SPECIAL REPORT 97-14

Ripping Frozen Ground with an Attachment for Dozers

Paul V. Sellmann and Dale R. Hill

June 1997

Abstract: Ripping of hard and frozen ground is commonly done by using crawler tractors with rear-mounted rippers that are usually a permanent part of the machine. Ripping is an attractive alternative to other methods of breaking a hard surface layer that restricts excavation, since it utilizes existing equipment and personnel, and a tractor that can be used for the excavation project. A simple ripper attachment for use on the blade of a dozer was used to determine if this easily installed tool could provide some ripping capability when machines with rear-mounted rippers are not available. This ripper attachment was used in a range of frozen soils that could not be excavated with a dozer, and was used on tractors ranging in size from small commercial dozers to a large military dozer with a suspension system. In all cases, at the sites used, the ripper attachment provided the machines with some ripping capability. The ripper was also easy to install, with no modifications required to the tractors or the rippers.

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Paul V. Sellmann and Dale R. Hill

June 1997

Prepared for
OFFICE OF THE CHIEF OF ENGINEERS

PREFACE

This report was prepared by Paul V. Sellmann, Consultant, Applied Research Division, and MAJ Dale R. Hill, Deputy Commander, U.S. Army Cold Regions Research and Engineering Laboratory. Funding for this work was provided by the Office of the Chief of Engineers through DA Project 4A762784AT42, Work Unit CS-C06, *Excavation in Frozen Materials*.

Technical review of this report was provided by Herbert Ueda and Wayne Tobiasson, both project engineers associated with CRREL. Appreciation is expressed to the GH Hensley Co. for providing product literature covering moldboard rippers.

The contents of this report are not to be used for advertising or promotional purposes. Citation of brand names does not constitute an official endorsement or approval of the use of such commercial products.

CONTENTS

ILLUSTRATIONS

TABLES

Table

Ripping Frozen Ground with an Attachment for Dozers

PAUL V. SELLMANN AND DALE R. HILL

INTRODUCTION

Objective

A ripper attachment was mounted on the dozer blades of commercial crawler tractors and on a military dozer (the M728 Combat Engineer Vehicle, CEV) in an attempt to improve performance for work in hard and frozen soil when more conventional rear-mounted rippers are not available. The tractors were selected to help predict the ripping performance of smaller military and commercial dozers, and that of a military dozer with a suspension system. This was done for a better understanding of how a blade-mounted ripper could be used for combat engineering operations during the winter, such as construction of fighting positions and denial structures. Observations were made at several sites with a range of ground conditions, including sites with seasonal frost greater than 2 ft (0.6 m) thick. Some of these observations were made during military exercises and during field demonstrations.

Background

Combat engineers have a number of missions that require excavation, including constructing fighting positions for combat vehicles, constructing obstacles, and maintaining and constructing roadways, runways, and other facilities in all terrain and weather. The difficulty of these missions significantly increases when construction is in hard and frozen ground. Reduced availability of the D7 tractor with a rear-mounted ripper and poor performance in hard ground of other available equipment further complicate this problem.

Dozers that lack ripping capability are usually restricted to operating in ground that is not highly compacted or bonded by ice or some chemical cement. Rippers greatly expand the capability of tractors, providing a means to break up and disagregate hard surface materials, preparing an area for more rapid excavation by conventional methods. In some quarry and mining operations, large ripper-equipped tractors are used in coal and rock, eliminating the need for drilling and blasting. Russian experiments with a ripper mounted on a modified military T-34 tractor indicated that ripping hard ground was 15 times less expensive than drilling and blasting (Zelenin et al. 1985). Some manufacturers of crawler tractors equipped for ripping provide data on ripability of materials to aid estimates of ripper performance and productivity (Nichols 1976, Caterpillar 1989), which helps to allow cost comparisons with other alternatives, such as drilling and blasting. Ripping is an appealing concept for military operations because a minimum amount of equipment and manpower is required.

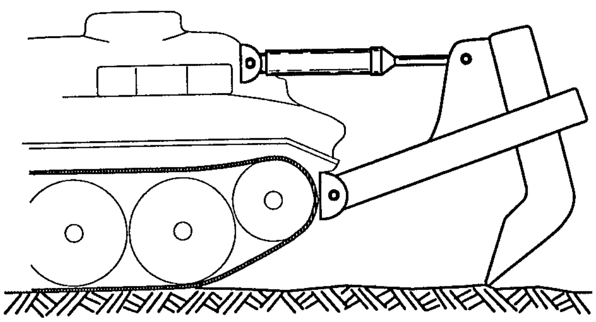
Rippers on dozers are commonly rear-mounted on a hydraulically operated linkage that is usually a permanent accessory to the tractor. This report discusses a less common ripper attachment used on the blades of crawler tractors. This device can be rapidly installed on most tractors that have a conventional dozer blade to provide some ripping capability. It can be easily transported to the field and installed with no modifications. For some tasks it can also be more versatile and less restricted by its location than a rear-mounted ripper. When mounted on part of the blade that is visible to the operator, it can be used to hook and remove rocks, barriers, and debris from the ground, and to trench for burying cables or small utility lines.

