road use Straight Frame Mode for deep ditch cutting passes to avoid possible:

- ***Tire Sidewall Damage.*** With articulation on straight sections, the front or rear tandem tire can be forced against the ditch backslope, possibly causing sidewall damage. Rocks or other objects can be trapped between the tire sidewall and ditch backslope, damaging the tire sidewall. In corners, articulation can prevent the rear tandem tires from tracking on the backslope.
- ***Loss of Air Pressure or Damage to the Rim.*** Using articulation on straight sections can force material between the tire bead and rim, causing loss of air pressure in the tire.

Have tire pressure at the proper level before starting any ditching work. Extended periods of deep ditching will require higher air pressure and/or tubes in the tires.

## Ditch Shoulder Cleanup



As the ditch becomes deeper, material tends to roll under the tandem tires. When this occurs, the windrow must be moved off the road shoulder toward the road center line.

Do this in straight or articulated mode. The machine configuration should be:

1. Toe at the center or inside edge of front tire.
2. Front tire straddling the windrow and at desired shoulder height, and lean the top of the front wheels toward the heel of the moldboard.
3. Drawbar shifted away from the ditch, with a steep blade angle.
4. Heel outside tandem tire.

When roughing in an area or where the road shoulder and inner slope are not accurately controlled, the windrow can be moved in one pass to the outside of the opposite tandem tire. In some soils, this technique may result in material loss around the moldboard toe back onto the road ditch slope.

Drive as straight as possible on this pass to assure a straight shoulder line .

Attempting to pull too much material in one pass will cause the front end to be pulled down into the ditch destroying both the shoulder and ditch slope grade. Pull only as much as the machine can handle in a single pass. This type pass can normally be made in third or fourth gear.

## Finish Shoulder Cut



Use a finish shoulder cut when a precise shoulder line is required or in dry material to prevent material from spilling back into the ditch.

Use the same method as above, but shift the circle 8 to 12 inches (20.3 to 30.5 centimeters) toward the ditch. Use a steep blade angle and extend the toe of the moldboard well beyond the windrow and very close to the front tire. Tip the blade slightly forward.

Place the windrow between the tandem tires.

Material cast inside the tandems must not be allowed to roll under the opposite tandem tire or the shoulder cut will be irregular. Casting material inside the tandem tire would only be done where precise cuts must be made or to reduce material loss around the toe of moldboard in dry soil. Normally material would be cast outside the tandem tire.

This pass is normally made in third or fourth gear. Both tandems must be on a smooth surface for good results.

## Articulated Shoulder Cuts

There are three articulated frame techniques that are useful for moving large shoulder windrows. These modes will normally allow the motor grader to move the entire windrow in a single pass rather than using multiple passes. The first two techniques are performed with the centershift pin in the center position. The last technique described requires repositioning the linkbar.

With large shoulder windrows or when roughing in the ditch, larger loads may be moved by using articulated frame. (These methods also work well in wet slabby material where the material does not slide along the moldboard as desired.) See photos 1, 2 and 3 on page 18.



1. Articulate the mainframe 15 to 20 degrees. Place the rear wheels into the ditch against the backslope with the front wheels on the shoulder and straddling the windrow. This mode will normally allow the motor grader to move the entire windrow in a single pass rather than multiple passes.



2. Articulate 10 to 20 degrees. Keep all the wheels on the road without the front wheels straddling the windrow. Place the material outside of the tandems toward the centerline of the road. This technique is most effective on machines equipped with optional longer moldboards or moldboards equipped with extensions.



3. Move the linkbar two or three holes towards the shoulder. Articulate 10 to 20 degrees. Sideshift the drawbar toward the shoulder. Place the toe of the moldboard beyond the windrow and outside of the front tire. Place the heel below the center of the mainframe and place the windrow between the tandems.

## Other Ditch Cuts



In areas where position of the ditch centerline and slopes are not critical, shift the drawbar and circle toward the road centerline. Straddle the desired ditch line with the moldboard toe near the machine's centerline. Cut to the desired ditch depth.

This technique allows deeper cuts but with less control of the slope or ditch bottom because the machine's tandems are running on uneven surfaces.

This technique is recommended only where ditch slope and bottom accuracy are not important.

## Ditch Back Slope

1. When cutting the road ditch backslope, the ditch and shoulder should be smooth and uniform: a rough surface will be magnified at the moldboard's toe.
2. Start by checking the sideshift anchor position. To back slope on the right, the anchor should be mounted in the left set of holes, (to back slope on the left, the anchor should be mounted in the right set of holes) then move the linkbar to its maximum position toward the slope.

Tip the moldboard to near the center of its tip range. Adjust tip to material need after starting the cut.

3. Place the machine in the ditch with the heel of the moldboard near the outer edge of the rear tire. Adjust the toe of the moldboard to obtain the desired slope.
4. Start with the front wheels vertical.
 

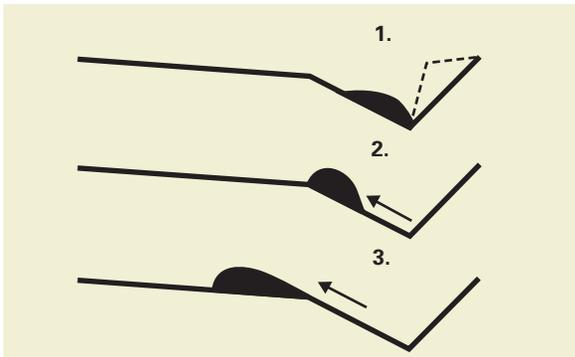
Lean wheels can be used to vary cut depth over the entire moldboard length without affecting the set slope.



Also true of the moldboard tip: forward for deeper cuts, rearward for less cut.

## CAUTION

**Tipping the moldboard to the rear may result in rear blade support and blade beams contacting the bank and preventing the cutting edges from reaching the material.**



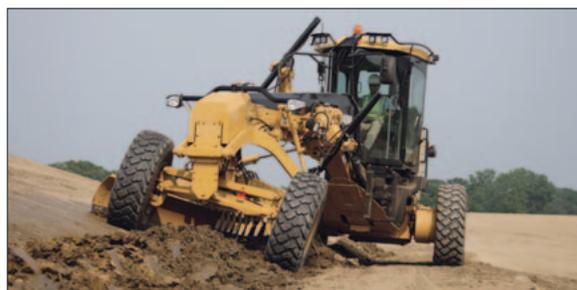
1. Material from the backslope will be deposited inside the rear tandem tires. Move this material out of the ditch using a very steep blade angle and the vee ditch position, being careful not to gouge the backslope or contact the front tire.
2. In dry, free-flowing material, use a very steep blade angle and deposit the material between the tandems part way up the road shoulder slope.  
This helps prevent the material from spilling around the toe of the moldboard and refilling the ditch. This method gives a more accurate ditch bottom.
3. A second ditch pass will be required to bring this material up onto the shoulder.

