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Forester C-2000 Road Reconditioning — 3 Demonstration Projects



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EXECUTIVE SUMMARY

This paper describes the results and conclusions gained from the three demonstration projects. The paper concentrates on the characteristics of the processed material, equipment production, and the cost of the operation. Samples taken from windrows during the crushing operation were tested to determine hardness and gradations before and after crushing. The test results are included in the appendix. Cost varied from \$6.38 to \$18.83 per cubic yard, including roadbed preparation, crushing and blading. Rocks and boulders to 16-inch (406 millimeter) maximum size were crushed. The processed material has a maximum size of 2 to 3 inches (50 to 75 millimeters).

The product produced by the crusher offers a viable alternative for aggregate on a road surface, particularly as a road surface cushion material, where the quality and expense of standard crushed aggregate are not warranted.

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INTRODUCTION

In November 1996 San Dimas Technology and Development Center (SDTDC) published a report documenting the use of the Forester C-2000 for an in-place, road-reconditioning project on the Coronado National Forest in Arizona (1). In 1997, SDTDC, in partnership with the Coronado National Forest, sponsored two demonstration projects to further test the Forester C-2000 at unique locations to gain additional information from actual field trials. These projects were located on the Rio Grande National Forest in Colorado and the Plumas National Forest in California.

FORESTER C-2000

The Forester C-2000 (Figure 1) was developed by F.A.H.R. Industries, Saint-Jacques, New Brunswick, Canada, and mounts on the front of a CAT 950F front-end loader. The crusher is powered by a CAT 3208, 255 horsepower (190-kilowatt) diesel engine, and consists of eight hammers bolted through a solid steel rotor. The rotor spins opposite

to the direction of travel of the loader. Rocks are crushed between rotating hammers and steel anvils bolted to the top of the crusher rather than the rocks being pushed out as the loader moves forward. When the rock material is crushed small enough to fit through the spaces between the hammers and the anvils, the crushed material is passed under a flexible belting screen on the crusher into a new windrow (2).

The crushing operation begins with the motor grader ripping the road surface. The ripped material, along with loose rock on the shoulders and ditches, is windrowed. The water truck wets the windrow for dust abatement before the crusher processes the material. The crusher then travels over the windrow crushing the material. A second motor grader follows, spreading the crushed material on the roadway and watering as needed.

The crusher is designed to process most types and hardness of material as long as these materials can be windrowed and as long as the maximum size is 16 inches (404 millimeters) in diameter. The crusher



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Figure 1—Forester C-2000 Road Crusher.

works best on hard cobble or boulder rock types that are angular or rounded. In-place bedrock cannot be processed using the crusher since bedrock cannot be windrowed.

Hammers last for 6 to 8 hours and then must be replaced. Under normal operating conditions this task must be done daily and takes about 30 minutes. Anvils, depending on wear, usually need to be changed once a week; this process takes about two hours. The crusher must be lubricated several times a day, and the air filter must be cleaned once a day and replaced when necessary.

Crusher box liner packs, designed to protect the crusher liner, are rotated and replaced when they are worn out. During the two months of use, only one pack had to be rotated. The amount of wear depends on the type of rock and the amount of material crushed. The hammer rotor shaft has to be hard-surfaced every two to three months. The main bearings on the rotor have to be replaced every two to three months.

THREE DEMONSTRATION PROJECTS

Coronado National Forest

In the summer of 1995, the Coronado National Forest used the crusher for eight weeks for a project that was 29 lane-miles (46.7 lane-kilometers) long, a two-lane road, and designed for passenger vehicles. It ranged in elevation from 4,920 feet to 8,530 feet (1,500 to 2,600 meters).

The crusher processed oversized material collected from shoulders, ditches, and roadway, resulting in a 4-inch (100-millimeter) thick road surface. An estimated 30,000 cubic yards (22,937 cubic meters) or 43,054 tons (39,069 metric tons) were processed using the Forester C-2000. The cost of the project was \$191,430 resulting in an in-place unit cost of \$6.38 per cubic yard (\$8.35 per cubic meter) or \$4.44 per ton (\$4.90 per metric ton).

The Coronado National Forest used their nine-person road crew and a three-person crushing crew. Fire crews ran the pumps and filled the water trucks; a technical representative from F.A.H.R. was also present.