TRACTOR-MOUNTED RIPPERS

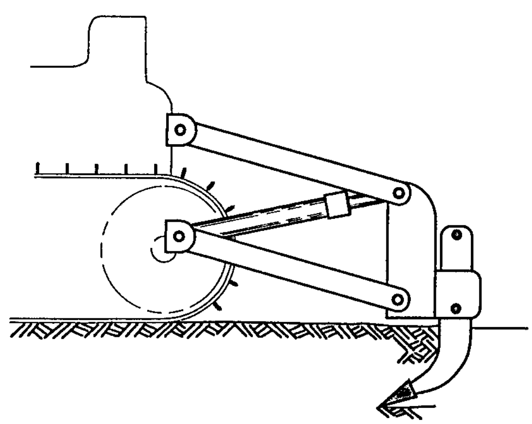
Rear-mounted rippers

Crawler tractors have been fitted with a variety of ripping schemes, as mentioned in the following discussion. Rear-mounted rippers are often fitted on modern crawler tractors and are specifically designed by the manufacturer to match machine characteristics. They are made for a large range of tractor sizes with various ripper configurations and linkage designs for depth control and adjustment. This type of ripper provides the greatest penetration and highest productivity. Penetration depth using rippers on very large machines can be as great as 4 to 5 ft (1.2 to 1.5 m) and range from 10 to 30 in. (0.25 to 0.75 m) on machines of the D7 class and smaller.

Rippers are hydraulically controlled through their linkage systems, with radial and parallelogram attachments common. The radial system in Figure 1a is an idealized version of a ripper used on the Russian T-34 tractor. Ripper tooth angles change with depth with the radial system. The parallelogram attachment (Fig. 1b) has the advantage of maintaining the same ripper angle at all depth settings. A single ripper is usually used to concentrate forces when ripping is difficult or when deep penetration is needed. Multiple ripper arrangements are often used on large tractors and when ripping is less difficult. Increased productivity and performance in hard ground and rock is possible with new hybrid rippers that create high ripping forces at the ripper tooth using a hydraulically powered impact system.



a. Radial.



b. Parallelogram.

Figure 1. Idealized view of linkages commonly used for attachment and adjustment of rear-mounted rippers. Variants of these attachments have additional control for adjusting the angle of the ripper tooth.

Dozer back-rippers

Back-rippers are attached to the rear of a dozer blade in a manner that allows them to swing down into place for use when a tractor reverses. They rip and scarify a surface so that on a following forward pass loosened material can be moved with the blade. These rippers do not interfere when dozing, since forward motion causes them to swing to the rear from their upper connection and drag along the ground as shown in Figure 2. When not in use they can be moved up and secured. These small blade-mounted rippers are installed on the Caterpillar DEUCE, and are also fitted on the Army D7 bulldozer. Ripping with this type of ripper is also discussed in FM 5-434 (U.S. Army 1992).

Removable ripper attachment for dozers

A less common commercial ripper attachment is available for use on the moldboards of dozers (moldboard refers to the curved metal plate that makes up most of the blade on a dozer, snow, or land plow; it is a continuation of the cutting edge

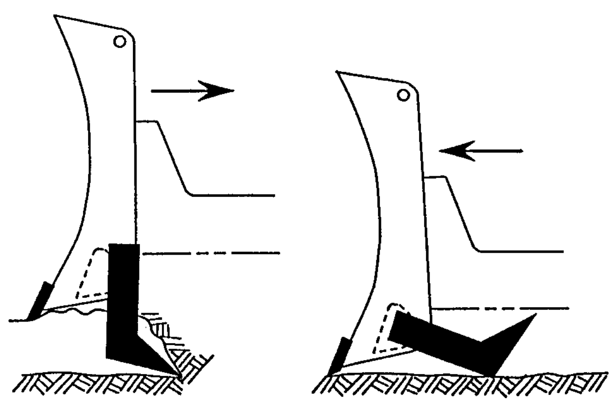


Figure 2. Back-rippers attached to the rear of a dozer blade for ripping and scarifying.