## Tips for High Bank Slope 2.5:1 and Steeper

When cutting high bank slopes from a ditch, the application is similar to cutting a ditch backslope except for the height of the cut. Follow the ditch backslope instructions for setting up the machine for this application.

When cutting a high bank from a flat surface:

- Position your machine at the slope base with the blade to the machine's side as in backsloping. The slope will normally be cut with the machine at the base of the slope and in straight frame mode.
- Before starting the slope work, smooth the base where the machine will be traveling so the base is as uniform and hard as possible. A slight variation in the slope base will have a large effect on the moldboard toe and the slope's finished surface.
- Tilt the base toward the slope being cut to help hold the machine against the slope.
- Position the moldboard heel near the outer edge of the rear tire and adjust the toe to obtain the desired slope. After starting the cut, fine tune this position to the material.
- Tip the blade forward approximately one-half its travel range to position the cutting edges to the material. Make your final adjustment to meet the material needs after you start the pass.
- The machine should be operated at slow speed to allow maximum control (first or second gear, low to medium engine rpms).
- On deep cuts dress the slope often as the material is removed. In normal conditions, bank height should not be allowed to exceed 6 to 8 feet (1.8 to 2.4 meters) before it is dressed.



## Tips for High Bank Slope 2.5:1 and Steeper Continued

- Use frame articulation to place one or both front tires on the slope with the rear frame at the slope's base. This extends maximum reach up the slope, if required, but will reduce some control of the finished slope.
- Lean front wheels down slope or the front axle oscillation limit may be reached and only the top front tire will be on the ground. This reduces machine stability and control of the cut surface. Tipping the front wheels down slope will frequently eliminate the problem. Again, place the windrowed material inside the tandem tires closest to the slope.

## Bank Slopes: Machine on the Slope

- Using frame articulation allows the machine to be operated on steeper slopes with safety. Here are some tips for this application:
- Use low ground speeds for maximum control of the machine. Use the accelerator, not the hand throttle. In an emergency, releasing the accelerator will result in immediate reduction in engine rpms and ground speed.
- Keep the differential locked while working on slopes.
- On steeper slopes shift the drawbar uphill toward the toe of moldboard. Articulate the rear frame placing the heavy engine frame down slope for more stability.



- Deposit the windrow between the tandem tires and keep the upper tandem tires above this windrow to reduce sliding.
- On slopes less than 2.5:1, start at the top of the slope. Cast the windrow material outside the rear tandem tires to help prevent the rear tires from sliding.

- On subsequent passes, place the uphill front tire above the windrow with the frame in articulated mode. Continue this mode until all material is at the slope base, then return to straight frame to clean up the windrow.

## Narrow Shoulder Cut

On a hard surface road when working narrow 3- to 6-foot (0.9- to 1.8- meter) shoulders, use the high bank, extreme reach position described in backslope positioning.

The moldboard is placed horizontal to the ground and tipped to near the center of its travel range. Hold the heel slightly above the pavement to prevent damaging its surface or edge markers. This allows you to place the windrow just inside the rear tandem tire on the outer edge of the roadway, not on the main travel area. Position the right front and tandem tires just off the road edge to help compact the material. For safety, work in the direction of traffic where possible.



## NOTE

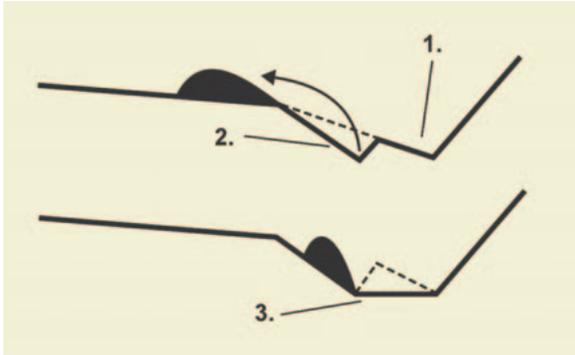
**The moldboard heel should be placed at the pavement edge.**

When moving this windrow back onto the shoulder, use a steep blade angle to prevent material from running around the toe of the moldboard onto the road travel surface.

If road edge markers are painted and clear of other obstructions, the toe of the moldboard can be placed in float position (if equipped) to match the pavement. The windrow can be feathered off the moldboard heel to the desired shoulder slope.

## Cutting a Narrow, Flat Bottom Ditch

The flat bottom ditch is cut from a vee ditch. Cut a vee ditch to the desired depth with a flatter than normal road shoulder slope. Rough finish the ditch and backslope.



### 1. Original Vee Ditch, 2. Second Vee Ditch, 3. Flat Bottom Ditch

1. Place the motor grader into the original vee ditch and use the backslope to keep the front tires from sliding off the desired line.

Place the centershift linkbar one hole off center away from the ditch.

Place the moldboard toe inside the front tire to the desired flat bottom width, and cut a second vee ditch nearly the same depth as the first. Cut the desired road shoulder slope angle and place the material onto the road shoulder. Move the windrow to the road center and smooth the shoulder to make a uniform surface.

2. Move the centershift linkbar two holes toward the ditch. Put the machine in crab mode. Place the tandems into the original vee ditch. Position one front tire in the secondary ditch and the other one on the ditch slope. The toe of the moldboard should be near the bottom of the backslope and the heel between the tandems at the desired ditch bottom width and at the base of the ditch slope.

Tip the moldboard further forward than normal. Cut out the center ridge between the two vees, placing the cut-out material onto the road shoulder slope. This material can be moved onto the shoulder using the normal ditch cut position.

With dry or free flowing material, keep the lock pin in the same position but use a very steep blade angle to move the material only part way up the ditch slope. A second pass will be needed to move it onto the road shoulder. This method prevents free flowing material from flowing back into the ditch affecting the ditch depth and slope angle.