The production rate of the crusher was determined by the size of the windrow, the quantity and size of rock, and the road alignment. An overly large windrow clogged the crusher. The optimal windrow size was determined to be 5 feet (1.5-meter) wide by 1 foot (0.3-meter) high.

Rio Grande National Forest

In July 1997, the Rio Grande National Forest used the crusher for three weeks to process 8.0 lane-miles (12.9 lane-kilometers) of the Conejos River Road, which is heavily used by passenger vehicles. The road was constructed in the nineteenth century as a mining trail and subsequently converted into a two-lane road for hauling timber, gold, and silver. Today, the road is used primarily for recreation and for transportation to houses and summer cottages. Figures 2 and 3 are photographs of the road before and after processing.

The result was an estimated 7,304 cubic yards (5,589 cubic meters) or 10,496 tons (9,525 metric tons) of processed material. The cost of the project was about \$81,000, with an in-place unit cost of \$11.09 per cubic yard (\$14.49 per cubic meter) or \$7.71 per ton (\$8.50 per metric ton).

The project operation was similar to that used by the Coronado National Forest with the exception that a dozer ripped the road instead of a motor grader and a grid roller was used on the final pass to compact the surface.

The Forest maintained traffic control during the project, however there was adequate room for the maintenance equipment to maneuver. The Rio Grande National Forest used a seven-person road crew and a three-person crushing crew.



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Figure 2—Conejos River Road before processing (Rio Grande National Forest).



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Figure 3—Conejos River Road after processing (Rio Grande National Forest).

Plumas National Forest

In August 1997 the Plumas National Forest used the crusher for three weeks to process 4.9 lane-miles (7.9 lane-kilometers) of the Dixie Mountain Lookout Road. The road was built in the 1920's to serve as access to a lookout. In the 1970's the road was upgraded from a 4-wheel-drive road to low-standard passenger vehicle use. The road is narrow, between 10 to 13 feet (3 to 4 meters) wide with few turnouts, steep side slopes, and tight (less than 50 foot [15.24 meters] radius) curves and road grades in excess of 12 percent. Figures 4 and 5 are photographs of the road before and after processing.

An estimated 4,467 cubic yards (3,418 cubic meters) or 6,421 tons (5,827 metric tons) of material was processed using the Forester C-2000. The total cost was \$84,150 with an in-place unit cost of \$18.83 per cubic yard (\$24.62 per cubic meter) or \$13.10 per ton (\$14.44 per metric ton) .

The crushing operation on the Plumas was the same as the other two sites except that the road was closed to all public traffic. The crusher was on-site for two

weeks; and the dozer, grader, and water truck prepared the site one week prior to the crushing operation.

A five-person road crew and the same three-person crushing crew from the Coronado were used on this project.

MATERIALS TESTING

Tests were taken at random locations on all three projects during crushing operations. Samples were taken both before and after crushing and from where work was being performed that particular day.

For the tests taken on the Coronado, all rocks larger than 4 inches (100 millimeter) were discarded from the before sample. Some of the discarded rocks were as large as 10 inches (250 millimeter) diameter and are not included in the before sieve analysis. All sample materials taken for the sieve analysis from the Rio Grande and Plumas National Forests were used. A representative sample analysis from each forest is provided in Table 1.



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Figure 4—Dixie Mountain Lookout Road before processing (Plumas National Forest).



