Recycling of Road Surfaces with the Roto Trimmer Mobile Rock Processor

Donna McConnaha Sheehy, *USDA Forest Service, Missoula, Montana*

How can we recycle existing road materials in place to reduce their size and develop a tough, long-lasting, maintainable cushion that will weather well and cost substantially less than importing materials processed elsewhere? Current methods of reconditioning worn-out native-surfaced roads have had limited success and can be quite costly. Development of aggregate pit sites for resurfacing roads can also be an expensive and lengthy process. In addition, there may be environmental impacts connected with opening the pit and any associated road construction or reconstruction. Since 1990 the Northern Region of the USDA Forest Service has been utilizing and evaluating a machine called the Roto Trimmer mobile rock processor. It has been used to recondition approximately 185 m (115 mi) of worn-out native-surfaced roads with varying degrees of success in Montana, Idaho, Wyoming, and Alaska. This process is expected to become a viable tool for reconditioning existing roads and provide future cost savings and environmental benefits.

The Northern Region of the USDA Forest Service—which includes Montana, portions of North and South Dakota, and northern Idaho—contains more than 78 100 km (48,500 mi) of roads of which 82 percent is native-surfaced, 16 percent is aggregate surfaced, and 2 percent is paved. With years of historically low maintenance budgets, many of these native-surfaced roads are worn out and not maintainable. The existing roadbeds are extremely rough and composed of cobbles, ledge rock, and boulders, with little or no fines. There is a great need for a maintainable road.

Traditionally, roads of this type were maintained either by ripping, grading, and grid rolling or by importing aggregate surfacing. Ripping and grading do not always result in a satisfactory end product. Resurfacing requires either hauling material from existing pits or developing new pits. Development of new material sources requires the proper permits, royalty fees, and environmental assessments or impact statements and can become quite expensive and involve possible delays. In addition, pit sites can have undesirable impacts on the environment.

In 1990 the Northern Region began experimenting with an alternative method of reconditioning worn-out, native-surfaced roads. The Roto Trimmer mobile rock processor was first used to recondition 37 km (23 mi) of road on the Lolo National Forest. Since then the machine has been used on several projects throughout the region and in Alaska. The Canadian government has also expressed an interest in the machine and the process. The region is continuing to utilize this process to produce a maintainable road as it has become a viable, cost-effective tool for road maintenance.

Equipment

The process of recycling existing road surfaces involves the use of the Roto Trimmer mobile rock processor, usually followed by the use of a motor grader of 135 hp or greater, an Elliot grid roller, a traditional vibratory roller, and an optional water truck.

The original model for the Roto Trimmer was a rock crusher developed by Crude Tool Works of Kenai, Alaska. The 1991 purchase price was $196,500. This machine was designed to break up permafrost and had not been utilized as a road maintenance device.

Triple Tree Inc., of Missoula, Montana, purchased the rock crusher and made more than $45,000 worth of modifications to the machine in order to process road surfaces more effectively. A patent on these modifications is pending.

The machine, shown in Figure 1, resembles a giant Rototiller and consists of a two-component kit: a front rotary drum attachment and a rear power pack. This kit mounts on any suitable carrier such as a loader, grader, or scraper. It is essentially balanced as the drum and the power pack each weigh approximately 5 450 kg (12,000 lb). The kit components can be mounted or removed from a loader in approximately 12 person-hr.

Rotary Drum Attachment

The rotary drum attachment consists of the drum and a 76-mm (3-in.), removable, solid steel rear-impact plate. The rotary drum is 0.9 m (3 ft) in diameter by 3 m (10 ft) wide and can turn in forward and reverse motion at 84 rpm. It can also be raised for slope work. Three types of drums have been constructed: one that produces a level surface, one that produces a windrow to the middle, and one that produces a windrow to the sides.

The drum has 184 carbide-tipped teeth in knuckle holders mounted in a spiraled-inward pattern, as shown

FIGURE 1 Roto Trimmer mounted on a Caterpillar loader (rotary drum on front lift arms and power pack at rear).

FIGURE 2 Rotary drum attachment with carbide-tipped teeth.

in Figure 2. The teeth rotate after every strike to produce even wear. Teeth have an average life of 8 hr and are the only routine replacement item. They are quickly removed with either a forked tool and hammer or an air drill and are easily installed with a tap of the hammer. Teeth cost approximately $3.20 each in 1993.

A tooth hits every 3.175 mm (0.125 in.) of soil. The teeth crush the rock and rip the material as the drum rotates. The loose rock revolves counterclockwise to the impact plate on which it is further fractured and blended.