## Windrows and Truck Dumped Material

A motor grader is frequently used to level fill or material for the travel surface that has been dumped by trucks. Using crab mode allows you to make better use of machine horsepower and have better machine control. Driving over loose material wastes engine power, and the up-and-down motion of the mainframe affects your ability to smooth the surface. Crab mode keeps the front wheels on a smooth surface for faster finishing and better directional control. Power is placed behind the area of maximum load for more productivity.



### a. Heel, b. Toe

1. Articulate the back frame toward the heel of the moldboard 15 to 18 degrees.

Shift the drawbar, circle and moldboard toward the piles with the moldboard at a 30 to 40 degree blade angle.

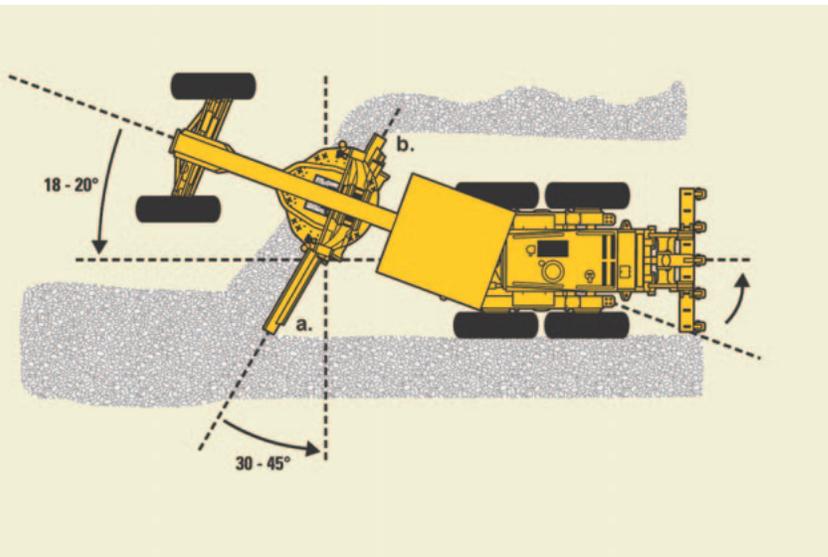
Cut out a windrow the machine can handle and spread it over the road surface. Work the material in both directions or material may be moved beyond the intended limit. Keep the differential locked to prevent tire spin.

- Where material must be moved straight ahead, keep the blade nearly square to the main frame but shifted toward the piles. Place the drawbar circle near its center position.

## Large Windrows, Material Mixing

Frequently a motor grader is used to spread windrowed material dumped by bottom dumps or to mix material. Use crab mode for this application (similar to THAT DESCRIBED ABOVE IN THE SECTION ON WINDROWS & TRUCK DUMPED MATERIAL).

Tip the top of the moldboard approximately 4 to 5 inches (10.2 to 12.7 centimeters) ahead of the cutting edge.



*a. Toe, b. Heel*

Angle the blade approximately 30 to 45 degrees to the mainframe. The angle will change with material type and moisture content. Increased blade angle will be required with wet material; less with dry material.

Articulate the back frame toward the heel of the moldboard 18 to 20 degrees.

On very large windrows, do not attempt to move the entire windrow in one pass. Take only the amount of material that can be handled without excessive engine lugging or tire slip. Tire slip will disturb the finished surface and should be avoided. Tires are frequently hydro-inflated in these applications to minimize slip and the disturbance it can cause.

Ground speed is very important for good rolling/mixing of material and to control wheel slip. Lighter blade loads and higher gear ratios are frequently used in low traction conditions to control wheel slip. The best gear speeds for mixing materials are third and fourth (4 to 6 mph [6 to 10 km/h]). Keep ground speed below your machine's bounce point or a rippled surface will result.

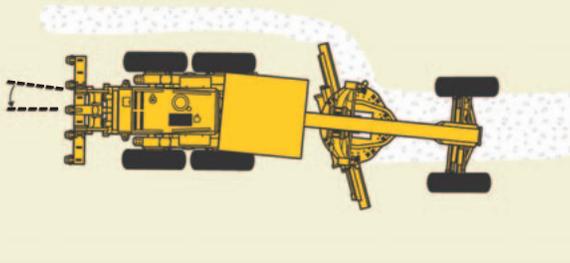
Using the proper blade tip angle results in better mixing and requires less horsepower to move material. The correct blade tip angle combined with the blade curvature causes material to move up and forward off the moldboard. Throat clearance can also be affected by changing blade tip angles. Tipping the moldboard forward increases the distance between the top of the moldboard and the bottom of the circle; this helps prevent material from being forced up into the circle support area. When carrying heavy loads, tipping the moldboard too far forward can reduce the rolling action of the material.

Tipping the moldboard too far to the rear can cause material to be forced up into the circle support area reducing throat clearance. This can stop the rolling/mixing action and causes material to be bulldozed, not rolled and mixed. This requires more rimpull, horsepower and fuel, and reduces productivity.

# Other uses of Articulation in Motor Grader Work

## Counteracting Side Loads

Articulate back frame towards the toe of the moldboard.

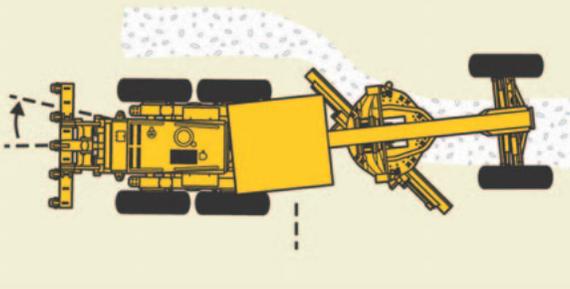


Articulation can be used to counteract side draft when you're making a heavy cutting pass.

As the rear of the machine starts to slide away from the moldboard heel, articulate the back frame toward the toe to offset the side load.

## Reducing Blade Loads

Articulate back frame towards the heel of the moldboard.



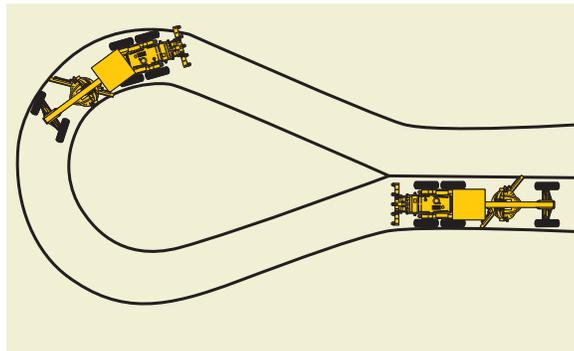
To reduce blade loads without circling the blade under the load or where maximum circle torque has been reached, articulate the back frame towards the heel of the moldboard. This reduces the width of cut and the load.