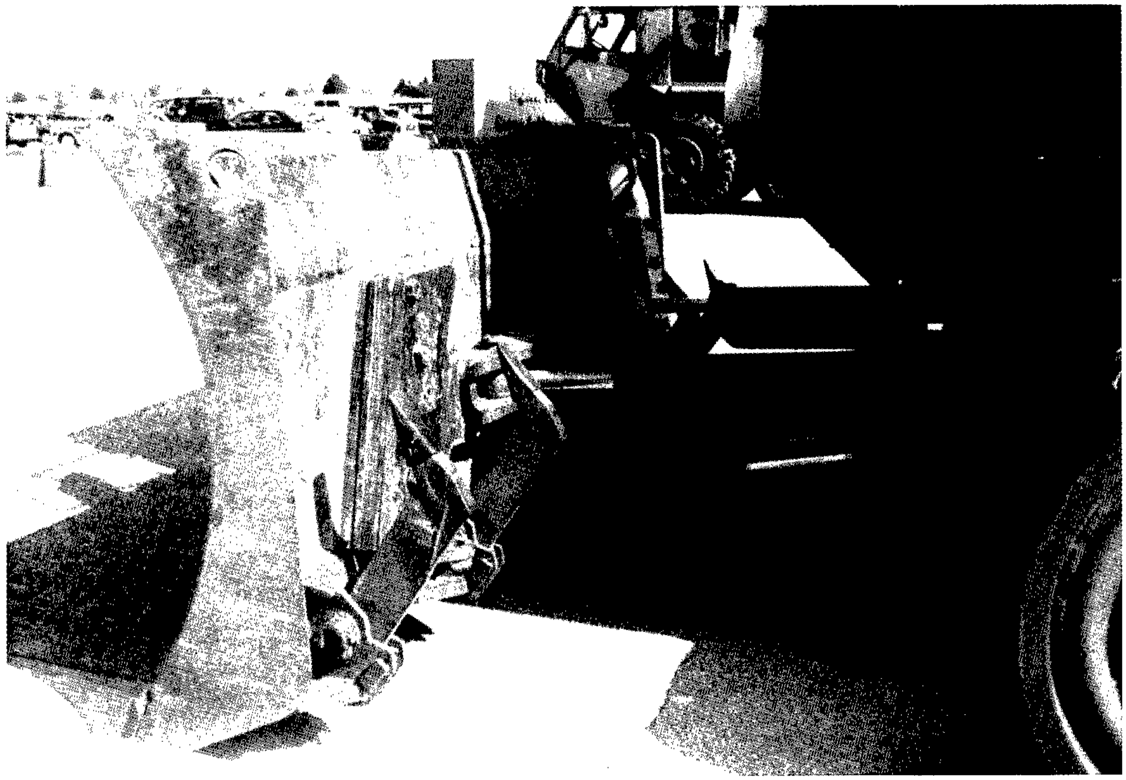


Figure 2 (cont'd).

and is used to direct the material being displaced). The attachment was introduced around 1947* and is still available in several sizes for use on a large range of bulldozers, depending on blade size, tractor power, and weight. The length of these rippers also increases with tractor size and weight, with a maximum penetration depth of 2 ft (61 cm) for the largest model. Attachment is not difficult. The top of the ripper is secured with an adjustable yoke that clamps at the top of the dozer blade, and the bottom is engaged by placing the lower part of the blade into a notch in the ripper shank. This notch is constructed to distribute forces to the lower part of the blade and cutting edge. Figure 3 shows all the components of the ripper, including the replaceable ripper tooth or wear point. Rippers for smaller tractors can be easily installed by two people since they can be put on one component at a time. On the smallest model, the largest and heaviest component is the ripper shank, which weighs 112 lb (51 kg). The total weight of the Hensley rippers varies from

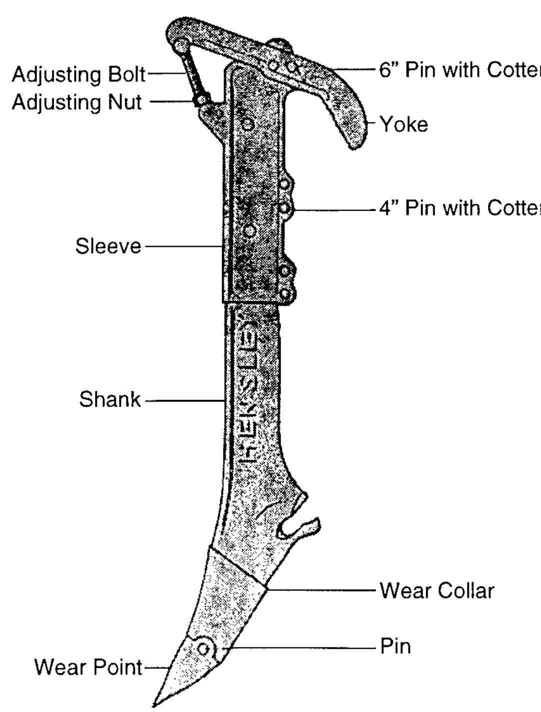


Figure 3. Ripper attachment for use on moldboards of dozers (used with permission of the GH Hensley Co.).

* Personal communication with GH Hensley Co.