Power Pack Attachment

The power pack attachment includes a Caterpillar Model 3406 (D-9) diesel engine rated at 400 hp, a hydraulic pump with reservoir and related hardware, and work lights and taillights. The power pack allows the machine to operate at temperatures from −45°C to 26°C (−50°F to 80°F).

Machine Modifications

After the first project, the Roto Trimmer was modified by the road contractor, Triple Tree Inc., to increase its efficiency and to produce a better end product that met gradation specifications (*1*). These modifications resulted in better rock fragmentation and decreased the outcasting of larger rocks. They also added further protection and stability, simplified the machine's operation, and increased its maneuverability.

Machine Capabilities

The machine processes most existing road surface materials to a specified depth of 0 to 150 mm (0 to 6 in.)

and a gradation of −100 mm (4 in.). It cuts a path 3 m (10 ft) wide and leaves the road material in a well-mixed state.

Technical Specifications

Work is controlled by a special project specification developed for use in the Northern Region. This specification describes the process and the desired end product. It is modified as needed. The specification and an equipment specification developed for some contracts to provide additional quality assurance are shown in Figures 3 and 4.

Measurement for contract payment has usually been by slope distance along the centerline of the road. Payment is either by kilometer, by station, or by lump sum. Some contracts were simply for equipment rental by the hour.

Operation

Generally no preparatory work is required other than blasting or breaking of large oversized rock or outcroppings to save on tooth breakage. A handheld Pionjar rock hammer is used where blasting is not an option.

The optimal procedure has been to operate the machine at idling speed against the grain of the rock. A pass 3 m (10 ft) wide by 100 to 150 mm (4 to 6 in.) deep is made (see Figure 5), followed by another pass alongside for most roads wider than 3 m (10 ft). When attempting to grind to a depth of 150 mm (6 in.), the machine will usually make two passes to obtain full breakage of the rock material. Small sidecast windrows are made, which are reripped to produce material of a smaller particle size. A grader smoothes the windrows, a water truck applies compaction water and controls the minimal dust, and a traditional vibratory roller used in conjunction with an Elliot grid vibratory compactor brings up fines and compacts the soil. The result is a finished road with a hard, smooth, maintainable driving surface.

This process works well in frozen soil, as the rocks stay in place for crushing. Some dampness in the soil is preferred for decreased machine wear, dust control, and compaction.

Material Quality

The quality of the recycled road material cannot be regulated to the extent that the quality of crushed or screened material can. However, tests have shown that there is a substantial improvement to most materials processed by this recycling method. The materials are reduced to approximately the 100-mm (4-in.) class with a large increase in fines. This, combined with adjustable depth control and good compaction, provides an excellent, long-lasting, and maintainable road cushion material (see Figure 6). It appears that roads would not need to be recrushed for 6 to 10 years.

Project Areas

Since 1990, approximately 185 km (115 mi) of roads have been reconditioned with this process with varying degrees of success. A sampling of these projects follows.

Gilbert/Schwartz Creek Demonstration Project

The Gilbert/Schwartz Creek project was located in Lolo National Forest, Missoula, Montana, in 1990.

Project Description

This demonstration project consisted of reconditioning portions of 37 km (23 mi) of very rough, worn-out roads with excessive rock and little or no fine material. The road was built in 1963 and had little use and no maintenance since that time. Sample sites were chosen in a variety of rock types common to the area, including massive limestone/dolomite outcrops and boulders with some to no fracturing; fractured, brittle metaquartzite; and an igneous intrusion. Samples were taken before and after processing and tested for plastic and liquid limits, plasticity index, abrasion, sieve analysis, and durability (*1*).

Project Results

The test results showed significant improvements in gradation and a substantial reduction in rock greater than 75 mm (3 in.). The oversized rock was fragmented, and an appreciable amount of fines was produced. There was a thorough mixing of the processed material, which tends to reduce pothole development. A few isolated sections had noticeably oversized material. The sections showing the greatest improvement had rocks that displayed weathering, internal fracturing, or jointing (*1*).

Project Costs

Time and cost comparisons were difficult to make since this was an experimental project. Operating costs and production rates were reasonably close to those of conventional methods. Machine operating costs were approximately $52 per 300 m (100 ft) of road for the

Special Project Specification

Section 815 - Reestablishing Native Surface

DESCRIPTION

815.01 Work This work shall involve using state-of-the-art mobile, rock milling equipment to manufacture cushion material to a specified depth on a native surface road. The surface shall be well blended. Work shall include reducing bedrock and oversized rock down to a specified size. All oversize material shall be broken down and incorporated into the road, or sidecast to the downhill side of the road. It also includes watering, mixing, rolling, blading and shaping of the manufactured cushion material into a smooth, non-segregated road surface.