This method can be used on large windrows and many other applications, but will not work in applications that do not allow use of crab mode. For example, when ditching, crab mode may cause sidewalls of tandem tires to rub against the backslope causing damage to the sidewalls.

Use this technique whenever possible to reduce wear on the circle.

When working in wet clay, material will frequently stop moving along the moldboard, sharply increasing horsepower and traction requirements. When this occurs, a quick change in the articulation angle will frequently start material moving again.

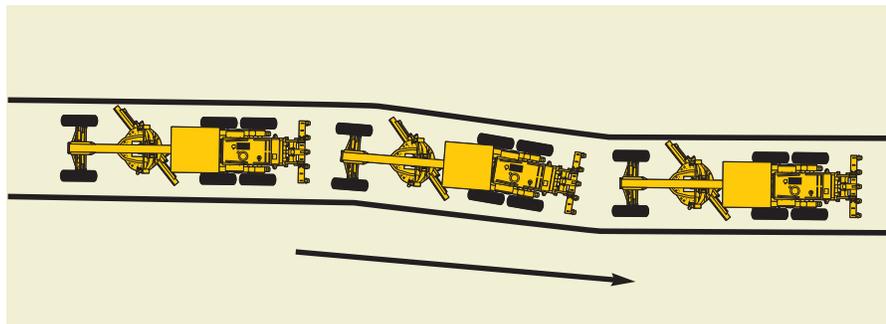
## Machine Turnaround



One of the most common uses for articulation is on machine turnaround on long or short pass work.

The articulated unit can frequently turn around without stopping. This usually means faster cycle times and more productivity.

## Work in Confined Areas



When working in confined areas or where the machine must be operated in reverse, the ability to steer the leading end of the machine gives outstanding maneuverability and allows it to be safely operated at higher reverse speeds.

## Cul-de-sac

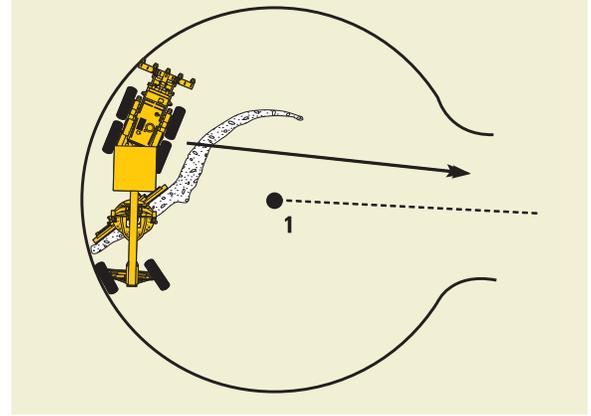
To finish grade or clear a cul-de-sac is simple work for the articulated motor grader. Use the motor grader to finish near the curb line where rear wheels are kept on a smooth surface, the moldboard near a 30 degree angle, and the drawbar centered under the frame. Extend the moldboard to near three-fourths of its travel toward the heel end and lean the wheels near the center of its travel.



As the motor grader nears the cul-de-sac entrance, articulate the rear frame toward the toe of the moldboard. Use moldboard sideshift to maintain the moldboard near the curb.

With the moldboard at the corner, steer the front wheels in the proper direction and use circle rotation, side shift and wheel lean to keep the moldboard toe positioned against the curb or back of the cut.

When the front of the tandems is beyond the corner, articulate the rear frame away from the curb or back of the cut. Be careful not to articulate too fast and scuff the finished surface. Turn the front wheels in the proper direction, use circle, sideshift and wheel lean to keep the moldboard toe position to the curb or back of the cut. Continue to articulate so as to follow the cul-de-sac radius.



### 1. Center Line Crown

After the curb pass has been widened by a second pass, back onto the finished surface and move any excess material out of the cul-de-sac as indicated by the arrow.

Remember: the centerline crown extends all the way to the center of the cul-de-sac. Do not straddle the crown or grade perpendicular to it at the entrance of the cul-de-sac.

## Backfilling Curbs in a Cul-de-sac

Backfilling cul-de-sac curbs with a straight frame machine is challenging and requires patience and skill. Articulating frames make this job easier, even in the throat area.



Backfill the corner in the normal manner using articulation to fill most of the area.

To fill areas, shift the drawbar two holes toward the heel and near its maximum position. Carry a full blade load near the heel of the moldboard as you near the vee of the curb.

Slow the machine. Use the inching pedal to slowly move the machine as required.

Use circle rotation and moldboard sideshift to place material into the corners.

When backfilling curbs in a cul-de-sac, use articulation and offset the machine's rear away from the curb placing the lighter front wheel close enough to compact the material next to the curb.

Be very careful not to move the curb out of position while backfilling material.

## Articulation in Ditch Turns

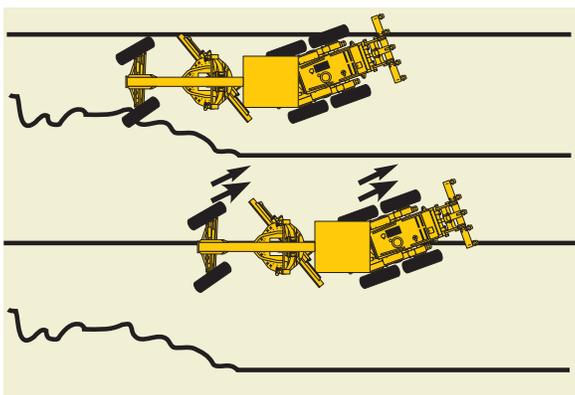


Articulation makes the operator's job easy by allowing the front and rear wheels to track in turns.

When cutting a ditch in a curve, the tandem tires remain in the ditch bottom by using articulation. The tandem will not climb the backslope, thus allowing the job to be completed faster and with greater precision.

This also applies when working ditch shoulders and cul-de-sacs.

## Work-Alone Capability



Articulation can frequently prevent a machine from becoming stuck by allowing the rear end to be kept on a hard surface. It can also help remove a stuck machine.