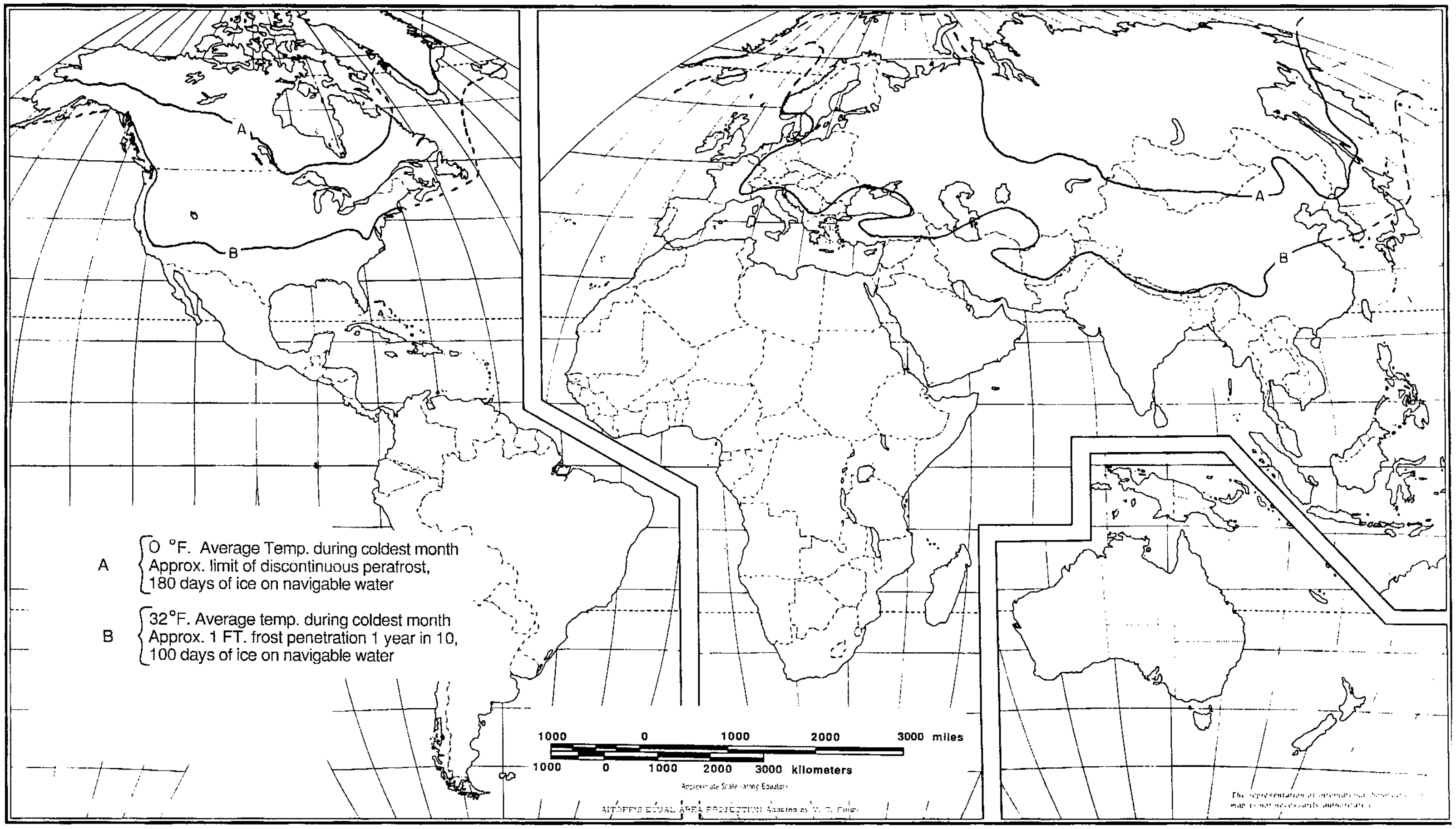


Figure 4. Distribution of permafrost and seasonally frozen ground in the Northern Hemisphere (after Bates and Bilello 1966). Note the B line for the southern limit of seasonal frost as defined in the illustration.

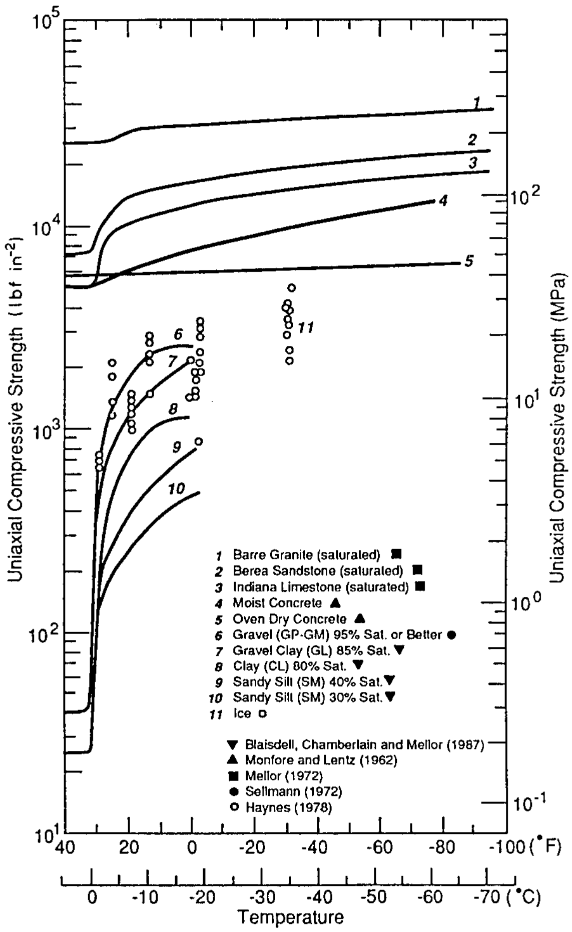


Figure 5. Effect of freezing and subsequent cooling on the unconfined compressive strength of concrete and earth materials: soil, rock, and ice (from Sellmann 1989).

about 170 to 870 lb (77 to 395 kg). The smallest model has 11 in. (28 cm) of penetration and, for our observations, was attached to the blade of a John Deere 550 dozer.

Quantitative performance information for blade-mounted rippers is not readily available, compared to the large background of experience and information on the more common rear-mounted rippers. However, if it is assumed that dozer blade penetration force and rear-mounted ripper penetration force are similar for most crawler tractors, it may then be possible to make some performance predictions for the less common blade-mounted attachment. It is interesting to note that data for the D7H indicate that down force on the cutting edge of the dozer blade is approximately 21,000 lbf* (93 kN), which is very close to the penetration force developed for a rear-mounted parallelogram ripper on this tractor. Horizontal force should also be similar when considering either a front- or rear-mounted tool, both having similar configurations.

EXCAVATING HARD AND FROZEN GROUND

A variety of hard ground conditions cause problems for conventional, unassisted dozers. These commonly include frozen ground, dense over-consolidated sediments, weak rock, coral, and desert caliche. Seasonally frozen ground causes significant problems because it is very common and because freezing greatly increases the strength of the ground surface, often preventing penetration with conventional tools. Seasonal frost is widespread in the Northern Hemisphere, and can be several feet thick. The southern limit of substantial frost penetration, where frost depth is about 12 in. (30.5 cm) once in every 10 years, is shown in Figure 4 (Bates and Bilello 1966); however, south of this limit seasonal frost can be thick enough to frequently hinder excavation.

Soil and rock significantly increase in strength with freezing (Fig. 5), with more than an order of magnitude increase common for most soils (Sellmann 1989). The strength of frozen soils continues to increase with cooling at temperatures normally encountered during winter. Frozen soils' strengths can approach those of unfrozen chemically bonded materials, such as weak rock and concrete. Therefore, excavation problems are caused by even thin layers of frozen ground.