CONSTRUCTION

815.02 Method The cushion material shall be produced by processing the existing surface as **SHOWN ON THE DRAWINGS**. The cushion material shall be developed by blending, breaking, grinding and pulverizing bedrock and oversized rock contained within those dimensions down to the maximum size of 100 mm (4 in) or as specified in the drawings.

The cushion material shall have the fine and coarse particles uniformly mixed across the entire width of the road to eliminate localized pockets of open graded rock or fractured ledge rock.

The floor beneath the native surface cushion shall be uniform across the total width of the road such that the required

FIGURE 3 Special Project Specification for reestablishing native-surfaced roads.

depth of 150 mm (6 in) (or as specified) is reasonably uniform to meet the road typical section. No bedrock or oversized rock will be allowed within the specified depth of the cushion material. Oversized material shall be disposed of as designated by the engineer.

In limited situations, when approved in writing by the Engineer, the contractor may elect to cover segments of bedrock with imported material. This imported material must meet all the requirements of the specified cushion material and its source must be approved by the Engineer. There shall be a minimum grade transition of 15 m (50 ft) on each side of the covered section. Approval of this option will be infrequent and will not include segments of loose rock or boulders.

815.03 Compaction After development of the cushion material, the traveled way and shoulders shall be uniformly crowned, insloped, outsloped, or superelevated as **SHOWN ON THE DRAWINGS**. The entire roadway shall be compacted by operating compaction equipment over the full width of the layer until visible deformation ceases. At least three complete passes shall be made. Compaction equipment shall be capable of obtaining compaction requirements without detrimentally affecting the compacted material.

815.04 Water While compacting, blending and finishing, the cushion material shall have sufficient moisture, either natural or added, to prevent segregation and to facilitate compaction.

815.05 Finishing At the conclusion of the blading, shaping, and compaction operations, the roadbed shall have a uniform grade and smooth surface free of hollows, depressions, segregation and projections above the road surface. No berm or ridge shall be left along either shoulder of the roadbed, unless directed by the engineer.

FIGURE 3 *(continued)*

(a) - Road Reclaimer and Carrier

(1) Carrier must be capable of carrying and maneuvering cutting head at required depths.

(2) Cutting head weight shall be 6,800 kg (15,000 lb) or more to avoid excessive bouncing.

(3) Rotary drum shall have at least 184 carbide teeth set in a spiral inward pattern.

(4) Rotary drum should be able to make a 3 m (10 ft) wide cut and rotate at 94 rpm's minimum and exert a force of 34,450 kPa (5,000 psi).

(5) Power plant shall be a minimum 400 hp, have hydraulic pump with reservoir and related hardware.

(6) Manufacture date shall be 1990 model or newer.

(b) - Road Grader

(1) Grader shall have a 3.7 to 4.3 m (12 to 14 ft) hydraulic moldboard equipped with serrated blade and appropriate end pieces to sift out oversized material.

(2) Basic operating weight shall be 13,170 kg (29,000 lb) or more.

(3) Have a ripper attachment.

(4) Minimum rated flywheel horsepower shall be 135 hp.

(5) Manufacture date shall be 1977 or newer.

FIGURE 4 Equipment specification for use with Special Project Specification.

(c) - Water Truck

(1) Minimum capacity of 11,355 L (3,000 gal). .

(2) Shall have a spreader bar. Water application may be gravity fed or pressurized.

(3) Draw or suction hose for filling must reach a minimum of 10.7 m (35 ft).

(4) Manufacture date shall be 1977 or newer.

(d) - Vibratory Compactor

(1) Compactor shall have minimum 22,700 kg (50,000 lb) dynamic force.

(2) Dual amplitude and variable frequency of 0-265 Hz.

(3) Compactor shall be vibrating smooth steel drum with Elliot Grid or comparable system.

(4) Date of manufacture 1985 or newer.

(e) - D6 or D7G Dozer

(1) Must have ripper and dozer.

(2) Must have at least 170 to 200 hp.

(3) Manufacture date 1977 or newer.

FIGURE 4 *(continued)*

FIGURE 5 Roto Trimmer making first pass.

Roto Trimmer, a grader, a vibratory roller, and a water truck. The contract for this project cost about $2,500/km ($4,000/mi).