1. Turn the rear frame and front wheels away from the dropoff.
2. Use articulation to duck walk (side-to-side articulation while backing up) the motor grader's way free.

## Ripper-Scarifier Types

Motor graders can be equipped with scarifiers or rippers. These attachments are used in a wide range of applications, from conditioning soils, mixing materials, and loosening hard material, to ripping asphalt. The motor grader is not designed to continuously rip hard material, but will do a good job if properly applied. There is a possibility for abuse, especially to the drive tires, if the ripper or scarifier is not operated properly. Ripper-Scarifier attachments come in three different arrangements:

### *1. Front mounted ahead of the front wheels.*



This arrangement is normally used for light work. It has some operational advantages and can double as a front lift group for other attachments.

Its disadvantages include less control of direction and cut depth when ripping, due to its location ahead of the steering wheels. This location provides limited visibility to the scarifier teeth and material fracture.

## 2. Mid mounted behind the front axle.



Its advantages, when compared to the front mounted scarifier, are better control of cut depth, improved visibility, and ability to fracture harder material.

Disadvantages are interference with blade positioning, interference with material flow along the moldboard in some applications, and problems working into corners and close to objects.

## 3. Rear mounted ripper-scarifier.



This arrangement allows the maximum ripping capability by placing the ripper weight on the rear drive tires. It can be used to rip into corners, along walls or close to an object. The ripper shanks are used for heavy ripping; the scarifier shanks for light work where maximum surface fracture is desired. Both sets of shanks can be stored on top of the bar to give maximum lift height.

The drive tires on the first pass are on an unripped surface for maximum traction.

## Tips on Use of Ripper-Scarifier

- Use straight frame mode for maximum traction.
- Use minimal articulation while ripping to avoid side loading the ripper or shanks causing possible failures. Raise the ripper or scarifier out of the material before turning to prevent shank damage. Raise the unit high enough to clear all objects.
- To maximize production, rip as deep as possible and to a uniform depth but avoid bulldozing with the ripper bar.
- Avoid excessive tire slippage. Use lower gears (first and second) and reduced engine rpms.
- Use only the number of teeth required for material fracture. Too many teeth will prevent material penetration, bridging material between teeth and causing excessive tire slip.
- To penetrate material, lower shanks into the ground slowly while traveling in a straight line.
- Cross rip only when material fracture cannot be achieved otherwise.
- Three to five ripper shanks are used in most materials. With the ripper use only one shank when ripping extremely hard material; keep this shank in the center position. If the single shank is used in the outside pockets, use extreme caution to avoid damage to the machine or ripper assembly.
- **Never use a single scarifier shank** in hard material with the rear ripper-scarifier.
- Do not operate ripper or scarifier with badly worn or missing tips: damage to the shank will occur.

## All Wheel Drive (AWD) System

The optional AWD system utilizes dedicated left and right pumps for precise hydraulic control. The infinitely variable pumps and motors maximize torque in each gear delivering the most power to the ground in the industry and increasing productivity in the most demanding applications.

### **AWD: Constant Net Power.**

When equipped with AWD, the 120M will automatically increase the gross power up to 26 kW (35 hp) when the system is engaged. This offsets the parasitic losses and maintains a constant net power to the ground for maximum productivity.

### **AWD: Hydrostatic Mode.**

Standard with AWD, this mode disengages the transmission and provides hydraulic power to the front wheels only. The ground speed is infinitely variable between 0-8 km/h (0-5 mph), perfect for precise finish work.

### **AWD: Steering Compensation.**

The Caterpillar exclusive Steering Compensation System is standard with All Wheel Drive. This feature enables a “powered turn” by adjusting the outside front tire speed up to 50% faster than the inside tire. The result is improved control, less damage to surfaces and a dramatic reduction of turning radius in poor underfoot conditions.

# Snow Plowing

## C A U T I O N

**In snow plowing applications, machines are frequently equipped with bulky attachments on the front, side and rear. Blowing snow and other conditions may cause restricted visibility. Machines often work in areas with heavy traffic, or the application may require frequent changes of direction. Safety must be your Number One objective.**

***Before moving or reversing the machine, check all directions to assure there are no personnel or vehicles in your path.***

***For safety, work in the direction of traffic when possible.***

Motor graders have long been recognized as excellent tools for snow plowing. The introduction of high speed hydraulics and frame steering has made the motor grader even more productive in this application.



Snow plowing techniques and the type of plowing equipment mounted on the motor grader vary greatly in different areas of the country due to:

- Terrain
- Type of snow and its moisture content
- Depth of snowfall normally expected
- Normal wind velocity that can cause extremely tight drifting
- Length of time after the snowfall before plowing was started
- How much melting has occurred
- Amount of dirt mixed with snow

A major factor is traction. Snow plowing usually occurs under poor traction conditions which often require different operating techniques and the use of tire chains.

In snowplowing, operating speeds are normally higher than in earthmoving work. Normal work speeds are in the 5 to 20 mph range. The moldboard should be tipped well forward to prevent damage to the machine and road surface. This allows the cutting edge to ride over rather than try to cut minor obstructions, and may prevent operator injury, cutting edge breakage or machine damage.

Objects can be hidden under the snow so wear your seat belt. Put a standard circle slip clutch attachment on the machine to prevent possible operator injury or machine damage. For safety, work in the direction of traffic when possible.

Blade float is frequently used in snow plowing work. This allows the blade to follow a varying surface using only the weight of the drawbar, circle and moldboard. Blade float prevents damage to uneven surfaces but requires a hard surface such as asphalt or frozen ground to prevent gouging the surface. In areas with loose gravel on the road surface, using blade float may windrow the gravel onto the road shoulder.

***The many variables of snow plowing applications make it impossible to recommend one machine, one configuration, or one technique for all areas. This guide covers equipment and techniques most commonly used, so they may be used as a guide in your conditions.***

## Standard Motor Grader Moldboard



The motor grader's standard moldboard is the most commonly used attachment for snow plowing. It is used in areas where snow depths are low, the terrain is relatively flat, and where excessive drifting does not occur.

***The standard moldboard can also be used to wing snow by repositioning the linkbar as shown above.***

Tip the moldboard well forward to prevent damage to the road surface and allow the cutting edge to ride over rather than try to cut minor obstructions.