Soil strength depends on several factors, including moisture content, grain size, and ground temperature. For purposes of excavation, frozen soils can be grouped into two general categories based on their grain size: 1) fine-grained soils that include various mixtures of silt, clay, organic material, and ice, and 2) coarse-grained soils consisting primarily of sand and gravel, with aggregates ranging from small pebbles to large cobbles. Of these the frozen fine-grained soils usually are most easily ripped and cut, and tend to be more ductile compared to the more brittle and abrasive coarse-grained material. The high strength and often large particle size and abrasive nature of the coarse-grained material make excavation difficult to impossible for small machines. Machines that can generate high tool forces, and have large teeth compared to aggregate size, have the best chance of working the coarse material.

* Personal communication with Caterpillar, Inc., 1994.

OBSERVATIONS OF WORK USING THE RIPPER ATTACHMENT

Dozers

To determine if this type of ripper might have military applications, rippers were acquired that would fit on a large military dozer and on two commercial dozers selected to represent smaller commercial and military tractors. The military tractor was an Army Combat Engineer Vehicle (CEV), constructed on the M-60 tank chassis with modifications to armament and addition of a lifting boom and hydraulically operated dozer blade. It was selected because it is unable to excavate in hard or frozen ground. It also represents a type of softly suspended tractor, based on fighting machine chassis, that has suspension characteristics that may affect ripper performance and control. This tractor with a ripper attachment is shown in Figure 6.

The smaller commercial tractors were used to gain an understanding of ripping characteristics and limits in frozen ground and of the potential performance of proposed military tractors. The John Deere 550 and 750 used are shown in Figures 7 and 8 with ripper attachments. General information on the tractors and rippers is given in Table 1.

The ACE (Armored Combat Earthmover) was not considered for mounting a ripper attachment because of aspects of blade geometry, construction, and ground clearance of the blade.

Figure 6. Ripper attached to the dozer blade of an Army Combat Engineer Vehicle (CEV).

Excavation sites

Observations were made at several locations with different soil types and frost conditions. Sites free of frost, but with hard ground, were also used. Frost thickness varied from approximately 4 in. (10 cm) to greater than 2 ft (60 cm). Soils included a frozen loamy soil in a natural setting with a sod cover, a dense frozen silty sand with local zones containing clay and scattered gravel at an old borrow pit, and a more rocky soil that contained some very coarse gravel. Frost greater than 2 ft (60 cm) thick occurred at two of the sites, and the ground at these locations was well frozen and strong.

The objective was to learn more about ripping performance and characteristics, taking into consideration tractor size, traction, tractor suspension (rigid versus sprung), ripping depth, and machine control during ripping. Attempts to tilt-doze with the corners of the commercial tractor blades were used to help assess ground strength and as a comparison for judging ripper effective-

Table 1. Machine and ripper specifications.

	Weight		*Power*	
Tractors	*(lb)*	*(kg)*	*(hp)*	*(kW)*
CEV*	114,000	65,300	750	559
JD550	20,000	9,000	90	67
JD750	29,000	13,150	110	82
D7 Cat.	45,000	20,400	200	149
	Weight†		*Penetration*	
Ripper	*(lb)*	*(kg)*	*(in.)*	*(cm)*
750-H	170	77	11	28
1000-HL	305	138	14	36

* The CEV is several tons heavier than the D9 Cat. and has twice the power.

† Total weight. The ripper attachment consists of three components. The individual parts were handled by two people for installation and transport.

a. Ripping frozen ground.

b. Close-up of fractured material produced after one pass.

Figure 7. John Deere 750 fitted with a moldboard ripper.