Eagle Creek Road Reconditioning Project

The Eagle Creek project was performed in 1991 in the Gallatin National Forest, Bozeman, Montana.

Project Description

This project consisted of reconditioning 9 km (5.6 mi) of road on which the surfacing had worn away, leaving very hard, protruding rocks ranging in size from 150 to 400 mm (6 to 16 in.). Little or no fines were present.

Project Results

Many of the protruding rocks were broken during the rototilling process. Others were pulled up by the grader and sidecast. Although a 4-in. minus surface was not obtained in all cases, sufficient fines were produced to allow the grader to blade and restore the road to its original template. In addition, the ditches were pulled and the turnouts were milled, bladed, and rolled. The finished road surface averaged 4.6 m (15 ft) in width. The finished product has not required any additional maintenance blading for the last 2 years.

FIGURE 6 Typical road surfacing after being processed with Roto Trimmer.

Project Costs

Average production rates were 0.19 km/hr (0.12 mi/hr) for the Roto Trimmer, 0.18 km/hr (0.11 mi/hr) for the grader, and 0.18 km/hr (0.11 mi/hr) for smoothing with the vibratory roller. Average costs were approximately $2,730/km ($4,400/mi). The total cost was $24,987.50, based on a time-and-equipment contract.

For the sake of comparison, an estimate was made for the cost of placing pit-run material on the project. Placing 5,200 m^3 (6,800 y^3) of material hauled from a distance of 5 km (3 mi) and adding a 10 percent mobilization factor would have resulted in a total cost of $58,800.

Comments

Many oversized rocks were sidecast by the Roto Trimmer. The contractor indicated that on the basis of the size and hardness of the material, the oversized material should have been ripped with a Caterpillar bulldozer and hoe before being processed with the Roto Trimmer.

Forestwide Road Reconditioning Project

The Idaho Panhandle National Forest, Coeur d'Alene, Idaho, was the location of a reconditioning project in 1993.

Project Description

The project consisted of reconditioning approximately 39 km (24 mi) of native-surfaced roads and 3.2 km (2 mi) of a chipsealed road. Roads were located throughout the forest. Road widths varied from 3.7 to 5.5 m (12 to 18 ft) with turnouts. The roads exhibited rough surfaces, large rock protrusions, and exposed bedrock, and most fines were worn off.

The roughness (rideability) of the roads was measured with a Cox roughness meter before and after processing by the Roto Trimmer. In addition, gradations were obtained before and after processing (2).

Project Results

Overall, the recycling process proved very successful. Instead of blasting, a Pionjar rock hammer was used to fracture some of the more difficult rock. This allowed the Roto Trimmer to move through the rock sections more easily, resulting in cost savings. The native-surfaced roads were worked to a depth of 150 mm (6 in.) and the chipseal surface was worked to a depth of between 100 and 150 mm (4 and 6 in.). The maximum-size rock allowed in the cushion material was 100 mm (4 in.). Most of the project roads are adjacent to streams or rivers. As the Roto Trimmer did not throw rock or generate excess dust, there was no noticeable impact on drainage during reconstruction (Figure 7).

The roughness counts were reduced by 50 to 70 percent. This reduction is equivalent to changing from a rough or an extremely rough surface to a moderately rough surface. Before processing, the speed of the roads was controlled by the rough character of the surface. After processing, the speed is controlled primarily by the alignment (2).

In general, the existing gradation of 250 to 300 mm (10 to 12 in.) minus was reduced to 75 to 100 mm (3 to 4 in.) minus. The roads can now be graded where previously it was not possible (2).

Project Costs

Average production rates were 1.2 km/day (0.75 mi/day). Average production costs were approximately \$3,650/km (\$5,900/mi), not including mobilization and costs for moving between work sites. Meeting the specifications and the equipment requirements resulted in a total project cost of \$169,300.

Comments

Working the chipseal surface was an experiment to determine what type of finished product would be generated. Under one section of chipseal was a gravel surface. The end result was a good, finished surface with a well-mixed, chipseal and gravel material. Another section of the chipseal was mixed with a latex material. This surface caused some problems and was difficult to process.

Some of the roads within this project required spot work on rocky sections only. It appears that doing work in spots rather than in a continuous length was more expensive and harder to accomplish.

Round rock caused some problems in that the drum could not break it down. The rock would roll around in the drum until it was sidecast.

Potential effects on water quality were reduced as the higher-standard surface resists traffic-induced damage and erosion. Other environmental benefits and significant cost savings were realized as no pit development and hauling of surfacing material were required.