## Snow Wing

The snow wing is a common snowplowing tool. It is a moldboard that normally mounts to the machine's right side. It can be used alone or in conjunction with the motor grader moldboard to move snow off the road or other surface and to provide a wider cleared area per machine pass. The moldboard is frequently used to cut the material and feed it onto the wing. The wing curvature is designed to lift the material and throw it off the plowed surface. The ground speed needed to move snow off the roadway will vary with snow type and many other factors, but generally winging speeds fall in the 10 to 20 mph (16 to 32 km/h) range.

When using the moldboard-wing combination, it is desirable to have similar angles on both units for good material flow. To accomplish this:



1. Shift the drawbar toward the wing as far as it will go. Use articulation to place the front wheels approximately 12 to 24 inches (30.5 to 61 centimeters) toward the wing. Use crab mode.

This mode resists front end sliding, places the wing and moldboard at near equal angles, provides more moldboard heel-to-mast clearance, and places the unit's power almost directly behind the area of highest resistance (toe of moldboard).

2. Shift the centershift lock pin right two holes with the drawbar fully shifted toward the wing. This provides nearly equal angles on the wing and moldboard with the frame straight.

To increase blade angle further, use crab mode as described above.



## N O T E

**Shifting the lock pin off center as shown here will reduce blade lift height on the side opposite from pin movement.**

**Use caution when using steep moldboard angles. Contact between the moldboard sideshift cylinder rod and wing mast and the moldboard heel and leading end of the wing can occur. Damage to these components can result from this contact. Tipping the blade forward approximately three-fourths of its maximum travel helps reduce the problem.**

## Wing Controls

During winging operations, you're normally turned toward the right side to observe the wing. M Series wing controls are located on the right hand side. This allows the operator to comfortably steer the machine with their left hand while adjusting the snow wing with the right.

Snow wings come in a variety of sizes and actuation methods. Earlier units were cable actuated. This release focuses on the hydraulic wing design, which is now the most popular due to improvements in design and hydraulics.

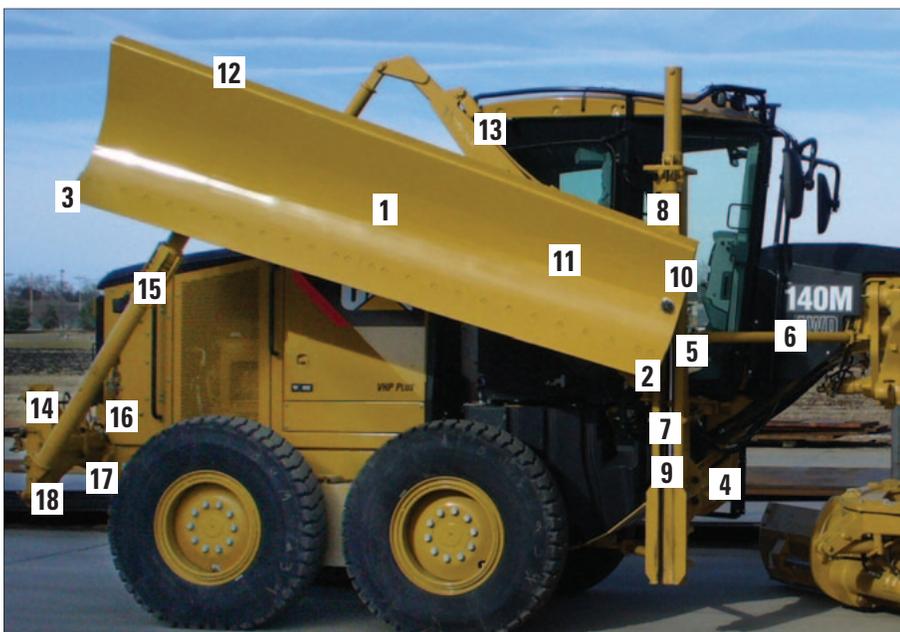
## Common Terms Used to Describe Snow Wing Components

1. **Wing Moldboard.** Normally mounts on the right side of the motor grader. Both ends can be raised at the same time or separately due to individual hydraulic cylinders and pivot area (10).
2. **Toe.** Leading end of wing moldboard.
3. **Heel.** Trailing end of wing moldboard.
4. **Front Wing Mounting.** Attached to the mainframe, it supports the wing mast (5), wing (1), slide assembly (7 & 8), and the wing pivot area (10).
5. **Wing Mast.** Guide for wing slide that allows the wing moldboard (1) to be moved up and down in relation to the main frame.
6. **Wing Mast Brace.** Attaches the mast to mainframe for strength.
7. **Wing Slide.** Allows the wing to move up and down.
8. **Slide Assembly.** Connection between the slide and wing. Provides a pivot for the wing.
9. **Mast Cylinder.** Supplies power to slide the wing moldboard up and down in the mast.
10. **Pivot.** Allows movement so the toe and heel of the wing can be independently raised or lowered.
11. **Hydraulic Cylinder.** Supplies force to raise and lower the heel of the moldboard through the top link connected to the mast, and vertical strut (12) connected to the wing heel (3) (trailing end).
12. **Vertical Link.** Solid connection to wing heel. Allows down pressure to be applied to the wing trailing end (heel).
13. **Cable Connection.** Stored on top link, replaces solid link (12). It allows the heel of the wing to float up and down under its own weight and match varying surfaces.
14. **Rear Support.** Mounts to the rear of the motor grader and supports the heel (3) (trailing end of the wing moldboard.)
15. **Wing Strut.** Supports the wing's heel. Its length can be changed. This allows the wing angle to be varied from approximately 30 to 50 degrees. 30 degrees is the most common angle. It provides the widest possible cut width and this angle works well in most snow.

The 50 degree wing angle reduces side draft on the machine, but also reduces cutting width.

Note the shock spring in the strut.

Use the 30 degree wing angle and articulate the frame to change the wing angle as needed.



**16. Strut Safety Cable.** A safety cable is provided to prevent the accidental lowering of the snow wing moldboard. This cable should be attached whenever the moldboard is in a folded up or roading position.

*Before attempting to lower the wing, disconnect the safety cable to prevent cable breakage rear strut bending. Make sure cable is connected for traveling.*

## C A U T I O N

**Lower the wing slightly from its travel position before making a left turn using articulation. Failure to do this may result in damage to the wing lift system.**

**17. Shear Pin.** Located in the rear strut. It's designed to shear on higher than normal shock loads to prevent wing or machine structural damage from hidden objects, rocks, etc.