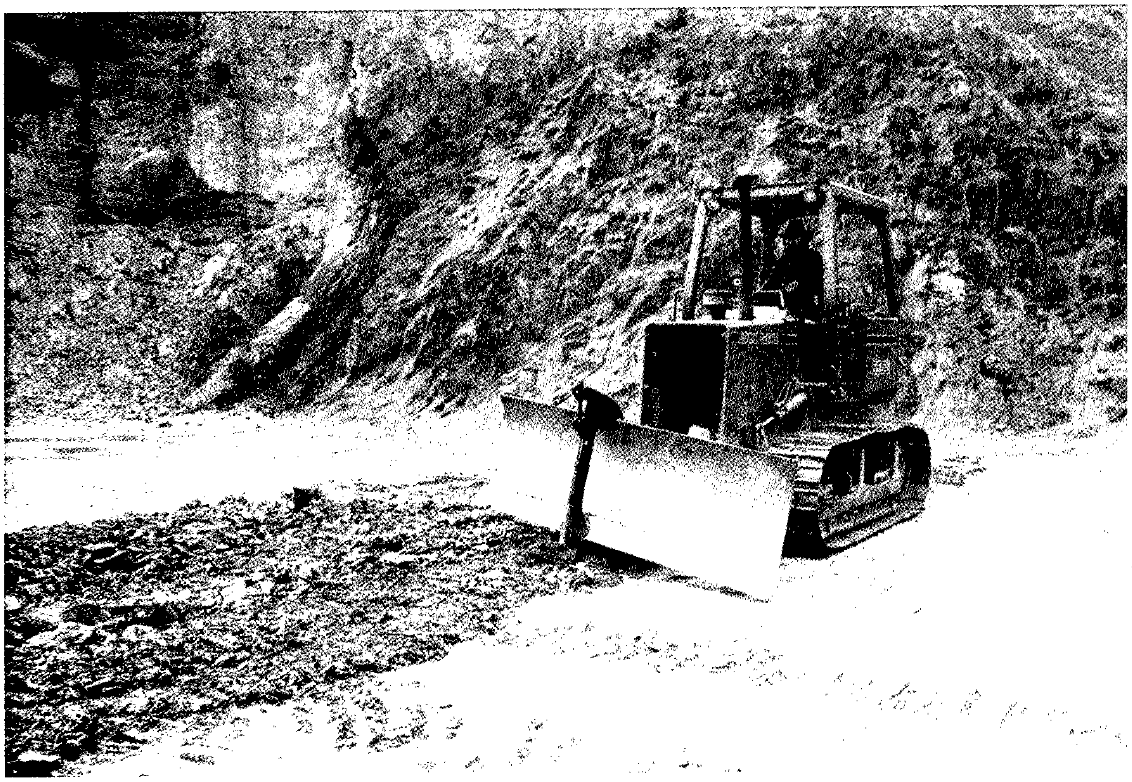


Figure 8. John Deere 550 with blade tilted to use its corner as a slide to limit depth of cut and control ripping depth.

ness. The observations were made during field demonstrations, and during runs planned for observing ripping characteristics. The observations in frozen ground were made at sites in northern New England. The CEV was used at the site with the strongest and most difficult ground conditions.

Rippers on commercial tractors

The GH Hensley model 750-H and 1000-HL rippers were used on the John Deere tractors. The 1000-HL ripper was attached to the center of the blade on the John Deere 750 without difficulty in about 5 to 10 minutes. The 750-H used on the John Deere 550 could not be installed on the center of the blade because controls on the rear of the blade interfered with the attachment yoke. Also, this ripper's standard yoke was not long enough to solidly engage the back of the blade. The 750-H was securely attached to the 550 blade by placing it just off center and using the longer yoke from the larger 1000-HL ripper. The lighter weight of the 750-H ripper also made installation easier. As mentioned, the ripper was installed in pieces to reduce the weight of the equipment handled. The ripper shank was first positioned on the blade, then the sleeve, followed by the yoke.

The 550 tractor was selected to help predict the potential ripping capability of the smaller military machines, such as the DEUCE, being tested by the Army. Caterpillar indicated that the down pressure on the blade edge of the DEUCE is approximately 7900 lbf (35 kN), which is similar to the John Deere 550 and some Caterpillar D4 and D5 tractors. The 750-H provided an indication of ripping performance of machines larger than the 550, but smaller than the D7 tractors used by the Army (Table 1).

Ripping with the John Deere 750

At the borrow pit, the seasonal frost was just over 2 ft (60 cm) thick. The surface and this layer were well frozen. Note in Figure 8 that the track grousers do not penetrate the surface and only mark the ground on high areas and in the turns. We initially tried to penetrate the frozen ground by tilt dozing (no ripper) with the corner of the blade. Tilt-dozing passes did not penetrate and only smoothed and polished the ground surface.

With the 1000-HL ripper attached, continual forward progress could be made when passes were less than full ripping depth. At this site 5 to 6 in. (13 to 15 cm) was routinely ripped (Fig. 7a).

Figure 9. John Deere 550 ripping the frozen surface of the test site; total ripping depth is approximately 1 ft (30 cm).

A close-up of the fractured material is shown in Figure 7b. Attempts to immediately go to full depth (14 in. [36 cm]) usually stopped the tractor and caused it to lose traction. The best performance was obtained when three to four passes were made to rip a single starting slot to full depth. This cut to full depth along a 60-ft (18-m) excavation took less than 5 minutes. Parallel offset passes were then made with less effort, with material failing to the prior cut; however, multiple passes (usually two or three) were still required for full penetration. The tractor and blade were stable and the ripper did not noticeably pull down the blade or the front of the tractor. Generally, forward travel was not smooth, and usually would slow when the ripper caught, loaded, and failed a slab. Occasionally, when the track slipped, lifting the blade would help fail the ground and restore forward motion. Failure of the frozen ground was often accompanied by a noticeable bang as the ground fractured and the blade unloaded. Forward progress was also restored by reversing and starting again, ripping at a shallower depth. At this site 10 to 14 passes were required to rip the frost to a depth of 14 in. (36 cm) over a swath approximately the width of the blade.

Ripping with the John Deere 550

The John Deere 550 with the model 750-H ripper attachment also effectively ripped frozen ground at the barrow pit. During these observations, ripping performance was improved with less catching and much better control over the ripping depth. The depth of cut was controlled by tilting the blade and using its corner as a skid. This prevented the ripper from pulling down the front of the tractor, which increased the depth of cut and occasionally stalled forward progress. The ripper was mounted just left of center on the blade, as shown in Figure 8, with the right corner placed on the ground and used as a skid. With this control, a 3- to 4-in. (8- to 10-cm) depth of cut could be maintained at a uniform forward rate. On an average it took 45 seconds to make a 50-ft-long (15-m) pass, ripping to this depth. It took approximately 10 minutes to rip an 11-in. (28-cm) frost layer in a 10- × 50-ft (3- × 15-m) area, which is about half of the area required for construction of some vehicle fighting positions. The 550 is shown ripping at this site and some of the large slabs produced can be seen in Figure 9.

During these observations the ground was flat, well frozen, and free of snow and ice. Traction was good, with the grousers only rarely slipping on the frozen soil surface. Although the effect of having the ripper slightly off-center on the 550 was not substantial, it occasionally caused the tractor to crab when ripping resistance was great.