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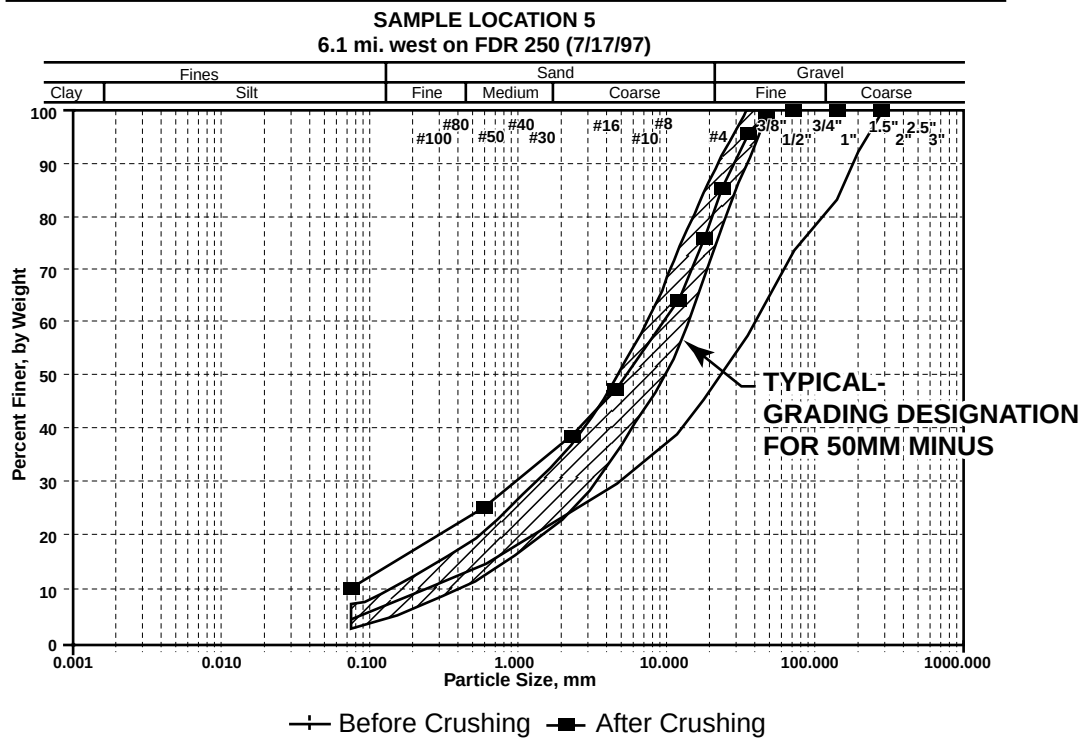
Figure 5—Dixie Mountain Lookout Road after processing (Plumas National Forest).

Table 1. Representative sample from each forest.

Location (sample #)	Passing 3 inch (% before)	Passing 3 inch (% after)	Passing #200 (% before)	Passing #200 (% after)	L.A. Abrasion (% loss at 500 revs)
Coronado National Forest (sample 2)	89	100	8.9	19.3	25
Rio Grande National Forest (sample 5)	73.8	100	4.2	10.2	21
Plumas National Forest (sample 3)	68	100	10.0	18.3	37.2

Note: Throughout the document both English and metric units are used. However, for clarity of information in the tables, only the English units are shown.

RIO GRANDE NATIONAL FOREST



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Figure 6—Sieve analysis for sample location 5 on the Rio Grande National Forest.

Figure 6 is a representative graph of one sieve analysis sample site and a typical grading designation for 2 inch (50 millimeter) minus.

COST

The unit cost of the Plumas National Forest project, \$18.83 per cubic yard (\$24.62 per cubic meter) is high when compared to the other projects. The high cost was due in part to the narrow, steep road which limited the mobility and logistics of equipment, and the short length of the project. Unit costs increase as the job length shortens primarily due to the greater impact that mobilization plays on these short projects. Road reconditioning is however, less costly than locally crushed quarry rock, \$19.12 per cubic yard (\$25.00 per cubic meter), when it is available, and

considerably less expensive than commercially available aggregate, \$24.86 per cubic yard (\$40.00 per cubic meter).

As with any unique project there is a learning curve for the crew; a coordination of the work effort; and certain fixed costs such as mobilization. These costs are amortized over the length of the project. However, when the project covers only a short distance, as on the Plumas, the unit cost is high; when the project is over a longer distance, as on the Coronado, the unit price is low.

Table 2 provides a summary of the data from the three project locations.

Table 2. Summary of projects.