## N O T E

**Keep spare shear pins in the machine. Never substitute a hardened bolt for the shear pin. Personal injury or machine damage could result.**

**A second safety cable, located in the rear strut is designed to prevent the strut from dropping onto the ground if the safety pin is broken. Check all safety cables often and keep them in good condition.**

**18. Optional Moveable Rear Strut.** Allows the strut's rear mounting point to move up and down for more effective bracing of the wing heel when winging in deep snow (6 to 8 foot [1.8 to 2.4 meters] drifts). Without this attachment the strut would dig into the bank bringing snow back onto the road surface, and the strut angle to wing in benching applications could allow overcentering the strut causing possible damage to both units.

Snow must be removed from the road surface as quickly as possible to permit vehicle travel, and to prevent road damage from moisture and possible drifting if the windrows are allowed to remain on the road or shoulder.

The wing is used in a variety of ways to accomplish snow removal. Some of the more common ways follow.

## Wing Applications and Tips on Use

### Ground Level Winging



The wing is generally used as an extension of the motor grader's moldboard.

Lower the wing horizontal to the travel surface; a small amount of free movement is built into the mast slide to allow the toe to ride over uneven surfaces. **Do not use down pressure unless it is needed to cut the material, or rapid cutting edge wear or damage to the road surface could result.**

The wing can be used alone to move an existing windrow off the road shoulder, or the motor grader's blade can be used to cut the material and feed it to the wing where it will be moved completely off the road into the ditch area. **If possible, use a ground speed high enough to move the snow completely off the road without leaving a windrow.**

## ***Benching***



Benching occurs in areas that normally receive high amounts of snowfall or in areas of drifting. It is used when ditches are full and more storage area must be found for additional snow.

Benching is accomplished by raising the wing approximately one-half the bank height (or whatever depth the machine can handle).

This operation is usually done in straight frame mode. Place the wing in near horizontal position. Drive along the base of the slope and cut a notch into the bank to make room for additional snow storage.

This type operation may require the optional hydraulic strut group (4) for adequate support of the wing heel if the bank height exceeds 5 to 6 feet (1.5 to 1.8 meters) and to prevent the strut from cutting away the edge of bank, pulling the material back onto the road surface.



## ***Tapered Bank***

The purpose of this operation is the same as benching: to clear away existing snow by moving it up away from the roadway to provide more storage for new snowfall.

It is normally used in areas of high annual snowfall where drifting is a problem, the ditches are full and the only way to obtain space is piling the snow higher.

Place the wing toe at ground level with the heel set to discharge the snow uphill onto the bank top. This operation may also require the optional rear support group (4) to provide adequate support to the wing heel.

## ***Winging Down Slope***



This application is used to move snow down a slope or ditch and place it as far as possible from the road travel surface.

This reduces the chance of moisture from melting snow softening or damaging the road surface.

Place the wing toe at the road shoulder height and lower the heel to match the slope. Deposit material well away from the travel surface. **Use slower ground speeds in this application.**

Use crab mode, use articulation and place the front wheels 24 to 30 inches (61 to 76.2 centimeters) from the shoulder with the tandems at the shoulder line. This mode reduces front end sliding and helps prevent the machine from getting stuck should the rear slide toward the ditch.

Wing angles are adjustable by the rear strut (4) from approximately 30 to 45 degrees. With the articulated machine, use the 30 degree wing angle and use articulation to counteract the side draft. Steeper wing angles place less side draft on the machine but also reduce wing cutting width.

*Articulation should be used frequently in snow plowing applications. It can help material flow off the wing by changing the wing angle, reducing cutting width and wing load, and helping hold the machine against the snow bank. Its use will also reduce front end sliding, help prevent the machine from getting stuck and help get it out should that occur.*

*Check the moldboard and wing cutting edges often and replace them when required. When replacing the wing front cutting edge (toe), be sure its leading edge has been rounded off to prevent it from gouging the road surface causing damage.*

## C A U T I O N

**Use the seat belt at all times, especially in high speed operations such as snow plowing. A circle slip clutch can also reduce the effect felt by the operator and the machine when a hidden object is hit at these higher speeds.**

# AEM Supplied Attachments

Other snow plowing attachments are usually mounted on a quick attachment lift group such as the one shown here.



This allows the front attachment to be quickly mounted or dismantled from the machine when desired.

## V Plow



This attachment mounts on the motor grader's front frame, usually with a fast coupler arrangement.

It is designed high and in a V shape to cast material to both sides. The V shape centers the load on the machine for better material penetration and front end control in deep snows.

It is used mainly to open deep snow or drifts, and can be used alone or in conjunction with the wing and motor grader moldboard.

## Tips on Use of a V Plow

V plows are designed to dig into and lift packed snow. **To prevent damage to the lift group do not hit a snow bank at high speed with the plow raised.**

In deep drifts keep the frame straight on the first pass and hit the drift on the deep side with the plow close to the ground. Move the snow toward the low side of the drift. Work downhill when possible for maximum efficiency.

Penetrate the drift as far as power and traction allow, but use caution as the V plow can become stuck in the drift and cause problems for the machine when you attempt to reverse. **This is especially true when working downhill and you must reverse uphill.**

After penetrating the drift as far as possible, use one-half of the V plow to widen the path before attempting further penetration. If this is not done, snow sliding off the banks can trap the plow and front wheels, causing problems when you attempt to reverse. Normally in 3- to 4-foot (0.9- to 1.2- meter) drifts moving one side is sufficient, but on deeper drifts use the V plow to move back both sides of the cut before making the next cutting pass.

When using one-half of the V plow, offset frame articulation approximately 10 degrees to reduce front end sliding and to keep the tandems on a previously cleared path for maximum traction productivity.

After the first pass through the drift, use one half of the V plow as shown to move snow off the road surface. Then use the motor grader's moldboard and wing to finish the clearing process.

Should the V plow become stuck in a drift, use wheel lean and articulation in a side-to-side motion to help free it.

Traction is usually a problem in snow plowing. Use higher gears, machine momentum, and downgrades to aid snow plowing when possible.

Use tire chains when needed but be very careful about tire spin. Tire chains can quickly dig down into the surface being plowed and cause extensive damage.

All Wheel Drive can also help maintain traction at both low and high speeds.