Ripping with the CEV

The model 1000-HL ripper used on the John Deere 750 was also attached to the dozer blade on the Combat Engineer Vehicle (Fig. 10). A larger ripper model would have fit on this machine for greater ripping depth and a closer match with machine power; however, the greater weight of a larger ripper would have been much more difficult to handle and installation would have required mechanical assistance. This model was selected because it fit the CEV blade, it could be handled in pieces without mechanical assistance, the 14-in. (36-cm) penetration depth matched our requirements, and, if mechanical problems occurred, damage to the ripper was preferred to damage to the machine. The tool also appears to have value for general engineering tasks, such as moving obstacles. Use in a range of site conditions demonstrated its value for ripping hard, compacted soils and asphalt pavement.

The CEV was used at two sites with seasonally frozen soils: an undisturbed site with thin frost (4 to 5 in. [10 to 13 cm]) and a sod cover, and an area with a frost layer greater than 14 in. (36 cm) consisting of gravely material with sufficient fines and moisture to form very strong well-bonded ground. Both sites also had a thin snow cover (approximately 1 in. [3 cm]). A thin snow cover over smooth frozen ground can provide poor traction for the CEV fitted with rubber road pads.

The thin frost layer was easily ripped. The ripper was lowered to full depth as the machine advanced and the cutting edge of the dozer slid over the frozen surface. A narrow groove was produced that appeared very similar to the ones made ripping asphalt pavement at the engineer

Figure 10. Ripper attachment on the blade of the Combat Engineer Vehicle (CEV). This ripper is the same model that was used on the John Deere 750.

Figure 11. Ripper shown at full penetration in asphalt pavement with the blade sliding along the pavement surface. The slots cut during the previous passes are similar to those produced in thin seasonal frost.

school (Fig. 11). At no time was ripping resistance great enough to cause track slip or any significant motion in the suspension of the machine. Ripping this thin frost seemed effortless.

In contrast, ripping at the site with thick frost was noticeably different, with much greater resistance to ripper advance. Ripping to the depth of the ripper (14 in. [36 cm]) usually required three passes. Ripping forces were also great enough to affect traction and cause significant interaction with the suspension. As with the commercial tractors, the best performance was obtained when passes were made parallel to a cut ripped to full depth, which provides an additional free face for material failure. The large size of the frozen blocks produced can be seen in Figure 12. Since ripping to full depth required successive passes, it was necessary to hold the blade in a position that would permit incremental penetration.

Initial penetration was not difficult, and Figure 12 shows the CEV starting a pass while holding the blade in a position that would allow 6 to 8 in. (15 to 20 cm) of penetration. Very little down pressure on the blade was required to reach the planned depth. In hard ground, maintaining the depth was a problem, since tooth configuration and variations in material properties tended to cause large fluctuations in the vertical force required to control the ripper. The ripper would tend to grab and pull into the ground, loading the suspension system. This would result in the ripper cutting a deeper groove, which could slow forward progress and occasionally stop the machine. Attempts to respond by pulling up the blade only compressed the suspension further until sufficient vertical force was available to pull the ripper up, out of the ground; sometimes the ripper jumped to a position above the ground surface when the suspension unloaded. It was not possible to fine tune the depth of cut as it was with the commercial tractors that have no suspension system. However, careful teamwork between the operator and the spotter on the ground and good operating technique can reduce this problem and maintain productive ripping.

A technique that worked well was based on responding to changes in forward progress. Once the operator sensed that forward progress was

Figure 12. Ripping seasonally frozen ground to the total depth of 14 in. (36 cm) with the CEV. Ripping to this depth (i.e., the length of the ripper below the blade) required multiple passes along the same path.

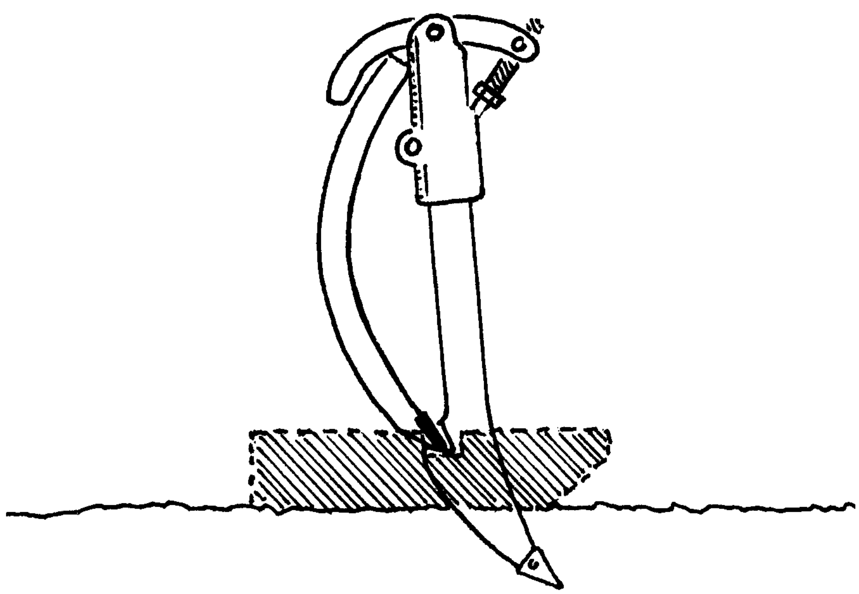


Figure 13. Dozer blade, ripper, and simple skid used to control depth of cut, independent of CEV suspension.

slowing because of increased ripping resistance, instead of making a blade adjustment, it was best to stop, reverse, and let the suspension unload, then advance again, essentially starting over with a shallow cut. In hard ground productivity was greatest with successive shallow cuts compared to fewer deep cuts.