Project Location	Coronado National Forest	Rio Grande National Forest	Plumas National Forest
Project Description	2-lane road; design speed 18 mph; ADT 25; traffic type: recreation	2-lane road; design speed 18 mph; ADT 150; traffic type: recreation	1-lane road; design speed 5 mph; ADT 5; traffic type: administrative
Material Type	Primary rock: rhyolite, with bedded sand/siltstone and shale	Primary rock: igneous volcanic	Primary rock: volcanic; andesitic flows and andesitic mudflow breccias
Length of Project (lane-miles)	29	8	4.9
Estimated Crush (Cubic yards)	30,000	7,304	4,467
Total Cost	\$191,430	\$81,000	\$84,150
Unit Cost (per cubic yard)	\$6.38	\$11.09	\$18.83
Approximate Average Production Rate (lane/mile/day)	.87	.81	.68

DISCUSSION OF DEMONSTRATION RESULTS & LESSONS LEARNED

Some important observations can be made when evaluating the results of all three demonstration projects.

- **Change in Erodible Silts and Sands:** The silt and sand component of road surfaces for all three demonstrations increased after processing with the Forester C-2000. The silt component increased from a low of 5% up to a high of 30%. The sand component increased a significant amount as well for all three demonstrations. This is important since the main contribution of sediment from roads over long periods has been from traffic on road surfaces. By increasing the silt and sand content of the surface material; an additional source of potential sediment is available to enter stream courses. This may not be necessarily detrimental if the road is located away from live streams and has proper drainage control.

It should be considered however when proposing road reconditioning projects. An imported aggregate meeting Forest Service specifications will usually produce a surface that is tighter, stronger and consequently less erodible than a reconditioned road.

- **Control over Final Gradation:** The Forester C-2000, as well as other road reconditioners, offers very little control over the final gradation. Some influence on the final gradation can be gained by physically carrying large rocks into the windrow on road surfaces that are deficient of rock material. However, for the most part, the composition of the existing surface determines the final gradation.
- **Length of Project and Unit Cost:** The length of job was the primary determinate effecting the unit cost of the project. Small projects (less than 3-5 miles) using the Forester C-2000 can be cost

prohibitive. The cost to mobilize the equipment and crew must be spread over a minimum number of miles before it is cost effective to perform in-place road reconditioning. The break-even point between using in-place road reconditioning equipment or importing a crushed aggregate from a local source is dependent on the local costs and conditions. A good rule of thumb to use for minimum job size is between 6-8 miles.

- **Crew Experience and Production:** Another factor effecting cost is the skill level and experience of the crew. Breaking in a new crew results in constantly “climbing the learning curve.” In most instances, it may be wise to use an experienced crew loaned by a Forest skilled in this technology rather than training a local crew with little experience in in-place road reconditioning.
- **Narrow Roads and Production:** The width of the road dramatically impacts production of the road reconditioning operation. Forming windrows becomes very difficult on roads less than 10 feet wide. A large reason for high costs on the Plumas project was due to the inability of the large equipment to negotiate the tight curves and narrow surface.
- **Hard Surfaces and Production:** Very hard road surfaces that are difficult to rip with motor grader rippers result in lower production of the operation. Much of the high costs associated with the Plumas project was due more to the road conditions rather than limitations of the Forester C-2000.

CONCLUSION

The demonstration projects using the Forester C-2000 proved to be successes. The 40.0 lane-miles (67.5 lane-kilometers) of road reconditioned with the crusher is expected to remain in relatively good condition with only a minimal amount of additional work required.

The crusher does an amazingly good job of crushing large, hard rocks and boulders up to 16 inches (405 millimeters) in diameter and reducing them to a gravelly 4 inches (50 millimeters) minus material.

The quality of the crushed rock product is variable. What is put into the windrow directly affects the final crushed product. Quality control is determined by the care taken to develop material in the windrow. Road preparation is very important.

If the windrowed material is fines rich, the crushed product will be even richer in fines. If the windrowed material is very rocky, the crushed product will be coarse and boney. Ideally the material worked into the windrow should be predominantly rocky material (60 to 70 percent) and a moderate amount of silts and sands (30 to 40 percent).

The best application of the Forester C-2000 appears to be on a very rocky, rough riding road with a difficult driving surface caused by 5 inch (75 millimeters) diameter and larger rocks. The crusher will break down the coarse rock into roughly 4 inch (50 millimeter) diameter and smaller rock which is driveable.

The Forester C-2000 is a viable alternative in lieu of importing aggregate. Particularly as a road surface cushion material, where the quality and expense of standard crushed aggregate, such as base course material are not needed on low-volume roads.

LITERATURE CITED

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