Use of moldboard hydraulics, wheel lean and articulation will often help remove the machine from a stuck condition.

## Skid Shoe



On hard surface roads, set the plow skid shoe up so its cutting edge is close to the pavement to remove as much snow as possible.

On paved or frozen roads the plow control can be placed in float and allowed to ride on the skids if desired.

In other areas it is advisable to remove most of the plow's weight to reduce skid shoe resistance. This will frequently allow the machine to keep moving in traction-limited situations.

On gravel roads set the skids down to maintain cutting edge height at 1 to 2 inches (2.5 to 5.1 centimeters) off the surface. This will reduce the amount of gravel or wear material swept onto the road shoulder or into ditches.

## Reversible Snow Plow Features and Tips on Use



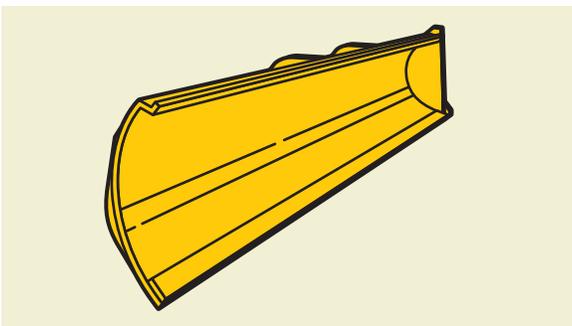
This attachment is mounted on the motor grader's front frame similar to the V plow. It is normally a combination unit that can be used for light dozing and snow removal work.

Maximum plow angle is 30 degrees. It can be hydraulically reversed changing the direction of material flow, or held in any position desired.

The angle plow extends well outside the machine width. This causes the front end to be pulled toward the leading end in deep snows causing steering problems. Use frame articulation to place the tandems as close as possible to the bank being cut by the plow's leading edge. This increases the plow's cutting angle and places the leading edge closer to the machine's centerline to reduce front end sliding and the amount of side draft on the machine. Use the V plow in deep snows or drifts for best results.

The reversible plow's height is low, so snow is forced over its top quickly. **Use caution so this will not trap the plow or front end causing the machine to get stuck.**

## One Way Snow Plow



This unit mounts on the motor grader like the V plow, but is lighter duty and intended for lower snow depths.

It has a fixed angle to the main frame near 30 degrees. Its angle and direction of material flow cannot be changed.

## Tire Chains

Because of the limited traction normally available in winter operations, tire chains are frequently required. Several different types of chains are available, each designed for specific conditions.

Tire chains are normally used on rear drive tires but are used on front tires of both AWD and standard motor graders for traction and to reduce front end sliding.

In some areas, rib tires are preferred for the front: it is felt the ribs give better directional control than traction tires.

General comments on tire chain use:

- Keep a set with the machine. Most are placed on the wing rear support where they are easy to reach.
- Plan ahead. Chains are heavy to lift and hard to install, especially on the tire near the wing.
- Avoid excessive tire spinning when chains are installed. This can cause expensive chain damage as well as damage to the road or work surface.
- Check chains often during operation and keep them tight by proper adjustment and use of bungee cords when possible. Loose floppy chains may come off when traveling or cause damage to the machine. Repair broken cross links as quickly as possible since a loose cross link can cause extensive and expensive damage to the machine. Keep chain repair pliers and repair links in the machine.
- Do not travel for long distances on hard surface roads with chains installed. This increases operating cost because of rapid chain and tire tread wear.
- Chains normally restrict machine travel speed to 6 to 8 mph (10 to 13 km/h) on any hard or frozen surface. Attempting to travel faster than this will result in rapid tire chain wear, machine loping and in some cases vibration that can loosen or damage machine components.



Motor graders are frequently required to cut hard packed snow or ice off roadways or city streets. The unit's standard moldboard is frequently used for this purpose, but this method is slow and machine productivity is low.

Several attachments are available to help in these applications. Some of these are:

## Serrated or Carbide Cutting Edges



These units cut grooves in the hard surface, improve material penetration and speed up snow or ice removal.

The rough surface provides more surface for tires to grip and aids the sun or salt in melting material quicker.

Although they improve performance in removing packed snow or ice, caution must be used with this attachment to prevent damaging the travel surface.



# About The Authors



## Phil Newberry

Phil was in the construction industry for 20 years prior to joining Caterpillar. As a private contractor from 1978 to 1988, his experience covered all phases of construction, from site clearing to laying asphalt.

He then worked for a contractor as an Operations Supervisor, overseeing projects from beginning to end, with a focus on motor grader operations.

In August 1998 Phil joined Caterpillar as Product Evaluation Engineer, working on the Tier 2 H Series Program, the K Series Program, and the M Series and M Series 2 Motor Grader Programs. He is presently employed as a Motor Grader Market Development Engineer at Caterpillar in Decatur, Illinois.

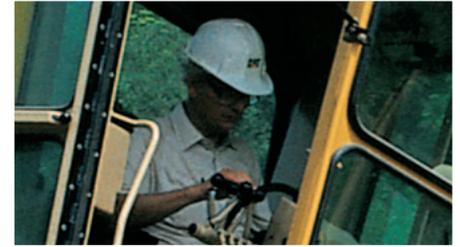


## Randy Krieg

Randy operated motor graders and heavy equipment for over 20 years and is a member of the International Union of Operating Engineers.

In the summer of 1973 he started working at the family business, Krieg Construction Co., as a stake chaser for finish grading work. The following summer his grandfather and father started his operator training on scrapers and motor graders. After graduating from high school in 1976, he spent 6 1/2 years operating full-time for the family business.

In 1983 he moved to Alaska. There he spent 14 years operating Cat Motor Graders on highway, airport, and erosion control projects for Wilder Construction Co. and Rogers and Bablar Inc. He was employed at Caterpillar in Decatur, Illinois, as a Motor Grader Product Evaluation Engineer until 1997 when he returned to Alaska.



## Don Hess

Don Hess operated heavy equipment for more than 50 years, and motor graders since 1950.

Don began his career operating equipment for a number of contractors in the Eastern and Midwestern areas of the United States. He joined Caterpillar in the late 1950's spending time in sales development and 5 years as a machine applications representative in California. He spent 36 years with the company, retiring May 1, 1995.

From 1970 to 1995, Don was a Product Evaluation Engineer. During that time, he was instrumental in helping to develop the Cat G and H Series Motor Graders.

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