FIGURE 7 Roto Trimmer in operation; note small amount of dust and sidecast material.

Leigh Lake Road No. 4786

The Leigh Lake Road project, located in the Kootenai National Forest, Libby, Montana, was performed in 1993.

Project Description

The project consisted of reconstruction of 2.7 km (1.7 mi) of a road that had not been maintained but received a large amount of recreational use, primarily by high-clearance vehicles. Over the years, the road had become a trench with no drain dips or open tops and an occasional nonfunctioning culvert. The surface was quite rough—many of the users would walk rather than drive on the road. There were several concerns over the reconstruction: how to maintain the integrity of the road with minimum clearing; what to do with the outside shoulder that was primarily a disposal area for rocks; how to provide adequate drainage; and where to obtain a suitable source for surfacing the road. Figures 8 and 9 show conditions before and after processing of the road surface with the Roto Trimmer.

Project Results

The project was considered quite successful. The native-surfaced rock fractured to a fairly uniform 100 mm (4 in.) pit-run surface, eliminating the need for a borrow source. The material in the outside berm was utilized in place, so disposal of oversize material was kept to a minimum. The reconstructed road maintained the integrity of the original location but with a drivable, maintainable surface. The road was shaped to drain with open tops.

FIGURE 8 Leigh Lake Road: typical section before processing with Roto Trimmer.

FIGURE 9 Leigh Lake Road: typical section after processing with Roto Trimmer.

Project Costs

The total cost for the project was $32,655: $1,800 for clearing; $11,355 for mobilization; and $19,500 for reestablishing the native surface. Mobilization included an excavator, Roto Trimmer, a grader, and a roller.

Comments

Mobilization costs would have been much less if several projects had been located within the same area. This single project took place approximately 320 km (200 mi) from the construction company's location.

SUMMARY

Limitations

There are limitations to the materials that can be processed. Most large metamorphic or igneous boulders are not easily reduced and may require some preprocessing. Some are just too hard. Generally, if the material can be ripped with a D8 size bulldozer, then it can be processed by the Roto Trimmer.

Round rocks cause some problems in that they become stuck between the teeth or roll around in the drum until they are sidecast, rather than being processed.

Benefits

Economics

In most cases the cost of Roto Trimming is a fraction of the cost of crushing material or hauling pit-run material to the site. Operating costs and production rates appear to be reasonably close to those of the conventional methods of ripping, grading, and grid rolling.

This process eliminates the road surface memory, which may contain soft spots, potholing, and washboarding. The cushion and subsurface have been trimmed to a smooth flat plane that will dissipate most moisture laterally and eliminate previous problem areas. The road surfaces produced with this recycling process should make for less maintenance and a longer life, resulting in long-term cost savings.

Environmental Impacts

The recycling of road surfaces eliminates the need for opening new material sources and any associated new road construction. As shown in Figure 7, the actual reconstruction process generates less dust and sidecasting than traditional methods, resulting in fewer impacts on adjacent drainages and any associated fisheries. It utilizes the existing materials in the road surface to build a stable cushion. When the material is compacted with a vibratory roller, a finished product is developed that will last for years without harming the environment.

Other Applications

Aggregate-Surfaced Roads

The process of reconditioning native-surfaced roads should also apply to crushed or pit-run road surfaces that may be experiencing rutting, washboarding, potholing, or material segregation. Binders could be added that would lengthen the life of the road.

Road Stabilization

When roads are no longer needed for resource management, they need to be closed or obliterated and the existing surfaces stabilized to prevent erosion. Scarifying an inch of the native surface material produces a roadbed ready to be seeded and fertilized. Because the process leaves the road surface in a well-defined and shaped cross section, the seeded roadbed can still provide access during emergencies such as forest fires.

ACKNOWLEDGMENTS

The author would like to acknowledge the cooperation of the following individuals in supplying the relevant data and information: Mary Northrup and Jim Northrup of the Idaho Panhandle National Forest, Paul Hayes of the Gallatin National Forest, Darrel Steinberg of the Lolo National Forest, Donna Tucker of the Kootenai National Forest, and Bob Greil, Dick Greil, Tom Greil, and Jim Greil of Triple Tree Inc., Missoula, Montana.

REFERENCES

1. Hegman, S., and K. Kreyns. *Field Testing of Roto Trimmer Mobile Rock Processor.* USDA Forest Service Engineering Field Notes, Volume 23, September–October 1991.
2. Northrup, J. *Development of Cushion Aggregate on Native Surfaced Roads by Use of the Roto Trimmer.* USDA Forest Service, 1994.