Since the blade of the CEV can not be tilted, this means of controlling depth of cut and reducing the influence of the suspension was not available. However, to see if overall performance could be improved with better control of ripping depth, a skid was used on the blade to make depth of cut independent of the suspension. This was done in a very expedient manner. A section of railroad tie, approximately 3 ft (90 cm) long, was used as a skid and placed under the blade like a ski. The front was cut with a ramp, and a shallow notch in the top engaged the blade (Fig. 13). The blade was lowered into the notch, limiting penetration to about 8 in. (20 cm). Passes made with the skid were noticeably different from those made when depth was controlled by blade adjustments alone. With the skid, forward progress was smooth with no stalling and loss of traction.

Considering the poor traction usually attributed to the CEV when it is operated on packed snow with road pads, we found that performance was good. Traction was lost only a few times, and on those occasions it usually could be anticipated. Ripping was resumed by reversing the machine for a new start at a shallower depth.

Figure 14. GH Hensley 1000-HL ripper attached to the outer part of the blade on an Army Caterpillar D7 tractor. This model was also used on the CEV and John Deere 750.

Ripper on the Caterpillar D7

The model 1000-HL can also be attached (fully extended) to the outer part of the 7-S dozer blade used on some Army D7 tractors (Fig. 14). The ripper was used to rip compacted gravel and asphalt pavement; no frozen ground was available at the time. However, with the tractor's weight, power, and blade control, good ripping performance in frozen ground would be expected.

CONCLUSIONS AND RECOMMENDATIONS

The moldboard ripper attached to the blades of commercial and military dozers provided a rapid, low cost means of developing a ripping capability. The rippers were easily attached in the field in less than 10 minutes with no modification required to the tractor or the ripper. At our sites the ripper attachment provided the dozers a means of ripping hard and frozen ground.

We observed no significant difficulty with ripping, given the ground conditions that existed at the time of testing, which included some hard, well-frozen soils. Ripping performance can vary greatly, depending on the strength properties of the frozen ground, which is controlled by the soil type, moisture content, and ground temperature. Much less than ideal traction was available at the sites since grouser penetration was not possible. However, after a few passes with the ripper, traction should have improved.

Full penetration (14 in. [36 cm]) of the large ripper in one pass was not possible when frost thickness approached this depth. Asphalt pavement and a seasonal frost layer, both varying from 3 to 5 in. (8 to 13 cm) thick, were ripped by the CEV with little noticeable resistance to both initial penetration and forward progress. In both cases the ripper was placed at full depth and the dozer blade was allowed to slide on the surface.

Multiple passes were required to rip to the full depth of the rippers when frost thickness was greater than about 6 in. (15 cm). The depth of penetration for a single pass uninterrupted by stalling and catching was similar for the JD750 and the CEV using the model 1000-HL ripper and ranged from 4 to 8 in. (10 to 20 cm); however, soil properties were a little more difficult at the CEV site. Three to four passes were required to make the first cut to the depth of 14 in. (36 cm). The suspension on the CEV made maintaining optimum depth of cut and smooth forward progress a difficult task. Depth control was more easily regulated with the JD750 and JD550, since the machines were more rigid and tilt-blading could be used to control depth of cut.

The more limited control over ripping depth with the CEV did not prevent it from ripping. It required a technique to minimize the effect of the suspension system. This involved stopping forward progress as soon as the front of the machine started to drop and forward progress began to slow. Starting again by reversing a short distance to free the ripper, then advancing while slowly lowering the ripper to a depth that allowed smooth forward progress was quite effective. Also, it is important for an operator to work closely with a spotter on the ground for better control of depth of cut and spacing of the paths to be ripped. A number of shallower cuts can be made faster than a few deeper ones.

A ripping depth of several inches was easily controlled with the JD550 and 750-H ripper by tilting the blade and letting the corner act as a slide to limit the depth of cut. Forward progress was smooth using this technique and overall productivity of the JD550 using the smaller 750-H ripper was similar to that of the JD750 with the larger 1000-HL ripper. Smoother and uninterrupted ripping was also possible with the CEV when depth of cut was controlled by using a skid under the blade, which eliminated the influence of the suspension.

For some tasks a blade-mounted ripper can be more versatile than a rear-mounted ripper. With slightly better visibility for the operator, it can be more easily used to remove barriers, rocks, stumps, and other obstacles; however, it can not be expected to have the performance of a rugged rear-mounted ripper that is designed for production ripping.

The rippers fit well on all of the machines, and neither the rippers nor machines were damaged during these observation. Once the rippers were adequately tightened, they were stable on the blades and moved only slightly.

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13. ABSTRACT (*Maximum 200 words*)

Ripping of hard and frozen ground is commonly done by using crawler tractors with rear-mounted rippers that are usually a permanent part of the machine. Ripping is an attractive alternative to other methods of breaking a hard surface layer that restricts excavation, since it utilizes existing equipment and personnel, and a tractor that can be used for the excavation project. A simple ripper attachment for use on the blade of a dozer was used to determine if this easily installed tool could provide some ripping capability when machines with rear-mounted rippers are not available. This ripper attachment was used in a range of frozen soils that could not be excavated with a dozer, and was used on tractors ranging in size from small commercial dozers to a large military dozer with a suspension system. In all cases, at the sites used, the ripper attachment provided the machines with some ripping capability. The ripper was also easy to install, with no modifications required to the tractors or the rippers.

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